Sea-Level Rise and Flooding Estimates for New Brunswick Coastal Sections 2017

Based on IPCC 5th Assessment Report

October 2017

R.J. Daigle Enviro

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Report Title

Updated Sea-Level Rise and Flooding Estimates for New Brunswick Coastal Sections

Based on IPCC 5th Assessment Report

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Letter of Transmittal

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I am pleased to submit the following report in fulfilment of the contract between R. J. Daigle Enviro and the New Brunswick Department of Environment and Local Government dated October 27th, 2017.

This report provides up-to-date sea-level rise estimates and flooding scenarios for the coastlines of New Brunswick based on the most recent climate change science.

I hope the information in this report will help facilitate informed decision-making and planning on climate change adaptation leading to sustainable communities.

Sincerely,

Réal Daigle

R. J. Daigle Enviro

Contents

List of Acronyms

AES40	Quality-controlled gridded surface wind database
AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
CD	Chart Datum
CGVD28	Canadian Geodetic Vertical Datum of 1928
CGVD2013	Canadian Geodetic Vertical Datum of 2013
GHG	Greenhouse gas
CHS	Canadian Hydrographic Service
HHWLT	Higher High Water at Large Tides
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
LN	Natural Logarithm
MWL	Mean Water Level
RCP	Representative Concentration Pathway
SEM	Semi-empirical Modeling
VLM	Vertical Land Motion

Glossary

Chart datum

Chart datum is the plane of vertical reference to which all charted depths and drying heights on navigation charts are related and is selected so that the water level will seldom fall below it and only rarely will there be less depth available than what is portrayed on the chart.

Geodetic datum

A vertical datum is used as a reference point for elevations of surfaces and features on the Earth including terrain, bathymetry, water levels, and man-made structures. Geodetic vertical datums are based on ellipsoid models of the Earth used for computing horizontal datums. Geodetic datums such as CGVD28 and CGVD2013 (the new Canadian standard) are used in geographic information systems.

Higher high water at large tide

The higher high water at large tide value is calculated over a 19-year cycle and represents the average of the predicted highest annual astronomical tide, one for each of the 19 years of prediction, thus representing a baseline level that is not necessarily reached every single year, but can be also be exceeded during several years of the 19-year cycle.

LiDAR

LiDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses, combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. LiDAR vertical elevations are normally precise within 10-15 cm.

Return period

Return period represents the average time between occurrences of an event exceeding a given level. Another way of interpreting a level with a given return period (T) is that in any year there is a 1/T chance that the return level will be exceeded. For example, in any given year there is a 10% chance that 10-year return period value will be exceeded. Similarly, in any given year there is a 1% chance that a 100-year return period will be exceeded. It is therefore possible that several 100-year events could occur within any 100-year period

Storm surge

A storm surge can be defined at the coast as the difference between the observed water levels and the predicted tides. Storm surges can be positive or negative and may therefore raise or lower sea level from its predicted value. Storm surges occur everywhere along our coastlines and can occur at any time during the tidal cycle or may last over several tidal cycles. Large positive storm surges at times of high tide are events that lead to coastal flooding, whereas when they coincide with low tides, flooding problems are not expected.

Storm surge residual

The storm surge residual is defined as the difference between the predicted astronomical tide and the measured water level.

Vertical Land Motion

Vertical Land Motion, also referred to as isostatic rebound, relates to a post-glacial adjustment of the earth’s crust. The rebound (maximum in the Hudson Bay area) and a corresponding subsidence along Atlantic Canada coastlines is in response to a depression of the earth’s crust caused by the immense weight of continental ice sheets during the last Ice Age.

Spring tide

The tides of increased range occurring near the times of full moon and new moon.

Tide

Tides result from the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the moon and the sun and the rotation of the Earth. Observed tide levels are rarely as predicted for the simple fact that their predicted levels are based on standard atmospheric pressure conditions, being a mean sea level pressure of 101.33 kilopascals (1013.3 millibars). When the atmospheric pressure is lower than the standard, observed tides are higher than predicted and the opposite is true for higher atmospheric pressure. Additionally, onshore and offshore winds will respectively increase and diminish the water level.

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1 Executive Summary

1.1 *Overview*

The coasts of Atlantic Canada have been shown to have significant sensitivity to sea-level rise and associated storm impacts (Geological Survey of Canada, 1998). Areas with the highest sensitivity include most of the Gulf of St. Lawrence coast of New Brunswick, the north shore of Prince Edward Island, the south coast of Nova Scotia and the southwest coast and Burin Peninsula regions of Newfoundland & Labrador. Accelerated sea-level rise under greenhouse warming is expected to aggravate these impacts, increasing the need for adaptation to minimize damage and costs. Threats in these areas come primarily from impacts of greater coastal flooding and erosion. To further complicate matters, there has been a modern society trend to build homes and cottages (usually very expensive) often within tens of metres of coastlines, directly in harm's way of damaging coastal storms.

There is now widespread scientific agreement that accelerated climate change is happening and that human activities are the principal cause (IPCC, 2013). However, measures to reduce greenhouse gas emissions are only part of the climate change challenge. Even if significant reductions in emissions were put in place tomorrow, the lag in the climate system means that past emissions will continue to affect the climate for several decades to come. Climate change will have impacts on places where citizens live. Proactively adapting to climate change is therefore an essential part of ensuring our communities remain safe, resilient and sustainable.

Coastal flooding normally occurs during the late Fall to early Spring when fierce storms develop during periods of high tides, which naturally occur near the full and new moon cycles. At times, the flooding impacts in New Brunswick can be catastrophic, as was the case at the height of the record storm surge event of January 21, 2000, and then again ten years later, with the December 21, 2010 storm. The impacts from such storms range from the destruction of natural habitats such as protective sand dunes, of built-up coastal infrastructure such as roadways, fishing wharves and erosion protection structures, and in some cases homes and cottages.

1.2 *Storm Surge Flooding*

A storm surge can be defined at the coast as the difference between the observed water levels and the predicted tides. Tides result from the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the moon and the sun and the rotation of the Earth. Observed tide levels are rarely as predicted for the simple reason that their predicted levels are based on standard atmospheric conditions. When the atmospheric pressure is lower than the standard, observed tides are higher than predicted and the opposite is true for higher atmospheric pressure. Additionally, onshore and offshore winds will respectively increase and diminish the tide level.

Storm surges can be positive or negative and may therefore raise or lower sea level from its predicted value. Storm surges occur everywhere along our coastlines, can occur at any time during the tidal cycle, and may last over several tidal cycles. Large positive storm surges at times of high tide are events that lead to coastal flooding, whereas when they coincide with low tides, flooding problems are not expected.

1.3 *Impacts of Climate Change on Coastal Flooding*

Climate change is expected to further increase ocean temperatures and accelerate the melting of land glaciers and polar ice sheets (Greenland and Antarctica) resulting in further rise in global sea levels of nearly one metre by the year 2100. The scientific community is concerned about the potential collapse of marine-based sectors of the West Antarctic ice sheet, which if initiated, could cause global mean sea level to rise substantially more than the approximate one metre mentioned above. This report has addressed this uncertainty by suggesting that a further 65 cm of sea-level rise be added to the RCP8.5/2100 estimates for adaptation applications where the tolerance to the risks of sea-level rise is very low.

Regionally, as ocean temperatures increase it is expected that the winter sea ice season in the Gulf of St. Lawrence will continue to shorten and that by the period 2040-2050 winter ice will no longer develop in this region. Until then, due to climate variability, abnormal relatively ice-free seasons such as those which occurred in 2010 and 2011 will become more frequent. With less or no ice to help buffer ocean wave action during intense storms, coastal erosion rates will likely increase resulting in more extensive damage to ecosystems (such as wetlands and sand dunes) and coastal structures (such as wharves, erosion protection structures and dwellings). Coastal flooding will become more frequent due to sea-level rise because in the future, even weaker storm systems will produce flooding impacts like the most extreme storms of the past.

1.4 *Flooding Scenarios*

The coastlines of Atlantic Canada, due to their proximity to storm tracks, have been exposed to destructive flooding events over the years. When the timing of the most extreme storms coincides with high tide cycles, the associated impacts can be catastrophic. After the benchmark flooding event of January 21, 2000 in the southern Gulf of St. Lawrence a research project was launched to evaluate the impact of the 2000 flooding event at Charlottetown in the context of both the year 2000 and future elevated sea levels due to climate change (McCulloch, et al., 2002). In that research project and a follow-up larger project (Daigle, et al., 2006) focussed on coastal areas of southeastern New Brunswick, an innovative mapping approach was used using Light Detection and

Ranging (LiDAR), thereby providing a highly effective visual tool to display flood zones and to conduct socio-economic impact analyses (see Figure 1 for example of LiDAR mapping scenario in the Shediac Bay coastal zone).

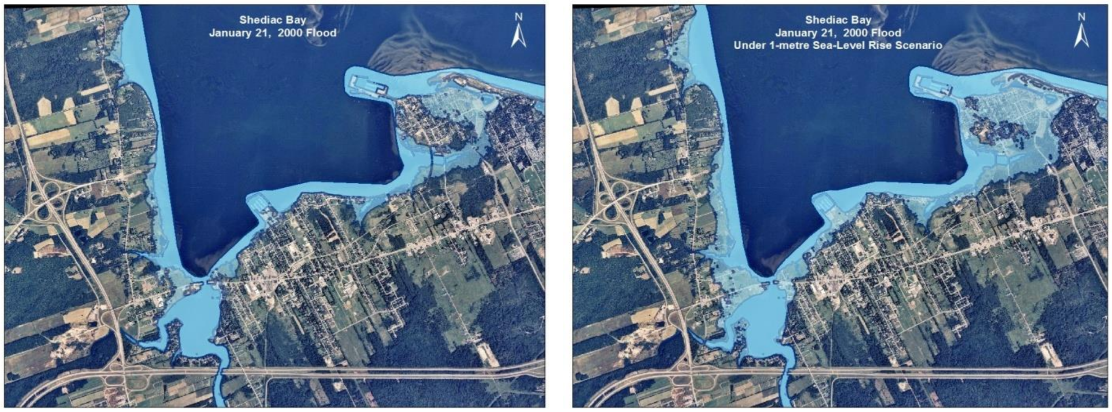

Figure 1. LiDAR-derived maps showing the January 21, 2000 flooding event (left) and the same event (right) given a sea-level rise scenario of one metre on an orthophoto (geometrically corrected aerial photo) background map.

The shaded light blue area represents the flooding that would result if the water level reached at the peak of the January 21, 2000 flooding event (left image) was raised by one metre, a potential sea-level rise scenario by year 2100 (right image). (Background aerial photo courtesy of Service New Brunswick)

The sea-level rise and flooding scenarios presented in this report reflect projections of sea-level rise from the IPCC Fifth Assessment Report (AR5) as well as the application of the regional impacts of vertical land movement, land glacier and ice sheet meltwater redistribution, dynamic oceanographic effects, land water storage and expected increases in the Bay of Fundy tidal range. The predictions of the vertical land motion field over New Brunswick are now based on a better understanding of this component (James, et al., 2014).

The flooding level scenarios (see Appendices A and B) are representative of the impact of storm surge flooding on runs of higher tides that normally occur near Full Moon and New Moon cycles. The scenarios have been built around the higher annual tidal cycles, referred to as the Higher High Water at Large Tides (HHWLT). The HHWLT value is calculated over a 19-year cycle and represents the average of the highest annual high water, one for each of the 19 years of prediction.

The HHWLT value was added to sea-level estimates and to documented storm-surge return period climatology to come up with flooding scenarios for future milestones of 2030, 2050 and 2100. It should be noted that with a 1-metre sea level rise scenario, the flooding levels reached at the height of the January 21, 2000 along the southeast coastline of New Brunswick (then close to a 1 in 100-year event), could statistically occur every year.

2 Context

The objective of this report is to create a single document containing the extreme sea level predictions for coastal sections of New Brunswick, which were previously prepared for the New Brunswick Department of Environment and Local Government by R.J. Daigle Enviro in 2012 and subsequently updated in 2014. Both reports were then reviewed by Dr. Tim Webster in 2017. This new single document incorporates where appropriate the recommendations of this review and provides an additional set of Total Sea Level Tables reflecting the recently adopted new height reference system by the Province of New Brunswick called the Canadian Geodetic Vertical Datum of 2013 (CGVD2013).

3 Sea-Level Rise Overview

The sea-level rise estimates produced in this report are based on the latest science on global sea-level rise such as the Intergovernmental Panel on Climate Change (IPCC). These global estimates were then modified for regional effects based on up-to-date research by the Geological Survey of Canada (James et al., 2014).

3.1 *IPCC AR5 Report*

The IPCC is a scientific body under the auspices of the United Nations. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. Thousands of scientists from all over the world contribute to the publication of consensus-based research results by way of IPCC reports published on a 6-year cycle. The latest IPCC report (AR5) was released in 2013.

This latest IPCC Report concludes that “It is extremely likely (95-100% confidence) that human influence has been the dominant cause of the observed warming since the mid-20th century”.

Similar to previous IPCC reports, projections of future temperatures and related physical impacts, such as sea levels and precipitation regimes, are generated by participating countries’ global climate prediction models using prescribed greenhouse gas (GHG) emissions scenarios. These results are then published as a range of predictions centered on a mean value. For AR5, the emissions scenarios are known as Representative Concentration Pathways (RCPs), meant to represent a range of plausible potential GHG mitigation scenarios ranging from drastic reductions (RCP2.6) to near “business-as usual” (RCP8.5).

Due to the previous constraint of low sea-level rise estimates by the previous IPCC report (AR4), the previously generated flooding scenarios for New Brunswick provided by R.J. Daigle Enviro in 2012 adopted a semi-empirical (SEM) approach (Rahmstorf, 2007) yielding a "conservative" 0.85 m estimate of global sea-level rise. There were some published SEM estimates with upper limits near 2 metres. The IPCC AR5 sea-level rise estimates (Figure 2) now include dynamical modelling of accelerated Ice Sheet melting (Greenland and West Antarctic), not included in the previous AR4 report. The AR5 projections include an upper limit of 0.98 m (95% confidence range of RCP8.5) of global sea-level rise by 2100.

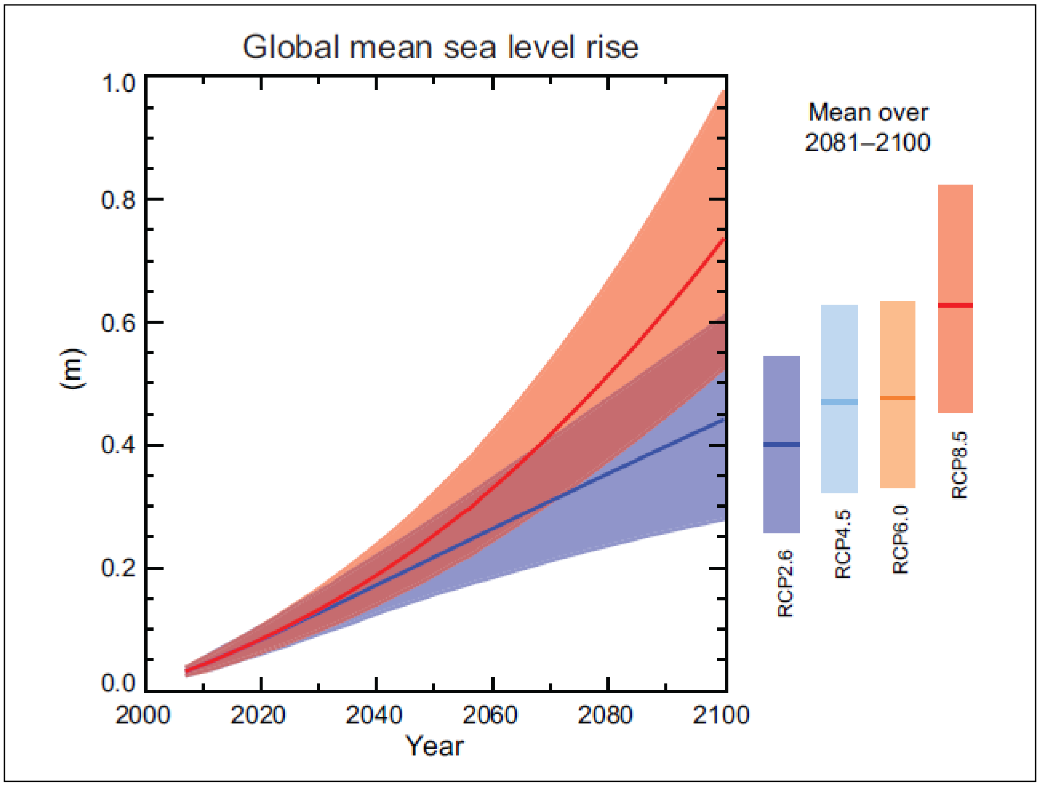

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Figure 2. Global sea-level rise estimates for RCPs 2.6, 4.5, 6.0 and 8.5 from AR5

AR5 includes a discussion on the SEM approach that had been published after the release of AR4, and concludes that "Despite their successful calibration and evaluation against the observed 20th century sea level record, there is low agreement in their projections and no consensus in the scientific community about the reliability of SEM projections, and there is *low confidence* in their projections".

3.2 *James et al. Report*

Sea-level change is not distributed equally around the globe due to a combination of regional physical factors, such as vertical land motion (VLM), redistribution of glacial meltwater and dynamic oceanographic effects. James et al. (2014) have taken the IPCC AR5 global sea-level rise predictions and have "downscaled" its results to a regional level (for the east coast of Canada and the adjacent United States) by incorporating the relative impacts of: VLM also known as crustal subsidence; redistribution of land glacier and ice sheet (Greenland and West Antarctica) meltwater (also known as fingerprinting); and oceanographic effects of an expected slowing down of the Gulf Stream. These factors are explained in Section 4.

