Atlantic Climate Adaptation Solutions Association
Solutions d'adaptation aux changements climatiques pour l'Atlantique

Flood Risk and Vulnerability Analysis Project

Submitted by :
AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
133 Crosbie Road, PO Box 13216
St. John's, Newfoundland & Labrador
Canada, A1B 4A5

June 13, 2012

Report prepared by: AMEC Environmental and Infrastructure and commissioned by the Atlantic Climate Adaptation Solutions Association (ACASA), a non-profit organization formed to coordinate project management and planning for climate change adaptation initiatives in Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland and Labrador and supported through the Regional Adaptation Collaborative, a joint undertaking between the Atlantic provinces, Natural Resources Canada and regional municipalities and other partners.

Project management: Policy and Planning Division and the Water Resources Management Division of the Department of Environment and Conservation, Newfoundland and Labrador. Phone: (709)729-0027.

This report is also available for download from the ACASA website at:
www.atlanticadaptation.ca

GOVERNMENT OF
NEWFOUNDLAND AND LABRADOR

FLOOD RISK AND VULNERABILITY ANALYSIS PROJECT

Submitted to:

Water Resources Management Division
Department of Environment and Conservation
Government of Newfoundland and Labrador

Submitted by:

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
133 Crosbie Road, PO Box 13216
St. John's, Newfoundland & Labrador
Canada, A1B 4A5

June 13, 2012
TA1112733

This page left blank intentionally

June 13, 2012

AMEC Project #TA1112733

To: Department of Environment and Conservation
Government of Newfoundland and Labrador
4th Floor, Confederation Building, West Block
PO Box 8700, St. John's, NL
Canada A1B 4J6

Attn: Mr. Amir Ali Khan, Ph.D, P.Eng
Manager
Hydrologic Modelling Section
Water Resources Management Division

Dear Mr. Khan

Re: Flood Risk And Vulnerability Analysis Project
Draft Report

AMEC Environment & Infrastructure, a division of AMEC Americas Limited (AMEC), is pleased to provide the attached final report for the above noted project.

Yours truly,
AMEC Environment & Infrastructure,
a division of AMEC Americas Limited

J. Chris Innes
Information Management Group Lead
Ottawa, Ontario

Peter Nimmrichter, M.Eng. P.Eng.
Senior Water Resources Engineer
Mississauga, Ontario

This page left blank intentionally

EXECUTIVE SUMMARY

The Government of Newfoundland and Labrador, Department of Environment and Conservation, Water Resources Management Division (WRMD), in conjunction with the federal government, has worked to reduce the human hardship and economic loss caused by floods, through the Canada-Newfoundland Flood Damage Reduction Program. Work under this program was carried out from 1981 to 1993. From 1993 to 1996 further flood studies were carried out under the federal-provincial "*General Agreement Respecting Water Resource Management*". Flood plain mapping associated with thirty-seven (37) communities was developed in this time frame.

The Province's *Policy for Flood Plain Management*, administered through the *Water Resources Act, 2002*, regulates development in designated flood plains. In 2010, climate change flood plains were added to the policy.

In 2009, the WRMD initiated new studies focused on both the development of flood plain mapping for communities which had not previously had such mapping; and update studies for communities which previously had flood plain mapping but which were considered out of date.

However, with over 500 communities across the Province and limited budgets to complete such studies, a framework was required to assist the Provincial Government in choosing communities which would most benefit from assistance with flood risk mitigation and adaptation.

The present study, the Flood Risk and Vulnerability Analysis Project, will assist the Provincial Government to:

- Understand the historical context of flooding in the Province;
- Understand land use changes to watersheds in the Province;
- Identify potential impacts of the changing climate;
- Identify communities vulnerable to flooding that should be considered for new or updated flood risk mapping studies;
- Identify communities vulnerable to flooding that should be considered for flood forecasting and flood warning systems; and,
- Identify flood risk mitigation and/or adaptation opportunities.

The Flood Events Inventory

The Flood Events Inventory is a database of flood events which have occurred in the Province over the period 1950-2011. The database was compiled through a review of existing information contained in the previous Flood Events Inventory and the collection and compilation of new data. The updated inventory now documents 650 flood events and 269 storm events over the period 1950 to 2011. The inventory documents flood events at ninety-eight (98) communities in the Province. Rainfall events result in the greatest number of flood events representing the causal event in 66% of the flood events in the inventory. Other casual factors include coastal processes, snow melt and ice jams. The average annual damage associated with flooding is estimated to be between $8.1 million and $22.5 million.

Land Use Change

A land cover classification analysis was conducted in thirty-nine community flood watersheds across the island of Newfoundland. Across the thirty-nine community flood watersheds assessed, only one did not experience a loss of forest cover over the assessment period. The other community flood watersheds experienced loss of forest cover in the range of about 4% to almost 28%.

Climate Change

The particular time frames of interest for the climate change assessment were 2020, 2050 and 2080. Areas of focus for the climate change assessment were projected climate, hurricanes and tropical storms, sea level rise, ocean currents, and some possible worst case scenarios.

Precipitation is anticipated to increase in the future as average temperatures rise across the Province. This represents an influence towards increased flood risk across the Province, especially in winter for all WRMD regions. Additionally, storms are expected to mature into more intense hurricanes (higher category) and are expected to have an increased ability to survive their track towards Atlantic Canada, arriving with more force as the increasing water temperatures south of Newfoundland will not provide as much resistance to promote weakening as experienced before the 1990's.

Sea level is an ocean indicator for climate change. Sea level in the Province has been observed to be rising relative to benchmarks and wharf deck elevations.

The two major ocean currents that influence the local weather and global climate of Newfoundland are the Labrador Current and the Gulf Stream. These currents, which exert a major influence on Newfoundland and Labrador climate, are not expected to change significantly as a result of global warming over this century.

Worst case scenarios are intense phenomena that may occur in isolation or in combination with other events, or circumstances that could lead to extreme water levels and hence flooding conditions. A preliminary, largely qualitative, assessment of scenarios that could lead to extreme flooding in parts of Newfoundland and Labrador was completed, focusing on winter rain, weather bombs, hurricanes and tropical storms, and severe summer weather. While these phenomena are considered rare, most of these events have occurred in the past and are likely to occur again.

Assessing the Need for New or Updated Flood Risk Mapping

The objective of this project task was the identification of communities vulnerable to flooding that should be considered for new or updated flood risk mapping studies. This assessment was founded on the updated Flood Events Inventory, the re-assessment of Flood Risk Maps, a detailed review of the technical components comprising the existing flood plain maps and linkage of a variety of datasets relevant to flood risk assessment in the Province. A decision matrix was developed outlining community ranking based on the prioritization parameters.

Assessing Need for Flood Forecasting / Flood Warning System

The objective of this task was to identify communities vulnerable to flooding that should be considered for flood forecasting and/or flood warning systems. The task was completed through a review of historical flood observations (i.e., the Flood Events Inventory) and existing flood hazard and risk maps, combined with ancillary data on precipitation, topography, lifelines (roads, bridges, etc.), and with census information on population densities, types, and fluxes.

The methodology used for this study generally consisted of identifying vulnerable communities and subsequently assessing their susceptibility to direct and indirect effects of flooding. First, potentially vulnerable communities were identified by reviewing the event frequency and damage estimates contained in the updated Flood Events Inventory. After communities were identified, the physical hazard for each community was assessed. The next step was to determine each community's vulnerability to the direct effects of flooding (e.g., inundation). Third, potential indirect effects, such as isolation, were assessed for each of the identified communities. Finally, the results of each of the above steps are summarised in a decision matrix, highlighting those communities that should be considered for flood forecasting and/or flood warning systems.

Identifying Flood Vulnerability Mitigation and Adaptation Strategies

An integrated strategy is required that will stipulate the WRMD's goals, objectives and actions to reduce the vulnerability of the Province to effects of floods; but which recognize the size of individual communities, their flood vulnerabilities, and the potential for loss of both life and property. These Integrated Flood Management (IFM) plans depend critically on the hydrological and hydraulic characteristics of the subject river system and region. A decision matrix was developed integrating the three linked factors that determined which strategy or combination of strategies is likely to be appropriate in a particular river basin, namely: the climate, the basin characteristics and the socio-economic conditions in the region. Mitigation strategies, organized into Structural and Non-Structural categories, were presented for eleven Sub-regions of Newfoundland. These strategies represent a first set of options for communities to consider towards reduction of flood risk, minimization of flood damages and threats to public safety, and to expedite the post-flood recovery process.

This page left blank intentionally

SUMMARY

The Government of Newfoundland and Labrador, Department of Environment and Conservation, Water Resources Management Division (WRMD), in conjunction with the federal government, has worked to reduce the human hardship and economic loss of floods through the Canada-Newfoundland Flood Damage Reduction Program. Work under this program was carried out from 1981 to 1993. From 1993 to 1996 further flood studies were carried out under the federal-provincial "*General Agreement Respecting Water Resource Management*". Flood plain mapping associated with thirty-seven (37) communities was developed in this time frame.

The Province's *Policy for Flood Plain Management*, administered through the *Water Resources Act, 2002*, regulates development in designated flood plains. In 2010, climate change flood plains were added to the policy.

In 2009, the WRMD initiated new studies focused at both development of flood plain mapping for communities which had not previously had such mapping and update studies for communities which previously had flood plain mapping but which were considered out of date.

However, with over 500 communities across the Province and limited budgets to complete such studies, a framework was required to assist the Provincial Government to choose communities which would most benefit from assistance with flood risk mitigation and adaptation.

The present study, the Flood Risk and Vulnerability Analysis Project, will assist the Provincial Government to:

- Understand the historical context of flooding in the Province;
- Understand land use changes to watersheds in the Province;
- Identify potential impacts of the changing climate;
- Identify communities vulnerable to flooding that should be considered for new or updated flood risk mapping studies;
- Identify communities vulnerable to flooding that should be considered for flood forecasting and flood warning systems; and,
- Identify flood risk mitigation and/or adaptation opportunities.

The Flood Events Inventory

The Flood Events Inventory is a database of flood events which have occurred in the Province over the period 1950-2011. The database was compiled through a review of existing information contained in the previous Flood Events Inventory and the collection and compilation of new data. The updated inventory now documents 650 flood events and 269 storm events over the period 1950 to 2011.

The Eastern and Western regions have more documented flood producing storm events than the Central region with a total of 148, 91, 29 storm events documented in the inventory, respectively.

The inventory documents flood events at ninety-eight (98) communities in the Province. St. John’s has had the most reported floods with seventy-three or about 11% of the documented floods in the inventory. Stephenville, Corner Brook, Deer Lake and Placentia have all reported multiple floods. Flooding in Labrador is extremely rare with only one documented flood event in the current inventory.

Rainfall events result in the greatest number of flood events representing the causal event in 66% of the flood events in the inventory. Flood events associated with coastal events occur most frequently in the fall and winter. Together, flood events resulting from rainfall or coastal processes represent 87% of the events documented in the inventory. Other casual factors include snow melt and ice jams.

Beyond simply documenting location and date/time of a flood or storm, the Inventory also includes damage estimates, and some basic information about impacts (homes flooded, people displaced, etc.). A link to the source information for the data record is also defined.

Two sources of damages data are presently available in the Flood Event Inventory, namely; damage estimates abstracted from the source data and Disaster Financial Assistance Arrangements (DFAA) damage estimates.

Of the 650 flood events in the Flood Events Inventory, only fifty-three flood events have damage estimates [based on source data reports] totalling about $252 million (normalized to 2011 dollars). Damage estimates range from a few thousand dollars to over $100 million associated with Hurricane Igor in 2010. Eighteen flood events in the inventory have documented damages of $1 million or more. The average annual cost is estimated to be about $8.1 million over the period (1962-2011) represented by data records with damage information (i.e., $252M/31) or $4.5 million (i.e., $252M/56) if it is assumed that years with no recorded flood damages are taken into account.

Similarly, eleven flood events have damage estimates (based on DFAA Damage Reports) totalling about $180 million (normalized to 2011 dollars). All DFAA damage estimates are greater than $1 million. The average annual cost is estimated to be about $22.5 million over the period (2000-2010) represented by data records with damage information (i.e., $180M/8) or $16.3 million (i.e., $180M/11) if it is assumed that years with no recorded flood damages are taken into account.

It is suspected that average annual damages may be higher as many of the records in the inventory lack damages estimate data.

Land Use Change

A pre-cursor effort to the land use change analysis was the development of digital community flood watersheds. A community flood watershed is defined by the Water Resources Management Division (WRMD) as a “watershed for a community / water body that has experienced a documented flood event”. It includes all areas of the watershed upstream of the community.

A land cover classification analysis was conducted in the thirty-nine community flood watersheds across the island of Newfoundland. Seven (7) land cover classes were identified from 10-meter resolution, 4-band multispectral SPOT imagery captured between 2005 and 2010. Additionally, two (2) land cover change classes, deforested areas due to development and other deforested areas were derived from Earth Observation for Sustainable Development of Forests data which was generated from 30-meter Landsat satellite imagery from the year 2000. The resulting nine (9) classes of land cover represent both time periods and were summarized for each of the thirty-nine watersheds.

Across the thirty-nine community flood watersheds assessed, only one did not experience a loss of forest cover over the assessment period, namely Hant’s Harbour. The other community flood watersheds experienced loss of forest cover in the range of about 4% to almost 28%.

Climate Change

Infrastructure, whether built, human or natural, is critically important to individuals and communities. The purpose of infrastructure is to protect the life, health, and social welfare of all of its inhabitants from the weather elements, to host economic activities and to sustain aesthetic and cultural values. When infrastructure fails under extreme weather conditions and can no longer provide services to communities, the result is often a disaster. As the climate changes, it is likely that risks for infrastructure failure will increase as weather patterns shift and extreme weather conditions become more variable and regionally more intense. Since infrastructure underpins so many economic activities of societies, these impacts will be significant and will require adaptation measures.

The particular time frames of interest for the climate change assessment were 2020, 2050 and 2080. Areas of focus for the climate change assessment were projected climate, hurricanes and tropical storms, sea level rise, ocean currents, and some possible worst case scenarios.

Precipitation is anticipated to increase into the future as average temperatures rise across the Province. Summer precipitation on the island remains basically neutral in the first half of the century with mild increases thereafter while Labrador sees a steady rise in summer precipitation. There is a clear steady rise in winter precipitation across all WRMD regions through the century. The differential change in precipitation across the island’s three WRMD regions is very small. The West sees slightly larger winter increases while Labrador shows large steady increases in both summer and winter. This represents an influence towards increased flood risk across the Province, especially in winter for all WRMD regions. Winter thaws and rain events could lead to increases in rain on snow flooding. Winter rains also lead to greater risk of rain on frozen ground events where the ground's ability to absorb liquid is compromised.

On average, Newfoundland and Labrador is affected, or threatened, by one or two tropical storm systems each year, based on 21 tropical storms tracking across or near Newfoundland and Labrador from 1954 – 2011.

Climate change currently being experienced across much of the globe, including Newfoundland and Labrador, will continue to promote an increase in the frequency of tropical cyclone development over the Tropical Atlantic through the end of the 21st century. Additionally, storms are expected to mature into more intense hurricanes (higher category) and are expected to have an increased ability to survive their track towards Atlantic Canada, arriving with more force as the increasing water temperatures south of Newfoundland will not provide as much resistance to promote weakening as experienced before the 1990's.

Hurricanes, with their combination of abundant rains over wide areas and strong winds producing significant storm surge and waves, have, like Hurricane Igor, caused some of the worst and costliest floods in Newfoundland. With increased frequencies and intensities anticipated in the coming decades, flooding events of the magnitude of Hurricane Igor, a Category 1 storm, are likely to occur more frequently. As Atlantic sea surface temperatures warm, the probability of another Category 2 hurricane making landfall in Newfoundland increases. In addition, it would not be unrealistic to expect a first Category 3 hurricane to make landfall in Newfoundland before 2080, perhaps before 2050.

Sea level is an ocean indicator for climate change. Sea level in the Province has been observed to be rising relative to benchmarks and wharf deck elevations. The rate of global mean sea level rise is presently estimated at about 3 mm/year, yet another confirmation that global warming is already underway. There are regional differences also. For the North Atlantic, a comparable rate of about 2.5 mm/year is estimated. These rates may increase with continued melting of the polar ice caps and warming of the oceans.

Sea level also changes locally in relation to the geological uplift or subsidence of the earth which is in response to the retreat of the ice sheets that covered and depressed the land during the last glaciation, some 10,000 to 20,000 years ago. Though uplift has slowed since the glacial sheet melted, it is still occurring at different rates over the Province. Geophysical modelling indicates uplift rates of 0 to 4 mm/year for Labrador and the Northern Peninsula, and subsidence rates of 0 to 2 mm/year for Newfoundland. The net long term sea level effect is the sum of global sea level changes and local geological impact.

The two major currents that influence the local weather and global climate of Newfoundland are the Labrador Current and the Gulf Stream. The Labrador Current carries cold and relatively fresh water from the Arctic south along the continental shelf and slope of Labrador and Newfoundland. The Gulf Stream brings warm and salty water north from the Gulf of Mexico along the continental slope of North America. It veers to the northeast away from the continent at Cape Hatteras and flows eastward just south of the Grand Banks, occasionally moving north onto their southern edge. The presence of the air masses over the two currents, moist and cold over the Labrador Current, moist and warm over the Gulf Stream, directly affects the temperature, precipitation and formation of fog, especially on the eastern coastal region of the island of Newfoundland.

The ocean currents which exert a major influence on Newfoundland and Labrador climate are not expected to change significantly as a result of global warming over this century. The ocean-atmosphere oscillations that are responsible, to some extent, for the observed decadal (and longer) cycles in warmer and colder periods and periods with greater tropical storm intensity, continue through to the end of this century, if not beyond. Their periodicity and intensity may change somewhat over the coming decades and tracking those may help to predict climate anomalies in particular years or series of years in the future. But because these planetary scale general circulation features are in all likelihood well handled by global climate models, the gradual upward trends in temperature and precipitation seen out to 2050 and 2080 likely capture the long term effects of the small changes in these large ocean currents and oscillations

Worst case scenarios are intense phenomena that may occur in isolation or in combination with other events or circumstances that could lead to extreme water levels and hence flooding conditions. A preliminary, largely qualitative, assessment of scenarios that could lead to extreme flooding in parts of Newfoundland and Labrador was completed focusing on winter rain, Weather bombs, hurricanes and tropical storms, and severe summer weather. While these phenomena are considered rare, most of these events have occurred in the past and are likely to occur again.

Assessing the Need for New or Updated Flood Risk Mapping

The objective of this project task was the identification of communities vulnerable to flooding that should be considered for new or updated flood risk mapping studies. This assessment was founded on the updated Flood Events Inventory, the re-assessment of Flood Risk Maps, a detailed review of the technical components comprising the existing flood plain maps and linkage of a variety of datasets relevant to flood risk assessment in the Province. The definition of communities was based on the Local Government Profile (LGP) number dataset.

A decision matrix was developed outlining community ranking based on the prioritization parameters outlined in the table below. One additional consideration was integrated into the analysis at this stage, namely, the hierarchy of prioritization parameters. In other words, the concept that some of the parameters used for prioritization are more important for the analysis than others. In review of the parameters, some, such as number of flood events reported in a community or reported flood damages, are documented evidence of flood risk. These parameters were deemed 1st order parameters. On the other hand, some parameters, such as watershed deforestation or dominant soil hydrologic soil class, attempt to quantify the potential for community flood risk. This concept is important to consider in applying the parameters in the prioritization process. These parameters were deemed 2nd order parameters.

The application of the prioritized data and methods developed for this project yields the ranking of communities provided in the report; for communities with flood plain mapping presently and for communities without flood plain mapping presently.

Assessing Need for Flood Forecasting / Flood Warning System

The objective of this task was to identify communities vulnerable to flooding that should be considered for flood forecasting and/or flood warning systems. The task was completed through a review of historical flood observations (i.e., the Flood Events Inventory) and existing flood hazard and risk maps, combined with ancillary data on precipitation, topography, lifelines (roads, bridges, etc.), and with census information on population densities, types, and fluxes.

The methodology used for this study generally consisted of identifying vulnerable communities and subsequently assessing their susceptibility to direct and indirect effects of flooding. First, potentially vulnerable communities were identified by reviewing the event frequency and damage estimates contained in the updated Flood Events Inventory. After communities were identified, the physical hazard for each community was assessed. The next step was to determine each community's vulnerability to the direct effects of flooding (e.g., inundation). Third, potential indirect effects, such as isolation, were assessed for each of the identified communities. Finally, the results of each of the above steps are summarised in a decision matrix, highlighting those communities most vulnerable to flooding.

The results of this assessment indicate that the communities that should receive the highest priority for flood forecasting and warning systems include Corner Brook, Marystown, Placentia, Codroy Valley, St. John's, Deer Lake and Stephenville. Corner Brook, St. John's, and Stephenville are major population centers. Deer Lake is located in the Humber River Watershed, and already has WRMD provided forecasting in place. Placentia and Marystown are both located on the coast of Placentia Bay. These two towns, along with St. John's, Codroy, and Stephenville are communities lying directly in hurricane storm tracks.

Those communities representing a medium priority include Badger, Belleoram, Carbonear, Gander, Grand Bank, Hermitage-Sandyville, King's Point, Middle Arm, Mount Pearl, Rocky Harbour, Rushoon, and Steady Brook. Some of these fall within the same watersheds as communities included in the high priority grouping. Mount Pearl is located in the same watershed as St. John's, while Steady Brook is located in the Humber River Watershed. A number of these communities (Hermitage-Sandyville, Grand Bank, Belleoram, Rushoon, Middle Arm, and Carbonear) were in the direct path of past hurricane tracks. Rocky Harbour may be vulnerable to those storms tracking west of the island. Badger lies in the Exploits River watershed, which appears to already benefit from a significant forecasting effort (Department of Environment and Conservation, 2011).

Communities with the lowest priority are Cold Brook, Daniel's Harbour, Ferryland, Gambo, Grand Falls, Goulds, Petty Harbour-Maddox Cove, New-wes-valley, and Port Blandford. Of these lowest priority communities, Daniel's Harbour, New-wes-valley, and Ferryland lie in past hurricane storm tracks. Cold Brook would also benefit from any forecasting or warning efforts initiated for Stephenville.

Identifying Flood Vulnerability Mitigation and Adaptation Strategies

If we could simply move all flood prone infrastructure out of the way of floods, the development of a Flood Management Strategy would be simple. However, this is not the case and flood susceptible infrastructure does and will continue to reside in the flood plain. As such, an integrated strategy is required that will stipulate the WRMD's goals, objectives and actions to reduce the vulnerability of the Province to effects of floods but which recognize the size of individual communities, their flood vulnerabilities, and the potential for loss of both life and property.

These Integrated Flood Management (IFM) plans depend critically on the hydrological and hydraulic characteristics of the subject river system and region. A decision matrix was developed integrating the three linked factors that determined which strategy or combination of strategies is likely to be appropriate in a particular river basin, namely: the climate, the basin characteristics and the socio-economic conditions in the region.

Mitigation strategies, organized into Structural and Non-Structural categories, were presented for eleven Sub-regions of Newfoundland. These strategies represent a first set of options for communities to consider towards reduction of flood risk, minimization of flood damages and threats to public safety, and to expedite the post-flood recovery process.

This page left blank intentionally

RECOMMENDATION SUMMARY

Infrastructure, whether built, human or natural, is critically important to individuals and communities. The purpose of infrastructure is to protect the life, health, and social welfare of all of its inhabitants from the weather elements, to host economic activities and to sustain aesthetic and cultural values. When infrastructure fails under extreme weather conditions and can no longer provide services to communities, the result is often a disaster. It is understood that many communities across the Province presently face potential flood risk. However, with anticipated climate changes into the future, it is likely that flood risks for infrastructure failure and communities as whole will increase as weather patterns shift and extreme weather conditions become more variable and regionally more intense. Since infrastructure underpins so many economic activities of societies, these impacts will be significant and will require mitigation and adaptation measures.

Even though municipalities share responsibilities associated with infrastructure with other levels of government, any effect of climate change is ultimately experienced locally, even if its origins are outside local jurisdictions, such as disruption of electrical power or transportation networks.

The degree to which a municipality is able to deal with the impact of climate change is often referred to as “adaptive capacity” or “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with consequences” (Intergovernmental Panel on Climate Change, 2001). Building adaptive capacity is a key aspect of resiliency or to the ability of people, ecosystems, communities, etc. to resist or recover from damage, in this case from flood damage.

The vulnerability of individual communities and their infrastructure systems should be assessed as part of municipal risk management and decision making. This also helps determine the specific level of adaptation required as a means of mitigating flood and climate change vulnerability. Understanding the level of vulnerability also contributes to better, more informed decision-making and policy development by providing a basis for establishing priorities.

Adaptive planning is an on-going effort evolving and reflecting new information, new technology, and changing circumstance. The following recommendations are offered to assist the Government of Newfoundland and Labrador in its future planning and adaptive capacity and resiliency building efforts.

Update of the Flood Events Inventory

1. It is recommended that WRMD endeavor to include flood events which occurred earlier than 1950 in the Inventory with the next Flood Events Inventory update. The selection of the period of 1950 to 2011 was selected by WRMD as it was felt that prior to confederation there would be limited data available. Many flood events pre-dating 1950 are documented

in the source data collections used for this update effort. Having these events included may assist in better defining/understanding the long-term cyclical nature of storm events in the Province.

2. It is recommended that some consideration be given to splitting the ‘Types of Event’ field into primary and secondary (and perhaps even tertiary) causal factors. This would allow for consolidation of entries within a more concise listing of primary/secondary causes and perhaps better understanding of the nature of flood events.
3. It is recommended that WRMD consider the addition of a data field to identify the watershed within which the community is located.[1]
4. It is recommended that the WRMD give consideration to evolving the Flood Events Inventory software platform from Microsoft Excel© to a database platform such as Microsoft Access©. This would facilitate capture of additional flood related information from multiple sources, better data entry and management, in addition, to the ability for more efficient linking to other databases (such as the Local Government Profiles database) and GIS.

Remote Sensing and Land Cover Classification

5. For future change detection work on the land cover WRMD should obtain consistent imagery for change detection applications and clearly match the type of change that is desired with the need of the project application.The process of mapping changes in land use / land cover over time can be simplified and the products/outcomes more reliable with better, more similar imagery from “before and after” time periods. It is recommended that WRMD consider the use and need for atmospheric correction on a case-by-case, or project-by-project basis. Atmospheric correction is most useful when trying to separate features in imagery that have similar spectral signatures/responses or removing noise such as haze. It is not required for many types of land use / land cover classification and does not mitigate issues from different seasonal conditions in imagery. It was determined for this study that atmospheric correction would not provide a benefit across such varying seasons and years of imagery acquisition.
6. It is recommended that WRMD establish set protocols for training and verification samples for remote sensing projects across large areas. These known features types from ground measurements or photographs assist in both training remote sensing software during classification as well as in verifying accuracy at the end. It is recommended that WRMD merge projects involving land cover classification. If possible, future studies that involve remote sensing should merge land cover classification tasks to increase production efficiencies, reduce costs associated with data gathering, pre-processing and classification, and increase consistency in methods and QA/QC.

Assessment of Climate Change Impacts

[1] An initial effort towards this end has been substantially completed as a component of the Flood Risk Assessment (Task E) for this project.

7. It is recommended that WRMD develop updated and projected IDF relationships for locations across the Province with suitable past precipitation intensity records. While IDFs characterize only one flood risk factor, precipitation, and do not capture the seasonality of precipitation, developing projected IDFs for future time frames is a worthwhile exercise especially if a means can be found to incorporate in that effort, the results of dynamical modeling of hurricanes to 2050 and beyond. Seasonal IDFs could also be developed and may be useful given that specific hazards are associated with particular seasons (e.g., hurricanes/tropical storms in the fall and Weather bombs in the fall and early winter).
8. It is recommended that WRMD require future net sea level rise be incorporated into flood plain map development for coastal communities.
9. It is recommended that the Province of NL actively track ocean-atmosphere oscillations in an effort to predict climate anomalies and hurricane intensity in particular years or series of years in the future. The warm and cold cycles in the various ocean-atmosphere oscillations that influence tropical storm frequency and intensity and other aspects of Newfoundland and Labrador weather year-over-year, will also continue through to the end of this century though their periodicity and intensity may change over the coming decades.
10. It is recommended that the Province of NL complete a more detailed analysis of Weather Bombs, similar to that conducted within this study on Tropical Systems, to determine if these storms, often approaching Hurricane strength, are increasing in intensity and/or frequency. This would be particularly useful in assessment flood potential on the island of Newfoundland's east and north coasts.
11. A hurricane making landfall on the island would produce the very highest water levels in Newfoundland. A coarse preliminary attempt at quantifying the cumulative factors was presented for illustration purposes only. Numerous other factors, unique to each storm and its particular behavior, as well as the local topography would affect that high water mark both downward as well as upward. As a result, a range of recommendations to mitigate damages should be considered. Firstly, since a 1 in 50 year event could occur in a year or two from now, local emergency plans should be reviewed to ensure they include the potential impacts of a Hurricane. Additional measures may also be required to ensure public safety such as evacuation routes etc. Secondly, a closer study of Hurricanes is recommended to determine a range of likely tracks and intensities with a view to better assessing the likely wind directions and storm surges which specific communities may have to deal with. Such a greater understanding of the Hurricane threat to the island may then allow a close assessment of the impacts of such hypothetical storms in specific communities given their unique topography. Finally, flood plain maps for these vulnerable communities could be updated and other defenses considered.

Assess Need for New / Updated Flood Risk Mapping

12. It is recommended that the WRMD encourage alignment between databases that reference communities in the Province. An example would be alignment between the LGP database and those maintained by Statistics Canada which track census information.

13. It is recommended that the WRMD maintain/update the decision matrix when new information becomes available which has founded the prioritization of communities for updated or new flood plain mapping.

Assess Need for Flood Forecasting / Flood Warning Systems

14. It is recommended that WRMD expend additional efforts focused on those communities identified in the high priority group towards specific identification of risk in each community's watershed, for a given flood event. This effort would benefit from the acquisition of additional detailed spatial information to determine exactly what resources (e.g., critical infrastructure) are at risk in each community's watershed, for a given flood event. The collection of community plan and parcel data, identification of specific damage estimates and/or flood damages modeling, and mapping of critical infrastructure would greatly facilitate vulnerability studies for Newfoundland and Labrador. This information, combined with efforts to model flood inundation levels and hydraulics would not only help determine vulnerabilities, it would also guide the selection of the most appropriate flood forecasting and/or warning system.

15. It is recommended that the WRMD maintain/update the decision matrix when new information becomes available which has founded the prioritization of communities that could benefit from a Flood Forecasting / Flood Warning System.

TABLE OF CONTENTS

PAGE

This page left blank intentionally

LIST OF TABLES

LIST OF FIGURES

1. OVERVIEW

In the 1980's, under the Canada Newfoundland Flood Damage Reduction Program, hydrotechnical studies were carried out for 37 communities in the province. These communities, with a history of extensive flooding events, were mapped with 100-year and 20-year return period, or 1:20 and 1:100 Annual Exceedance Probability (AEP), flood risk zones. Since their creation, these maps have been incorporated into a wide range of land use related policies by provincial and municipal governments, including transportation planning and infrastructure design, water resources, land use development and municipal plans.

It is speculated that Canada may in the future experience changes in the frequency and/or severity of extreme weather as well as changes to average climate over several decades or more as a result of the predicted impacts attributed to climate change. These changes are expected to affect natural, social and built infrastructure, potentially having significant socio-economic consequences. The climate change assessment focus has most often been directed towards a range of mitigation options related to energy use. These have been targeted at reducing greenhouse gas emissions, encouraging public transport and energy efficiency at all scales in the community. However more recently, the focus has shifted toward adaptation recognizing how a community must adapt to changing climatic conditions. The need for this shift in focus was highlighted was recent severe flood events in Newfoundland and Labrador and especially in the aftermath of Hurricane Igor. As such, a need to update the Flood Events Inventory, re-assess the existing flood risk maps, and identify additional communities that should be considered for flood risk mapping was determined.

This Flood Risk and Vulnerability Analysis Project will assist the Provincial Government identify communities at risk to flooding and the potential impacts of the changing climate, drive projects to update existing and create new flood risk mapping, to improve or establish flood forecasting / flood warning systems and to identify mitigation and/or adaptation opportunities.

AMEC Environment & Infrastructure, a division of AMEC Americas Limited (AMEC) was contracted by the Water Resources Management Division, Department of Environment and Conservation of the Province of Government of Newfoundland and Labrador (the "WRMD") to complete the Project compliant with the Terms and Conditions as outlined in the WRMD's Request for Proposals dated October 18, 2010 (the "RFP").

1.1 Project Objectives

The objectives of this Project are as follows:

- Task A: Create the project workplan[2].

[2] The project has been submitted separate from this report.

- Task B: Update the existing Flood Events Inventory;
- Task C: Assess existing flood risk maps;
  - Delineate community flood watersheds, at a scale of 1:50,000, for communities vulnerable to flooding;
  - Based on best available science, determine the impact the changing climate will have on communities vulnerable to flooding and observed changes in land cover;
- Task D: Assess the need for new / updated flood risk mapping;
- Task E: From the Flood Events Inventory and the map reassessment, identify communities vulnerable to flooding that should be considered for new or updated flood risk mapping studies;
- Task F: From the Flood Events Inventory and the map reassessment, identify communities vulnerable to flooding that should be considered for flood forecasting and flood warning systems; and
- Make recommendations on addressing vulnerabilities identified above.

1.2 Definitions

The relevant legislation for flood plain management in the Province is the *Water Resources Act*, SNL 2002 cW-4.01, ("the Act") sections 30, 32, 33, 34, 35, 48, 64 and 90, the Lands Act SNL1991 CHAPTER 36 Section 7. The following definitions[3] are outlined in the Act, are relevant to flood plain mapping in the province and have been used in this report.

Body of Water	(Statutory definition from the Act) "body of water" means a surface or subterranean source of fresh or salt water within the jurisdiction of the province, whether that source usually contains liquid or frozen water or not, and includes water above the bed of the sea that is within the jurisdiction of the province, a river, stream, brook, creek, watercourse, lake, pond, spring, lagoon, ravine, gully, canal, wetland and other flowing or standing water and the land usually or at any time occupied by that body of water;
Flood Plain	An area adjacent to a lake, river, seashore etc. which is inundated or covered with water on average at least once in 100 years. Note that a flood plain is considered to be an integral part of a body of water as defined above because it includes "the land usually or at a time occupied by that body of water" and "whether that source usually contains water or not".
Designated Area	A specific flood plain in a community for which a hydrotechnical study has determined the extent of flooding and for which flood risk maps are available. The designation is in accordance with the Canada - Newfoundland Flood Damage Reduction Program Agreements.

[3] from http://www.env.gov.nl.ca/env/waterres/regulations/policies/flood_plain.html

Floodway	The portion of a flood plain where the most frequent flooding occurs and where the flow of water is fastest. This area is determined on the basis of the 1 in 20 year (1:20) return period flood.
Floodway Fringe	The portion of a flood plain where less frequent flooding occurs and where the flow of water is considered to be tranquil. This area is where flooding occurs up to 1 in 100 years (1:100) on average.
Climate Change Flood Zone	Based on extension of the floodway fringe, this is the area which is likely to be impacted due to the latest forecasted affects of climate change.
Other Flood Risk Area	An area where flooding is known or has some probability to occur due to unique or unusual circumstances such as areas subject to shoreline recession, areas downstream of dams or areas adjacent to watercourses potentially prone to ice jams.
Flood Control Area	An area that is subject to periodic flooding which has been designated (by the Department) a control area in order to reduce the risks to public health and safety and property damages. This area shall normally be treated as a floodway zone (1:20), unless otherwise determined by the Department.
Buffer Zone	A zone of land that is in its natural state and that is intended to separate developed areas from bodies of water to provide basic protection of water resources. This zone may coincide with a Crown land reservation of a shoreline as prescribed by Section 7(1) of the Lands Act. In the absence of specific setback requirements (depending on the activity) the buffer is taken to be 15 metres measured from the high water mark which in turn is understood to be the 1 in 100 year (1:100) high water mark or the Climate Change Flood Zone, where they have been identified.

2. Task B – Updated Flood Events Inventory

The most common type of disaster occurring in Canada is flooding (Tudor, 1997). Therefore, an understanding of the history of flooding in the province is a critical piece of the flood forecasting / risk assessment puzzle, and a critical component of the Project. The starting point of this Project component was the inventory of flood event information that accompanied the WRMD report *"A Preliminary Study of Flooding in Newfoundland and Labrador (1998-2008)".* The original inventory contained 179 records and 70 storm events.

The Flood Events Inventory was updated, as a component of the current Project, for the period 1950-present. This update was based on a review of existing information contained in the current Flood Events Inventory and the collection and compilation of new data necessary for updating the Flood Events Inventory for the required period. The updated inventory now contains 650 flood events and 269 storm events over the period 1950 to 2011.

In the context of this report the following terms are used relative to the data contained flood events inventory:

- A "flood event" represents the affects of a storm event on a single community or damage centre and is equal to a single record in the inventory.
- A "storm event" is the event that initiates a flood event. As single storm event is, in many cases, associated with multiple flood events.

Please note for Task B the names used for communities and areas are a combination of those that were in place when the FRM studies were done in the 1980s and 1990s and those reflected by the new LGP numbers due to a need to use data from both old FRM studies and the LGP list.

2.1 Data Sources

In preparing the updated Flood Events Inventory, AMEC conducted a thorough review of the following existing information and data sources:

- The existing Flood Events Inventory
- Newfoundland and Labrador, Department of Environment and Conservation Flood Studies website[4]
- A collection of previous completed flooding studies.
- Centre for Newfoundland Studies, Memorial University of Newfoundland

[4] available at http://www.env.gov.nl.ca/env/waterres/flooding/frm.html

The Centre for Newfoundland Studies is located in the Queen Elizabeth II Library at the Memorial University of Newfoundland. Collections of information on various topics affecting the province, named 'Vertical Files', are maintained at the library. The Vertical Files contain collections of newspaper clippings focused on a particular topic. The Vertical Files named 'Floods', 'Natural Disasters' and 'Hurricanes" were researched for this project task.

- Newfoundland and Labrador, Department of Natural Resources Flooding Events website[5]

  The study, through which the information available at the website was compiled, was aimed mainly at identifying incidents of coastal flooding rather than providing a comprehensive listing of flood events in Newfoundland.

  Additional flood events are documented at this website that occurred earlier than 1950 (which was a boundary for the present update effort). It is recommended that WRMD endeavour to include these events with the next Flood Events Inventory update.

- Newfoundland and Labrador Heritage (Coastal Flooding) website[6]

  The Coastal Flooding Map shows the locations of all recorded coastal flooding in Newfoundland and Labrador from 1755 to 1992 with links to associated information about the flood event.

  Again, additional flood events are documented at this website that occurred earlier than 1950 (which was a boundary for the present update effort). It is recommended that WRMD endeavour to include these events with the next Flood Events Inventory update.

- Media reports; Provincial Government Departments, including Department of Environment and Conservation, Department of Municipal Affairs, Department of Natural Resources, and Department of Transportation and Works;
- Public Safety Canada – Canadian Disaster Database[7]

  The Canadian Disaster Database ("CDD") contains detailed disaster information on more than 900 natural, technological and conflict events (excluding war) that have happened since 1900 at home or abroad and that have directly affected Canadians. Of these events, 35 are flood related events which have occurred in Newfoundland and Labrador. The CDD tracks "significant disaster events" which conform to the Emergency

[5] available at http://www.nr.gov.nl.ca/nr/mines/outreach/disasters/flooding/index.html
[6] available at http://www.heritage.nf.ca/environment/c_flooding.html#map4
[7] available at http://www.publicsafety.gc.ca/prg/em/cdd/index-eng.aspx

Management Framework for Canada definition of a “disaster” and meet one or more of the following criteria:

- 10 or more people killed;
- 100 or more people affected/injured/affected/evacuated or homeless;
- an appeal for national/international assistance;
- historical significance; and
- significant damage/interruption of normal processes such that the community affected cannot recover on its own.

The database describes where and when a disaster occurred, the number of injuries, evacuations, and fatalities, as well as a rough estimate of the costs. As much as possible, the CDD contains primary data that is valid, current and supported by reliable and traceable sources, including federal institutions, provincial/territorial governments, non-governmental organizations and media sources. Data is updated and reviewed on a semi-annual basis.

Additional flood events are documented at this website that occurred earlier than 1950 (which was a boundary for the present update effort). It is recommended that WRMD endeavour to include these events with the next Flood Events Inventory update. It is further recommended that the CDD be reviewed on an annual basis to include relevant new flood data.

- Environment Canada
- Geological Survey of Canada, Flood Disasters in Canada website[8]

This database contains summary information for 168 Canadian flood disasters that occurred between 1900 and June 1997. This database is not, by any means, a complete list of flood ’events’ in Canada since the vast majority of the floods did not cause ’disasters’. All mentions of damage costs have not been corrected for inflation. The database also is biased towards the more densely populated areas of Canada where floods are more likely to impact humans. Despite these limitations, the database provides an indication of the significance, impact, and location of damaging floods in Canada

- Government of Newfoundland and Labrador – News Release website[9]
- Environment Canada. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Prepared by A.D. Kindervater, Inland Waters Directorate, Halifax, Nova Scotia. 80-WPMB-4. July 1980.

[8] available at http://www.gsc.nrcan.gc.ca/floods/database_e.php
[9] Available at http://www.releases.gov.nl.ca/releases/

- Information directly obtained from newspapers and television/radio stations (such as the CBC).

Two related documents identified through this Project task, which may contain information relevant to the Flood Events Inventory update, were not available to AMEC for review, namely:

- Ruffman, A, Hattie, K, Boyce, D, Stevenson, B, Smith, A, Buchan, G and Snow, D. 1990. Historic Seismicity and Record of Severe Storms with Coastal Flooding for Western Newfoundland: Search of the Western Star of Corner Brook, Newfoundland, April 4, 1900-June 15, 1964, Album of Articles. Geological Survey of Canada, Open File No. 2407(1991), 637 pages.
- Ruffman, A; Hattie, K; Boyce, D; Stevenson, B; Smith, A; Buchan, G; Snow, D Historic Seismicity and Record of Severe Storms With Coastal Flooding For Western Newfoundland - Volume 2, Geological Survey of Canada, Open File 2407, 1991, 432 pages.

The fact that these two references were not reviewed is not considered significant in the context of the Flood Events Inventory update as the first volume is based on a search for flood events within the archives of the Western Star (newspaper) of Corner Brook. It is anticipated that this search would yield Western Star newspaper articles embodied within the Vertical Files of the Centre for Newfoundland Studies.

The updated, current Flood Events Inventory contains 650 flood events and documents 269 storm events, an addition of 471 flood events and 202 storm events. Source data for new records added to the inventory are available electronically as a component deliverable with the inventory.

2.2 Description of Inventory Data

The Flood Events Inventory is, presently, maintained in a Microsoft Excel spreadsheet format. Table 2-1 outlines the list of data which is compiled in the inventory. Some additional information related to individual data fields is provided below:

- Not all the fields listed in Table 2-1 are provided in the source data.

  Hence, any data fields with no entry can be interpreted as not having any source data to support data entry in the field.

  A detailed investigation of individual flood events may be able to ascertain all, or at least additional, relevant data, however, this was not the objective of this Project task.

- The 'Types of Events' field is based on an interpretation of information provided with the source data for the particular flood or storm event.

  The present list of entries/categories (see below) reflects this interpretation effort.

Rainfall	Dam Break	Snowmelt/Ice Jams
Snowmelt	Flash Flood	Snow Storm/Winds
Rainfall and Snowmelt	Flood	Storm Surge
Ice Jam	Rainfall/Snowmelt/Ice Jams	Winds
Coastal Waves	Rainfall and Ice Jams	Winds/Tides
Coastal Flooding	Rapid Snowmelt	Winds/Tides/Rainfall

  It is recommended that some consideration be given the splitting the 'Types of Event' field into primary and secondary (and perhaps even tertiary) causal factors. This would allow for consolidation of entries within a more concise listing of primary/secondary causes and perhaps better understanding of the nature of flood events.

  An example would be the current entry for 'Rainfall/Snowmelt/Ice Jams'. Further investigation of this event may yield the cause of the flooding as one or more ice jams. However, the ice jams were the result of break-up due to high water levels caused by a winter rainfall event. The rainfall and above freezing temperatures may have also caused accelerated snowmelt which contributed to the high water levels.

- It is recommended that WRMD consider the addition of a data field to identify the watershed within which the community is located.

  The inventory presently maintains a data field identifying the flooded waterbody. However, this information is not always recorded or identified in the source data for a flood event. Watershed delineation across the province (at a minimum across Newfoundland) is available through various datasets. As well, the Local Government Profile dataset (available from the Department of Municipal and Provincial Affairs) maintains a geographic reference point for communities across the province. The linking of these two data layers would provide a means of identifying the watershed.

The data presented in the updated Flood Events Inventory is considered as complete and correct as possible in the context of Project objectives.

Field	Description
Flood#	A flood event reference number, also a unique record identifier
Storm #	A storm event reference number. Areas affected by the same storm will have the same Storm #.
General Location	The areas of the province that are affected by the flood. e.g., Flood: St.

Field	Description
	John's Area
Start Year	The year (yyyy) in which the flood started.
Start Month	The month (mm) in which the flood started.
Start Day	The day (dd) on which the flood started.
Start Time (#)	The documented or estimated time at which the flood started using a 24 hour clock reference in Excel "Time" format.
End Year	The year (yyyy) in which the flood ended.
End Month	The month (mm) in which the flood ended.
End Day	The day (dd) on which the flood ended.
End Time (#)	The documented or estimated time at which the flood ended using a 24 hour clock reference in Excel "Time" format.
Duration	The number of days which the flood lasted.
Season	The season in which the flood occurred. Seasons are defined as: Spring 21 March – 20 June Summer 21 June – 20 September Fall 21 September – 20 December Winter 21 December – 20 March
Region	Please refer to Figure 2-1 for a map of WRMD regions.
LGP#	Local Government Profile number. A unique number given to each community in Newfoundland and Labrador. A few communities do not have a number.
Community Name	The official name used by the Department of Municipal Affairs
Water Bodies	The rivers and lakes (and ocean) that flooded.
Type of Event	The cause of the flood. The events are broken down into the following categories which have been based on the description provided in the source data for the event. Rainfall; Dam Break; Snowmelt/Ice Jams Snowmelt; Flash Flood; Snow Storm/Winds Rainfall and Snowmelt; Flood; Storm Surge Ice Jam; Rainfall/Snowmelt/Ice Jams; Winds Coastal Waves; Rainfall and Ice Jams; Winds/Tides Coastal Flooding; Rapid Snowmelt; Winds/Tides/Rainfall
Rainfall Amount	When applicable, the total rainfall, in millimetres, associated with the flood event.
Snowfall Amount	When applicable, the total snowfall estimate, in millimetres, associated with the flood event.
Sea Height	When applicable, the height of the waves, in metres, associated with the flood event.
Jam Height	When applicable, how high the ice caused a water body to rise in metres.

Field	Description
Damage Estimate by Community	The non-adjusted dollar-amount estimate of the cost of the clean-up by flood.
Damage Estimate by Storm	The non-adjusted dollar-amount estimate of the cost of the clean-up by storm.
DFAA Damage Report	Disaster Financial Assistance Arrangements reported damages by flood.
DFAA Damage Report (once per storm)	Disaster Financial Assistance Arrangements reported damages by storm.
Homes Flooded	The reported number of homes that were flooded.
People Displaced	The number of people who were forced to leave their home during a flood event.
Description	A brief description of the flood summarizing the event in a sentence or two, like a headline.
Source	Sources of information on the flood.
Attachment	Link to source information.
Data Added By	Who added the data record

Table 2-1. Flood Events Inventory - Field Descriptions

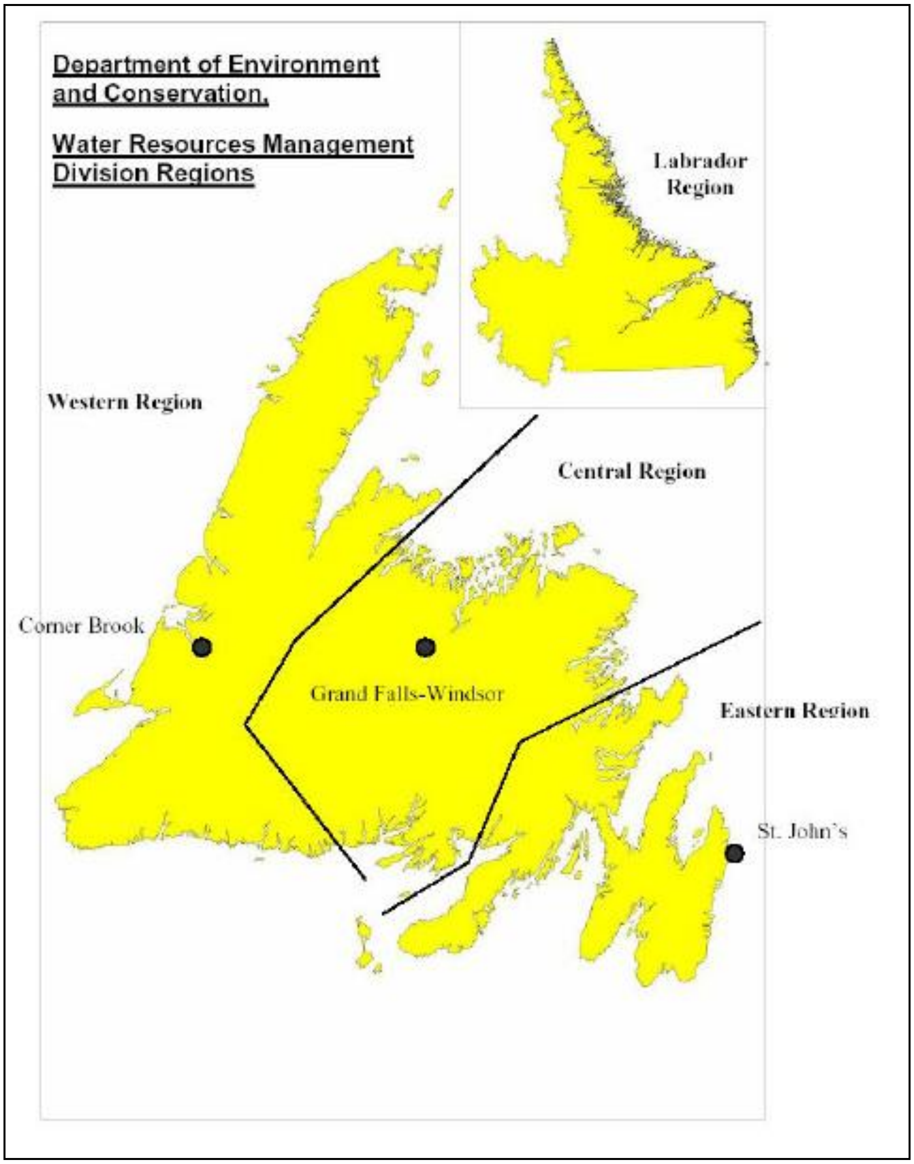


Figure 2-1. Water Resource Management Division Regions

2.3 Data Summaries

The following sections provide some insight into the data by graphical representation under a number of themes relevant to other aspects of the current Project.

2.3.1 Cost of Floods

Damage data is not provided for all flood events and when available is not always accurate or all inclusive. Two sources of damages data are presently available in the Flood Event Inventory, namely; damage estimates abstracted from the source data and Disaster Financial Assistance

Arrangements[10] (DFAA) damage estimates. The DFAA estimates were compiled at the request of WRMD by Fire and Emergency Services-Newfoundland and Labrador (FES-NL) for the most significant storm events of the last decade. An objective estimate would also include insurance claims, however this data is rarely available. The Insurance Bureau of Canada was contacted specifically to obtain claims information for flood events in Newfoundland and Labrador but no response was received.

The DFAA, administered by Public Safety Canada, is used by the Government of Canada to provide financial assistance to provincial and territorial governments in the event of a large-scale natural disaster. When response and recovery costs exceed what individual provinces or territories could reasonably be expected to bear on their own, the DFAA provide the Government of Canada with a fair and equitable means of assisting provincial and territorial governments. Examples (from the DFAA website) of provincial/territorial expenses that may be eligible for cost sharing under the DFAA:

- Evacuation, transportation, emergency food, shelter and clothing;
- Emergency provision of essential community services;
- Security measures including the removal of valuable assets and hazardous materials from a threatened area;
- Repairs to public buildings and related equipment;
- Repairs to public infrastructure such as roads and bridges;
- Removal of damaged structures constituting a threat to public safety;
- Restoration, replacement or repairs to an individual's dwelling (principal residence only);
- Restoration, replacement or repairs to essential personal furnishings, appliances and clothing;
- Restoration of small businesses and farmsteads including buildings and equipment; and
- Costs of damage inspection, appraisal and clean up.

Examples of expenses that would not be eligible for reimbursement:

- Repairs to a non-primary dwelling (e.g., cottage or ski chalet);
- Repairs that are eligible for reimbursement through insurance;
- Costs that are covered in whole or in part by another government program;
- Normal operating expenses of a government department or agency;
- Assistance to large businesses and crown corporations; and
- Loss of income and economic recovery.

[10] Additional information regarding DFAA is available at their website via the following link - http://www.publicsafety.gc.ca/prg/em/dfaa/index-eng.aspx#a04#a04

Of the 650 flood events in the Flood Events Inventory, fifty-three (53) flood events have damage estimates [based on data column '*Damage Estimate by Storm (once per storm)*]' totalling about $252 million (normalized to 2011 dollars)[11]. Damage estimates range from a few thousand dollars to over $100 million associated with Hurricane Igor in 2010. Eighteen (18) flood events in the inventory have documented damages of $1 million[8] or more. Damages were identified in the inventory in 31 of the 56 years over the period 1955 to 2010.The average annual cost is estimated to be about $8.1 million over the period (1962-2011) represented by data records with damage information (i.e., $252M/31) or $4.5 million (i.e., $252M/56) if it is assumed that years with no recorded flood damages are taken into account.

Similarly, eleven (11) flood events have damage estimates [based on data column '*DFAA Damage Report (once per storm)*]' totalling about $180 million (normalized to 2011 dollars)[8]. All DFAA damage estimates are greater than $1 million. Damages were identified in the inventory in 8 of the 11 years over the period 2000 to 2010.The average annual cost is estimated to be about $22.5 million over the period (2000-2010) represented by data records with damage information (i.e., $180M/8) or $16.3 million (i.e., $180M/11) if it is assumed that years with no recorded flood damages are taken into account.

It is suspected though that average annual damages may be higher as many of the records in the inventory lack damages estimate data.

Table 2-2 summarizes the comparison of the two available damage estimates for events where both estimates are available. It is clear from this comparison that the estimated damages resulting from flood events can vary substantially, in some cases by tens of millions of dollars. Although the DFAA estimates are considered accurate they are not all inclusive (as noted above) particularly as they do not include damages compensated for through insurance.

Figure 2-2 provides a graphical illustration of flood damage estimates by year. Figure 2-3 provides a summary view of estimated flood damages by decade. Both figures suggest an increasing trend in flood damages in recent years, however, this is likely related more to the availability of flood damages data than to the damages themselves.

Figure 2-4 indicates that flood damages related to fall and winter events result in the greatest dollar value flood damages.

---

[11] Normalization of damage estimates was based on Consumer Price Index (CPI) values from Statistics Canada. Data was sourced from the Statistics Canada website at http://www40.statcan.ca/l01/cst01/econ150a-eng.htm. The source reference is documented at the website as 'Statistics Canada, CANSIM, table 326-0021 and Catalogue no. 62-001-X'. Provincial CPI values for Newfoundland were available from 1987 to present. Composite Canadian CPI values were used for dates earlier than 1987.

Storm #	General Location	Year	Season	Region	Type of Event	Damage Estimate by Storm (once per storm)	DFAA Damage Report (once per storm)
178	South Coast	2000	Winter	Western	Storm Surge	$1,623,465	$5,462,099
183	St. John's	2001	Summer	Eastern	Rainfall	$8,325,281	$7,558,912
195	West Coast	2003	Spring	Western	Rainfall and Snowmelt	$1,651,701	$11,313,573
193	Badger	2003	Winter	Central	Ice Jam	$3,102,838	$9,701,686
217	Burin Peninsula	2005	Spring	Eastern	Rainfall	$112,825	$1,512,396
220	Stephenville Area	2005	Fall	Western	Rainfall	$11,282,528	$31,911,260
228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	Spring	Western	Rainfall	$33,260	$5,166,002
237	Western Newfoundland	2007	Winter	Western	Coastal Flooding	$3,343,690	$3,235,258
239	Western Avalon Peninsula	2007	Summer	Eastern	Rainfall	$6,556,256	$26,795,772
247	Gambo	2008	Summer	Central	Rainfall	$1,893,447	$1,893,447
283	Southern and Eastern Newfoundland	2010	Fall	Central	not specified	$103,407,155	$75,208,905
					Totals	$141,332,446	$179,759,310

Table 2-2. Comparison of Damage Estimates

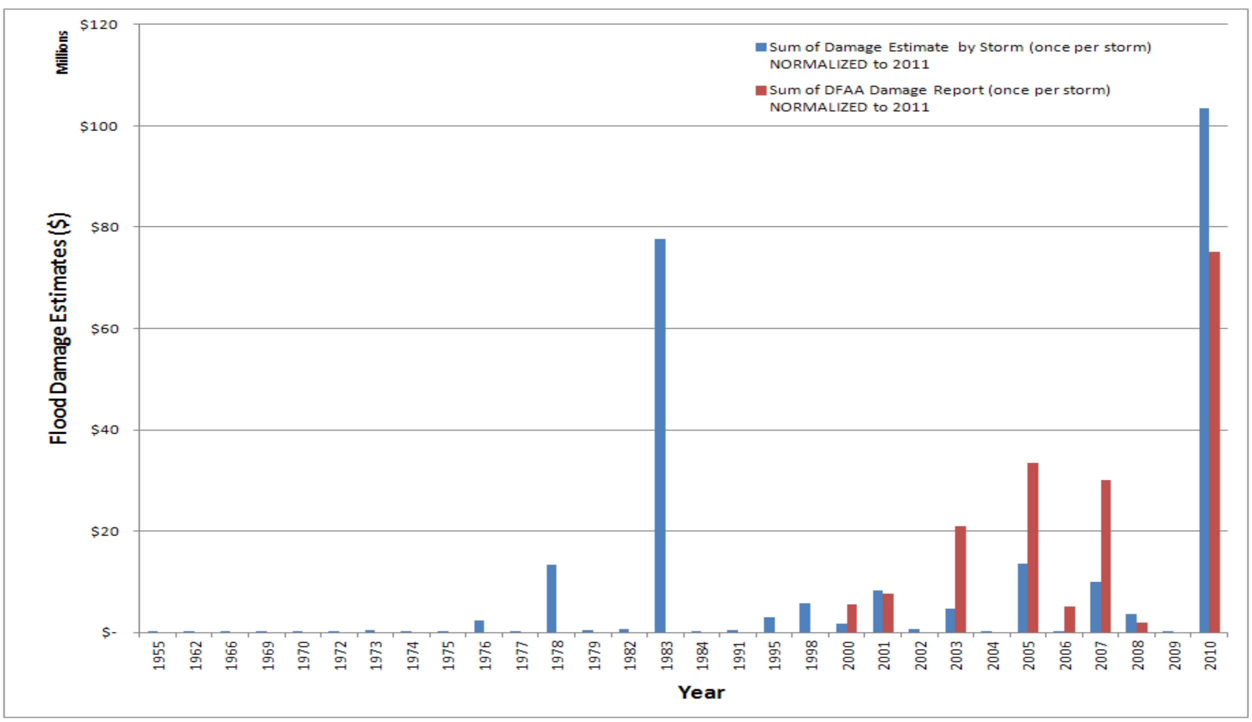


Figure 2-2. Total Flood Damages Estimate by Year

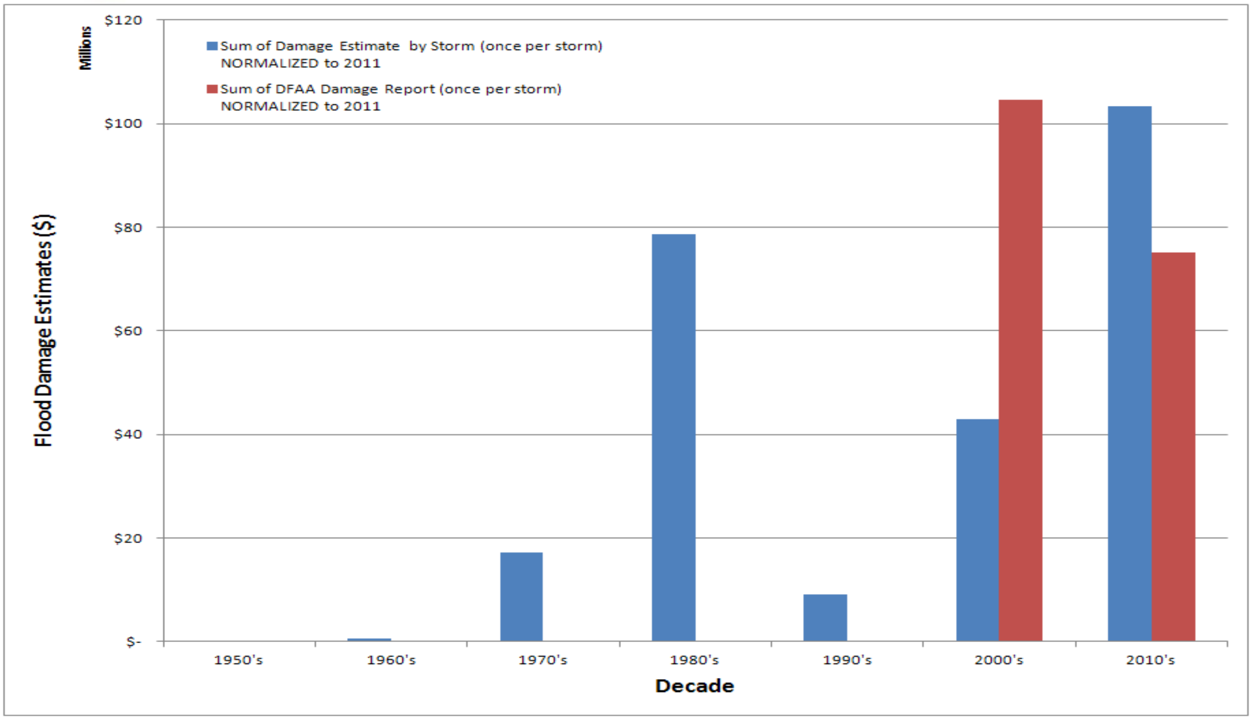


Figure 2-3. Total Flood Damage Estimates by Decade

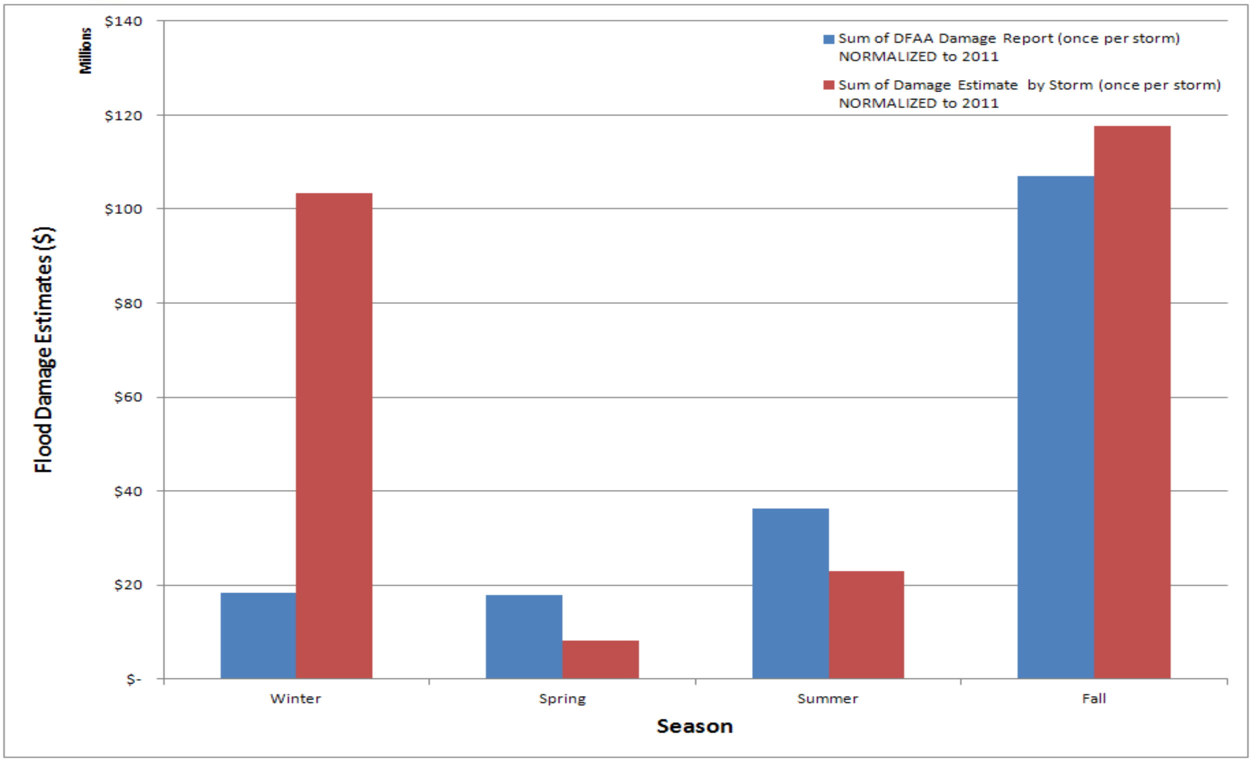


Figure 2-4. Total Flood Damage Estimates by Season[12]

2.3.2 Weather Events - Annual Occurrence

A graphical representation of storm event occurrence is illustrated in Figure 2-5. Over the entire inventory period (i.e., 1950 through 2011) a total of 269 storm events are documented, averaging about 4 storm events per year. However a single weather event can result in flooding that impacts numerous communities such as Hurricane Igor which impacted 97 separate communities.