The James et al. (2014) results were subsequently used as the basis for the latest Natural Resources Canada Coastal Assessment report, *Canada's Marine Coasts in a Changing Climate*, Lemmen et al. (2016).

4 Components of Regional Sea-Level Rise

4.1 *Global Sea-Level Rise*

James et al. (2014) adopted the global sea-level rise estimates from AR5 (specifically Church et al., 2013) to generate sea-level rise estimates beyond 2010 values, based on RCPs 2.6min (RCP2.6 5% error bar), 2.6, 4.5, 8.5 and 8.5max (RCP8.5 95% error bar) for years 2030, 2050 and 2100. The resulting sea-level rise estimates are reproduced in Table 1.

Table 1. AR5 global sea-level rise projections (cm) from James et al. (2014)

Year	RCP2.6min	RCP2.6	RCP4.5	RCP8.5	RCP8.5max
2010 - 2030	5.9	8.2	8.2	8.6	11.1
2010 - 2050	12.3	17.0	18.5	20.2	26.3
2010 - 2100	23.1	37.7	46.5	66.3	90.1

Figure 3 shows a regional sea-level rise increase trend of 33 cm per century over the period of record of 106 years at Charlottetown and an apparent accelerated rate of 38 cm per century over the past 30 years (Figure 4). When the VLM trend of 11 cm per century (James et al., 2014) is subtracted from those rates, the remaining 103 year/22 cm and 30 year/27 cm per century is already within range of the RCP2.6 estimates. These lower RCP2.6 estimates will almost certainly be surpassed.

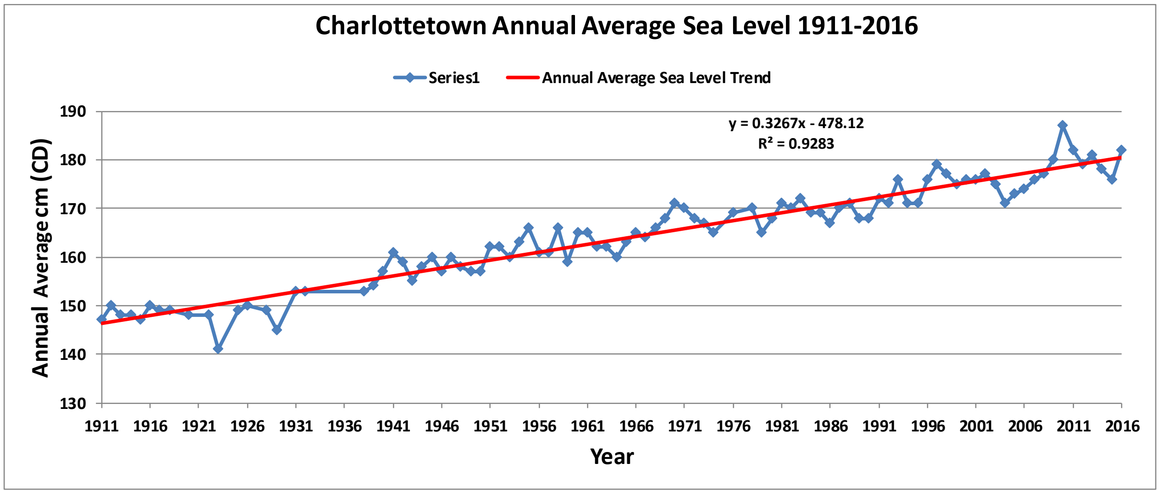

Figure 3. Chart showing average annual water level and trendline at Charlottetown for the period 1911-2016 showing a sea-level rise trend of 33 cm per century.

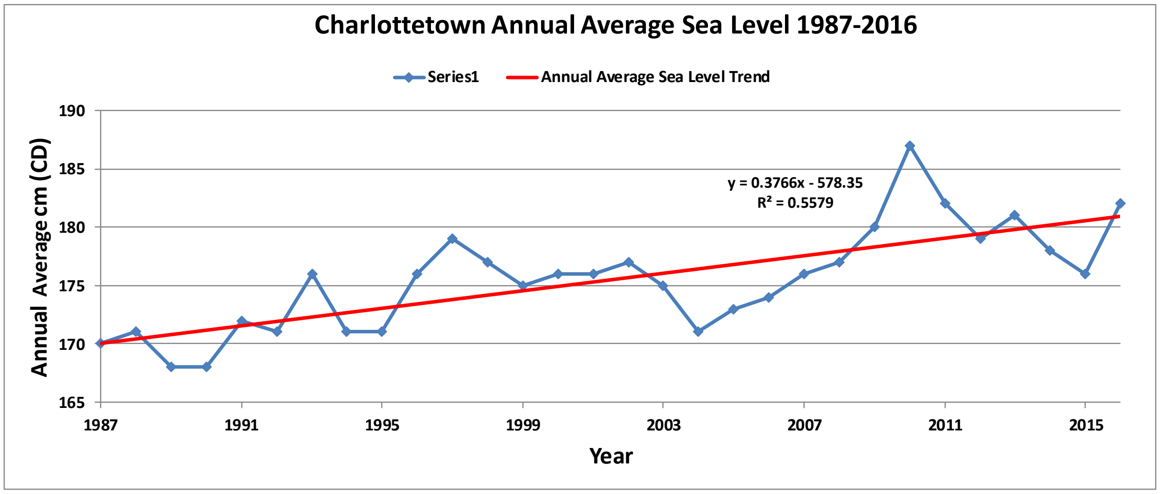

Figure 4. Chart showing average annual water level and trendline at Charlottetown for the past 30 years showing an apparent accelerated sea-level rise trend of 38 cm per century.

Based on the above discussion and considering that current GHG emissions are continuing to track near the highest IPCC pathway (RCP 8.5), this report will focus its global sea-level rise “input” (meaning before fingerprinting adjustments) to the range of RCP8.5 with an error bar up to the RCP8.5max estimates (from James, et al., 2014).

An important but poorly constrained factor in projections of global sea level is the stability of the West Antarctic Ice Sheet (Church et al., 2013). There is concern that because most of the West Antarctic Ice Sheet is based below sea level, its direct contact to warming oceans makes it sensitive to thermal erosion and subsequent destabilization. The AR5 Summary for Policymakers (IPCC, 2013) reports:

"Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the *likely* range during the 21st century. However, there is *medium confidence* that this additional contribution would not exceed several tenths of a meter of sea level rise during the 21st century."

James et al. (2014) have addressed this uncertainty by suggesting that a further 65 cm of sea-level rise be added to the RCP8.5/2100 estimates for adaptation applications where the tolerance to the risks of sea-level rise is very low. The sea-level rise estimates provided in this report have hence adopted this uncertainty by including a column called 2100 + 0.65 m in Table 5 by merely adding 0.65 m to the RCP8.5/ 2100 estimates.

4.2 ***Distribution of Glacial Meltwater***

The concept of glacial meltwater distribution (also known as fingerprinting) from land glaciers and ice sheets is discussed in AR5 and its impacts for Atlantic Canada and adjoining Gulf of Maine have been presented in specific detail by James et al., 2014:

> "Meltwater from glaciers, ice caps and ice sheets is not distributed uniformly throughout the world's oceans (Farrell and Clark, 1976; Mitrovica et al., 2001; 2009). As an ice sheet melts, it exerts a reduced gravitational pull on the surrounding ocean water, causing the nearby ocean surface to fall."

The net result is that for ocean areas adjacent to the meltwater source sea levels actually fall due to the reduced gravitational pull from the ice mass. In addition, the reduced load causes the underlying earth surface at the source of ice loss to rebound elastically thereby counteracting the impacts of global sea-level rise. The impact of this factor decreases proportionately with distance away from the meltwater source.

By way of example, for every cm of meltwater from Greenland, in Atlantic Canada there would be a reduced sea-level rise portion of approximately 0.4 to 0.5 cm; for every cm of meltwater from Antarctica, an increased proportion of approximately 1.1 cm; and for every cm from mountain glaciers and ice caps, a reduced proportion of approximately 0.8 to 0.9 cm (Figure 5).

The diagrams in Figure 5 reflect these impacts from Antarctica, Greenland and mountain glaciers and ice caps.

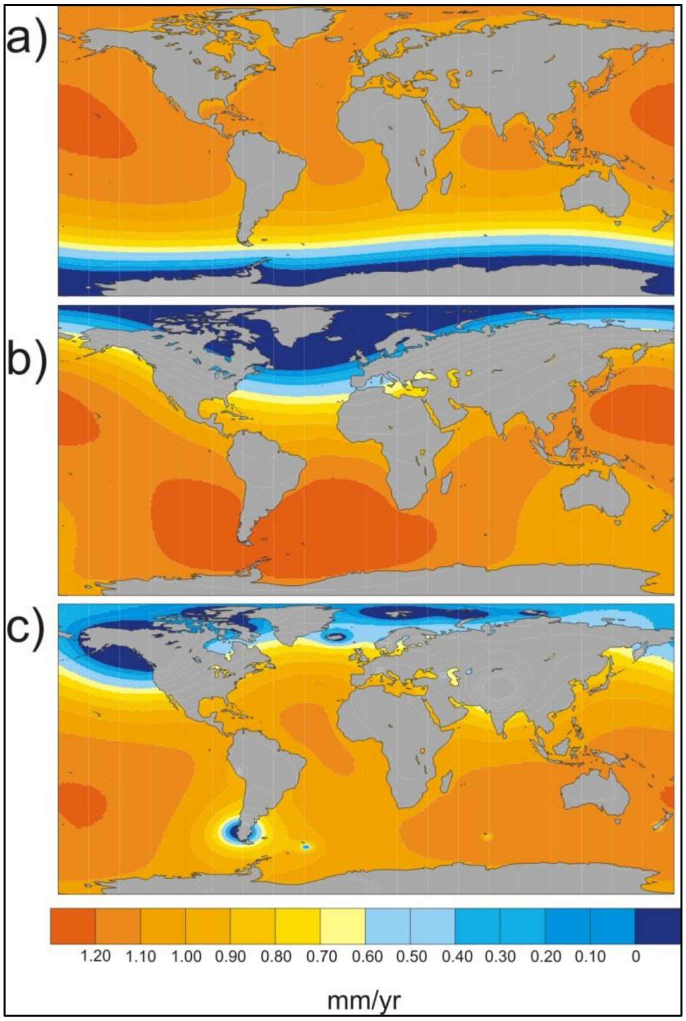

Figure 5. The amount of sea-level rise, in millimetres per year, for an assumed 1 mm/yr contribution to global sea level rise from (a) Antarctica, (b) Greenland, and (c) mountain glaciers and ice caps (Figure source: Mitrovica et al., 2001)

4.3 *Vertical Land Motion*

The concept of VLM, also referred to as isostatic rebound relates to a post-glacial adjustment of the earth's crust. The rebound (maximum in the Hudson Bay area) and a corresponding subsidence along coastlines is in response to a depression of the earth's crust caused by the immense weight of continental ice sheets during the last Ice Age. James et al. (2014) have incorporated the results of a precise GPS-based network of earth's vertical movements as displayed in Figure 6. The vertical arrows on the map identify the present-day vertical movement field.

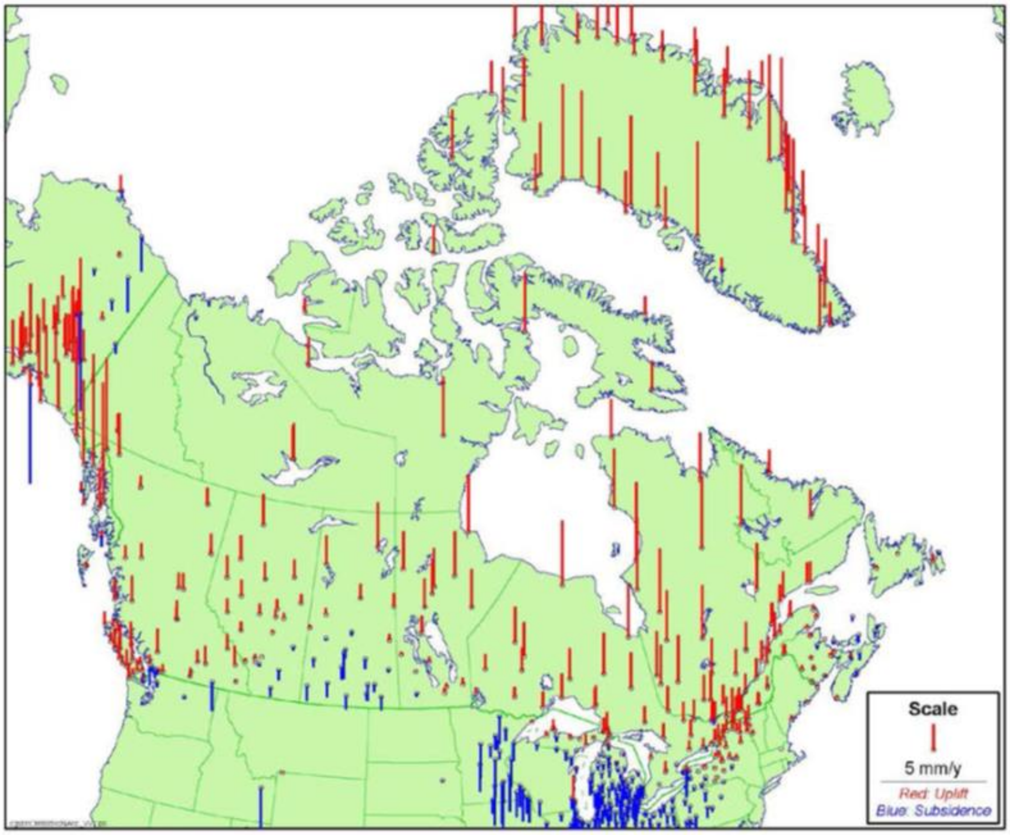

Figure 6. Network of GPS stations and associated vertical motion field. (Source: James et al., 2014)

The present-day vertical motion fields were then calculated by James et al. (2014) for tide gauge locations (displayed in Figure 7) and the values have been contoured by R.J. Daigle Enviro.

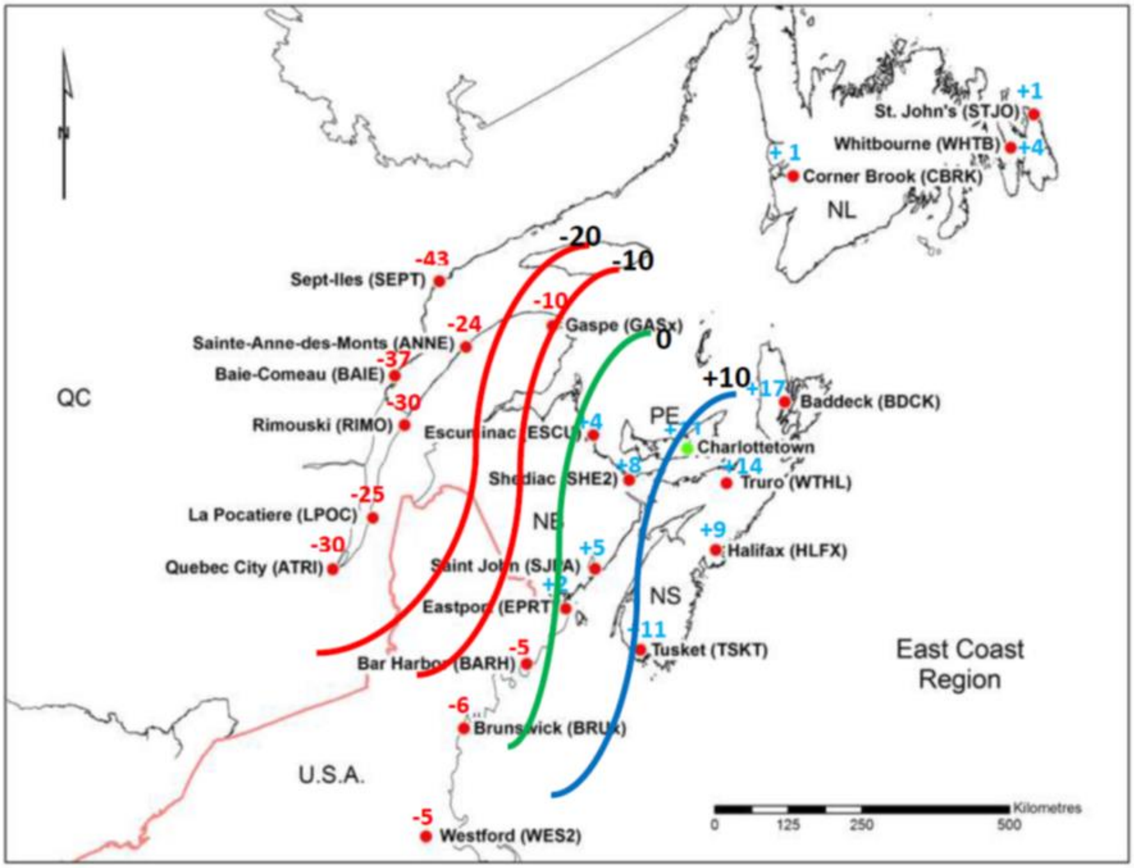

Figure 7. Map of East Coast Region showing plots of the contribution of VLM to regional sea-level change values (in cm) for the period 1995 to 2100. Green contour shows the division between areas of rebound (red figures and contours) and subsidence (blue figures and contours) over the Maritime provinces. (Data source: James et al., 2014)

Specific VLM values for each New Brunswick coastal section were extrapolated from the map in Figure 7 and are explained in greater detail in Section 6.

4.4 *Regional Oceanographic Effects*

Global ocean currents like the Gulf Stream generate dynamic sea-surface topography of more than one metre in amplitude, thereby reducing present regional sea levels. Changes to the currents can lead to changes in the sea-surface topography and hence to changes to local relative sea level. Yin (2012) has computed that climate change is expected to lead to a diminution of the Gulf Stream associated with a regional sea-level rise component for northeastern North America. James et al. (2014) have calculated this component for Atlantic Canada locations for RCP8.5. The results for New Brunswick show regional sea-level rise values for 2030, 2050 and 2100 of 2, 5 and 18 cm respectively.

4.5 *Bay of Fundy Tidal Range*

The amplitude of the Bay of Fundy tides has been observed to slowly increase, based on a study of long-term water measurements from tidal gauges from Boston to Halifax and throughout the Gulf of Maine (Greenberg et al., 2012). Their conclusions are that by 2100 a combination of VLM and amplitude change would increase the amplitude of Bay of Fundy tides by 30cm. Their findings are based on a VLM component estimated at 20 cm per century, hence leaving 10 cm for the amplitude change.

4.6 *Land Water Storage*

Groundwater extraction causes global mean sea-level to rise because water that is extracted from the ground enters the hydrological cycle and returns to the oceans. Reservoir impoundment, generated by construction of dams, prevents water from returning to the oceans and causes global sea-level to fall. The combined effects of these factors have been estimated to amount to -1 to +9 cm of sea-level change by 2081–2100 relative to 1986–2005 (Church et al., 2013a). This is a relatively small contribution to the total projected global sea-level rise.

5 Storm Surge Flooding

A storm surge can be defined at the coast as the difference between the observed water level and the predicted astronomical tide. Tides result from the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the moon and the sun and the rotation of the Earth. Observed tide levels are rarely as predicted for the simple fact that their predicted levels are based on standard atmospheric pressure conditions, being a mean sea level pressure of 101.33 kilopascals (1013.3 millibars). When the atmospheric pressure is lower than the standard, observed tides are higher than predicted and the opposite is true for higher atmospheric pressure. Additionally, onshore and offshore winds will respectively increase and diminish the water level.

Storm surges can be positive or negative and may therefore raise or lower sea level from its predicted value. Storm surges occur everywhere along our coastlines and can occur at any time during the tidal cycle or may last over several tidal cycles. Large positive storm surges at times of high tide are events that lead to coastal flooding, whereas when they coincide with low tides, flooding problems are not expected.

Elevated sea levels also enhance wave attack and coastal erosion and in the presence of ice, pressure can lead to ice ride-up and pile-up. The magnitude of storm surges depends on the nature of the meteorological event responsible for the reduced atmospheric pressure and the strength, duration and direction of the winds associated with a particular event. The most common devastating storms are the synoptic scale (meaning a horizontal scale of the order of 1000 km) events that typically intensify or re-form off the US east coast. The centre of these storms typically crosses Nova Scotia and tracks through the Gulf of Saint Lawrence.

6 Methodology

6.1 *Regional Sea-Level Rise*

James et al., (2014) calculated regional sea-level scenarios for Canada and the adjacent mainland United States, including 22 Atlantic Canada and adjoining Gulf of Maine locations considering the respective effects of fingerprinting, VLM, dynamic oceanographic effects (adds 18 cm) and land water storage for each of the RCP scenarios (see Table 4 for results). As stated in Section 3.1, this report will include only the RCP8.5 with an uncertainty factor (confidence interval) up to 95% for the compilation of results for the New Brunswick coastal zones.

The locations of Escuminac, Shediac, Charlottetown, Saint John and Eastport were selected as points from which extrapolated values were calculated for each of the 14 New Brunswick coastal zones by adjusting only the VLM field, since the other contributing factors to regional sea-level rise remain constant for the entire New Brunswick coastal zones. Table 4 shows the extrapolated average VLM fields for each coastal zone and Table 5 shows the total regional sea-level rise (sum of fingerprinted sea-level rise, dynamic oceanographic effect, VLM, land water storage and Bay of Fundy effect) based on RCP8.5 projections by 2030, 2050 and 2100. Uncertainty ranges represent the 95% confidence interval of the total regional sea-level rise values as displayed in Table 2. Projections for years 2030 and 2050 were scaled proportionate to the rate of increase of the IPCC AR5 global decadal projections as displayed in Table 3.

Table 2. Projected Relative Sea-level Change from 2010 to 2100 (cm) (Reproduced from James, et al., 2014). Values above zero indicate a net rise in sea level.

	RCP 8.5 Projection at 2010			RCP 8.5 Projection at 2100		
Location	**Sea-level change (5%) (cm)**	**Sea-level change (median) (cm)**	**Sea-level change (95%) (cm)**	**Sea-level change (5%) (cm)**	**Sea-level change (median) (cm)**	**Sea-level change (95%) (cm)**
Quebec City, QC	-5.3	0.2	5.8	7.2	47.3	87.4
La Pocatière, QC	-4.5	0.7	5.8	12.2	50.5	88.7
Rimouski, QC	-4.5	0.3	5.1	5.5	44.2	82.9
Baie-Comeau, QC	-5.4	-0.6	4.3	-1.6	37.4	76.5
Sainte-Anne-des-Monts, QC	-3.2	1.5	6.3	10.6	49.6	88.6
Sept-Iles. QC	-6.0	-1.2	3.5	-8.1	30.9	70.0
Gaspé, QC	-1.8	3.6	9.1	24.1	65.3	106.5
Escuminac, NB	1.2	5.6	10.0	38.9	78.8	118.6
Shediac, NB	1.5	6.0	10.5	45.0	83.0	121.1
Charlottetown, PE	2.2	6.6	11.1	45.8	82.6	119.4
Baddeck, NS	3.2	7.0	10.7	55.0	93.0	131.0

Truro, NS	2.2	6.6	10.9	51.4	89.2	127.1
Halifax, NS	0.8	5.6	10.4	51.0	90.3	129.6
Tusket, NS	1.4	6.2	11.1	49.3	87.8	126.2
Saint John, NB	0.6	5.4	10.2	42.8	81.1	119.4
Eastport, ME	-0.3	4.7	9.7	39.4	77.8	116.1
Bar Harbor, ME	-1.3	3.8	8.9	33.1	71.8	110.5
Brunswick, ME	-1.7	3.8	9.3	32.0	72.1	112.3
Westford, MA	-2.0	3.9	9.8	31.7	72.5	113.4
Corner Brook, NL	0.1	4.4	8.8	37.5	73.1	108.7
Withbourne, NL	0.1	4.6	9.1	40.7	78.2	115.6
St John's, NL	-0.2	4.0	8.2	40.0	76.5	113.0

Table **3. Decadal global sea-level rise estimates from IPCC AR5, Annex II**

Year	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Mean Value (m)	0.04	0.08	0.13	0.19	0.25	0.33	0.41	0.51	0.62	0.74

The Coastal Section flooding scenarios prepared for this report, displayed in Figure 8, were developed based on combined quasi-homogeneous HHWLT elevations and storm-surge flooding climatology. The methodology for this determination is explained in Section 6.3.

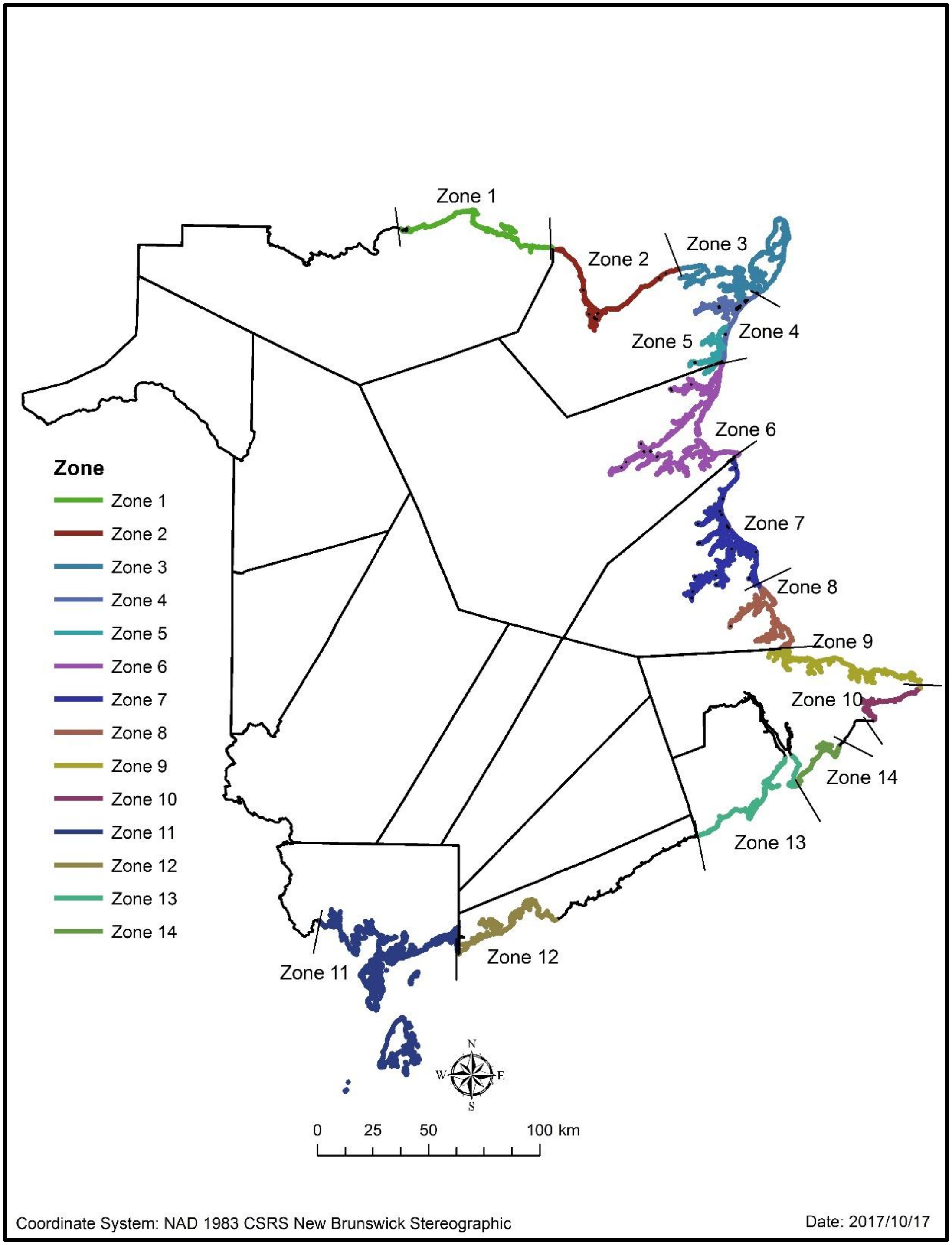

Figure 8. Map showing Coastal Zones based on quasi-homogeneous HHWLT and storm surge flooding climatology (Map source: NB Department of Environment and Local Government)

Table 4. Extrapolated average VLM rate for each coastal zone and total VLM over each of the periods 2010-2030, 2010-2050 and 2010-2100. Positive values imply a subsiding earth surface thereby increasing the regional net sea-level rise. Negative values imply a rebounding earth surface thereby counteracting regional sea-level rise (extracted from James et al., 2014 as contoured in Figure 7)

Location	VLM Rates (mm/year)	VLM 2010-2030 (cm)	VLM 2010-2050 (cm)	VLM 2010-2100 (cm)
Zone 1: Restigouche County	-1.5	-3	-6	-14
Zone 2: Gloucester County - County Line to Grande-Anse (inclusive)	-0.8	-2	-3	-7
Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage	-0.7	-1	-3	-6
Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County Line	-0.4	-1	-2	-4
Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau)	-0.4	-1	-2	-4
Zone 6: Northumberland County (Miramichi Bay)	0.0	0	0	0
Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive)	0.2	0	1	2
Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County Line	0.5	1	2	5
Zone 9: Westmorland County - County Line to Cape Spear	0.8	2	3	7

Location	VLM Rates (mm/year)	VLM 2010-2030 (cm)	VLM 2010-2050 (cm)	VLM 2010-2100 (cm)
Zone 10: Westmorland County - Cape Spear to Port Elgin	0.9	2	4	8
Zone 11: Charlotte County (including Grand Manan)	0.2	0	1	2
Zone 12: Saint John County - County Line to Cape Spencer	0.4	1	2	4
Zone 13: Albert County - Alma to Hopewell (Shepody Bay)	0.8	2	3	7
Zone 14: Westmorland County - Rockport to Sackville	0.9	2	4	8

Table 5. Total regional sea-level rise (sum of fingerprinted sea-level rise, dynamic oceanographic effect, VLM and Bay of Fundy effect (for zones 11-14 only)) based on RCP8.5 projections

Coastal Section	Total Change 2010-2030 (m)[1]	Total Change 2010-2050 (m)[2]	Total Change 2010-2100 (m)[3]	Total Change 2010-2100 (m) Including additional 0.65 m[4]
Zone 1: Restigouche County	0.11 ± 0.07	0.21 ± 0.14	0.59 ± 0.38	1.24 ± 0.38
Zone 2: Gloucester County - County Line to Grande-Anse (incl.)	0.12 ± 0.07	0.24 ± 0.14	0.66 ± 0.38	1.31 ± 0.38
Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage	0.12 ± 0.07	0.24 ± 0.14	0.67 ± 0.38	1.32 ± 0.38
Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County Line	0.13 ± 0.07	0.25 ± 0.14	0.69 ± 0.38	1.34 ± 0.38
Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau)	0.13 ± 0.07	0.25 ± 0.14	0.69 ± 0.38	1.34 ± 0.38
Zone 6: Northumberland County (Miramichi Bay)	0.14 ± 0.07	0.26 ± 0.14	0.73 ± 0.38	1.38 ± 0.38
Zone 7: Kent County - County Line to Saint Édouard-de-Kent (incl.)	0.14 ± 0.07	0.27 ± 0.14	0.75 ± 0.38	1.40 ± 0.38

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[1] Range of uncertainty represents 95% uncertainty factor of RCP8.5 projection by 2030
[2] Range of uncertainty represents 95% uncertainty factor of RCP8.5 projection by 2050
[3] Range of uncertainty represents 95% uncertainty factor of RCP8.5 projection by 2100
[4] Additional 0.65 m as potential Antarctic Ice Sheet contribution

Coastal Section	Total Change 2010-2030 (m)[1]	Total Change 2010-2050 (m)[2]	Total Change 2010-2100 (m)[3]	Total Change 2010-2100 (m) Including additional 0.65 m[4]
Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County Line	0.15 ± 0.07	0.28 ± 0.14	0.76 ± 0.38	1.41 ± 0.38
Zone 9: Westmorland County - County Line to Cape Spear	0.16 ± 0.07	0.29 ± 0.14	0.77 ± 0.38	1.42 ± 0.38
Zone 10: Westmorland County - Cape Spear to Port Elgin	0.16 ± 0.07	0.30 ± 0.14	0.78 ± 0.38	1.43 ± 0.38
Zone 11: Charlotte County (including Grand Manan)	0.16 ± 0.07	0.30 ± 0.14	0.84 ± 0.38	1.49 ± 0.38
Zone 12: Saint John County - County Line to Cape Spencer	0.17 ± 0.07	0.31 ± 0.14	0.86 ± 0.38	1.51 ± 0.38
Zone 13: Albert County - Alma to Hopewell (Shepody Bay)	0.18 ± 0.07	0.32 ± 0.14	0.87 ± 0.38	1.52 ± 0.38
Zone 14: Westmorland County - Rockport to Sackville	0.18 ± 0.07	0.33 ± 0.14	0.88 ± 0.38	1.53 ± 0.38

6.2 *Storm Surge Flooding*

Estimates of extreme total sea levels and associated levels of risk for this report were extracted from published results (Bernier, 2005). The storm surge values in Bernier (2005) were calculated by subtracting the total observed water level from the predicted tide level. These residual or surge values were then used in the extreme analysis to calculate return periods and probabilities of occurrence. In this report, these residual statistics have been applied as if they would occur at a high part of the tide cycle, as defined further below.

Figures 9 and 10, extracted from the above results, show the statistically-derived total sea levels and storm surge residuals from the Escuminac and Shediac tide gauge database (Bernier, 2005). The storm surge residual is defined as the difference between the predicted astronomical tide and the actual water level as measured, in this case, by a tide gauge.