Flood reports for the years 1998 through 2011 are readily accessible, generally, over the Internet. Flood reports prior to 1998 are, in many cases, maintained in hardcopy form only whether in library collections of newspapers and other articles or as local knowledge if the flood event was small and isolated. As such, evidence of floods, as documented in the inventory, for the years 1998-2011 is considered complete and during this period a total of 102 storm events are documented in the inventory for an average occurrence of about 7 per year. Further, two distinct peaks can be seen in the data around the years 1975/76 and 2005/06. A total of 387 flood events are associated with these 102 storm events in the inventory.

[12] Flood damages data available in the inventory is very limited (53 of 650 records) over the period 1955 to 2011 for 'Damage Estimate by Storm' and (11 of 650 records) for 'DFAA Damage Report' information.

Figure 2-6 illustrates storm event occurrence in the three (3) WRMD regions of the province. The Eastern and Western regions have more documented flood producing storm events than the Central region with a total of 148, 91, 29 storm events documented in the inventory, respectively. Flooding in Labrador is extremely rare with only one documented flood event in the current inventory.

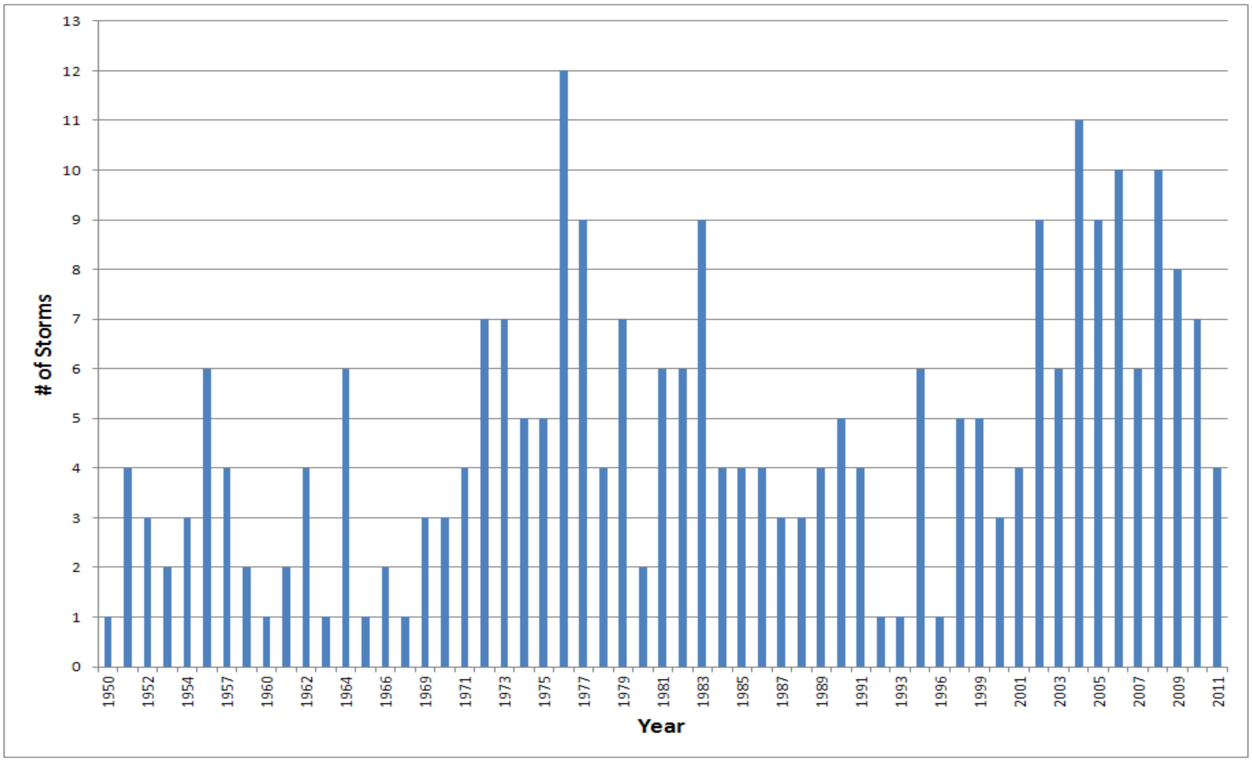


Figure 2-5. Storm Occurrence by Year

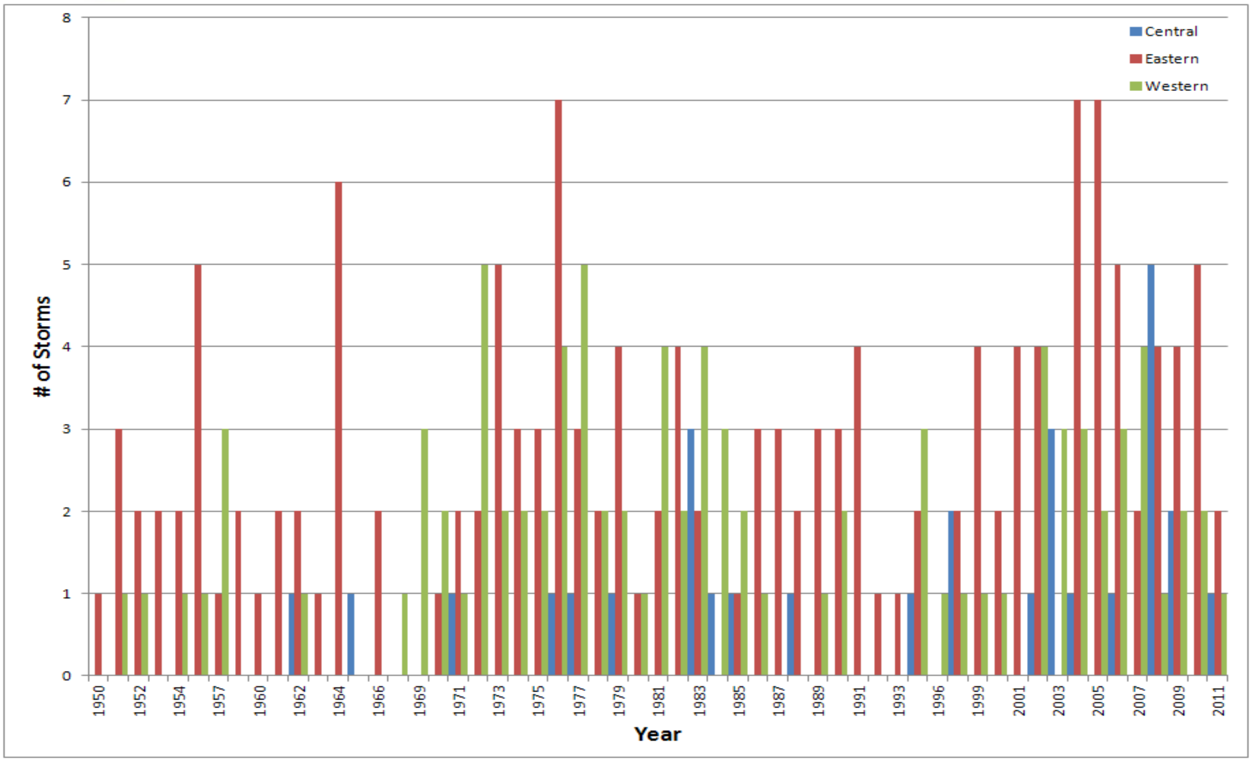


Figure 2-6. Storm Occurrence by Year and Region

2.3.3 Storm Events - Seasonal and Monthly Occurrence

Over the entire inventory, January and February are the months where storm events are most common with about 30% of the storm events occurring in these months alone. December is also a significant storm event month with 10% occurrence. The remainder of the months experience less than 10% occurrence each as outlined in Table 2-3. Notwithstanding, storm events in September have caused the greatest impact in terms of locations experiencing flooding. Generally, as illustrated in Figure 2-7, Figure 2-8 and Figure 2-9, Newfoundland is most storm event prone in the winter, fall and spring and least prone over the summer months. However, Central Newfoundland does show a more even expectation of storm events throughout the year on a seasonal basis.

Month	Storms	Floods	Month	Storms	Floods
January	15%	13%	July	2%	7%
February	15%	10%	August	9%	5%
March	8%	9%	September	7%	26%
April	6%	7%	October	9%	5%
May	4%	3%	November	9%	5%
June	4%	2%	December	10%	8%

Season	Storms	Floods
Winter	45%	35%
Spring	13%	14%
Summer	20%	20%
Fall	22%	31%

Notes: Presently, 2% of the storms identified in the inventory have no specified start month.

Table 2-3. Storm/Flood Occurrence by Month and Season

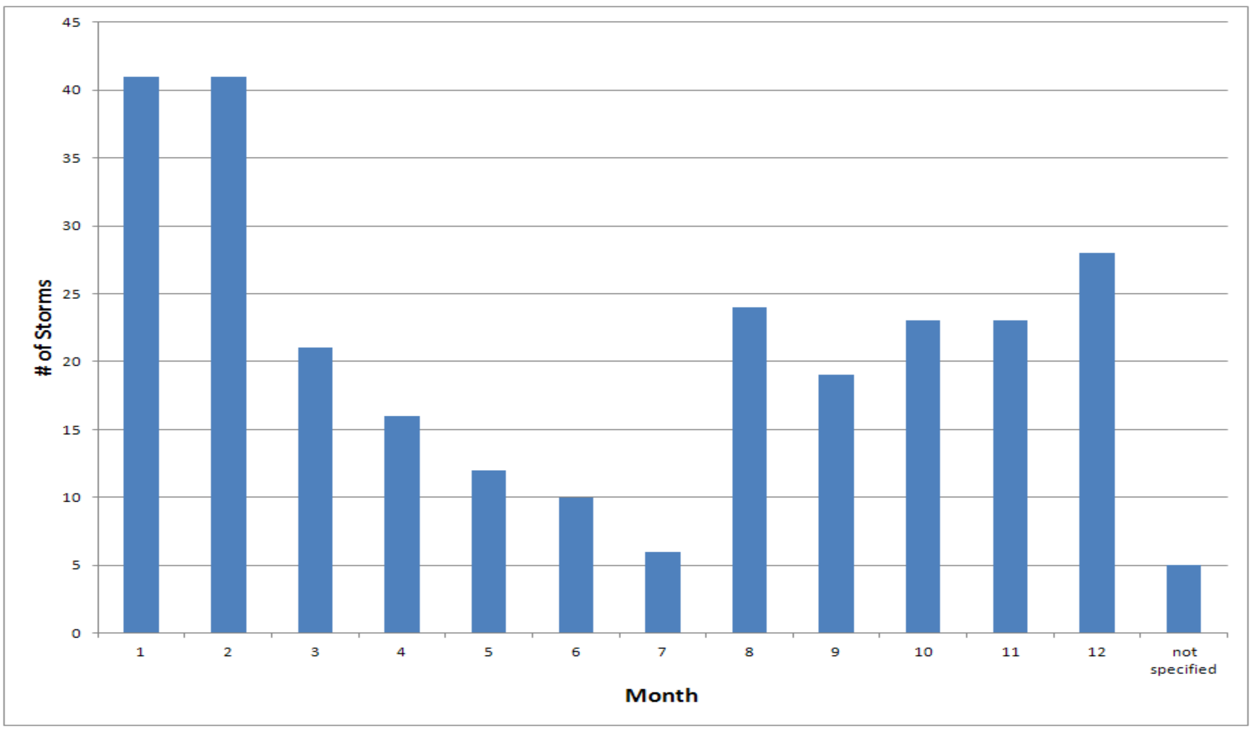


Figure 2-7. Storm Occurrence by Month

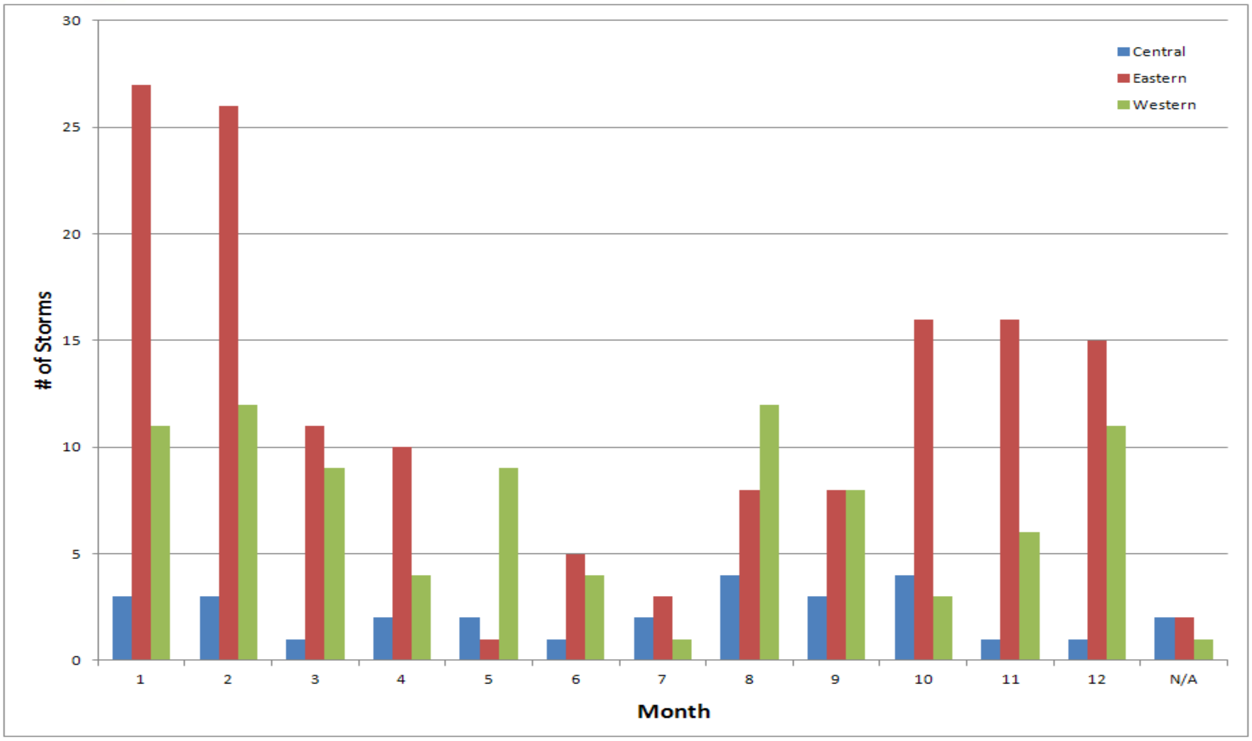


Figure 2-8. Storm Occurrence by Month and Region

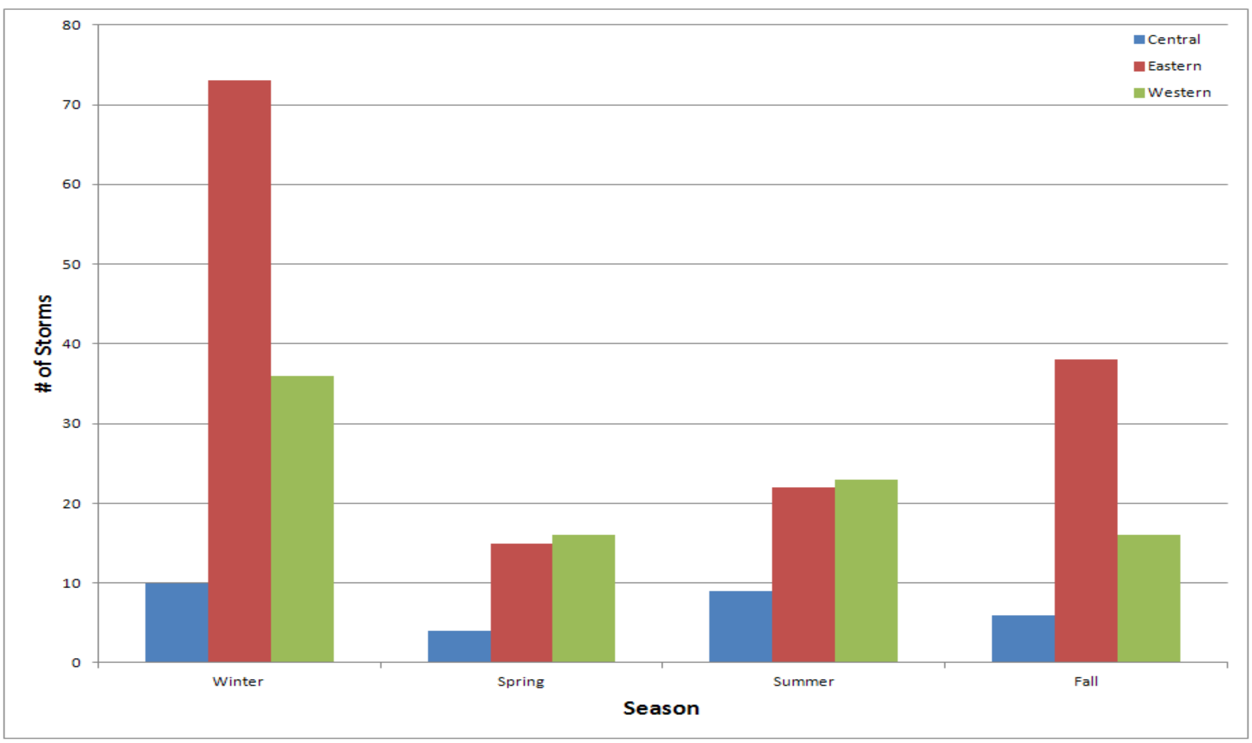


Figure 2-9. Storm Occurrence by Season and Region

2.3.4 Causes of Flooding

As noted previously, the data field describing the 'Types of Events' is based on an interpretation of information provided with the source data for the particular flood or storm event. At times the source data for a flood event is not specific as to the primary initiating cause (i.e., rainfall, ice jam, storm surge, etc.). Figure 2-10 details flood occurrence based on the information in the 'Types of Events' field. It is clear from Figure 2-10 that the primary causal event for flooding in the province is rainfall with the secondary causal event related to coastal processes (e.g., storm surge and waves).

Table 2-4 details the occurrence the flood event type grouped both on a seasonal basis and in the context of all flood events in the inventory. Again, it is clear that rainfall events result in the greatest number of flood events representing the causal event in 66% of the flood events in the inventory. Also of interest is that flood events resulting from rainfall occur somewhat evenly over the year. Flood events associated with coastal events occur most frequently in the fall and winter. Together, flood events resulting from rainfall or coastal processes represent 87% of the events documented in the inventory.

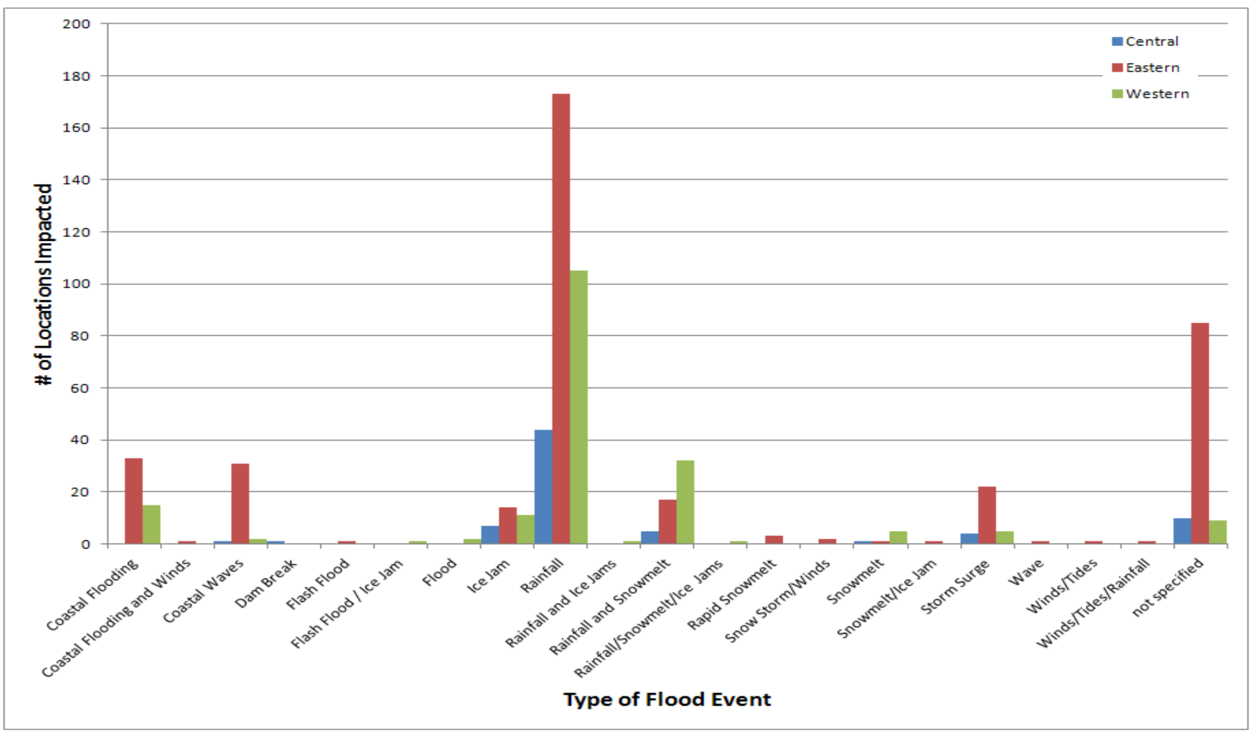


Figure 2-10. Flood Occurrence by 'Types of Events'

Type of Event (Grouped)	% Occurrence of Type of Grouped Event by Season				% Occurrence of Flood Events by Type of Event Group
	Winter	Spring	Summer	Fall	
Rainfall	28%	21%	29%	22%	58%
Coastal	68%	0%	11%	21%	18%
Other	5%	5%	5%	86%	17%
Ice Jam	85%	12%	0%	3%	5%
Snowmelt	77%	8%	0%	15%	2%

Table 2-4. Event Type Occurrence

2.3.5 Flooded Communities

Table 2-5 details flood events by community. St. John's has had the most reported floods in the province with 73 floods, or about 11% of the documented flood events in the inventory. Stephenville, Corner Brook and Deer Lake have all reported multiple flood events in the Western Region. There has only been one reported flood event in Labrador. Those communities with a single flood event (202 presently in the inventory) are grouped into the "Other" section.

Figure 2-11 illustrates the seasonality of flood events in communities which have experienced more than 10 flood events as documented in the inventory. As illustrated, these communities have a general expectation of winter flooding, with the exception of Deer Lake where more floods have occurred in the summer season.

Figure 2-12 illustrates the types of flood events that are experienced by these communities. Again, flood producing rainfall events are most commonly experienced in these communities, with the exception of Placentia which has experience more flood events as a result of coastal phenomena. Table 2-6 outlines the type of event groupings referenced in Figure 2-12.

St. John's	73
Corner Brook	42
Stephenville	27
Deer Lake	16
Placentia	12
Ferryland	7
Noel's Pond	7
Codroy Valley	6
Gould's	6
Carbonear	5
Gambo	5
Gander	5
Grand Bank	5
Grand Falls	5
King's Point	5
Marystown	5
Middle Arm	5
Mount Pearl	5
Maddox Cove	5
Rushoon	5
Steady Brook	5
Badger	4
Black Duck Siding	4
Burin	4
Clarkes Beach	4
Cox's Cove	4
Lamaline	4
Lawn	4
Trepassey	4
Victoria	4
Bay Roberts	3
Belleoram	3
Burin Peninsula	3
Cold Brook	3
Conception Bay South	3
Dunville	3
Epworth	3
Fortune	3
Glovertown	3
Hant's Harbour	3
Harbour Grace	3
Little Bay	3
Little St. Lawrence	3
Point aux Gaul	3
Red Harbour	3
Rocky Harbour	3
The Beaches	3
Torbay	3
Trout River	3
Whiteway	3
Admirals Beach	2
Allan's Island	2
Baie Verte	2
Bay de Verde	2
Bay L'Argent	2
Bay of Islands	2
Bishops Falls	2
Branch	2
Brigus	2
Burlington	2
Cavendish	2
Channel-Port aux Basques	2
Clarenville	2
Clarke's Beach	2
Cupids	2
Flat Bay	2
Flat Rock	2
Fox Cove-Mortier	2
Fox Harbour	2
Frenchman's Cove	2
Greenspond	2
Harbour Mille	2
Holyrood	2
Indian Bay	2
Lark Harbour	2
Lethbridge	2
Lewisporte	2
Long Harbour	2
Mount Carmel	2
Norman's Cove	2
North Harbour	2
Parson's Pond	2
Point May	2
Portugal Cove-St. Phillips	2
Pouch Cove	2
Random Island	2
Rattling Brook	2
Reidville	2
Seal Cove	2
Ship Harbour	2
Smith's Harbour	2
South River	2
St. Brides	2
St. Lawrence	2
Sunnyside	2
Whitbourne	2
Winterton	2
Witless Bay	2
Other	202

Table 2-5. Flood Occurrence by Community

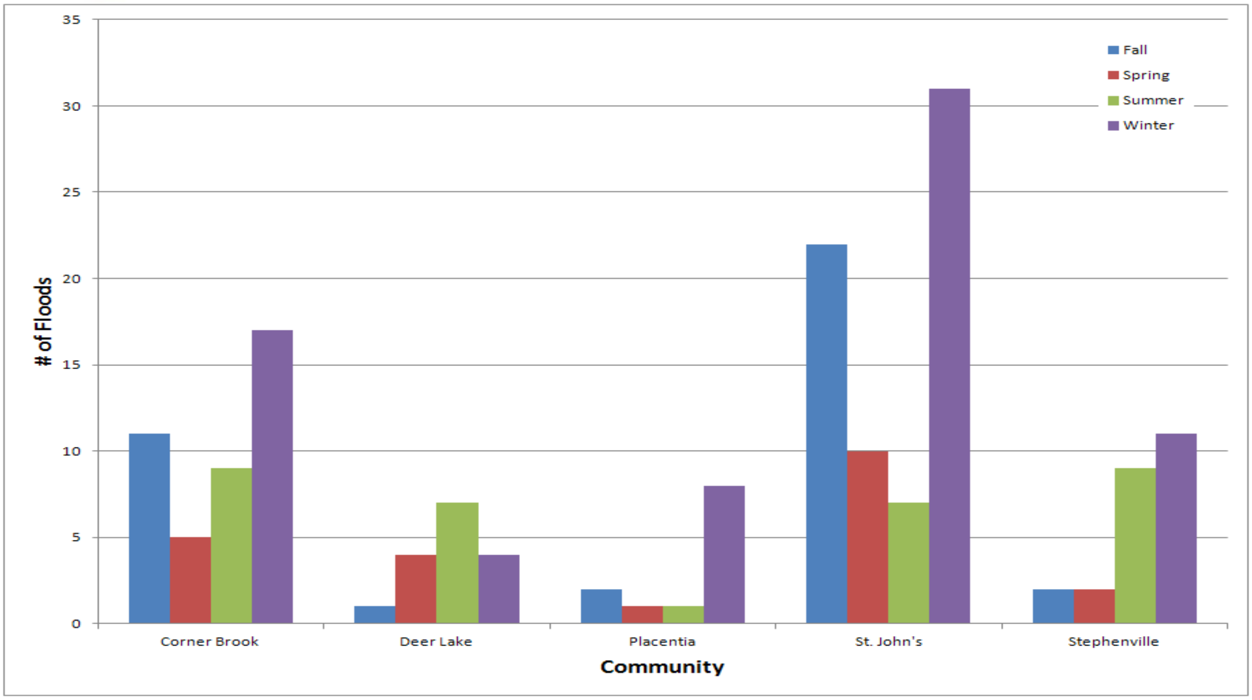


Figure 2-11. Flood Occurrence by Season in Specific Communities

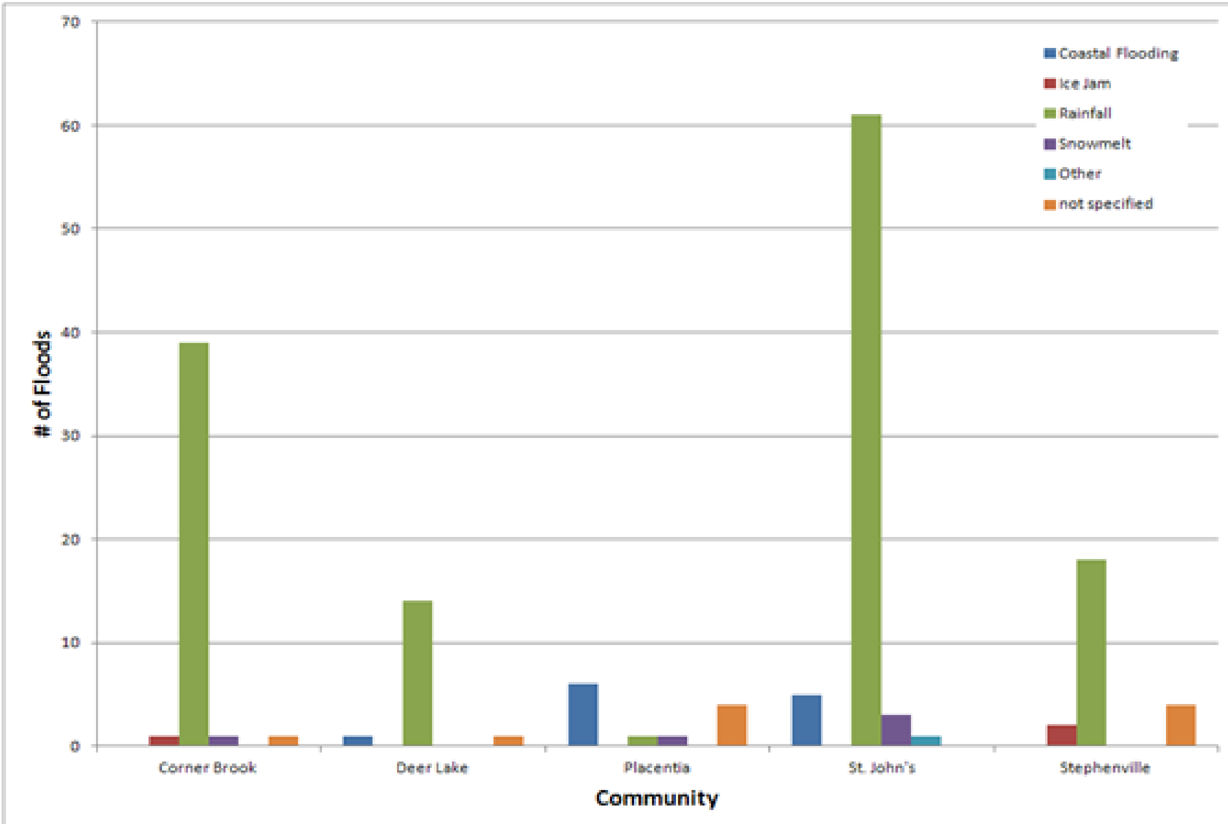


Figure 2-12. Flood Occurrence by Community and Type of Event

Coastal Flooding	Coastal Flooding
Coastal Flooding and Winds	Coastal Flooding
Coastal Waves	Coastal Flooding
Storm Surge	Coastal Flooding
Wave	Coastal Flooding
Winds/Tides	Coastal Flooding
Winds/Tides/Rainfall	Coastal Flooding
Flash Flood / Ice Jam	Ice Jam
Ice Jam	Ice Jam
Dam Break	Other
Flash Flood	Other
Flood	Other
Rainfall	Rainfall
Rainfall and Ice Jams	Rainfall
Rainfall and Snowmelt	Rainfall
Rainfall/Snowmelt/Ice Jams	Rainfall
Rapid Snowmelt	Snowmelt
Snow Storm/Winds	Snowmelt
Snowmelt	Snowmelt
Snowmelt/Ice Jam	Snowmelt
Dam Break	Other
Flash Flood	Other
Flood	Other
not specified	not specified

Table 2-6. Event Type Groupings

2.4 Summary

The Flood Events Inventory update effort focused on the period 1950-present. This update was based on a review of existing information contained in the current Flood Events Inventory and the collection and compilation of new data necessary for updating the Flood Events Inventory for the required period. The starting point was the inventory of flood event information that accompanied the WRMD report *"A Preliminary Study of Flooding in Newfoundland and Labrador (1998-2008)" which* identified 179 flood occurrences and 70 flood producing events. The updated, current Flood Events Inventory contains 650 flood occurrences and documents 269 flood producing events, an addition of 471 records, identifying a flood event at a location (community or damage area), and 199 storm events. Source data for new records added to the inventory are available electronically as a component deliverable with the inventory. The data presented in the updated Flood Events Inventory is considered as complete and as correct as possible in the context of Project objectives.

Analysis of the updated Flood Events Inventory yielded the following comments:

Damages

- Of the 650 records in the Flood Events Inventory, 53 records have damage estimates, abstracted from source documents used to update the inventory, totaling about $252 million (normalized to 2011).
- Of the 650 records in the Flood Events Inventory, 11 records have damage estimates, based on DFAA reporting, totaling about $180 million (normalized to 2011).
- Damage estimates range from a few thousand dollars to over $100 million associated with Hurricane Igor in 2010.
- Eighteen (18) flood events in the inventory have documented damages of $1 million or more (damage estimates based on source literature review).
- All DFAA damage estimates are greater than $1 million.
- The average annual flood damages are estimated to be about $8.1 million over the period (1955-2010) represented by data records with damage information sourced from the background review.
- The average annual flood damages are estimated to be about $22.5 million over the period (2000-2010) represented by data records with damage information sourced DFAA reporting.
- Fall and winter floods generally produce damages with the greatest dollar value.

Annual Flooding

- Over the entire inventory period (i.e., 1950 through 2011) a total of 650 flood events are documented, averaging about 10 flood events per year.
- The years 1998 through 2011 are considered complete in terms of documentation of known storm events and during this period a total of 102 storm events are documented in the inventory for an average occurrence of about 7 per year.
- The Eastern and Western regions have more documented storm events than the Central region with a total of 148, 91, 29 events documented in the inventory, respectively.
- Flooding in Labrador is extremely rare with only one documented flood event in the current inventory.

Storms by Season and Month

- Over the entire inventory period (i.e., 1950 through 2011) a total of 269 storm events are documented, averaging about 4 storm events per year.
- Over the entire inventory, January and February are the months with the highest occurrence of storm events.

- September is associated, presently, with the greatest number of flood events in the inventory representing about 26% of the records.
- December is also a significant storm event month with 10% of the documented storm occurrence.
- The remainder of the months experience less than 10% storm occurrence each.
- Flood events occur to the greatest extent in the winter, fall, and spring.

Causes of Flooding

- The primary causal event for flooding in the province is rainfall associated with 58% of the flood events documented in the inventory.
- Flood events resulting from rainfall occur somewhat evenly over the year.
- Flood events resulting with coastal phenomena are the second most common occurring most frequently in the fall and winter.
- Flood events resulting from rainfall or coastal phenomena represent 76% of the flood events documented in the inventory.

Flooded Communities

- The inventory documents flood events at ninety-eight (98) communities in the province.
- St. John's has had the most reported floods with seventy-three (73), or about 11% of the documented floods in the inventory.
- Stephenville, Corner Brook, Deer Lake and Placentia have all reported multiple floods.
- There has only been one reported flood in Labrador

2.5 Recommendations for Update of the Flood Events Inventory

The following recommendations stem from the effort to update the Flood Events Inventory:

1. It is recommended that WRMD endeavor to include flood events which occurred earlier than 1950 in the Inventory with the next Flood Events Inventory update. The selection of the period of 1950 to 2011 was selected by WRMD as it was felt that prior to confederation there would be limited data available. Many flood events pre-dating 1950 are documented in the same source data collections used for this update effort. Please refer to the inventory for a list of these sources. Having these events included may assist in better defining/understanding the long-term cyclical nature of storm events in the Province.
2. It is recommended that some consideration be given to splitting the 'Types of Event' field into primary and secondary (and perhaps even tertiary) causal factors. This would allow for consolidation of entries within a more concise listing of primary/secondary causes and perhaps better understanding of the nature of flood events.

3. It is recommended that WRMD consider the addition of a data field to identify the watershed within which the community is located.[13]

4. It is recommended that the WRMD give consideration to evolving the Flood Events Inventory software platform from Microsoft Excel© to a database platform such as Microsoft Access©. This would facilitate capture of additional flood related information from multiple sources, better data entry and management, in addition, to the ability for more efficient linking to other databases (such as the Local Government Profiles database) and GIS.

[13] An initial effort towards this end has been substantially completed as a component of the Flood Risk Assessment (Task E) for this project.

3. Task C – Assess Existing Flood Risk Maps

The Flood Risk Mapping Studies / Public Information Maps page from the Department of Environment and Conservation website provides access to digital flood plain data for communities where floodplain mapping has been developed. Table 3-1 lists the communities for which flood plain data is available on WRMD's website and the available data formats. These communities were the focus of the project objectives related to flood risk map re-assessment.

Five basic objectives were identified for this project task, namely:

- Preparation of GIS base maps for communities vulnerable to flooding identified in Table 3-1,
- Digitization of flood plain data for communities identified in Table 3-1,
- Delineation of community flood watersheds for those communities identified in Table 3-1,
- Land cover classification within community flood watersheds and comparison to earlier classifications, and,
- Determination, based on best available science, of the impact the changing climate will have on communities vulnerable to flooding.

Badger	Goulds	Salmon Cove
Bishops Falls	Hant's Harbour	Shoal Harbour / Hodges Cove
Brigus	Heart's Delight	Steady Brook
Carbonear	Hickman's Harbour	Stephenville
Codroy Valley	Outer Cove	Stephenville Crossing / Black Duck Siding
Cox's Cove	Parson's Pond	Trout River
Deer Lake	Petty Harbour	Victoria
Ferryland	Placentia	Waterford River
Gaudon's Brook / Cold Brook	Portugal Cove / St. Philips	Whitbourne
Glenwood / Appleton	Rushoon	Winterton
Glovertown	Rushy Pond	

Table 3-1. Communities for which Flood Mapping is Presently Available

Please note for Task C the names used for communities and areas are a combination of those that were in place when the FRM studies were done in the 1980s and 1990s and those reflected by the new LGP numbers due to a need to use data from both old FRM studies and the LGP list.

3.1 C1 – Compile GIS Base Maps

For each of the communities and areas identified in Table 3-1, a base map was created from the best available source data. Where available the 1:2500 scale structured digital community map layers available from the Department of Environment and Conservation Surveys and Mapping division was used. Where 1:2500 scale structured vector data was not available, the 1:50,000 scale National Topographic Series (NTS) mapping, the best available alternate dataset, was used. Key layers making up the base maps include: roads, buildings, waterbodies, wetlands, rivers, contour lines, and other built structures. Satellite imagery collected for this project was used as a backdrop for the map.

Note: Structured data refers to Shapefiles that were received from the Provincial Government in which attribution on the individual geometry records within the Shapefiles have been captured. Unstructured Shapefiles represent records with no attribution making it virtually impossible to ascertain the details on the geometry feature in question.

3.1.1 Digitization of Flood Plain Data

The primary operational layer to be added to each GIS base map was the flood risk map data obtained from WRMD (via website download in most cases); specifically the 1:20 and 1:100 year flood lines.

As noted above, some of these needed to be digitized by AMEC GIS staff and converted to a format compatible with ArcGIS.

Flood lines for 11 communities were digitized from PDF or JPG drawings downloaded from the Departments website. In many cases these drawings did not line up with the base map and as such AMEC approximated to positioning of the flood lines.

Bishops Falls	Deer Lake	Trout River
Brigus	Glenwood / Appleton	Placentia
Carbonear	Glovertown	Rushy Pond
Codroy Valley	Steady Brook	

Table 3-2. Communities for which Flood Mapping required digitizing from PDF or JPG drawings

Flood lines for 2 communites where captured from Shapefiles posted on the WRMD website.

Gaudon's Brook / Cold Brook	Stephenville	

Table 3-3. Communities for which Flood Mapping data was provided by WRMD in Shapefile format.

Flood lines for 17 communiites were captured from AutoCAD files posted on the WRMD website.

Badger	Outer Cove	Shoal Harbour / Hodges Cove
Cox's Cove	Parson's Pont	Stephenville Crossing / Black Duck Siding
Ferryland	Petty Harbour	Victoria
Hant's Harbour	Portugal Cove / St. Philips	Whiteboune
Heart's Delight	Rushoon	Winterton
Hickman's Harbour	Salmon Cove	

Table 3-4 Communities for which flood mapping data was captured from Autocad files

Flood lines for Goulds were not captured during this project as the data was not available.

Flood lines for the community of Waterford River were received in part by the City of Mount Pearl and in part by the City of St. John's. The City of St. John's indicated the flood lines were digitized from the WRMD maps and "approximately corrected" where the City of Mount Pearl indicated the flood lines are considered unofficial and were originally in multiple sections and these sections were joined where possible.

3.2 C2 – Delineate Community Flood Watersheds

A community flood watershed is defined in the *Feature Codes – Flood Risk Mapping* document provided by WRMD as a "watershed for a community / water body that has experienced a documented flood event". It includes all areas of the watershed upstream of the community.

Delineation of community flood watersheds was completed in accordance with the standards established by WRMD. The following key steps for this effort are outlined below:

- The most up-to-date 1:50,000 NTS digital topographic data available from NRCan GeoBase (January 2012) was obtained for the areas of interest.
- The most up-to-date 1:50,000 DEMs from NRCan GeoBase (January 2012) for the areas of interest were obtained. Where the information was not available, DEMs were created using the 1:50,000 NTS vector topographic data.

- Watershed boundaries were created by referencing the drainage network and watershed topography. Only areas upstream of the community were included. This was further interpreted as areas upstream of the downstream limit of the existing flood plain mapping.
- The watersheds were digitized as polygons.
- Where watershed lines were coincident, the lines were digitized as the same line and copied to the other appropriate layer(s).
- Watersheds along shorelines of waterbodies and/or coastlines did NOT use these features as the edges of polygons as shorelines and coastlines are prone to significant changes in water features.
- Feature codes are compliant with those defined in *Feature Codes – Flood Risk Mapping* document provided by WRMD.
- The geo-referenced digital map layers for the watersheds are provided, as a deliverable of this project, as ESRI Shapefiles and as AutoCAD R2000 DWG Files. All digital files are provided in provincial MTM projections (NAD83).

3.3 C3 - Land Cover Classification

3.3.1 Introduction

To support flood risk assessment, a land cover classification was conducted in 39 community flood watersheds across the island of Newfoundland in Labrador, Canada. Seven (7) land cover classes (excluding an eight "unclassified" class comprised of ice, clouds and shadows) were classified from 10-meter resolution, 4-band multispectral SPOT imagery captured between 2005 and 2010. Additionally, two (2) land cover change classes, deforested areas due to development and other deforested areas were derived from Earth Observation for Sustainable Development of Forests (EOSD) data which was generated from 30-meter Landsat satellite imagery from the year 2000. The resulting nine (9) classes of land cover represent both time periods and were summarized for each of the 39 watersheds. The data was used as an input to hydrologic models described in the main body of this report. This section documents the imagery and data sources provided to AMEC, the imagery classification methods, the results, and provides recommendations for future similar studies.

3.3.2 Imagery and Data Sources

The inputs to the land cover classification were 2010 SPOT satellite imagery, 2000 EOSD data, and ancillary GIS data such as watershed and municipal boundaries. Approximately 90% of the watersheds were in UTM Zone 21, but the eastern watersheds are in Zone 22. Vector data was provided in the MTM projection and was reprojected to matching UTM zones from respective SPOT images.

3.3.2.1 Community Flood Watersheds

The delineation of community flood watershed boundaries is described in Section 3.2 of this report. The 39 drainage basins analyzed in this study do not represent exclusive geographic areas, as many are sub-basins to a larger watershed. Watersheds boundaries were buffered by 100 meters to ensure land cover classification data provided full coverage during computation of land cover metrics. Basin and sub-basin names and associations are presented in the Results section (See Table 3-7).

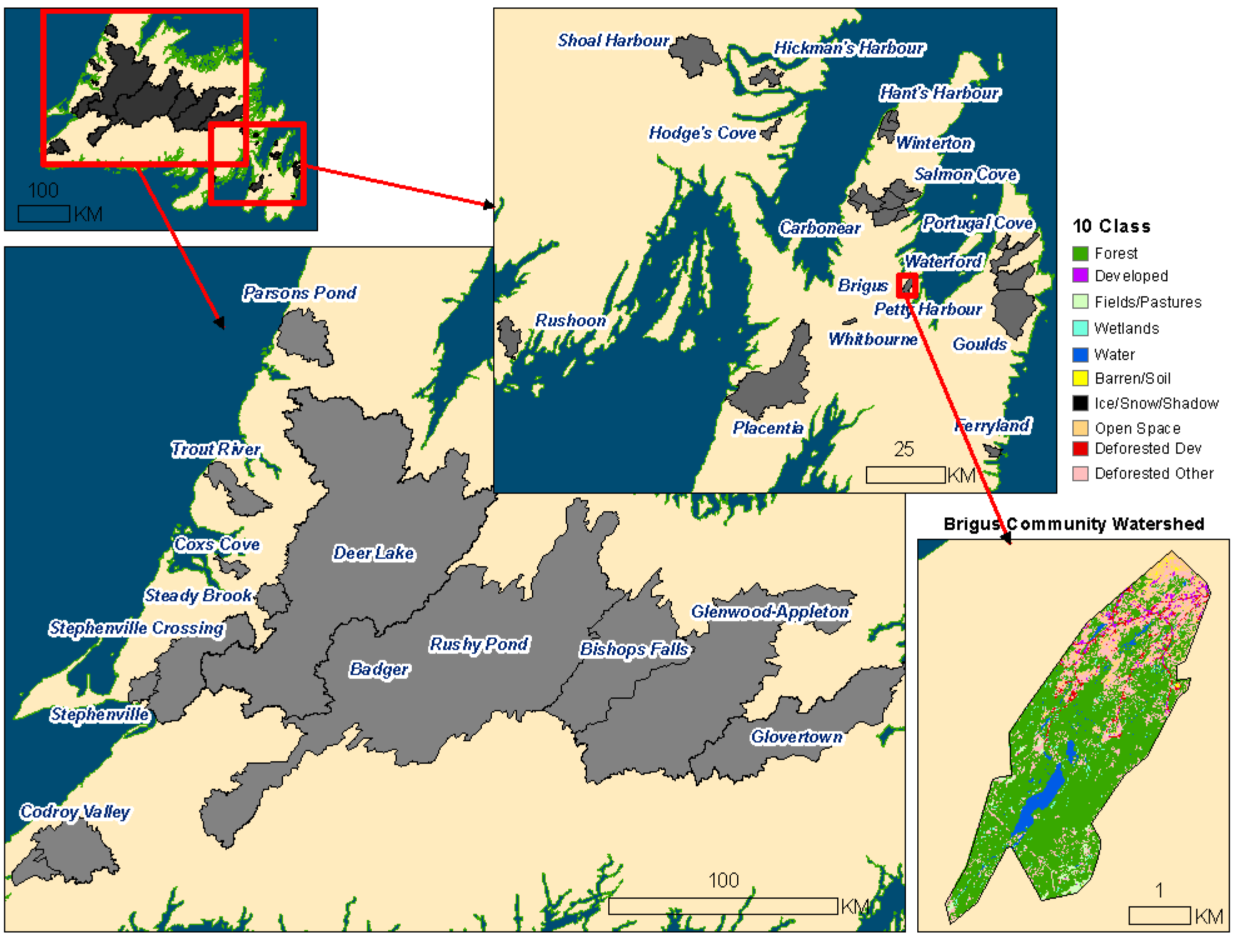


Figure 3-1. Evaluated Watersheds

As seen in Figure 3-1, thirty-nine (39) watersheds were evaluated for land cover and land cover change across Newfoundland Island (inset upper left). The bulk of the watershed area is located in the center of the island (large inset center), while the major count of watersheds are located east on the island (inset upper right). A classification example of Brigus community watershed is provided in the lower right.

3.3.2.2 SPOT Satellite Imagery

All SPOT imagery was provided to AMEC by the WRMD with assistance from Iunctus Geomatics Corp. The SPOT images were delivered as previously orthorectified datasets and with a combination of clipped and/or full scenes that included 2.5-meter panchromatic, 2.5-meter fused natural color (3-band), and 10-meter resolution multispectral (4-band). Fused natural color images were used for training and verification purposes while the 10-meter multispectral imagery was used for classification. Image acquisition dates spanned from 2005 to 2010, with the majority of images used being collected in 2009 and 2010. Most SPOT imagery was provided by hard drive with supplemental images needed to fill gaps in coverage provided by Iunctus via FTP. Recommendations at the end of this section offer suggestions for improved data management of imagery ordering, tracking and delivery to vendors on future projects as well as other general best practices for leveraging remotely sensed imagery.

Additionally, the following description was provided by Iunctus to describe their image preprocessing methods and accuracies:

> *"The data set is derived from SPOT5 2.5m panchromatic and 10m multispectral raw image level 1A. It has been processed to Level 3A orthorectified dataset using the most accurate control available. This includes (in order of priority) 1) NRN from GeoBase; and 2) LANDSAT 7 ortho-imagery from GeoBase. The methodology ensures adequate distribution of the control points within the image. The parametric model was developed by Dr. Thierry Toutin at the Canada Centre for Remote Sensing (CCRS), Natural Resources Canada. This model is based on principles related to orbitography, photogrammetry, geodesy, and cartography. It reflects the physical reality of the complete viewing geometry and corrects distortions that occur due to platform, sensor, Earth, and cartography projection. The Digital Elevation Model (DEM) is the most accurate source available from GeoBase as of the date of orthorectification. This is the Canadian Digital Elevation Data (CDED). The CDED can be a combination of data at the 1:50 000 or 1:250 000 scale. Level 3A orthorectified images are resampled using an 8-point SinX method. The preprocessing applied to level 1A data for SPOT satellites is minimal. Only detector equalization is performed: it consists of compensating for the differences of sensitivities between the elementary detectors of the CCD (Charged Coupled Device) arrays, using a linear model. Absolute calibration coefficients posted in the ancillary data can be used to convert the pixel counts into irradiance values. No geometric corrections are performed, and, when displayed, the SPOT Scene image in level 1A is a square. Ancillary data (coordinates of the scene center as well as the four corners) describe the image location with an accuracy better than 500m root mean square error (rms) for SPOT4 and an accuracy better than 30m rms for SPOT5."*

3.3.2.3 Earth Observation for Sustainable Development of Forests

	Class		Class
	No Data		Wetland - Shrub
	Shadow		Wetland - Herb
	Cloud		Coniferous - Dense
	Snow/Ice		Coniferous - Open
	Rock/Rubble		Coniferous - Sparse
	Exposed Land		Broadleaf - Dense
	Water		Broadleaf - Open
	Shrub - Tall		Broadleaf - Sparse
	Shrub - Low		Mixed Wood - Dense
	Herb		Mixed Wood - Open
	Bryoids		Mixed Wood - Sparse
	Wetland - Treed		

Figure 3-2. EOSD Land Cover Classification

The Earth Observation for Sustainable Development of Forests (EOSD) is a land cover classification consisting of 23 vegetation (Figure 3-2), and other cover type classes based on year 2000, 30-meter Landsat satellite imagery. EOSD data were downloaded from the Canadian Forest Service's CFSNet website[14] and reviewed to ensure complete watershed coverage of the data. Upon review, a few areas were found to be missing data ("NoData" pixel values). Personal correspondence with Chris West of the Natural Resources Canada, Canadian Forest Service verified the issue and provided only a partial solution in some areas. In the areas with unclassified pixels, no change detection was able to be reported.

All EOSD raster images were combined into a single mosaic and clipped to the watershed boundaries. An additional buffer was applied to the previously buffered watershed boundaries to make certain all data was captured for this process. Upon review of the data, it was found that there were spatial shifts in the southeastern watershed study areas. To address this issue, a mosaic raster dataset was created for all areas where spatial shifts did not exist to hold their positions constant. A subset of the larger EOSD data was then created for the shifted areas, and the ArcMap Georeferencing tool was utilized to register the EOSD data to the spatial

[14] CFS Net Website https://pfc.cfsnet.nfis.org/mapserver/eosd_portal/htdocs/eosd-cfsnet.phtml

coordinates of the SPOT imagery using control points. A reasonable root mean squared error (RMSE) was achieved during the registration process, but it is important to note that the classified EOSD dataset was processed using coarser resolution than the reference SPOT data; therefore, spatial shifts may still exist but are minor. After georeferencing was complete, a final EOSD mosaic dataset was created.

3.3.3 Land Cover Classification

Land cover classification was performed through a multi-step process detailed below. General steps include; (1) image preprocessing and mosaicing, (2) ISODATA unsupervised classification and aggregation, (3) change detection processes, (4) classification corrections and manual edits, (5) land cover tabulations by watershed, and (6) accuracy assessment. Accuracy assessment results are presented in the results section.

3.3.3.1 Image Preprocessing

Due to the large geographic area and the high frequency of clouds and ice in the study area, more than 100 SPOT images and image fragments were used in this study. For each watershed, mosaics of images with similar reflectance characteristics were combined to create larger images where possible. Histogram matching was used to reduce pixel variation within aggregated images. For the remaining, adjacent datasets with high levels of variation in pixel values at overlapping areas (likely due to temporal resolution), performing an atmospheric correction process to apparent reflectance values would not have provided any benefit (see additional information in Recommendations). Clouds and ice were then masked from areas where they represented a large proportion of existing imagery in order to remove these skewed pixel values during the classification.

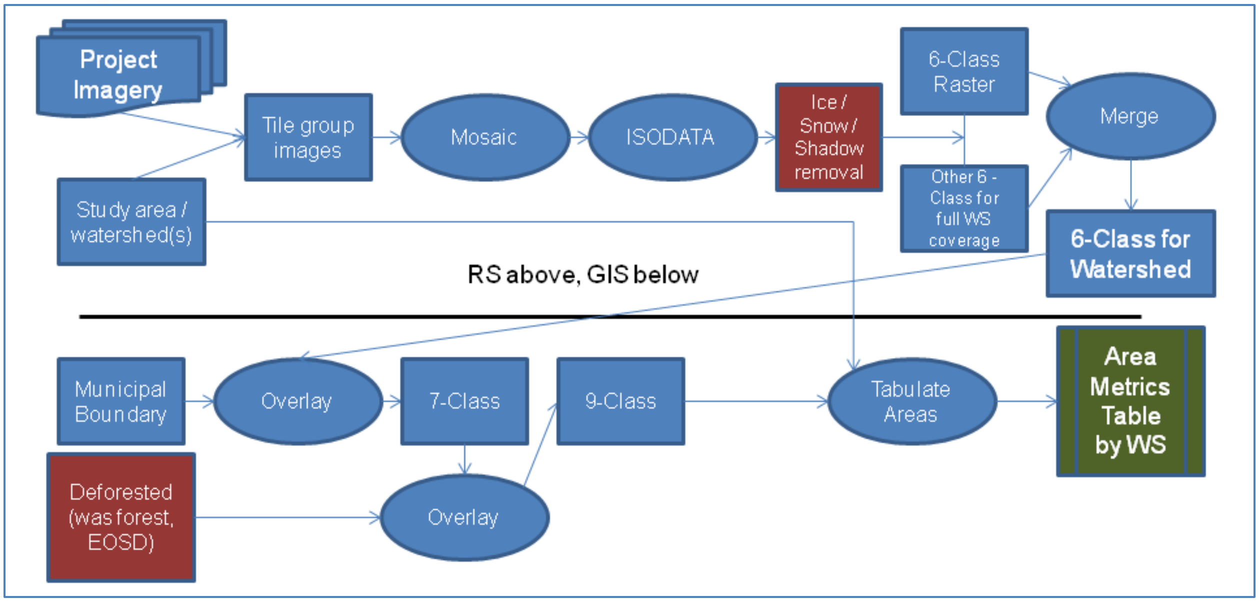


Figure 3-3. Graphical model of land cover/land use classification methods used in this study

3.3.3.2 ISODATA Classification and Aggregation

Images and image groups with similar visual characteristics were then classified using the ISODATA (Iterative Self Organizing Data Analysis Techniques) algorithm within the software ERDAS Imagine. The ISODATA algorithm is an unsupervised classification that generates statistically significant clusters of similar pixels based on values within each band and the user-defined number of clusters. The number of clusters selected for a particular classification was dependent on the overall size of the image or image group but ranged from 20 for small images to 100 for large images (the larger the image, the greater number of pixels, the greater number of clusters selected). Clusters were then manually assigned to one of six land cover classes using higher resolution aerial and satellite imagery. ISODATA is very similar to the Fuzzy K Means unsupervised classification used in the Stephenville, Newfoundland land cover classification study. To create the 7th land cover class for 2010 conditions, municipal area[15] boundaries were then used to separate non-forest vegetation into open space (municipal green space) vs. fields/pasture (agricultural land outside municipal boundaries). The classification at this point takes on more of a land cover / land use data set with the influence of supporting GIS data. The 8th and 9th classes showing the type of deforested land conversion were then accomplished with an overlay and reclassify of EOSD data (methods described below).

Final land cover classes (Table 3-5) for the Flood Vulnerability study. Non-forest vegetation from the original classification is separated into Fields/Pastures or Open Space relative to municipal boundaries. Two types of deforestation are reported based on original land cover class.

---

[15] Municipal boundaries provided by Charmaine Winter, Computer Programmer 1 (GIS), NL Dept. of Municipal Affairs, (709) 729-6666, cwinter@gov.nl.ca.

Class Number	Final Land Cover Classes	Definition
1	Forest	
2	Developed	
3	Fields/Pastures	Vegetation land cover outside municipal areas
4	Wetland	
5	Water	
6	Barren	
7	Open Space	Vegetation land cover within municipal areas
8	Deforested-Dev	Deforested for Development. Forested areas in 2000 that are currently classified as Developed.
9	Deforested-Other	Deforested. Forested areas in 2000 that are currently classified as Fields/Pastures, Barren, or Open Space.

Table 3-5. Land Cover Classes

3.3.3.3 Land Cover Change

Change detection analysis compared 2010 SPOT-based classified images to EOSD land cover data from 2000. EOSD data were aggregated to forest and non-forest classes and compared to the classified land cover (Table 3-6). Given the coarser resolution of the EOSD compared with the SPOT image classification, a review of the 3 “sparse” forest classes in the table below was conducted to consider whether these pixels should be included in the Open Spaces or Fields/Pastures classes. Upon review, the sparse forest classes provided an accurate representation of sparse forest cover and were therefore kept in the forest class and subsequent analysis of deforested areas. Table 3-6 illustrates how the EOSD classes were aggregated for change detection.