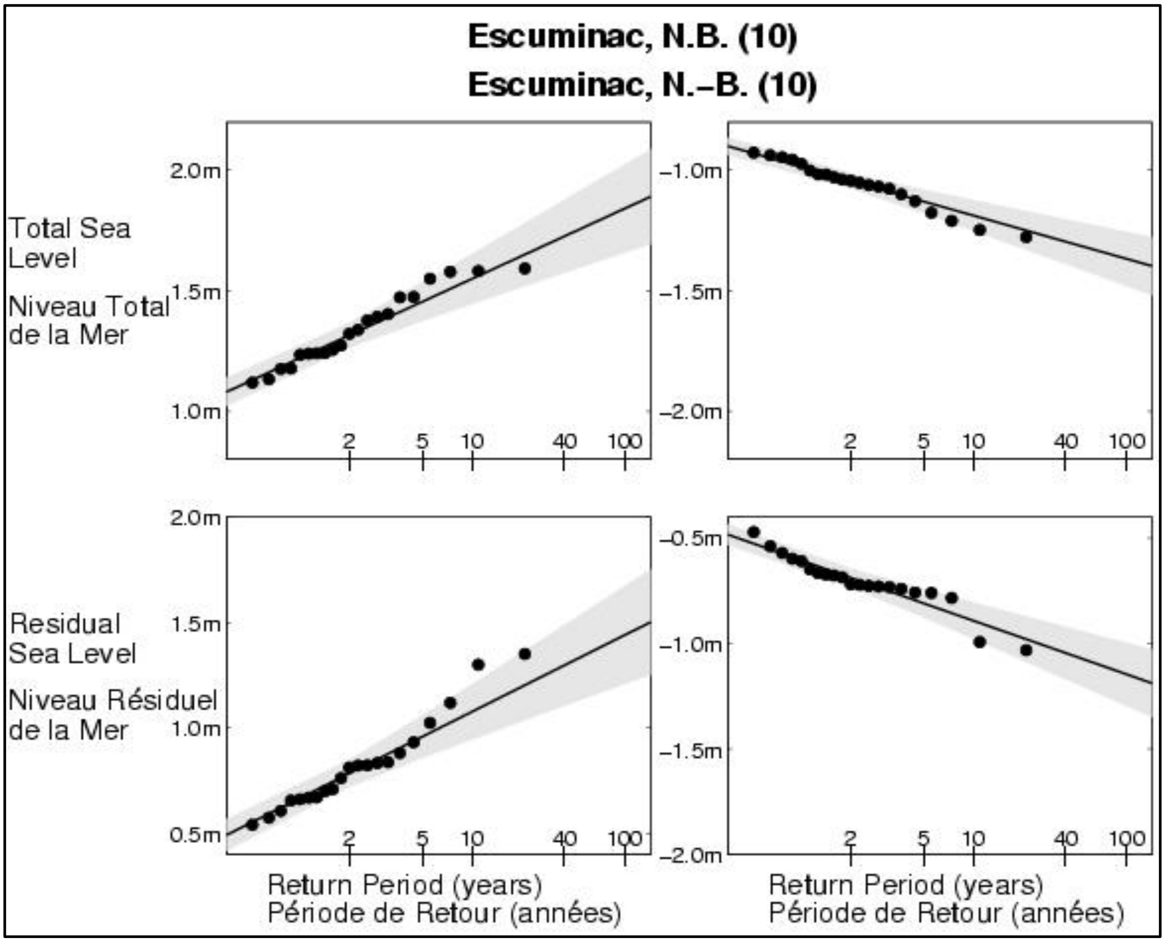

Figure 9 Total sea levels (upper left) and storm surge residual plots (lower left) for Escuminac from Bernier, N.B. (2005). The grey shading represents the range of uncertainty of the modeled results.

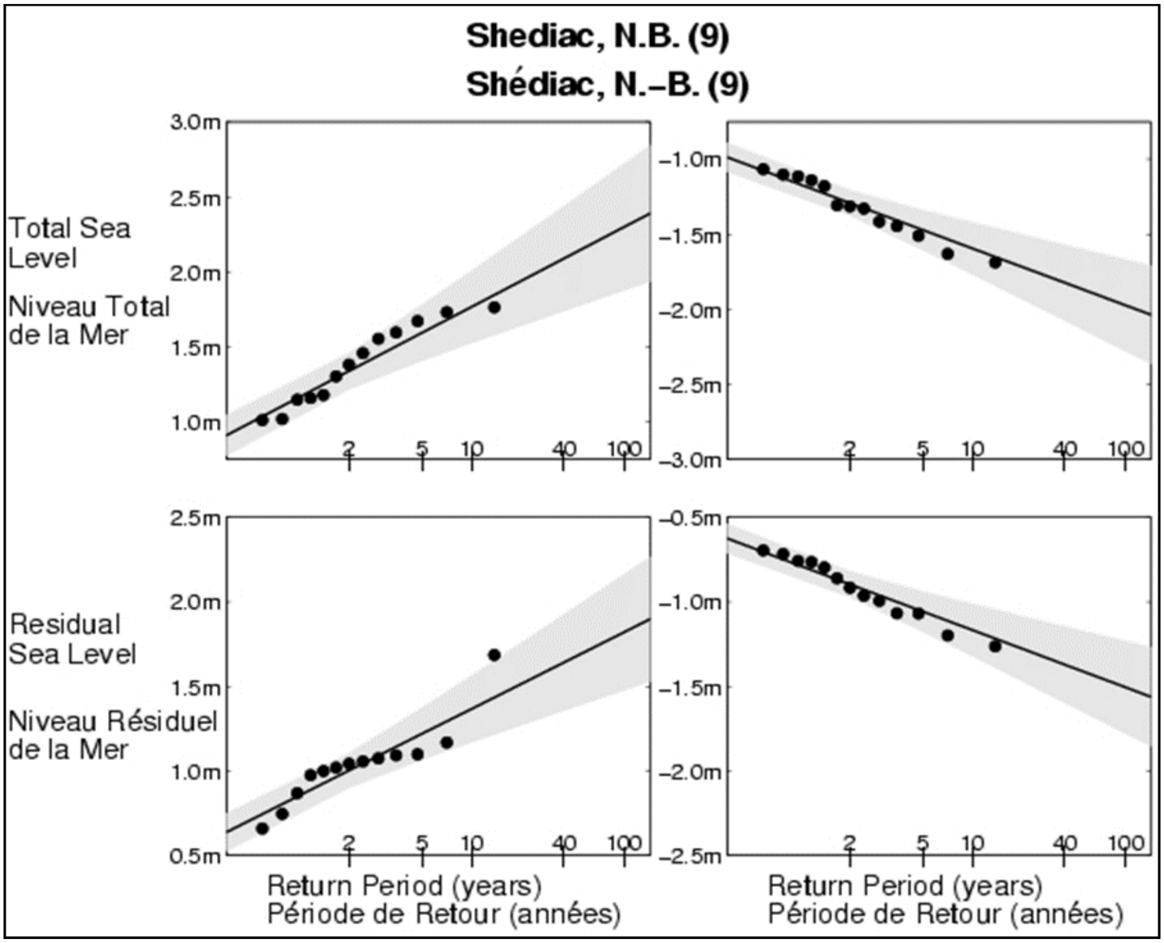

Figure 10. Total sea levels (upper left) and storm surge residual plots (lower left) for Shediac from Bernier, N.B. (2005). The grey shading represents the range of uncertainty of the modeled results.

Figures 9 and 10 also show negative surges (upper and lower right), which occur when the atmospheric pressure is higher than normal.

Close inspection of the published residual graphs (difference between the observed sea level and the anticipated tides) reveals that a significant number of recorded extreme storm surge events (black dots), in particular for Escuminac, fall within range of the 95% range of uncertainty of the modeled results (upper portion of grey-shaded area). It should be noted that the maximum water level recorded in Shediac Bay (21 Jan 2000, 3.62 m above Chart Datum (CD) including a residual storm surge component of 2.0 m) is not plotted on the graphs because the Bernier (2005) analysis covers only the storms that occurred during period 1960-1999.

Bernier (2005) results were achieved by running a Dalhousie University storm surge prediction model (later adopted by Environment and Climate Change Canada as an operational storm surge prediction model) using a quality-controlled gridded surface wind database (AES40) and inferred atmospheric pressure against expected normal tide cycles. Bernier (2005) states that there is a tendency to underestimate storm surge return levels due in part to the coarseness of the AES40 winds (0.625° latitude, 0.833° longitude) and 6-hour time resolution. This limitation could hence filter out some short-lived events such as hurricanes or extra-tropical weather systems.

It should be noted, however that the occurrence of a hurricane landfall along the coasts of New Brunswick has been extremely rare and would be limited to the coastline of the Bay of Fundy. One notable example was the October 1869 Saxby Gale, which according to a forensic analysis of newspapers and primary reports by Ruffman (1999), was a hurricane that transformed into a deep extratropical depression resulting in an estimated storm surge of the order of 1.7 to 2.1 m, the largest historically documented storm surge along the Bay of Fundy. The highest storm surge ever recorded by the Saint John tide gauge (1.49 m) occurred with the Groundhog Day storm of February 2, 1976.

It is also suggested that some of the gap between the storm surge model predicted mean values (black line) and the actual events (black dots) (Figures 9 and 10) could be linked to the fact that the storm surge prediction model did not have the capability to predict wave set-up (Pers. Comm. S. Desjardins, Environment and Climate Change Canada), whereas the actual events as measured by a tide gauge could in fact include any wave set-up component of the surge.

The concept of wave set-up is depicted in Figure 11, whereby when waves approach a beach or coastline, there is a slight lowering of the still water level called wave setdown that occurs just seaward of where the waves break due to the reduced water depth. Landward of where waves break an increase in the still water level occurs due to the excess water from the breaking wave; this is called wave set-up. Wave set-up is influenced by the offshore wave height and wave period, together with the nearshore seabed floor.

Wave run-up represents the extra height (and associated horizontal penetration) that breaking waves reach as they run up the beach or coastal barrier. The wave run-up factor will be particularly enhanced by the strength and duration of onshore winds, and by bays and estuaries. This factor was documented by the author of this report in an extraordinary storm surge event (6 Dec 2010) in the Eel River Bar First Nation Community. In this case, the extended period of strong easterly winds (more than 36 hours) blowing into the Bay of Chaleur contributed a wave run-up factor of approximately one metre along the exposed coastlines of the northern portion of the Eel River Bar community; the southern part of the community did not experience this higher wave run-up factor due to the protection by Eel River Bar (Route 134). The wave run-up component would not normally be measured by a tide gauge.

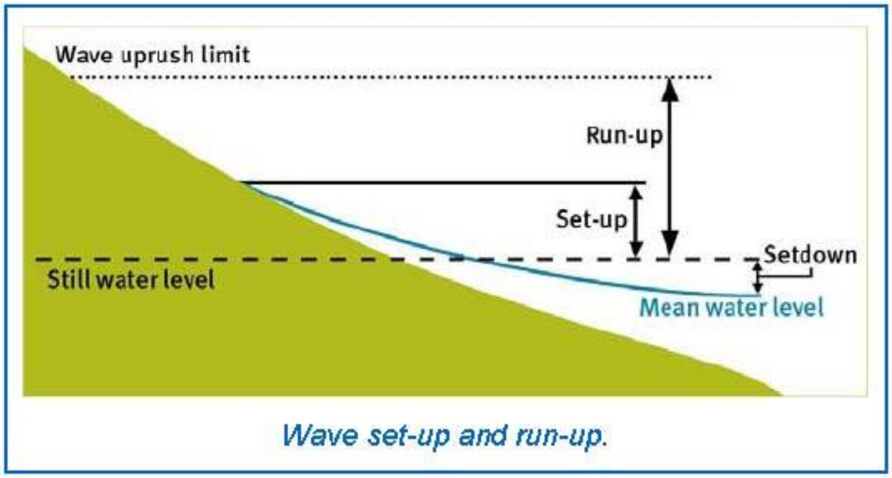

Figure 11. Diagrams showing relationship between mean water level, wave set-up and wave run-up. (Source: New Zealand Ministry of the Environment)

For the reasons detailed above, the flooding estimates in this report are based on storm surge return levels being extracted from the upper bound of the 95% range of uncertainty (confidence interval). The calculations in this report differ from the previous Daigle (2012 and 2014) reports in that the storm surge residuals have been assigned an increasing level of uncertainty with increasing return periods in line with the expanding uncertainty (grey zones) as depicted in Figures 9, 10 and 13. Previous reports had assigned a constant interval value of 0.20 m.

A return period represents the average time between occurrences of an event exceeding a given level. Another way of interpreting a level with a given return period (T) is that in any year there is a 1/T chance that the return level will be exceeded. For example, in any given year there is a 10% chance that 10-year return period value will be exceeded. Similarly, in any given year there is a 1% chance that a 100-year return period will be exceeded. It is therefore possible that several 100-year events could occur within any 100-year period. An example of a 100-year storm surge return period map can be seen in Figure 12, where the color-coded areas represent the mean value of the 100-year storm surge return levels.

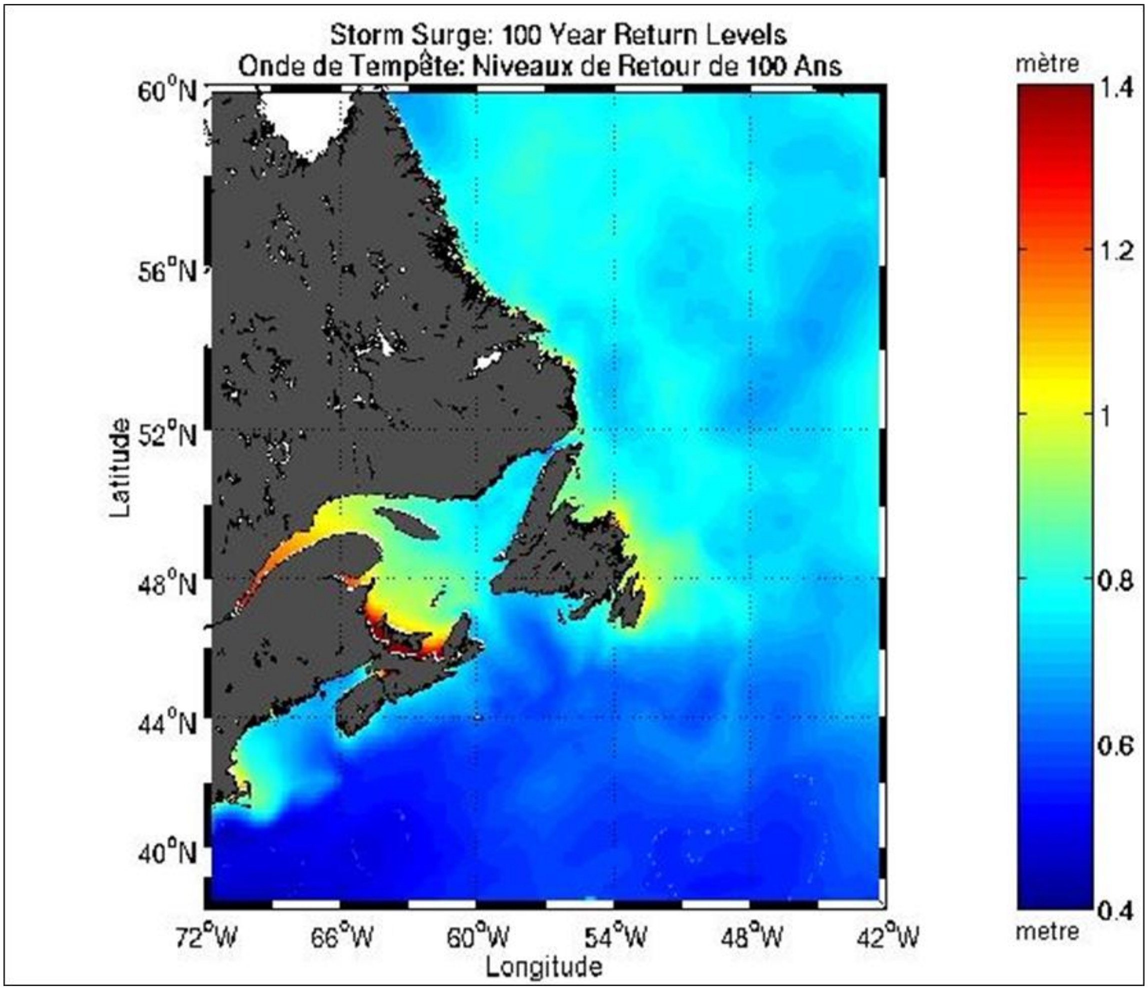

Figure 12. Storm surge (mean value) 100-year return period map. (Bernier, 2005)

The storm surge data used to estimate the extreme total sea-level return periods was extracted from the median values with range of uncertainty at the upper boundary of the shaded area (95% level of uncertainty) on the representative graphs. The procedure used was as follows.

Residual sea-level values for the 2-,10-, 40- and 100-year return periods, mined from the published semi-logarithmic graphs, were subsequently plotted on a linear graph and fitted to a natural logarithm (LN) regression curve; values were then calculated from the regression equation for the 1-,2-, 5-,10-, 25-, 40- and 100-year return periods. See Figures 13 and 14 for a Saint John example.

Storm-surge residual values for locations without tide gauge statistics were estimated from the Bernier (2005) color-coded return-period maps (Figure 12 shows 100-year return period map) and from the author’s understanding of the behaviour of synoptic storms in the region.

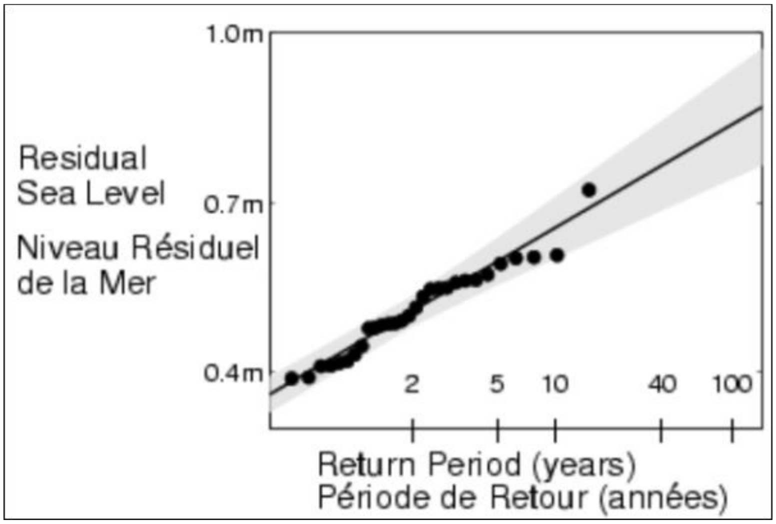

Figure 13. Residual sea levels (with 5 to 95% uncertainty in grey) and associated return periods for Saint John, with x-axis values on logarithmic scale (Bernier, 2005).

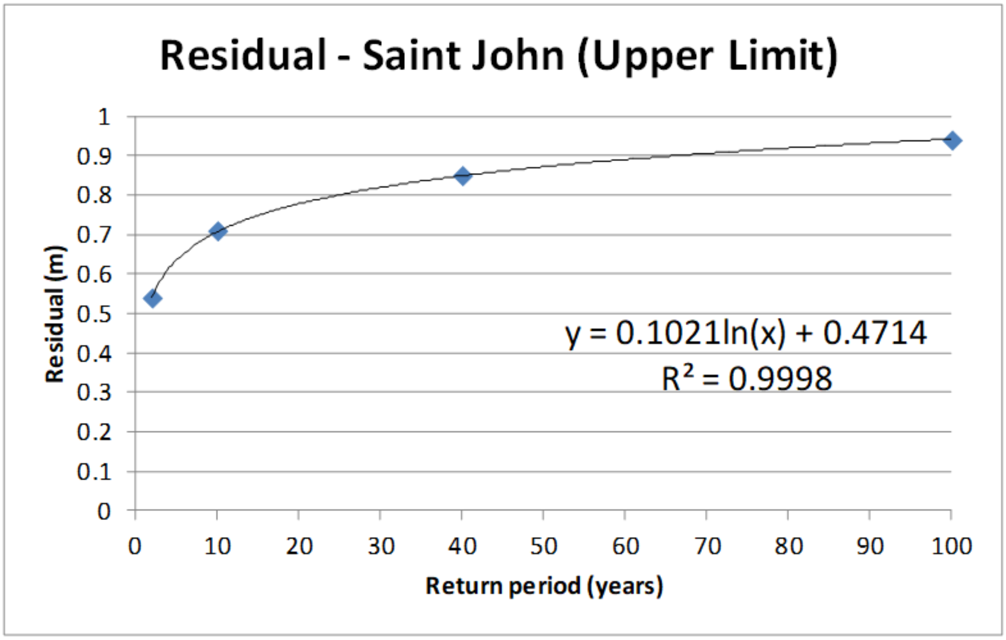

Figure 14. Saint John residuals showing the same data as in Figure 12, but with x-axis values on a linear scale and the associated regression equation used to calculate residual values for 1-, 2-, 5-, 10-, 25-, 50- and 100-year return periods.

Total estimated return-period sea levels (storm surge + tide levels) for the years 2030, 2050 and 2100 were then calculated as the sum of the relevant incremental values (estimated sea-level rise + storm surge) and the current Higher High Water at Large Tide (HHWLT) values as provided by the Canadian Hydrographic Service (CHS) of Fisheries and Oceans Canada (Pers. Comm., P. MacAulay, CHS). The HHWLT value is calculated over a 19-year cycle (specifically 18.6 years) and represents the average of the highest annual high water, one for each of the 19 years of prediction, thus representing a baseline level that is not necessarily reached every single year, but can be also be exceeded during several years of the 19-year cycle. The graph in Figure 15 shows a typical 19-year tide cycle for Shediac.

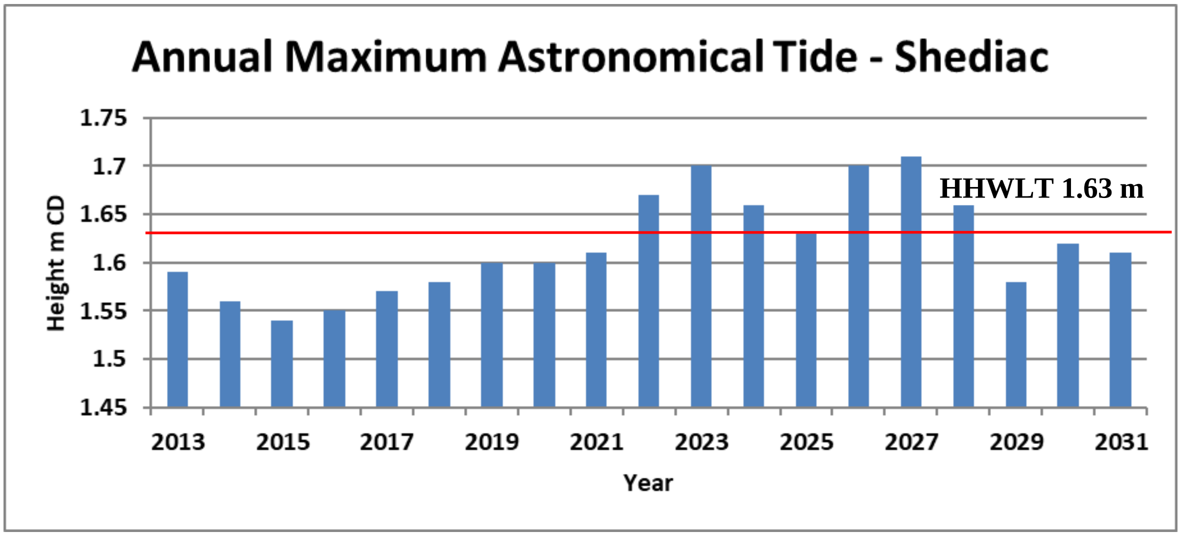

Figure 15 Annual maximum astronomical tide for Shediac (calculated from JTides), over a 19-year period from which the HHWLT value is calculated as 1.63 m (relative to Chart Datum).

In more practical terms, the HHWLT value is representative of the higher astronomical tides possible for a given location; the Chart Datum (CD)-zero value is representative of the lowest possible tide for a given location; the Mean Water Level (MWL) value is representative of the average of HHWLT and CD-zero; and the CGVD28-zero value represents approximately the MWL value, but there are varying differences depending on the location (normally within 10-25 cm).

It is to be noted that HHWLT and Extreme Total Sea Levels (defined as the sum of HHWLT, sea-level rise and storm surge return-period values) presented in this report are referenced to the geodetic reference level CGVD28. These values were calculated, requiring a conversion between CD and CGVD28 reference levels that are specific to each location, as provided by the CHS where available. Where the conversion was not available from the CHS, the New Brunswick Department of Natural Resources (D. Bérubé and M. Desrosiers) calculated the values through precise GPS surveys at the locations in question. Results from previous research were used for HHWLT values in the Tantramar area (Ollerhead, J., 2011).

Natural Resources Canada has released a new Canadian Geodetic Vertical Datum of 2013 (CGVD2013), which is now the new reference standard for heights across Canada. This new height reference system is replacing the Canadian Geodetic Vertical Datum of 1928

(CGVD28). The province of New Brunswick has recently adopted CGVD2013 and has provided a conversion from the CGVD28 datum (see converted values in Figure 15) to the new standard (R. McLean, Pers Comm). This report has now incorporated this new standard and has included a separate set of Total Sea Level tables (Appendix B) in addition to the tables with CGVD28 reference levels (Appendix A).

6.3 *New Brunswick Coastal Zone Determination*

The Coastal Section flooding scenarios prepared for this report were developed based on combined quasi-homogeneous HHWLT elevations and storm-surge flooding climatology. The resulting HHWLT values (in geodetic reference frames CGVD28 and CGVD2013), were calculated as the difference between the HHWLT (CD) and the difference between CD and geodetic (as provided by CHS where available or surveyed by the New Brunswick Department of Natural Resources). The resulting HHWLT values are displayed on the map in Figure 16 (HHWLT in geodetic reference frame CGVD2013 in red). Based on the above-noted rationale, a total of 14 coastal section segments, identified as Zones 1-14, are shown in Figure 17.

There was one location, (Tracadie Sheila) where the above-mentioned calculations produced much lower HHWLT results than the surrounding coastal segment, due most likely to the sheltered nature of Tracadie Bay. A separate Zone was therefore produced for that location.

The Bay of Fundy was problematic due to the lack of CHS tidal prediction points between Saint Martins and Alma. Since there was not a CD to geodetic conversion available for Saint Martins, estimates of future sea level for the Bay of Fundy coastline between Cape Spencer and Alma are not provided in this report.

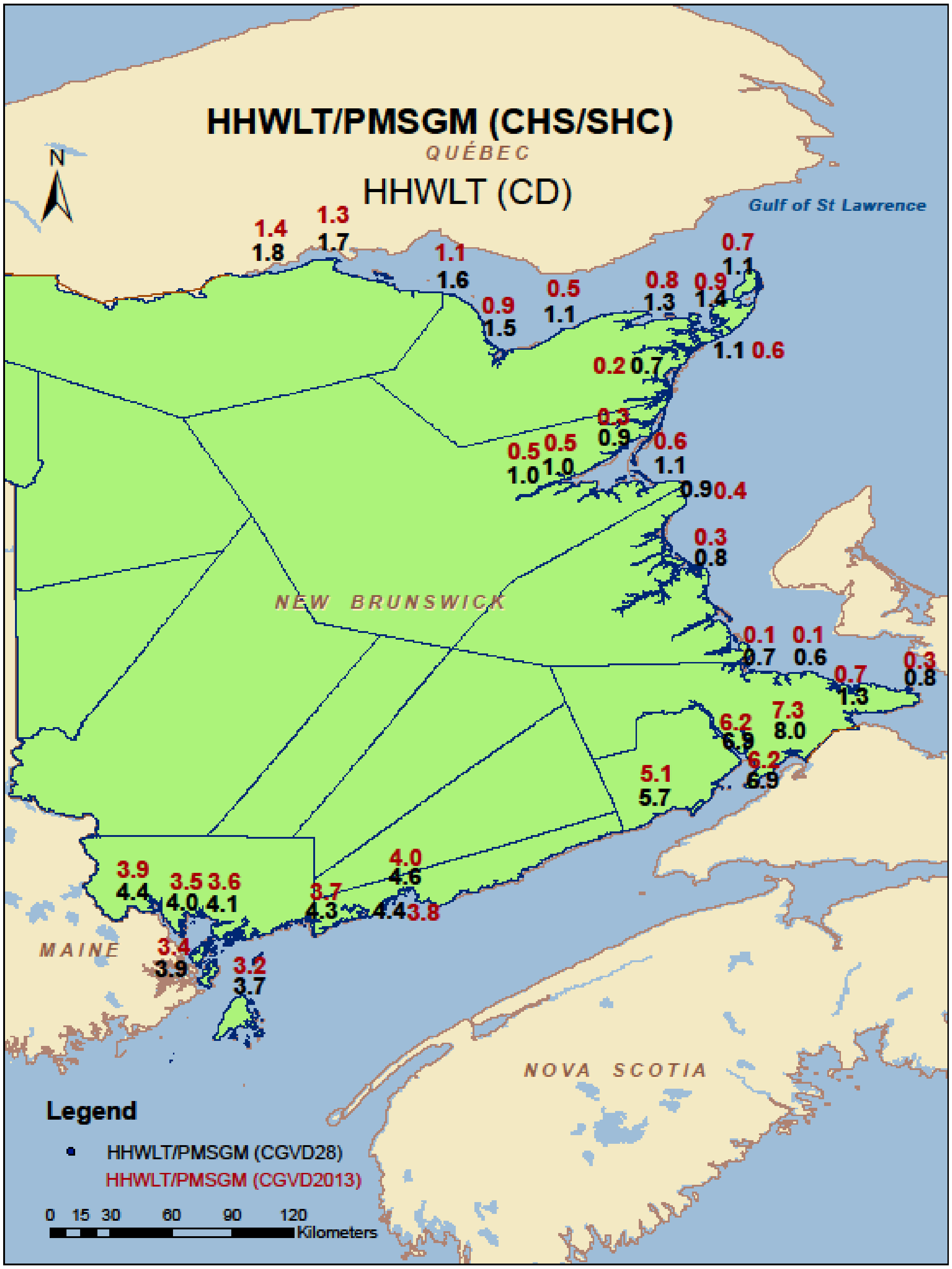

Figure 16. Map showing HHWLT values (metres above CGVD28 in black/metres above CGVD2013 in red) used as a guideline for Coastal Zone selection. (Data source, CHS)

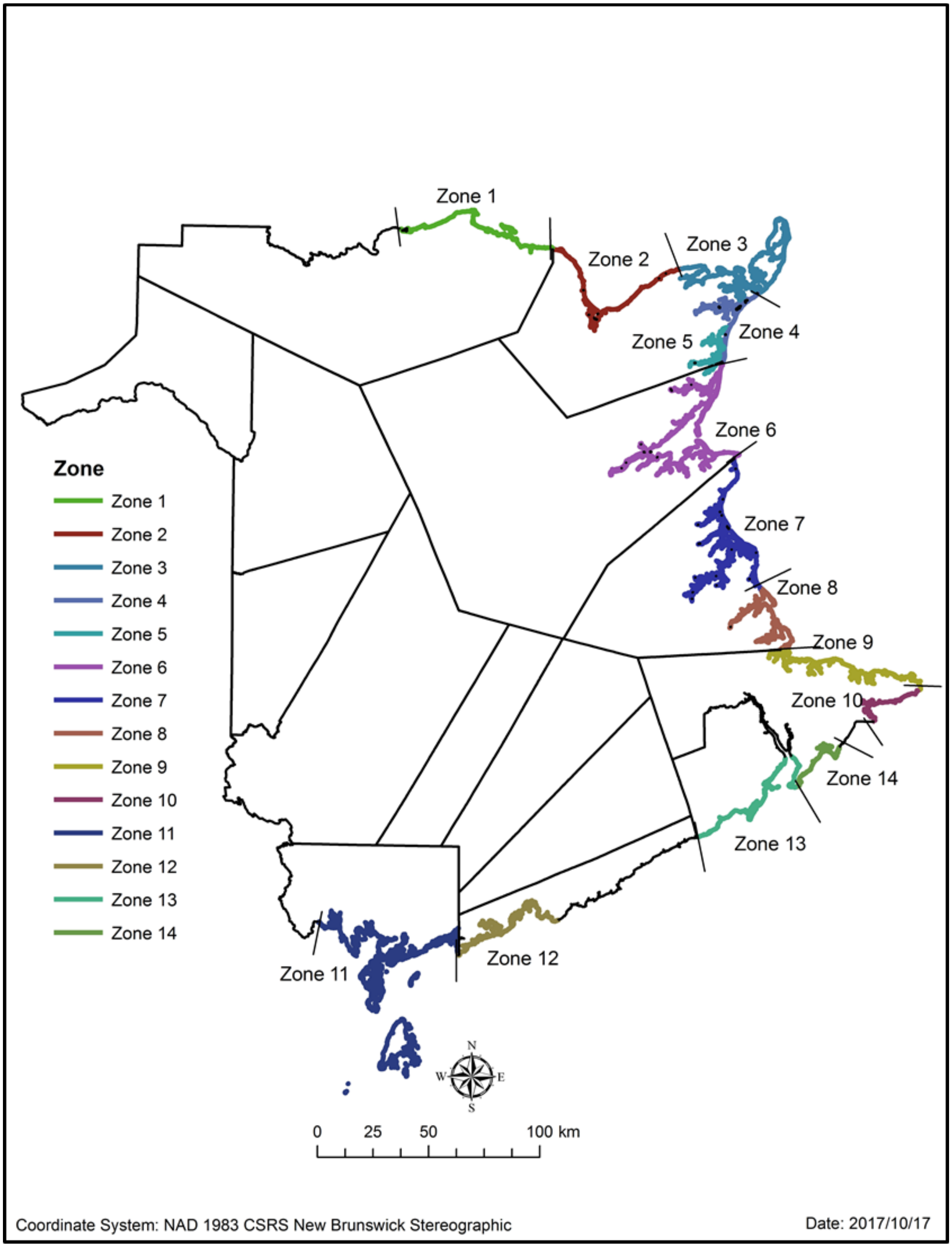

Figure 17. Map showing Coastal Zones based on quasi-homogeneous HHWLT and storm surge flooding climatology (Map source: NB Department of Environment and Local Government)

7 Flooding Scenarios

Extreme Total Sea Level values, also referred to as Flooding Scenarios, have been calculated to represent the worst-case flooding scenario whereby a storm-surge event would occur near the high portion of the tide cycle (Spring Tide). In the opposite case where a storm-surge event coincides with the low portion of the tide cycle, the chance of flooding is eliminated. The flooding scenarios have been calculated to represent the relative probability that a given storm surge value (also defined as Surge Residual) would coincide with the higher portion of the tide cycle. In the Bay of Fundy the duration of the "semi-diurnal" high tide peak is short-lived (changes of over 1 metre per hour) and hence the risk of flooding is reduced compared to the Gulf of St Lawrence where the "mixed" tide cycles result at times in periods of up to 10 hours at the top of the tide cycle.

Regional sea-level rise estimates have been utilized in conjunction with storm surge return period statistics to produce flooding scenarios for 14 coastal Zones of New Brunswick. The flooding scenarios are presented in Appendix A (reference CGVD28 datum) in the form of Total Sea Levels (sum of average HHWLT, regional sea-level rise and respective storm surge components) for years 2010 (baseline), 2030, 2050 and 2100, and for each of return periods 1, 2, 5, 10, 25, 50 and 100 years (Tables A-1 to A-14).

From a precautionary principle approach to risk management it is advisable to consider the impacts of a plausible upper bound water level that would combine the upper limits of global sea-level rise, local crustal subsidence and the highest storm-surge factor previously recorded by a tide gauge, or where available, some high precision measurements of identified high water marks. Table A-15 provides the plausible upper bound flooding scenarios for each Zone.

For completeness, an additional Table A-16 lists Total Sea Levels for year 2100 for Bay of Fundy zones representative of a Saxby Gale event, estimated at 2.0 m.

Appendix B lists the above-noted Tables with the new CGVD2013 datum standard.