Original EOSD Classes	Aggregated Classes
Shadow	Non-Forest
Water	Non-Forest
Snow/Ice	Non-Forest
Rock/Rubble	Non-Forest
Exposed Land	Non-Forest
Bryoids	Non-Forest
Shrub Tall	Non-Forest
Shrub Low	Non-Forest
Wetland – Treed	Non-Forest
Wetland – Shrub	Non-Forest
Wetland – Herb	Non-Forest
Herb	Non-Forest
Coniferous Dense	Forest
Coniferous Open	Forest
Coniferous Sparse	Forest
Broadleaf Dense	Forest
Broadleaf Open	Forest
Broadleaf Sparse	Forest
Mixed Wood Dense	Forest
Mixed Wood Open	Forest
Mixed Wood Sparse	Forest

Table 3-6. Original (left) and aggregated (right) classes used to identify forest loss between 2000 and the dates of image classification.

It should be noted that the EOSD data lacks a land cover class representing impervious surfaces or related land use categories such as residential, commercial/industrial, or urban. Therefore, two types of deforestation were classified; areas that were forested in the 2000 EOSD which are now classified as developed (called "Deforested – Developed") and areas that were forested in the 2000 EOSD which are currently classified as field/pasture, open space, or barren (called "Deforested – Other"). The EOSD water class was evaluated for the possibility of measuring change in water area. However, due to the highly variable nature of water depth, inconsistencies between image dates, and coarse resolution of the EOSD data, change detection for water area was not conducted.

3.3.3.4 Manual Corrections

Primary edits required to improve consistency across land cover mosaics involved manual corrections to areas covered by shadows, clouds, and ice, and along image seamlines due to abrupt seasonal changes in images. Some seamlines were corrected manually by hand editing vector data, conversion to raster, and merged into new mosaics. For shadows, clouds, and ice, additional SPOT images were used where available and supervised classification steps were performed inside shadow, cloud and ice areas as masks. Results were verified against the original land cover mosaics for any potential seamline issues (abrupt changes between input images) and then the data was merged into final mosaic land cover data sets.

3.3.3.5 Land Cover Tabulations by Watershed

The final 9-class land cover data sets were then intersected with the 39 community flood watersheds to tabulate total area (in square kilometers) and percent coverage of each class by watershed name (Table 3-7). For Quality Assurance / Quality Control purposes, random watersheds were selected and land cover metrics were calculated by hand then checked against automated metrics. These tables were then used as direct inputs to the flood vulnerability assessment.

3.3.4 Results

Results are presented for the overall classification and for each community flood watershed delineation boundary inTable 3-7. Accuracy assessment results detail the effectiveness of the classification methods employed in this study. Land cover within 39 watersheds is presented covering the flood vulnerability areas for the 32 communities identified in the proposal. Table 3-7is presented in alphabetical order by watershed name.

3.3.4.1 Accuracy Assessment

An accuracy assessment was completed to measure the effectiveness of classifying six classes of land cover derived from the 10-meter SPOT imagery. Classification accuracy was assessed by comparing ground truth (from 2.5 meter resolution, natural color, pan-sharpened SPOT images) to the classified land cover at each assessment point. When interpreting the contingency table (Figure 3-5) a number of important precautions should be considered:

1. Ground truth data (2.5 m) used to assess the accuracy is of a higher spatial resolution than the data used in the classification (10 m). The difference in resolution and spatial shift can lead to exaggerated errors, since the larger pixels used in the classification can be a combination of a number of land cover classes (See Figure 3-4).
2. Ground truth data in some cases may be from a time period that differs from the time period of the classified imagery. While image dates are generally from the same period, not all 10-meter imagery used for classification had 2.5-meter imagery and vice versa. Spatial shifts and land cover change may have occurred between the ground truth image and classification image.
3. Ground truth data are natural color 3-band images, while the classification data use 4-bands. In natural color, wetlands and barren ground look very similar. Because of this,

surrounding areas were also evaluated during the accuracy assessment to determine the probable ground class.

4. See Recommendations section for improved training and verification data and processes

3.3.4.2 Accuracy Assessment Procedures

A grid of 100,000 points was distributed randomly throughout the study area. One hundred (100) points per class were randomly selected and assessed for true on-the-ground land cover using the 2.5 meter pan-sharpened imagery. Points falling on pixel edges, and points where interpretation of true land cover was obscured were excluded.

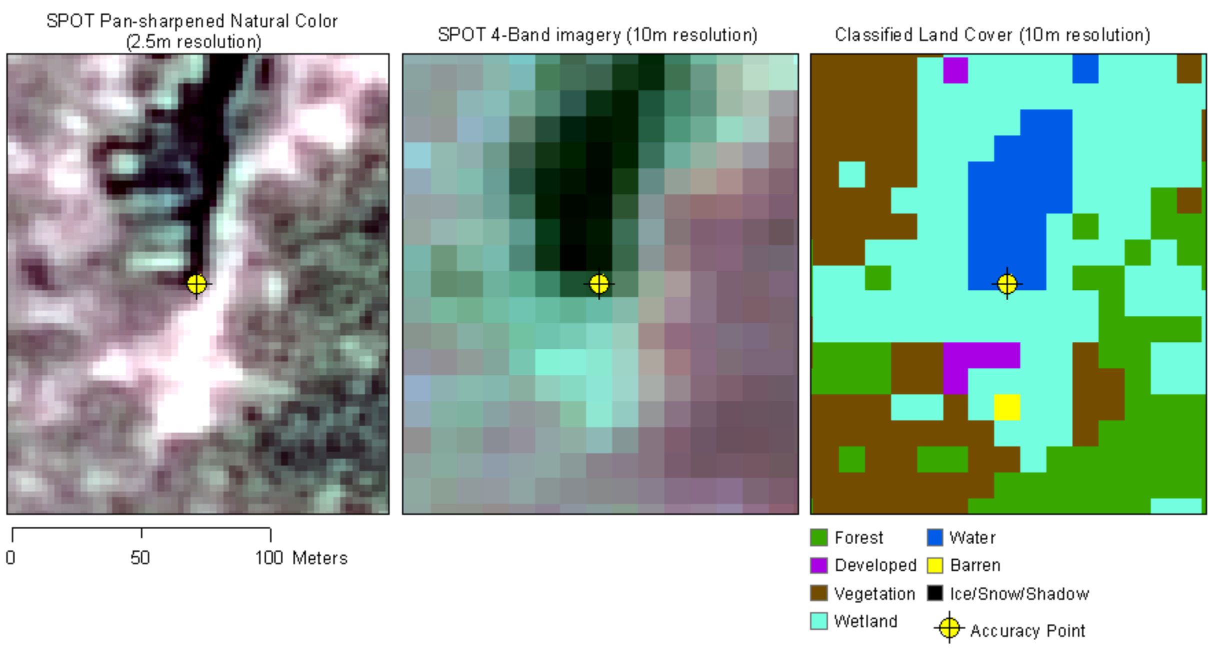


Figure 3-4. Pan-sharpened natural color, multi-spectral, and classified land cover example. Classified land cover is based on 10m resolution, multi-spectral imagery (center) while the 2.5m natural color imagery (left) was used to assess classification accuracy.

3.3.4.3 Interpretation

Figure 3-5 is referred to as a “standard error” or “confusion matrix” in a traditional accuracy assessment based on land cover at the location of each point. Data columns represent actual ground classes manually determined using 2.5 m pan-sharpened imagery. For example, 113 points were manually determined (by visually looking at the 2.5m pan-sharpened imagery) to be located on forest. Rows represent the classified land cover at the location of each point. For example, 103 points fell on land cover classified as forest. The values along the diagonals (in green) represent agreement between the ground truth and classified values. Percent correct for each class is presented in the Accuracy (ii) column and is calculated by dividing the number of correct points by the total number of points in the corresponding class (for example, the forest class accuracy is 98/103 = 95.10%). The average correct percentage across all six land cover classes is 88.8%. A total of 549 points were evaluated with 490 correct responses (overall accuracy of 89.25%).

Watershed Name	Community Name	Total Area (Sq. KM)	Forest (sq. km)	Forest (%)	Dev. (sq. km)	Dev. (%)	Field/Past. (sq. km)	Field/Past. (%)	Wetland (sq. km)	Wetland (%)	Water (sq. km)	Water (%)	Barren (sq. km)	Barren (%)	Open Space (sq. km)	Open Space (%)	Deforest-Dev. (sq. km)	Def.- Dev. (%)	Deforest-other (sq. km)	Def.-Other (%)
Badger	Badger	5383.18	2255.46	41.90	18.80	0.35	675.57	12.55	899.21	16.70	685.00	12.72	256.50	4.76	0.35	0.01	4.60	0.09	546.94	10.16
Bishops Falls	Bishops Falls	10247.47	4949.97	48.30	38.33	0.37	851.66	8.31	1571.20	15.33	1042.53	10.17	368.13	3.59	3.77	0.04	18.72	0.18	1213.81	11.84
Brigus	Brigus	10.30	6.71	65.19	0.19	1.83	0.19	1.88	0.17	1.69	0.45	4.33	0.03	0.29	0.72	7.02	0.25	2.47	1.58	15.31
Carbonear1	Carbonear	37.79	25.38	67.17	0.23	0.62	2.05	5.41	0.49	1.31	5.77	15.26	0.24	0.64	0.77	2.05	0.19	0.50	2.66	7.04
Carbonear2	Carbonear	8.78	6.47	73.66	0.42	4.78	0.09	1.05	0.02	0.25	0.22	2.49	0.06	0.72	0.37	4.27	0.24	2.76	0.88	10.02
Codroy Valley	Codroy Valley	822.51	595.60	72.41	0.30	0.04	21.89	2.66	50.25	6.11	38.79	4.72	52.55	6.39	0.00	0.00	0.13	0.02	55.16	6.71
Codroy Valley2	Codroy Valley	662.33	470.87	71.09	0.30	0.05	17.32	2.62	46.35	7.00	32.10	4.85	43.72	6.60	0.00	0.00	0.13	0.02	44.30	6.69
Coxs Cove	Coxs Cove	60.66	38.41	63.32	0.26	0.42	1.48	2.44	2.76	4.54	7.02	11.58	0.61	1.01	0.20	0.33	0.15	0.25	9.77	16.11
Deer Lake	Deer Lake	7775.14	3494.03	44.94	27.69	0.36	720.00	9.26	1070.61	13.77	1042.92	13.41	244.76	3.15	36.94	0.48	12.72	0.16	1042.92	13.41
Ferryland	Ferryland	12.97	6.38	49.23	0.28	2.14	0.09	0.67	0.04	0.33	1.81	13.96	0.01	0.08	0.77	5.92	0.40	3.07	3.19	24.61
Gaudons Brook / Cold Brook	Gaudons Brook / Cold Brook	25.35	13.42	52.93	0.11	0.44	2.68	10.58	0.77	3.05	0.11	0.43	1.97	7.77	0.00	0.00	0.11	0.42	6.18	24.38
Glenwood / Appleton	Glenwood / Appleton	4134.52	1927.04	46.61	10.20	0.25	163.16	3.95	698.69	16.90	343.49	8.31	146.31	3.54	4.90	0.12	10.43	0.25	760.14	18.39
Glovertown	Glovertown	1882.54	697.37	37.04	0.20	0.01	132.45	7.04	291.55	15.49	228.10	12.12	134.33	7.14	0.94	0.05	0.13	0.01	365.26	19.40
Goulds	Goulds	117.18	62.73	53.53	1.83	1.57	0.60	0.51	3.50	2.98	11.52	9.83	0.56	0.48	15.50	13.23	2.29	1.95	18.65	15.91
Hant's Harbour	Hant's Harbour	19.86	15.07	75.90	0.02	0.08	0.15	0.75	0.34	1.70	2.14	10.80	0.16	0.79	1.12	5.62	0.05	0.26	0.81	4.10
Hant's Harbour 2	Hant's Harbour	8.70	7.01	80.59	0.03	0.30	0.00	0.00	0.10	0.00	0.09	0.00	0.03	0.00	0.77	0.00	0.04	0.00	0.64	0.00
Heart's Delight	Heart's Delight	3.14	2.66	84.85	0.03	0.93	0.00	0.00	0.02	0.54	0.05	1.66	0.00	0.11	0.17	5.50	0.01	0.30	0.19	6.10
Heart's Delight2	Heart's Delight	43.71	30.51	69.81	0.02	0.04	2.02	4.62	0.59	1.36	7.01	16.04	0.09	0.20	0.55	1.26	0.01	0.03	2.90	6.64
Heart's Delight3	Heart's Delight	6.90	5.36	77.65	0.02	0.31	0.13	1.83	0.05	0.66	0.46	6.67	0.00	0.06	0.15	2.17	0.03	0.47	0.70	10.18
Hickman's Harbour	Hickman's Harbour	34.11	19.83	58.14	0.22	0.64	1.07	3.13	5.59	16.39	3.41	9.98	0.19	0.56	0.00	0.00	0.19	0.54	3.32	9.72
Hodges Cove	Shoal Harbour / Hodges Cove	15.03	11.97	79.64	0.06	0.41	0.60	3.98	0.28	1.84	0.73	4.85	0.04	0.23	0.00	0.00	0.04	0.25	1.32	8.80
Outer Cove	Outer Cove	8.96	3.20	35.69	1.25	13.94	0.00	0.00	0.12	1.37	0.17	1.89	0.08	0.94	1.75	19.56	0.68	7.58	1.71	19.03
Parson's Pond	Parson's Pond	391.22	177.31	45.32	1.42	0.36	63.83	16.31	14.98	3.83	53.89	13.77	15.64	4.00	2.58	0.66	0.22	0.06	48.93	12.51
Petty Harbour	Petty Harbour	144.09	81.57	56.61	1.94	1.34	0.60	0.42	4.03	2.79	13.98	9.71	0.56	0.39	17.31	12.02	2.45	1.70	21.65	15.03
Placentia	Placentia	340.66	224.39	65.87	1.14	0.33	14.84	4.36	21.99	6.45	38.90	11.42	8.00	2.35	1.19	0.35	1.17	0.34	29.05	8.53
Portugal Cove	Portugal Cove / St. Phillips	11.80	6.45	54.65	0.37	3.14	0.00	0.00	0.37	3.14	0.85	7.20	0.06	0.54	1.26	10.65	0.82	6.93	1.62	13.76
Rushoon	Rushoon	55.67	24.85	44.63	0.41	0.73	1.52	2.72	14.00	25.15	4.54	8.16	1.22	2.19	0.19	0.35	0.31	0.55	6.71	12.05
Rushy Pond	Rushy Pond	8376.79	3972.14	47.42	29.87	0.36	800.01	9.55	1306.50	15.60	901.23	10.76	320.70	3.83	1.94	0.02	13.12	0.16	946.36	11.30
Salmon Cove	Salmon Cove	68.34	41.77	61.12	0.29	0.43	4.93	7.22	2.30	3.37	6.36	9.30	1.17	1.72	1.89	2.77	0.32	0.47	9.30	13.61
Shoal Harbour	Shoal Harbour / Hodges Cove	125.55	53.65	42.73	1.72	1.37	2.00	1.59	35.37	28.17	8.54	6.80	1.61	1.28	3.48	2.78	0.86	0.68	16.85	13.42
St. Phillips	Portugal Cove / St. Phillips	35.53	20.55	57.84	1.46	4.10	0.00	0.00	0.68	1.92	8.18	23.03	0.11	0.32	1.30	3.65	1.29	3.63	1.96	5.52
Steady Brook	Steady Brook	7926.37	3595.43	45.36	28.69	0.36	723.44	9.13	1078.05	13.60	1052.36	13.28	246.73	3.11	37.23	0.47	13.23	0.17	1068.33	13.48
Stephenville	Stephenville	124.26	59.37	47.78	3.34	2.69	8.79	7.07	5.92	4.76	3.60	2.90	5.81	4.67	2.74	2.20	0.87	0.70	33.81	27.21
Stephenville Crossing / Black Duck	Stephenville Crossing / Black Duck	923.53	551.35	59.70	3.98	0.43	39.17	4.24	57.43	6.22	77.86	8.43	39.73	4.30	3.38	0.37	2.26	0.24	140.25	15.19
Trout River	Trout River	264.62	103.29	39.03	0.38	0.14	52.35	19.78	3.42	1.29	19.12	7.23	37.60	14.21	0.79	0.30	0.08	0.03	45.78	17.30
Victoria	Victoria	29.29	21.37	72.98	0.03	0.11	2.13	7.27	0.37	1.28	1.94	6.61	0.12	0.42	0.20	0.68	0.04	0.15	3.08	10.50
Waterford River	Waterford River	65.19	20.10	30.83	14.87	22.81	0.00	0.00	1.11	1.70	1.40	2.14	1.41	2.16	8.90	13.66	7.86	12.05	9.55	14.65
Whitbourne	Whitbourne	4.28	3.15	73.49	0.00	0.06	0.10	2.43	0.11	2.49	0.62	14.54	0.02	0.37	0.03	0.76	0.00	0.11	0.25	5.75
Winterton	Winterton	15.19	10.90	71.79	0.06	0.39	0.39	2.56	0.39	2.57	1.91	12.57	0.13	0.88	0.53	3.47	0.07	0.45	0.81	5.31

Table 3-7. Land cover metrics (area in square kilometres and percent of watershed area) for 39 watersheds and 32 communities.

	Forest	Developed	Vegetation	Wetland	Water	Barren	Total (i)	Accuracy (ii)
Forest	98	0	2	3	0	0	103	95.10%
Developed	0	51	2	1	0	6	60	85.00%
N.F. Vegetation	6	3	88	1	0	4	102	86.30%
Wetland	3	2	4	86	1	0	96	89.60%
Water	3	0	1	1	93	0	98	94.90%
Barren	3	1	8	4	0	74	90	82.20%
Column Total	113	57	105	96	94	84	549	88.80%
Column Multiples	11639	3420	10710	9216	9212	7560	490	3420

Sum of Diagonals (corrects)	490
N (Total Points Assessed)	549
Overall Accuracy	89.25%

	Omission (iii)	Commission (iv)	Low Limit	Upper Limit
Forest	5	15	83.80%	100.00%
Developed	9	6	73.70%	96.30%
N.F. Vegetation	14	17	75.00%	97.60%
Wetland	10	10	78.30%	100.00%
Water	5	1	83.60%	100.00%
Barren	16	10	70.90%	93.50%

Column Definitions

i: Row totals: Points assessed per class.

ii: Percent accuracy by class.

iii: Points falsely omitted from the row class.

iv: Points falsely committed to column class.

* Points falling in the Ice/Shadow/Snow class were excluded from the accuracy assessment.

Figure 3-5. Error Matrix and Accuracy Statistics

Figure 3-5 represents the error matrix (a) and accuracy statistics (b) for the accuracy assessment of the land cover classification of community watersheds in Newfoundland, Canada. Diagonal counts (in green) represent agreement between classified and ground truth data.

Additional accuracy assessment metrics are presented in section B of Figure 3-5. The omission (iii) column represents points that were identified as the row class in the ground-truth data, but were classified as some other land cover class. The commission (iv) column represent points that were classified as the row class, but identified as another class in the ground-truth data. The upper and lower limit columns represent the 95% confidence intervals for each class. Intervals represent the range of accuracy percents expected through the random selection of another set of points. Out of 1000 randomly selected set of points, 950 sets will generate accuracy percents within these values. Overall accuracy indicates that almost 9 out of 10 locations randomly checked by a user will be classified correctly. *Forests* and *water* have the highest accuracy, while *barren* ground and *developed* classes have the lowest. Of the 60 accuracy assessment points falling on areas classified as *developed*, 51 were verified as developed, 2 were non-forest *vegetation*, 1 was *wetland* and 6 were on *barren* land (85%

correct). Of the 90 accuracy assessment points falling on areas classified as *barren* 74 were verified as *barren*, 3 were actually *forest*, 1 *developed*, 8 *vegetation*, and 4 *wetland*.

Figure 3-5 section B indicates that forest cover is likely overestimated in the classification (5 accuracy points should have been forest, but were another class, 15 points were classified as forest, but should have been classified as something else). Barren land is likely underestimated.

3.3.5 Recommendations for Remote Sensing and Land Cover Classification

The following general recommendations are offered to assist the Government of Newfoundland and Labrador in designing and implementing future studies that involve remote sensing and land cover classification.

5. For future change detection work on the land cover WRMD should obtain consistent imagery for change detection applications and clearly match the type of change that is desired with the need of the project application.The process of mapping changes in land use / land cover over time can be simplified and the products/outcomes more reliable with better, more similar imagery from “before and after” time periods. .
6. It is recommended that WRMD consider the use and need for atmospheric correction on a case-by-case, or project-by-project basis. Atmospheric correction is most useful when trying to separate features in imagery that have similar spectral signatures/responses or removing noise such as haze. It is not required for many types of land use / land cover classification and does not mitigate issues from different seasonal conditions in imagery. It was determined for this study that atmospheric correction would not provide a benefit across such varying seasons and years of imagery acquisition.
7. It is recommended that WRMD establish set protocols for training and verification samples for remote sensing projects across large areas. These known features types from ground measurements or photographs assist in both training remote sensing software during classification as well as in verifying accuracy at the end
8. It is recommended that WRMD merge projects involving land cover classification. If possible, future studies that involve remote sensing should merge land cover classification tasks to increase production efficiencies, reduce costs associated with data gathering, pre-processing and classification, and increase consistency in methods and QA/QC.

3.4 C4 – Assess Climate Change Impacts

3.4.1 Introduction

Greenhouse gas (GHG) increases, have been overwhelmingly dominant in driving changes in global and large scale regional climate since about 1970. Recent information on GHG concentrations, emissions and impacts confirms that climate change is advancing more rapidly than estimated earlier (Bruce, 2011). When considering flooding risk, planning, and defenses to 2080, it is therefore important to also factor in the additional stresses that climate change may bring. A range of approaches, from sophisticated modeling to largely qualitative, have been applied in assessing the magnitude of the anticipated changes. Each has its strengths and weaknesses and some of these are discussed. One of the key climate drivers of Newfoundland and Labrador, ocean currents, are examined as well as sea level rise. An analysis of recurring phenomena responsible for some major floods on the island of Newfoundland, hurricanes and tropical storms, is also included. Finally, some possible worst case scenarios, that have occurred in the region or in Newfoundland with lesser intensity, and that are becoming more probable through this century, are considered.

As with the broader project of which this is a part, the particular time frames of interest will be 2020, 2050 and 2080 and, wherever possible, the analysis will focus on the province's four Water Resource Management Division (WRMD) regions illustrated at Figure 2-1.

3.4.1.1 Modeling

Numerical Weather Prediction (NWP) model data was obtained through the Canadian Climate Change Scenarios Network site[16] (CCCSN). Specifically, data from the Canadian Regional Climate Model (CRCM) 4.2.3, which is based on the Climate Model CRCM4.2 was obtained. The model was run over the North-American domain with a 45-km horizontal grid-size, 29 vertical levels and 15 minute time steps. The regional model was driven by CGCM3/T47 (Scinocca et al. 2008) outputs from a transient simulation following IPCC "observed 20th century" scenario for years 1961-2000 and SRES (Special Report on Emissions Scenarios) A2 scenario for years 2001-2100 (4th member from ensembles of five 20th century and SRES A2 simulations). In each figure, where appropriate, the year 2000 is represented by a dashed vertical line to delineate between the model runs based on historical data and the model runs based on the future scenario. The SRES A2 scenario assumes a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than other scenarios. The result of this scenario is that it produces the most carbon dioxide, methane and nitrogen dioxide than all other scenarios except for the one scenario which assumes a fossil fuel intensive future. As such it can be assumed to be a fairly realistic scenario for a changing world. However, no one model scenario can be claimed to be more possible than any other.

[16] CCCSN Website http://www.cccsn.ca/?page=ensemblescenarios

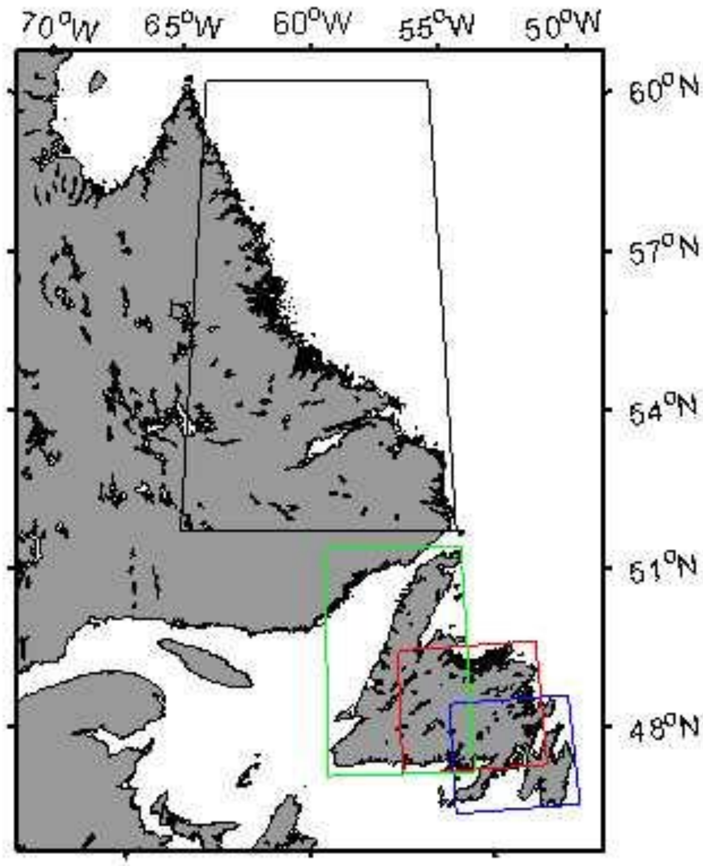


Figure 3-6. GCM sectors selected to correspond with WRMD regions.

The CRCM is driven at its lateral boundaries by CGCM3 atmospheric fields every 6 hours. Interpolation at CRCM's time steps was done linearly in time. The regional model was chosen for its finer resolution and the fact that the Canadian Regional Climate Models are tailored for Canadian conditions and topography. Furthermore, being a regional model it accomplishes the requirement for statistical downscaling compared to a global model (Lines et al., 2008). More information about the Canadian Regional Climate Model CRCM4.2.3 can be found in Music and Caya (2007).

3.4.1.2 Results

The data from CRCM4.2.3 was analyzed in 3 ways. First, it was averaged for the three future periods relevant to this study, namely; 2005 – 2034 (2020), 2035 – 2064 (2050) and 2065 – 2095 (2080) for both summer and winter periods. These periods were chosen as they were used in a previous study (which is attached as an appendix) and this makes the results comparable to those found in that study. Second, images were produced for the four regions shown in Figure 3-6 which were selected to correspond to the WRMD regions. Third, and finally, the data was averaged over the four areas and over time and compared to the 1961-1990 baseline average. The results are presented and discussed below.

It is apparent from Figure 3-7 and Figure 3-8 that there are significant differences in the future between the seasons over the entire province for both temperature and precipitation. Specifically the regions of Newfoundland will have mixed results including some areas having decreased summer precipitation and Labrador will see a varied increase during the summer whereas during the winter, all areas see increased precipitation over time. In general the winter season receives the greatest increase in precipitation over time, especially beyond 2050 for all regions with the greatest increases over Labrador. Given an increase in regional temperature due to climate change this is to be somewhat expected as the atmosphere could transport more water vapour. The change in temperature is also different between the seasons. The temperature over the whole province generally increases over time but this is most noticeable over Labrador and the Labrador Sea. As with precipitation, temperature increases are greatest in the winter months and trends accelerate beyond 2050. Although not examined in this document, for the island of Newfoundland, the biggest changes may occur in the transitional seasons when the island gets many of its biggest storms.

Figure 3-7 shows similar results for the precipitation changes during summer and winter. The three regions of Newfoundland are very similar with steadily increasing rainfall over time, and Labrador, which has a much lower average precipitation but whose precipitation increased much faster over time.

Figure 3-9 and Figure 3-10 show similar results for the precipitation during summer (Figure 3-9) and winter (Figure 3-10). The three regions of Newfoundland are very similar with steadily increasing rainfall over time and Labrador which has a much lower average precipitation but whose precipitation increased much faster over time.

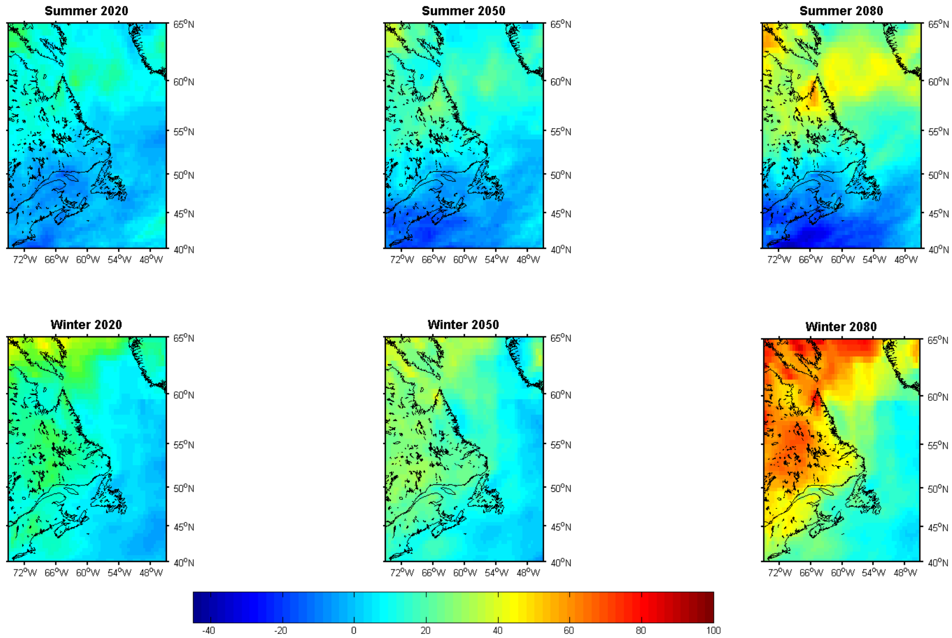


Figure 3-7. Percentage change of precipitation relative to 1961-1990 levels for summer and winter of 2020, 2050 and 2080.

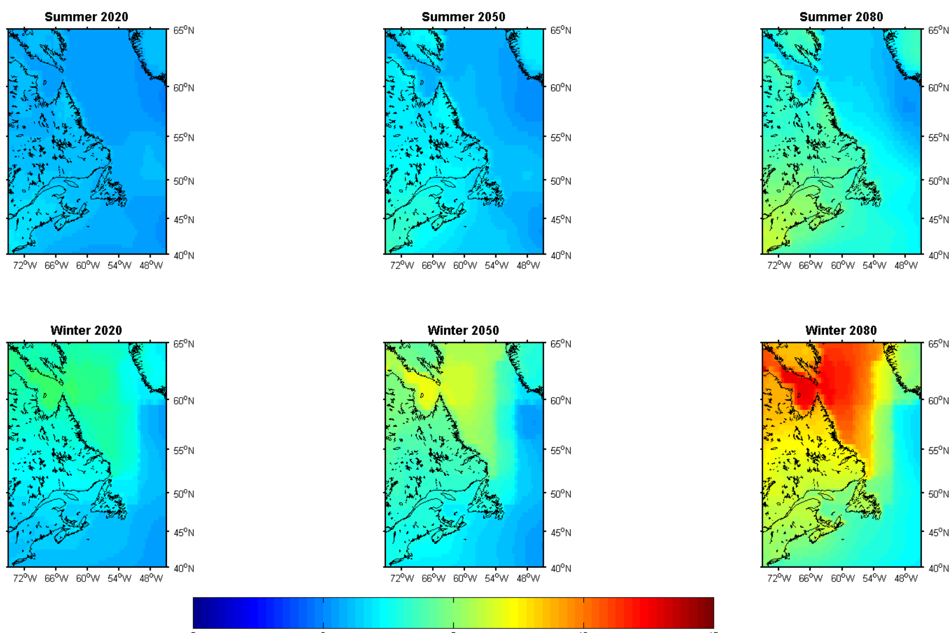


Figure 3-8. Temperature difference relative to 1961-1990 levels for summer and winter of 2020, 2050 and 2080.

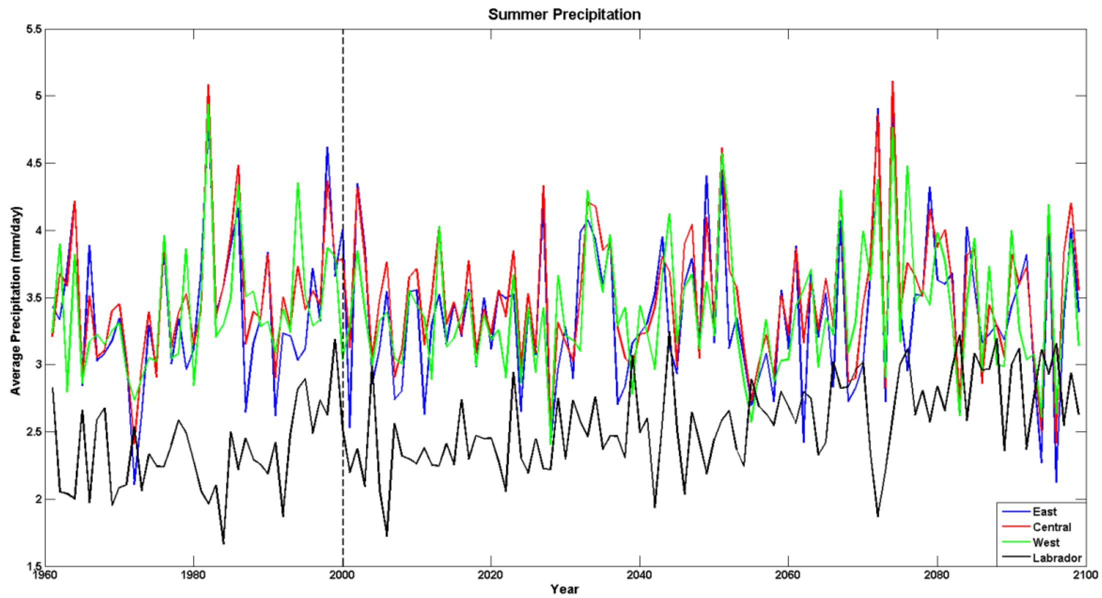


Figure 3-9. Average summer precipitation (mm/day) as a function of year for the various regions of Newfoundland and Labrador.

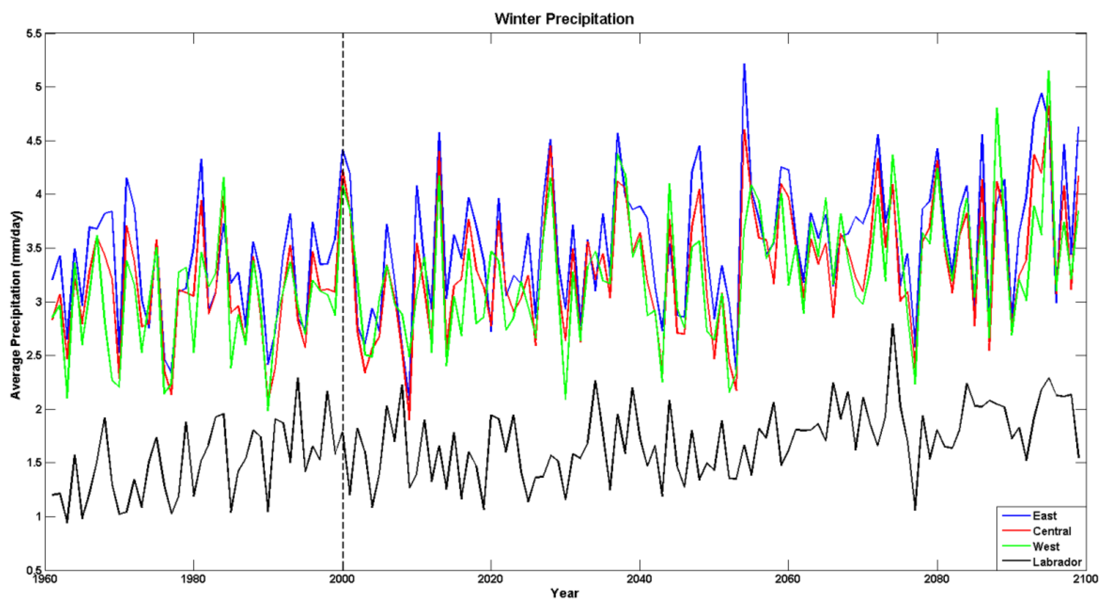


Figure 3-10. Average winter precipitation (mm/day) as a function of year for the various regions of Newfoundland and Labrador.

The results for temperature are similar to the results for the precipitation during summer. Figure 3-11 and Figure 3-12 also show that the three regions of the island of Newfoundland are very similar to each other with increasing temperatures over time. Labrador has lower temperatures than Newfoundland; however, it has a much more prominent increase in temperature over time, especially during winter. This increase in temperature over time in all regions would suggest that winter precipitation has a greater probability of being liquid in phase as the century advances with this winter precipitation phase shift being more likely in the three regions of Newfoundland as compared to Labrador. Furthermore, given that the average annual temperature by the end of the 21st century nears the freezing point, there should be an expectation of an increased occurrence of mixed phase precipitation and freezing rain events.

The values listed in Table 3-8 and Table 3-9 confirm the results in Figure 3-7 through Figure 3-12. That is, the regions of Newfoundland (WRMD East, Central, and West regions) are quite similar to each other, with little or no change in precipitation during summer except in 2080 and with increasing precipitation in the future in winter. The three regions of Newfoundland also see similar results with regards to temperature, i.e., most of the change occurring during the winter and accelerating through the century. Labrador sees a much greater increase in precipitation during both summer and winter into the future. Labrador is projected to see a greater increase in temperature during the winter but less in the summer compared to Newfoundland.

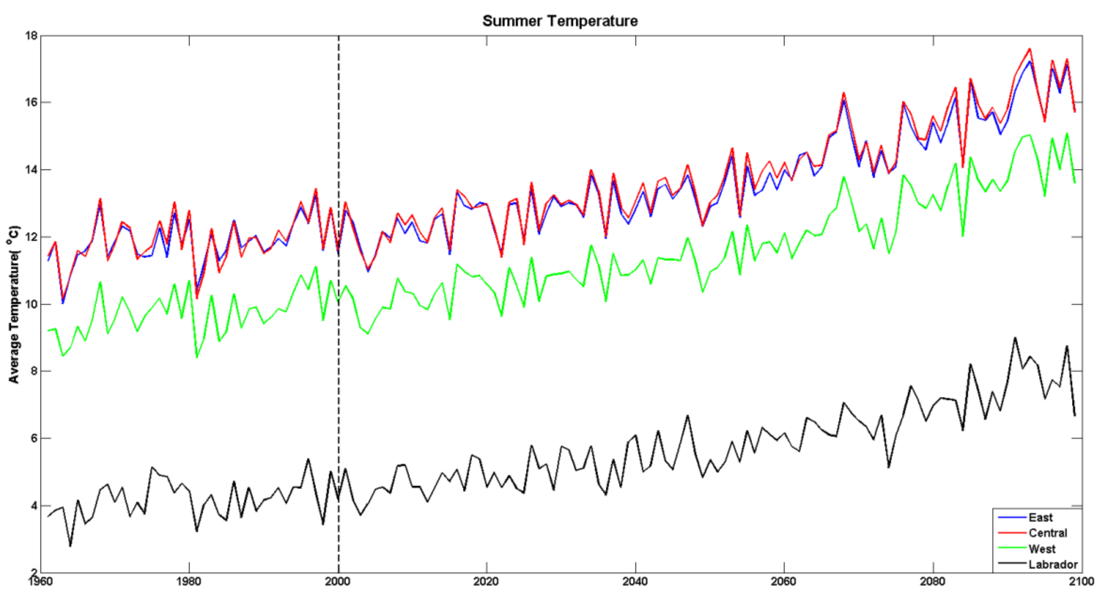


Figure 3-11. Average summer temperature (^oC) as a function of year for the various regions of Newfoundland and Labrador.

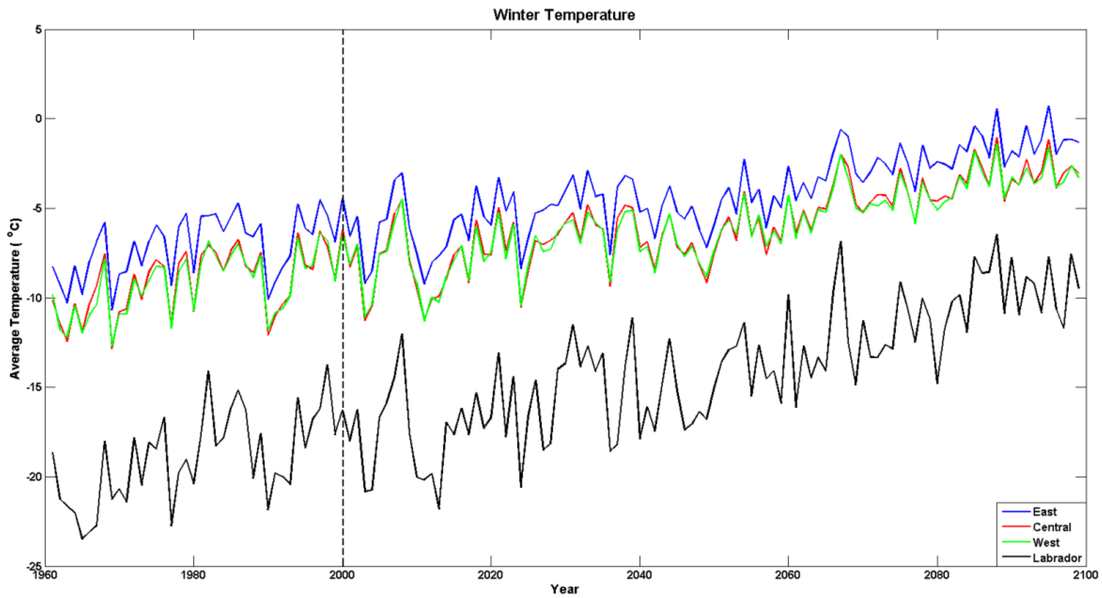


Figure 3-12. Average winter temperature (^oC) as a function of year for the various regions of Newfoundland and Labrador.

	Area			
	Labrador	**West**	**Central**	**East**
Summer 2020	5.3	-1.3	0.3	-1.4
Summer 2050	12.3	0.4	0.0	-1.0
Summer 2080	23.2	4.9	3.6	2.7
Winter 2020	13.5	5.8	4.2	3.7
Winter 2050	18.1	14.6	11.1	11.3
Winter 2080	36.6	21.4	16.7	16.2

Table 3-8. Percentage change in precipitation (mm/day) relative to 1961-1990 average precipitation.

	Area			
	Labrador	**West**	**Central**	**East**
Summer 2020	0.8	1.0	0.9	0.9
Summer 2050	1.5	1.8	1.8	1.7
Summer 2080	2.9	3.7	3.7	3.6
Winter 2020	3.2	2.1	2.1	1.9
Winter 2050	4.7	3.0	2.9	2.7
Winter 2080	8.7	5.7	5.6	5.3

Table 3-9. Change in temperature (^{o}C) relative to 1961-1990 average temperatures.

While Intensity-Duration-Frequency (IDF) curves/values were not calculated for the various time periods into the future, it is reasonable to expect the IDF values for the various return periods and durations to increase by the proportion as the values listed in Table 3-8 compared to current IDF values. This will be explored more in Section 3.4.2

3.4.1.3 Other Studies

There have been few academic publications and little climatic downscaling work dealing with anticipated temperature and precipitation changes resulting from global warming in Newfoundland and Labrador. The typical discussion point for climate change in the region in and around Newfoundland and Labrador is usually concerned with predicted changing pressure patterns and/or the expected changes to the North Atlantic Oscillation (NAO). However, while pressure patterns and the NAO are important drivers of precipitation and temperature, they will affect the different parts Newfoundland and Labrador in different ways. The NAO will be specifically commented on in Section 3.4.5. Most available documents that discuss expected changes to temperature and precipitation over the province are typically Government of Canada publications. Even then many of these documents discuss Atlantic Canada as a whole or Quebec/Labrador [Catto, 2010]. Three documents that discuss Newfoundland and Labrador specifically are Richter and Barnard (2004) Lines et al. (2008) and Vasseur and Catto (2008).

Richter and Barnard (2004) examined a variety of model scenarios for the province as a whole for the 2020 time period and broke the results into whether they were the wettest/driest and/or coldest/warmest etc. They found that in 2020 the temperature during the summer months would increase by approximately 1^{o}C to 2^{o}C depending on the model run and for the winter months approximately 0.5^{o}C to 3^{o}C depending on the model run and the month involved. These are comparable to the results shown in Table 3-9. Correspondingly, Richter and Barnard (2004) found that in 2020 the precipitation could change by anywhere from -10% to +20% depending on the model run. The "middle of the road" model run suggests a neutral or slightly negative change in precipitation during summer and an increase of up to 10% during fall. Only the wettest model scenario in Richter and Barnard (2004) produced any significant increase in precipitation during winter.

Lines et al. (2008) used the Hadley Research Center's Hadley Climate Model version3 (HadCM3) running the SRES emission scenario B2 and the Statistical Downscaling Model (SDSM) developed by Whilby et al. (2001) using predictor values from the Canadian Coupled General Circulation Model version 2 (CGCM2). The scenario B2 assumes a better world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development. It should also be pointed out that downscaling techniques face increased challenges where GCM results are not in agreement. Annual projected changes for 2020, 2050 and 2080 were presented for a variety of sites, including Gander and Goose Bay. The results presented indicated that an annual increase in temperature of slightly over 4 ^{o}C was possible at Goose Bay and slightly less than 4 ^{o}C at Gander by 2080. By 2080 Goose Bay precipitation was expected to have increased by as much as 10% compared to a 7% increase for Gander.

Vasseur and Catto (2008) examined the expected changes in temperature and precipitation over the Maritimes and over Newfoundland and Labrador at various times in the future (2020, 2050 and 2080) as well as seasonal changes over those periods in the future. A variety of models were included in their work. They found a general increase in both temperature and precipitation into the future over the province as a whole and that the winter season could expect a greater increase in temperature and precipitation compared to the summer by 2050. There was a wide variation in the results of individual models examined by Vasseur and Catto (2008), however they are not inconsistent with the results shown in Table 3-8 and Table 3-9 earlier.

The results presented in this document, it can be concluded, are considered as being comparable in nature to the results reported in the literature by Richter and Barnard (2004), Lines et al. (2008) and Vasseur and Catto (2008). It is cautioned that GCMs, due to their large grid spacing, have difficulty properly handling sub-synoptic features such as hurricanes, which can be important contributors to extreme weather in parts of the globe, like Newfoundland. Even downscaling techniques are challenged on this score since they use GCM outputs together with smaller grid sizes and finer surface masks to properly account for local topographic and other influences. GCMs do however provide an important overview of the general direction and magnitude of anticipated climate change.

In summary, with increasing temperature, precipitation is anticipated to increase into the future. Summer precipitation on the island remains basically neutral in the first half of the century with mild increases thereafter while Labrador sees a steady dramatic rise in summer precipitation. There is a clear steady rise in winter precipitation across all regions through the century. The differential change in precipitation across the island's three WRMD regions is very small. The

West sees slightly larger winter increases while Labrador shows large steady increases in both summer and winter. This represents an influence towards increased flood risk across the Province, especially in winter for all WRMD regions. Winter thaws and rain events could lead to increases in rain on snow flooding as has been pointed out by Catto and Hickman (2004). Winter rains also lead to greater risk of rain on frozen ground events where the ground's ability to absorb liquid is compromised.

3.4.2 Intensity Duration Frequency (IDF) Curves

AMEC has produced updated IDFs, for other projects, for Deer Lake and Stephenville (representative of Western WRMD), and for St. John's (representative of Eastern WRMD); as such it was decided to complete a simplified update of the IDF values for Gander (representative of Central WRMD) and Goose Bay (representative of Labrador). Proceeding in this manner would provide a current set of IDF curves for at least one representative location in each WRMD region. Precipitation data was obtained from Environment Canada for several sites in Newfoundland and Labrador and for a variety of durations. With regard to the case of Gander, the original Environment Canada site had been moved. The location change in Gander is considered negligible in terms of distance so it was felt that merging the new and old Gander datasets and producing updated IDF values was valid. With regards to Goose Bay only daily precipitation was recorded after 2009. Previously the IDF for Goose Bay was published as being compiled up to 2007. As such the IDF values for Goose Bay were updated to 2009 with the exception of the 24 h duration precipitation which was updated to 2011.

The technique used to update the IDF values is the same as used by Environment Canada, i.e., the statistics from the annual maxima at the various durations are calculated and a Gumbel distribution is then employed using the various standard return periods. In addition, results were calculated and included for the 1:20 year return period. The results of the updated IDFs for Gander and Goose Bay, respectively, can be seen in Table 3-10 and Table 3-11. As such, these updated IDFs then capture and characterise past precipitation events up to the most recent years.

The changes to the IDF values at Gander are minor but most values increased compared to the previously published value. Only one exception to this is evident, that being at very short durations (5 minutes). The biggest changes are at the longer durations where there is an increase of approximately 4% at all return periods compared to the previously published values. There was almost no change in the values for Goose Bay. This is to be expected since only 2 additional years of data were considered (2007 to 2009) except for 24 hour precipitation (2007-2011).

Duration	Return Periods (years)						
	2	5	10	20	25	50	100
5 min	4.4	6.3	7.6	8.8	9.2	10.4	11.5
10 min	6.5	9.4	11.2	10.8	13.6	15.4	17.1
15 min	7.8	11.3	13.6	15.9	16.6	18.7	20.9
30 min	10.4	15.2	18.4	21.5	22.5	25.5	28.5
1 h	13.3	18.4	21.7	24.9	25.9	29.0	32.1
2 h	18.3	23.7	27.4	30.8	31.9	35.3	38.7
6 h	30.1	37.9	43.1	48.1	49.7	54.5	59.3
12 h	38.7	49.0	55.8	62.3	64.3	70.7	77.0
24 h	47.3	62.4	72.4	82.0	85.0	94.4	103.7

Table 3-10. Updated IDF values for Gander based on data to 2011

Duration	Return Period (years)						
	2	5	10	20	25	50	100
5 min	3.9	5.6	6.6	7.6	8.0	9.0	10.0
10 min	5.7	8.5	10.3	12.1	12.7	14.4	16.1
15 min	6.9	10.3	12.6	14.8	15.5	17.7	19.8
30 min	8.8	13.3	16.3	19.2	20.1	22.9	25.7
1 h	11.2	15.7	18.6	21.5	22.4	25.2	27.9
2 h	14.5	19.5	22.8	26.0	27.0	30.1	33.2
6 h	24.1	31.1	35.7	40.2	41.6	45.9	50.2
12 h	32.1	40.3	45.8	51.0	52.7	57.8	62.9
24 h	40.7	51.4	58.4	65.2	67.4	74.0	80.6

Table 3-11. Updated IDF values for Goose Bay based on data to 2009 except for 24-hr precipitation which is to 2011.

In a concurrent study conducted by AMEC, IDF values were projected into the future (2020, 2050 and 2080) for St. John's, Stephenville and Deer Lake, all on the island of Newfoundland. At the 24 hr duration the IDF values for Deer Lake and Stephenville (both in WRMD's West Region) increased by a greater amount than St. John's (WRMD East Region). IDF values at a 24 hr duration for Deer Lake increased from 2-4 % in 2020 to 4-7 % in 2080. The IDF values for Stephenville showed consistent increases near 4-10 %. However, the 24 hr duration IDF values for St. John's only increased from 1 % in 2020 to 2-4 % in 2080. While the scale of increase may not precisely match the values given in Table 3-8, they are not inconceivable considering the values in Table 3-8 are for much larger geographical area versus points and for only two seasons using a somewhat conservative SRES scenario (A2). Also, the increase in precipitation at Deer Lake and Stephenville compared to St. John's is captured in the West vs. East region (respectively) values.

These increases, though slight, in the updated IDF values for Gander and Goose Bay, show that more intense precipitation events are already beginning to register in recent years. The projected curves for St. John's, Deer Lake and Stephenville, also show further increases in the frequency and intensity of precipitation going forward to 2080. This provides a valuable quantitative assessment of increases in precipitation leading to increased flood risk.

In the past, a set of IDF curves for a location, based on 50 or more years of past climate records, was applied without further modifications in developing plans and designing infrastructure with a life expectancy of 100 years or more. While updating IDFs is certainly still very important since they capture the real full character of precipitation from all manner of weather phenomena of all sizes recorded at a site, to use updated curves alone is no longer valid in an era of rapid climate change. Projecting IDFs forward uses sophisticated techniques and is highly recommended. But it must be recognized that the inputs used in making IDF adjustments are largely derived from GCM outputs. Those, as discussed earlier, have difficulty capturing some meso-scale weather phenomena and so may under-represent the return periods for extreme precipitation events.

Finally, it should also be noted that precipitation, while a key element in determining flood risk, is seldom the only factor leading to flooding. Other events such as storm surge, ice jams, spring snow melt and even the saturation of the soil can all play a significant role as can other possible future changes such as changing land cover. In addition, IDF curves do not capture the seasonality of precipitation. As such precipitation and IDF values, while useful, should not be examined in isolation.

3.4.3 Hurricanes and Tropical Storms

Historical track maps and data from the US National Hurricane Center (NHC) and the Canadian Hurricane Centre (CHC) were utilized to study the occurrence of tropical system occurrences over Newfoundland and Labrador, and its surrounding marine areas. For this report, tropical storm activity from 1954 through 2011 was researched and divided into five regions based on the storms track: Labrador, the three WRMD regions on the island of Newfoundland, and the Newfoundland Marine Area (described as the Environment Canada Newfoundland and Labrador marine districts north of Latitude 45.0 °N, shown in Figure 3-13). A particular focus was to determine whether the frequency and intensity of tropical storms and hurricanes has changed in recent decades and what can be said, if anything, about future trends.

Figure 3-13. Newfoundland and Labrador Marine Districts (Source: Environment Canada)

For the basis of this report, if a tropical storm or hurricane tracked across more than one region of Newfoundland and Labrador (or the marine area), the region where the storm first made landfall was the only area counted during its history. Additionally, any storm making landfall over Newfoundland and Labrador was not included in any Newfoundland marine area.

The Atlantic Ocean hurricane season runs from June 1 – November 30. Tropical storms and hurricanes are classified based on their intensity, which is a direct function of the maximum sustained wind speed. Tropical systems in North America are based on the Saffir-Simpson Hurricane Itensity Scale, provided in Table 3-12.

Classification	Maximum Sustained Surface Wind Speed (km/h)
Tropical Depression	<= 62
Tropical Storm	63 - 118
Category 1 Hurricane	119 - 153
Category 2 Hurricane	154 - 177
Category 3 Hurricane	178 - 209
Category 4 Hurricane	210 - 249
Category 5 Hurricane	>= 250

Table 3-12. Saffir Simpson Hurricane Scale Based on Storm Intensity

On average, Newfoundland and Labrador is affected, or threatened, by one or two tropical systems each year, based on 92 storms tracking across or near Newfoundland and Labrador from 1954 – 2011. A breakdown of tropical system frequency for each of the five regions of Newfoundland and Labrador, based on intensity, is provided in Table 3-13 and plotted in Figure 3-14. A post or extra tropical storm is a cyclone which has lost its tropical characteristics and peak wind speeds have diminished, typically when a storm begins interacting with colder water temperatures or has become absorbed within a larger synoptic system.

	Labrador	Western	Central	Eastern	NL Marine	Total
Post or Extra Tropical Storm	9	10	3	16	14	52
Tropical Storm	0	3	0	3	15	21
Category 1 Hurricane	0	3	0	4	8	15
Category 2 Hurricane	0	0	1	0	2	3
Category 3 Hurricane	0	0	0	0	1	1
Total	9	16	4	23	40	92

Table 3-13. Frequency of Tropical Systems Affecting Each Region of Newfoundland and Labrador, Based on Intensity (1954-2011)

As expected, a significant portion of tropical systems which have affected Newfoundland and Labrador track across or near Eastern Newfoundland, and its nearby marine areas. Of the 52 tropical systems which have made landfall over Newfoundland and Labrador since 1954, nearly 45 percent have crossed the Eastern Newfoundland region. Well over 50 percent of all tropical storms which have tracked over or near Newfoundland and Labrador were extra, or post, tropical in nature. While these storms tend to be weaker than tropical storms and hurricanes, they can often still produce significant rainfall as they continue to tap into tropical moisture, and strong winds due to the temperature contrast between the Gulf Stream southeast of Newfoundland and the nearby landmass.

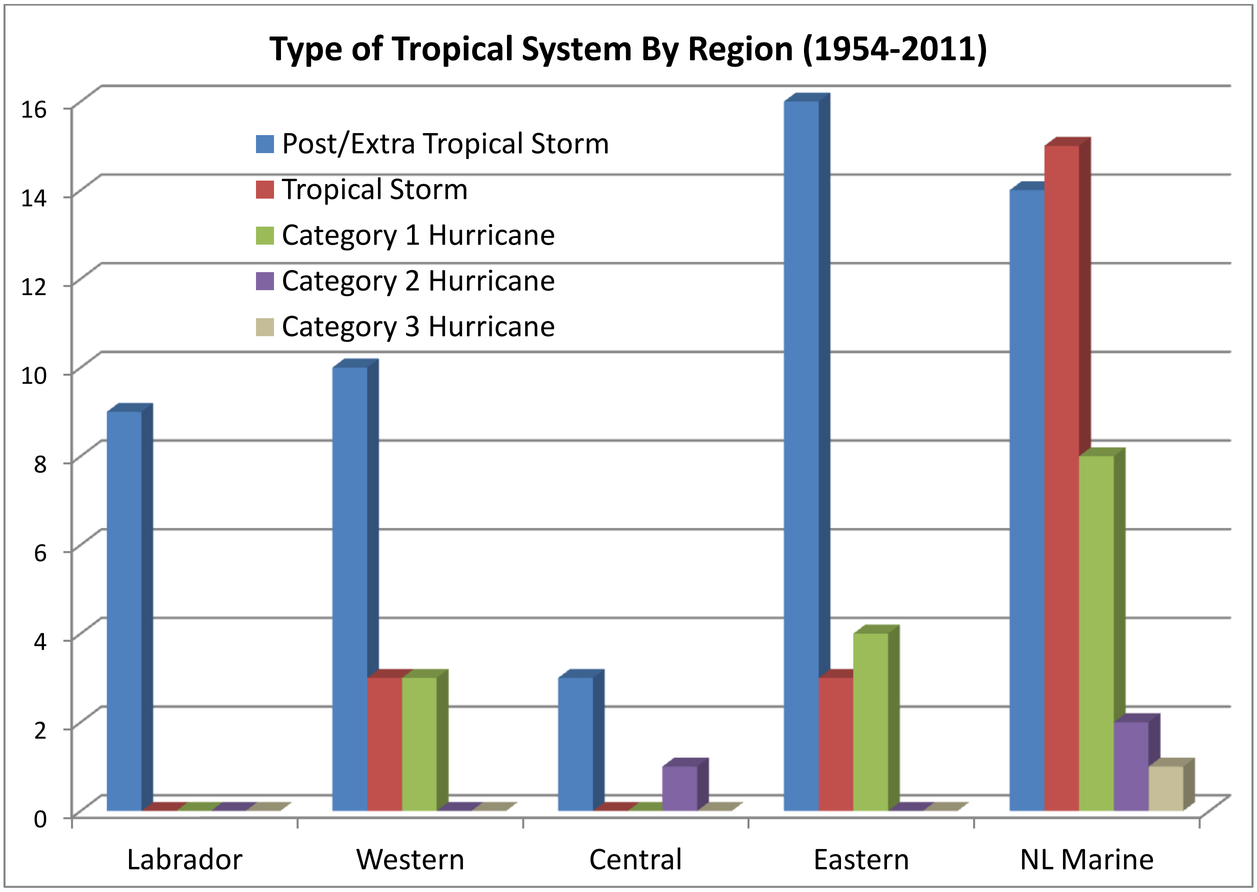


Figure 3-14. Tropical System Frequency Based on Region and Intensity

Since 1954, a total of 7 hurricanes have made landfall in Newfoundland as a Category 1 storm. The most recent Category 1 Hurricane to hit Newfoundland was Igor in September 2010, which produced upwards of 300 mm of rain to eastern sections of the Island and winds gusting well above 150 km/h. There has only been one Category 2 Hurricane which has made landfall over Newfoundland, since 1954, which was Hurricane Michael as it came ashore on the South Coast in October 2000. No hurricane on record, rated category 3 or higher, has ever come ashore in Newfoundland. However, Hurricane Ella, at Category 3, did track just southeast of the Avalon Peninsula in September 1978.

Early in the Atlantic Hurricane Season (typically June and July), most tropical systems originate off the west coast of Africa and are guided towards the Caribbean by a blocking area of high pressure south of Atlantic Canada, called the Bermuda High, a large semi-permanent system.

Since air flow around high pressure systems is clockwise, storms off the coast of Africa generally move in a westward direction towards the Caribbean Sea and the Southeastern United States. Towards late summer and early fall (August and September), the Bermuda High begins to shift to the east, allowing tropical systems to begin moving northward towards Eastern Canada. Because of this shift in the Bermuda High, the most frequent season of tropical storm activity in Newfoundland and Labrador is late August through early October. Tropical storms and hurricanes can still affect the province outside of this time interval, but do so much less frequently. The frequency and intensity of tropical systems affecting Newfoundland and Labrador by month, since 1954, is shown in Figure 3-15. In addition, the frequency of all tropical systems affecting each region of Newfoundland and Labrador by month is presented at Figure 3-16.