8 Summary

There is now widespread scientific agreement that accelerated climate change is happening and that human activities are the principal cause. However, measures to reduce greenhouse gas emissions are only part of the climate change challenge. Even if significant reductions in emissions were put in place tomorrow, the lag in the climate system means that past emissions will continue to affect the climate for several decades to come. Climate change will have impacts on places where citizens live. Proactively adapting to climate change is therefore an essential part of ensuring our communities remain safe, resilient and sustainable.

The sea-level rise and flooding scenarios presented in this report reflect projections of sea-level rise from the IPCC Fifth Assessment Report (AR5) as well as the application of the regional impacts of vertical land movement, land glacier and ice sheet meltwater redistribution, dynamic oceanographic effects and Bay of Fundy tidal range expected increases. The predictions of the vertical land motion field over New Brunswick are now based on a better understanding of this component (James, et al., 2014).

Users of the flooding estimates presented in this report should be aware that the baseline HHWLT tidal levels used as representative of Coastal Zones are based on available CHS prediction points; hence, care needs to be given to the application of the stated Zone HHWLT range of uncertainty to best suit the specific HHWLT of a location of interest.

The Surge Residual values listed in Tables A-1 to A-14 exclude the incremental value of any wave run-up (defined as the uprush of water from wave action on a shore barrier) that could potentially accompany a storm surge event. The wave run-up factor will be particularly enhanced by the strength and duration of onshore winds, and by bays and estuaries. This factor was documented in an extraordinary storm surge event (6 Dec 2010) in the Eel River Bar First Nation Community. In this case, the extended period of strong easterly winds (in excess of 36 hours) blowing into the Bay of Chaleur contributed a wave run-up factor of approximately one metre along the exposed coastlines of the northern portion of the Eel River Bar community; the southern part of the community did not experience this higher wave run-up factor due to the protection by Eel River Bar (Route 134).

It is recommended that the median values of the sea-level rise estimates for the selected return-period and year (Appendix A, Tables A-1 to A-14 for CGVD28 and Appendix B, Tables B-1 to B-14 for CGVD2013) be used as a tool for sea-level rise adaptation planning. The additional scenario provided in this report (Level 2100 + 0.65 m) associated with a partial collapse of a portion of the West Antarctic Ice Sheet, may be appropriate to consider in instances where the tolerance to the risk of sea-level rise is very low. As a further precaution, contingencies should be planned to account for the potential impact of the upper limits (median values + range of uncertainty), in the context of risk management. These upper limits, named Plausible Upper Bound Water Levels in this report, are listed in Appendix A (Table A-15, CGVD28) and Appendix B (table B-15 CGVD2013) with an estimated value for each Coastal Zone.

IPCC AR5 states that “It is virtually certain that global mean sea level rise will continue beyond 2100, with sea level rise due to thermal expansion to continue for many centuries. The amount of longer term sea level rise depends on future emissions.”

Sea-level projections presented in this report reflect a best understanding of the current state of the science of Climate Change and it is realistic to expect that future improvements and revisions are inevitable. It will hence be necessary to update sea-level projections on a periodic basis to re-evaluate the implications for infrastructure and habitat.

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10 Appendix A

Estimated Extreme Total Sea Levels for Years 2010, 2030, 2050 and 2100[5][6][7] (metres above reference-CGVD28)

Table A- 1. Zone 1: Restigouche County

Zone 1: Restigouche County, HHWLT 1.7 m ± 0.1 (CGVD28)[8]

Return Period	Surge Residual [9]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.02	0.61	2.3 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	2.9 ± 0.5	3.6 ± 0.5
2-Year	0.70 ± 0.05	0.75	2.5 ± 0.1	2.6 ± 0.2	2.7 ± 0.2	3.0 ± 0.5	3.7 ± 0.5
5-Year	0.85 ± 0.09	0.94	2.6 ± 0.1	2.8 ± 0.2	2.9 ± 0.2	3.2 ± 0.5	3.9 ± 0.5
10-Year	0.97 ± 0.12	1.09	2.8 ± 0.1	2.9 ± 0.2	3.0 ± 0.2	3.4 ± 0.5	4.0 ± 0.5
25-Year	1.11 ± 0.16	1.27	3.0 ± 0.1	3.1 ± 0.2	3.2 ± 0.2	3.6 ± 0.5	4.2 ± 0.5
50-Year	1.23 ± 0.19	1.42	3.1 ± 0.1	3.2 ± 0.2	3.3 ± 0.2	3.7 ± 0.5	4.4 ± 0.5
100-Year	1.34 ± 0.22	1.56	3.5 ± 0.1	3.6 ± 0.2	3.7 ± 0.2	4.1 ± 0.5	4.7 ± 0.5

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[5] Total Sea Level is defined as the sum of HHWLT, sea-level rise and storm surge return-period values for each return-period and for each of the years 2010, 2030, 2050 and 2100.

[6] Surge Residual uncertainty reflects the error bars between the mean surge and 95% uncertainty factor from *Storm Surge Extremal Analysis (Bernier, 2005)*

[7] Range of uncertainty for the Level 2010, 2030, 2050 and 2100 Extreme Total Sea Levels is the sum of the uncertainties for the HHWLT, Surge Residual and the respective Total Sea Level Changes from Table 5.

[8] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[9] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 2. Zone 2: Gloucester County - County Line to Grande-Anse (inclusive)

Zone 2: Gloucester County – County Line to Grande-Anse (Inclusive), HHWLT 1.5 m ± 0.1 (CGVD28)[10]

Return Period	Surge Residual [11]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.02	0.61	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.8 ± 0.5	3.4 ± 0.5
2-Year	0.70 ± 0.05	0.75	2.3 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	2.9 ± 0.5	3.6 ± 0.5
5-Year	0.85 ± 0.09	0.94	2.4 ± 0.1	2.6 ± 0.2	2.7 ± 0.2	3.1 ± 0.5	3.7 ± 0.5
10-Year	0.97 ± 0.12	1.09	2.6 ± 0.1	2.7 ± 0.2	2.8 ± 0.2	3.3 ± 0.5	3.9 ± 0.5
25-Year	1.11 ± 0.16	1.27	2.8 ± 0.1	2.9 ± 0.2	3.0 ± 0.2	3.4 ± 0.5	4.1 ± 0.5
50-Year	1.23 ± 0.19	1.42	2.9 ± 0.1	3.0 ± 0.2	3.2 ± 0.2	3.6 ± 0.5	4.2 ± 0.5
100-Year	1.34 ± 0.22	1.56	3.1 ± 0.1	3.2 ± 0.2	3.3 ± 0.2	3.7 ± 0.5	4.4 ± 0.5

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[10] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[11] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 3. Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage (inclusive)

Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage (inclusive), HHWLT 1.2 m ± 0.2 (CGVD28)[12]

Return Period	Surge Residual [13][14]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.0	0.59	1.8 ± 0.2	1.9 ± 0.3	2.0 ± 0.3	2.5 ± 0.6	3.1 ± 0.6
2-Year	0.67 ± 0.0	0.67	1.9 ± 0.2	2.0 ± 0.3	2.1 ± 0.3	2.5 ± 0.6	3.2 ± 0.6
5-Year	0.79 ± 0.0	0.79	2.0 ± 0.2	2.1 ± 0.3	2.2 ± 0.3	2.7 ± 0.6	3.3 ± 0.6
10-Year	0.97 ± 0.0	0.97	2.2 ± 0.2	2.3 ± 0.3	2.4 ± 0.3	2.8 ± 0.6	3.5 ± 0.6
25-Year	1.11 ± 0.0	1.11	2.3 ± 0.2	2.4 ± 0.3	2.6 ± 0.3	3.0 ± 0.6	3.6 ± 0.6
50-Year	1.23 ± 0.0	1.23	2.4 ± 0.2	2.6 ± 0.3	2.7 ± 0.3	3.1 ± 0.6	3.8 ± 0.6
100-Year	1.34 ± 0.0	1.34	2.5 ± 0.2	2.7 ± 0.3	2.8 ± 0.3	3.2 ± 0.6	3.9 ± 0.6

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[12] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[13] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value).

[14] As per Daigle (2012, 2014), Surge Residual is limited to Mean value from Bernier (2005), hence range of uncertainty of 0.0.

Table A- 4. Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County

Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County Line, HHWLT 1.0 m ± 0.1 (CGVD28)[15]

Return Period	Surge Residual [16][17]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.0	0.59	1.6 ± 0.1	1.7 ± 0.2	1.8 ± 0.2	2.3 ± 0.5	2.9 ± 0.5
2-Year	0.67 ± 0.0	0.67	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.0 ± 0.5
5-Year	0.79 ± 0.0	0.79	1.8 ± 0.1	1.9 ± 0.2	2.0 ± 0.2	2.5 ± 0.5	3.1 ± 0.5
10-Year	0.97 ± 0.0	0.97	2.0 ± 0.1	2.1 ± 0.2	2.2 ± 0.2	2.7 ± 0.5	3.3 ± 0.5
25-Year	1.11 ± 0.0	1.11	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.8 ± 0.5	3.5 ± 0.5
50-Year	1.23 ± 0.0	1.23	2.2 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	2.9 ± 0.5	3.6 ± 0.5
100-Year	1.34 ± 0.0	1.34	2.3 ± 0.1	2.5 ± 0.2	2.6 ± 0.2	3.0 ± 0.5	3.7 ± 0.5

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[15] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[16] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value).

[17] As per Daigle (2012, 2014), Surge Residual is limited to Mean value from Bernier (2005), hence range of uncertainty of 0.0.

Table A- 5. Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau)

Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau), HHWLT 0.7 m ± 0.1 (CGVD28)[18]							
Return Period	Surge Residual [19][20]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.0	0.59	1.3 ± 0.1	1.4 ± 0.2	1.5 ± 0.2	2.0 ± 0.5	2.6 ± 0.5
2-Year	0.67 ± 0.0	0.67	1.4 ± 0.1	1.5 ± 0.2	1.6 ± 0.2	2.1 ± 0.5	2.7 ± 0.5
5-Year	0.79 ± 0.0	0.79	1.5 ± 0.1	1.6 ± 0.2	1.7 ± 0.2	2.2 ± 0.5	2.8 ± 0.5
10-Year	0.97 ± 0.0	0.97	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.0 ± 0.5
25-Year	1.11 ± 0.0	1.11	1.8 ± 0.1	1.9 ± 0.2	2.1 ± 0.2	2.5 ± 0.5	3.2 ± 0.5
50-Year	1.23 ± 0.0	1.23	1.9 ± 0.1	2.1 ± 0.2	2.2 ± 0.2	2.6 ± 0.5	3.3 ± 0.5
100-Year	1.34 ± 0.0	1.34	2.0 ± 0.1	2.2 ± 0.2	2.3 ± 0.2	2.7 ± 0.5	3.4 ± 0.5

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[18] Specific value (i.e. zero uncertainty) for HHWLT based on 2013-2014 Study.

[19] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value).

[20] As per Daigle (2012, 2014), Surge Residual is limited to Mean value from Bernier (2005), hence range of uncertainty of 0.0.

Table A- 6. Zone 6: Northumberland County (Miramichi Bay)

Zone 6: Northumberland County (Miramichi Bay), HHWLT 1.0 m ± 0.1 (CGVD28)[21]

Return Period	Surge Residual [22]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.61 ± 0.02	0.63	1.6 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.0 ± 0.5
2-Year	0.74 ± 0.05	0.79	1.8 ± 0.1	1.9 ± 0.2	2.1 ± 0.2	2.5 ± 0.5	3.2 ± 0.5
5-Year	0.91 ± 0.09	1.00	2.0 ± 0.1	2.1 ± 0.2	2.3 ± 0.2	2.7 ± 0.5	3.4 ± 0.5
10-Year	1.04 ± 0.12	1.16	2.2 ± 0.1	2.3 ± 0.2	2.4 ± 0.2	2.9 ± 0.5	3.5 ± 0.5
25-Year	1.21 ± 0.16	1.37	2.4 ± 0.1	2.5 ± 0.2	2.6 ± 0.2	3.1 ± 0.5	3.8 ± 0.5
50-Year	1.34 ± 0.19	1.53	2.5 ± 0.1	2.7 ± 0.2	2.8 ± 0.2	3.3 ± 0.5	3.9 ± 0.5
100-Year	1.47 ± 0.22	1.69	2.7 ± 0.1	2.8 ± 0.2	3.0 ± 0.2	3.4 ± 0.5	4.1 ± 0.5

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[21] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[22] Storm surge residual estimated as Escuminac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 7. Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive)

Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive), HHWLT 0.9 m ± 0.1 (CGVD28)[23]

Return Period	Surge Residual [24]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.74 ± 0.04	0.78	1.7 ± 0.1	1.8 ± 0.2	2.0 ± 0.2	2.4 ± 0.5	3.1 ± 0.5
2-Year	0.88 ± 0.08	0.96	1.9 ± 0.1	2.0 ± 0.2	2.1 ± 0.2	2.6 ± 0.5	3.3 ± 0.5
5-Year	1.06 ± 0.12	1.18	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.8 ± 0.5	3.5 ± 0.5
10-Year	1.20 ± 0.16	1.36	2.3 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	3.0 ± 0.5	3.7 ± 0.5
25-Year	1.38 ± 0.21	1.61	2.5 ± 0.1	2.7 ± 0.2	2.8 ± 0.2	3.3 ± 0.5	3.9 ± 0.5
50-Year	1.51 ± 0.24	1.75	2.7 ± 0.1	2.8 ± 0.2	2.9 ± 0.2	3.4 ± 0.5	4.1 ± 0.5
100-Year	1.65 ± 0.28	1.93	2.8 ± 0.1	3.0 ± 0.2	3.1 ± 0.2	3.6 ± 0.5	4.2 ± 0.5

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[23] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[24] Storm surge residual estimated as average between Escuminac and Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 8. Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County

Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County Line, HHWLT 0.8 m ± 0.1 (CGVD28)[25]							
Return Period	**Surge Residual [26]**	**Residual + Uncertainty**	**Level 2010**	**Level 2030**	**Level 2050**	**Level 2100**	**Level 2100 + 0.65 m**
1-Year	0.87 ± 0.05	0.92	1.7 ± 0.1	1.9 ± 0.2	2.0 ± 0.2	2.5 ± 0.5	3.1 ± 0.5
2-Year	1.01 ± 0.10	1.10	1.9 ± 0.1	2.1 ± 0.2	2.2 ± 0.2	2.7 ± 0.5	3.3 ± 0.5
5-Year	1.21 ± 0.15	1.36	2.2 ± 0.1	2.3 ± 0.2	2.4 ± 0.2	2.9 ± 0.5	3.6 ± 0.5
10-Year	1.35 ± 0.19	1.54	2.3 ± 0.1	2.5 ± 0.2	2.6 ± 0.2	3.1 ± 0.5	3.8 ± 0.5
25-Year	1.54 ± 0.25	1.79	2.6 ± 0.1	2.7 ± 0.2	2.9 ± 0.2	3.4 ± 0.5	4.0 ± 0.5
50-Year	1.69 ± 0.29	1.98	2.8 ± 0.1	2.9 ± 0.2	3.1 ± 0.2	3.5 ± 0.5	4.2 ± 0.5
100-Year	1.83 ± 0.34	2.17	3.0 ± 0.1	3.1 ± 0.2	3.3 ± 0.2	3.7 ± 0.5	4.4 ± 0.5

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[25] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.
[26] Storm surge residual estimated as Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 9. Zone 9: Westmorland County - County Line to Cape Spear

Zone 9: Westmorland County - County Line to Cape Spear, HHWLT 0.7 m ± 0.1 (CGVD28)[27]

Return Period	Surge Residual [28]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.87 ± 0.05	0.92	1.6 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.0 ± 0.5
2-Year	1.01 ± 0.10	1.11	1.8 ± 0.1	2.0 ± 0.2	2.1 ± 0.2	2.6 ± 0.5	3.2 ± 0.5
5-Year	1.21 ± 0.15	1.36	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.8 ± 0.5	3.5 ± 0.5
10-Year	1.35 ± 0.19	1.54	2.2 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	3.0 ± 0.5	3.7 ± 0.5
25-Year	1.54 ± 0.25	1.79	2.5 ± 0.1	2.7 ± 0.2	2.8 ± 0.2	3.3 ± 0.5	3.9 ± 0.5
50-Year	1.69 ± 0.29	1.98	2.7 ± 0.1	2.8 ± 0.2	3.0 ± 0.2	3.5 ± 0.5	4.1 ± 0.5
100-Year	1.83 ± 0.34	2.17	2.9 ± 0.1	3.0 ± 0.2	3.2 ± 0.2	3.6 ± 0.5	4.3 ± 0.5

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[27] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[28] Storm surge residual estimated as Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 10. Zone 10: Westmorland County - Cape Spear to Port Elgin

Zone 10: Westmorland County - Cape Spear to Port Elgin, HHWLT 1.2 m ± 0.1 (CGVD28)[29]

Return Period	Surge Residual [30]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.87 ± 0.05	0.92	2.1 ± 0.1	2.3 ± 0.2	2.4 ± 0.2	2.9 ± 0.5	3.6 ± 0.5
2-Year	1.01 ± 0.10	1.11	2.3 ± 0.1	2.5 ± 0.2	2.6 ± 0.2	3.1 ± 0.5	3.7 ± 0.5
5-Year	1.21 ± 0.15	1.36	2.6 ± 0.1	2.7 ± 0.2	2.9 ± 0.2	3.3 ± 0.5	4.0 ± 0.5
10-Year	1.35 ± 0.19	1.54	2.7 ± 0.1	2.9 ± 0.2	3.0 ± 0.2	3.5 ± 0.5	4.2 ± 0.5
25-Year	1.54 ± 0.25	1.79	3.0 ± 0.1	3.2 ± 0.2	3.3 ± 0.2	3.8 ± 0.5	4.4 ± 0.5
50-Year	1.69 ± 0.29	1.98	3.2 ± 0.1	3.3 ± 0.2	3.5 ± 0.2	4.0 ± 0.5	4.6 ± 0.5
100-Year	1.83 ± 0.34	2.17	3.4 ± 0.1	3.5 ± 0.2	3.7 ± 0.2	4.2 ± 0.5	4.8 ± 0.5