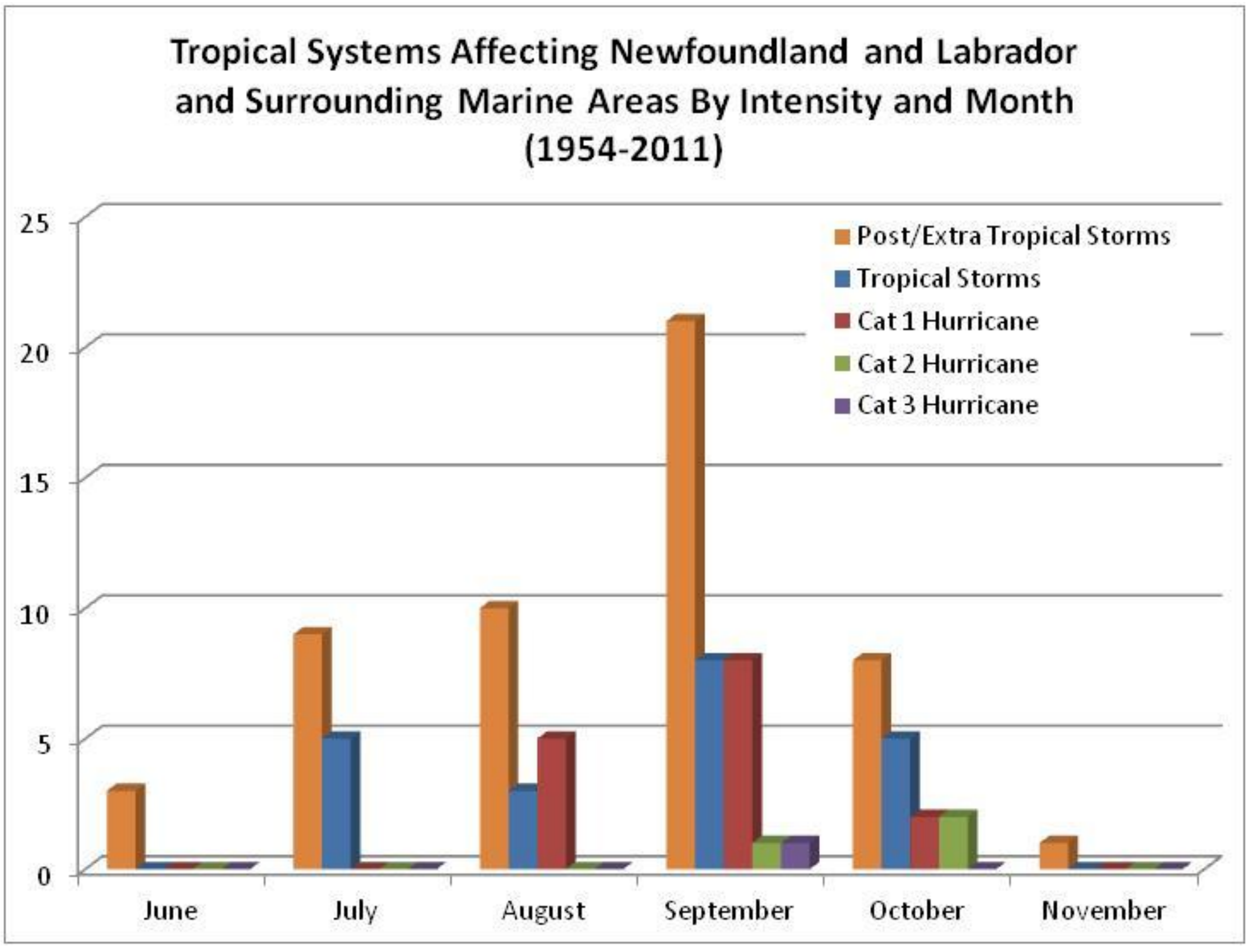


Figure 3-15. Frequency and Category of Tropical Systems Affecting Newfoundland and Labrador, by Month (1954-2011)

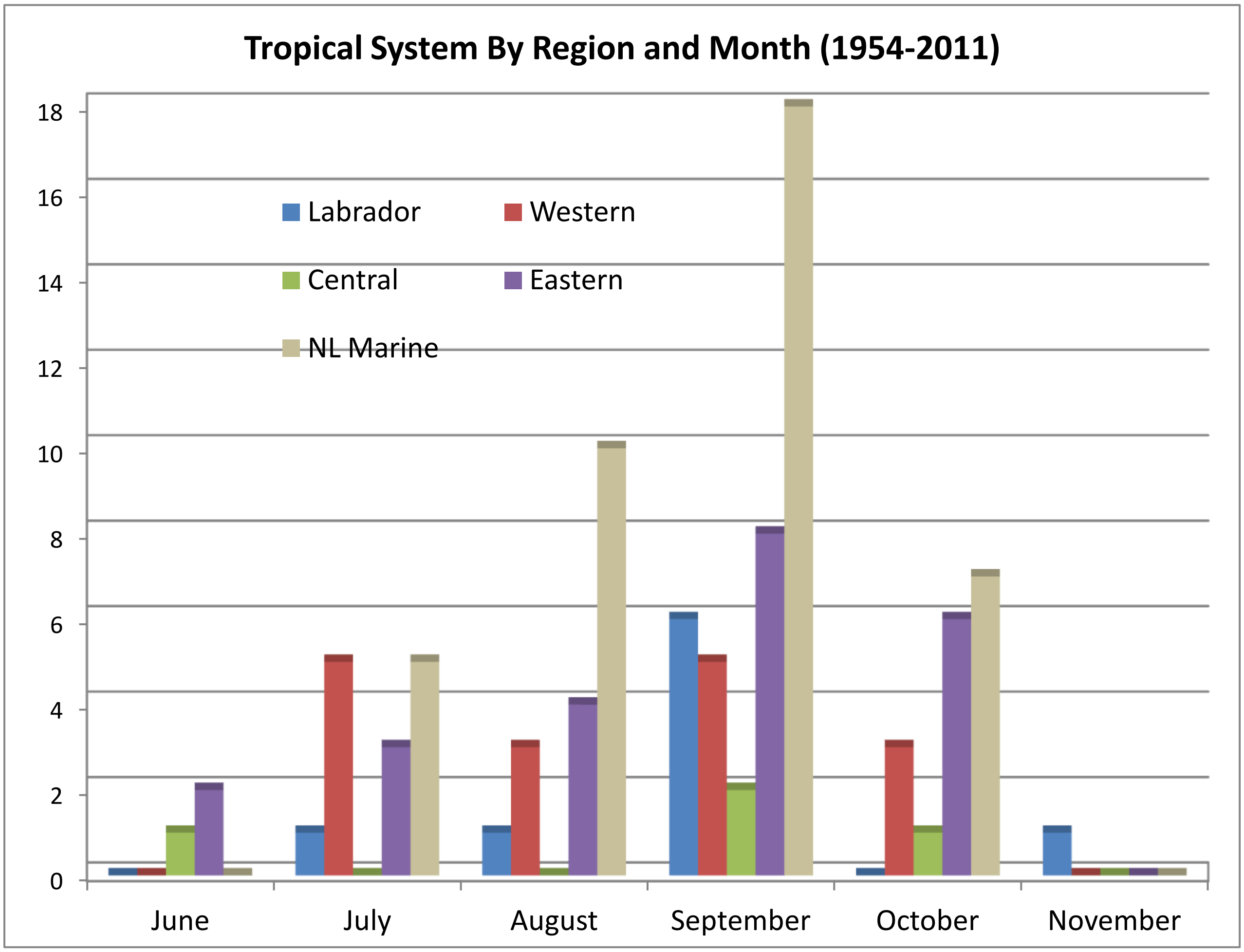


Figure 3-16. Tropical System Frequency for Each Region of Newfoundland and Labrador, by Month (1954-2011)

The frequency of tropical storm occurrence in Newfoundland and Labrador, and the entire North Atlantic, can vary considerably from year to year and decade to decade. Tropical storm activity in Newfoundland and Labrador peaked in the 1960's and 1970's before reaching its lowest levels in the 1980's. But, activity in the past 20 years has increased considerably, especially over Eastern Newfoundland and the surrounding marine areas. 1997 was the last year where no tropical storms affected Newfoundland and Labrador. Since that time, an average of 2 – 3 storms have tracked across or near the province, including the peak year of 2006 when 5 storms affected the region. The total number of tropical systems which have affected each region of Newfoundland and Labrador, by decade, is plotted in Figure 3-17.

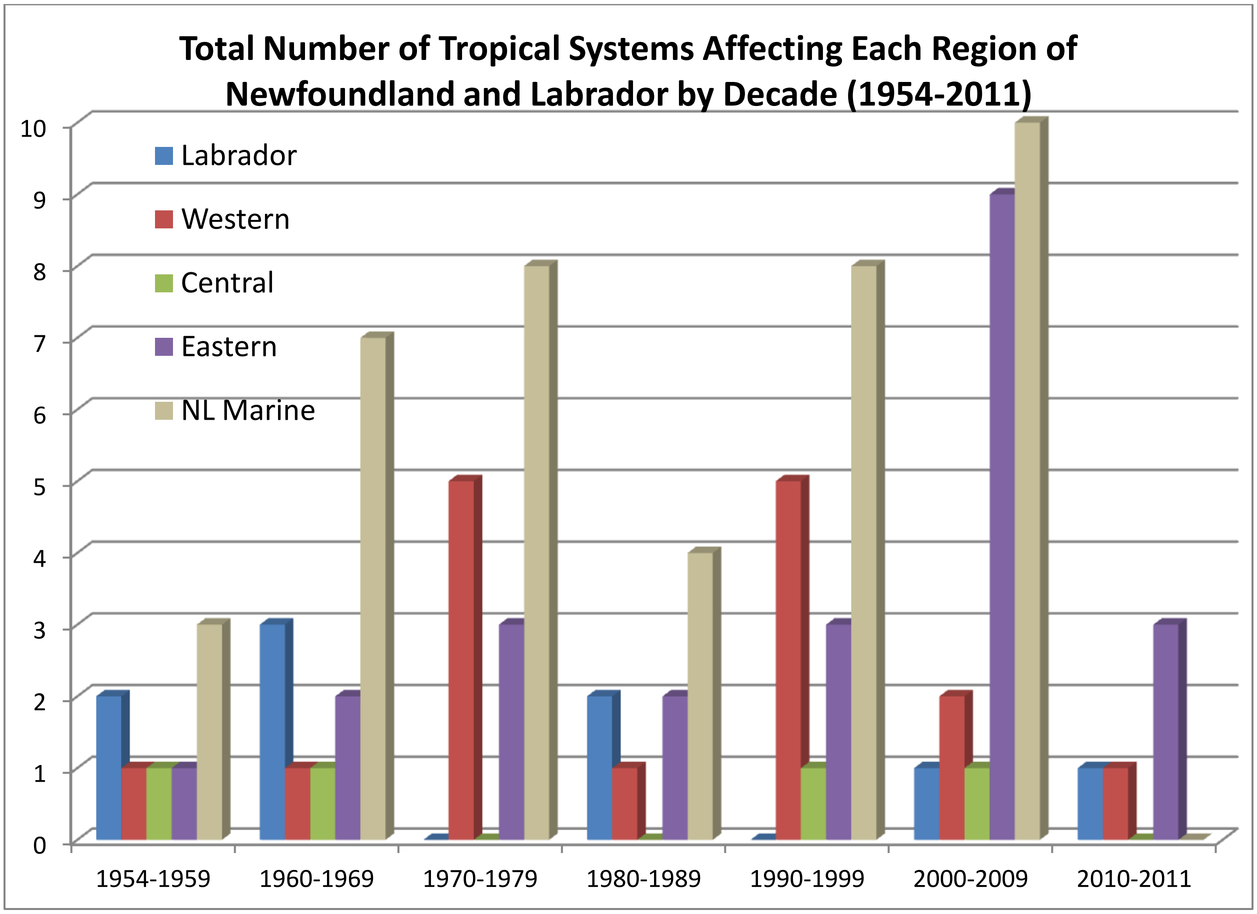


Figure 3-17. Frequency of Tropical Systems Affecting Newfoundland and Labrador Regions, by Decade, from 1954-2011

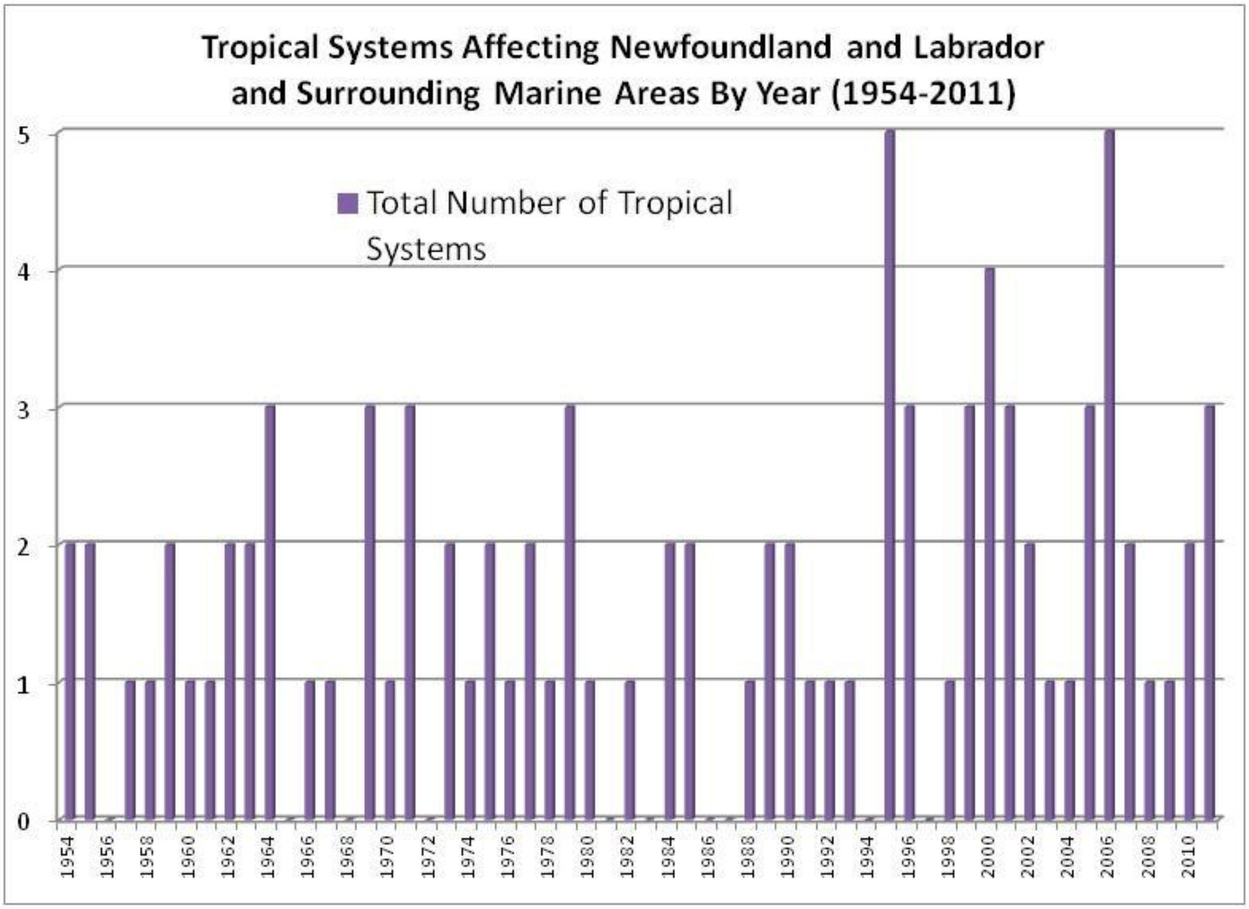


Figure 3-18. Tropical Systems Affecting Newfoundland and Labrador and Surrounding Marine Areas by Year (1954-2011).

Figure 3-18 presents the total number of tropical systems covering all intensity categories over all of Newfoundland and Labrador since 1954. There appears to be a cycle in tropical system frequency: relatively quiet periods followed by more active periods with the total cycle length lasting some 25 years (cautioned though that the record covers only 2 cycles). Because there have never been more than 5 tropical systems affecting any part of Newfoundland and Labrador in any one year since 1954, an obvious trend may be difficult to discern from the plot, but between 1954 and 1994 (40 years), only 4 hurricane seasons saw more than 2 tropical systems affect the province, while there have been 8 seasons since 1995 (16 years – twice as many in less than half the time interval) where the number of tropical systems exceeded 2, including 5 in each of 1995 and 2006. Based on these statistics, an upward trend in the frequency of tropical storm occurrence in Newfoundland and Labrador is apparent.

One of the reasons for this increase (there are likely others) in storm activity is the gradual warming of Atlantic sea surface temperatures and of the water temperatures south of Newfoundland. While this increase in sea surface temperature does not necessarily trigger the development of more tropical storms and hurricanes, it does allow more intense hurricanes to develop over the tropics. Then, approaching over the warmer waters east of the United States, they can maintain their intensity for a longer period of time as they do not encounter enough cold water to weaken significantly.

The Atlantic Multi-decadal Oscillation (AMO) is an ongoing series of long-duration cycles in the sea surface temperature of the North Atlantic Ocean, with cool and warm phases that may last for 20-40 years at a time. While the development and phase shift of the AMO is unable to be predicted by current weather models, it is possible to calculate the probability that a change in the AMO will occur over a given period of time. Since higher sea surface temperatures are associated with positive phases of the North Atlantic Oscillation (NAO), as will be explained more fully in later sections, anticipating phase shifts of the NAO would provide clues regarding general hurricane intensity changes.

While there is no scientifically proven link between the rise in sea surface temperatures and tropical storm activity, there appears to be a weak correlation between warm phases of the AMO and an increase in the occurrence of minor (Category 1 or 2) hurricanes (Chylek, P. & Lesins, G, 2008). Based on data from NOAA (the US National Oceanic and Atmospheric Association), there appears to be a significant increase in the frequency, at least twice as often, of weak storms maturing into severe hurricanes during warm phases of the AMO.

Since the mid 1990's, the AMO has been in a warm phase, which has been correlated with a significant increase in the frequency of tropical storms and hurricanes in the Atlantic Ocean, as shown in Figure 3-18. The number of named storms, hurricanes and major hurricanes (defined as Category 3 or higher) reached an all-time high in the 2000's decade, see Figure 3-18, and the last two years (2010/11) have been very active years as well. Based on the typical 60-70 year duration (Enfield, David B.; Cid-Serrano, Luis (2010)) of the negative (cool) and positive (warm) phases of the AMO, the current warm phase is expected to peak around 2020. Therefore, it is expected that tropical cyclone activity over the Atlantic Ocean will continue to increase for the next 10-15 years under the positive phase of the AMO.

Based on research conducted in the United States by the National Centre for Atmospheric Research (NCAR) and the Georgia Institute of Technology in 2011 (Holland et al, 2011), advanced dynamical and statistical modeling techniques have been implemented to determine the amount that tropical cyclone activity will increase through 2050. Results have shown that North Atlantic hurricanes will experience an accelerated increase in numbers from 1-3 percent per decade from the present up to 4-10 percent per decade leading up to 2050. Only a modest increase in mean intensity, on the order of 2 m/s (7.2 kph), is expected, but a significant increase in the frequency and intensity of the most intense hurricanes is expected over the next 40 years. Their statistical assessment predicts an increase in the annual number of storms from current climate by approximately 1 storm annually by the 2050's and by another 3 storms annually on average during the last half of the 21st century as shown in Figure 3-19.

Therefore, based on multiple studies conducted, the climate change currently being experienced across much of the globe, including Newfoundland and Labrador, will continue to promote an increase in the frequency of tropical cyclone development over the Tropical Atlantic through the end of the 21st century. Additionally, storms are expected to mature into more intense hurricanes (higher category) and are expected to have an increased ability to survive their track towards Atlantic Canada, arriving with more force as the increasing water temperatures south of Newfoundland will not provide as much resistance to promote weakening as experienced before the 1990's.

This analysis and the trends reported are especially valuable because, as explained earlier, GCMs are not able to properly handle these meso-scale phenomena and downscaling techniques and projected IDFs also use GCM outputs. Hurricanes, with their combination of abundant rains over wide areas and strong winds producing significant storm surge and waves, have, like Igor, caused some of the worst and costliest floods in Newfoundland (see Figure 2-2). With increased frequencies and intensities anticipated in the coming decades, flooding events of the magnitude of Igor, a Category 1 storm, are likely to occur more frequently. As Atlantic sea surface temperatures warm, the probability of another Category 2 hurricane making landfall in Newfoundland increases. In addition, it would not be unrealistic to expect a first Category 3 hurricane to make landfall in Newfoundland before 2080, perhaps before 2050.

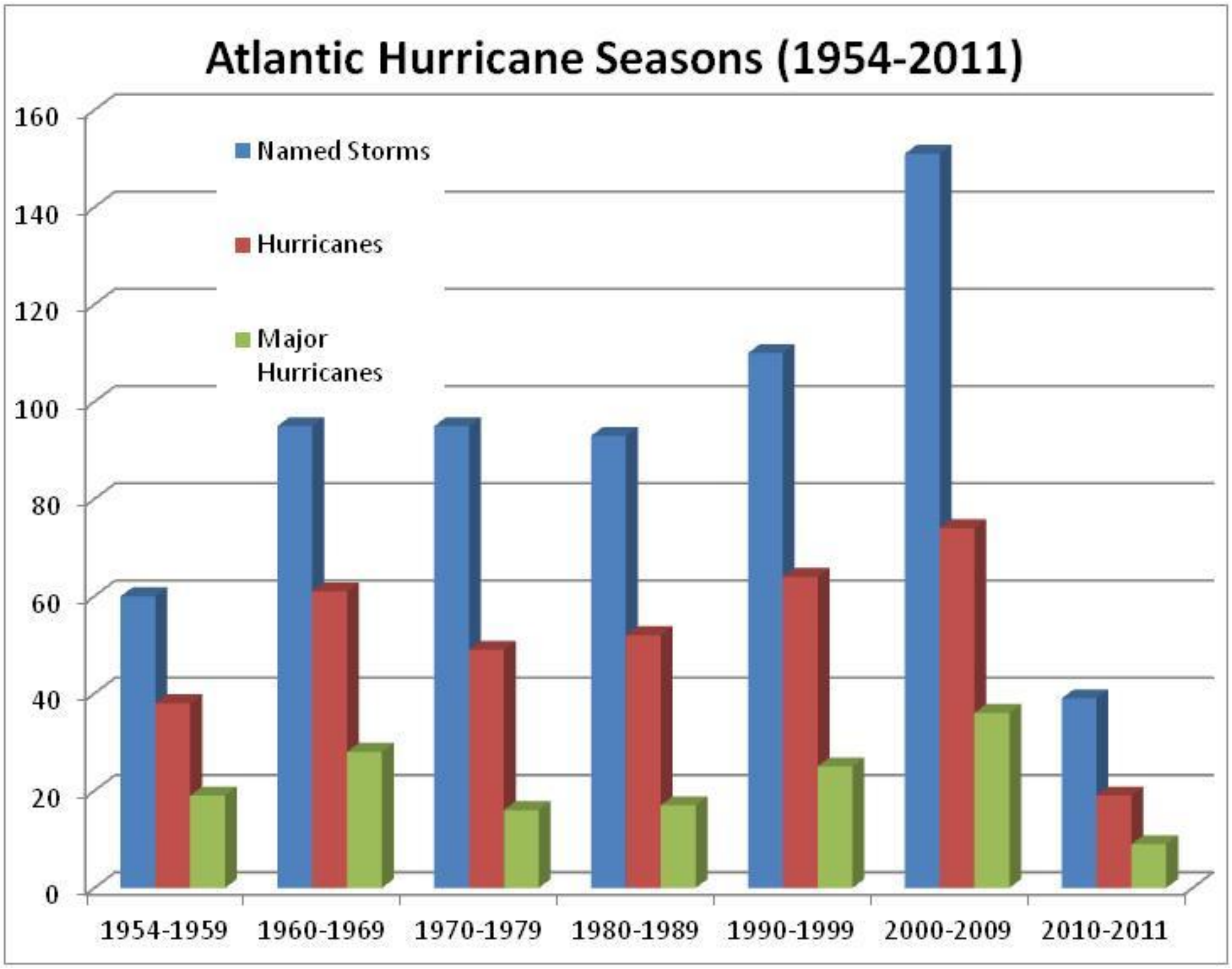


Figure 3-19. Frequency of Named Storms and Hurricanes in the Atlantic Ocean (1954-2011)

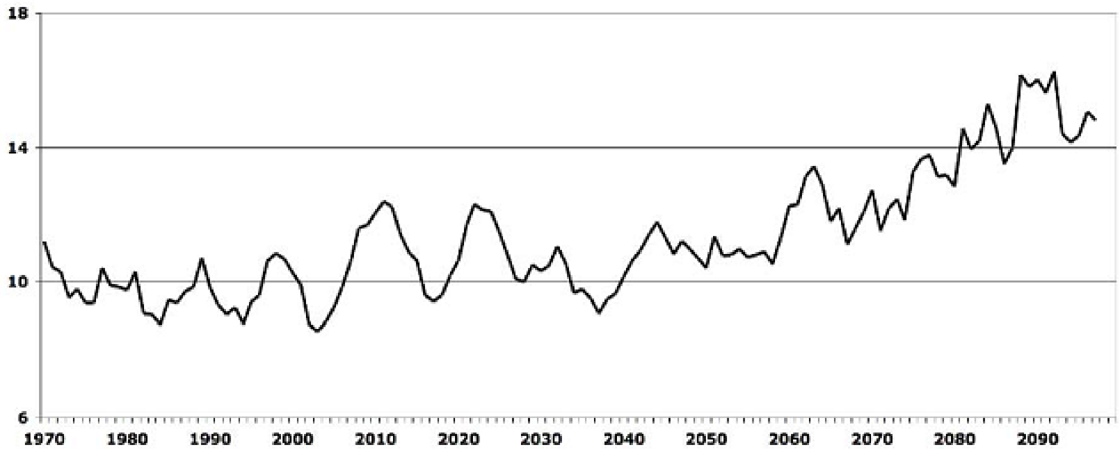


Figure 3-20. Predicted Annual Tropical Cyclone Frequency for the North Atlantic Ocean (based on Effect of Climate Variability and Change in Hurricane Activity in the North Atlantic Report, 2011)

3.4.4 Sea Level Rise

Sea level monitoring is an important activity as the data are used directly at the planning stage as inputs to the development of flood risk maps and at the operational level as part of flood forecasting and emergency measures response. This is particularly relevant for a province such as Newfoundland and Labrador with a preponderance of coastal municipalities.

Sea level is affected by short-term and longer-term causes. Short-term changes may include tides, seasonal fluctuations due to precipitation and evaporation, and temporary sea level changes from intense storms which result in reduced atmospheric pressure and storm surge or wind setup; both conditions that can effectively raise the sea level at the shoreline.

For the longer term, sea level is an ocean indicator for climate change. Sea level in the province has been observed to be rising relative to benchmarks and wharf deck elevations. The rate of global mean sea level rise is presently estimated at about 3 mm/year, yet another confirmation that global warming is already underway. There are regional differences. For the North Atlantic, a comparable rate of about 2.5 mm/year is estimated. This is illustrated in Figure 3-21 which is based on satellite altimetry data[17]. These rates may increase with continued melting of the polar ice caps and warming of the oceans.

---

[17] satellites, such as TOPEX/Poseidon, use radar altimetry to measure ocean surface topography: radio waves are sent to the ocean surface and timing their return gives very accurate (within a few centimeters) measurement of sea level.

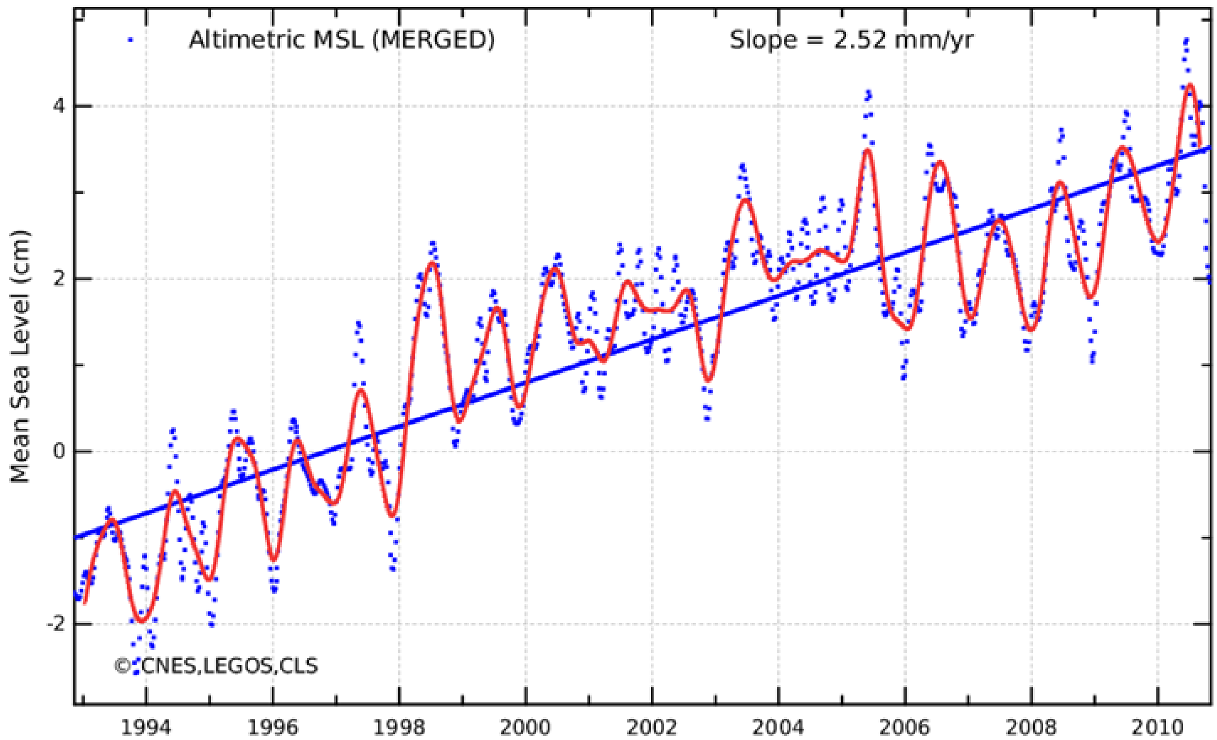


Figure 3-21. Change in Mean Sea Level, North Atlantic (Source: Aviso, 2011; Reference Satellite and Seasonal Signal removed settings)

Sea level also changes locally in relation to the geological uplift or subsidence of the earth which is in response to the retreat of the ice sheets that covered and depressed the land during the last glaciation, some 10,000 to 20,000 years ago. Though uplift has slowed since the glacial sheet melted, it is still occurring at different rates over the province. Geophysical modelling indicates uplift rates of 0 to 4 mm/year for Labrador and the Northern Peninsula, and subsidence rates of 0 to 2 mm/year for Newfoundland (Batterson and Liverman, 2010).

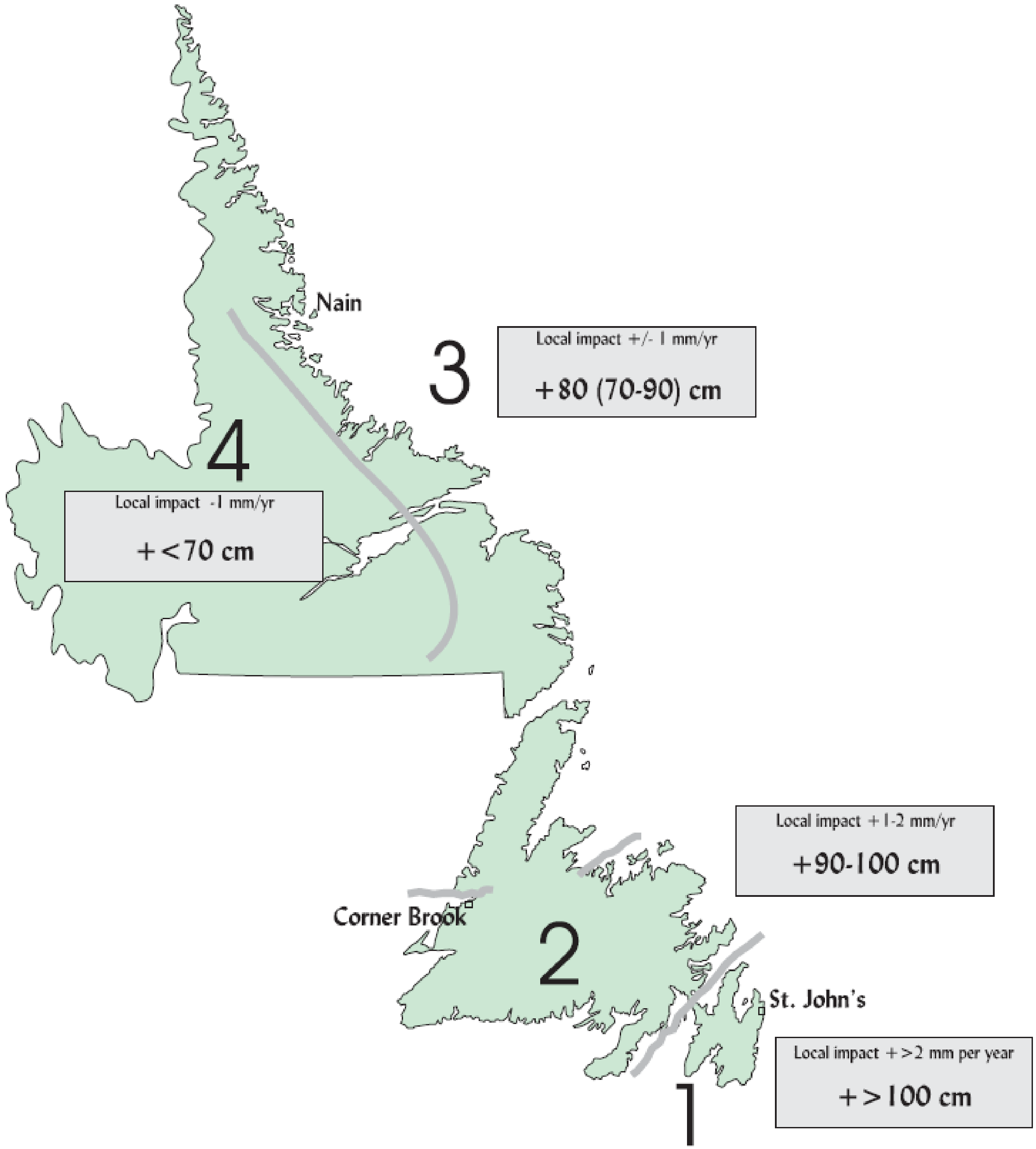


Figure 3-22. Projections of Potential Sea Level Rise in Newfoundland and Labrador by 2099, relative to 1990 Mean Sea Levels (Source: Batterson and Liverman, 2010)

The net long term sea level effect is the sum of global sea level changes and local geological impact. Batterson and Liverman (2010) have prepared projections of sea level rise by 2049 and 2099 relative to 1990 levels for four regions in Newfoundland and Labrador. The 2099 projections are shown in Figure 3-22. The projections are based on the Intergovernmental Panel on Climate Change (IPCC) predicted global sea level rise, potential accelerated ice melt, and regional trends of crustal rebound (uplift or subsidence) ranging from -1 to 2 mm/year. Disregarding any coastal erosion effects, itself significant in some areas, net sea level increases of 70 cm in Labrador to over 100 cm in the Avalon Peninsula are projected across the province by the end of the century. It is important to note however that Batterson and Liverman adopted the upper limits of projected climate change scenarios because of current trends in global CO_2 emissions and recent data on ice-sheet decay and global sea level rise.

Community	WRMD Region	Sea-Level Rise Projected[18]	Flood Risk Zone Elevation[19] Differences[20]
		(cm)	(cm)
Cox's Cove (Zone 2-3)	Central to Labrador	30/80 or 40/90	30 to 90
Stephenville Crossing (Zone 2)	Central	30/80	24
Placentia (Zone 1)	East	40/100	16

Table 3-14. Potential sea-level trends by 2099 and effect on flood-risk zone delineation.

Translating these net sea-level rises into flood risk zone delineations yields Table 3-14 adapted from Batterson and Liverman (2010). Note that while sea level rise is projected to 2050 and 2099, somewhat beyond the period of focus here, the flood risk zone elevation differences from 1 in 20 to 1 in 100 year return period events are only provided for 2099. Clearly it is necessary to also factor in net sea level rise in considering flood plain mapping for coastal communities. Finally, it is cautioned once again that coastal erosion, likely to increase with increased storm frequency and intensity combined with a reduction in shore fast ice, has not been included in this analysis.

3.4.5 Ocean Currents and Oscillations

The two major currents that influence the local weather and global climate of Newfoundland are the Labrador Current and the Gulf Stream (see Figure 3-23). The Labrador Current carries cold

[18] For 2050/2099
[19] Sources of flood-risk data: Acres (1985): Martec (1988); Shawmount Newfoundland (1985)
[20] Between 1:20 & 1:100 AEP (cm)

and relatively fresh water from the Arctic south along the continental shelf and slope of Labrador and Newfoundland. The Gulf Stream brings warm and salty water north from the Gulf of Mexico along the continental slope of North America. It veers to the northeast away from the continent at Cape Hatteras and flows eastward just south of the Grand Banks, occasionally moving north onto their southern edge. The presence of the air masses over the two currents, moist and cold over the Labrador Current, moist and warm over the Gulf Stream, directly affects the temperature, precipitation and formation of fog, especially on the eastern coastal region of the island of Newfoundland.

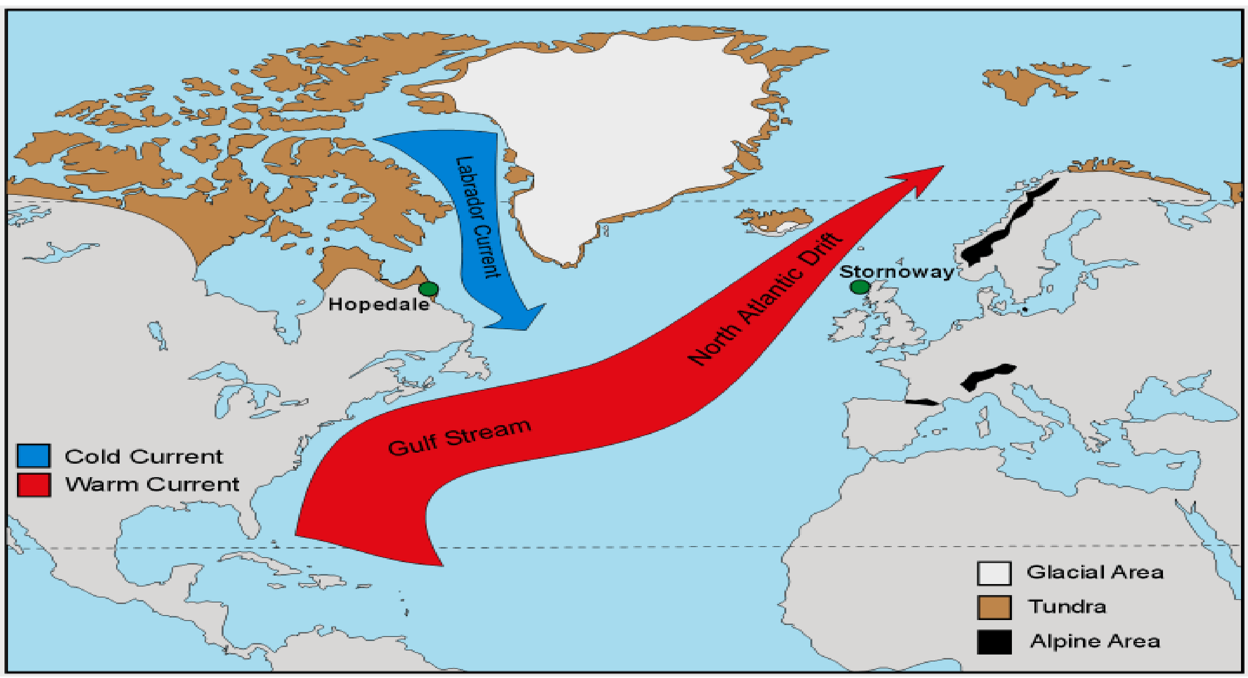


Figure 3-23. Major Ocean Currents affecting Newfoundland and Labrador (from Wikipedia).

The Gulf Stream is also the warm surface limb of the Meridional Overturning Circulation (MOC), illustrated in Figure 3-24. It brings warm salty water to northern regions where it loses heat to the colder atmosphere, mixes with cold arctic water and sinks to the bottom (deep convection in the Greenland Sea and Labrador Sea) as it encounters cold dense water flowing south as the lower limb of the MOC. The MOC is a very important process that efficiently redistributes the excess heat from tropical regions to heat deprived northern regions, thus playing a primary role in maintaining the earth's climate balance.

The climate of Newfoundland is also affected by four major atmospheric or coupled ocean-atmosphere phenomena: the North Atlantic Oscillation (NAO), the Arctic Oscillation (AO), the Atlantic Multi-decadal Oscillation (AMO) and, remotely from the Pacific Ocean, the El Nino

Southern Oscillation (ENSO). The AMO has already been discussed in Section 3.4.3. The other three oscillations will be considered in order.

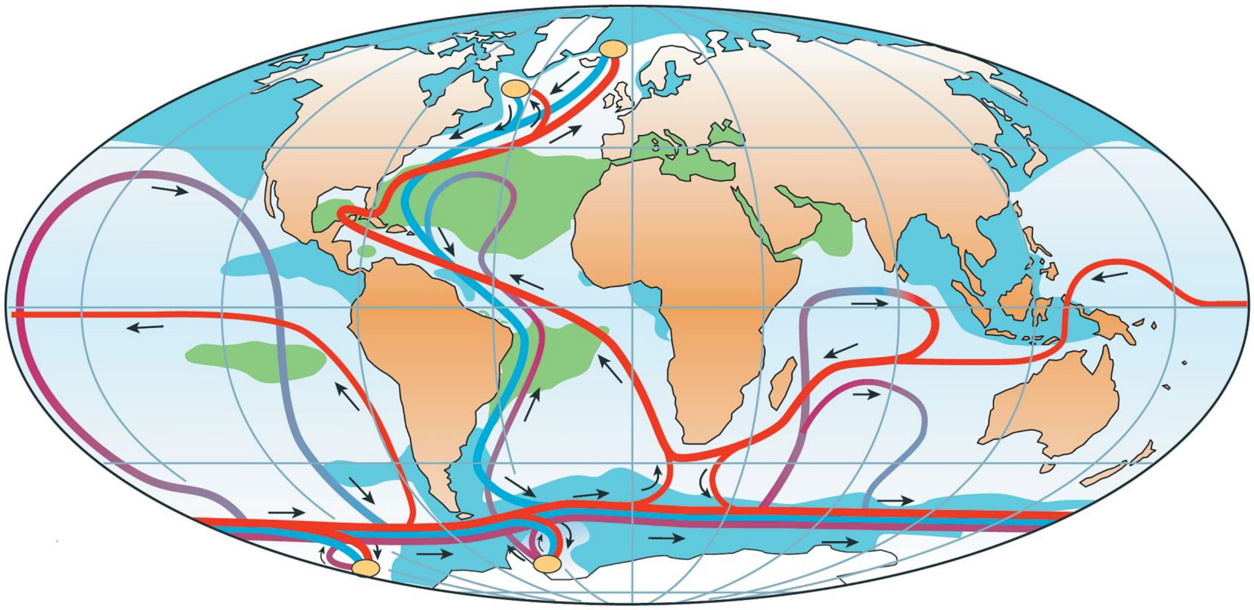


Figure 3-24. Schematic of the global or Meridional Overturning Circulation (MOC). From Kuhlbrodt et al, (2007).

The NAO is presented at Figure 3-25. During a positive phase of the NAO, the atmospheric pressure difference between the Azores high (also called the Bermuda high) and the Icelandic low is larger than average and results in an intensified south-westerly circulation over eastern North America which prevents Arctic air from plunging southward during winter, so that it veers to the east instead, resulting in colder temperatures over Newfoundland and Labrador and increased snow fall over the east coast region. In the summer, these strong westerlies tend to steer tropical storms away from the Gulf of Mexico, to the northeast, then north and finally northwest over the Atlantic Ocean, making them more likely to reach the Maritimes and Newfoundland. The higher summer sea surface temperature (SST) in the northeast Atlantic - driven by the AMO, is also associated with a positive phase of the NAO. This helps the tropical storms to conserve greater intensity while moving to higher latitudes as explained in Section 3.4.3.

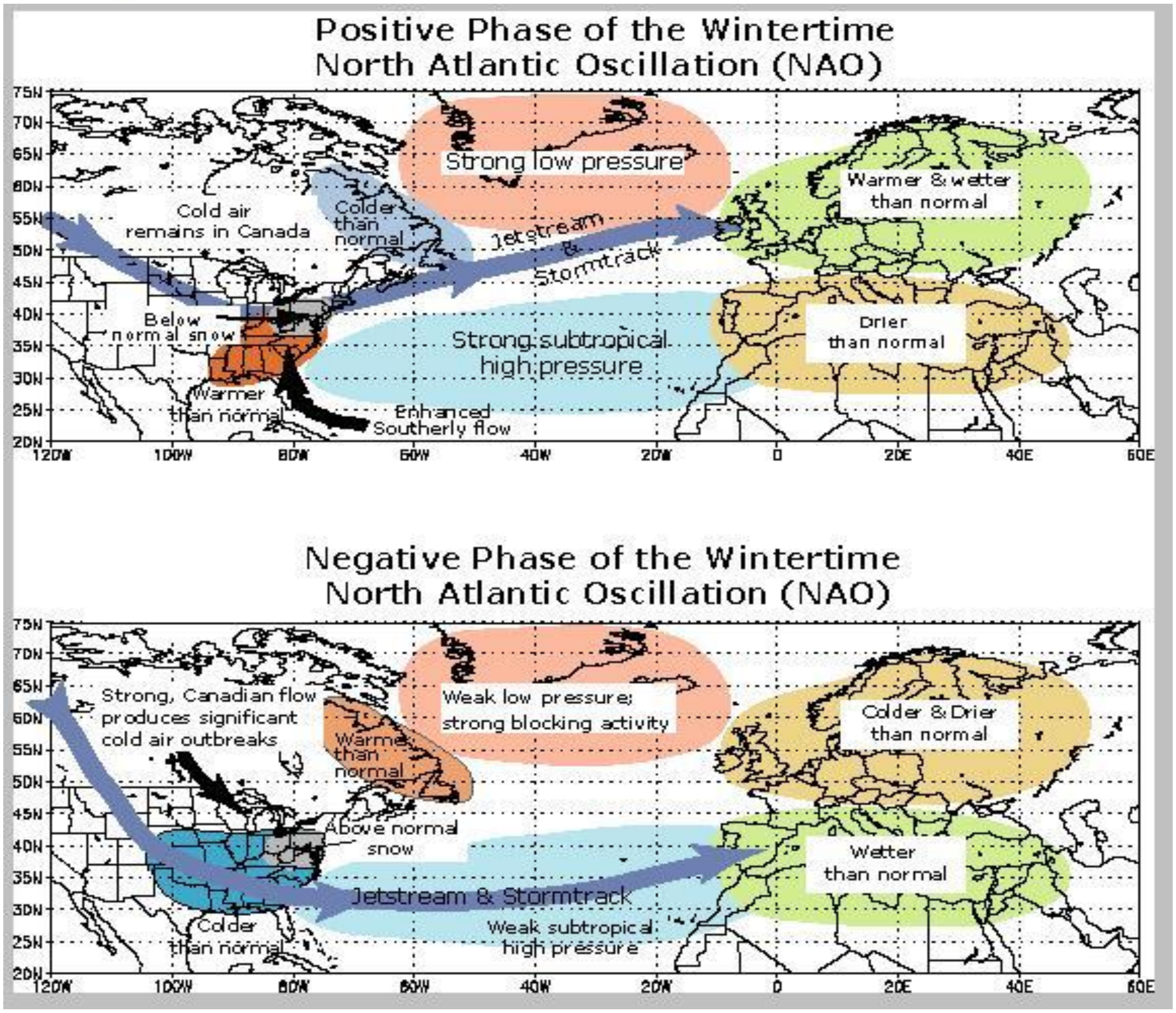


Figure 3-25. Phases of the North Atlantic Oscillation from NCDC.

The negative phase of the NAO is associated with blocking events around southern Greenland. This causes cyclones that move over Labrador and the Labrador Sea to stall in the area rather than following their typical tracks towards the east. Warmer temperatures and somewhat higher precipitation then occur in the province. The negative phase of the NAO is associated with the unusually warm winters of 2009-2010 & 2010-2011 in Labrador.

The AO (Figure 3-26) refers to opposing atmospheric patterns in northern mid and high latitudes. The positive phase of the AO sees relatively low pressure over the polar region and relatively high pressure at mid latitudes. Newfoundland's exposure to ocean storms is then increased as they are driven further north. Cold arctic air does not extend as far south in the middle of North America as it would during a negative phase of the AO and is instead deflected to the east, bringing colder temperatures than usual over Newfoundland and Labrador. As with the NAO, a positive phase of the AO tends to deflect tropical storms away from the Gulf of Mexico over to the Atlantic Ocean increasing the potential for landfall in Atlantic Canada.

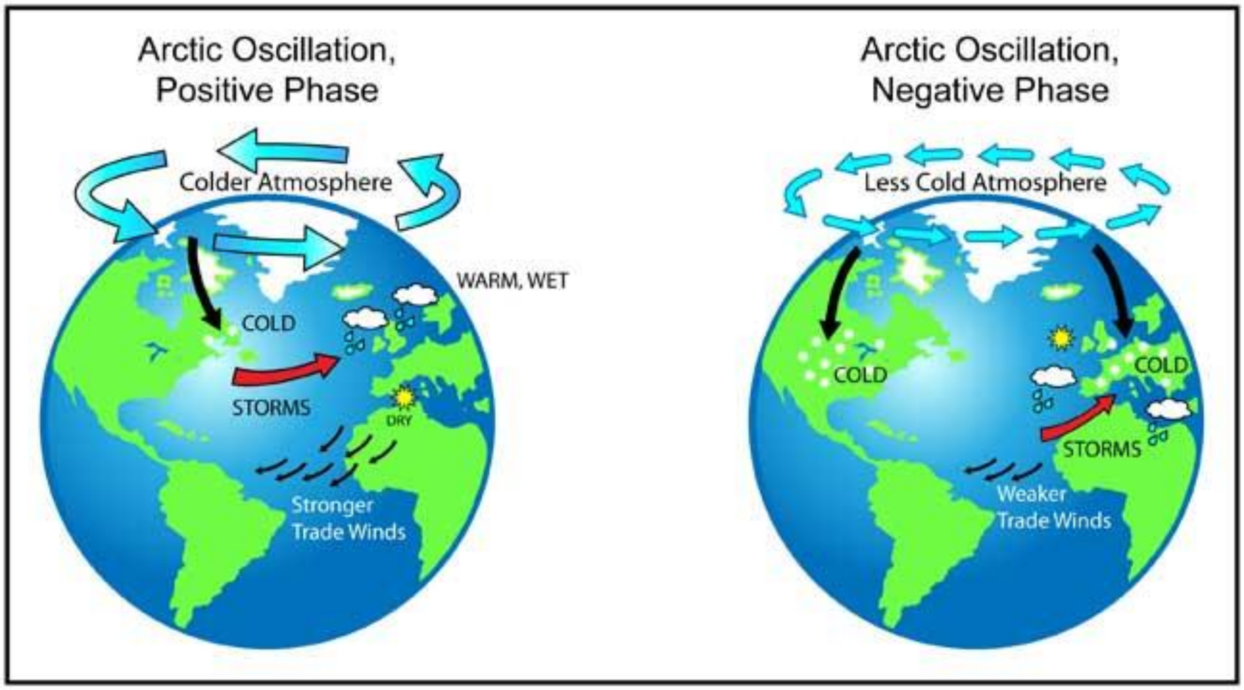


Figure 3-26. The Positive and Negative Phases of the Arctic Oscillation.

Finally, for completeness, the ENSO, whose effects on Newfoundland climate are indirect and slight, will be discussed. ENSO itself is a coupled ocean-atmosphere oscillation in the tropical Pacific Ocean and atmosphere. During an El Nino phase of ENSO, the atmospheric pressure difference between the eastern and western tropical Pacific decreases and the trade winds weaken, allowing warm western Pacific water to propagate eastward along the equator, pooling along the coast of South America, where cold water normally sits as a result of coastal upwelling. The La Nina phase is the opposite with particularly intensified easterly trade winds and a cold water pool in the east. El Nino years generally see a significant decrease in the number of tropical storms in the North Atlantic. Maps of precipitation departure from normal prepared by Environment Canada (http://www.ec.gc.ca/adsc-cmda) indicate drier winter conditions over Newfoundland during El Nino years. Similar maps for La Nina years indicate a tendency for winters with slightly higher precipitation than normal.

The IPCC 2007 report (IPCC, 2007) presents an extensive review of already observed changes in the atmospheric and oceanic circulation as well as further global warming induced anticipated changes predicted by climate models under various scenarios of increased anthropogenic CO_2 during the 21st century. The material presented below is summarized from Chapter 5 of the IPCC 2007 report.

Regarding observed changes in the North Atlantic sub polar gyre, the IPCC reports large salinity changes in the past 50 years associated with changed inputs of fresh water and with the NAO. These anomalies called 'Great Salinity Anomalies' (GSAs) have had time to travel around the gyre and are observed in the Labrador Sea and the Nordic Seas. They have affected the water masses formed by deep convection, Labrador Sea Water (LSW) and the North Atlantic Deep Water (NADW), which alternate between dense, cold types and less dense, warm types. There was an overall trend towards freshening of the sub polar gyre consistent with the positive phase of the NAO between 1960 and 1990. Since then, with a shift in the NAO, it has returned to being saltier and warmer, but not for long enough to have reverted the long term trend. These observed variations in high latitude salinities also result in variations in the depths and volumes of water formed by deep convection, possibly affecting the strength of the MOC. Although it is very likely that the MOC has experienced significant changes over interannual to decadal time scales up to the end of the 20th century, there is no coherent evidence of a trend in the mean strength of the MOC.

The IPCC found that an increase in high latitude temperature and precipitation was a common feature of all climate projections; both tend to make surface water less dense (warmer and less salty) which inhibits deep convection with, as a possible consequence, a reduction of the MOC. Models show a wide range of projections, from a reduction of the MOC by up to 50% or more to changes indistinguishable from simulated natural variability. The reduction of the MOC proceeds at the same rate as the simulated warming as it is a direct response to the increase in ocean surface buoyancy. This may be delayed by a few decades, but not prevented, by a positive trend in the NAO. No model shows an increase or an abrupt shut-down of the MOC during the 21st century. However the possibility of the latter beyond the end of the 21st century cannot be excluded. Indeed, overall simulations show a decrease of the MOC over the next 100 years, possibly associated with a significant reduction in the formation of the LSW. Under the assumption that warming would stop after a century, some models show a recovery of the MOC and others show the MOC remaining at reduced strength. A reduction of the MOC would result in a reduction of the heat flux towards high latitudes which would slow down the warming of the North Atlantic. However, no cooling is observed in the surrounding regions because it is overcompensated by radiating forcing. This would therefore potentially delay warming of the region but would not be expected to result in cooling over Newfoundland.

The IPCC reports that many simulations project an increase in the positive phase of both the AO and the NAO due to anthropogenic warming, although the changes might not be distinct from the larger multi-decadal internal variability observed during the first decade of the 21st century. One consequence of an increase in the positive phase of the AO and the NAO would be a higher incidence of tropical storms from the Atlantic Ocean potentially making landfall in Newfoundland.

Another consequence of an increase in a positive NAO phase might be that it brings colder water and air to the coastal regions of Labrador and of Newfoundland. As a result, general warming in inland and western parts of Newfoundland and Labrador are likely to be faster than that felt along the east coast (Bruce, 2011).

Regarding the variability of ENSO as a result of climate change, the IPCC found that all models were showing continued ENSO interannual variability. Models exhibited a wide range of behaviours, from little change to large changes in El Nino events. It is also difficult to discern whether any changes in El Nino amplitude predicted by models are due to external forcing resulting from global warming, or are simply a manifestation of internal multi-decadal variability. The IPCC concludes that there is no consistent indication at this time of discernible future changes in ENSO amplitude or frequency. In addition, a recent study simulating the effects of climate change on ENSO (Stevenson et al, 2011), confirms the IPCC conclusions. However, while it found no significant changes in the extent or frequency of ENSO, it also found that the warmer and moister atmosphere of the future could make ENSO events more extreme, in particular, stronger La Nina events. Since these are associated with higher winter precipitation in Newfoundland; this result is consistent with the GCM outputs discussed earlier. Overall though, as the ENSO regime is projected to remain quite similar to the present, its impact on Newfoundland climate is not expected to change dramatically.

In summary, it can be stated that the ocean currents which exert a major influence on Newfoundland and Labrador climate are not expected to change significantly as a result of global warming over this century. The ocean-atmosphere oscillations that are responsible, to some extent, for the observed decadal (and longer) cycles in warmer and colder periods and periods with greater tropical storm intensity, continue through to the end of this century, if not beyond. Their periodicity and intensity may change somewhat over the coming decades and tracking those may help to predict climate anomalies in particular years or series of years in the future. But because these planetary scale general circulation features are all likelihood well handled by global climate models, the gradual upward trends in temperature and precipitation seen out to 2050 and 2080 in the modeling section likely capture the long term effects of the small changes in these large ocean currents and oscillations.

3.4.6 Worst Case Scenario Analysis

In the interest of preventing natural hazards from becoming natural disasters, one must also consider worst case scenarios; intense phenomena that may occur in isolation or in combination with other events or circumstances, that could lead to extreme water levels. This section provides a preliminary, largely qualitative, assessment of scenarios that could lead to extreme flooding in parts of Newfoundland and Labrador. It is based on due consideration of the preceding sections of this report which deal primarily with average conditions but also some analysis of the key climate and extreme weather drivers, literature reviews and internet searches on this subject, and consultations with a number of weather and other professionals who have lived in Newfoundland at least several decades.

It is appreciated that others have attempted to quantify more precisely the return periods for precipitation events of various intensities. Earlier in this section, IDF curves were updated for at least one site within each WRMD region. These curves capture the character of precipitation at a specific location based on the past long record of precipitation intensity observations. Updating these frequently is crucially important in an era of changing climate.

Others (Lines et al, 2008; AMEC, on-going flood mapping project for Goulds/Petty Harbour and Corner Brook) have developed approaches to project IDF curves forward in time, thus producing forecast IDF curves for a specific period some decades into the future. However, the main inputs into the process are outputs from GCM runs. As Lines points out, those are very coarse models, grid spacing of 300 X 400 kms, and are not suitable when studying impacts on much smaller areas, 100 square kilometres or less. This gives rise to downscaling and statistical approaches to refine coarse GCM outputs at higher resolution over a limited domain. As was explained earlier, these approaches start with GCM outputs and a finer surface mask to run regional models on a finer scale over a smaller domain. These approaches remain largely dependent on the quality of the coarse GCM outputs.

Unfortunately coarse GCMs cannot be expected to capture well meteorological phenomena on smaller scales than the synoptic scale. Meso-scale phenomena such as hurricanes will be poorly resolved. Regional models with a domain size corresponding to Newfoundland and Labrador would be unable to capture a meso-scale phenomena, i.e., a hurricane, generated thousands of kilometres away in the equatorial Atlantic. Since these phenomena are responsible for some of the most extreme weather in this case, these approaches would miss the precipitation maxima likely with such events in the future.

When one considers flooding specifically, combinations of factors coming together need to be considered together. An updated or forecast IDF accounts only for the new water from precipitation. This is especially worrisome for Newfoundland which has a concentration of its communities along the coasts. Those communities would be subject to sea level rise and both ocean surge and waves as well as abundant precipitation from massive storms. Conditions could be rendered yet more dire if such storms also coincide with high tides.

A number of weather phenomena or scenarios will be considered in turn. They will be briefly introduced, similar recent events will be discussed, and some features that could render them extreme will be considered. Areas that may be affected will be identified and, where possible, some quantification will be attempted.

Winter Rains

- Results from modeling of future trends to late century indicate more marked increases in winter temperatures and precipitation (Bruce, 2011). Rain is usually a key flood inducer but often works in concert with other factors or events. While it is not possible to deal with all possibilities and all peculiar local effects, several scenarios arise:
    - Abundant winter rain combined with an intense and sudden warming affecting an area with significant snow cover. The rain combined with rapidly melting snow can exceed an areas ability to channel water off. The western and eastern parts of the Newfoundland are likely to be affected by different aspects of this issue. The west coast of Newfoundland is more likely to be susceptible to a heavy snow melt given the typically abundant winter snow packs in this region whereas the east coast is more likely to be afflicted by frequent heavy precipitation events given the its location relative to the Atlantic storm track ;
    - Abundant winter rains combined with an intense and sudden warming that would swell rivers and break up winter ice. Such a rapid break-up can cause ice jams which effectively dam water from escaping and cause water accumulation upstream leading to floods. A most noteworthy such event occurred at Badger in February, 2003. The flooding was followed by a return to very cold temperatures (-20 ºC) which froze the floodwaters encasing cars and homes in ice and keeping many of Badger's 1,100 residents homeless for several weeks;
    - Abundant winter rains falling on frozen ground which has a seriously compromised ability to absorb water. This would occur when an intense winter rain storm or a series of smaller ones arrive at the end of a prolonged cold period. An example of this occurred in Ontario in 1980 when a 5 year rainfall fell on frozen ground in the Ganaraska River watershed resulting in the highest documented flood on record. The island of Newfoundland is rendered especially vulnerable given the relatively thin soils and therefore the poor soil storage capacity;
- A key feature of these scenarios, abundant precipitation from synoptic scale phenomena, is likely well captured by GCMs and IDF curves. Another key ingredient in several of the above winter rain scenarios is a sudden and marked warming. Modeling also shows greater increases in winter temperatures but does not characterize them further. More marked temperature swings, including more frequent sudden winter warming events, going forward into this century, will likely be one of the mechanisms leading to increased winter temperatures. The potential for flooding events of these types to increase in frequency through this century is to be expected. They will affect especially the Western and Central WRMD regions.

Weather Bombs

- This increasingly accepted term refers to low pressure systems that develop rapidly, explosively deepening low pressure systems, and hence the word ‘bomb’, in the Cape Cod area off the coast of North America;
- This is a favored area for cyclogenesis or re-envirogation of storms moving off of the continent and encountering the warm waters of the Gulf Stream;
- Storms occur especially in the fall and winter and deepen further as they move rapidly north-east or north-north-east along the Gulf Stream skirting the island of Newfoundland;
- Some storms can reach Hurricane or near Hurricane force sustained wind speeds (> 100 km/hr) and give rise to the strong ‘Nor’easters’ that Newfoundland is known for (counter-clockwise cyclonic circulation on the north side of these systems);
- Typically tracking just off of Avalon or right over the Avalon Peninsula, these storms may become more intense with warming oceans and a more marked Gulf Stream which provides a main source of energy and moisture for their explosive development. However, it is uncertain what will happen with events of this nature as they could also become less intense given that the temperature gradients they draw energy from will also weaken in the future;
- An extensive area of strong and aligned northeast winds can sometimes be set up as the storms move along the Gulf Stream and are absorbed by the semi-permanent Icelandic low. This generates seas and waves over a long fetch area creating massive waves which affect Eastern and Northeastern Newfoundland producing coastal flooding; and
- The frequency and intensity of such events will also likely change through this century as a result of global warming. The most recent studies (Mizuta et al, 2011) suggest that mid-latitude cyclones, in general, will become less frequent in a warmer climate, but will be more intense on average.

Hurricanes and Tropical Storms

- These are major cyclones developing over the warm (> 26ºC) waters of the equatorial Atlantic Ocean;
- The island of Newfoundland lies at the outer north west reaches of typical Atlantic Hurricane tracks;
- Hurricanes and Tropical Storms from the Atlantic, see Figure 3-27, can pass on either side of the island of Newfoundland as has been seen in recent years by Chantal, Aug 2007, just east of the Avalon, and Earl, Aug 2010 through the Strait of Belle Isle though clearly, the eastern regions of the island are more exposed to the higher intensity storms;

- Storms weaken rapidly once they make landfall and most such storms have not been of Hurricane force when hitting Newfoundland, especially western Newfoundland given that for a hurricane to pass west of the island, it would almost necessarily have had to pass over some part of the Maritimes and would have been weakened considerably as a result;
- Several peer-reviewed studies show a global trend toward increased intensity of the strongest hurricanes over the past several decades. The strongest trends are in the North Atlantic Ocean and the Indian Ocean. This is consistent with this study's findings. Figure 3-17 confirms the increase in the last several decades. Figure 3-18 also shows an increase in Tropical Storms entering Newfoundland coastal waters in the last 2 decades and a very marked increase of storms making landfall in eastern Newfoundland in the last decade. According to the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4), it is "more likely than not" (better than even odds) that there is a human contribution to the observed trend of hurricane intensification since the 1970s. In the future, "it is likely [better than 2 to 1 odds] that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures";
- Bruce (2011) also points out that with increasing global temperatures and increasing equatorial water temperatures, more intense Hurricanes are likely to develop and, while tracks are not expected to change, the storms will retain greater force as they reach more northern latitudes. While it is not possible to state that any particular event is or is not a result of global warming, Hurricane Igor, was able to retain Category 1 strength as it passed over the Avalon Peninsula (see track at Figure 3-27) and it caused the most devastating floods in Newfoundland history (see Figure 2-2).
- Hurricanes and Tropical Storms combine intense rainfall with very strong winds (Category 1 Hurricanes ≥ 120 km/hr) producing significant storm surge and wind induced waves;
- Though there will likely continue to be decades in the future with greater and lesser activity, more intense Hurricanes and Tropical Storms will likely affect the island of Newfoundland with the higher intensity storms impacting especially the Eastern WRMD many of whose coastal communities would also be subject to storm surge and waves;
- In terms of worst case scenario for these cyclones, consider the Saxby Gale of Oct 1869:
    - This 'gale' was essentially a Hurricane which tracked over Cape Cod and made landfall in Maine, and then tracked across northern New Brunswick (see Figure 3-27);

- In addition to the abundant precipitation, the counter-clockwise cyclonic circulation around the storm caused sustained very strong south-westerly winds over the Bay of Fundy which experiences some of the highest tides in the world;
    - The situation was aggravated by the fact that the Bay of Fundy lies in a SW-NE orientation and narrows at the NE end thus causing surge to build further;
    - In addition, the Saxby Gale coincided with a perigean spring high tide causing widespread flooding and devastation;
- In the case of Newfoundland, it is clear that a Category 2 Hurricane could again make first landfall along the south coast of the island of Newfoundland as Hurricane Michael did in 2000;
- Category 3 Hurricanes have crossed NL Marine areas, Ella brushed the Avalon in 1978;
- Given the Hurricane analysis presented earlier and the trends reported in the literature, it is to be expected that a Category 3 Hurricane will likely make landfall in Newfoundland before 2080, perhaps before 2050;

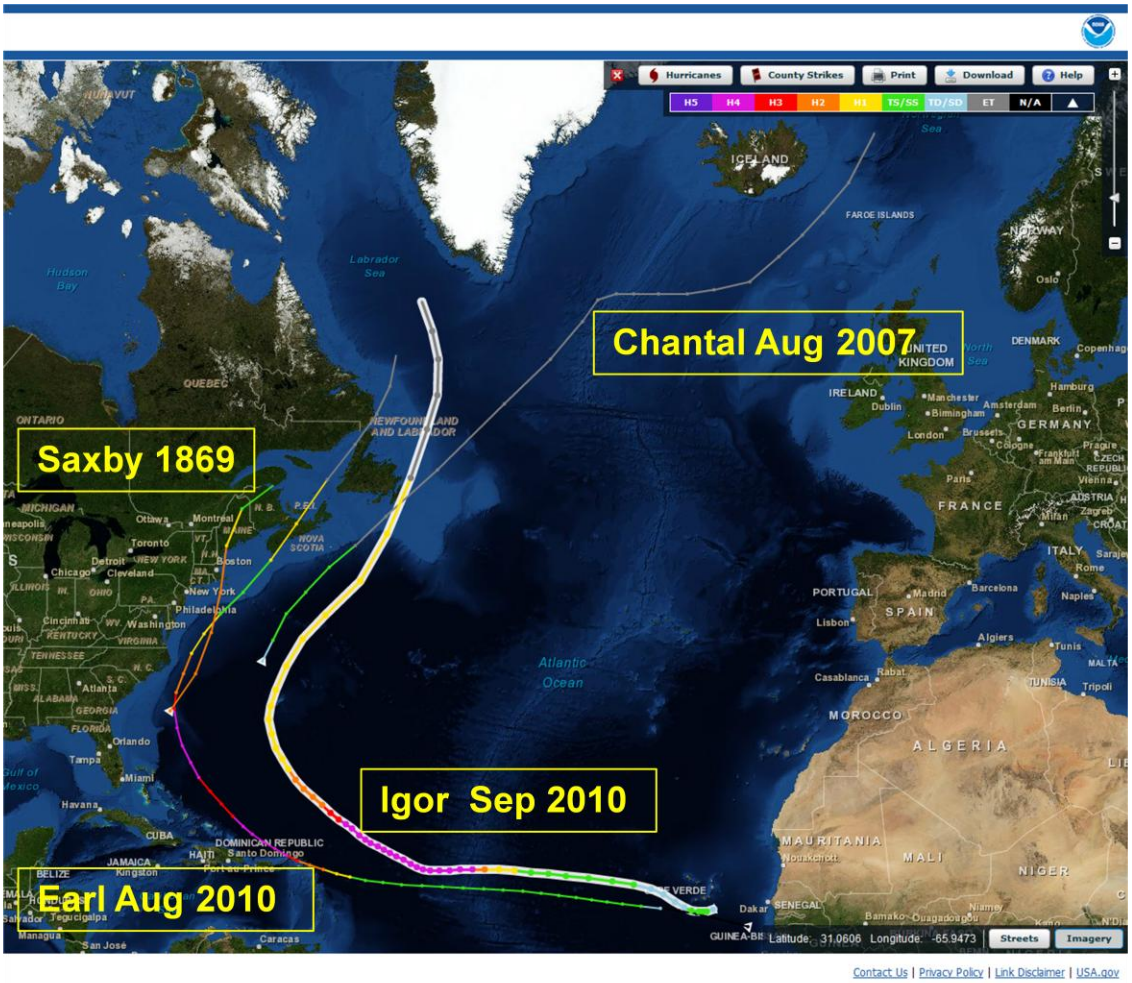


Figure 3-27. Selected Hurricane and Tropical Storm Tracks

- If a Hurricane of Category 2 or 3 were to make landfall in the area southern Newfoundland, then a situation similar to that produced by the Saxby Gale in the Bay of Fundy could result:
  - Newfoundland has a number of SW-NE oriented bays, narrowing northward along its south shore such as Fortune, Placentia, and St. Mary's bays;
  - The storm could coincide with one of the two daily high tides or nearly so;
  - Going forward to mid and late century, the added impact of net sea level rise would another factor aggravating the situation;
  - A first very crude attempt at representing the cumulative effects of the various factors at play to estimate the potential high water mark is presented at Figure 3-28 though it is cautioned that storm surge depends on a complex combination of factors in

addition to hurricane intensity such as spatial extent of tropical storm force winds (fetch), the continental shelf geometry and local topography which make it extremely difficult to precisely peg a high water mark which can be considerably lower or higher in specific communities;
    - Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm together with the greatly reduced atmospheric pressures;
    - In addition, wind generated waves are superimposed on the storm tide above but again, are exceedingly difficult to quantify precisely as the wave height would be highly dependent on storm depth, track, age, swath size etc. (e.g., Hurricane Igor, which tracked right along the eastern shore of the Avalon Peninsula, produced wave heights to the west of the track (south coast of NL) which reached 4.2 metres while near the track (south of Avalon) wave heights were 8 to 9 metres and to the east of the track, 12.5 metres);
    - The US National Oceanic and Atmospheric Administration (NOAA) indicate that the greatest potential for loss of life related to a hurricanes is from storm surge, which historically has claimed, in the US, nine of ten victims;
- To complete the Hurricane and Tropical Storm threat for Labrador, the following thoughts are offered:
    - Tropical systems do enter the Gulf of Mexico and from there veer North tracking up the Mississippi Valley and along the western side of the Appalachians through Ontario and Québec and into Labrador;
    - By then, these storms are much weakened and so Labrador would experience storm remnants only though precipitation could still be significant (remnants of tropical systems can cause widespread flooding as was seen with the remnants of Hurricane Rita flooding Stephenville, West WRMD, in September, 2005);
- Hurricanes represent the greatest threat to Newfoundland and are the weather phenomena affecting the island that will most likely produce the highest water levels and the most severe floods;
- Figure 3-28 provides a preliminary estimate of the cumulative effects of the various factors contributing to increased coastal water levels from Hurricanes (this was all that could be accomplished within the context of this project);
- From the analysis of past Hurricane events in this report and the climatic trends reported by others, and confirmed by analyses herein, it could be hypothesized that, while extremely difficult to estimate return periods, themselves changing, for rare events with data over a little more than the last half century, going forward through this century:
    - a Category 1 Hurricane making landfall on the island of Newfoundland appears to be about a 1 in 10 year event (though not all necessarily as damaging as Igor whose impact was amplified by other factors);

- a Category 2 Hurricane making landfall in Newfoundland should be considered an event with a return period of about 50 years;
- a Category 3 Hurricane making landfall in Newfoundland is likely a somewhat less than a 1 in 100 year event, perhaps occurring before 2080 (only NL Marine areas have been affected by such storms to date);

- Given the extreme conditions that such storms produce the following are recommended:
  - A second opinion be obtained, either from academia or from Environment Canada, concerning the threat that Hurricanes pose to Newfoundland;
  - Depending on the outcome of the above, commission additional analyses to more precisely estimate the high water levels that would result in specific coastal communities since not all would be exposed, due to their orientation and other factors, to the full storm surge and wave effects estimated at Figure 3-28;
  - Since it is possible that such intense Hurricanes could also occur earlier in the century, greater emergency preparedness and planning for the most exposed communities should be considered.

Hurricane (Cat 2)	Hurricane (Cat 3)	Factor
By 2050	By 2080	
160 km/hr	185 km/hr	Winds (6)
2 to 3 m	3 to 4 m	Waves (5)
2.0 to 2.5 m	2.0 to 2.5 m	Tides (4)
0.3 m	0.4 m	Precipitation (3)
2 to 3 m	3 to 4 m	Storm Surge (2)
0.4 m	1 m	Sea Level Rise (1)
		Mean Sea Level (present)

1. From Batterson and Liverman.
2. From Hurricane archive.
3. From Hurricane archive.
4. Canadian Hydrographic Service, Come by Chance, NL, Tides - Sept. 2010.

5. From wave calculation based on wind speed and fetch.
6. From Saffir Simpson Hurricane Scale.

Figure 3-28. Contributing factors and coarse preliminary estimates for each.

Summer Severe Weather

- It is appropriate to complete this analysis to briefly consider summer severe weather phenomena, thunderstorms and tornadoes, which are responsible for much of the localized flooding in other parts of Canada;
- Newfoundland is not known for severe deep convective weather although occurrences of summer severe weather appear to be on the rise;
- Most extreme weather in Newfoundland and Labrador results from synoptic scale systems or meso-systems like Hurricanes and Tropical Storms;
- Water spouts, essentially a tornado over water, have been reported in the Gulf of St. Lawrence and even off the south coast of Newfoundland, but water spouts dissipate extremely quickly after making landfall and so typically cause no damage (e.g., water spouts have been seen around Confederation Bridge but caused no damage);
- Tornadoes are virtually unheard of in Newfoundland as heating is seldom intense enough and terrain too rugged for their formation.

3.4.7 Summary and Conclusions

This section provides a summary of the main conclusions from each of the approaches used in the analysis of climate change impacts for Newfoundland and Labrador.

Modeling

- A somewhat conservative SRES scenario was used in the modeling runs performed for this project. However, given that global warming has been progressing at a higher rate than expected (Bruce, 2011), the modeling results are considered to be very likely and are certainly comparable to those reported in other literature;
- Temperatures and precipitation are expected to increase generally through this century though there are seasonal and location differences across Newfoundland and Labrador:
  - Summer precipitation on the island remains basically neutral in the first half of the century with mild increases thereafter while Labrador sees a steady dramatic rise in summer precipitation;
  - There is a clear steady rise in winter precipitation across all regions through the century;
  - The differential change in precipitation across the island's three WRMD regions is very small though the West sees slightly larger winter increases; and

- Because winter temperatures show the greatest increases, it is thought that in the future there may be more frequent sudden winter thaws and rain events which could lead to increases in rain on snow (Catto and Hickman, 2004) or rain on frozen ground events leading to flooding with the West and Central WRMD regions most susceptible to these events.

Intensity Duration Frequency Curves

- IDF curves for Gander and Goose Bay were updated, using the same approach as Environment Canada, to 2011 so that, together with outputs from other projects, at least one current representative IDF will be available for each WRMD;
- Only a few additional years of data were considered in updating Goose Bay IDF values and so there is almost no noticeable change there;
- The new IDF values for Gander are minor but do show increases compared to the previously published values except for the very short durations (5 minutes) and the biggest changes (4%) at the longer durations indicating, since this is all based on actual data, that precipitation intensity is already beginning to trend upward which supports the argument that global warming is already happening; and
- While IDFs characterize only one flood risk factor, precipitation, and do not capture the seasonality of precipitation, developing projected IDFs for future time frames is a worthwhile exercise and is recommended especially if a means can be found to incorporate in that effort, the results of dynamical modeling of hurricanes to 2050 and beyond. Seasonal IDFs could also be developed and may be useful given that specific hazards are associated with particular seasons (e.g., hurricanes/tropical storms in the fall and Weather Bombs in the fall and early winter).

Hurricanes and Tropical Storms

- Tropical systems are responsible for the most extreme and costly flooding events (e.g., Igor, 2010) in Newfoundland and so a very careful analysis of past hurricanes and tropical storms was conducted;
- Past records show that hurricanes can track on either side of the island of Newfoundland, that a category 2 storm has already made landfall along the south coast and that a category 3 storm has already narrowly missed the island;
- The analysis of past storms showed that there is a significant upward trend in the frequency of tropical storms and hurricanes affecting Newfoundland since 1954, and especially since 2000;
- This upward trend in tropical storm activity is associated with the gradual increase in Atlantic sea surface temperatures though there is no scientifically proven link;
- It is thought that tracking cool and warm phases of the Atlantic Multi-decadal Oscillation (AMO), a long-duration cycle (20-40 years) in sea surface temperatures in the North

Atlantic Ocean, may provide useful clues to periods of higher tropical storm activity and intensity;

- Advanced dynamical and statistical modeling by the US National Centre for Atmospheric Research and other institutions leads to the following conclusions:
  - North Atlantic hurricanes will experience an accelerated increase in numbers from 1-3 %/decade at present to 4-10%/decade to 2050;
  - Only a modest increase in intensity is expected but a significant increase in the frequency and intensity of the most intense hurricanes is expected over the next 40 years; and
  - Statistical analyses predict an increase in the annual number of storms from current numbers of approximately 1 more storm annually by 2050 and another 3 storms annually, on average, by the end of the century.

Sea Level Rise

- Sea level is an ocean indicator for climate change, which causes continued melting of polar ice caps and mountain glaciers in addition to a warming of the oceans, and is rising globally (3 mm/yr) though that has to be adjusted for the North Atlantic (2.5 mm/yr is estimated);
- The geological effects, such as rebounding from the last ice age, are also taken into account;
- Net sea level rise, by 2099, is estimated at from 100 cms for the East WRMD, 90 to 100 cms for the Central region, and about 80 cms for the West and Labrador regions;
- For coastal communities, it is important to factor in future net sea level rise in developing flood plain maps; and
- It is cautioned that coastal erosion may be a significant factor with great variability from location to location depending on geology and exposure and must be incorporated on a site by site basis (beyond the scope of the present work).

Ocean Current and Oscillations

- Literature reviews on this topic indicate that the ocean currents which exert a major influence on Newfoundland and Labrador climate are not expected to change significantly as a result of global warming over this century;
- The warm and cold cycles in the various ocean-atmosphere oscillations that influence tropical storm frequency and intensity and other aspects of Newfoundland and Labrador weather year-over-year, will also continue through to the end of this century though their periodicity and intensity may change over the coming decades; and
- Tracking these oscillations is a useful exercise that may help to predict climate anomalies and hurricane intensity in particular years or series of years in the future.

Worst Case Scenarios

- This section provided a preliminary assessment of weather phenomena or combinations of weather events and other circumstances which, when occurring simultaneously or in succession, can lead to significant flooding. While somewhat rare (an occurrence every few years or less often), most of the scenarios have occurred in the past and are likely to occur again, and so this section does not deal, per se, with highly unlikely events but rather very plausible events (one could conjure up much worst case scenarios);
- Considering, from the modeling work done here and reported elsewhere, the more marked increases in temperature and precipitation in the winter season and supported somewhat by updated IDFs, it is likely that winter rains will occur more frequently in the coming decades which gives rise to a number of scenarios all starting with abundant winter rains:
    - Combined with sudden melting of the winter snow pack to produce a greater threat of flooding especially likely for the West WRMD;
    - Together with sudden prolonged warming sufficient to break up river ice causing ice jams as has happened at Badger in 2003, Central WRMD;
    - Falling on frozen ground unable to absorb the added moisture which did lead to a major flood in Ontario in 1980 (noted again that Newfoundland may be especially vulnerable given the thin soils);
- Weather Bombs are explosively deepening low pressure systems typically starting in the Cape Cod area and tracking just east of Newfoundland as they continue to intensify rapidly. Such storms produce very strong (sometimes over 100 km/hr) wind bands which can generate, thanks to a fetch of many hundreds of kilometers across the North Atlantic, very significant waves. These are the 'Nor'easters' for which Newfoundland is famous. They are a threat especially for the coastal communities on the eastern and northern sides of the island of Newfoundland and it is speculated that they could increase in intensity, but likely not in frequency, under a warming climate scenario. Weather Bombs warrant closer examination, not possible here, given that they can approach Hurricane intensity.
- Hurricanes and tropical storms present the greatest threat of producing severe flooding for Newfoundland. The intensity and frequency of tropical systems affecting Newfoundland and neighboring waters has increased in the last several decades and especially since 2000. Hurricane level storms, Category 1 and 2, have occurred but remain rare events and so it is not possible to give precise return periods for these especially given the cyclical nature of some of the oscillations that may influence them;
- Many references support the argument that warmer tropical oceans together with warmer waters in the North Atlantic will allow more tropical systems to maintain greater intensity as they track northward along the east coast of North America. As such, it can be said that a Category 2 or 3 hurricane making landfall in Newfoundland is likely, if not

a near certainty, and an occurrence before 2050 (for a Category 2) and before 2080 (for Category 3) cannot be ruled out;

- A hurricane making landfall on the island would produce the very highest water levels in Newfoundland. A very coarse preliminary attempt at quantifying the cumulative factors was presented for illustration purposes only. Numerous other factors unique to each storm and its behavior as well as the local topography would affect that high water mark both downward as well as upward; and
- As a result, it is recommended that other opinions be obtained, that further studies be commissioned to more precisely estimate the high water levels, and that appropriate emergency plans be developed.

3.4.8 Recommendations for Assessment of Climate Change Impacts

The following general recommendations are offered to assist the Government of Newfoundland and Labrador in designing and implementing future studies that involve climate change analysis.

1. It is recommended that WRMD develop updated and projected IDF relationships for locations across the Province with suitable past precipitation intensity records. While IDFs characterize only one flood risk factor, precipitation, and do not capture the seasonality of precipitation, developing projected IDFs for future time frames is a worthwhile exercise especially if a means can be found to incorporate in that effort, the results of dynamical modeling of hurricanes to 2050 and beyond. Seasonal IDFs could also be developed and may be useful given that specific hazards are associated with particular seasons (e.g., hurricanes/tropical storms in the fall and Weather Bombs in the fall and early winter).
2. It is recommended that WRMD require that future net sea level rise be incorporated into flood plain map development for coastal communities.
3. It is recommended that the Province of NL actively track ocean-atmosphere oscillations in an effort to predict climate anomalies and hurricane intensity in particular years or series of years in the future. The warm and cold cycles in the various ocean-atmosphere oscillations that influence tropical storm frequency and intensity and other aspects of Newfoundland and Labrador weather year-over-year, will also continue through to the end of this century though their periodicity and intensity may change over the coming decades.
4. It is recommended that the Province of NL complete a more detailed analysis of Weather Bombs, similar to that conducted within this study on Tropical Systems, to determine if these storms, often approaching Hurricane strength, are increasing in intensity and/or frequency. This would be particularly useful in assessment flood potential on the island of Newfoundland’s east and north coasts.

5. A hurricane making landfall on the island would produce the very highest water levels in Newfoundland. A coarse preliminary attempt at quantifying the cumulative factors was presented for illustration purposes only. Numerous other factors, unique to each storm and its particular behavior, as well as the local topography would affect that high water mark both downward as well as upward. As a result, a range of recommendations to mitigate damages should be considered. Firstly, since a 1 in 50 year event could occur in a year or two from now, local emergency plans should be reviewed to ensure they include the potential impacts of a Hurricane. Additional measures may also be required to ensure public safety such as evacuation routes etc. Secondly, a closer study of Hurricanes is recommended to determine a range of likely tracks and intensities with a view to better assessing the likely wind directions and storm surges which specific communities may have to deal with. Such a greater understanding of the Hurricane threat to the island may then allow a close assessment of the impacts of such hypothetical storms in specific communities given their unique topography. Finally, flood plain maps for these vulnerable communities could be updated and other defenses considered.

3.4.9 Acknowledgements

The CRCM V4.2 monthly data (aet run) was generated and supplied by the Ouranos Climate Simulation Team via CCCma's data distribution Web page.

4. Task D – Assess Need for New / Updated Flood Risk Mapping

The objective of this project task is the identification of communities vulnerable to flooding that should be considered for new or updated flood risk mapping studies. This assessment has been founded on the updated Flood Events Inventory, the re-assessment of Flood Risk Maps, a detailed review of the technical components comprising the existing flood plain maps and linkage of a variety of datasets relevant to flood risk assessment.

The definition of communities has been based on the Local Government Profile (LGP) number dataset (XLS file with no spatial referencing). This unique number is assigned to each community in Newfoundland and Labrador although a few communities do not have a number.

A second dataset of communities in Newfoundland was obtained from Government of Newfoundland and Labrador, Department of Municipal Affairs, Municipal Planning and Design Engineering Division. This dataset was used to establish spatial locations of the communities but did not include an LGP number. Linkage with the LGP number dataset was completed through comparison of community name.

Please note for Task D the names used for communities and areas are a combination of those that were in place when the FRM studies were done in the 1980s and 1990s and those reflected by the new LGP numbers due to a need to use data from both old FRM studies and the LGP list.

The assessment of some communities has been limited by lack of data which has also impacted linkage to other datasets such as census data from Statistics Canada. To ensure that communities were adequately considered in the overall assessment, the prioritization followed a multi-tiered approach. Factors included in the assessment are outlined below:

4.1 Prioritization Parameters

4.1.1 Age of flood study

The age of flood plain mapping may be a sufficient trigger to initiate a re-mapping exercise. Flood plains maps will typically be re-evaluated after about 20 years. However, it is recommended that flood risk maps be updated whenever IDF relationships are updated. IDF relationships form the basis for hydrologic modeling which is one of the two fundamental elements of a flood risk assessment; the other being hydraulic assessment. The Canadian

Standards Association[21] recommends that IDF relationships be updated every 5 years due to projected climate change. As such, the following priority factors were applied:

Weighting	Description
0	Maps up to 5 years old were flagged as low priority for update
1	Maps up to 10 years old were flagged as high priority for update
2	Maps older than 20 yrs were flagged as urgent for update

Table 4-1. Age of Flood Study Weighting

4.1.2 Topographic Map Base

Base mapping has changed significantly since the wide availability of sophisticated GIS platforms and analytical tools. Provincial base mapping including topography and digital elevation/terrain models (DEM's/DTM's) are generally updated every few years.

The age/vintage of the base mapping used to delineate flood plains may be a trigger to initiate a re-mapping exercise. Upon reflection, the general approach is to use the most up to date mapping available at the time of the flood study. As such, the age of the flood plain map study is considered a sufficient recognition of base map age. As such, base map vintage was not given separate consideration in this evaluation.

4.1.3 Analytical Methods

Approximate vs. Engineered Methods

Flood plains are typically delineated using one of two basic methodologies, namely: approximate and engineered.

Approximate methods: as name implies, use simplified approaches for estimation of hydrology and hydraulics to estimate flood plains. Accuracy for approximate methods is generally accepted as 1 or 2 contour intervals. Approximate flood plains are meant to provide an "idea" of where the flood plain limit is.

Engineered methods: are much more rigorous and detailed in their analysis of hydrology and hydraulics. Engineered flood plains are used for development regulation.

[21] *Technical guide: Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners*, 1st ed., Canadian Standards Association, 2010. Available at http://shop.csa.ca/en/canada/infrastructure-and-public-works/plus-4013-1st-ed-pub-2010/invt/27030802010/

A priority factor of “1” was intended to be used where approximate methods are identified and “0” where engineered approaches were the basis for flood plain modeling. However, a review of the existing flood studies has provided no indication of hydraulic modeling using approximate methods. As such, this potential differentiator was not relevant to this assessment.

Future vs. Existing Development

In some jurisdictions, the hydrological assessment for flood plain mapping is based on a future, fully developed urban scenario. In others, flood plain mapping is based on the existing development conditions. The preferable approach is to assess the future fully developed urban scenario.

A review of the existing flood studies has provided no indication of hydrologic modeling using fully developed conditions. As such, this potential differentiator was not relevant to this assessment.

4.1.4 Software

Software is constantly evolving and becoming more sophisticated. HEC-RAS, the successor to HEC-2, and the defacto standard for flood plain hydraulic analysis in North America, has gone through 4 major versions since 1995. Each version provides more functionality and the opportunity for the analyst to better represent the hydraulic nature of the study area and hence better estimates of flood limits.

Flood plain mapping which is based on “old” software may be a trigger to initiate a re-mapping exercise.

Some considerations:

- The US Army Corps of Engineers no longer supports HEC-RAS 2.2 as a result of HEC-RAS 3.0 and later versions (HEC-RAS 3.0+) producing different water-surface elevations and floodway surcharges than HEC-RAS 2.2 with the same channel geometry and flow rates.
- After August 17, 2004, FEMA required that all new modeling in studies, restudies, and letters of map change (LOMCs) must use HEC-RAS 3.1.1 or a later version.
- The first version of HEC-RAS (version 1.0) was released in July 1995. Since that time there have been several major releases of this software package, including versions; 1.1, 1.2, 2.0, 2.1 in October 1997, 2.2 in September 1998, 3.0 in January 2001, 3.1 in September 2002, 3.1.1 in May 2003, 3.1.3 in May 2005, and the current version 4.0 in March 2008 and current up to date version 4.1.0 released in January 2010.

- WRMD has defined a preference for hydrologic and hydraulic modeling using HEC-HMS and HEC-RAS.
- HEC-GeoRAS, first released in 1999, is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface. The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS. This now mature (vs. 4.2) tool offers, among numerous other capabilities, the ability to optimize the positioning of cross-sections for input into RAS and also to rapidly generate scenario flood inundation surface outputs for QA/QC and to visualize these spatially together with input hydraulic parameters and ancillary data such as topography and aerial photos. Both approaches offer the potential to improve model performance and the reliability of resulting floodplain mapping.

The existing flood studies detail the name of the software which was used for hydrologic and hydraulic modeling but not the version of the HEC code used. However, by using the HEC release dates in conjunction with the reporting dates of the flood studies, an expectation of which version of software was used can be established.

For the prioritization effort, a weighting of “1” will be given to existing flood studies where the hydraulic model is outdated or no longer supported (i.e., pre-dating May 2003). Where the hydraulic modeling is based on HEC-RAS 3.1.1 or later, a weighting of “0” will be assigned. All of the presently available flood studies pre-date 2000 (except studies currently underway including Corner Brook Stream, Petrie’s Brook and Petty Harbour River and the study completed for Stephenville in 2009).

4.1.5 Climate Change

Newfoundland and Labrador is expected to experience changes in temperature, precipitation, sea level and other factors in the future as a result of climate change. These factors can influence the flood risk faced by a community directly or indirectly. Climate change may result in communities which are not presently at risk of flooding being included in the list of potential candidates for new flood plain mapping.

The potential impacts of climate change on flood risk were assessed as a component C4 – Assess Climate Change Impacts, of this project with the following general outcomes for each of the four WRMD regions as indicated below in Table 4-2.

Region	Precipitation	Hurricanes & Tropical Storms	Sea Level Rise	Ocean Currents and Oscillations
Eastern	1	2	1	0
Central	1	0.5	0.95	0
Western	1	1	0.8	0
Labrador	1.5	1	0.8	0

Table 4-2. Climate Change Prioritization Factors

4.1.6 Community Location and Linkage with Other Datasets

- A coastal community with assets at an elevation within the range of projected sea level rise will be at risk, if not already. Similarly, a community in the vicinity of a watercourse may also be at risk of flooding. The following analyses have been completed to expand the information base upon which to base prioritization.
- The coastal boundary of the Province was used in conjunction with the geographic names database of the Province (as available from GeoBase) to establish whether the community can be considered a coastal community. A value to be used as a basis for determining whether a community is a coastal community will be based on an assessment of known coastal communities and their computed offsets from the coast.

  An initial investigation of the data identified a "coastal" community as lying within 1000m of the coast. The communities in the threshold range were located using Google Earth for a visual assessment of coastal vs. interior designation. This secondary assessment identified a number of communities as "coastal" as it was evident from Google Earth that the municipal boundary extended to the coast. An example is the community of Paradise (LGP# 3655) which is identified as having a point location lying 2934m from the coast. However, the municipal boundary for the community is extensive (covering almost 30km2) and is bounded on the coast. As such, it was designated a "coastal" community.

  Through this assessment 505 communities were identified as "Coastal" and 57 were identified as "Interior".

- The 1:250,000 DEM of the Province was used to establish an elevation of the point location for the community based on the geographic names database. This raster DEM database was sourced from the United States Geological Survey (USGS) retrieved through the Global Data Explorer website[22.] This raster dataset is based on the Routine ASTER Global Digital Elevation Model[23].

[22] http://gdex.cr.usgs.gov/gdex/
[23] Information regarding this dataset is available via https://lpdaac.usgs.gov/content/view/full/11033

- The hydrographic network was used to support a proximity analysis of the community point location to the nearest water feature. The hydrographic network was defined using the National Hydro Network[24] (NHN) available from the Canadian Council on Geomatics, GeoBase.
- The community flood watersheds were created as a component deliverable of this project and were used in conjunction with the community point locations to identify which watershed a community is located in (i.e., communities upstream of the subject community related to the flood plain mapping).
- A second dataset defining watersheds across Newfoundland was sourced from GeoGratis. The Atlas of Canada 1:1,000,000 scale National Frameworks Data, Hydrology and Drainage Areas[25] dataset was used. The National Scale Frameworks Hydrology data consists of area, linear and point geospatial and attribute data for Canada's hydrology at a national scale. The Drainage Areas dataset is largely based on the Water Survey of Canada (WSC) drainage area boundaries at the sub-sub-basin level. Using this dataset a link between watersheds and communities not located within a community flood watershed could be established.
- The WRMD regions were used in conjunction with the community point location to create the community to region link. This allowed consideration of community watershed change assessment in the prioritization process. The WRMD regions GIS dataset were provided to AMEC through WRMD.

For the purposes of the prioritization analysis the following weighting factors are considered:

- If a community was identified as a coastal community and within an elevation range (see climate change discussion above) that could be influenced by sea level rise a weighting of “1” was used (otherwise “0”). The sea level rise factors identified in Table 4-2 have been used as analogous to actual projected sea level rise in centimeters.
- If a community is within approximately 1000m of a riverine water feature it was considered flood prone and a weighting factor of “1” was used (otherwise “0”).

These factors were combined in the prioritization process so that a community with potential coastal and riverine flood risk would take priority over communities with only one or the other potential flood risks.

---

[24] Sourced from …
http://www.geobase.ca/geobase/en/data/nhn/index.html;jsessionid=4709CC438D915362B95EF670A02C5F0A

[25] Sourced from …
http://geogratis.cgdi.gc.ca/geogratis/en/collection/detail.do;jsessionid=7AFD081709723996A1032E30C8624684?id=87B4BE8F-C67C-5545-80B5-AB6FC056149E

4.1.7 Population

Population statistics available through Newfoundland and Labrador Statistics Agency[26] were used as an indication of population growth to the year 2020 trending census data for the years 1991, 1996, 2001, 2006 and 2011, as available from the Agency website.

It was determined through efforts to link the census data to the LGP community reference that there was not a 100% match. Generally, most LGP communities identified as Towns could be linked, but other communities identified as having “Type” as “LSD” or “UNINC” could not be linked. It is surmised that these smaller communities are parceled in “Divisions” or “Unorganized CSD” as referenced in the censuses.

It was also determined that through the various census products some communities were removed or amalgamated. No effort was expended to rationalize this issue across the census data as this was beyond the scope of the current project.

Two elements of population were integrated into the prioritization process, namely absolute population and population growth.

A rapidly growing community has the potential to influence runoff potential through urbanization and may result in inhabitants being at flood risk. As such, the percentage increase in population at 2020, as projected (linearly) from the known census data and compared to the 2011 population from available census data, was used as the weighting factor for prioritization. If the percentage increase in population (as described above) was negative, which was the case for many communities, a prioritization factor of zero (“0”) was assigned.

The absolute 2011 census population of communities can be used to recognize the potential impact of flooding on a community and its infrastructure. The impacts of a similarly sized flood in a small community versus a large community will be different. It can be surmised that socio-economic damages resulting in the large community will be higher. As such, if all other factors are similar, and knowing that governments always face limited budgets, flood plain mapping should be completed for the large community in advance of the small community. As such, absolute population of a community as defined from the 2011 census was used as follows:

Weighting	Description
0	Communities with 2011 populations less than 500
1	Communities with 2011 populations between than 500 and 5000
2	Communities with 2011 populations greater than 5000

Table 4-3. Population Weighting

[26] http://www.stats.gov.nl.ca/

4.1.8 Flood History

Identification of flood occurrence by community was defined from the flood events inventory. A link was established between community name and flood occurrence and LGP number and flood occurrence. Upon review of the resultant data it was determined that an appropriate reflection of flood history is captured through the LGP number and flood occurrence association.

Prioritization weighting will be based on the number of flood events documented for a LGP number divided by 10.

4.1.9 Flood Damages Estimates

Flood damage estimates (reported damage and DFAA damage estimates) by community were defined from the flood events inventory. As noted in the flood inventory section of this report very little flood damage estimate data is available. As such, priority weighting was assigned simply as “1” if damage estimates (either) were available and “0” if neither were available.

4.1.10 Watershed Runoff Potential

Soils

The Soil Survey Reports for Newfoundland and Labrador available from Agriculture and Agri-Food Canada[27] formed the basis for identification of dominant soils in watersheds. The Drainage attribute (associated with the soils data) was interpreted as hydrologic soil classes (see Table 4-4). The areas associated with each hydrologic soil class were abstracted on a watershed basis, based on the National Frameworks Data, Hydrology and Drainage Areas, and the dominant soil class identified.

The prioritization weighting will reflect the dominant hydrologic soil group as follows

[27] Soils data references the Soil Survey Reports for Newfoundland and Labrador available from Agriculture and Agri-Food Canada from their website at http://sis.agr.gc.ca/cansis/publications/surveys/nf/index.html. The soil survey reports, while not extensive, is believed to be the best source of soil information available. See Figure 6-3 for a map of the soil data.

Drainage Attribute	Meaning	Hydrologic Soil Group
-	Not applicable	not applicable
VR	Very rapidly drained	A
R	Rapidly drained	A
W	Well drained	A
MW	Moderately well drained	B
I	Imperfectly drained	C
P	Poorly drained	D
VP	Very poorly drained	D

Table 4-4. Drainage Attribute to Hydrologic Soil Class Relationship

Weighting	Group	Description
0	A	Soils in this group have low runoff potential
1	B	Soils in this group have moderately low runoff potential
2	C	Soils in this group have moderately high runoff potential
3	D	Soils in this group have high runoff potential

Table 4-5. Dominant Hydrologic Soil Group Weighting

Drainage Density

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. Drainage density can also affect the shape of a river's hydrograph during a rain storm. Rivers that have a high drainage density will often have a more 'flashy' hydrograph with a steep falling limb. High densities can also indicate a greater flood risk.

The watersheds, for this assessment, were defined by the National Frameworks Data, Hydrology and Drainage Areas. These watersheds were used in conjunction with the NHN dataset to define stream density within a watershed.

This assessment identified drainage densities ranging from about 0.2 to 0.3. A review of literature focused on assessment of watershed response and drainage density provided no indication of what is considered a “high” drainage density vs. a “low” drainage density. As such, for the purposes of this prioritization effort the average computed drainage density of 0.26 was used as the dividing line between upper and lower categories. Drainage densities equal to or less than 0.26 were assigned a priority factor of “0” and those above the average were assigned “1”.

Watershed Slope

The slope attribute associated with the soils data were used to determine an approximate average slope across a watershed. In a manner similar to drainage density, higher average watershed slope can suggest both higher runoff rates and a more 'flashy' hydrograph.

The prioritization weighting will reflect the watershed slope as follows:

Weighting	Description
0	If the average slope is less than or equal to 5%
1	If the average slope is greater than 5% and less than or equal to 15%
2	if the average slope is greater than 15%

Table 4-6. Watershed Slope Weighting

Deforestation

Watershed runoff response will be influenced by changes in land cover as a result of community development. The change detection analysis completed as a component of the land classification analysis was used as the basis for this aspect of the assessment. The prioritization weighting was assigned as the combined “deforested to developed” plus “deforested to other” change detected.

Broader changes in land cover as a result of changing terrestrial communities due to climate change are addressed in Vasseur and Catto (2008). However, the sensitivity and vulnerability of forest communities in Atlantic Canada is considered to be low to moderate. Further, given that the Vasseur and Catto (2008) assessment of climate change influences on forest systems provided no specific guidance on regional variation of potential impacts across the Province, there was not any means of using this issue as a prioritization factor in the present assessment.

4.1.11 Watercourse Hydraulics

It was originally proposed to investigate potential changes to hydraulic response via co-analysis of a time series of (satellite) imagery available over a common location, interpretation of which might allow for identification of physical changes in the thalweg and banks of a watercourse indicative of channel forming flows during the periods between image acquisitions. This now commonly applied GIS methodology uses heads-up digitizing by a trained geomorphologist to delineate channel planform (active channel boundaries) as depicted and interpreted in a series of co-registered high resolution satellite images and/or aerial photographs. These are then overlaid in GIS to study recent channel change (e.g., 1980, 1990 and 2000) with the goal of capturing the impacts of at least one significant flood. Once recent river planform changes on the study reach have been identified, stable and unstable reaches can be defined allowing the determination of the degree and nature of instability, including watercourse changes and also quantification of active channel widths and gravel area, braiding indices, sinuosity and channel occupancy indices. Identification of meanders and related alternation of pool-riffle sequences controlling the local distribution of bank erosion can also enable construction of a channel migration zone (CMZ) hazard map. Using raster-based GIS techniques, these data can then be combined with measurements of distance from river channel and flood return periods, to create a model which enables spatial mapping of river bank erosion probabilities (probabilities that can then be mapped for hypothetical floods of, for example, 10 and 25 year recurrence interval).

In the initial stages of this analysis, however, three key reasons were identified why the above approach would not be practical for this study.

Firstly, this assessment was to be founded upon the satellite imagery that was acquired to support the land classification and change detection analysis which is also a component of this project. The initial investigation of the quality of available satellite data for the initial period (Earth Observation for Sustainable Development of Forests [EOSD] data which was generated from 30-meter Landsat satellite imagery from the year 2000) for this project indicated that the spatial resolution of the imagery would not support useful interpretation and delineation of most of the channels under scrutiny, i.e., the satellite imagery is too coarse to resolve subtle changes in the bank changes of quite narrow rivers. Use of aerial imagery may have improved the spatial resolution issue, but this approach was beyond the current project scope given the cost and effort involved to acquire and process the large number of images required to support analysis of even a single reach of watercourse.

Secondly, the geomorphologic context of many streams in the study is incised bedrock, meaning the importance of meandering is relatively insignificant compared to, for example, a dynamic gravel bed river in the Canadian Rockies.

Thirdly, we recognized that although this type of analysis might be worthwhile in a more detailed study (e.g., Phase II study), for this project the details obtainable using this approach would not be commensurate with the overall more general methodology developed for this prioritization analysis.

4.2 Prioritization Analysis

The overall results are summarized in an Excel spreadsheet based decision matrix outlining community ranking based on the prioritization parameters previously outlined. One additional consideration was integrated into the analysis at this stage, namely, the hierarchy of prioritization parameters. In other words, the concept that some of the parameters used for prioritization are more important for the analysis than others. In review of the parameters, some, such as number of flood events at a community or reported flood damages, are documented evidence of flood risk. On the other hand, some parameters, such as watershed deforestation or dominant soil hydrologic soil class, attempt to quantify the potential for community flood risk. This concept is important to consider in applying the parameters in the prioritization process.

The application of this concept led to the distinction between parameters outlined in Table 4-7.

All seven first order parameters, as well as all of the second order parameters, were applied for those communities where flood plain mapping is presently available. The first order parameters were applied for sorting of communities in the order presented in Table 4-7. The summation of the second order parameters was used for ranking.

First order parameters #2, #3, #4 and #6 and all of the second order parameters were applied for prioritization of communities which do not presently have flood plain mapping. The First order parameters noted above were applied for sorting of communities in the order presented in Table 4-7. Similar to above, the summation of the second order parameters was used for ranking.

The decision matrix was developed in such a way that allows for options assessment. That is, varying the application of the parameters to yield alternate prioritization patterns.

The application of the prioritization data and methods described above yields the following ranking of communities; for communities with flood plain mapping presently (see Table 4-8) and for communities (the first twenty) without flood plain mapping presently (see Table 4-9). The complete prioritization list of communities without flood plain mapping is provided in Appendix A - Prioritization of Communities for New Flood Plain Mapping.

As can be seen in Table 4-9, St. John's is identified as a priority community for new flood plain mapping. This is primarily due to the number of recorded flood events recorded for St. John's LGP number in the Flood Events Inventory. It is clear that the municipality of St. John's covers a large area and numerous smaller communities exist within St. John's, some of which already have flood plain mapping. The prioritization data and methods employed for this study are not suited to review of individual unique areas within a municipality, only the municipality as a whole. In order to prioritize individual areas within the municipality of St. John's for new flood plain mapping, a review of individual flood circumstances should be initiated by WRMD.

1st Order Parameters	Age of Study
	Entry in Flood Events Inventory
	Flood Damages Estimates
	2011 Community Population
	Software
	Change in Watershed Forestation
	Community Location
2nd Order Parameters	Dominant Soil Group
	Average Slope
	Drainage Density
	Climate Change - Precipitation
	Climate Change - Hurricanes & Tropical Storms
	Community Population Growth

Table 4-7. Prioritization Parameters Hierarchy

Deer Lake
Placentia
Codroy
Steady Brook
Rushoon
Mount Pearl
Cox's Cove
Badger
Glovertown
Stephenville Crossing
Parson's Pond
Bishop's Falls
Appleton
Glenwood
Black Duck Siding
Rushy Pond
Ferryland
Carbonear
Victoria
Portugal Cove-St. Philip’s
Trout River
Cold Brook
Hant's Harbour
Brigus
Whitbourne
Winterton
Logy Bay-Middle Cove-Outer Cove
Kippens
Salmon Cove
Hickman's Harbour
Hodge's Cove
Heart's Delight-Islington
Shoal Harbour
Corner Brook
Stephenville
Petty Harbour
Goulds

Table 4-8. Prioritization of Communities for Updating of Existing Flood Plain Mapping

St. John's
Noels Pond
Burin
Clarke's Beach
Grand Falls-Windsor
Marystown
Bay Roberts
Gander
Black Duck
Middle Arm
Grand Bank
Gambo
King's Point
Conception Bay South
Lawn
Trepassey
Epworth-Great Salmonier
Point Au Gaul
Lamaline
Long Harbour-Mount Arlington Heights

Table 4-9. Prioritization of Communities for New Flood Plain Mapping. The first twenty communities only in this table, see Appendix A for a complete list

4.3 Recommendations for Assessing the Need for New / Updated Flood Risk Mapping

1. It is recommended that the WRMD encourage alignment between databases that reference communities in the Province. An example would be alignment between the LGP database and those maintained by Statistics Canada which track census information.
2. It is recommended that the WRMD maintain/update the decision matrix when new information becomes available which has founded the prioritization of communities for updated or new flood plain mapping.

5. Task E – Assess Need for Flood Forecasting / Flood Warning System

The objective of this task is to identify communities vulnerable to flooding that should be considered for flood forecasting and/or flood warning systems. The task was completed through a review of historical flood observations (i.e., the Flood Events Inventory) and existing flood hazard and risk maps, combined with ancillary data on precipitation, topography, lifelines (roads, bridges, etc.), and with census information on population densities, types, and fluxes.

Please note for Task E the names used for communities and areas are a combination of those that were in place when the FRM studies were done in the 1980s and 1990s and those reflected by the new LGP numbers due to a need to use data from both old FRM studies and the LGP list.

5.1 Data Sources

For this identification of vulnerabilities, AMEC relied upon the following data sets:

- Updated Flood Events Inventory, as produced for section 0 of this report.
- Newfoundland and Labrador, Department of Environment and Conservation Flood Studies website (Department of Environment and Conservation, 2012) and the documents contained within, including:
  - Community Flood Risk Public Information Maps
  - Various hydrotechnical and flood studies for the available communities
- 1992 Water Resources Atlas of Newfoundland (Water Resources Division, 1992)
- ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) digital terrain data, available at a 20m ground sampling distance (USGS, 2012)
- National Hydro Network hydrography data from the GeoBase initiative, overseen by the Canadian Council on Geomatics (Canadian Council, March 15, 2012)
- National Road Network road data from the GeoBase initiative, overseen by the Canadian Council on Geomatics (Canadian Council, March 2, 2012)
- Approved watersheds geodatabase (TA1112733_Watersheds_Dec2011.gdb)
- Hurricane and tropical storm track data from Unisys Weather (Unisys Weather, 2011)
- Bing Maps Aerial Imagery Layer (ArcGIS, 2010)
- Statistics Canada 2011 census data (Statistics Canada, 2012)

5.2 Methods

The methodology used for this study generally consisted of identifying vulnerable communities and subsequently assessing their susceptibility to direct and indirect effects of flooding. First, potentially vulnerable communities were identified by reviewing the event frequency and damage estimates contained in the updated Flood Events Inventory. After communities were identified, the physical hazard for each community was assessed. The next step was to determine each community's vulnerability to the direct effects of flooding (e.g., inundation). Third, potential indirect effects, such as isolation, were assessed for each of the identified communities. Finally, the results of each of the above steps are summarised in a decision table, highlighting those communities most vulnerable to flooding.

5.3 Identify key communities from the Flood Events Inventory

The flood events Inventory presents a recent (1950 to present) history of flooding in Newfoundland and Labrador. Communities were initially ranked based on the number of recorded events, which ranged from just one event to 73 (for the city of St John's). As a starting point, those communities registering five or more events were initially included (Table 5-1).

Community	Number of Events	Community	Number of Events
St. John's	73	Gander	5
Corner Brook	42	Grand Bank	5
Stephenville	27	Grand Falls	5
Deer Lake	16	King's Point	5
Placentia	12	Marystown	5
Ferryland	7	Middle Arm	5
Noel's Pond	7	Mount Pearl	5
Codroy Valley	6	Maddox Cove	5
Goulds	6	Rushoon	5
Carbonear	5	Steady Brook	5
Gambo	5		

Table 5-1. Communities registering 5 or more flood events

The next step was to supplement the above with the damage estimate data. As noted in the updated Flood Events Inventory (produced for section 0 of this report), damage estimate data is not provided for all flood events, and most entries lack Disaster Financial Assistance

Arrangements (DFAA) numbers. Numbers from the DFAA were also included (Table 5-3). A particular challenge in using the damage numbers is that they represent total storm damage across all affected communities. For example, The DFAA damage estimate for Hurricane Igor of $73M is for 93 separate communities spread out over southern and eastern Newfoundland. Applying that damage estimate evenly over the identified communities, even at a per capita scale, fails to capture the spatial variability of storm damage. As such, those damage estimates could not be used. Ultimately, only those damage estimates for singular communities were considered, adding those communities to the list to be included for the physical, direct vulnerability and indirect vulnerability analyses.

Finally, those communities reporting (in the Flood events Inventory) isolated portions of the population as a result of flooding were identified and included in the final list of key communities. These communities are Codroy Valley, Cold Brook, Corner Brook, Mooring Cove, New-wes-valley, Port Blandford, and St. John's. Results are presented in section 5.5.1.

DFAA Damage Estimates				
Storm#	**Location**	**# Communities**	**TYPE**	**DFAA Damage**
283	Southern and Eastern Newfoundland	93	Rainfall (Igor)	$72,730,852
220	Stephenville area	11	Rainfall	$28,283,786
183	St. Johns	1	Rainfall	$6,083,243
239	Western Avalon Peninsula	33	Rainfall	$24,522

Table 5-2. Disaster Financial Assistance Arrangements values (as provided to AMEC by WRMD)

Reported Event Damages				
Storm#	Location	# Communities	TYPE	Damage (#)
283	Southern and Eastern Newfoundland	93	Rainfall (Igor)	$100,000,000
121	Bishop Falls, Stephenville, Deer Lake	3	Rain and Snowmelt	$34,000,000
220	Stephenville area	11	Rainfall	$10,000,000
183	St. Johns	1	Rainfall	$6,700,000
239	Western Avalon Peninsula	33	Rainfall	$5,000,000
096	Codroy Valley	4	Ice Jam	$4,000,000
127	Placentia	1	Coastal	$3,000,000
166	Hermitage-Sandyville	1	Dam Break	$3,000,000
237	Rocky Harbour	1	Coastal	$3,000,000
193	Badger	1	Ice Jam	$2,630,000
164	Burin Peninsula	6	Coastal	$2,200,000
216	Flatrock to Bonavista	10	Storm Surge	$2,000,000
195	West Coast	5	Rain and Snowmelt	$1,400,000
169	Central Newfoundland - Baie Verte Peninsula	9	Rainfall	$1,250,000
239	Placentia	1	Rainfall	$1,000,000
249	Belleoram	1	Rainfall	$1,000,000
237	Daniels Harbour	1	Coastal	$538,000

Table 5-3. Communities with damage estimates from the Flood Events Inventory

5.4 Review and Assess Physical Hazard

The term flood is used to generalize all types of water inundation events, but it is important to understand the causes of flooding present in individual watersheds. The Flood Events Inventory, Water Resources Atlas of Newfoundland, community flood risk maps (where available), and ancillary GIS (Geographic Information Systems) data were analyzed in order to determine the prevalent source of flooding for identified key communities. For example, Badger is an inland town located in northern-central Newfoundland at the convergence of the Exploits River with two smaller streams. The Flood Events Inventory indicates that the majority of floods at Badger take place in the winter and are the results of ice jams, with no recorded events during ice-free seasons (Dept. of Environment and Conservation, 2012). Whereas many Newfoundland towns are located in smaller coastal watersheds, Badger sits in a terrestrial watershed drained by the Exploits River, that covers much of inland Newfoundland (Figure 5-1). According to the Department of Environment and Conservation (Dept., 2011), the town of

Badger, as well as the Exploits River watershed, has an extensive and elaborate flood forecasting and early warning system in place.

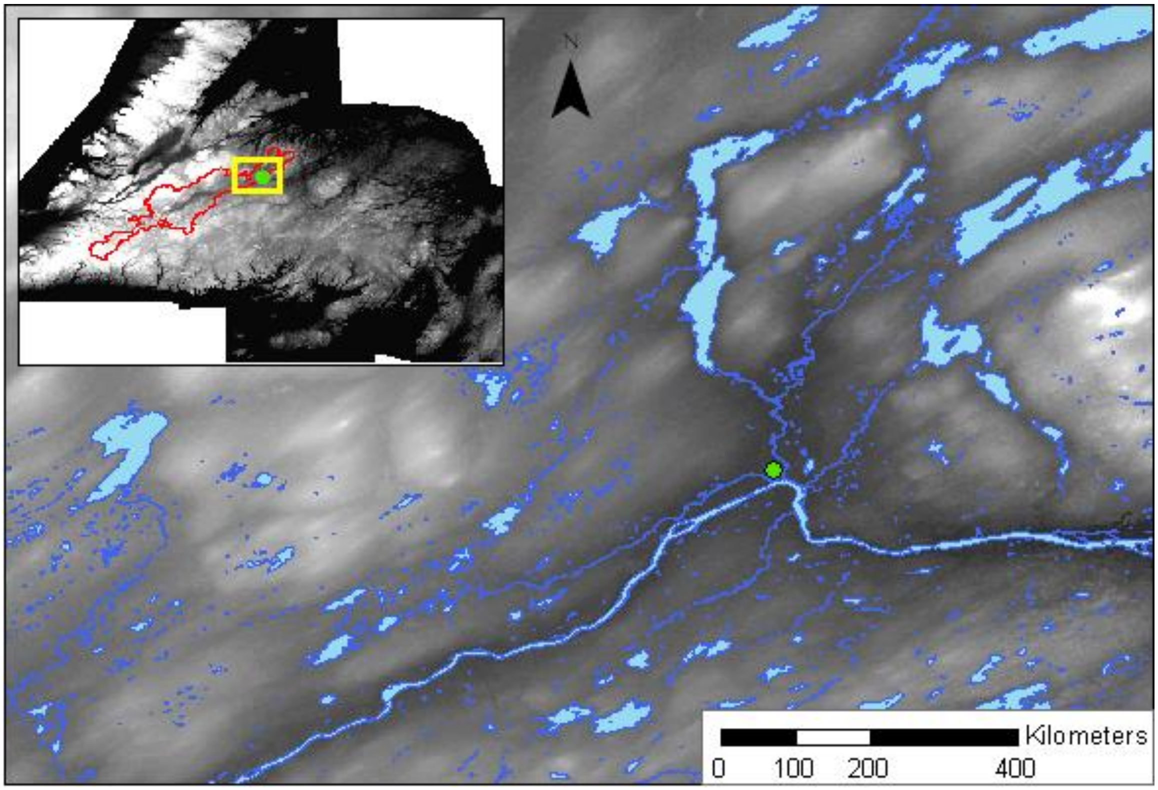


Figure 5-1. Badger (Green dot) shown with surrounding terrain and hydrography. Inset shows the Badger watershed in red, the town of Badger in green, and the map extent in yellow, overlain onto the ASTER DEM.

In contrast to Badger, Carbonear is located in a smaller coastal watershed on the Avalon Peninsula, on the western shore of Conception bay. According to the Flood Events Inventory it experiences floods during all four seasons, as a result of ice jams, rainfall, coastal storm surges, and snowmelt. This watershed is clearly vulnerable to flooding. Because of its relatively small size and coastal location, a flood early warning system composed of meteorological forecasts and a tidal warning system might be recommended.

The process described above was carried out for each of the identified key communities. Results are presented in Section 5.5.2.

Given the reported damages resulting from tropical storms and hurricanes (e.g., Igor), the Flood Events inventory was searched for mentions of floods resulting from these severe storms (Table 5-4). Storm track data (Unisys Weather, 2011) for each recorded event was imported into a GIS. Unfortunately, data for the October, 1955 event is not available. Storm tracks from 2000 through 2011 were examined, and data from those events with tracks near Newfoundland were brought into a GIS. Over the 12 year period, 30 total storm tracks were examined. Figure 5-3 uses 2010 as an example, showing storm tracks for hurricanes Earl and Igor. In the figure, Igor tracks along the eastern shore of Newfoundland, while Earl tracks along the western shore, continuing up into eastern Labrador. An examination of the storm tracks alone does not provide much new information, only highlighting the vulnerability of western, southern, and eastern shores to direct hurricane and tropical storm forces.

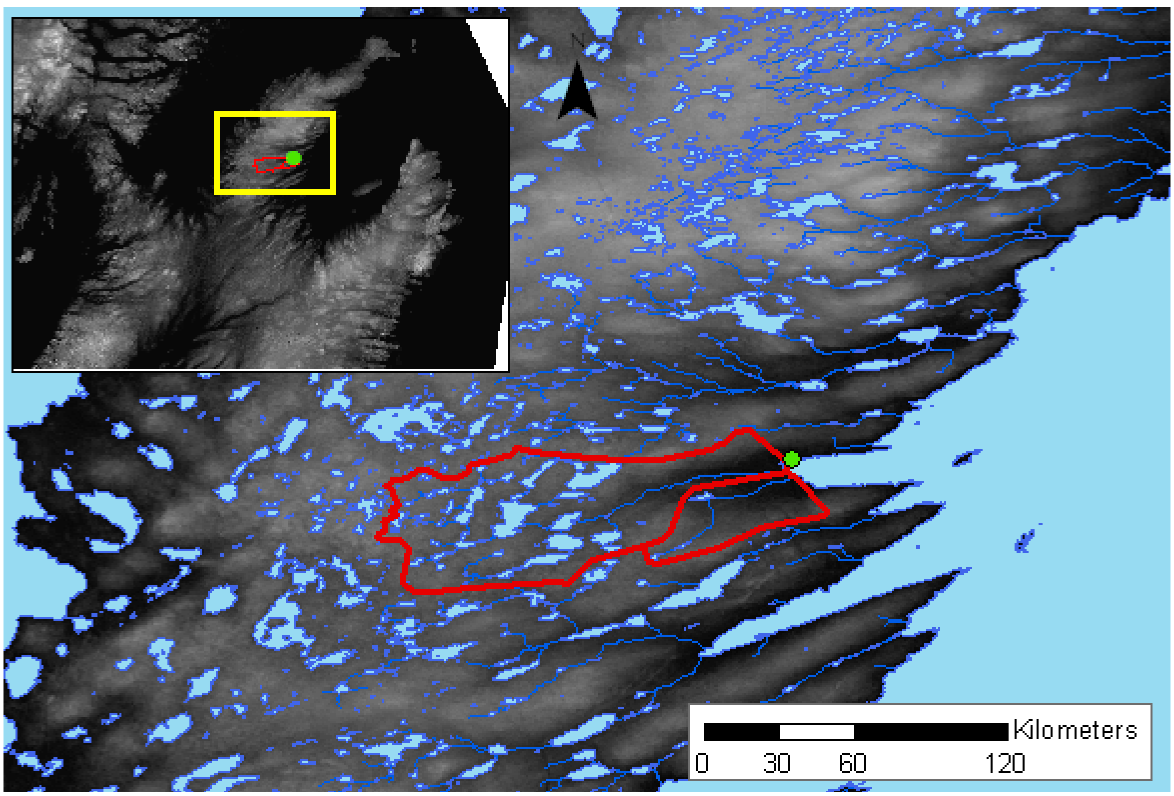


Figure 5-2.Carbonear (green dot) displayed with surrounding terrain, hydrography and watershed (red). Inset map shows location on Avalon Peninsula, with the map extent in yellow, watershed in red and town in green, overlain onto ASTER DEM.

Storm	Impacted Area	Date	Number of Communities	Storm Name
18	East Coast	October-55	3	*nameless*
164	Burin Peninsula	September-95	5	Luis
175	South Coast	September-99	2	Gert
211	Rocky Harbour	September-04	1	Frances
249	South Coast	September-08	2	Gustav
255	St John's	September-01	1	Gabrielle
283	Southern and Eastern Newfoundland	September-10	93	Igor
169	Central NF - Baie Verte Peninsula	September-98	9	Earl
189	Western Newfoundland	September-02	2	Gustav
210	Eastern, Central, Southern Shore	September-04	5	Ivan
234	South Coast	September-06	12	Florence
256	Gander	August-09	1	Bill
257	Gander	August-09	1	Danny

Table 5-4. Tropical Storms and hurricanes recorded in the Flood Events Inventory. Point data was not available for the unnamed October, 1955 event.

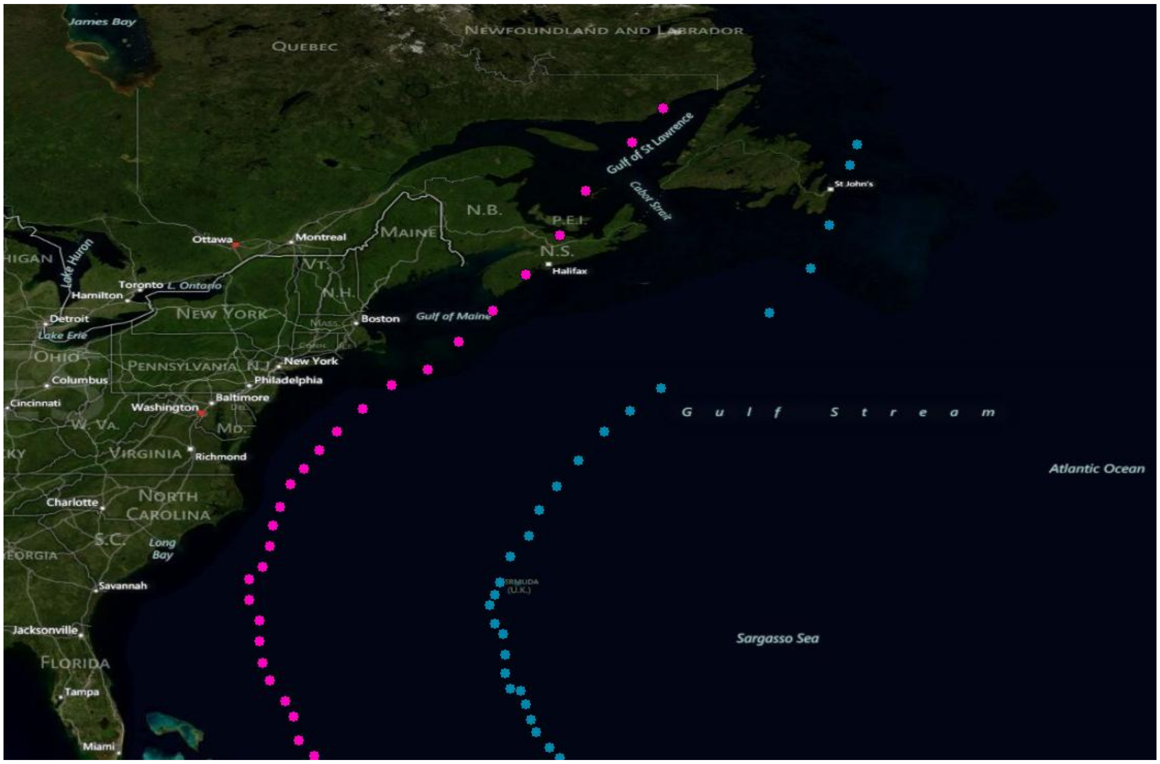


Figure 5-3. Storm tracks for select 2010 hurricanes (Unisys Weather, 2011). Igor is shown in blue and Earl is shown in pink.