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[29] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[30] Storm surge residual estimated as Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 11. Zone 11: Charlotte County (including Grand Manan)

Zone 11: Charlotte County (including Grand Manan), HHWLT 4.0 m ± 0.3 (CGVD28)[31]							
Return Period	**Surge Residual** [32]	**Residual + Uncertainty**	**Level 2010**	**Level 2030**	**Level 2050**	**Level 2100**	**Level 2100 + 0.65 m**
1-Year	0.46 ± 0.01	0.47	4.5 ± 0.3	4.6 ± 0.4	4.8 ± 0.4	5.3 ± 0.8	6.0 ± 0.8
2-Year	0.51 ± 0.03	0.54	4.5 ± 0.3	4.7 ± 0.4	4.8 ± 0.4	5.4 ± 0.8	6.0 ± 0.8
5-Year	0.59 ± 0.05	0.64	4.6 ± 0.3	4.8 ± 0.4	4.9 ± 0.4	5.5 ± 0.8	6.1 ± 0.8
10-Year	0.64 ± 0.07	0.71	4.7 ± 0.3	4.9 ± 0.4	5.0 ± 0.4	5.6 ± 0.8	6.2 ± 0.8
25-Year	0.72 ± 0.08	0.80	4.8 ± 0.3	5.0 ± 0.4	5.1 ± 0.4	5.6 ± 0.8	6.3 ± 0.8
50-Year	0.78 ± 0.09	0.87	4.9 ± 0.3	5.0 ± 0.4	5.2 ± 0.4	5.7 ± 0.8	6.4 ± 0.8
100-Year	0.83 ± 0.11	0.94	4.9 ± 0.3	5.1 ± 0.4	5.2 ± 0.4	5.8 ± 0.8	6.4 ± 0.8

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[31] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[32] Storm surge residual estimated as Saint John tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 12. Zone 12: Saint John County - County Line to Cape Spencer

Zone 12: Saint John County - County Line to Cape Spencer, HHWLT 4.4 m ± 0.2 (CGVD28)[33]							
Return Period	**Surge Residual [34]**	**Residual + Uncertainty**	**Level 2010**	**Level 2030**	**Level 2050**	**Level 2100**	**Level 2100 + 0.65 m**
1-Year	0.46 ± 0.01	0.47	4.9 ± 0.2	5.0 ± 0.3	5.2 ± 0.3	5.7 ± 0.6	6.4 ± 0.6
2-Year	0.51 ± 0.03	0.54	4.9 ± 0.2	5.1 ± 0.3	5.3 ± 0.3	5.8 ± 0.6	6.5 ± 0.6
5-Year	0.59 ± 0.05	0.64	5.0 ± 0.2	5.2 ± 0.3	5.4 ± 0.3	5.9 ± 0.6	6.6 ± 0.6
10-Year	0.64 ± 0.07	0.71	5.1 ± 0.2	5.3 ± 0.3	5.4 ± 0.3	6.0 ± 0.6	6.6 ± 0.6
25-Year	0.72 ± 0.08	0.80	5.2 ± 0.2	5.4 ± 0.3	5.5 ± 0.3	6.1 ± 0.6	6.7 ± 0.6
50-Year	0.78 ± 0.09	0.87	5.3 ± 0.2	5.4 ± 0.3	5.6 ± 0.3	6.1 ± 0.6	6.8 ± 0.6
100-Year	0.83 ± 0.11	0.94	5.3 ± 0.2	5.5 ± 0.3	5.7 ± 0.3	6.2 ± 0.6	6.9 ± 0.6

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[33] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[34] Storm surge residual estimated as Saint John tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 13. Zone 13: Albert County - Alma to Hopewell (Shepody Bay)

Zone 13: Albert County - Alma to Hopewell (Shepody Bay), HHWLT 6.5 m ± 0.5 (CGVD28)[35]

Return Period	Surge Residual [36]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.53 ± 0.01	0.54	7.0 ± 0.5	7.2 ± 0.6	7.4 ± 0.6	7.9 ± 0.9	8.6 ± 0.9
2-Year	0.59 ± 0.03	0.62	7.1 ± 0.5	7.3 ± 0.6	7.4 ± 0.6	8.0 ± 0.9	8.6 ± 0.9
5-Year	0.68 ± 0.05	0.73	7.2 ± 0.5	7.4 ± 0.6	7.6 ± 0.6	8.1 ± 0.9	8.8 ± 0.9
10-Year	0.74 ± 0.07	0.81	7.3 ± 0.5	7.5 ± 0.6	7.6 ± 0.6	8.2 ± 0.9	8.8 ± 0.9
25-Year	0.83 ± 0.09	0.92	7.4 ± 0.5	7.6 ± 0.6	7.7 ± 0.6	8.3 ± 0.9	8.9 ± 0.9
50-Year	0.90 ± 0.10	1.00	7.5 ± 0.5	7.7 ± 0.6	7.8 ± 0.6	8.4 ± 0.9	9.0 ± 0.9
100-Year	0.95 ± 0.13	1.08	7.6 ± 0.5	7.8 ± 0.6	7.9 ± 0.6	8.5 ± 0.9	9.1 ± 0.9

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[35] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[36] Storm surge residual estimated as 115% Saint John tide gauge statistics (mean value + 95% range of uncertainty).

Table A- 14. Zone 14: Westmorland County - Rockport to Sackville

Zone 14: Westmorland County - Rockport to Sackville, HHWLT 7.5m ± 0.5 (CGVD28)[37]

Return Period	Surge Residual [38]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.54 ± 0.03	0.57	8.1 ± 0.5	8.3 ± 0.6	8.4 ± 0.6	9.0 ± 0.9	9.6 ± 0.9
2-Year	0.61 ± 0.04	0.65	8.2 ± 0.5	8.3 ± 0.6	8.5 ± 0.6	9.0 ± 0.9	9.7 ± 0.9
5-Year	0.71 ± 0.05	0.76	8.3 ± 0.5	8.4 ± 0.6	8.6 ± 0.6	9.1 ± 0.9	9.8 ± 0.9
10-Year	0.78 ± 0.07	0.85	8.4 ± 0.5	8.5 ± 0.6	8.7 ± 0.6	9.2 ± 0.9	9.9 ± 0.9
25-Year	0.88 ± 0.08	0.96	8.5 ± 0.5	8.6 ± 0.6	8.8 ± 0.6	9.3 ± 0.9	10.0 ± 0.9
50-Year	0.95 ± 0.09	1.04	8.5 ± 0.5	8.7 ± 0.6	8.9 ± 0.6	9.4 ± 0.9	10.1 ± 0.9
100-Year	1.02 ± 0.11	1.13	8.6 ± 0.5	8.8 ± 0.6	9.0 ± 0.6	9.5 ± 0.9	10.2 ± 0.9

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[37] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[38] Storm surge residual estimated as 120% Saint John tide gauge statistics (mean value + 95% range of uncertainty

Plausible Upper Bound Water Levels

Table A- 15. Plausible upper bound water levels (metres above CGVD28). [39]

Coastal Section	HHWLT (m) (CGVD28)	Sea-Level Rise (2100) + Error Bar (m)	100-Year Return Period Storm Surge + Error Bar (m)	Plausible Upper Bound Water Level (m) (CGVD28) by Year 2100	Plausible Upper Bound Water Level (m) (CGVD28) by Year 2100 + 0.65 m
Zone 1: Restigouche County	1.8	1.0	1.6	4.3	5.0
Zone 2: Gloucester County - County Line to Grande-Anse (inclusive)	1.6	1.0	1.6	4.2	4.9
Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage	1.4	1.1	1.3	3.8	4.4
Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County Line	1.1	1.1	1.3	3.5	4.2
Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau)	0.8	1.1	1.3	3.2	3.9
Zone 6: Northumberland County (Miramichi Bay)	1.1	1.1	1.7	3.9	4.6
Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive)	1.0	1.1	1.9	4.1	4.7

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[39] The Plausible Upper Bound Water Level is calculated as the sum of each of the components' value plus respective upper error bars of; HHWLT, sea-level rise to year 2100 and 100-year storm surge residual.

Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County Line	0.9	1.1	2.2	4.2	4.9
Zone 9: Westmorland County - County Line to Cape Spear	0.8	1.2	2.2	4.1	4.8
Zone 10: Westmorland County - Cape Spear to Port Elgin	1.3	1.2	2.2	4.6	5.3
Zone 11: Charlotte County	4.3	1.2	0.9	6.5	7.1
Zone 12: Saint John County - County Line to Cape Spencer	4.6	1.2	1.5	7.3	8.0
Zone 13: Albert County - Alma to Hopewell (Shepody Bay)	7.0	1.3	1.1	9.3	10.0
Zone 14: Westmorland County - Rockport to Sackville	8.0	1.3	1.1	10.4	11.0

Table A- 16. Plausible upper bound water levels – Saxby Gale, Bay of Fundy Zones (metres above CGVD28).

Coastal Section	HHWLT (m) (CGVD28)	Sea-Level Rise (2100) + Error Bar (m)	Saxby Gale Estimated Storm Surge (m)	Plausible Upper Bound Water Level (m) (CGVD28) by Year 2100	Plausible Upper Bound Water Level (m) (CGVD28) by Year 2100 + 0.65 m
Zone 11: Charlotte County (including Grand Manan)	4.3	1.2	2.0	7.5	8.2
Zone 12: Saint John County – Country Line to Cape Spencer	4.6	1.2	2.0	7.8	8.5
Zone 13: Albert County – Alma to Hopewell (Shepody Bay)	7.0	1.3	2.0	10.3	10.9
Zone 44: Westmorland County – Rockport to Sackville	8.0	1.3	2.0	11.3	12.0

11 Appendix B

Estimated Extreme Total Sea Levels for Years 2010, 2030, 2050 and 2100[40,41,42] (metres above reference-CGVD2013)

Table B- 1. Zone 1: Restigouche County

Zone 1: Restigouche County, HHWLT 1.4 m ± 0.1 (CGVD2013)[43]

Return Period	Surge Residual [44]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.02	0.61	2.0 ± 0.1	2.1 ± 0.2	2.2 ± 0.2	2.6 ± 0.5	3.2 ± 0.5
2-Year	0.70 ± 0.05	0.75	2.1 ± 0.1	2.2 ± 0.2	2.3 ± 0.2	2.7 ± 0.5	3.4 ± 0.5
5-Year	0.85 ± 0.09	0.94	2.3 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	2.9 ± 0.5	3.6 ± 0.5
10-Year	0.97 ± 0.12	1.09	2.5 ± 0.1	2.6 ± 0.2	2.7 ± 0.2	3.1 ± 0.5	3.7 ± 0.5
25-Year	1.11 ± 0.16	1.27	2.6 ± 0.1	2.8 ± 0.2	2.9 ± 0.2	3.2 ± 0.5	3.9 ± 0.5
50-Year	1.23 ± 0.19	1.42	2.8 ± 0.1	2.9 ± 0.2	3.0 ± 0.2	3.4 ± 0.5	4.0 ± 0.5
100-Year	1.34 ± 0.22	1.56	3.1 ± 0.1	3.2 ± 0.2	3.3 ± 0.2	3.7 ± 0.5	4.4 ± 0.5

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[40] Total Sea Level is defined as the sum of HHWLT, sea-level rise and storm surge return-period values for each return-period and for each of the years 2010, 2030, 2050 and 2100.

[41] Surge Residual uncertainty reflects the error bars between the mean surge and 95% uncertainty factor from *Storm Surge Extremal Analysis (Bernier, 2005)*

[42] Range of uncertainty for the Level 2010, 2030, 2050 and 2100 Extreme Total Sea Levels is the sum of the uncertainties for the HHWLT, Surge Residual and the respective Total Sea Level Changes from Table 5.

[43] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[44] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 2. Zone 2: Gloucester County - County Line to Grande-Anse (inclusive)

Zone 2: Gloucester County – County Line to Grande-Anse (Inclusive), HHWLT 0.9 m ± 0.1 (CGVD2013)[45]

Return Period	Surge Residual [46]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.02	0.61	1.6 ± 0.1	1.7 ± 0.2	1.8 ± 0.2	2.2 ± 0.5	2.9 ± 0.5
2-Year	0.70 ± 0.05	0.75	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.3 ± 0.5	3.0 ± 0.5
5-Year	0.85 ± 0.09	0.94	1.9 ± 0.1	2.0 ± 0.2	2.1 ± 0.2	2.5 ± 0.5	3.1 ± 0.5
10-Year	0.97 ± 0.12	1.09	2.0 ± 0.1	2.2 ± 0.2	2.3 ± 0.2	2.7 ± 0.5	3.3 ± 0.5
25-Year	1.11 ± 0.16	1.27	2.2 ± 0.1	2.3 ± 0.2	2.5 ± 0.2	2.9 ± 0.5	3.5 ± 0.5
50-Year	1.23 ± 0.19	1.42	2.4 ± 0.1	2.5 ± 0.2	2.6 ± 0.2	3.0 ± 0.5	3.7 ± 0.5
100-Year	1.34 ± 0.22	1.56	2.5 ± 0.1	2.6 ± 0.2	2.7 ± 0.2	3.2 ± 0.5	3.8 ± 0.5

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[45] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.
[46] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 3. Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage (inclusive)

Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage (inclusive), HHWLT 0.7 m ± 0.2 (CGVD2013)[47]

Return Period	Surge Residual [48][49]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.0	0.59	1.3 ± 0.2	1.5 ± 0.3	1.6 ± 0.3	2.0 ± 0.6	2.7 ± 0.6
2-Year	0.67 ± 0.0	0.67	1.4 ± 0.2	1.5 ± 0.3	1.7 ± 0.3	2.1 ± 0.6	2.7 ± 0.6
5-Year	0.79 ± 0.0	0.79	1.5 ± 0.2	1.7 ± 0.3	1.8 ± 0.3	2.2 ± 0.6	2.9 ± 0.6
10-Year	0.97 ± 0.0	0.97	1.7 ± 0.2	1.8 ± 0.3	2.0 ± 0.3	2.4 ± 0.6	3.0 ± 0.6
25-Year	1.11 ± 0.0	1.11	1.9 ± 0.2	2.0 ± 0.3	2.1 ± 0.3	2.5 ± 0.6	3.2 ± 0.6
50-Year	1.23 ± 0.0	1.23	2.0 ± 0.2	2.1 ± 0.3	2.2 ± 0.3	2.6 ± 0.6	3.3 ± 0.6
100-Year	1.34 ± 0.0	1.34	2.1 ± 0.2	2.2 ± 0.3	2.3 ± 0.3	2.8 ± 0.6	3.4 ± 0.6

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[47] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[48] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value).

[49] As per Daigle (2012, 2014), Surge Residual is limited to Mean value from Bernier (2005), hence range of uncertainty of 0.0.

Table B- 4. Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County

Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County Line, HHWLT 0.6 m ± 0.1 (CGVD2013)[50]							
Return Period	Surge Residual [51][52]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.0	0.59	1.2 ± 0.1	1.3 ± 0.2	1.4 ± 0.2	1.9 ± 0.5	2.5 ± 0.5
2-Year	0.67 ± 0.0	0.67	1.2 ± 0.1	1.4 ± 0.2	1.5 ± 0.2	1.9 ± 0.5	2.6 ± 0.5
5-Year	0.79 ± 0.0	0.79	1.4 ± 0.1	1.5 ± 0.2	1.6 ± 0.2	2.1 ± 0.5	2.7 ± 0.5
10-Year	0.97 ± 0.0	0.97	1.5 ± 0.1	1.7 ± 0.2	1.8 ± 0.2	2.2 ± 0.5	2.9 ± 0.5
25-Year	1.11 ± 0.0	1.11	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.0 ± 0.5
50-Year	1.23 ± 0.0	1.23	1.8 ± 0.1	1.9 ± 0.2	2.1 ± 0.2	2.5 ± 0.5	3.1 ± 0.5
100-Year	1.34 ± 0.0	1.34	1.9 ± 0.1	2.0 ± 0.2	2.2 ± 0.2	2.6 ± 0.5	3.3 ± 0.5

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[50] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[51] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value).

[52] As per Daigle (2012, 2014), Surge Residual is limited to Mean value from Bernier (2005), hence range of uncertainty of 0.0.

Table B- 5. Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau)

Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau), HHWLT 0.2 m ± 0.1 (CGVD2013)[53]

Return Period	Surge Residual [54][55]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.59 ± 0.0	0.59	0.8 ± 0.1	0.9 ± 0.2	1.0 ± 0.2	1.5 ± 0.5	2.1 ± 0.5
2-Year	0.67 ± 0.0	0.67	0.9 ± 0.1	1.0 ± 0.2	1.1 ± 0.2	1.6 ± 0.5	2.2 ± 0.5
5-Year	0.79 ± 0.0	0.79	1.0 ± 0.1	1.1 ± 0.2	1.2 ± 0.2	1.7 ± 0.5	2.3 ± 0.5
10-Year	0.97 ± 0.0	0.97	1.2 ± 0.1	1.3 ± 0.2	1.4 ± 0.2	1.9 ± 0.5	2.5 ± 0.5
25-Year	1.11 ± 0.0	1.11	1.3 ± 0.1	1.4 ± 0.2	1.6 ± 0.2	2.0 ± 0.5	2.7 ± 0.5
50-Year	1.23 ± 0.0	1.23	1.4 ± 0.1	1.6 ± 0.2	1.7 ± 0.2	2.1 ± 0.5	2.8 ± 0.5
100-Year	1.34 ± 0.0	1.34	1.5 ± 0.1	1.7 ± 0.2	1.8 ± 0.2	2.2 ± 0.5	2.9 ± 0.5

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[53] Specific value (i.e. zero uncertainty) for HHWLT based on 2013-2014 Study.