5.4.1 Community Vulnerability to Direct Impacts of Flooding

Direct impacts are defined as damages to life, property, employment, and critical facilities resulting from inundation by flood waters. In order to assess the impacts to personal injury or life, Canadian census data (Statistics Canada, 2012) were obtained and mapped in a GIS. Given the lack of infrastructure and property data in a usable spatial format, the Flood Events Inventory and community flood risk maps were examined for instances of flooded and/or damaged infrastructure. Additionally, ancillary GIS data such as terrain, imagery, and roads (Canadian Council, March 2, 2012) were analysed.

For example, Petty Harbour-Maddox Cove is located along the eastern coast of the Avalon Peninsula, south of St. John's (Figure 5-4). The Flood Events Inventory contains reports of damaged wharves, flooded basements, and a flooded senior citizens home. In examination of the area in the GIS, we see that much of the community infrastructure is located along the harbour, but the flood risk map (Dept. of Energy and Conservation, 2012) shows relatively few resources in the 1:20 year flood zone.

This process was carried out for each identified key community, utilizing available data. Results are presented in section 5.5.3.

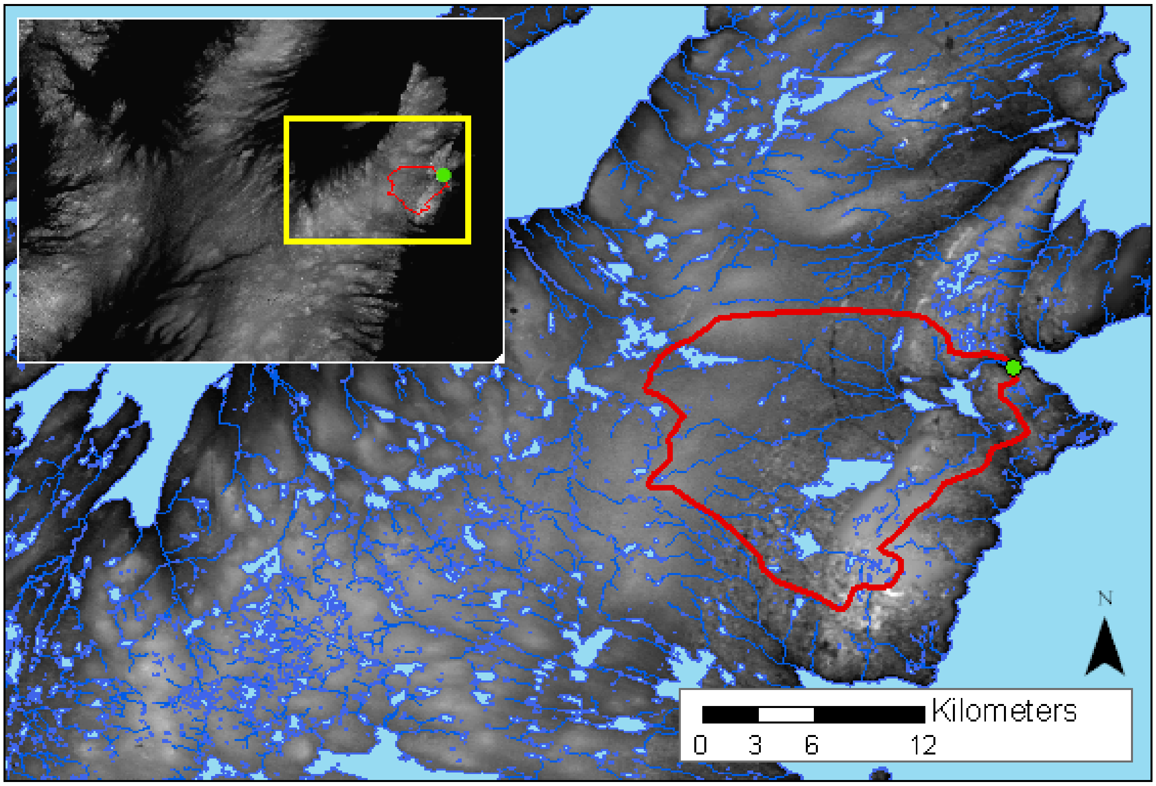


Figure 5-4. Petty Harbour- Maddox Cove (green dot) shown with surrounding terrain, hydrography and watershed (red). Inset map shows location on Avalon Peninsula, with the map extent in yellow, watershed in red and town in green, overlain onto ASTER DEM.

5.4.2 Community Vulnerability to Indirect Flooding Impacts and Isolation

Newfoundland exhibits a relatively complex geography, full of peninsulas and constrictions, which limit the placement and options for evacuation routes. As such, persistent, large floods can have an isolating effect, as seen in numerous entries in the Flood Events Inventory. In order to assess vulnerability to isolation, the physical setting, road location and distribution, and population size were evaluated.

The physical setting of each of the key communities was analyzed in a GIS. ASTER terrain data (USGS, 2012), imagery, and the GeoBase National Roads and Hydro Networks were combined in order to assess each community's level of isolation. The terrain was examined for natural constrictions. The number and location of evacuation and connection options for each community was noted. Potential evacuation and connection routes were examined for low spots (i.e., those areas likely to be inundated during a flood event) and stream or water body crossings. Additionally, notes from the Flood Events Inventory were examined for records of historic isolation and/or road damage. Population sizes were also noted to get a sense of how many people could possibly be isolated.

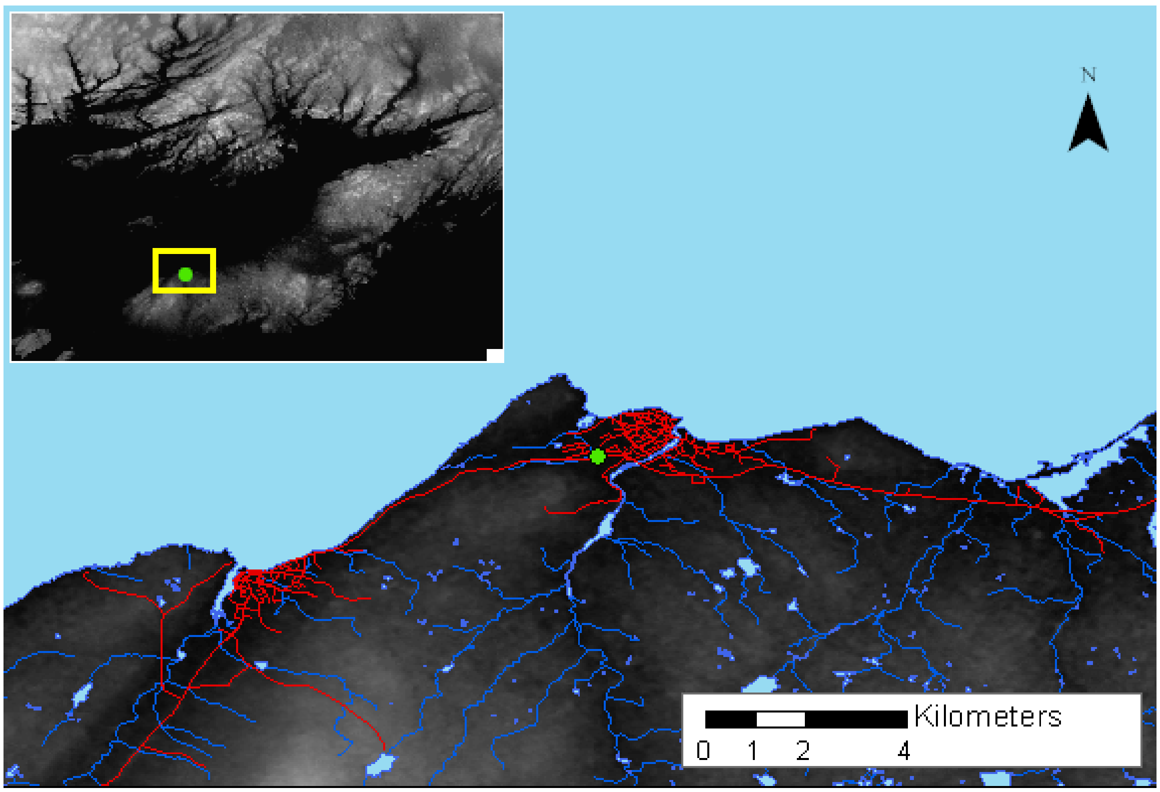


Figure 5-5. Grand Bank (green dot) shown with surrounding terrain, hydrography and roads (red). Inset map shows location on Avalon Peninsula, with the map extent in yellow and town in green, overlain onto the ASTER DEM.

For example, Grand Bank is a small coastal town (Pop. 2415) located on the Burin Peninsula (Figure 5-5). The town appears to have one main road leaving in either direction along the coast. The road leading to the nearby services in the larger town of Marystown crosses several streams. There does not appear to be any evacuation options leading to higher ground.

5.5 Results

5.5.1 Identified key communities

Table 5-5 presents a list of identified key communities. These are the communities identified from the flood events inventory as having five or more recorded flood events, estimates of damage cost for a singular community, and/or reports of isolation in the Flood Events Inventory. The *Reports of Isolated Residents* field in Table 5-5 notes the presence or absence of reports of isolated residents in the available sources of information (e.g., the flood events inventory, flood risk maps) for each community.

Community	Number of Events	Damage Estimate	Reports of Isolated Residents
Badger	4	Yes	No
Belleoram	3	Yes	No
Carbonear	5	No	No
Codroy Valley	6	No	Yes
Cold Brook	3	No	Yes
Corner Brook	42	No	Yes
Daniels Harbour	1	Yes	No
Deer Lake	16	No	No
Ferryland	7	No	No
Gambo	5	No	No
Gander	5	No	No
Grand Bank	5	No	No
Grand Falls	5	No	No
Goulds	6	No	No
Hermitage-Sandyville	2	Yes	No
King's Point	5	No	Yes
Maddox Cove	5	No	No
Marystown	6	No	Yes
Middle Arm	5	No	No
Mount Pearl	5	No	No
New-wes-valley	1	No	Yes
Placentia	12	Yes	No
Port Blandford	1	No	Yes
Rocky Harbour	3	Yes	No
Rushoon	5	No	No
St. John's	79	Yes	Yes
Steady Brook	5	No	No
Stephenville	34	No	No

Table 5-5. Identified key communities. Mooring Cove is included with Marystown, and Noel's Pond is included with Stephenville.

5.5.2 Community Exposure to Physical Hazard

Table 5-6 presents the physical hazard ranking for each identified community.

Community	Flood Risk Map	Causes	Number of Events	Rating
Badger	Yes	Ice jams, snowmelt	4	2
Belleoram	No	Rainfall, storm surge	3	1
Carbonear	Yes	Ice jams, costal, rainfall, snowmelt	5	2
Codroy Valley	Yes	Rainfall, snowmelt, Ice jams	6	2
Cold Brook	Yes	Rainfall, snowmelt, ice jams	3	0
Corner Brook	No	Rainfall, snowmelt, ice jams	42	3
Daniels Harbour	No	Coastal	1	0
Deer Lake	Yes	Rainfall, snowmelt, ice jams	16	3
Ferryland	Yes	Coastal	7	1
Gambo	No	Rainfall, snowmelt	5	0
Gander	No	Rainfall	5	1
Grand Bank	No	Rainfall, Ice jams, coastal	5	1
Grand Falls	No	Rainfall, snowmelt	5	1
Goulds	Yes	Rainfall, snowmelt, ice jams	6	2
Hermitage-Sandyville	No	Rainfall, dam break	2	0
King's Point	No	Rainfall, snowmelt	5	1
Maddox Cove	Yes	Rainfall, snowmelt, coastal	5	1
Marystown	No	Rainfall, coastal, ice jams	5	1
Middle Arm	No	Rainfall, coastal	5	1
Mount Pearl	No	Rainfall, snowmelt	5	1
New-wes-valley	No	Coastal	1	0
Placentia	Yes	Coastal	12	1
Port Blandford	No	Coastal	1	0
Rocky Harbour	No	Rainfall, coastal	3	0
Rushoon	Yes	Ice Jam, coastal	5	1
St. John's	No	Ice jams, costal, rainfall, snowmelt	79	3
Steady Brook	Yes	Rainfall, snowmelt, Ice jams	5	1
Stephenville	Yes	Rainfall, snowmelt, Ice jams	34	3

Table 5-6. Physical hazard ranking results.

Watersheds were numerically classified on a 0 – 3 scale, based on the severity of their exposure to various flood hazards. For example, a coastal watershed that has experienced terrestrial flooding of significant extent and frequency might be classified as a 1 (moderate) or 2 (high) Physical Hazard, whereas a watershed that experiences floods resulting from terrestrial flooding where ice has exacerbated the impacts, and that also experiences storm surge from Hurricanes, would be classified as 3 (extreme). Guidelines for the classifications are as follows:

Weighting	Description
0	Relatively few instances of flooding
1	Moderately lower frequency events from one source
2	Moderately higher frequency events from one or two sources
3	Community exposed to multiple sources of flooding with relatively frequent recurrence

Table 5-7. Physical Hazard Weighting

5.5.3 Community Vulnerability to Direct Impacts of Flooding

Once the spatial data was accumulated and incorporated into a GIS, the vulnerability of each of the communities was assessed (Table 5-8).

Community	Number of Events	2011 Population	Rank
Badger	4	793	1
Belleoram	3	409	0
Carbonear	5	4739	2
Codroy Valley	6	N/A	1
Cold Brook	3	N/A	0
Corner Brook	42	19886	3
Daniels Harbour	1	265	1
Deer Lake	16	4995	2
Ferryland	7	465	0
Gambo	5	1984	1
Gander	5	11054	3
Grand Bank	5	2415	1
Grand Falls	5	13725	1
Goulds	6	N/A	0
Hermitage-Sandyville	2	450	1
King's Point	5	675	1
Petty Harbour/Maddox Cove	5	924	1
Marystown	6	5506	3
Middle Arm	5	476	2
Mount Pearl	5	24284	3
New-wes-valley	1	2265	1
Placentia	12	3643	2
Port Blandford	1	483	0
Rocky Harbour	3	979	1
Rushoon	5	288	0
St. John's	79	106172	3
Steady Brook	5	408	1
Stephenville	34	6719	3

Table 5-8. Rankings of vulnerability to direct impacts to flooding. Census data for the Codroy Valley, Cold Brook, and Goulds could not be obtained.

Using the available data sources, ranking decisions regarding the direct impacts of flooding were based on which communities have the most value (people, property, business, and critical services) exposed to the highest number of events. For example, communities with higher population densities, containing critical infrastructure (e.g., a hospital) that service a surrounding hinterland will be ranked higher than communities with smaller populations. For consistency, a similar 0 – 3 scale was used, defined by the following guidelines:

Weighting	Description
0	Relatively few resources at risk
1	Moderately low amount of resources at risk to flood damage
2	Moderately high amount of resources at risk to flood damage
3	Relatively large populations and/or critical infrastructure located in flood zone with a history of costly flood damages

Table 5-9. Vulnerability to Direct Impact to Flooding Weighting

5.5.4 Community Vulnerability to Indirect Flooding Impacts or Isolation

Communities were ranked based on physical confinement (as determined by the DEM) and the presence or absence of access routes into and out of the community noted (Table 5-10).

Community	Access Notes	Confinement	Isolation Report	Ranking
Badger	Multiple access routes all cross waterways near town	Unconfined	No	1
Belleoram	Isolated, coastal town; roads along coast	High	No	3
Carbonear	Coastal valley with many access routes	Low	No	1
Codroy Valley	River crosses main access road in several locations	Moderate	Yes	3
Cold Brook	River crosses access road in several locations	Moderate	Yes	3
Corner Brook	Several other rivers flow into area, main access roads cross rivers; few options	Moderate	Yes	2
Daniel's Harbour	Coastal town with main n-s road, but appear to be alternative access options	Unconfined	No	1
Deer Lake	Many roads, but many cut by streams	Low	No	1
Ferryland	Several access routes; only n-s roads along coast	Low	No	2
Gambo	Several access routes along coast and upland; water a factor with each route	Unconfined	No	0
Gander	Many roads along Gander River, into upland	Unconfined	No	0
Grand Bank	Main coastal road cut by waterways in both directions; no upland options	Moderate	No	3
Grand Falls	Many alternatives, several cut by rivers, especially on south side of Exploits	Unconfined	No	1
Goulds	No access issues	Unconfined	No	0
Hermitage-Sandyville	Singular highway located on peninsula high point; crosses many water bodies	Confined	No	3
King's Point	Few access roads cross small streams	Low	Yes	2
Petty-Harbour/ Maddox Cove	Few access routes; small stream crossing	Moderate	No	1
Marystown	Many roads but most in low-lying areas or	Low	Yes	3

Community	Access Notes	Confinement	Isolation Report	Ranking
	cross rivers			
Middle Arm	Small coastal town; limited access all along water	Moderate	No	2
Mount Pearl	Many options	Unconfined	No	0
New-wes-valley	Coastal access ways; few low spots	Low	Yes	2
Placentia	Access roads cut by rivers, cutting off access to hospital	Moderate	No	3
Port Blandford	Several access options	Low	Yes	2
Rocky Harbour	Few access options crossing several low spots and streams	Confined	No	3
Rushoon	Singular access cut by river	Confined	No	3
St. John's	Many access options	Low	Yes	2
Steady Brook	Alternative access crosses stream	Confined	No	3
Stephenville	Many road options, many cross water	Low	No	1

Table 5-10. Ranking for vulnerability to indirect effects of flooding

It was also noted whether or not roads crossed streams or other water bodies. Potential isolation results in an increase to a community's vulnerability ranking. The rankings were defined as follows:

Weighting	Description
0	Relatively unconfined with multiple access options
1	Moderately low confinement with access options
2	Moderately high confinement or limited access options
3	Confined communities with exposed access option(s)

Table 5-11. Vulnerability to Indirect Flooding Impact Weighting

5.6 Results of Assessment and Conclusion

The physical hazard, direct vulnerability, and indirect vulnerability rankings are presented in Table 5-12. These relative rankings can then be used to group communities into priority levels, based on how the community ranked in each category. This is represented by the color coding provided in the community column of Table 5-12 and Figure 5-6.

Community	Physical Hazard Ranking	Direct Vulnerability Ranking	Indirect Vulnerability Ranking
Badger	2	1	1
Belleoram	1	0	3
Carbonear	2	2	1
Codroy Valley	2	1	3
Cold Brook	0	0	3
Corner Brook	3	3	2
Daniels Harbour	0	1	1
Deer Lake	3	2	1
Ferryland	1	0	2
Gambo	0	1	0
Gander	1	3	0
Grand Bank	1	1	3
Grand Falls	1	1	1
Goulds	2	0	0
Hermitage-Sandyville	0	1	3
King's Point	1	1	2
Petty-Harbour/ Maddox Cove	1	1	1
Marystown	1	3	3
Middle Arm	1	2	2
Mount Pearl	1	3	0
New-wes-valley	0	1	2
Placentia	1	2	3
Port Blandford	0	0	2
Rocky Harbour	0	1	3
Rushoon	1	0	3
St. John's	3	3	2
Steady Brook	1	1	3
Stephenville	3	3	1

Table 5-12. Physical hazard, direct and indirect vulnerability rankings for identified key communities. Communities are coloured by a suggested level of priority, with red being the highest priority, yellow representing medium, and green being lowest priority.

These priority levels can then be used to determine towards which communities further study and funding should be directed. Those communities that should receive the highest priority include Corner Brook, Marystown, Placentia, Codroy Valley, St. John's, Deer Lake and Stephenville. These are the communities identified as being most vulnerable with the greatest need for flood forecasting and/or flood warning systems. Corner Brook, St. John's, and Stephenville represent three major population centers on the island of Newfoundland. Corner

Brook and Deer Lake are both located in Humber River Watershed, from which future forecasting systems can benefit from past forecasting efforts implemented by the Department of Environment and Conservation, as discussed in Tom(2010). Tom(2010) provides recommendations for future forecasting efforts in the Humber watershed, including moving from numerical to physics-based hydrology models, installing snow surveys to facilitate the use of remotely-sensed snow cover data, and extending the methods to the Exploits River watershed. Placentia and Marystown are both located on the coast of Placentia Bay. These two towns, along with St. John's, Codroy, and Stephenville are those towns lying directly in hurricane storm tracks.

Those communities representing a medium priority include Badger, Belleoram, Carbonear, Gander, Grand Bank, Hermitage-Sandyville, King's Point, Middle Arm, Mount Pearl, Rocky Harbour, Rushoon, and Steady Brook. Some of these communities fall within the same watersheds as communities included in the high priority grouping. Mount Pearl is located in the same watershed as St. John's, while Steady Brook is located in the Humber River Watershed. A number of these communities (Hermitage-Sandyville, Grand Bank, Belleoram, Rushoon, Middle Arm, and Carbonear) were in the direct path of past hurricane tracks. Rocky Harbour may be vulnerable to those storms tracking west of the island. Badger lies in the Exploits River watershed, which appears to already benefit from a significant forecasting effort (Dept., 2011).

Communities with the lowest priority are Cold Brook, Daniel's Harbour, Ferryland, Gambo, Grand Falls, Goulds, Petty Harbour-Maddox Cove, New-wes-valley, and Port Blandford. Of these lowest priority communities, Daniel's Harbour, New-wes-valley, and Ferryland lie in past hurricane storm tracks. Cold Brook would benefit from any forecasting or warning efforts initiated for Stephenville.

To conclude, additional efforts should be first focused on those communities identified in the high priority group. More detailed spatial information is needed to determine exactly what resources (e.g., critical infrastructure) are at risk in each community's watershed, for a given flood event. The collection of community plot and parcel data, identification of specific damage estimates, and mapping of critical infrastructure would greatly facilitate vulnerability studies for Newfoundland and Labrador. This information, combined with efforts to model flow inundation levels and hydraulics would not only help determine vulnerabilities, it would also guide the selection of the most appropriate flood forecasting and/or warning system. Newfoundland seems to have relatively sophisticated forecasting efforts in place for two terrestrial watersheds (Humber and Exploits Rivers) covering large portions of the island, as well as many of the communities identified as vulnerable for this study. However, Newfoundland also has many coastal communities, located in smaller coastal watersheds, subject to flashier flood regimes. If not already in place, these watersheds will likely benefit more from a combination of meteorological forecasts and coastal flood warning systems (see USGS, 2011 for an example).

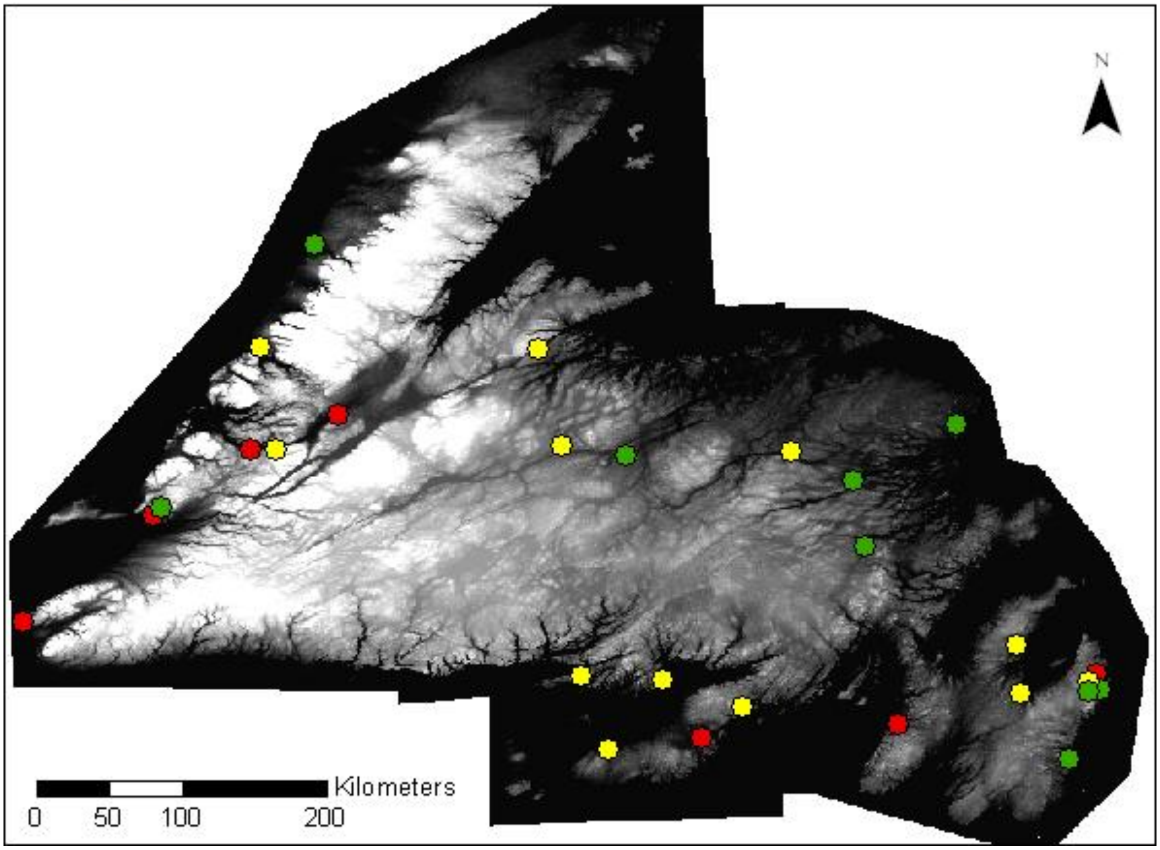


Figure 5-6. Spatial distribution of identified key communities. They are color-coded to match their respective priority groups.

5.7 Recommendations for Assessing the Need for Flood Forecasting / Flood

Warning Systems

1. It is recommended that WRMD expend additional efforts focused on those communities identified in the high priority group towards specific identification of risk in each community's watershed, for a given flood event. This effort would benefit from the acquisition of additional detailed spatial information to determine exactly what resources (e.g., critical infrastructure) are at risk in each community's watershed, for a given flood event. The collection of community plan and parcel data, identification of specific damage estimates and/or flood damages modeling, and mapping of critical infrastructure would greatly facilitate vulnerability studies for Newfoundland and Labrador. This information, combined with efforts to model flood inundation levels and hydraulics would not only help determine vulnerabilities, it would also guide the selection of the most appropriate flood forecasting and/or warning system.

2. It is recommended that the WRMD conduct a thorough performance review of the forecasting systems in place for the Humber and Exploits River basins. The main goals of this exercise being the identification of extendable information or approaches to other Newfoundland and Labrador watersheds, as well as the identification of data gaps in the current forecasting systems that could be filled with additional resources.

3. It is recommended that the WRMD maintain/update the decision matrix when new information becomes available which has founded the prioritization of communities that could benefit from a Flood Forecasting / Flood Warning System.

6. Task F – Identify Flood Vulnerability Mitigation and Adaptation Strategies

There are 529 communities identified in Newfoundland and Labrador, each designated with a Local Government Profile number. A list of these communities is included as Appendix A - Prioritization of Communities for New Flood Plain Mapping of this report. This list of communities is sorted based on the determined prioritization for updates to the communities existing flood plain maps. In addition to flood plain mapping updates, there is a suite of flood mitigation measures that Provincial government officials and the decision makers should consider for adoption to most effectively serve and protect population, property, and infrastructure. It is recommended that every community across the Province, including those not designated as a high priority for map updates, implement an active process, at a level appropriate to their issues and needs, to develop, renew and update local flood mitigation mechanisms, as a result of land use, watershed conditions, and climate change effects. The goal of these mitigation and adaptation strategies is to reduce the risk to life and property from current flooding vulnerabilities, as well as those projected to occur.

Communities throughout Newfoundland were grouped based on their generally common physiographic characteristics, and then each group's general flood vulnerability was evaluated, based upon watershed characteristics, climate change factors, and socio-economic factors, to make recommendations of applicable potential flood mitigation strategies for each grouping. The Provincial government, along with individual communities, should evaluate the applicability of each of the strategies recommended for each grouping, followed by an assessment of implementation costs and associated benefits to the community. The strategies suggested in this section could be then used as the basis for a community's overall Flood Mitigation & Adaptation Program.

Communities in Labrador have not been included in this identification of flood mitigation and adaptation strategies. This is because there have been few reported instances of property damage due to flooding in Labrador. This does not preclude application of the general flood mitigation and adaptation themes discussed in this section.

Please note for Task F the names used for communities and areas are a combination of those that were in place when the FRM studies were done in the 1980s and 1990s and those reflected by the new LGP numbers due to a need to use data from both old FRM studies and the LGP list.

6.1 Community Analysis

To identify appropriate flood mitigation and adaptation strategies to include in a Flood Mitigation & Adaptation Program, communities must first identify flood vulnerabilities. Upon studying the source of flood vulnerabilities common to Newfoundland communities, three linked factors emerge that are important for communities to understand in order to set priorities and establish goals.

- **Watershed characteristics** include those physical attributes of a watershed, both natural and man-made that affects the flow of water through a stream system. Characteristics include land use and associated impervious cover, topography, soil characteristics, and stream system complexity.
- **Climate effects** include the general trends of precipitation amounts, precipitation frequency, snow-melt events, storm events, and tidal activity that helped shape stream networks and impact coastal areas.
- **Socio-economic conditions** are those factors such as population density, land development patterns, infrastructure and property investments, and social equity issues, which guide policies and become the basis for setting priorities.

6.1.1 Newfoundland Regions and Sub-regions

As shown in Figure 2-1, the Department of Environment and Conservation, Water Resources Management Division divides Newfoundland into three regions. These three regions enable a better understanding of the watershed characteristics and climatic effects across the island. As described earlier in this report, the Eastern Region is the most susceptible to hurricanes and the Western Region's stream network experiences higher volume runoff events, as a result of spring snow-melt events.

The intent of this section is to offer high-level guidance for Newfoundland communities, related to their decisions for adopting flood mitigation strategies that are intended to address the three linked factors presented above. The three Regions were divided into 11 smaller Sub-regions, based on their general physiographic composition (i.e., coastal and inland). To enable additional analysis, Sub-regions surrounding the more intensely developed areas around Corner Brook and the urbanized areas near St. John's were created. Sub-regions are presented inFigure 6-1. The Digital Elevation Model of Newfoundland (seeFigure 6-2) that shows island topography was also used to help define the Sub-regions. These Sub-regions were then utilized to assess potential flood vulnerabilities.

Further subdivision could take into account additional details related to other factors that affect flooding (e.g., soil types, forest age, impervious cover, storm surge); however, these eleven Sub-regions provide an appropriate level of detail, based upon the scope of this evaluation and available data, to initiate flood mitigation strategy discussions at both the Provincial and local level. Appendix B Sub-region Communities presents a complete listing of the communities included in each Sub-region.

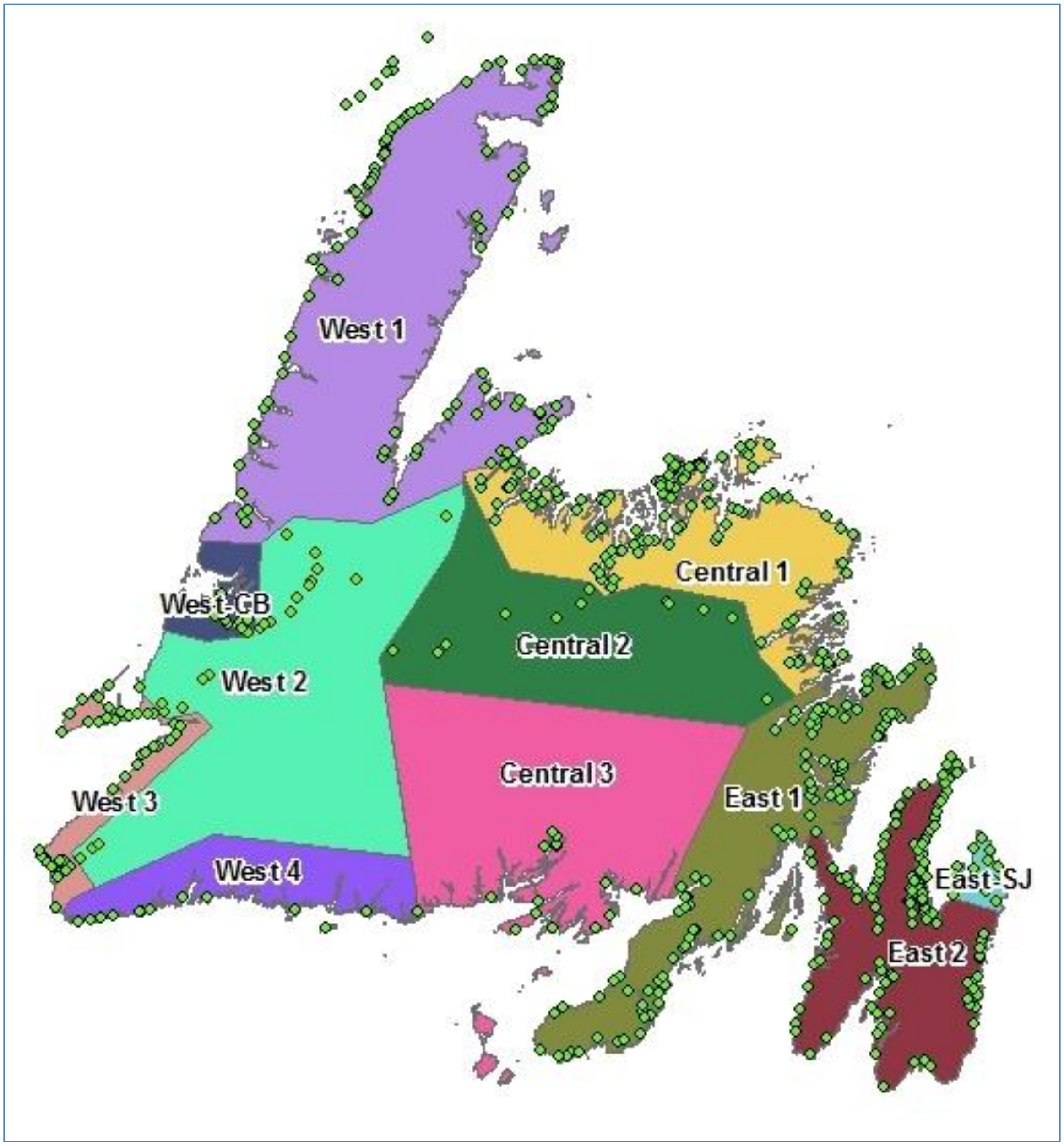


Figure 6-1. Newfoundland Sub-regions

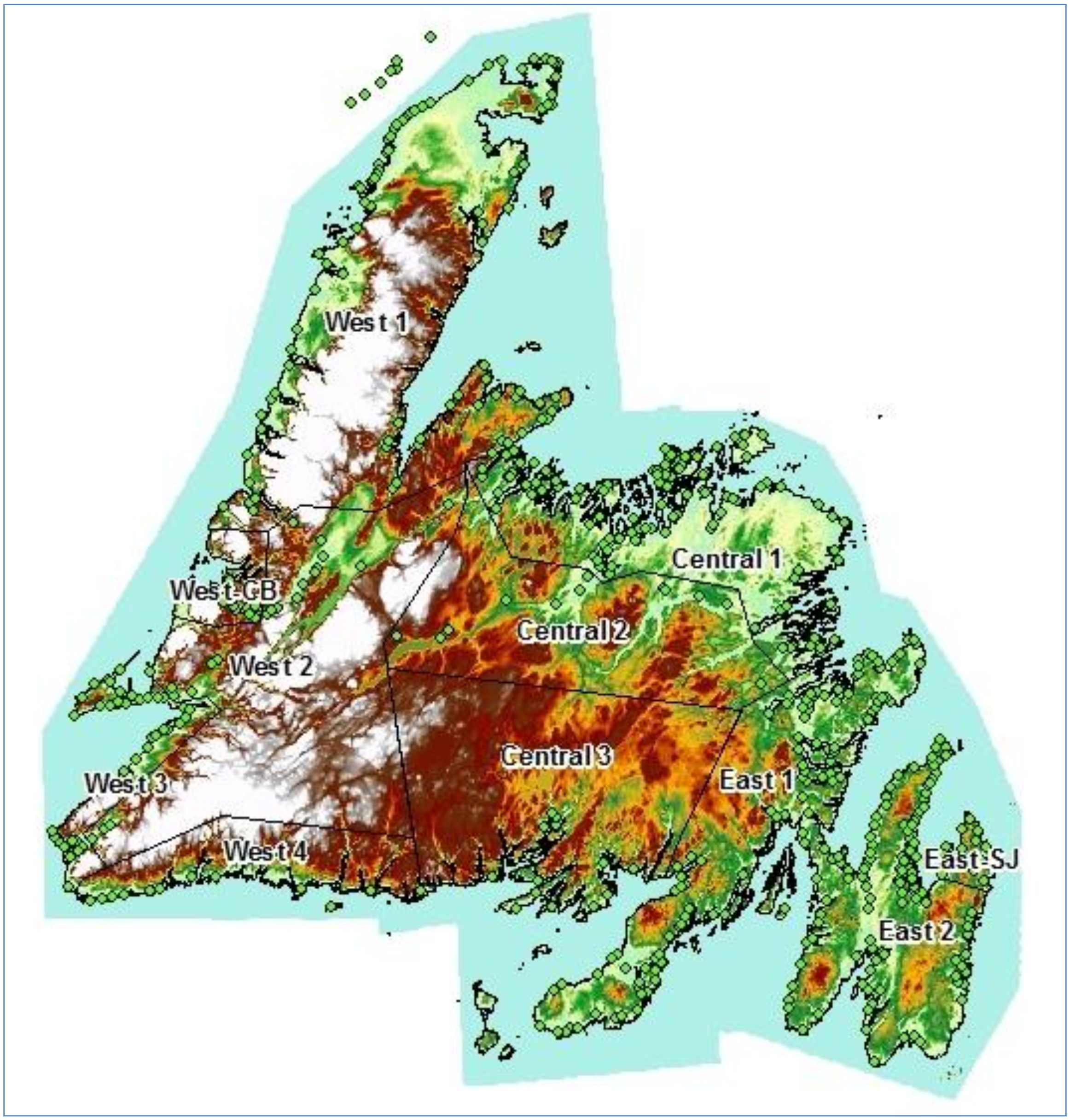


Figure 6-2. Newfoundland Digital Elevation Model

6.1.2 General Characterizations of Sub-regions

Communities within each Sub-region share important elements of each of the three linked factors, such as elevation, soils, population, precipitation trends, and sea level rise impacts. These similarities present common vulnerabilities and, in most cases, common solutions. Table 6-1 through Table 6-3 present generalized characteristics of each Sub-region using some of the same priority factors developed in Task D – Assess Need for New / Updated Flood Risk Mapping.

Specific for this section, the Priority Factors were calculated using the following methods.

- Location Priority Factor is a function of the community's designation as a Riverine Hazard community, its status as either coastal or riverine, and its elevation. Communities that are classified as Coastal and lie at sea level, have a high Location Priority Factor. Further, those communities classified as a Riverine Hazard that lie within 1,500 meters of a stream, have an even higher Location Priority Factor. As an example, the community of Carbonear 1) is a coastal community at sea level and 2) lies approximately within 1,500 meters of the stream (i.e., 1,148 meters). Therefore, Carbonear has a Location Priority Factor of 2. In contrast, Brigus is also a Coastal community but lies well above sea level (12 meters). Brigus also lies a distant 2,400 meters from the nearest stream. Taking into account both of these physical characteristics, Brigus' Location Priority Factor is 0.
- Soils Priority Factor is based on hydrologic soil groups. Soils with low runoff potential ranked as "0"; soils with high runoff potential ranked as "4". Soils data references the Soil Survey Reports for Newfoundland and Labrador available from Agriculture and Agri-Food Canada[28]. Detailed explanation of data fields is also provided through this website.
- Slope Priority Factor is based on average slope of the watershed with "0" for slopes less than or equal to 5%; "1" for slopes greater than 5% and less than or equal to 15%; and "2" for slopes greater than 15%.
- Drainage Density Priority Factors is a function of the drainage densities (linear distance of streams divided by land area) where the density value equal to or less than the average of 0.26 km/square km were assigned a priority factor of "0" and those above that average were assigned "1".

Then, within each Sub-region, an average was found for each individual Priority Factor. The results shown on Table 6-1 are averages of all individual communities' priority factors within each Sub-region. For example, the 12 communities categorized into the West-CB Sub-region all had their own Location Priority Factor. GIS analysis quantified the status of each of the 12

[28] http://sis.agr.gc.ca/cansis/publications/surveys/nf/index.html

communities (Gillams, Hughes Brook, etc.) designation as a Riverine Hazard community, its coastal/riverine status, and its elevation. All of these 12 individual Location Priority Factors were then averaged to yield 0.67, the Location Priority Factor for the entire Sub-region.

$$\text{Corner Brook Location Priority Factor} = \frac{\Sigma\,(\text{individual communities}'\text{Location Priority Factor})}{12\text{ communities}}$$

Sub-region	Watershed Characteristics			
	Location Priority Factor	Soil Group Priority Factor	Average Slope Priority Factor	Drainage Density Priority Factor
West-CB	0.67	1.50	2.00	0.00
West-1	0.46	0.93	0.51	0.55
West-2	0.81	1.10	1.71	0.10
West-3	0.58	0.58	1.45	0.00
West-4	0.31	1.00	1.38	0.15
Central-1	0.33	0.53	0.92	0.69
Central-2	2.00	0.92	0.42	0.92
Central-3	0.36	1.00	0.93	0.93
East-1	0.45	0.95	1.24	0.38
East-2	0.68	0.28	0.88	0.78
East-SJ	0.57	0.00	0.50	1.00

Table 6-1. Sub-region Watershed Characteristics

The above table indicates that those Sub-regions consisting of inland communities (West-2, Central-2) have a higher Location Priority Factor than Sub-regions comprised of coastal communities, which is likely due to the general siting of communities within those Sub-region in relatively close proximity to stream and river networks. Communities within Sub-regions in the western part of the island tend to have a higher soil group priority factor, due to the higher presence of runoff producing soil types. See Figure 6-3, soil map of Newfoundland interpreted as hydrological soil groups. Communities within western Sub-regions have the highest average slope priority factor, due to steeper terrain, as compared to the rest of the island. Communities in the Central Sub-regions, with the exception of East-SJ, tend to have the highest drainage density priority factor, due to the relative abundance of surface water systems.

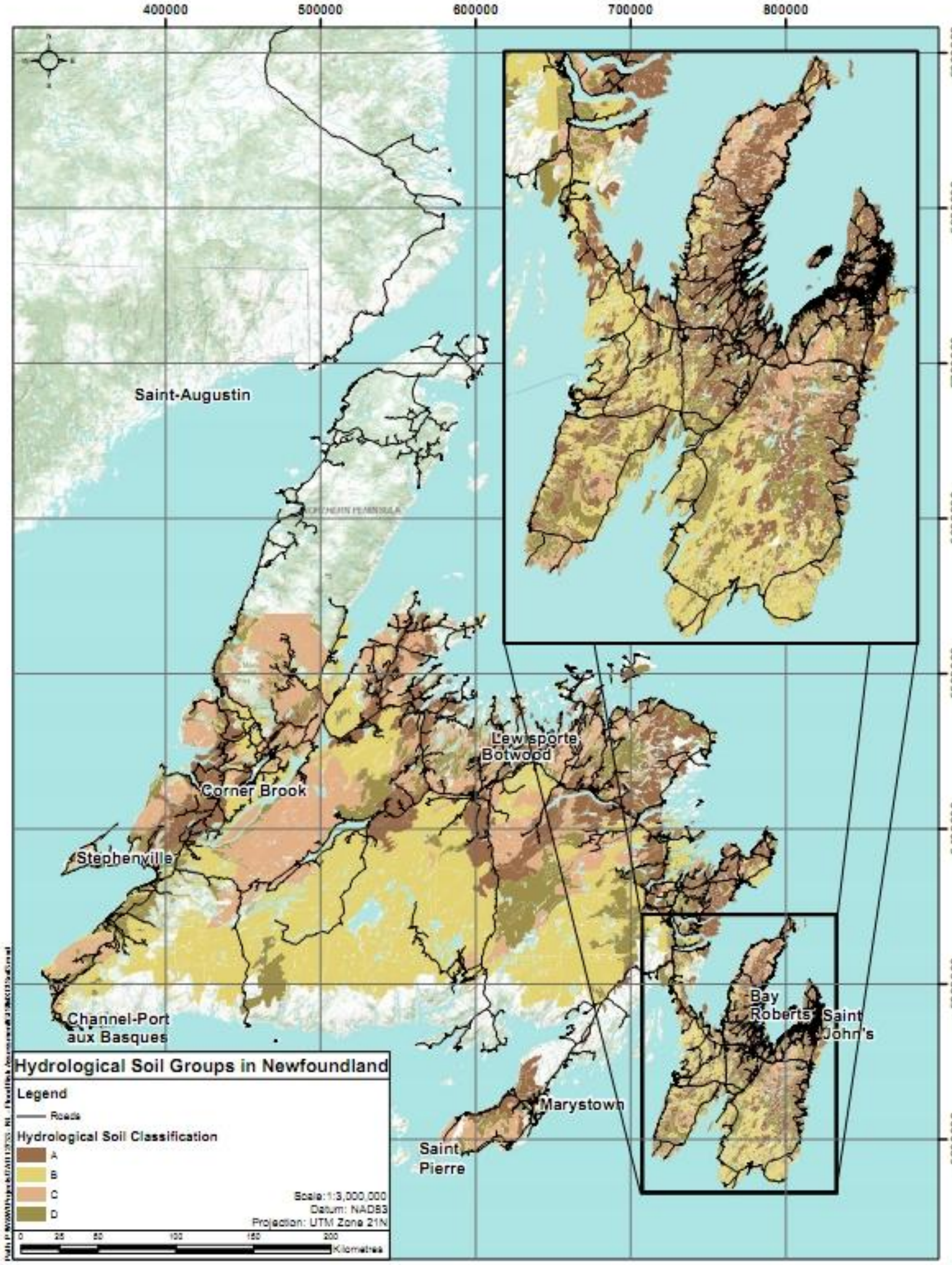


Figure 6-3. Soil map of Newfoundland interpreted as hydrological soil groups

Sub-region	Climate Change Factors		
	Precipitation	Hurricanes & Tropical Storms	Sea Level Rise
West-CB	1.00	1.00	0.80
West-1	1.00	1.00	0.80
West-2	1.00	1.00	0.00
West-3	1.00	1.00	0.80
West-4	1.00	1.00	0.80
Central-1	1.00	0.50	0.95
Central-2	1.00	0.50	0.00
Central-3	1.00	0.50	0.95
East-1	1.00	2.00	1.00
East-2	1.00	2.00	1.00
East-SJ	1.00	2.00	1.00

Table 6-2. Sub-region Climate Change Factors

Data presented in Table 6-2 summarizes the information presented in Table 4-2 in Task D – Assess Need for New / Updated Flood Risk Mapping. The Eastern Region is most susceptible to threats from hurricanes, tropical storms, and sea level rise, compared to the other two regions of the island. It should be noted that Sub-regions West-2 and Central-2 are inland regions and therefore not affected by sea level rise.

For this section the socio-economic factors were calculated as follows:

- 2011 Population represent the sum of the population of each of the communities included in each Sub-region. The source of the community population data is Statistics Canada.
- Population Priority Factor represents the average of those communities included in each Sub-region. For individual communities, communities with a 2011 population less than 500 residents were issued a 0. Communities with a 2011 population between 501 and 5,000 were issued a 1. Communities with a 2011 population greater than 5,000 were issued a 2 as a Priority Factor.

- 2012 Projected Growth Population represents the combined projected population growth of all communities within each Sub-region between 2011 and 2020. Population statistics available through Newfoundland and Labrador Statistics Agency were used as an indication of population growth to the year 2020 trending census data for the years 1991, 1996, 2001, 2006 and 2011, as available from the Agency website.
- Growth Priority Factor represents the average of those communities included in each Sub-region. For individual communities, communities with a 2020 projected population less than 500 residents were issued a 0. Communities with a 2020 projected population between 501 and 5,000 were issued a 1. Communities with a 2020 projected population greater than 5,000 were issued a 2 as a Priority Factor
- Flood Damages Estimates Priority Factor represents the average of those communities included in each Sub-region. For individual communities, this Priority Factor indicates if a community has reported flood loss or has been documented by Public Safety Canada's Disaster Financial Assistance Arrangements. Communities reporting flood loss were issued a 1. Communities not reporting a flood loss were issued a 0.

Sub-region	Socio-Economic Factors				
	2011 Population	Population Priority Factor	2020 Projected Growth Population	Growth Priority Factor	Flood Damages Estimates Priority Factor
West-CB	28,542	0.83	26,319	0.58	0.17
West-1	16,094	0.10	11,905	0.07	0.02
West-2	10,114	0.14	9,468	0.19	0.24
West-3	13,695	0.20	12,070	0.18	0.08
West-4	3,132	0.23	1,780	0.08	0.08
Central-1	36,460	0.22	30,018	0.17	0.04
Central-2	31,204	0.75	28,957	0.67	0.33
Central-3	4,422	0.14	3,369	0.14	0.14
East-1	29,987	0.13	25,561	0.09	0.04
East-2	71,613	0.24	65,788	0.22	0.03
East-SJ	188,560	1.00	191,467	1.00	0.07

Table 6-3. Sub-region Socio-Economic Conditions

Analysis of the socio-economic data presented in Table 6-3 reveals reveals, through the flood damage estimates priority factor, that previous property loss is highest for Sub-regions comprised of inland communities (West-2, Central-2). The three Sub-regions with Growth Priority Factors greater than 0.5 contain the three largest communities on the island (Corner Brook, St John's, and Grand Falls Windsor in Central-2), supporting an observed trend of growth and re-investment of urban areas and a loss of population in rural communities. It should be noted that some of the most densely populated Sub-regions have the smallest Flood Damages Estimates Priority Factors (Central-1, East-1, East-2)

6.1.3 Summary of Sub-region Characteristics

West-CB

Corner Brook is the second largest community in Newfoundland (pop. 28,542) and is the focal point of this Sub-region of 12 communities. Communities here are located in close proximity to coastal and tidal areas and water bodies. Soils have low infiltration rates and nearby slopes are steep, further contributing to flood effects. These factors contribute to the fact that flood damages for the communities in the Sub-region are generally above average, with respect to the rest of the island. Population is growing in some of these communities, which may lead to a higher chance of flood damages in the future.

West-1

This Sub-region is dominated by the Great Northern Peninsula on the northwest corner of the island. All 91 communities in the Sub-region lie along the coast; however, due to broad coastal plains and low population densities, previous damages caused by flooding have not been high. Considering the relatively moderate sea level rise projections in this Western Region, there is also a relatively lower risk of future flood damages.

West-2

The majority of the communities included in Sub-region West-2 occur along the Trans-Canada Highway and Deer Lake. Damage from flooding is relatively high across these 21 communities, possibly due to the very close proximity of the Sub-region's communities to water bodies, threats from snow melt, and relatively steep slopes.

West-3

This Sub-region includes the farthest west coastal portion of the Gulf of St. Lawrence, including Lourdes and Stephenville. The 40 communities within this Sub-region are tightly clustered in two main groups along the coast in his Sub-region; however, previous flood damages in this area are relatively low. This may be due in part to soils in the Sub-region with relatively good infiltration characteristics.

West-4

The 13 communities located within this Sub-region line the southwest corner of the island, from Margaree to Parsons Harbour. West-4 has the lowest Location Priority Factor of any of the Sub-regions, and it also has one of the lowest Flood Damages Estimates Priority Factor on the island. As West-4 is located in the Western Region, it also has a relatively low flooding risk, as a result of both sea level rise, as well as a relatively moderate threat risk from hurricanes and tropical storms.

Central-1

This Sub-region includes the largest number of communities, 103, that are clustered along the north central coast of Newfoundland, from Kings Point to Salvage. Central-1 has over 36,000 residents; however, its Growth Priority Factor is low to moderate, as population is expected to decline to about 30,000 by 2020. Despite its large population, Flood Damages in the Sub-region are relatively low.

Central-2

Twelve communities make up the Central-2 Sub-region. These inland communities are mostly linked by the Trans-Canada Highway. Grand Falls Windsor is the largest community in Central-2, accounting for most of the population. These communities have, by far, the highest Location Priority Factor of any Sub-region. Similarly, the Sub-region has the highest Flood Damages Priority Factor.

Central-3

Sub-region Central-3 includes 11 communities along the south central coast and up through Bay D'Espoir. This Sub-region has the lowest population and low to moderate values on the major priority indicators: soils, slopes, and growth priority factors.

East-1

This Sub-region spans the width of the island, with coastal communities on the Gulf of St. Lawrence and the Atlantic Ocean, including the Burin Peninsula. The 108 coastal communities within this Sub-region are split between the north and south coasts. Socio-Economic priority factor figures for this Sub-region are the second lowest for the island, across all categories.

East-2

Coastal communities line nearly all of this Sub-region, which includes the Avalon Peninsula, the farthest eastern portion of the island. Mount Pearl is one of the largest communities in the Sub-region, which has a total population of over 71,000. Even with this many residents in these 121 communities, the Sub-region has a very low Flood Damages Priority Factor.

East-SJ

Fourteen communities lie on the peninsula that includes the City of St. John's (pop. 106,000) and Conception Bay South (pop. 22,000). Statistics Canada projects a small growth in the Sub-region through 2020. Of interest is the Drainage Density Priority Factor for East-SJ is the highest on the island. Due to its position in the Eastern Region of the island, this smallest Sub-region is projected to be highly susceptible to sea level rise and hurricanes/tropical storms.

Upon reviewing the values associated with each of the three linked factors for each Sub-region and their relation to flood and climate vulnerabilities, mitigation strategies can be considered that generally could be applicable to each Sub-region. These generalizations are the basis for an initial set of strategies that the Provincial government and local communities should consider when updating Flood Mitigation & Adaptation Programs.

6.2 Mitigation Strategies

To cope with existing and anticipated future flooding, each community should evaluate and eventually adopt its own suite of flood mitigation strategies. To select appropriate strategies, communities may elect to develop a comprehensive flood mitigation and adaption program that includes watershed modeling, sea level predictions, and public involvement and education campaign, to determine local priorities and flood mitigation goals. In smaller communities, where flooding issues may be less complex, communities may elect to apply a less formal, yet still systematic, planning process to establish their flood mitigation goals. Using a process most appropriate for the community, the decision makers need to consider the three linked factors assessed in Table 6-1 to Table 6-3 above and understand their dynamics, in order to pursue the most appropriate set of mitigation strategies applicable to local conditions and flood vulnerabilities.

Table 6-4 presents a list of those strategies that each community should consider to determine the strategy's applicability to their flooding issues and inclusion in their Plan. These strategies should be considered for their ability to mitigate current and adapt to projected flooding risk. Each of these strategies has the ability to perform at least one of the following tasks.

- Reduce the risk to public safety during flood events
- Reduce incidents of flooding,
- Reduce susceptibility to flood damage,
- Mitigate the impacts of flooding, and
- Preserve the natural resources of flood plains.

6.2.1 Structural and Non-Structural Strategies

Strategies can be Structural (e.g., dams, levees, shore stabilization), or Non-Structural (e.g., building codes, regulations and flood forecasting warnings). It should be noted that although flood insurance is not currently available in Canada, it is listed here as a Non-Structural strategy. Structural strategies can effectively address site or location specific threats, such as reducing the flood frequency along a river corridor or limiting erosion along a coastline. Structural strategies utilize engineering approaches to make defined improvements to address a defined need. However, Structural strategies are generally higher cost flood mitigation strategies than Non-Structural mechanisms.

Given the scope of this evaluation and available data, this report does not specify locations for structural mitigation measures in the Sub-regions. Instead, this report provides general guidance that those communities for which structural mitigation measures may be applicable. Communities should consider identifying locations, through more detailed evaluations, where construction of structural practices may be appropriate, as part of a more comprehensive flood mitigation strategy.

Table 6-4 also includes a larger set of Non-Structural strategies. Although there may be structural components to several of these strategies, Non-Structural strategies are generally more programmatic in nature, often requiring contributions by regional and local government entities. For instance, building code standards define structural components required for development, yet because the components are the result of policy decisions that primarily affect the development process and a site’s usability, building codes are considered a Non-Structural strategy.

Local and Provincial officials should first consider the benefits of Non-Structural strategies, before Structural ones, as their costs are typically significantly lower. This is especially the case where population densities and infrastructure investments are relatively low and the benefits of large engineered structures, in terms of flood loss mitigation, are also low.

6.2.2 Potential Strategies

Table 6-4 presents a list of Mitigation Strategies, organized into Structural and Non-Structural categories. Following the table are recommendations specific to each Sub-region that communities within each Sub-region could consider as their first set of options to reduce their risk of flooding events, minimize flood damages and threats to public safety, and expedite the post-flood recovery process. Although Table 6-4 includes the most common strategies in use throughout Canada, it is not meant to be exhaustive. Decision makers should maintain their flexibility to determine if additional measures will be effective for their specific circumstances and flood vulnerabilities.

Mitigation Strategy		Description
S	Dams and reservoirs	Impoundments to control volume and rate of runoff for downstream areas.
	Dikes, levees and flood embankments	Protects flood prone areas along rivers and coastlines.
	High flow diversions	Provides additional or alternate conveyance capacity to main channels by diverting flows during high stage events.
	Infiltration and detention structures	Manages runoff at its source and reduces downstream runoff volumes.
	Channel Improvements	Increases main channel capacity and/or stabilizes overbanks and channel cross sections to improve flow capacity.
NS1	Flood plain planning	Systematic development of community goals and implementation strategies.
NS2	Flood plain zoning and regulation	Defines how property owners' can develop land in the floodplain.
NS3	Design and location of facilities	Minimum design standards for new and redevelopment activities to promote the reduction of peak flow rates and volumes, as well as protect infrastructure.
NS4	Building codes	Established standards requiring minimum building elevations, utility design, and structural components to minimize the risk of flood damage.
NS5	Information and education	Campaign to inform residents and property owners of flood prone areas, regulated activities, and emergency response procedures.
NS6	Disaster preparedness	An emergency management plan that defines roles and responsibilities of key officials, responders, and public.
NS7	Post flood recovery	Identification of funding sources and stakeholders that play a role in post-flood recovery operations.
NS8	Development and re-development policies	Defines how new and redevelopment activities will comply with minimum standards to minimize and/or mitigate flooding.
NS9	Flood proofing	A program to promote property owners to seal doors and windows to keep flood waters from entering structures.
NS10	Flood forecasting and warning	Establishment of monitoring stations and probabilistic models to inform key officials and responders, and public of anticipated flood risks.
NS11	Flood insurance[29]	Purchase of insurance from a private company to share common flood risk and mitigate individual losses.
NS12	Property acquisition	Purchase of flood prone properties to remove structures from floodplains and eliminate future property damage.

Table 6-4. Potential Flood Mitigation Strategies

[29] Flood insurance is not currently available although the industry appears to be moving in this direction.

6.3 Mitigation Recommendations

Based on the generalizations of the Sub-region communities presented in Table 6-1 throughTable 6-3, mitigation and adaptation strategies were developed that likely apply to the communities in that Sub-region. Although the same strategy may be recommended for communities in multiple Sub-regions, this in no way implies that these strategies will be implemented in the same way in different communities. It will be up to the decision makers to identify how best to apply strategies, and at what level of complexity, that serves local needs in the most efficient manner.

6.3.1 Strategies Applicable to All Communities

Across Newfoundland, the following mitigation and adaptation strategies apply to nearly every community. Each of these should be considered for inclusion into a community's flood mitigation and adaptation program. It should be noted that some of these strategies have already been implemented in Newfloundland and should continue to be implemented.

- **Flood Plain Planning (NS1)**. As stated before, communities can proceed with planning activities at various levels of detail and complexity. The level of detail for each community will vary, depending upon a variety of parameters, including existing and future development, current and projected flood risk, and relative impact to communities' social and economic structure. The level of complexity of a community's flood mitigation and adaption program should match the level of detail needed to address flood vulnerabilities and potential mitigation strategies, as well as the interconnection of the three linked factors of climate, basin characteristics, and socio-economic conditions. These plans should have defined goals about which resources to protect, which strategies are most applicable, schedule for implementation, and a monitoring plan to measure the progress towards implementation and effectiveness.
- **Flood Plain Zoning and Regulation (NS2)**. The best tool to reduce property loss from flood events is to avoid building in flood prone areas. Communities should have minimum requirements for the ability of a landowner to build within or near a flood prone area and modify existing structures already in a designated flood plain or flood fringe. These requirements should be based on a minimum Provincial regulation, applicable across the island, or be specific for certain communities. The Water Resources Act, SNL 2002 cW-4.01, sections 30, 32, 33, 34, 35, 48, 64 and 90 present the minimum standards. Also see the Policy for Flood Plain Management[30]. To be eligible for Provincial FRMS communities must contact ENVC.

[30] http://www.env.gov.nl.ca/env/waterres/regulations/policies/flood_plain.html

- **Design and Location of Facilities (NS3)**. The minimum design standards and location requirements of future permanent building structures within flood prone areas should be established, as well as the minimum design standards for structural stormwater runoff management and flood protection practices. Having these minimum standards and requirements can reduce flooding impacts, as well as help mitigate sources of flooding.
- **Building Codes (NS4)**. Specific building codes should be established for permanent structures to be built in areas permitted by flood plain zoning and regulation, as well as flood prone areas. These codes will establish minimum requirements to minimize life and property losses due to flooding. Building codes also take into account historical experience. However as climate change occurs, they may need additional analysis to assess their current and future effectiveness.
- **Information and Education (NS5)**. Government has the responsibility, from a public safety perspective, to inform all flood plain property owners and residents of the risks that exist in the flood plain, as well as the steps they can take to minimize loss of life and property. The Provincial flood plain mapping program is an element of this strategy. Information and education should be an ongoing program, to address future changes in flood risks and communities. The existing flood risk mapping studies and relevant material are publically available today on the Department of Environment and Conservation website[31].
- **Disaster Preparedness (NS6)**. This type of planning is also a government public safety responsibility. Governments should review their vulnerabilities to flooding (and other disasters), and identify the roles and responsibilities of local officials, responders, and the public to protect life and property.
- **Post Flood Recovery (NS7)**. Governments should have in place adequate plans to respond to flooding events. These plans would include roles and responsibilities of government agencies and officials, access to flooded areas, rescue and recovery of citizens, damage assessment, and dedicated funding to support these activities. Another element of this strategy is data collection. Documented evidence of flooding and resulting impacts has proved invaluable for this assessment.

6.3.2 Property Acquisition

The Provincial government is in the process of updating old and undertaking new flood risk mapping. As flood risk mapping occurs, the Province should consider gathering specific data on those properties that have experienced high flood damages or repetitive loss. The Province should also consider its role in assisting communities through the process of buying out flood prone properties to reduce future losses.

[31] http://www.env.gov.nl.ca/env

Table 6-5 presents the range of average dwelling values in each Sub-region as published by Statistics Canada (based on Dissemination Areas) in their report on the 2006 Census of Population. The highest dwelling values are in West-2 and Central-1. The greatest range of average dwelling values is in East-1. This information may be beneficial to provincial and the decision makers when evaluating their general ability to purchase properties as a mitigation strategy.

Sub-region	Range of Average Dwelling Values[32] ($1,000s)
West-CB	36 - 167
West-1	27 - 119
West-2	35 - 284
West-3	55 - 145
West-4	26 - 119
Central-1	38 - 225
Central-2	35 - 152
Central-3	28 - 74
East-1	25 - 391
East-2	37 - 209
East-SJ	47 - 204

Table 6-5. Range of Average Dwelling Values for each Sub-region

6.3.3 Strategies Applicable to Specific Sub-regions

Table 6-6 lists the mitigation and adaptation strategies that communities within each Sub-region should first consider as part of a community'sflood mitigation and adaption program. Depending on specific conditions in each community, other strategies not identified for that Sub-region, may be applicable.

[32] Statistics Canada (2012)

	S	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8	NS9	NS10	NS11	NS12
West-CB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
West-1		✓	✓	✓	✓	✓	✓	✓					
West-2		✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
West-3		✓	✓	✓	✓	✓	✓	✓					
West-4		✓	✓	✓	✓	✓	✓	✓					
Central-1		✓	✓	✓	✓	✓	✓	✓			✓		
Central-2	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Central-3		✓	✓	✓	✓	✓	✓	✓					
East-1	✓	✓	✓	✓	✓	✓	✓	✓					
East-2	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
East-SJ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 6-6. Specific Strategies for Each Sub-region

Please refer to Section 6.1.2 for definition on the priority factors.

West-CB and East-SJ

Because of the historic land use patterns, the high population densities, the magnitude of investment in infrastructure, and projected growth, all of the mitigation strategies presented in Table 6-4 are recommended for these two Sub-regions. In addition, these Sub-regions should initiate a formal and comprehensive review of their current flood management planning documents that includes multiple municipal departments and community stakeholders. Structural strategies are more applicable to these Sub-regions, as the high population densities and high infrastructure investments typically justifies the higher cost of implementation.

West-1

West-1 has the lowest Flood Damages Estimates Priority Factor on the island. Therefore, no additional strategies beyond the seven applicable to all Sub-regions are included on the priority strategy list. These same recommendations apply to the seven communities located in Labrador across the Gulf of St. Lawrence from Newfoundland's Great Northern Peninsula.

West-2

The region surrounding Deer Lake and served by the Trans Canada Highway may have the potential to see additional growth. In addition, flood damages in communities in this region and the close proximity of communities to water bodies, make the promotion of flood insurance and the consideration of acquisition of properties in areas prone to flooding applicable mechanisms in this Sub-region.

West-3, West-4, and Central-3

These three Sub-regions of mainly coastal communities are adjacent to each other along the southern coast of the Western Region. Due to the low Growth Priority Factors and the relatively low Flood Damages Estimates Priority Factor, additional strategies are not recommended beyond those appropriate for all Sub-regions.

Central-1 and Central-2

This Sub-region, based on its relatively high population density and high density of communities would benefit from a flood forecasting and warning system. As this region receives much of its overland flow from Sub-region Central-2, such an early warning system could be established across both sets of Sub-regions to minimize flooding impacts to downstream areas.

In addition, communities in Central-2 have the highest Flood Damages Estimates Priority Factor of any Sub-region. Therefore, these Central-2 communities also have the third highest Growth Priority Factor of all Sub-regions and should consider adding four additional strategies to their Plan:

- Development and re-development policies,
- Promotion of flood insurance to landowners,
- A formal process to identify and evaluate properties for which acquisition has a strong potential to reduce flood losses in the future, and
- Structural flood mitigation strategies to reduce flood impacts on those communities and portions of communities with the greatest flood vulnerabilities.

East-1

Despite the relatively high density of communities in this Sub-region, population in each community is low. This is likely the reason for the relatively low Flood Damages Estimates Priority Factor. Therefore, no additional Non-Structural strategies are recommended for East-1. However, due to the Sub-region’s location on the eastern side of the island, with its higher vulnerability to expected sea level rise and hurricanes/tropical storms, local communities should add strategies in their flood mitigation and adaption program to identify locations for structural flood protection measures.

East-2

East-2 communities have a relatively high population within each community. Therefore, with relatively significant existing infrastructure and high population densities along the coast, these communities should consider adding flood proofing standards, flood forecasting and warning systems, flood insurance promotion, and property acquisition guidelines to their flood mitigation and adaption program. As in all the Eastern Sub-regions, structural strategies apply to help communities adapt to more rapid changes to sea level changes and storm frequency.

6.3.4 Mitigation Strategy Cost and Potential Benefits

In developing a flood mitigation and adaptation program, decision makers should consider how the strategy will provide a positive impact in the area. The impact will be different for each area, based on flood vulnerabilities that are affected by the three linked factors of climate, basin characteristics, and socio-economic conditions. Local flood management goals included in a community's flood mitigation and adaption program could include strategies aimed at mitigating risks on the following:

- Local industries that employ local residents;
- Transportation systems and public infrastructure; or
- Landowners in specific neighborhoods and districts.

Mitigation strategies that can help achieve these goals span a wide variety of activities, from administrative to construction. Similarly, mitigation strategies span the spectrum of implementation costs to communities. For instance, dam and levee projects, accounting for both design and construction costs, typically have significant implementation costs. In contrast, communities can implement non-structural strategies, such as reviewing and updating building codes that enhance Provincial standards and guidance, relatively inexpensively, taking into account staff time, advertising requirements for ordinance changes, and codification.

Therefore, planning efforts must evaluate the cost of mitigation and adaptation strategies when developing their Plans. When goals and objectives are defined early in the planning process and periodically updated, communities can measure the cost-effectiveness of different options towards meeting these goals and objectives. Communities need to assess the full cost of strategy implementation and measure that cost against the expected benefit the strategy will have on meeting community goals. Table 6-7 presents the relative cost to implement the individual mitigation and adaptation strategies applicable to Newfoundland communities.

Mitigation Strategy			Cost to Implement
Structural	S1	Dams and reservoirs	$$$
	S2	Dikes, levees and flood embankments	$$$
	S3	High flow diversions	$$
	S4	Infiltration and detention structures	$$
	S5	Channel Improvements	$$
Non-Structural	NS1	Flood plain planning	$$
	NS2	Flood plain zoning and regulation	$
	NS3	Design and location of facilities	$
	NS4	Building codes	$
	NS5	Information and education	$
	NS6	Disaster preparedness	$
	NS7	Post flood recovery	$$
	NS8	Development and re-development policies	$
	NS9	Flood proofing	$$
	NS10	Flood forecasting and warning	$$
	NS11	Flood insurance	$$
	NS12	Property acquisition	$$

Approximate rage of values of associated cost to implement.
($) <$50,000
($$) $50,000 – $250,000
($$$) >$250,000

Table 6-7. Relative Costs of Mitigation Strategies

The Province's Policy for Flood Plain Management provides the following guidance about investments in structural strategies:

> *"Proposals for flood control measures such as construction of dykes, river diversions, retaining walls or flood control dams will only be considered where the alternative with the highest benefit/cost ratio is recommended. Alternatives considered may also include possible compensation for flood victims or the cost of relocating the inhabitants of the flood risk areas or maintaining the status quo."*[33]

[33] www.env.gov.nl.ca/env/waterres/regulations/policies/flood_plain.html

6.3.5 Sub-regions Prioritization Considerations

Table 6-11 presents the results of summary calculations of the Priority Factors included in Table 6-1 throughTable 6-3. This summary enables the evaluation and prioritization of Sub-regions based on their communities' ratings within each the three linked factors: Climate, Watershed Characteristics, and Socio-Economic Factors. This summary can assist decision makers with initial implementation of mitigation and adaptation strategies. In the Table, the higher the values relative to others in the column, indicates the higher the flood vulnerability from that linked factor.

As not all Priority Factors equally characterize flood vulnerability, a weighted average was developed to further evaluate the factors presented Table 6-1 throughTable 6-3. The following list presents the multiplier used for each Priority Factor when calculating the values in Table 6-11.

Weighting	Description
1	Soil Group
1	Average Slope
2	Location
2	Drainage Density

Table 6-8. Watershed Characteristics Weighting

Weighting	Description
1	Precipitation
2	Sea Level Rise
2	Hurricanes/Tropical Storms

Table 6-9. Climate Change Weighting

Weighting	Description
1	Population
2	Flood Damages Estimates
2	Growth

Table 6-10. Socio-Economic Factors Weighting

The above multipliers were applied to the respective Priority Factor (PF) in each table, and then a weighted average was calculated to yield an overall factor for each linked factor (Watershed Characteristics, Climate Change, and Socio-Economic). The weighted averages presented in Table 6-11 were calculated using the following formulas and using the factor weightings in Tables 6-8 through 6-10.

$$\text{Watershed Characteristics} = \frac{2*(\text{Location PF}) + 1*(\text{Soil Group PF}) + 1*(\text{Average Slope PF}) + 2*(\text{Drainage Density PF})}{4}$$

$$\text{Climate Change Factors} = \frac{1*(\text{Precipitation}) + 2*(\text{Hurricanes \& } Tropical\ Storms) + 2*(\text{Sea Level Rise})}{3}$$

$$\text{Socio} - \text{Economic Factors} = \frac{1*(\text{Population PF}) + 1*(\text{Growth PF}) + 2*(\text{Flood Damages Estimates PF})}{3}$$

Sub-region	Watershed Characteristics	Climate Change Factors	Socio-Economic Factors
West-CB	1.2	1.53	0.58
West-1	0.9	1.53	0.07
West-2	1.2	1.00	0.27
West-3	0.8	1.53	0.18
West-4	0.8	1.53	0.15
Central-1	0.9	1.30	0.16
Central-2	1.3	0.67	0.69
Central-3	1.1	1.30	0.19
East-1	1.0	2.33	0.10
East-2	1.0	2.33	0.18
East-SJ	0.9	2.33	0.71

Table 6-11. Summary of Linked Factors for Each Sub-region

Table 6-11 presents some generalized figures for consideration by decision makers tasked with evaluating the relative flood risks associated with each of the three linked factors for each Sub-region. These figures are not intended to be precise, nor cumulative; but to offer decision makers a summary view of the relative risks each of the linked factors present to each Sub-region. When a linked factor is high for a Sub-region, relative to other Sub-regions, it means that the linked factor poses a higher flood risk for that Sub-region. For example, East-1 has a relatively high Climate Change Factor, yet a relatively low Socio-Economic Factor. This means that communities in this Sub-region may be significantly affected by climate change, but population attributes and historic flood loss figures are low and therefore may not make this

Sub-region a priority for action for this linked factor. In addition to the generalizations for each factor offered in this table, decision makers should consider other Provincial and local issues and needs outside the scope of this evaluation, including existing public policy and the availability of funding.

6.4 Recommendations

Communities in Newfoundland should each have a Flood Mitigation & Adaptation Program that is applicable to the size of their community, their flood vulnerabilities, and the potential for loss of both life and property. For those communities that have a Program in place, the mitigation strategies should be reviewed to evaluate their effectiveness to mitigate flood events taking into to account the trends in climate change..

Table 6-6 makes specific recommendations for each island Sub-region that are generally applicable to that grouping of communities based on physiographic region and density of communities. These are high level recommendations that should be assessed individually by each community for their applicability. However, these recommended strategies should be a starting point for each community to engage stakeholders, assess land use, identify barriers, and establish community development and protection goals as part of a fully developed, comprehensive Flood Mitigation & Adaptation Program. Guidance for how to develop a Flood Mitigation & Adaptation Program can be found in through Public Safety Canada's 2010-2011 *Emergency Management Planning Guide*. This document gives clear guidance to communities about how to Initiate the planning process, orientate the community to emergency planning issues, develop plan building blocks, write the plan, and implement the plan.

7. References

7.1 Flood Events Inventory References

Environment Canada, 1980	*Flooding Events in Newfoundland and Labrador - An Historical Perspective*. Prepared by A.D. Kindervater, Environment Canada, Inland Waters Directorate, Halifax, Nova Scotia. 80-WPMB-4. July 1980.
Rogers, 2008	*A Preliminary Study of Flooding in Newfoundland and Labrador (1998-2008) – Final Report,* submitted by Felix Rogers, Summer Student, Water Resources Management Division, Department of Environment and Conservation, Government of Newfoundland and Labrador, 31 July 2008
Ruffman et al, 1990	*Historic Seismicity and Record of Severe Storms with Coastal Flooding for Western Newfoundland: Search of the Western Star of Corner Brook, Newfoundland, April 4, 1900-June 15, 1964*, Ruffman, A, Hattie, K, Boyce, D, Stevenson, B, Smith, A, Buchan, G and Snow, D. 1990. Album of Articles. Geological Survey of Canada, Open File No. 2407(1991), 637 pages.
Ruffman et al, 1991	Historic Seismicity and Record of Severe Storms With Coastal Flooding For Western Newfoundland - Volume 2, Ruffman, A; Hattie, K; Boyce, D; Stevenson, B; Smith, A; Buchan, G; Snow, D, Geological Survey of Canada, Open File 2407, 1991, 432 pages.
Tudor, 1997	*EPC Electronic Disaster Database and Its Characteristics, Project Report 97-1*, by Carol Tudor, Office of the Senior Scientific Advisor, Emergency Preparedness Canada, August 1997, available at http://dsp-psd.pwgsc.gc.ca/Collection/D83-5-97-1E.pdf accessed October 21, 2011

7.2 Climate Change References

Modeling

Catto, 2010	Catto, N., 2010. A review of academic literature related to climate change impacts and adaptation in Newfoundland and Labrador. *Health San Francisco*, (March), p.124 pp. Available at: http://www.exec.gov.nl.ca/exec/cceeet/publications/Review_Literature_ClimateChangeImpactsAdaptation_inNL.pdf.
Catto and Hickman, 2004	Catto, N.R., Hickman, H., 2004. *Flood hazard and vulnerability in Newfoundland communities.* Office of Critical Infrastructure and Emergency Preparedness Canada.
Lines et al, 2008	Lines, G. S., M. Pancura, C. Lander and L. Titus, 2008. Climate Change Scenarios for Atlantic Canada Utilizing a Statistical Downscaling Model Based on Two Global Climate Models. Environment Canada, Meteorological Service of Canada, Atlantic Region. Science Report Series No. 2009-01, July 2008.

Music and Caya, 2007	Music, B., and D. Caya, 2007: Evaluation of the Hydrological Cycle over the Mississippi River Basin as Simulated by the Canadian Regional Climate Model (CRCM). *J. Hydromet.*, 8(5), 969-988.
Richter and Barnard, 2004	Richter, S., Barnard, J., 2004. *Impacts of Climate Change on Hydroelectric Generation in Newfoundland.* Climate Change Impacts and Adaptations Directorate, Report A283.
Scinocca et al, 2008	Scinocca, J. F., N. A. McFarlane, M. Lazare, J. Li, and D. Plummer, 2008: The CCCma third generation AGCM and its extension into the middle atmosphere. *Atmos. Chem. Phys. Discuss.*, 8, 7883-7930. www.atmos-chem-phys-discuss.net/8/7883/2008/.
Vasseur and Catto, 2008	Vasseur, L. and Catto, N. (2008): Atlantic Canada; *in* From Impacts to Adaptation: Canada in a Changing Climate 2007, *edited by* D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, ON, p. 119-170.
Wilby et al, 2002	Wilby, R.L., Dawson, C.W. and Barrow, E.M. (2002): *SDSM - a decision support tool for the assessment of regional climate change impacts*. Environmental Modeling Software, 17, p145-157.

Hurricane and Tropical Storms

Chylek and Lesins, 2008	Chylek, P., and G. Lesins (2008), Multidecadal variability of Atlantic hurricane activity: 1851–2007, J. Geophys. Res., 113, D22106, doi:10.1029/2008JD010036 NOAA FAQ on the Atlantic Multidecadal Oscillation (AMO): http://www.aoml.noaa.gov/phod/amo_faq.php
Enfield, David B.; Cid-Serrano, Luis 2010	Enfield, David B.; Cid-Serrano, Luis (2010). Secular and multidecadal warming's in the North Atlantic and their relationships with major hurricane activity. International Journal of Climatology 30 (2): 174–184. doi:10.1002/joc.1881
Holland et al, 2011	Holland, Greg J.; Done, James; Bruyere, Cindy; Hurrell, Jim, NCAR; Webster, Peter; Suzuki-Parker, Asuka, Georgia Institute of Technology (2011). Effect of Climate Variability and Change in Hurricane Activity in the North Atlantic

Sea Level Rise

Batterson & Liverman	Batterson, M., and D. Liverman, Past and Future Sea-Level Change in Newfoundland and Labrador: Guidelines for Policy and Planning. *Current Research (2010), Newfoundland and Labrador Department of Natural Resources Geological Survey, Report 10-1, pages 129-141.*

Ocean Currents and Oscillations

IPCC, 2007	IPCC Chapter 5 (Bindoff, N.L., J. Willebrand, V. Artale, A, Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum,

L.D. Talley and A. Unnikrishnan, 2007: Observations: Oceanic Climate Change and Sea Level. In: *Climate Change 2007: The Physical Science Basis*. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.) and Chapter 10 (Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.)

Stevenson et al, 2011 — (Stevenson, S., B. Fox-Kemper, M. Jochum, R. Neale, C. Deser, and G. Meehl, "Will there be a Significant Change to El Nino in the 21st Century?," Journal of Climate, 2011; DOI: 10.1175/JCLI-D-11-00252.1);

Kuhlbrodt et al, 2007 — Kuhlbrodt, T., A. Griesel, M. Montoya, A. Levermann, M. Hofmann, and S. Rahmstorf, On the driving processes of the Atlantic meridional overturning circulation, *Rev. Geophys.*, 45, RG2001, 2007, doi:10.1029/2004RG000166.

Worst Case Scenarios

Bruce, 2011 — Bruce, J. P., March 2011: Climate Change Information for Adaptation – Climate Trends and Projected Values for Canada from 2010 to 2050, Institute for Catastrophic Loss Reduction, 38-40 and 49-51.

7.3 References for Assess Need for New/Updated Flood Risk Mapping

Vasseur and Catto, 2008 — Vasseur, L. and Catto, N. (2008): Atlantic Canada; *in* From Impacts to Adaptation: Canada in a Changing Climate 2007, *edited by* D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, ON, p. 119-170.

7.4 References for Assess Need for Flood Forecasting / Flood Warning System

ESRI, 2010 — ArcGIS. (Updated: May 18, 2010). *Bing Maps Aerial, Hybrid, Road group layer*. Available from http://www.arcgis.com/home/item.html?id=303116b7ebf44f4eb6dcf1648e346f46

GeoBase, 2012 — Canadian Council on Geomatics, GeoBase. (Updated: 2012, March 2). *National Road Network*. Retrieved January 5, 2012 from http://www.geobase.ca/geobase/en/data/nrn/index.html

GeoBase, 2012 — Canadian Council on Geomatics, GeoBase. (Updated: 2012, March 15). *National Hydro Network (NHN)*. Retrieved January 5, 2012 from http://www.geobase.ca/geobase/en/data/nhn/index.html

WRMD, 2011 — Department of Environment and Conservation. (2011). *Badger Water Level Information*. Available from http://www.env.gov.nl.ca/env/waterres/flooding/badger.html

WRMD, 2012 — Department of Environment and Conservation, Flood Risk Mapping Studies/Public information Maps. (Updated January 23, 2012). Available at http://www.env.gov.nl.ca/env/waterres/flooding/frm.html

Statistics Canada, 2012 — Statistics Canada. (2012). *2011 Census of Population – Population by Census Subdivision*. Available from the Newfoundland and Labrador Statistics Agency: http://www.stats.gov.nl.ca/

Tom, 2010 — Tom, Melissa. (2010). *Adapting remotely sensed snow data for daily flow modeling on the Upper Humber River, Newfoundland and Labrador*. Available from http://www.env.gov.nl.ca/env/waterres/flooding/adapting_remotely_sensed_snow_data.pdf

USGS, 2011 — USGS (United States Geological Survey). (September, 2011). *Southeastern New York Tide-Telemetry and Coastal-Flood-Warning System.* Available from http://ny.cf.er.usgs.gov/nyprojectsearch/projects/TideWarning.pdf

USGS, 2012 — USGS (United States Geological Survey). (Updated: 2012, January 25). *Global Data Explorer*. Retrieved December 29, 2011 from http://gdex.cr.usgs.gov/gdex/

Unisys, 2011 — Unisys Weather. (2011). *Hurricane/Tropical Data*. Retrieved March 12, 2012 from http://weather.unisys.com/hurricane/

WRMD, 1992 — Water Resources Division, Department of Environment and Lands, Government of Newfoundland and Labrador. (1992). *Water Resources Atlas of Newfoundland*. Retrieved January 25, 2012 from http://www.env.gov.nl.ca/env/waterres/cycle/hydrologic/atlas.html

8. Appendix A - Prioritization of Communities for New Flood Plain Mapping

Rank	Community Name	LGP#
1	St. John's	4400
2	Noels Pond	3485
3	Burin	725
4	Clarke's Beach	1060
5	Grand Falls-Windsor	1960
6	Marystown	3155
7	Bay Roberts	265
8	Gander	1760
9	Black Duck	420
10	Middle Arm	3210
11	Grand Bank	1940
12	Gambo	1755
13	King's Point	2595
14	Conception Bay South	1145
15	Lawn	2745
16	Trepassey	5145
17	Epworth-Great Salmonier	1545
18	Point Au Gaul	3830
19	Lamaline	2675
20	Long Harbour-Mount Arlington Heights	2970
21	Frenchman's Cove	1710
22	Trinity, T.B.	5155
23	Channel-Port Aux Basque	1025
24	Belleoram	315
25	Dunfield	1455
26	Torbay	5125
27	Clarenville	1055
28	Fortune	1650
29	South River	4835
30	Harbour Grace	2125
31	Rocky Harbour	4245
32	Little St. Lawrence	2885
33	Red Harbour	4143
34	Fox Cove-Mortier	1665
35	Beaches	270
36	Whiteway	5365
37	Random Island West*	4104
38	Witless Bay	5455
39	New-Wes-Valley	165
40	Reidville	4172
41	Hermitage-Sandyville	2265
42	Greenspond	2040
43	St. Lawrence	4435
44	Holyrood	2320
45	Cupids	1280
46	Bonavista	525
47	Lewisporte	2775
48	Pouch Cove	4015
49	Port Au Port East	3940
50	Norman's Cove-Long Cove	3500
51	Lark Harbour	2730
52	Baie Verte	170
53	Parkers Cove	3665
54	Ship Harbour	4680
55	Branch	575
56	Bay L'argent	260
57	Admiral's Beach	20
58	St. Bride's	4345
59	Point May	3865
60	Harbour Mille-Little Ha	2150
61	Fox Harbour	1675
62	Mount Carmel-Mitchell's	3335
63	St. Vincent's-St. Steph	4505
64	Goobies	1885
65	Summerville-Princeton-S	4985
66	Lethbridge	2765
67	King's Cove	2585
68	Bay De Verde	251
69	Cavendish	990
70	Sunnyside	4990
71	Flat Bay	1605
72	Indian Bay	2385
73	Burlington	740
74	Smith's Harbour	4760
75	Rattling Brook	4110
76	Little Bay	2790
77	Forest Field-Newbridge	1637
78	Daniel's Harbour	1315
79	Cape Ray	905
80	Fortune Harbour	1655
81	Lewin's Cove	2770

Rank	Community Name	LGP#
82	Massey Drive	3167
83	Garnish	1780
84	Southern Harbour	4850
85	Terrenceville	5040
86	Irishtown-Summerside	2425
87	Cormack	1195
88	Spaniard's Bay	4860
89	Musgravetown	3385
90	Colliers	1125
91	Upper Island Cove	5215
92	Wabana	5245
93	St. Alban's	4305
94	Harbour Breton	2110
95	Campbellton	830
96	Bay Bulls	245
97	Logy Bay-Middle Cove-Outer Cove	2945
98	Old Perlican	3595
99	Lumsden	3040
100	Hare Bay	2165
101	Dover	1435
102	Musgrave Harbour	3380
103	Point Leamington	3860
104	Springdale	4910
105	St. Lunaire-Griquet	2050
106	Boat Harbour	510
107	Petit Forte	3740
108	Beau Bois	290
109	Jean De Baie	2495
110	Baine Harbour	180
111	Lord's Cove	2995
112	Harricott	2170
113	Grand Le Pierre	1965
114	Riverhead	4215
115	Pynn's Brook	4065
116	Gillams	1825
117	North Harbour	3530
118	North Harbour	3530
119	St. Mary's	4455
120	St. Joseph's, S.M.B.	4415
121	St. Bernards-Jacques Fo	4335
122	English Harbour East	1530
123	Little Rapids	2882

Rank	Community Name	LGP#
124	Portland Creek	3995
125	Cow Head	1230
126	Swift Current	5005
127	Small Point-Broad Cove-	4755
128	Garden Cove	1775
129	Port Blandford	3945
130	Bristols Hope	520
131	Caplin Cove	935
132	Makinsons	3105
133	Marysvale	3165
134	Roache's Line	4225
135	Bryant's Cove	680
136	Harbour Main-Chapel's Cove	2145
137	Wild Cove	5390
138	Hampden	2090
139	Bunyan's Cove	710
140	Canning's Cove	845
141	Charleston	1040
142	Monkstown	3285
143	Southeast Bight	4825
144	Duntara	1460
145	Grate's Cove	1975
146	Red Head Cove	4150
147	Seal Cove, W.B.	4605
148	Petites	3745
149	St. Jacques-Coomb's Cov	4385
150	Seal Cove, F.B.	4600
151	Norris Arm North	3510
152	Pool's Cove	3895
153	Chapel Arm	1030
154	George's Brook-Milton	1800
155	Green's Harbour	2015
156	Hopeall	2335
157	Mobile	3275
158	New Harbour	3415
159	Old Shop	3600
160	Trouty	5180
161	New Perlican	3435
162	Little Catalina	2830
163	Bay St. George South	268
164	Benoit's Siding	340
165	Georges Lake	1807

Rank	Community Name	LGP#
166	Gallants	1750
167	Hillview - Adeytown	2305
168	New Chelsea-Lead Cove	3405
169	Heart's Content	2240
170	Port Rexton	3965
171	Chance Cove	1010
172	Heart's Desire	2250
173	Elliston	1510
174	Ramea	4100
175	Boswarlos	546
176	Fox Island River-Point	1681
177	Three Rock Cove	5090
178	Woody Point	5490
179	Port Au Port West-Aguat	3941
180	Terra Nova	5035
181	Sandringham	4545
182	Deadman's Bay	1350
183	Roddickton	4250
184	Snook's Arm	4770
185	Fleur De Lys	1620
186	Hawke's Bay	2205
187	Lascie	2735
188	Nippers Harbour	3475
189	Coachman's Cove	1095
190	Francois	1695
191	Black Duck Cove	430
192	Ming's Bight	3265
193	Brent's Cove	580
194	Pacquet	3645
195	Raleigh	4095
196	Glovers Harbour	1860
197	Harry's Harbour	2190
198	Horwood	2360
199	Brighton	610
200	Beachside	272
201	Great Brehat	1985
202	St. Carols	4350
203	Paradise	3655
204	Mount Moriah	3340
205	Pasadena	3685
206	Meadows	3175
207	Humber Arm South	335
208	Arnold's Cove	110
209	North River	3541
210	Avondale	125
211	Conception Harbour	1148
212	Burnt Islands	775
213	Isle Aux Morts	2450
214	Buchans	685
215	Birchy Bay	375
216	Embree	1515
217	Botwood	550
218	Summerford	4975
219	Twillingate	5195
220	Norris Arm	3505
221	Peterview	3735
222	Flatrock	1610
223	Cape Broyle	860
224	Burgeo	715
225	Cape St. George	916
226	Norris Point	3515
227	St. George's	4380
228	Lourdes	3006
229	Carmanville	960
230	Fogo	1630
231	Port Au Choix	3935
232	Port Saunders	3975
233	Englee	1520
234	Robert's Arm	4230
235	St. Anthony	4320
236	Brookside	660
237	Salmonier	4530
238	Spanish Room	4870
239	Winterland	5445
240	Corbin	1190
241	Rock Harbour	4240
242	Taylors Bay	5010
243	Hughes Brook	2373
244	Cuslett	1305
245	Fairhaven	1560
246	Grand Beach	1950
247	Great Barasway	1980
248	Patrick's Cove-Angel's	3690
249	Point Verde	3880
250	Turks Water	5190
251	Point Lance	3855

Rank	Community Name	LGP#
252	Little Bay East	2800
253	Colinet	1120
254	St. Shott's	4485
255	Humber Village	2380
256	St. Judes	4421
257	River Of Ponds	4220
258	Howley	2370
259	Bellburns	305
260	Sally's Cove	4550
261	Little Harbour East	2850
262	Mall Bay	3115
263	Markland	3145
264	O'donnells	3585
265	Gaskiers-Point La Haye	1785
266	Three Mile Rock	5085
267	Mcivers	3065
268	St. Pauls	4475
269	Brooklyn	650
270	Knights Cove	2630
271	Morley's Siding	3309
272	Stock Cove	4955
273	Winter Brook	5425
274	Plate Cove East	3812
275	Plate Cove West	3814
276	Bareneed	195
277	Brigus Junction	616
278	Emerald Vale	1518
279	Georgetown	1820
280	Gould's Road	1920
281	Juniper Stump	2545
282	Kingston	2605
283	Port De Grave	3950
284	Western Bay	5320
285	Bauline	240
286	Bishop's Cove	400
287	Pollard's Point	3886
288	Purbecks Cove	4050
289	Diamond Cove	1390
290	Birchy Cove	380
291	Bloomfield	485
292	Charlottetown	1047
293	Jamestown	2490
294	Lower Amherst Cove	3015

Rank	Community Name	LGP#
295	Middle Amherst Cove	3200
296	Newman's Cove	3445
297	Open Hall-Red Cliffe	3605
298	Portland	3990
299	Red Island	4155
300	Sweet Bay	5000
301	Tickle Cove	5092
302	Upper Amherst Cove	5200
303	Keels	2565
304	Blow Me Down	490
305	Burnt Point	795
306	Freshwater	1720
307	Freshwater	1720
308	Hibbs Cove	2275
309	Job's Cove	2530
310	Lance Cove	2680
311	Long Beach	2954
312	Low Point	3010
313	Lower Island Cove	3030
314	Ochre Pit Cove	3575
315	Perry's Cove	3720
316	The Dock	5043
317	George's Cove	1805
318	Sop's Arm	4791
319	Westport	5335
320	Fox Roost-Margaree	1685
321	Grand Bruit	1955
322	La Poile	2725
323	Jackson's Arm	2475
324	Rose Blanche-Harbour Le Cou	4265
325	Buchans Junction	690
326	Millertown	3240
327	Boyd's Cove	560
328	Bridgeport	595
329	Brown's Arm	670
330	Kettle Cove	2570
331	Laurenceton	2740
332	Loon Bay	2985
333	Newville	3463
334	Phillip's Head	3765
335	Porterville	3985
336	Purcell's Harbour	4055

Rank	Community Name	LGP#
337	Ragged Point	4090
338	Stanhope	4930
339	Too Good Arm	5115
340	Wooddale	5460
341	Northern Arm	3560
342	Point Of Bay	3870
343	Rencontre East	4120
344	Cottlesville	1205
345	Milltown-Head Of Bay D'	3245
346	Chanceport	1015
347	Cobb's Arm	1100
348	Conne River	1155
349	Fairbanks-Hillgrade	1552
350	Green Cove	2010
351	Herring Neck	2270
352	Indian Cove	2390
353	Little Harbour	2860
354	Merritt's Harbour	3190
355	Michaels Harbour	3195
356	Moreton's Harbour	3305
357	Pike's Arm	3781
358	Port Albert	3910
359	Sandy Point	4570
360	St. Joseph's Cove-St. V	4420
361	Tizzard's Harbour	5100
362	Valley Pond	5220
363	Virgin Arm-Carter's Cov	5235
364	Baytona	266
365	Comfort Cove-Newstead	1140
366	Crow Head	1270
367	Little Burnt Bay	2825
368	Morrisville	3310
369	Gaultois	1790
370	Portugal Cove South	4005
371	Admirals Cove	25
372	Blaketown	475
373	Burgoyne's Cove	720
374	Burnt Cove-St.Michael	750
375	Champneys East	1000
376	Champneys West	1005
377	Dildo	1395
378	Harcourt-Monroe-Watervi	2160
379	Lockston	2920

Rank	Community Name	LGP#
380	North West Brook	3550
381	South Dildo	4820
382	St. Jones Within	4405
383	Tors Cove	5130
384	Turks Cove	5185
385	Port Kirwan	3962
386	Renews-Cappahayden	4185
387	Aquaforte	100
388	Biscay Bay	395
389	Barachois Brook	65
390	Coal Brook	1097
391	Doyles	1440
392	Fishells	1585
393	Flat Bay Brook River	1606
394	Great Codroy	1990
395	Journois	2540
396	Maidstone	3075
397	Millville	3255
398	O'regans East	3587
399	South Branch	4805
400	St. Andrew's	4310
401	St. Teresa	4495
402	Tompkins	5110
403	Upper Ferry	5205
404	Woodville	5475
405	Black Duck Brook-Winter	425
406	West Bay	5295
407	Bellevue	330
408	Bellevue Beach	332
409	Brigus South	617
410	Britannia	625
411	Calvert	820
412	Daniels Cove	1310
413	Deep Bight	1365
414	English Harbour	1525
415	Hatchet Cove	2200
416	Little Hearts Ease	2870
417	Lower Lance Cove	3035
418	New Bonaventure	3395
419	Old Bonaventure	3590
420	Petley	3750
421	Queen's Cove	4070
422	Spillar's Cove	4880

Rank	Community Name	LGP#
423	Thornlea	5045
424	Trinity East	5150
425	Fermeuse	1575
426	Cape Anguille	850
427	Loch Lomond	2915
428	Mattis Point	3170
429	Searston	4610
430	Campbell's Creek	825
431	Mainland	3101
432	Piccadilly Head	3771
433	Piccadilly Slant-Abra	3773
434	Sheaves Cove	4655
435	Ship Cove-Lower Cove	4665
436	Wiltondale	5410
437	York Harbour	5495
438	Glenburnie-Birchy Head-	1845
439	Capstan Island	945
440	L'anse Au Loup	2715
441	Forteau	1645
442	L'anse Au Clair	2700
443	Red Bay	4125
444	West St. Modeste	5310
445	Pinware	3795
446	Sandy Cove, B.B.	4515
447	Burnside- St. Chad's	745
448	Culls Harbour	1275
449	Eastport	1490
450	Traytown	5135
451	Happy Adventure	2100
452	Salvage	4540
453	St. Brendan's	4340
454	Aspen Cove	120
455	Cape Freels North	875
456	Ladle Cove	2640
457	Noggin Cove	3490
458	Centreville-Wareham-Tri	993
459	Seldom-Little Seldom	4630
460	Joe Batt's Arm-Barr'd Island	2535
461	Tilting	5095
462	Fogo Island Region	1635
463	Bartlett's Harbour	215
464	Grey River	2045
465	Barr'd Harbour	

Rank	Community Name	LGP#
466	Big Brook	355
467	Blue Cove	495
468	Castor River North	980
469	Castors River South	981
470	Eddies Cove	1496
471	Forrester's Point	1640
472	Green Island Brook	2025
473	Harbour Round	2155
474	Nameless Cove	3393
475	Plum Point	3825
476	Round Harbour	4275
477	Sheppardville	4657
478	Shoal Cove East	4700
479	Flower's Cove	1625
480	Woodstock	5470
481	Bear Cove	280
482	Brig Bay	605
483	Cape Onion	4675
484	Deadman's Cove	1355
485	Eddies Cove West	1500
486	Green Island Cove	2030
487	Hay Cove	2210
488	L'anse Aux Meadows	2720
489	Noddy Bay	3480
490	North Boat Harbour	3520
491	Pidgeon Cove-St. Barbe	3779
492	Pines Cove	3790
493	Pond Cove	3890
494	Reef's Harbour/Shoal Co	4165
495	Ship Cove	4670
496	Shoal Cove West	4705
497	Anchor Point	35
498	Savage Cove-Sandy Cove	4590
499	Bird Cove	390
500	Bide Arm	350
501	Cook's Harbour	1165
502	Tilt Cove	5094
503	Mccallum	3055
504	Benton	345
505	Coffee Cove	1109
506	Cottrell's Cove	1210
507	Gander Bay South	1770
508	Moore's Cove	3295

Rank	Community Name	LGP#
509	Pleasantview	3820
510	St. Patrick's	4470
511	Port Anson	3920
512	Leading Tickles	2755
513	Frederickton	1700
514	Gander Bay North	1765
515	Jackson's Cv-Langdon's	2480
516	Main Point-Davidsville	1335
517	Stoneville	4965
518	Triton-Jim's Cove-Card'	5170
519	South Brook	4810
520	Pilley's Island	3785
521	Lushes Bight-Beaumont-B	3050
522	Miles Cove	3230
523	Change Islands	1020
524	Little Bay Islands	2805
525	Croque	1255
526	St. Anthony Bight	4325
527	Main Brook	3085
528	Quirpon	4075
529	St. Juliens	4425
530	Conche	1150

9. Appendix B Sub-region Communities

Corner Brook

CORNER BROOK
COX'S COVE
GILLAMS
HUGHES BROOK
HUMBER ARM SOUTH
IRISHTOWN-SUMMERSIDE
LARK HARBOUR
MASSEY DRIVE
MCIVERS
MEADOWS
MOUNT MORIAH
YORK HARBOUR

West-1

ANCHOR POINT
BAIE VERTE
BARR'D HARBOUR
BARTLETT'S HARBOUR
BEACHES
BEAR COVE
BELLBURNS
BIDE ARM
BIG BROOK
BIRD COVE
BLACK DUCK COVE
BLUE COVE
BRENT'S COVE
BRIG BAY
BURLINGTON
CAPE ONION
CASTOR RIVER NORTH
CASTORS RIVER SOUTH
COACHMAN'S COVE
CONCHE
COOK'S HARBOUR
COW HEAD
CROQUE
DANIEL'S HARBOUR
DEADMAN'S COVE
EDDIES COVE
EDDIES COVE WEST
ENGLEE
FLEUR DE LYS
FLOWER'S COVE
FORRESTER'S POINT
GEORGE'S COVE
GLENBURNIE-BIRCHY HEAD-
GREAT BREHAT
GREEN ISLAND BROOK
GREEN ISLAND COVE
HAMPDEN
HARBOUR ROUND
HAWKE'S BAY
HAY COVE
JACKSON'S ARM
L'ANSE AUX MEADOWS
LASCIE
MAIN BROOK
MIDDLE ARM
MING'S BIGHT
NAMELESS COVE
NIPPERS HARBOUR
NODDY BAY
NORRIS POINT
NORTH BOAT HARBOUR
PACQUET
PARSON'S POND
PIDGEON COVE-ST. BARBE
PINES COVE
PLUM POINT
POLLARD'S POINT
POND COVE
PORT AU CHOIX
PORT SAUNDERS
PORTLAND CREEK
PURBECKS COVE
QUIRPON
RALEIGH
REEF'S HARBOUR/SHOAL CO
RIVER OF PONDS
ROCKY HARBOUR
RODDICKTON
ROUND HARBOUR
SALLY'S COVE
SAVAGE COVE-SANDY COVE
SEAL COVE, W.B.
SHIP COVE
SHOAL COVE EAST
SHOAL COVE WEST
SMITH'S HARBOUR
SNOOK'S ARM
SOP'S ARM
ST. ANTHONY
ST. ANTHONY BIGHT
ST. CAROLS
ST. JULIENS
ST. LUNAIRE-GRIQUET
ST. PAULS
THREE MILE ROCK
TILT COVE
TROUT RIVER
WESTPORT
WILD COVE
WOODSTOCK
WOODY POINT

West-2

BENOIT'S SIDING
BLACK DUCK
COAL BROOK
COLD BROOK
CORMACK
DEER LAKE

FOX ISLAND RIVER-POINT
GALLANTS
GEORGES LAKE
HOWLEY
HUMBER VILLAGE
LITTLE RAPIDS
NOELS POND
PASADENA
PYNN'S BROOK
REIDVILLE
SHEPPARDVILLE
SOUTH BRANCH
ST. JUDES
STEADY BROOK
WILTONDALE

West-3

BARACHOIS BROOK
BAY ST. GEORGE SOUTH
BLACK DUCK BROOK-WINTER
BOSWARLOS
CAMPBELL'S CREEK
CAPE ANGUILLE
CAPE RAY
CAPE ST. GEORGE
CODROY
DOYLES
FISHELLS
FLAT BAY
FLAT BAY BROOK RIVER
GREAT CODROY
JOURNOIS
KIPPENS
LOCH LOMOND
LOURDES
MAIDSTONE
MAINLAND
MATTIS POINT
MILLVILLE
O'REGANS EAST
PICCADILLY HEAD
PICCADILLY SLANT-ABRA
PORT AU PORT EAST
PORT AU PORT WEST-AGUAT
SEARSTON
SHEAVES COVE
SHIP COVE-LOWER COVE
ST. ANDREW'S
ST. GEORGE'S
ST. TERESA
STEPHENVILLE
STEPHENVILLE CROSSING
THREE ROCK COVE
TOMPKINS
UPPER FERRY
WEST BAY
WOODVILLE

West-4

BURGEO
BURNT ISLANDS
CHANNEL-PORT AUX
BASQUE
DIAMOND COVE
FOX ROOST-MARGAREE
FRANCOIS
GRAND BRUIT
GREY RIVER
ISLE AUX MORTS
LA POILE
PETITES
RAMEA
ROSE BLANCHE-HARBOUR
LE COU

Central-1

ASPEN COVE
BAYTONA
BEACHSIDE
BIRCHY BAY
BOTWOOD
BOYD'S COVE
BRIDGEPORT
BRIGHTON
BROWN'S ARM
BUCHANS
BURNSIDE- ST. CHAD'S
CAMPBELLTON
CAPE FREELS NORTH
CARMANVILLE
CENTREVILLE-WAREHAM-TRI
CHANCEPORT
CHANGE ISLANDS
COBB'S ARM
COFFEE COVE
COMFORT COVE-NEWSTEAD
COTTLESVILLE
COTTRELL'S COVE
CROW HEAD
CULLS HARBOUR
DEADMAN'S BAY
DOVER
EASTPORT
EMBREE
FAIRBANKS-HILLGRADE
FOGO
FOGO ISLAND REGION
FORTUNE HARBOUR
FREDERICKTON
GAMBO
GANDER BAY NORTH
GANDER BAY SOUTH
GLOVERS HARBOUR
GLOVERTOWN
GREEN COVE
GREENSPOND
HAPPY ADVENTURE
HARE BAY
HARRY'S HARBOUR
HERRING NECK
HORWOOD

INDIAN BAY
INDIAN COVE
JACKSON'S CV-LANGDON'S
JOE BATT'S ARM-BARR'D
ISLAND
KETTLE COVE
KING'S POINT
LADLE COVE
LAURENCETON
LEADING TICKLES
LEWISPORTE
LITTLE BAY
LITTLE BAY ISLANDS
LITTLE BURNT BAY
LITTLE HARBOUR
LOON BAY
LUMSDEN
LUSHES BIGHT-BEAUMONT-B
MAIN POINT-DAVIDSVILLE
MERRITT'S HARBOUR
MICHAELS HARBOUR
MILES COVE
MORETON'S HARBOUR
MUSGRAVE HARBOUR
NEW-WES-VALLEY
NOGGIN COVE
NORRIS ARM
NORRIS ARM NORTH
NORTHERN ARM
PETERVIEW
PHILLIP'S HEAD
PIKE'S ARM
PILLEY'S ISLAND
PLEASANTVIEW
POINT LEAMINGTON
PORT ALBERT
PORTERVILLE
PURCELL'S HARBOUR
RAGGED POINT
ROBERT'S ARM
SALVAGE
SANDRINGHAM
SANDY COVE, B.B.
SANDY POINT
SELDOM-LITTLE SELDOM
SOUTH BROOK
SPRINGDALE
ST. BRENDAN'S
ST. PATRICK'S
STANHOPE
STONEVILLE
SUMMERFORD
TILTING
TIZZARD'S HARBOUR
TOO GOOD ARM
TRAYTOWN
TRITON-JIM'S COVE-CARD'
TWILLINGATE
VIRGIN ARM-CARTER'S COV

Central-2

APPLETON
BADGER
BENTON
BISHOP'S FALLS
BUCHANS
BUCHANS JUNCTION
GANDER
GLENWOOD
GRAND FALLS-WINDSOR
MILLERTOWN
TERRA NOVA
WOODDALE

Central-3

HARBOUR BRETON
HERMITAGE-SANDYVILLE
McCALLUM
MILLTOWN-HEAD OF BAY D'
MORRISVILLE
POOL'S COVE
RENCONTRE EAST
SEAL COVE, F.B.
ST. ALBAN'S
ST. JACQUES-COOMB'S COV
ST. JOSEPH'S COVE-ST. V

East-1

BAINE HARBOUR
BAY L'ARGENT
BEAU BOIS
BIRCHY COVE
BLOOMFIELD
BOAT HARBOUR
BONAVISTA
BRITANNIA
BROOKLYN
BROOKSIDE
BUNYAN'S COVE
BURGOYNE'S COVE
BURIN
CANNING'S COVE
CHAMPNEYS EAST
CHAMPNEYS WEST
CHARLESTON
CHARLOTTETOWN
CLARENVILLE
CORBIN
DEEP BIGHT
DUNFIELD
DUNTARA
ELLISTON
ENGLISH HARBOUR
ENGLISH HARBOUR EAST
EPWORTH-GREAT
SALMONIER
FORTUNE
FOX COVE-MORTIER
FRENCHMAN'S COVE
GARDEN COVE
GARNISH

GEORGE'S BROOK-MILTON
GOOBIES
GRAND BANK
GRAND BEACH
GRAND LE PIERRE
HARBOUR MILLE-LITTLE HA
HARCOURT-MONROE-WATERVI
HATCHET COVE
HICKMAN'S HARBOUR
HILLVIEW - ADEYTOWN
HODGE'S COVE
JAMESTOWN
JEAN DE BAIE
KEELS
KING'S COVE
KNIGHTS COVE
LAMALINE
LAWN
LETHBRIDGE
LEWIN'S COVE
LITTLE BAY EAST
LITTLE CATALINA
LITTLE HARBOUR EAST
LITTLE HEARTS EASE
LITTLE ST. LAWRENCE
LOCKSTON
LORD'S COVE
LOWER AMHERST COVE
LOWER LANCE COVE
MARYSTOWN
MIDDLE AMHERST COVE
MONKSTOWN
MORLEY'S SIDING
MUSGRAVETOWN
NEW BONAVENTURE
NEWMAN'S COVE
NORTH HARBOUR
NORTH WEST BROOK
OLD BONAVENTURE
OPEN HALL-RED CLIFFE
PARKERS COVE
PETIT FORTE
PETLEY
PLATE COVE EAST
PLATE COVE WEST
POINT AU GAUL
POINT MAY
PORT BLANDFORD
PORT REXTON
PORTLAND
QUEEN'S COVE
RANDOM ISLAND WEST*
RED HARBOUR
RED ISLAND
ROCK HARBOUR
RUSHOON
SALMONIER
SOUTHEAST BIGHT
SPANISH ROOM
SPILLAR'S COVE
ST. BERNARDS-JACQUES FO
ST. JONES WITHIN
ST. LAWRENCE
STOCK COVE
SUMMERVILLE-PRINCETON-S
SWEET BAY
SWIFT CURRENT
TAYLORS BAY
TERRENCEVILLE
TICKLE COVE
TRINITY EAST
TRINITY, T.B.
TROUTY
UPPER AMHERST COVE
WINTER BROOK
WINTERLAND

East-2

ADMIRAL'S BEACH
ADMIRALS COVE
AQUAFORTE
ARNOLD'S COVE
AVONDALE
BARENEED
BAY BULLS
BAY DE VERDE
BAY ROBERTS
BELLEVUE
BELLEVUE BEACH
BISCAY BAY
BISHOP'S COVE
BLAKETOWN
BLOW ME DOWN
BRANCH
BRIGUS
BRIGUS JUNCTION
BRIGUS SOUTH
BRISTOLS HOPE
BRYANT'S COVE
BURNT COVE-ST.MICHAEL
BURNT POINT-GULL ISLAND-NORTHERN BAY
CALVERT
CAPE BROYLE
CAPLIN COVE
CARBONEAR
CAVENDISH
CHANCE COVE
CHAPEL ARM
CLARKE'S BEACH
COLINET
COLLIERS
CONCEPTION HARBOUR
CUPIDS
CUSLETT
DANIELS COVE
DILDO
EMERALD VALE
FAIRHAVEN
FERMEUSE
FERRYLAND
FOREST FIELD-NEWBRIDGE
FOX HARBOUR
FRESHWATER
GASKIERS-POINT LA HAYE
GEORGETOWN
GOULD'S ROAD
GRATE'S COVE
GREAT BARASWAY

GREEN'S HARBOUR
HANT'S HARBOUR
HARBOUR GRACE
HARRICOTT
HEART'S CONTENT
HEART'S DELIGHT-ISLINGT
HEART'S DESIRE
HIBBS COVE
HOLYROOD
HOPEALL
JOB'S COVE
JUNIPER STUMP
KINGSTON
LONG BEACH
LONG HARBOUR-MOUNT ARLINGTON HEIGHTS
LOW POINT
LOWER ISLAND COVE
MAKINSONS
MALL BAY
MARKLAND
MARYSVALE
MOBILE
MOUNT CARMEL-MITCHELL'S
MOUNT PEARL
NEW CHELSEA-LEAD COVE
NEW HARBOUR
NEW PERLICAN
NORMAN'S COVE-LONG COVE
NORTH HARBOUR
NORTH RIVER
OCHRE PIT COVE
O'DONNELLS
OLD PERLICAN
OLD SHOP
PATRICK'S COVE-ANGEL'S
PERRY'S COVE
PLACENTIA
POINT LANCE
POINT VERDE
PORT DE GRAVE
PORTUGAL COVE SOUTH
RED HEAD COVE
RENEWS-CAPPAHAYDEN
RIVERHEAD
SALMON COVE
SALMONIER
SHIP HARBOUR
SMALL POINT-BROAD COVE-
SOUTH DILDO
SOUTH RIVER
SOUTHERN HARBOUR
SPANIARD'S BAY
ST. BRIDE'S
ST. JOSEPH'S, S.M.B.
ST. MARY'S
ST. SHOTT'S
ST. VINCENT'S-ST. STEPH
SUNNYSIDE
THE DOCK
THORNLEA
TORS COVE
TREPASSEY
TURKS COVE
TURKS WATER
UPPER ISLAND COVE
VICTORIA
WESTERN BAY
WHITBOURNE
WHITEWAY
WINTERTON
WITLESS BAY

St John’s

BAULINE
CONCEPTION BAY SOUTH
FLATROCK
FRESHWATER
LANCE COVE
LOGY BAY-MIDDLE COVE-OUTER COVE
MOUNT PEARL
PARADISE
PETTY HARBOUR-MADDOX CO
PORTUGAL COVE-ST. PHILI
POUCH COVE
ST. JOHN'S
TORBAY
WABANA