[54] Storm surge residual estimated as average between Rivière-au-Renard and Escuminac tide gauge statistics (mean value).

[55] As per Daigle (2012, 2014), Surge Residual is limited to Mean value from Bernier (2005), hence range of uncertainty of 0.0.

Table B- 6. Zone 6: Northumberland County (Miramichi Bay)

Zone 6: Northumberland County (Miramichi Bay), HHWLT 0.5 m ± 0.1 (CGVD2013)[56]

Return Period	Surge Residual [57]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.61 ± 0.02	0.63	1.1 ± 0.1	1.3 ± 0.2	1.4 ± 0.2	1.9 ± 0.5	2.5 ± 0.5
2-Year	0.74 ± 0.05	0.79	1.3 ± 0.1	1.4 ± 0.2	1.6 ± 0.2	2.0 ± 0.5	2.7 ± 0.5
5-Year	0.91 ± 0.09	1.00	1.5 ± 0.1	1.6 ± 0.2	1.8 ± 0.2	2.2 ± 0.5	2.9 ± 0.5
10-Year	1.04 ± 0.12	1.16	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.0 ± 0.5
25-Year	1.21 ± 0.16	1.37	1.9 ± 0.1	2.0 ± 0.2	2.1 ± 0.2	2.6 ± 0.5	3.3 ± 0.5
50-Year	1.34 ± 0.19	1.53	2.0 ± 0.1	2.2 ± 0.2	2.3 ± 0.2	2.8 ± 0.5	3.4 ± 0.5
100-Year	1.47 ± 0.22	1.69	2.2 ± 0.1	2.3 ± 0.2	2.5 ± 0.2	2.9 ± 0.5	3.6 ± 0.5

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[56] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[57] Storm surge residual estimated as Escuminac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 7. Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive)

Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive), HHWLT 0.3 m ± 0.1 (CGVD2013)[58]

Return Period	Surge Residual [59]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.74 ± 0.04	0.78	1.1 ± 0.1	1.2 ± 0.2	1.4 ± 0.2	1.8 ± 0.5	2.5 ± 0.5
2-Year	0.88 ± 0.08	0.96	1.3 ± 0.1	1.4 ± 0.2	1.5 ± 0.2	2.0 ± 0.5	2.7 ± 0.5
5-Year	1.06 ± 0.12	1.18	1.5 ± 0.1	1.6 ± 0.2	1.8 ± 0.2	2.2 ± 0.5	2.9 ± 0.5
10-Year	1.20 ± 0.16	1.36	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.1 ± 0.5
25-Year	1.38 ± 0.21	1.61	1.9 ± 0.1	2.1 ± 0.2	2.2 ± 0.2	2.7 ± 0.5	3.3 ± 0.5
50-Year	1.51 ± 0.24	1.75	2.1 ± 0.1	2.2 ± 0.2	2.3 ± 0.2	2.8 ± 0.5	3.5 ± 0.5
100-Year	1.65 ± 0.28	1.93	2.2 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	3.0 ± 0.5	3.6 ± 0.5

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[58] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.
[59] Storm surge residual estimated as average between Escuminac and Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 8. Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County

Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County Line, HHWLT 0.3 m ± 0.1 (CGVD2013)[60]							
Return Period	Surge Residual [61]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.87 ± 0.05	0.92	1.2 ± 0.1	1.4 ± 0.2	1.5 ± 0.2	2.0 ± 0.5	2.6 ± 0.5
2-Year	1.01 ± 0.10	1.10	1.4 ± 0.1	1.6 ± 0.2	1.7 ± 0.2	2.2 ± 0.5	2.8 ± 0.5
5-Year	1.21 ± 0.15	1.36	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.1 ± 0.5
10-Year	1.35 ± 0.19	1.54	1.8 ± 0.1	2.0 ± 0.2	2.1 ± 0.2	2.6 ± 0.5	3.3 ± 0.5
25-Year	1.54 ± 0.25	1.79	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.9 ± 0.5	3.5 ± 0.5
50-Year	1.69 ± 0.29	1.98	2.3 ± 0.1	2.4 ± 0.2	2.6 ± 0.2	3.0 ± 0.5	3.7 ± 0.5
100-Year	1.83 ± 0.34	2.17	2.5 ± 0.1	2.6 ± 0.2	2.8 ± 0.2	3.2 ± 0.5	3.9 ± 0.5

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[60] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.
[61] Storm surge residual estimated as Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 9. Zone 9: Westmorland County - County Line to Cape Spear

Zone 9: Westmorland County - County Line to Cape Spear, HHWLT 0.1 m ± 0.1 (CGVD2013)[62]

Return Period	Surge Residual [63]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.87 ± 0.05	0.92	1.0 ± 0.1	1.2 ± 0.2	1.3 ± 0.2	1.8 ± 0.5	2.4 ± 0.5
2-Year	1.01 ± 0.10	1.11	1.2 ± 0.1	1.4 ± 0.2	1.5 ± 0.2	2.0 ± 0.5	2.6 ± 0.5
5-Year	1.21 ± 0.15	1.36	1.5 ± 0.1	1.6 ± 0.2	1.8 ± 0.2	2.2 ± 0.5	2.9 ± 0.5
10-Year	1.35 ± 0.19	1.54	1.6 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.1 ± 0.5
25-Year	1.54 ± 0.25	1.79	1.9 ± 0.1	2.1 ± 0.2	2.2 ± 0.2	2.7 ± 0.5	3.3 ± 0.5
50-Year	1.69 ± 0.29	1.98	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.9 ± 0.5	3.5 ± 0.5
100-Year	1.83 ± 0.34	2.17	2.3 ± 0.1	2.4 ± 0.2	2.6 ± 0.2	3.0 ± 0.5	3.7 ± 0.5

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[62] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[63] Storm surge residual estimated as Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 10. Zone 10: Westmorland County - Cape Spear to Port Elgin

Zone 10: Westmorland County - Cape Spear to Port Elgin, HHWLT 0.7 m ± 0.1 (CGVD2013)[64]

Return Period	Surge Residual [65]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.87 ± 0.05	0.92	1.6 ± 0.1	1.8 ± 0.2	1.9 ± 0.2	2.4 ± 0.5	3.1 ± 0.5
2-Year	1.01 ± 0.10	1.11	1.8 ± 0.1	2.0 ± 0.2	2.1 ± 0.2	2.6 ± 0.5	3.2 ± 0.5
5-Year	1.21 ± 0.15	1.36	2.1 ± 0.1	2.2 ± 0.2	2.4 ± 0.2	2.8 ± 0.5	3.5 ± 0.5
10-Year	1.35 ± 0.19	1.54	2.2 ± 0.1	2.4 ± 0.2	2.5 ± 0.2	3.0 ± 0.5	3.7 ± 0.5
25-Year	1.54 ± 0.25	1.79	2.5 ± 0.1	2.7 ± 0.2	2.8 ± 0.2	3.3 ± 0.5	3.9 ± 0.5
50-Year	1.69 ± 0.29	1.98	2.7 ± 0.1	2.8 ± 0.2	3.0 ± 0.2	3.5 ± 0.5	4.1 ± 0.5
100-Year	1.83 ± 0.34	2.17	2.9 ± 0.1	3.0 ± 0.2	3.2 ± 0.2	3.7 ± 0.5	4.3 ± 0.5

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[64] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[65] Storm surge residual estimated as Shediac tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 11. Zone 11: Charlotte County (including Grand Manan)

Zone 11: Charlotte County (including Grand Manan), HHWLT 3.5 m ± 0.3 (CGVD2013)[66]

Return Period	Surge Residual [67]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.46 ± 0.01	0.47	4.0 ± 0.3	4.1 ± 0.4	4.3 ± 0.4	4.8 ± 0.8	5.5 ± 0.8
2-Year	0.51 ± 0.03	0.54	4.0 ± 0.3	4.2 ± 0.4	4.3 ± 0.4	4.9 ± 0.8	5.5 ± 0.8
5-Year	0.59 ± 0.05	0.64	4.1 ± 0.3	4.3 ± 0.4	4.4 ± 0.4	5.0 ± 0.8	5.6 ± 0.8
10-Year	0.64 ± 0.07	0.71	4.2 ± 0.3	4.4 ± 0.4	4.5 ± 0.4	5.1 ± 0.8	5.7 ± 0.8
25-Year	0.72 ± 0.08	0.80	4.3 ± 0.3	4.5 ± 0.4	4.6 ± 0.4	5.1 ± 0.8	5.8 ± 0.8
50-Year	0.78 ± 0.09	0.87	4.4 ± 0.3	4.5 ± 0.4	4.7 ± 0.4	5.2 ± 0.8	5.9 ± 0.8
100-Year	0.83 ± 0.11	0.94	4.4 ± 0.3	4.6 ± 0.4	4.7 ± 0.4	5.3 ± 0.8	5.9 ± 0.8

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[66] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[67] Storm surge residual estimated as Saint John tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 12. Zone 12: Saint John County - County Line to Cape Spencer

Zone 12: Saint John County - County Line to Cape Spencer, HHWLT 3.8 m ± 0.2 (CGVD2013)[68]

Return Period	Surge Residual [69]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.46 ± 0.01	0.47	4.3 ± 0.2	4.4 ± 0.3	4.6 ± 0.3	5.1 ± 0.6	5.8 ± 0.6
2-Year	0.51 ± 0.03	0.54	4.3 ± 0.2	4.5 ± 0.3	4.7 ± 0.3	5.2 ± 0.6	5.9 ± 0.6
5-Year	0.59 ± 0.05	0.64	4.4 ± 0.2	4.6 ± 0.3	4.8 ± 0.3	5.3 ± 0.6	6.0 ± 0.6
10-Year	0.64 ± 0.07	0.71	4.5 ± 0.2	4.7 ± 0.3	4.8 ± 0.3	5.4 ± 0.6	6.0 ± 0.6
25-Year	0.72 ± 0.08	0.80	4.6 ± 0.2	4.8 ± 0.3	4.9 ± 0.3	5.5 ± 0.6	6.1 ± 0.6
50-Year	0.78 ± 0.09	0.87	4.7 ± 0.2	4.8 ± 0.3	5.0 ± 0.3	5.5 ± 0.6	6.2 ± 0.6
100-Year	0.83 ± 0.11	0.94	4.7 ± 0.2	4.9 ± 0.3	5.1 ± 0.3	5.6 ± 0.6	6.3 ± 0.6

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[68] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[69] Storm surge residual estimated as Saint John tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 13. Zone 13: Albert County - Alma to Hopewell (Shepody Bay)

Zone 13: Albert County - Alma to Hopewell (Shepody Bay), HHWLT 5.8 m ± 0.5 (CGVD2013)[70]

Return Period	Surge Residual [71]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.53 ± 0.01	0.54	6.3 ± 0.5	6.5 ± 0.6	6.7 ± 0.6	7.2 ± 0.9	7.9 ± 0.9
2-Year	0.59 ± 0.03	0.62	6.4 ± 0.5	6.6 ± 0.6	6.7 ± 0.6	7.3 ± 0.9	7.9 ± 0.9
5-Year	0.68 ± 0.05	0.73	6.5 ± 0.5	6.7 ± 0.6	6.9 ± 0.6	7.4 ± 0.9	8.1 ±0.9
10-Year	0.74 ± 0.07	0.81	6.6 ± 0.5	6.8 ± 0.6	6.9 ± 0.6	7.5 ± 0.9	8.1 ± 0.9
25-Year	0.83 ± 0.09	0.92	6.7 ± 0.5	6.9 ± 0.6	7.0 ± 0.6	7.6 ± 0.9	8.2 ± 0.9
50-Year	0.90 ± 0.10	1.00	6.8 ± 0.5	7.0 ± 0.6	7.1 ± 0.6	7.7 ± 0.9	8.3 ± 0.9
100-Year	0.95 ± 0.13	1.08	6.9 ± 0.5	7.1 ± 0.6	7.2 ± 0.6	7.8 ± 0.9	8.4 ± 0.9

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[70] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.

[71] Storm surge residual estimated as 115% Saint John tide gauge statistics (mean value + 95% range of uncertainty).

Table B- 14. Zone 14: Westmorland County - Rockport to Sackville

Zone 14: Westmorland County - Rockport to Sackville, HHWLT 6.8 m ± 0.5 (CGVD2013)[72]

Return Period	Surge Residual [73]	Residual + Uncertainty	Level 2010	Level 2030	Level 2050	Level 2100	Level 2100 + 0.65 m
1-Year	0.54 ± 0.03	0.57	7.4 ± 0.5	7.6 ± 0.6	7.7 ± 0.6	8.3 ± 0.9	8.9 ± 0.9
2-Year	0.61 ± 0.04	0.65	7.5 ± 0.5	7.6 ± 0.6	7.8 ± 0.6	8.3 ± 0.9	9.0 ± 0.9
5-Year	0.71 ± 0.05	0.76	7.6 ± 0.5	7.7 ± 0.6	7.9 ± 0.6	8.4 ± 0.9	9.1 ± 0.9
10-Year	0.78 ± 0.07	0.85	7.7 ± 0.5	7.8 ± 0.6	8.0 ± 0.6	8.5 ± 0.9	9.2 ± 0.9
25-Year	0.88 ± 0.08	0.96	7.8 ± 0.5	7.9 ± 0.6	8.1 ± 0.6	8.6 ± 0.9	9.3 ± 0.9
50-Year	0.95 ± 0.09	1.04	7.8 ± 0.5	8.0 ± 0.6	8.2 ± 0.6	8.7 ± 0.9	9.4 ± 0.9
100-Year	1.02 ± 0.11	1.13	7.9 ± 0.5	8.1 ± 0.6	8.3 ± 0.6	8.8 ± 0.9	9.5 ± 0.9

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[72] Range of uncertainty represents the difference between the selected HHWLT value for Zone and the range of HHWLT values for Zone.
[73] Storm surge residual estimated as 120% Saint John tide gauge statistics (mean value + 95% range of uncertainty

Plausible Upper Bound Water Levels

Table B- 15. Plausible upper bound water levels (metres above CGVD2013). [74]

Coastal Section	HHWLT (m) (CGVD2013)	Sea-Level Rise (2100) + Error Bar (m)	100-Year Return Period Storm Surge + Error Bar (m)	Plausible Upper Bound Water Level (m) (CGVD2013) by Year 2100	Plausible Upper Bound Water Level (m) (CGVD2013) by Year 2100 + 0.65 m
Zone 1: Restigouche County	1.5	1.0	1.6	4.0	4.7
Zone 2: Gloucester County - County Line to Grande-Anse (inclusive)	1.0	1.0	1.6	3.6	4.3
Zone 3: Gloucester County - Grande-Anse to Pointe-Sauvage	0.9	1.1	1.3	3.3	4.0
Zone 4: Gloucester County - Pointe-Sauvage to Northumberland County Line	0.7	1.1	1.3	3.1	3.7
Zone 5: Gloucester County - Tracadie-Sheila (Tracadie Bay including Val-Comeau)	0.3	1.1	1.3	2.7	3.4
Zone 6: Northumberland County (Miramichi Bay)	0.6	1.1	1.7	3.4	4.1
Zone 7: Kent County - County Line to Saint Édouard-de-Kent (inclusive)	0.4	1.1	1.9	3.5	4.1

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[74] The Plausible Upper Bound Water Level is calculated as the sum of each of the components' value plus respective upper error bars of; HHWLT, sea-level rise to year 2100 and 100-year storm surge residual.

Zone 8: Kent County - Saint-Édouard-de-Kent to Westmorland County Line	0.4	1.1	2.2	3.7	4.4
Zone 9: Westmorland County - County Line to Cape Spear	0.2	1.2	2.2	3.6	4.2
Zone 10: Westmorland County - Cape Spear to Port Elgin	0.8	1.2	2.2	4.1	4.8
Zone 11: Charlotte County	3.8	1.2	0.9	6.0	6.6
Zone 12: Saint John County - County Line to Cape Spencer	4.0	1.2	1.5	6.7	7.4
Zone 13: Albert County - Alma to Hopewell (Shepody Bay)	6.3	1.3	1.1	8.6	9.3
Zone 14: Westmorland County - Rockport to Sackville	7.3	1.3	1.1	9.7	10.3

Saxby Gale like event at Year 2100

Table B- 16. Plausible upper bound water levels – Saxby Gale, Bay of Fundy Zones (metres above CGVD2013).

Coastal Section	HHWLT (m) (CGVD2013)	Sea-Level Rise (2100) + Error Bar (m)	Saxby Gale Estimated Storm Surge (m)	Plausible Upper Bound Water Level (m) (CGVD2013) by Year 2100	Plausible Upper Bound Water Level (m) (CGVD2013) by Year 2100 + 0.65 m
Zone 11: Charlotte County (including Grand Manan)	3.8	1.2	2.0	7.0	7.7
Zone 12: Saint John County – Country Line to Cape Spencer	4.0	1.2	2.0	7.2	7.9
Zone 13: Albert County – Alma to Hopewell (Shepody Bay)	6.3	1.3	2.0	9.6	10.2
Zone 44: Westmorland County – Rockport to Sackville	7.3	1.3	2.0	10.6	11.2