10. Appendix C Flood Inventory Report

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
1	001	Waterford River Basin	1950	10	31		1950	11	1		2	Fall	Eastern	4400	St. John's	Waterford River	Rainfall	77										Over 77mm of rainfall in 2 days led to general overbank flooding, particularly in Bowering Park	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
2	002	Torbay, Waterford River Basin	1951	4	10		1951	4	12		3	Spring	Eastern	5125	Torbay	Waterford River / Rennie's River / Quidi Vidi River	Rainfall	170										MR: Heavy rainfall raised local lakes to remarkably high elevations. City streets were washed out, houses flooded and blocked traffic	MR: Flood Risk Mapping Study of Goulds, Petty Harbour and Ferryland, Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
3	002	Torbay, Waterford River Basin	1951	4	10		1951	4	13		3	Spring	Eastern	4400	St. John's	Waterford River / Rennie's River / Quidi Vidi River	Rainfall	170										MR: Heavy rainfall raised local lakes to remarkably high elevations. City streets were washed out, houses flooded and blocked traffic	MR: Flood Risk Mapping Study of Goulds, Petty Harbour and Ferryland, Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
4	003	Waterford River Basin	1951	11	4		1951	11	5		1	Fall	Eastern	4400	St. John's	Waterford River	Flash Flood	44										Some sections of the city were inundated as a result of blocked storm drains and culverts.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
5	004	Waterford River Basin	1951	11	30		1951	12	1		1	Fall	Eastern	4400	St. John's	Waterford River	Rainfall	73										Rainfall over a 2 day period caused flooding at St. John's Bridge and Waterford Bridge	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
6	005	Stephenville Crossing	1951	12	18		1951	12	19		1	Fall	Western	4950	Stephenville Crossing		Coastal Flooding										600	MR: Storm washed out rail bed and 15 telephone poles blown down. Streets were flooded and there was interior damages to several homes. Damage was also reported at Summerside, Bay of Islands and many fisherman lost boats and gear.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website, Department of Natural Resources Website	307	AMEC
7	005	Stephenville Crossing	1951	12	18		1951	12	19		1	Fall	Western	4985	Summerside		Coastal Flooding										600	MR: Storm washed out rail bed and 15 telephone poles blown down. Streets were flooded and there was interior damages to several homes. Damage was also reported at Summerside, Bay of Islands and many fisherman lost boats and gear.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website, Department of Natural Resources Website	307	AMEC
8	006	St. John's	1952	2	6		1952	2	7		1	Winter	Eastern	4400	St. John's		Rainfall	32.8										Torrential rains and inadequate storm sewers caused flooding problems	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
9	007	West Coast	1952	2	28		1952	2	29		1	Winter	Western	1025	Port aux Basques		Rainfall											A washout around the Port aux Basque area halted trains	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
10	008	Burin Peninsula	1952	11	5		1952	11	6		1	Fall	Eastern		Allan's Island		Coastal Flooding											MR: The approaches to a bridge at Allan's Island were washed out. A small bridge was washed inland about 100 ft	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
11	008	Burin Peninsula	1952	11	5		1952	11	6		1	Fall	Eastern	1545	Epworth		Coastal Flooding											MR: The approaches to a bridge at Allan's Island were washed out. A small bridge was washed inland about 100 ft	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
12	009	St. John's	1953	10	6		1953	10	7		1	Fall	Eastern	4400	St. John's		Rainfall	111										Heavy rainfall in one day filled Southside Hills gullies but only caused minor problems	Waterford River Area - Hydro technical Study, Dept of Natural Resources Website	303	AMEC
13	010	St. John's	1953	12	26		1953	12	27		1	Winter	Eastern	4400	St. John's		Rainfall	85.1										Rainfall caused destruction of Steady Waters Bridge, washouts at, Mundy Pond brook overflowed flooding Victoria Park	Waterford River Area - Hydro technical Study	No	AMEC
14	011	St. John's	1954	3	10		1954	3	11		1	Winter	Eastern	4400	St. John's	Long Pond / Rennie's River	Rainfall	80										Many basements flooded and some city streets were turned into rivers	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
15	012	St. John's	1954	12	7		1954	12	8		1	Fall	Eastern	4400	St. John's		Rainfall	28.4										Heavy rains sent water cascading down the Southside Hills flooding basements and some residents were temporarily out of their homes	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
16	013	Corner Brook	1954	12	20		1954	12	N/A		1	Winter	Western	1200	Corner Brook		Rainfall	65.8										Street flooded and 12 basements reported flooding.	Department of Natural Resources Website	13	AMEC
17	014	East Coast, St. John's and Carbonear	1955	1	10		1955	1	10		1	Winter	Eastern	4400	St. John's		Coastal Flooding					$12,000						MR: The "worst storm in memory" battered the East Coast. Surging waves sent water 200 feet in the air against the steep cliffs around St. John's Harbour. 12 wharves and two small boats were destroyed. General damages were said to be extensive	MR: Department of Natural Resources Website, The Daily News|	14	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (If known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
18	014	East Coast, St. John's and Carbonear	1955	1	10		1955	1	10		1	Winter	Eastern	1580	Ferryland		Coastal Flooding					$12,000						MR: The "worst storm in memory" battered the East Coast. Surging waves sent water 200 feet in the air against the steep cliffs around St. John's Harbour. 12 wharves and two small boats were destroyed. General damages were said to be extensive	MR: Department of Natural Resources Website, The Daily News|	14	AMEC
19	014	East Coast, St. John's and Carbonear	1955	1	10		1955	1	10		1	Winter	Eastern	950	Carbonear		Coastal Flooding					$12,000						MR: The "worst storm in memory" battered the East Coast. Surging waves sent water 200 feet in the air against the steep cliffs around St. John's Harbour. 12 wharves and two small boats were destroyed. General damages were said to be extensive	MR: Department of Natural Resources Website, The Daily News|	14	AMEC
20	014	East Coast, St. John's and Carbonear	1955	1	10		1955	1	10		1	Winter	Eastern	265	Bay Roberts		Coastal Flooding					$12,000	$12,000					MR: The "worst storm in memory" battered the East Coast. Surging waves sent water 200 feet in the air against the steep cliffs around St. John's Harbour. 12 wharves and two small boats were destroyed. General damages were said to be extensive	MR: Department of Natural Resources Website, The Daily News|	14	AMEC
21	015	St. John's	1955	1	4		1955	1	17		12	Winter	Eastern	4400	St. John's		Rainfall	164.6										Scores of new homes had flooded basements as a result of continuous rainfall	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
22	016	St. John's	1955	2	12		1955	2	13		1	Winter	Eastern	4400	St. John's	Waterford / Rennie's River	Rainfall	51.1										MR: Flooding reported at the mouth of Old Mill Bridge. Flooding reported.	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
23	016	St. John's	1955	2	12		1955	2	13		1	Winter	Eastern	3275	Mobile	Waterford / Rennie's River	Rainfall											MR: Flooding reported at the mouth of Old Mill Bridge. Flooding reported.	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
24	017	Placentia	1955	9	N/A		1955	9	N/A		N/A	Fall	Eastern	3800	Placentia		unknown												Hydro technical Study of the Placentia Area Flood Plain	No	AMEC
25	018	East Coast	1955	10	22		1955	10	22		1	Fall	Eastern	4400	St. John's		Coastal Flooding											MR: Stages were damaged in Petty Harbour and along the Southern Shore. The lowlands were flooded with seawater, the road near Cappahayden was washed out. high winds and waves and water levels generated by a nameless hurricane damaged stages at Petty Harbour.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
26	018	East Coast	1955	10	22		1955	10	22		1	Fall	Eastern	1580	Ferryland		Coastal Flooding											MR: Stages were damaged in Petty Harbour and along the Southern Shore. The lowlands were flooded with seawater, the road near Cappahayden was washed out. high winds and waves and water levels generated by a nameless hurricane damaged stages at Petty Harbour.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
27	018	East Coast	1955	10	22		1955	10	22		1	Fall	Eastern	3760	Petty Harbour - Maddox Cove		Coastal Flooding											MR: Stages were damaged in Petty Harbour and along the Southern Shore. The lowlands were flooded with seawater, the road near Cappahayden was washed out. high winds and waves and water levels generated by a nameless hurricane damaged stages at Petty Harbour.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
28	019	Cox's Cove	1955	11	27		1955	11	27		1	Fall	Western	1235	Cox's Cove	Cox's Brook	Coastal Flooding	35										Coastal flooding coupled with increased stream runoff damaged community. 30 to 40 mm of rain.	Heritage Newfoundland Website, Dept of Natural Resources Website	19, 286	AMEC
29	020	Corner Brook	1957	1	23		1957	1	24		2	Winter	Western	1200	Corner Brook		Rainfall	40.13										Low lying sections of the city began to fill with water as blocked sewers and high snow ban, damage to several roads.	Dept Natural Resources Website	20	AMEC
30	021	St. John's	1957	2	15		1957	2	17		1	Winter	Eastern	4400	St. John's		Rainfall and Snowmelt	65										Sections of streets washed out, basements in several homes and businesses were flooded.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
31	022	Corner Brook	1957	10	2		1957	10	3		1	Fall	Western	1200	Corner Brook	Bell's Brook	Rainfall	91.19										During a rainstorm several catch basins were not cleared causing streets to become eroded and washed out. At least 12 basements were flooded and the bridge over Bells Brook was damaged	Dept Natural Resources Website	22	AMEC
32	023	Corner Brook	1957	11	9		1957	11	9		1	Fall	Western	1200	Corner Brook		Rainfall	41.91										Several sections of the roads in town were washed out and severely damaged	Dept Natural Resources Website	23	AMEC
33	024	St. John's	1959	11	1		1959	11	2		1	Fall	Eastern	4400	St. John's		Rainfall	83.6										Wind damages in St. John's area, reporting's showed about 2 feet of water over a road in the west end of the city, near stamps lane	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
34	025	St. John's	1959	11	10		1959	11	11		1	Fall	Eastern	4400	St. John's		Rainfall	70										Intense rainfall caused overbank flows and flooding in low lying areas on the Avalon Peninsula	Waterford River Area - Hydro technical Study	No	AMEC
35	026	St. John's	1960	10	17		1960	10	18		2	Fall	Eastern	4400	St. John's		Rainfall	75.2										Some areas had up to 2feet of water, the storm was described as the heaviest rainfall for a single day in seven years	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
36	027	St. John's	1961	3	21		1961	3	22		2	Spring	Eastern	4400	St. John's		Rainfall and Snowmelt	39.4	355.6									Flooding occurred in some sections of the city, stamps lane and other sections reported flooding.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
37	028	East Coast, St. John's and Carbonear	1961	4	5		1961	4	6		1	Spring	Eastern	950	Carbonear		Ice Jam											MR: An ice jam at the piers of an abandoned railway caused a backup which inundated a warehouse in Carbonear. Flooded farmland in Bonavista South area, one farmer was reported as leaving after his property was inundated.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
38	028	East Coast, St. John's and Carbonear	1961	4	5		1961	4	6		1	Spring	Central	2765	Lethbridge		Ice Jam											MR: An ice jam at the piers of an abandoned railway caused a backup which inundated a warehouse in Carbonear. Flooded farmland in Bonavista South area, one farmer was reported as leaving after his property was inundated.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
39	029	Avalon Peninsula	1962	2	10		1962	2	11		2	Winter	Eastern	2145	Lakeview/Harbour Main		Rainfall and Snowmelt	62										Many homes in the Lakeview area were reported to be damaged	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
40	030	Central Newfoundland	1962	3	2		1962	3	5		3	Winter	Central	1055	Clarenville		Rainfall and Snowmelt	125										MR: A 2000 foot section of the CNR rail service became inundated. The highway bridge was reported as being under four feet of water. A large section of the highway was inundated	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
41	030	Central Newfoundland	1962	3	2		1962	3	5		3	Winter	Central	1755	Gambo		Rainfall and Snowmelt	125										MR: A 2000 foot section of the CNR rail service became inundated. The highway bridge was reported as being under four feet of water. A large section of the highway was inundated	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
42	030	Central Newfoundland	1962	3	2		1962	3	5		3	Winter	Central	3380	Musgrave Harbour		Rainfall and Snowmelt	125										MR: A 2000 foot section of the CNR rail service became inundated. The highway bridge was reported as being under four feet of water. A large section of the highway was inundated	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
43	031	Corner Brook	1962	11	1		1962	11	1		1	Fall	Western	1200	Corner Brook		Rainfall	44.45										Many gravel roads were washed out, also much private property damage.	Dept Natural Resources Website	31	AMEC
44	032	Waterford River Basin	1962	11	19		1962	11	20		1	Fall	Eastern	4400	St. John's	Mundy Pond	Rainfall	48	78.7			$13,500	$13,500					Rainfall and Snowfall caused flooding along Mundy Pond outlet stream	Waterford River Area - Hydro technical Study	No	AMEC
45	033	Avalon Peninsula	1963	1	1		1963	1	3		2	Winter	Eastern	4400	St. John's	Waterford River	Snowmelt / Ice Jam											Rain, melting snow and ice jams caused significant flooding in the St. John's and along the coastline extending to Notre Dame Bay	Waterford River Area - Hydro technical Study	No	AMEC
46	034	Placentia	1964	2	3		1964	2	3		1	Winter	Eastern	3800	Placentia		Coastal Flooding											Severe flooding. Houses flooded, people forced to row along roads in dories. Unusually high tides flooded houses in St. Mary's.	Heritage Newfoundland Website	34	AMEC
47	034	Placentia	1964	2	3		1964	2	3		1	Winter	Eastern	4455	St. Mary's		Coastal Flooding											Severe flooding. Houses flooded, people forced to row along roads in dories. Unusually high tides flooded houses in St. Mary's.	Heritage Newfoundland Website	34	AMEC
48	035	St. John's	1964	8	4		1964	8	5		2	Summer	Eastern	4400	St. John's	Waterford River / Bowering Park	Rainfall	76										Two days of raining caused flooding along Waterford River banks and in Bowering Park	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
49	036	East Coast	1964	10	11		1964	10	12		1	Fall	Eastern	1885	Goobies area		Rainfall											A section of the main highway in the Goobies area was inundated halting traffic	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
50	037	St. John's	1964	12	18		1964	12	19		2	Winter	Eastern	4400	St. John's	Quidi Vidi Lake	Rainfall	64										Quidi Vidi overflowed its banks, a picture was published showing a car stranded in about 2 feet of water	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
51	038	Grand Falls Area	1965	6	5		1965	6	6		2	Summer	Central	1960	Grand Falls	Exploits River	Rainfall	104.6										Many people remember this flood which inundated a portion of the uncompleted Trans Canada Highway for about 500ft	Flooding Events in Newfoundland and Labrador - An Historical Perspective, Dept of Natural Resources Website	290	AMEC
52	039	La Manche, South and East Coast	1966	1	28		1966	1	28		1	Winter	Eastern		La Manche		Coastal Flooding					$30,000	$30,000					Major storm washed away all boats, anchors, stores and flakes, damaged houses. Some people lost up to $30,000 in property. Community was resettled following storm.	Heritage Newfoundland Website, Dept of Natural Resources Website	39	AMEC
53	040	Parsons Pond	1976	12	6		1976	12	6		1	Fall	Western	3675	Parsons Pond		Coastal Flooding											Onshore winds and high tides destroyed the protective natural beach barrier allowing sea water to flood area north of river	Heritage Newfoundland Website	40	AMEC
54	041	La Manche, South and East Coast	1966	12	20		1966	12	22		2	Winter	Eastern	4400	St. John's		Rainfall	102.8										MR: Many roads were flooded and shoulders washed out, numerous basements were flooded, a bridge between Rennie's River and the Stadium was completely submerged. The reservoir overflowed spilling water down to the powerhouse, inundating the lower levels of the powerhouse. A bridge at Northeast Trepassey was completely submerged	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
55	041	La Manche, South and East Coast	1966	12	20		1966	12	22		2	Winter	Central		Bay d'Espoir		Rainfall	102.8										MR: Many roads were flooded and shoulders washed out, numerous basements were flooded, a bridge between Rennie's River and the Stadium was completely submerged. The reservoir overflowed spilling water down to the powerhouse, inundating the lower levels of the powerhouse. A bridge at Northeast Trepassey was completely submerged	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
56	041	La Manche, South and East Coast	1966	12	20		1966	12	22		2	Winter	Eastern	5145	Trepassey		Rainfall	102.8										MR: Many roads were flooded and shoulders washed out, numerous basements were flooded, a bridge between Rennie's River and the Stadium was completely submerged. The reservoir overflowed spilling water down to the powerhouse, inundating the lower levels of the powerhouse. A bridge at Northeast Trepassey was completely submerged	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
57	042	Corner Brook	1968	11	26		1968	11	26		1	Fall	Western	1200	Corner Brook		Rainfall											A section of the railway was washed away.	Dept Natural Resources Website	42	AMEC
58	043	Codroy Valley	1969	3	19		1969	3	21		2	Spring	Western	1105	Codroy Valley		Rainfall and Snowmelt											Railway line damaged at Codroy Pond.	Flood Risk Mapping Study of the Codroy Valley Area	No	AMEC
59	044	Stephenville, Steady Brook, Deer Lake	1969	5	19		1969	5	21		2	Summer	Western	4945	Stephenville	Warm Creek / Blanche Brook	Rainfall											MR: Several basements and some outside property was flooded. Several homes were flooded, two were considered to be a total write off. Three houses were flooded, a section of the highway was flooded	MR: Environment Canada Report January 8th, 1976. Hydro technical Study of Steady Brook Area	No	AMEC
60	044	Stephenville, Steady Brook, Deer Lake	1969	5	19		1969	5	21		2	Summer	Western	4935	Steady Brook	Warm Creek / Blanche Brook	Rainfall					$40,000	$40,000					MR: Several basements and some outside property was flooded. Several homes were flooded, two were considered to be a total write off. Three houses were flooded, a section of the highway was flooded	MR: Environment Canada Report January 8th, 1976. Hydro technical Study of Steady Brook Area	No	AMEC
61	044	Stephenville, Steady Brook, Deer Lake	1969	5	19		1969	5	21		2	Summer	Western	1380	Deer Lake	Humber River	Rainfall											MR: Several basements and some outside property was flooded. Several homes were flooded, two were considered to be a total write off. Three houses were flooded, a section of the highway was flooded	MR: Environment Canada Report January 8th, 1976. Hydro technical Study of Steady Brook Area	No	AMEC
62	045	Deer Lake	1969	5	21		1969	5	30		9	Spring	Western	1380	Deer Lake	Humber River	Rainfall and Snowmelt											Several homes along Humber River from Corner Brook to Nicholsville were inundated. Highways were blocked for a period of time	Hydro technical Study of the Deer Lake Area	No	AMEC
63	046	Avalon Peninsula	1970	2	27		1970	3	2		4	Winter	Eastern	4400	St. John's	Waterford River / Quidi Vidi River	Rainfall	114										4 day rainfall resulted in general flooding	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
64	047	West Coast	1970	5	22		1970	6	3		10	Spring	Western	1200	Corner Brook	Majestic Brook	Rainfall	48.8				$17,500	$17,500					MR: Heavy rainfall of 257.6 mm caused streams to flood their banks resulting in extensive damage to roads, culverts, and bridges. Several streets including Watson's Road was inundated by heavy runoff causing erosion, culverts were blocked with debris and one river overflowed its bank	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
65	047	Burin Peninsula	1970	8	11		1970	8	12		2	Summer	Eastern	725	Burin Peninsula		Rainfall	257.6										MR: Heavy rainfall of 257.6 mm caused streams to flood their banks resulting in extensive damage to roads, culverts, and bridges. Several streets including Watson's Road was inundated by heavy runoff causing erosion, culverts were blocked with debris and one river overflowed its bank	Department of Natural Resources Website	47	AMEC
66	048	Corner Brook	1970	11	24		1970	11	26		2	Fall	Western	1200	Corner Brook		Rainfall	100.9										A major washout was reported in the Elizabeth Street area, as well as many others throughout the city, many basements were flooded resulting in damages.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
67	049	Avalon Peninsula	1971	1	31		1971	2	1		1	Winter	Eastern	4400	St. John's	Waterford River	Rainfall and Snowmelt	48.8										Melting snow and rainfall caused flooding at many locations (St. Brides College)	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
68	050	Codroy Valley	1971	2	14		1971	2	15		1	Winter	Western	1105	Codroy Valley		Ice Jam											Some roads washed out in Corner Brook or badly rutted, a bridge washed out in Port au Basque, some flooding on the TCH	Flood Risk Mapping Study of the Codroy Valley Area	No	AMEC
69	051	St. John's	1971	11	14		1971	11	15		2	Fall	Eastern	4400	St. John's	Quidi Vidi River	Rainfall and Snowmelt											Local flooding reported in St. John's and within Bowering Park	Waterford River Area - Hydro technical Study	No	AMEC
70	052	Grand Falls Area	1971	12	30		1972	1	4		6	Winter	Central	1960	Grand Falls	Rushy Pond	unknown											Ice cover and high water flows raised the level of Rushy Pond to road level	Hydro technical Study of the Badger and Rushy Pond Area, Dept of Natural Resources Website	290	AMEC
71	053	Corner Brook	1972	N/A	N/A		1972	N/A	N/A		N/A	Spring	Western	1200	Corner Brook		Rainfall and Snowmelt											A three year old drowned when swept away by a swollen stream behind her house.	Department of Natural Resources Website	53	AMEC
72	054	Corner Brook	1972	3	9		1972	3	10		1	Winter	Western	1200	Corner Brook		Rainfall	20.3				$20,000	$20,000					Damage to streets and city property	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
73	055	Stephenville, Corner Brook	1972	5	15		1972	5	17		2	Spring	Western	4945	Stephenville	Warm Creek	Rainfall					$1,500	$1,500					MR: Corner Brook NL, May 15, 1972. Spring runoff accompanied by rainfall caused flooding affecting communities on the Port au Prince Peninsula and area; damage to CNR; in Corner Brook, a 3-year old child drowned when swept away by a swollen brook behind her home. The causeway washed out at Mississippi Drive, water washed out sections of the roadway.	MR: Canadian Disaster Database. Environment Canada Report January 8th, 1976	No	AMEC
74	055	Stephenville, Corner Brook	1972	5	15		1972	5	17		2	Spring	Western	1200	Corner Brook		Rainfall											MR: Corner Brook NL, May 15, 1972. Spring runoff accompanied by rainfall caused flooding affecting communities on the Port au Prince Peninsula and area; damage to CNR; in Corner Brook, a 3-year old child drowned when swept away by a swollen brook behind her home. The causeway washed out at Mississippi Drive, water washed out sections of the roadway.	MR: Canadian Disaster Database. Environment Canada Report January 8th, 1976	No	AMEC
75	056	St. John's	1972	11	10		1972	11	12		2	Fall	Eastern	4400	St. John's	Waterford River	Rainfall	116										Rainfall resulted in local flooding and road washouts in St. John's near the Waterford River mouth	Waterford River Area - Hydro technical Study	No	AMEC
76	057	North Harbour, Corner Brook	1972	11	27		1972	11	28		1	Fall	Eastern	3535	North Harbour		Rainfall and Snowmelt	40.6										MR: A newly constructed culvert and about 200ft of the Branch road (St. Mary's Bay). Drainage systems were overtaxed causing overflow in some areas, many basements throughout the city were flooded.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
77	057	North Harbour, Corner Brook	1972	11	27		1972	11	28		1	Fall	Eastern	1200	Corner Brook	Bell's Brook	Rainfall and Snowmelt	40.6				$30,000	$30,000					MR: A newly constructed culvert and about 200ft of the Branch road (St. Mary's Bay). Drainage systems were overtaxed causing overflow in some areas, many basements throughout the city were flooded.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
78	058	Corner Brook	1972	12	7		1972	12	8		1	Winter	Western	1200	Corner Brook	Bell's Brook	Rainfall											Bell's Brook overflowed inundating the road and flooding property.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
79	059	Codroy Valley	1972	12	9		1972	12	10		1	Fall	Western	1105	Codroy Valley	Codroy River	Flood											Heavy rain caused a flash flood and inundated the St. Croix farm near Cold Brook	Flood Risk Mapping Study of the Codroy Valley Area	No	AMEC
80	060	St. John's	1973	1	20		1973	1	21		1	Winter	Eastern	4400	St. John's		Rainfall											Minor damages to some unpaved roads in the city	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
81	061	St. John's	1973	2	22		1973	2	23		1	Winter	Eastern	4400	St. John's		Rainfall	68.3										Flooding near the river mouth (Southside Road, Water Street West)	Waterford River Area - Hydro technical Study	No	AMEC
82	062	Rushoon, Stephenville, Burin Peninsula	1973	2	2		1973	2	5		4	Winter	Eastern	4295	Rushoon	Rushoon Brook	Ice Jam											MR: The Burin Peninsula highway was closed due to washouts at Grand Le Pierre, Southwest Arm, Hodges Cove and close to Swift Current. Several streets were blocked with Ice and water. Some areas escaped flooding thanks to the dykes that were constructed after the last flood. Rain and warm weather and an ice jam caused Rushoon River to flood, several damaged houses were reported.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Stephenville Area. Rushoon Flood Study Report, Dept of Natural Resources Website	302	AMEC
83	062	Rushoon, Stephenville, Burin Peninsula	1973	2	2		1973	2	3		1	Winter	Western	4945	Stephenville	Blanche Brook	Ice Jam											MR: The Burin Peninsula highway was closed due to washouts at Grand Le Pierre, Southwest Arm, Hodges Cove and close to Swift Current. Several streets were blocked with Ice and water. Some areas escaped flooding thanks to the dykes that were constructed after the last flood. Rain and warm weather and an ice jam caused Rushoon River to flood, several damaged houses were reported.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Stephenville Area. Rushoon Flood Study Report, Dept of Natural Resources Website	302	AMEC
84	062	Rushoon, Stephenville, Burin Peninsula	1973	2	2		1973	2	5		4	Winter	Eastern	725	Burin Peninsula	Rushoon Brook	Ice Jam											MR: The Burin Peninsula highway was closed due to washouts at Grand Le Pierre, Southwest Arm, Hodges Cove and close to Swift Current. Several streets were blocked with Ice and water. Some areas escaped flooding thanks to the dykes that were constructed after the last flood. Rain and warm weather and an ice jam caused Rushoon River to flood, several damaged houses were reported.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Stephenville Area. Rushoon Flood Study Report, Dept of Natural Resources Website	302	AMEC
85	063	St. John's	1973	6	17		1973	6	17		1	Summer	Eastern	4400	St. John's		Rainfall	50										Rainfall caused isolated flooding and landslides down Southside Hills at Kilbride	Waterford River Area - Hydro technical Study	No	AMEC
86	064	Corner Brook	1973	6	23		1973	6	24		1	Summer	Eastern	1200	Corner Brook		Rainfall					$30,000	$30,000					Rainfall caused considerable damages to some homes and property	Hydro technical Study of the Steady Brook Area	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
87	065	Stephenville	1973	8	2		1973	8	3		1	Summer	Western	4945	Stephenville	Warm Creek / Blanche Brook	Rainfall	50.8				$70,000						MR: The worst recorded flooding in the towns history. The main highway into the town was under water and a bridge was washed out, Basements were flooded and a waterline was damaged leaving many people without water. Four families forced to evacuate due to 4-6inches of water on floor.	Environment Canada Report January 8th, 1976	No	AMEC
88	065	Stephenville	1973	8	2		1973	8	3		1	Summer	Western	3485	Noel's Pond	Warm Creek / Blanche Brook	Rainfall	50.8				$70,000	$70,000					MR: The worst recorded flooding in the towns history. The main highway into the town was under water and a bridge was washed out, Basements were flooded and a waterline was damaged leaving many people without water. Four families forced to evacuate due to 4-6inches of water on floor.	Environment Canada Report January 8th, 1976	No	AMEC
89	066	Port au Port Peninsula	1973	8	1		1973	8	4		3	Summer	Western	1380	Deer Lake	Corner Brook Stream / Bell's Brook	Rainfall											MR: A landslide occurred upstream bringing 30-40 cords of pulpwood and trees down the river with the flood, several boats were dragged out to sea. Highway 47 was underwater in at least two places and a bridge was washed out. At least 4 families were forced to leave their homes because of the flood waters. A number of basements were flooded as Bell's Brook overflowed. Corner Brook Stream and Bell's Brook overflowed resulting in some inundation.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area	No	AMEC
90	066	Port au Port Peninsula	1973	8	1		1973	8	4		3	Summer	Western	1681	Fox Island River		Rainfall											MR: A landslide occurred upstream bringing 30-40 cords of pulpwood and trees down the river with the flood, several boats were dragged out to sea. Highway 47 was underwater in at least two places and a bridge was washed out. At least 4 families were forced to leave their homes because of the flood waters. A number of basements were flooded as Bell's Brook overflowed. Corner Brook Stream and Bell's Brook overflowed resulting in some inundation.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area	No	AMEC
91	066	Port au Port Peninsula	1973	8	1		1973	8	4		3	Summer	Western	4945	Stephenville		Rainfall											MR: A landslide occurred upstream bringing 30-40 cords of pulpwood and trees down the river with the flood, several boats were dragged out to sea. Highway 47 was underwater in at least two places and a bridge was washed out. At least 4 families were forced to leave their homes because of the flood waters. A number of basements were flooded as Bell's Brook overflowed. Corner Brook Stream and Bell's Brook overflowed resulting in some inundation.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area	No	AMEC
92	066	Port au Port Peninsula	1973	8	1		1973	8	4		3	Summer	Western	3485	Noel's Pond		Rainfall											MR: A landslide occurred upstream bringing 30-40 cords of pulpwood and trees down the river with the flood, several boats were dragged out to sea. Highway 47 was underwater in at least two places and a bridge was washed out. At least 4 families were forced to leave their homes because of the flood waters. A number of basements were flooded as Bell's Brook overflowed. Corner Brook Stream and Bell's Brook overflowed resulting in some inundation.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area	No	AMEC
93	066	Port au Port Peninsula	1973	8	1		1973	8	4		3	Summer	Western	1200	Corner Brook	Bell's Brook	Rainfall											MR: A landslide occurred upstream bringing 30-40 cords of pulpwood and trees down the river with the flood, several boats were dragged out to sea. Highway 47 was underwater in at least two places and a bridge was washed out. At least 4 families were forced to leave their homes because of the flood waters. A number of basements were flooded as Bell's Brook overflowed. Corner Brook Stream and Bell's Brook overflowed resulting in some inundation.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area	No	AMEC
94	067	St. John's	1974	8	23		1974	8	24		1	Summer	Eastern	3345	Mount Pearl		Rainfall											Storm water runoff led to basement flooding in Mount Pearl	Waterford River Area - Hydro technical Study	No	AMEC
95	068	St. John's	1974	8	30		1974	8	30		1	Summer	Eastern	3345	Mount Pearl		Rainfall											Several basements were flooded in Donovans Street area	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
96	069	Corner Brook	1974	9	12		1974	9	13		1	Summer	Western	1200	Corner Brook		Rainfall											A home on Old Humber Road was Inundated	Hydro technical Study of the Steady Brook Area	No	AMEC
97	070	Cape Ray	1974	10	20		1974	10	20		1	Fall	Eastern	905	Cape Ray		Coastal Flooding and Winds					$1,000	$1,000					MR: High Seas at Cape Ray washed out 30m of track causing derailment of 2 diesel locomotives. High seas at Cape Ray washed out about 30 m of railway track causing derailment of 2 diesel locomotives.	Department of Natural Resources Website, Heritage Newfoundland Website.	70	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
99	071	Stephenville, Cold Brook, Noels Pond	1974	11	1		1974	11	2		2	Fall	Western	4945	Stephenville	Blanche Brook	Rainfall											MR: Heavy rainfall caused flooding. Cold Brook was isolated by the washout of the wooden bridge on the main road connecting that community with Stephenville. Noels Pond was also reported to have flooding	Environment Canada Report January 8th, 1976	No	AMEC
100	071	Stephenville, Cold Brook, Noels Pond	1974	11	1		1974	11	2		2	Fall	Western	1114	Cold Brook	Blanche Brook	Rainfall											MR: Heavy rainfall caused flooding. Cold Brook was isolated by the washout of the wooden bridge on the main road connecting that community with Stephenville. Noels Pond was also reported to have flooding	Environment Canada Report January 8th, 1976	No	AMEC
101	071	Stephenville, Cold Brook, Noels Pond	1974	11	1		1974	11	2		2	Fall	Western	3485	Noel's Pond	Blanche Brook	Rainfall											MR: Heavy rainfall caused flooding. Cold Brook was isolated by the washout of the wooden bridge on the main road connecting that community with Stephenville. Noels Pond was also reported to have flooding	Environment Canada Report January 8th, 1976	No	AMEC
102	072	Rushoon, Grand Bank	1975	3	22		1975	3	23		1	Spring	Eastern	4295	Rushoon		Ice Jam										4 families	MR: Flooding heavy in some sections of Grand Bank. The river overflowed its banks causing some people to have to evacuate.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Rushoon Flood Study Report	No	AMEC
103	072	Rushoon, Grand Bank	1975	3	22		1975	3	23		1	Spring	Eastern	1940	Grand Bank		Ice Jam											MR: Flooding heavy in some sections of Grand Bank. The river overflowed its banks causing some people to have to evacuate.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Rushoon Flood Study Report	No	AMEC
104	073	St. John's	1975	8	23		1975	8	24		1	Summer	Eastern	4400	St. John's		Rainfall	75										Rainfall caused localized flooding and debris slides down Southside hills	Waterford River Area - Hydro technical Study	No	AMEC
105	074	Corner Brook	1975	9	21		1975	9	22		1	Summer	Western	1200	Corner Brook		Rainfall	46.7				$50,000	$50,000					Storm sewers and ditches just couldn't cope with the heavy rain in a short period of time resulting in flooding streets and washouts. Many basements in low lying areas were inundated.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
106	075	Stephenville, Corner Brook, Grand Falls	1975	12	22		1975	12	25		3	Winter	Western	4945	Stephenville		Rainfall and Snowmelt	52.1										MR: Flooding in the streets was said to be extensive as sewer systems could not handle the water. Storm damage was reported to be quite extensive to the streets, road shoulders were also damaged. A section of the highway in the Exploits region near Grand Falls was underwater.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
107	075	Stephenville, Corner Brook, Grand Falls	1975	12	22		1975	12	25		3	Winter	Western	1200	Corner Brook		Rainfall and Snowmelt	24.9										MR: Flooding in the streets was said to be extensive as sewer systems could not handle the water. Storm damage was reported to be quite extensive to the streets, road shoulders were also damaged. A section of the highway in the Exploits region near Grand Falls was underwater.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
108	075	Stephenville, Corner Brook, Grand Falls	1975	12	22		1975	12	25		3	Winter	Western	1960	Grand Falls		Rainfall and Snowmelt	45.5										MR: Flooding in the streets was said to be extensive as sewer systems could not handle the water. Storm damage was reported to be quite extensive to the streets, road shoulders were also damaged. A section of the highway in the Exploits region near Grand Falls was underwater.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
109	076	St. John's	1976	1	8		1976	1	10		2	Winter	Eastern	4400	St. John's	Mundy Pond	Rainfall	54.5										Flood waters caused considerable damage, water flowed up through the ground behind Carling O'Keefe brewery. This water then damaged the several trucks and the building housing Eastern Paper Products	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
110	077	St. John's	1976	1	25		1976	1	26		1	Winter	Eastern	4400	St. John's		Rainfall and Snowmelt											snow followed by snowmelt and rain brought the river to bank full stage, little flooding occurred	Waterford River Area - Hydro technical Study	No	AMEC
111	078	Bay of Islands	1976	1	27		1976	1	28		2	Winter	Eastern	1710	Frenchmans Cove		Rainfall	22.4				$100,000						MR: Ice piled up at the mouth of Clark's Brook causing some problems. Several road washouts had occurred, one resident on Massey Drive was reported to have lost his driveway. The area was plugged with ice causing the water to back up inundating 4 homes and threatening 10 others. Several road washouts reported. Homes in Frenchmans Cove, Benoit's Cove and Lark Harbour damaged by flood waters. Steady Brook clogged with ice causing inundation of 4 homes and threatening another 10	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area, Dept of Natural Resources Website	279	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
112	078	Bay of Islands	1976	1	27		1976	1	28		2	Winter	Eastern	340	Benoit's Cove		Rainfall					$100,000						MR: Ice piled up at the mouth of Clark's Brook causing some problems. Several road washouts had occurred, one resident on Massey Drive was reported to have lost his driveway. The area was plugged with ice causing the water to back up inundating 4 homes and threatening 10 others. Several road washouts reported. Homes in Frenchmans Cove, Benoit's Cove and Lark Harbour damaged by flood waters. Steady Brook clogged with ice causing inundation of 4 homes and threatening another 10	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area, Dept of Natural Resources Website	279	AMEC
113	078	Bay of Islands	1976	1	27		1976	1	28		2	Winter	Western	2730	Lark Harbour		Rainfall	22.4				$100,000						MR: Ice piled up at the mouth of Clark's Brook causing some problems. Several road washouts had occurred, one resident on Massey Drive was reported to have lost his driveway. The area was plugged with ice causing the water to back up inundating 4 homes and threatening 10 others. Several road washouts reported. Homes in Frenchman's Cove, Benoit's Cove and Lark Harbour damaged by flood waters. Steady Brook clogged with ice causing inundation of 4 homes and threatening another 10	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area, Dept of Natural Resources Website	279	AMEC
114	078	Bay of Islands	1976	1	27		1976	1	28		2	Winter	Western	1200	Corner Brook		Rainfall	22.4				$100,000	$100,000					MR: Ice piled up at the mouth of Clark's Brook causing some problems. Several road washouts had occurred, one resident on Massey Drive was reported to have lost his driveway. The area was plugged with ice causing the water to back up inundating 4 homes and threatening 10 others. Several road washouts reported. Homes in Frenchman's Cove, Benoit's Cove and Lark Harbour damaged by flood waters. Steady Brook clogged with ice causing inundation of 4 homes and threatening another 10	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area, Dept of Natural Resources Website	279	AMEC
115	078	Bay of Islands	1976	1	27		1976	1	28		2	Winter	Western	4935	Steady Brook		Rainfall					$100,000					2 families	MR: Ice piled up at the mouth of Clark's Brook causing some problems. Several road washouts had occurred, one resident on Massey Drive was reported to have lost his driveway. The area was plugged with ice causing the water to back up inundating 4 homes and threatening 10 others. Several road washouts reported. Homes in Frenchman's Cove, Benoit's Cove and Lark Harbour damaged by flood waters. Steady Brook clogged with ice causing inundation of 4 homes and threatening another 10	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area	No	AMEC
116	078	Bay of Islands	1976	1	27		1976	1	28		1	Winter	Western	1380	Deer Lake	Steady Brook	Rainfall / Snowmelt / Ice Jams	22.4				$100,000						MR: Ice piled up at the mouth of Clark's Brook causing some problems. Several road washouts had occurred, one resident on Massey Drive was reported to have lost his driveway. The area was plugged with ice causing the water to back up inundating 4 homes and threatening 10 others. Several road washouts reported. Homes in Frenchman's Cove, Benoit's Cove and Lark Harbour damaged by flood waters. Steady Brook clogged with ice causing inundation of 4 homes and threatening another 10	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area, Dept of Natural Resources Website	279	AMEC
117	079	St. John's	1976	2	22		1976	2	23		1	Winter	Eastern	4400	St. John's		Rainfall	40.4										Hundreds of people reported flooded basements, according to a City Engineer it was said to be the worst in two years	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
118	080	Humber Arm Region	1976	3	21		1976	3	23		3	Spring	Western	1200	Corner Brook		Rainfall											Heavy rain and snowmelt caused flooding on several streets and private property was damaged	Flooding Events in Newfoundland and Labrador - An Historical Perspective, Dept of Natural Resources Website	292	AMEC
119	081	Placentia	1976	3	18		1976	3	18		1	Spring	Eastern	3800	Placentia		unknown												Hydro technical Study of the Placentia Area Flood Plain	No	AMEC
120	082	Grand Falls Area	1976	5	4		1976	5	4		1	Spring	Central	1960	Grand Falls	Exploits River	Rainfall					$500,000	$500,000					Flooding from Rushy Pond caused by spring runoff caused damages to the highway	Flooding Events in Newfoundland and Labrador - An Historical Perspective, Dept of Natural Resources Website	290	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
121	083	Corner Brook	1976	10	31		1976	11	1		1	Fall	Western	1200	Corner Brook		Rainfall	45.5										2 days of rainfall resulted in damage to roads and property.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
122	084	Burin Peninsula	1976	11	10		1976	11	12		2	Fall	Eastern	2745	Lawn		Coastal Flooding											MR: Three motor boats were swamped and in Lamaline the high winds and rough seas were reported to have caused some damage. Damages said to be severe in this region, reports of lost gear, damages to sheds and wharves, damage to breakwater. Wharves were washed away and sheds were damaged, the road to the community was also reported to be impassable because of a washout. The remainder of the breakwater was said to be destroyed	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
123	084	Burin Peninsula	1976	11	10		1976	11	12		2	Fall	Eastern	3665	Parker's Cove - Rushoon		Coastal Flooding										1 family	MR: Three motor boats were swamped and in Lamaline the high winds and rough seas were reported to have caused some damage. Damages said to be severe in this region, reports of lost gear, damages to sheds and wharves, damage to breakwater. Wharves were washed away and sheds were damaged, the road to the community was also reported to be impassable because of a washout. The remainder of the breakwater was said to be destroyed	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
124	084	Burin Peninsula	1976	11	10		1976	11	12		2	Fall	Eastern	4143	Red Harbour		Coastal Flooding											MR: Three motor boats were swamped and in Lamaline the high winds and rough seas were reported to have caused some damage. Damages said to be severe in this region, reports of lost gear, damages to sheds and wharves, damage to breakwater. Wharves were washed away and sheds were damaged, the road to the community was also reported to be impassable because of a washout. The remainder of the breakwater was said to be destroyed	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
125	084	Burin Peninsula	1976	11	10		1976	11	12		2	Fall	Eastern	1710	Frenchman's Cove		Coastal Flooding											MR: Three motor boats were swamped and in Lamaline the high winds and rough seas were reported to have caused some damage. Damages said to be severe in this region, reports of lost gear, damages to sheds and wharves, damage to breakwater. Wharves were washed away and sheds were damaged, the road to the community was also reported to be impassable because of a washout. The remainder of the breakwater was said to be destroyed	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
126	085	West Coast	1976	12	6		1976	12	6		1	Winter	Western	3675	Parson's Pond		Coastal Flooding											On shore winds and high tides destroyed a protective beach barrier allowing sea water to flood the area north of the river, flooding several homes, some people had to be evacuated by boat	Historical Flooding Review and Flood Risk Mapping Study for Parson's Pond, Dept of Natural Resources Website	298	AMEC
127	086	St. John's	1976	12	24		1976	12	26		2	Winter	Eastern	4400	St. John's	Mundy Pond	Rainfall	31										Rainfall with snowmelt caused Mundy Pond to overflow and slides down Southside Hills	Waterford River Area - Hydro technical Study	No	AMEC
128	087	Corner Brook	1977	1	4		1977	1	5		1	Winter	Western	1200	Corner Brook		Rainfall and Snowmelt	9.1	25									A blocked catch basin caused heavy runoff on Humber Road	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
129	088	Steady Brook	1977	1	N/A		1977	1	N/A		N/A	Winter	Western	4935	Steady Brook		Rainfall											Two homes in the community were flooded according to a newspaper report	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
130	089	Badger	1977	1	17		1977	1	24		1	Winter	Central	155	Badger	Exploits River / Badger Brook / Red Indian Brook	Ice Jam				0.8	$20,000	$20,000				200	The three rivers overflowed their banks and flowed into Badger, only 8 of the evacuated houses had several inches of water in them	Flooding Events in Newfoundland and Labrador - An Historical Perspective	276	AMEC
131	090	St. John's, Placentia	1977	1	20		1977	1	21		1	Winter	Eastern	4400	St. John's		Snow Storm / Winds											MR: High seas caused damages to fisherman's wharves in the Battery area. high winds and heavy seas damaged wharves (potentially Petty Harbour). High winds and heavy seas damaged wharves (potentially Ferryland). The seas were so high in Placentia that the spray went over the barrier beach and mixed with snow and rain causing basement flooding	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
132	090	St. John's, Placentia	1977	1	20		1977	1	21		1	Winter	Eastern	3760	Petty Harbour - Maddox Cove		Coastal Flooding											MR: High seas caused damages to fisherman's wharves in the Battery area. high winds and heavy seas damaged wharves (potentially Petty Harbour). High winds and heavy seas damaged wharves (potentially Ferryland). The seas were so high in Placentia that the spray went over the barrier beach and mixed with snow and rain causing basement flooding	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
133	090	St. John's, Placentia	1977	1	20		1977	1	21		1	Winter	Eastern	1580	Ferryland		Coastal Flooding											MR: High seas caused damages to fisherman's wharves in the Battery area. high winds and heavy seas damaged wharves (potentially Petty Harbour). High winds and heavy seas damaged wharves (potentially Ferryland). The seas were so high in Placentia that the spray went over the barrier beach and mixed with snow and rain causing basement flooding	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
134	090	St. John's, Placentia	1977	1	20		1977	1	21		1	Winter	Eastern	3800	Placentia		Snow Storm / Winds											MR: High seas caused damages to fisherman's wharves in the Battery area. high winds and heavy seas damaged wharves (potentially Petty Harbour). High winds and heavy seas damaged wharves (potentially Ferryland). The seas were so high in Placentia that the spray went over the barrier beach and mixed with snow and rain causing basement flooding	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
135	091	Deer Lake	1977	6	8		1977	6	10		2	Summer	Western	1380	Deer Lake		Rainfall											Water levels reported to be high	Hydro technical Study of the Deer Lake Area	No	AMEC
136	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Western	3675	Parson's Pond		Coastal Flooding										100+	MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area	92	AMEC
137	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Western	2730	Lark Harbour		Coastal Flooding											MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area	No	AMEC
138	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Western	3745	Petites		Coastal Flooding											MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area	No	AMEC
139	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Western	4950	Stephenville Crossing		Coastal Flooding											MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area	92	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
140	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Western	3485	Noel's Pond	Warm Creek	Flood											MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area	92	AMEC
141	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Western	1380	Deer Lake		Coastal Flooding											MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. AF20 Hydro technical Study of the Deer Lake Area	No	AMEC
142	092	West Coast, Stephenville, Deer Lake, Cox's Cove	1977	12	11		1977	12	12		1	Winter	Eastern	1235	Cox's Cove	Cox's Brook	Coastal Flooding											MR: Noels Pond area flooded as a result of debris. About 21 families were forced to leave their homes, it is reported that some homes had to be evacuated by boat. Some eight wharves and a community stage were reported as being destroyed. Water came over a section of the breakwater and rose to approx 18 inches over Pleasant Street. Waves went over breakwater, washed away part of road, damaged slipways and flooded homes. Caused widespread flooding. Bay of Islands, Cox's Cove, Lark Harbour and Frenchman's Cove reported damages due to inundation.	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area	92	AMEC
143	093	South eastern Newfoundland	1977	12	21		1977	12	22		1	Winter	Eastern	4400	Flat Rock		Coastal Flooding											MR: At least 9 stages were demolished and at least two families had to evacuate their homes until the water subsided. Five stages demolished and some boats were reported to have been swept out to sea. Fishing stages, boats and equipment were destroyed.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
144	093	South eastern Newfoundland	1977	12	21		1977	12	22		1	Winter	Eastern	4400	Quidi Vidi Village		Coastal Flooding											MR: At least 9 stages were demolished and at least two families had to evacuate their homes until the water subsided. Five stages demolished and some boats were reported to have been swept out to sea. Fishing stages, boats and equipment were destroyed.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
145	093	South eastern Newfoundland	1977	12	21		1977	12	22		1	Winter	Eastern	4015	Pouch Cove		Coastal Flooding											MR: At least 9 stages were demolished and at least two families had to evacuate their homes until the water subsided. Five stages demolished and some boats were reported to have been swept out to sea. Fishing stages, boats and equipment were destroyed.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
146	094	Corner Brook	1977	12	25		1977	12	26		2	Winter	Western	1200	Corner Brook		Rainfall	31.8										Road damage occurred due to rain. Tons of mud and water flooded homes in the area.	Flooding Events in Newfoundland and Labrador - An Historical Perspective, Dept of Natural Resources Website	285, 296	AMEC
147	095	Avalon Peninsula, Corner Brook, King's Point, Grand Falls, Gander	1977	12	27		1977	12	29		2	Winter	Eastern	4400	St. John's		Rainfall and Snowmelt	45.7										MR: Rainfall with snowmelt flooded parts of Bowering Park, Kinsman Park and Squires Avenue. Several roads were damaged and some homes were inundated. Guard rails and hydro poles along the Humber River were left with little support as the flood eroded tons of earth. 100 foot section of the main street was tore up isolating about 40 families. Some flooding to basements and some tenants were forced out of their homes. Many basement apartments were flooded, many people forced to leave their homes	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area. Hydro technical Study of the Steady Brook Area	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
148	095	Avalon Peninsula, Corner Brook, King's Point, Grand Falls, Gander	1977	12	27		1977	12	29		1	Winter	Western	1200	Corner Brook	Birchy Lake	Snowmelt											MR: Rainfall with snowmelt flooded parts of Bowering Park, Kinsman Park and Squires Avenue. Several roads were damaged and some homes were inundated. Guard rails and hydro poles along the Humber River were left with little support as the flood eroded tons of earth. 100 foot section of the main street was tore up isolating about 40 families. Some flooding to basements and some tenants were forced out of their homes. Many basement apartments were flooded, many people forced to leave their homes	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area. Hydro technical Study of the Steady Brook Area	No	AMEC
149	095	Avalon Peninsula, Corner Brook, King's Point, Grand Falls, Gander	1977	12	27		1977	12	29		1	Winter	Western	2585	King's Point		Snowmelt											MR: Rainfall with snowmelt flooded parts of Bowering Park, Kinsman Park and Squires Avenue. Several roads were damaged and some homes were inundated. Guard rails and hydro poles along the Humber River were left with little support as the flood eroded tons of earth. 100 foot section of the main street was tore up isolating about 40 families. Some flooding to basements and some tenants were forced out of their homes. Many basement apartments were flooded, many people forced to leave their homes	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area. Hydro technical Study of the Steady Brook Area	No	AMEC
150	095	Avalon Peninsula, Corner Brook, King's Point, Grand Falls, Gander	1977	12	27		1977	12	29		1	Winter	Western	1960	Grand Falls		Snowmelt											Some flooding to basements and some tenants were forced out of their homes	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area. Hydro technical Study of the Steady Brook Area	No	AMEC
151	095	Avalon Peninsula, Corner Brook, King's Point, Grand Falls, Gander	1977	12	27		1977	12	29		1	Winter	Western	1760	Gander		Snowmelt											MR: Rainfall with snowmelt flooded parts of Bowering Park, Kinsman Park and Squires Avenue. Several roads were damaged and some homes were inundated. Guard rails and hydro poles along the Humber River were left with little support as the flood eroded tons of earth. 100 foot section of the main street was tore up isolating about 40 families. Some flooding to basements and some tenants were forced out of their homes. Many basement apartments were flooded, many people forced to leave their homes	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Deer Lake Area. Hydro technical Study of the Steady Brook Area	No	AMEC
152	096	Codroy Valley	1978	1	14		1978	1	16		2	Winter	Western	1200	Corner Brook		Ice Jam					$4,000,000						MR: City crews were kept busy repairing several city streets. A 500ft section of the bridge was destroyed isolating 4 communities and 1500 residents, a temp bridge was constructed further downstream 3 months after. Blocked culverts caused minor flooding on the highway	Flood Risk Mapping Study of the Codroy Valley Area, Dept of Natural Resources Website	297	AMEC
153	096	Codroy Valley	1978	1	14		1978	1	16		2	Winter	Western	1105	Codroy Valley		Ice Jam					$4,000,000	$4,000,000					MR: City crews were kept busy repairing several city streets. A 500ft section of the bridge was destroyed isolating 4 communities and 1500 residents, a temp bridge was constructed further downstream 3 months after. Blocked culverts caused minor flooding on the highway	Flood Risk Mapping Study of the Codroy Valley Area, Dept of Natural Resources Website	297	AMEC
154	096	Codroy Valley	1978	1	14		1978	1	16		2	Winter	Western	1825	Gilliams		Ice Jam					$4,000,000						MR: City crews were kept busy repairing several city streets. A 500ft section of the bridge was destroyed isolating 4 communities and 1500 residents, a temp bridge was constructed further downstream 3 months after. Blocked culverts caused minor flooding on the highway	Flood Risk Mapping Study of the Codroy Valley Area, Dept of Natural Resources Website	297	AMEC
155	096	Codroy Valley	1978	1	14		1978	1	16		2	Winter	Western	2882	Little Rapids		Ice Jam					$4,000,000						MR: City crews were kept busy repairing several city streets. A 500ft section of the bridge was destroyed isolating 4 communities and 1500 residents, a temp bridge was constructed further downstream 3 months after. Blocked culverts caused minor flooding on the highway	Flood Risk Mapping Study of the Codroy Valley Area, Dept of Natural Resources Website	297	AMEC
156	097	St. John's	1978	1	27		1978	1	27		1	Winter	Eastern	4400	St. John's		Rainfall and Snowmelt											Rainfall and snowmelt combined to flood many streets, but not significantly along the river	Waterford River Area - Hydro technical Study	No	AMEC
157	098	Deer Lake, Steady Brook	1978	5	17		1978	5	20		3	Spring	Western	1380	Deer Lake	Humber River	unknown											The Humber River was overflowing at Steady Brook, Bowaters reported as not having spilled water from the main dam	Hydro technical Study of the Deer Lake Area	No	AMEC
158	098	Deer Lake, Steady Brook	1978	5	17		1978	5	20		3	Spring	Western	4935	Steady Brook	Humber River	Snowmelt											The Humber River was overflowing at Steady Brook, Bowaters reported as not having spilled water from the main dam	Hydro technical Study of the Deer Lake Area	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
159	099	St. John's	1978	12	18		1978	12	19		1	Winter	Eastern	4400	St. John's		Rainfall											Considerable flooding in the city with one section of road having to be closed as a result of the heavy rains. Water was said to be up to the bumpers of some vehicles	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
160	100	St. John's	1979	1	8		1979	1	9		1	Winter	Eastern	4400	St. John's		Rainfall	38										Throughout St. John's, streets, driveways and some basements were flooded because of clogged drains and melting snow	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
161	101	Avalon Peninsula	1979	1	28		1979	1	30		6	Winter	Eastern	4400	St. John's	Quidi Vidi Lake	Rainfall	91										MR: City crews were busy cleaning up flooded sewers and basements, entrance to The Health Sciences Centre was flooded by a nearby pond. Ice backed up water inundating the road between Robinsons and Cartyville with about 12 inches of water. A section of the Cabot Highway near Catalina was under 6 inches of water but remained passable. A stream overflowed its banks and 4 families were forced to leave their homes. Extensive damages to roads in Marystown. Extensive damages to roads, 1 family had to evacuate because of rising water in main area of their home.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
162	101	Avalon Peninsula	1979	1	28		1979	1	30		6	Winter	Eastern		Robinson's	Robinson's River	Rainfall											MR: City crews were busy cleaning up flooded sewers and basements, entrance to The Health Sciences Centre was flooded by a nearby pond. Ice backed up water inundating the road between Robinsons and Cartyville with about 12 inches of water. A section of the Cabot Highway near Catalina was under 6 inches of water but remained passable. A stream overflowed its banks and 4 families were forced to leave their homes. Extensive damages to roads in Marystown. Extensive damages to roads, 1 family had to evacuate because of rising water in main area of their home.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
163	101	Avalon Peninsula	1979	1	28		1979	1	30		6	Winter	Eastern		Catalina		Rainfall											MR: City crews were busy cleaning up flooded sewers and basements, entrance to The Health Sciences Centre was flooded by a nearby pond. Ice backed up water inundating the road between Robinsons and Cartyville with about 12 inches of water. A section of the Cabot Highway near Catalina was under 6 inches of water but remained passable. A stream overflowed its banks and 4 families were forced to leave their homes. Extensive damages to roads in Marystown. Extensive damages to roads, 1 family had to evacuate because of rising water in main area of their home.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
164	101	Avalon Peninsula	1979	1	28		1979	1	30		6	Winter	Eastern	1800	Georges Brook		Rainfall										4 families	MR: City crews were busy cleaning up flooded sewers and basements, entrance to The Health Sciences Centre was flooded by a nearby pond. Ice backed up water inundating the road between Robinsons and Cartyville with about 12 inches of water. A section of the Cabot Highway near Catalina was under 6 inches of water but remained passable. A stream overflowed its banks and 4 families were forced to leave their homes. Extensive damages to roads in Marystown. Extensive damages to roads, 1 family had to evacuate because of rising water in main area of their home.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
165	101	Avalon Peninsula	1979	1	28		1979	1	30		6	Winter	Eastern	3155	Marystown		Rainfall											MR: City crews were busy cleaning up flooded sewers and basements, entrance to The Health Sciences Centre was flooded by a nearby pond. Ice backed up water inundating the road between Robinsons and Cartyville with about 12 inches of water. A section of the Cabot Highway near Catalina was under 6 inches of water but remained passable. A stream overflowed its banks and 4 families were forced to leave their homes. Extensive damages to roads in Marystown. Extensive damages to roads, 1 family had to evacuate because of rising water in main area of their home.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
166	101	Avalon Peninsula	1979	1	28		1979	1	30		6	Winter	Eastern	2790	Little Bay		Rainfall											MR: City crews were busy cleaning up flooded sewers and basements, entrance to The Health Sciences Centre was flooded by a nearby pond. Ice backed up water inundating the road between Robinsons and Cartyville with about 12 inches of water. A section of the Cabot Highway near Catalina was under 6 inches of water but remained passable. A stream overflowed its banks and 4 families were forced to leave their homes. Extensive damages to roads in Marystown. Extensive damages to roads, 1 family had to evacuate because of rising water in main area of their home.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
167	102	Stephenville, Corner Brook, Roddickton	1979	3	6		1979	3	9		3	Winter	Western	4945	Stephenville	Blanche Brook	Rainfall and Snowmelt	64				$120,000						MR: 80ft section of retaining wall felled by high flows and ice. Some basement flooding and minor road damages was reported throughout the city. Blocked culverts and ditches caused some flooding in the roads	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
168	102	Stephenville, Corner Brook, Roddickton	1979	3	6		1979	3	9		3	Winter	Western	1200	Corner Brook		Rainfall and Snowmelt	64				$120,000	$120,000					MR: 80ft section of retaining wall felled by high flows and ice. Some basement flooding and minor road damages was reported throughout the city. Blocked culverts and ditches caused some flooding in the roads	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
169	102	Stephenville, Corner Brook, Roddickton	1979	3	6		1979	3	9		3	Winter	Western	4250	Roddickton		Rainfall and Snowmelt	64				$120,000						MR: 80ft section of retaining wall felled by high flows and ice. Some basement flooding and minor road damages was reported throughout the city. Blocked culverts and ditches caused some flooding in the roads	MR: Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook. Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
170	103	Stephenville	1979	7	17		1979	7	20		3	Summer	Western	4945	Stephenville	Blanche Brook	Rainfall	42.2										Hansen Hwy bridge jammed with debris, there was also some basement flooding	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
171	104	Bishops Falls	1979	8	17		1979	8	18		1	Summer	Central	405	Bishops Falls		Rainfall											A river flowing through the town overflowed causing considerable damage to dwellings, the towns bridge, culverts, the towns street was also washed out.	Flooding Events in Newfoundland and Labrador - An Historical Perspective	No	AMEC
172	105	Burin Peninsula	1979	11	10		1979	11	12		3	Fall	Eastern	2790	Little Bay		unknown									1		One family had to evacuate, water began to rise to the main floor of their home.	Flooding Events in Newfoundland and Labrador - An Historical Perspective, Dept of Natural Resources Website	293	AMEC
173	106	Portland Creek, Hawke's Bay, Corner Brook	1979	11	4		1979	11	7		4	Fall	Eastern	3995	Portland Creek		Rainfall	91										MR: Section of highway under 0.5m of water. Flooding and rockslides reported at several locations.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Steady Brook Area	No	AMEC
174	106	Portland Creek, Hawke's Bay, Corner Brook	1979	11	4		1979	11	7		4	Fall	Eastern	2205	Hawke's Bay	Big East River	Rainfall	91										MR: Section of highway under 0.5m of water. Flooding and rockslides reported at several locations.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Steady Brook Area	No	AMEC
175	106	Portland Creek, Hawke's Bay, Corner Brook	1979	11	4		1979	11	7		4	Fall	Western	1200	Corner Brook		Rainfall											MR: Section of highway under 0.5m of water. Flooding and rockslides reported at several locations.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Hydro technical Study of the Steady Brook Area	No	AMEC
176	107	Corner Brook	1980	8	10		1980	8	11		1	Summer	Western	1200	Corner Brook		Rainfall										1 family	Minimal damage to city streets. One family forced to vacate basement apartment	Hydro technical Study of the Steady Brook Area	No	AMEC
177	108	St. John's	1980	11	N/A		1980	11	N/A		N/A	Fall	Eastern	4400	St. John's		Snowmelt											Unconfirmed reporting of flooding in Bowering Park	Waterford River Area - Hydro technical Study	No	AMEC
178	109	Corner Brook	1981	2	3		1981	2	4		1	Winter	Western	1200	Corner Brook		Rainfall											20-25 washouts reported	Hydro technical Study of Steady Brook Area	No	AMEC
179	110	Codroy Valley	1981	2	5		1981	2	7		2	Winter	Western	1105	Codroy Valley		Ice Jam											Ice Jams caused flooding to 2 nearby homes and surrounding farmland	Flood Risk Mapping Study of the Codroy Valley Area	No	AMEC
180	111	Corner Brook	1981	2	12		1981	2	13		1	Winter	Western	1200	Corner Brook		Rainfall											Minor Flooding reported in Corner Brook	Hydro technical Study of the Steady Brook Area	No	AMEC
181	112	Deer Lake	1981	5	4		1981	5	16		12	Spring	Western	1380	Deer Lake		Rainfall											Serious flooding of south shore of Deer Lake and Nicholsville reported	Hydro technical Study of the Deer Lake Area	No	AMEC
182	113	Avalon Peninsula	1981	10	10		1981	10	11		1	Fall	Eastern	4400	St. John's		Rainfall	121										121mm of rain over 2.5 days resulted in serious flooding in the Southside Hills area and Mundy Pond area	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
183	114	Avalon Peninsula	1981	11	26		1981	11	26		1	Fall	Eastern	4400	St. John's	Waterford River	Rainfall	76										Heavy rain in one day caused overbank flooding in a number of areas around St. John's (Southside Road)	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
184	115	Placentia	1982	1	10	10:00	1982	1	10	13:00	1	Winter	Eastern	3800	Placentia		Coastal Flooding											Worst flooding in history of community. Houses flooded, people forced to row along road in dories. Unusually high tides flooded houses in St. M	Heritage Newfoundland Website	No	AMEC
185	116	Placentia	1982	1	16		1982	1	16		1	Winter	Eastern	3800	Placentia		Coastal Flooding					$300,000	$300,000					Waves broke through the beach and washed across the road in the area of the high school. The water flooded some areas that were still under water from the flood a week earlier	Hydro technical Study of the Placentia Area Flood Plain	No	AMEC
186	117	Stephenville	1982	4	N/A		1982	4	N/A		N/A	Spring	Western	3485	Noel's Pond	Warm Creek	unknown											Extensive basement flooding in community of Noel's Pond	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
187	118	Steady Brook	1982	5	4		1982	5	10		6	Spring	Western	4935	Steady Brook		Rainfall											Some property damage reported in the community of Steady Brook	Hydro technical Study of the Steady Brook Area	No	AMEC
188	119	St. John's	1982	10	3		1982	10	5		1	Fall	Eastern	4400	St. John's		Rainfall	100										Over 100mm of rain fell in one day during a severe storm but little or no flooding recorded	Waterford River Area - Hydro technical Study	No	AMEC
189	120	Glenwood-Appleton	1983	1	1		1983	1	14		13	Winter	Central	85	Glenwood-Appleton	Gander River	Rainfall											Water from the Gander River flooded the communities to a depth of 2m, marooning houses, cars boats, etc 40 basements were flooded and 12 families were forced to evacuate.	Glenwood-Appleton Flood Study Report	No	AMEC
190	121	Bishops Falls, Stephenville, Deer Lake	1983	1	11		1983	1	19		8	Winter	Central	405	Bishops Falls	Exploits River	Rainfall	200				$34,000,000	$34,000,000				180	MR: Heavy rain and mild temperatures caused damages along the Exploits and Gander Rivers, the Conne River and Stephenville. Caused damages to homes and roads. The exploits river flooded its banks after 10inch rainfall. Transportation routes affected in the South Brook area. In January heavy rains combined with snow melt caused Blanche Brook and Warm Creek to burst their banks.	MR: Environment Canada. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area. Stephenville Flood Information map, Department of the Environment, Water Resources Division	121, 121b	AMEC
191	121	Bishops Falls, Stephenville, Deer Lake	1983	1	11		1983	1	19		8	Winter	Central		Central		Rainfall	189				$34,000,000						MR: Heavy rain and mild temperatures caused damages along the Exploits and Gander Rivers, the Conne River and Stephenville. Caused damages to homes and roads. The exploits river flooded its banks after 10inch rainfall. Transportation routes affected in the South Brook area. In January heavy rains combined with snow melt caused Blanche Brook and Warm Creek to burst their banks.	MR: Environment Canada. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area. Stephenville Flood Information map, Department of the Environment, Water Resources Division	284	AMEC
192	121	Bishops Falls, Stephenville, Deer Lake	1983	1	11		1983	1	19		8	Winter	Western	4945	Stephenville		Rainfall	189				$34,000,000						MR: Heavy rain and mild temperatures caused damages along the Exploits and Gander Rivers, the Conne River and Stephenville. Caused damages to homes and roads. The exploits river flooded its banks after 10inch rainfall. Transportation routes affected in the South Brook area. In January heavy rains combined with snow melt caused Blanche Brook and Warm Creek to burst their banks.	MR: Environment Canada. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area. Stephenville Flood Information map, Department of the Environment, Water Resources Division	284	AMEC
193	121	Bishops Falls, Stephenville, Deer Lake	1983	1	11		1983	1	19		8	Winter	Western	1380	Deer Lake		Rainfall and Snowmelt	189				$34,000,000						MR: Heavy rain and mild temperatures caused damages along the Exploits and Gander Rivers, the Conne River and Stephenville. Caused damages to homes and roads. The exploits river flooded its banks after 10inch rainfall. Transportation routes affected in the South Brook area. In January heavy rains combined with snow melt caused Blanche Brook and Warm Creek to burst their banks.	MR: Environment Canada. Heritage Newfoundland Website. Hydro technical Study of the Deer Lake Area. Stephenville Flood Information map, Department of the Environment, Water Resources Division	284	AMEC
194	122	Badger	1983	2	15		1983	2	17		3	Winter	Central	155	Badger	Exploits River	Ice Jam					$89,000	$89,000					Several homes were evacuated, 40 affected by flooding	Hydro technical Study of the Badger and Rushy Pond Area, Department of the Environment, Water Resources Division	276	AMEC
195	123	Rushoon	1983	3	3	18:30	1983	3	8	20:30	5	Winter	Eastern	4295	Rushoon		Ice Jam					$25,000	$25,000			8		Eight houses were flooded. Seven families were evacuated for 3 days	Rushoon Flood Study Report, Dept of Natural Resources Website	301	AMEC
196	124	Deer Lake	1983	4	20		1983	4	20		1	Spring	Western	1380	Deer Lake	Humber River	Rainfall and Snowmelt											Minor flooding was reported along the Humber River downstream of Deer Lake	Hydro technical Study of the Deer Lake Area	No	AMEC
197	125	Stephenville	1983	6	N/A		1983	6	N/A		N/A	Summer	Western	3485	Noel's Pond	Warm Creek												Minor basement flooding	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
198	126	Stephenville, Deer Lake	1983	8	7		1983	8	13		6	Summer	Western	4945	Stephenville		Rainfall					$100,000						MR: Many properties were noted to be partially under water along Steady Brook and the Humber River. Flooding on Deer Lake caused the abandonment of some municipal parks. Heavy rainfall resulted in flooding described as the worst in the town's history. $100,000 of damage was reported.	MR: Hydro technical Study of the Deer Lake Area. Stephenville Flood Information map, Department of the Environment, Water Resources Division, Department of Natural Resources Website.	306	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
199	126	Stephenville, Deer Lake	1983	8	7		1983	8	13		6	Summer	Western	1380	Deer Lake	Humber River / Steady Brook	Rainfall					$100,000	$100,000					MR: Many properties were noted to be partially under water along Steady Brook and the Humber River. Flooding on Deer Lake caused the abandonment of some municipal parks. Heavy rainfall resulted in flooding described as the worst in the town's history. $100,000 of damage was reported.	MR: Hydro technical Study of the Deer Lake Area. Stephenville Flood Information map, Department of the Environment, Water Resources Division, Department of Natural Resources Website.	306	AMEC
200	127	Placentia	1983	12	22		1983	12	22		1	Winter	Eastern	3800	Placentia		Coastal Flooding					$3,000,000	$3,000,000				70-80	Severe flooding occurred during storm. Remedial measures cost in excess of $3,000,000	Heritage Newfoundland Website	127	AMEC
202	128	Western and Eastern Newfoundland	1984	2	4		1984	2	16		12	Winter	Western	4945	Stephenville	Harry's River	Rainfall											MR: Flooding due to torrential rainfalls. Minor flooding due to high temperatures and rain. Many flooded basements and the airport was closed. Flooding due to torrential rainfalls. Harry's River was blocked and water rose over farmland, 20 people were evacuated	MR: Department of Natural Resources (website). Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area.	128	AMEC
203	128	Western and Eastern Newfoundland	1984	2	4		1984	2	16		12	Winter	Western	420	Black Duck		Rainfall											MR: Flooding due to torrential rainfalls. Minor flooding due to high temperatures and rain. Many flooded basements and the airport was closed. Flooding due to torrential rainfalls. Harry's River was blocked and water rose over farmland, 20 people were evacuated	MR: Department of Natural Resources (website). Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area.	128	AMEC
204	128	Western and Eastern Newfoundland	1984	2	4		1984	2	16		12	Winter	Western	3940	Port au Port		Rainfall											MR: Flooding due to torrential rainfalls. Minor flooding due to high temperatures and rain. Many flooded basements and the airport was closed. Flooding due to torrential rainfalls. Harry's River was blocked and water rose over farmland, 20 people were evacuated	MR: Department of Natural Resources (website). Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area.	128	AMEC
205	128	Western and Eastern Newfoundland	1984	2	4		1984	2	16		12	Winter	Eastern	4400	St. John's		Rainfall											MR: Flooding due to torrential rainfalls. Minor flooding due to high temperatures and rain. Many flooded basements and the airport was closed. Flooding due to torrential rainfalls. Harry's River was blocked and water rose over farmland, 20 people were evacuated	MR: Department of Natural Resources (website). Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area.	128	AMEC
206	128	Western and Eastern Newfoundland	1984	2	4		1984	2	16		12	Winter	Central	1760	Gander		Rainfall	45										MR: Flooding due to torrential rainfalls. Minor flooding due to high temperatures and rain. Many flooded basements and the airport was closed. Flooding due to torrential rainfalls. Harry's River was blocked and water rose over farmland, 20 people were evacuated	MR: Department of Natural Resources (website). Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area.	128	AMEC
207	129	Stephenville Crossing/Black Duck Siding Area	1984	2	4		1984	2	5	12:45	1	Winter	Western	420	Black Duck Siding	Harry's River	Rainfall and Ice Jams	58.3			2.5	$100,000	$100,000			2		Cold temps in Jan and warmer temps with rain in Feb cause the ice to break in Harry's River. This caused flooding over several properties and farmland	Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area	No	AMEC
208	130	Deer Lake	1984	6	3		1984	6	6		3	Summer	Western	1380	Deer Lake	Deer Lake / Humber River	Rainfall											At Nicholsville the basements of 4 or 5 houses were flooded as a result of high water levels on Deer Lake and the Upper Humber River	Hydro technical Study of the Deer Lake Area	No	AMEC
209	131	Stephenville Crossing/Black Duck Siding Area	1985	1	4		1985	1	7		3	Winter	Western	420	Black Duck Siding	Harry's River	Ice Jam											The ice jammed the river and caused the water to flow over the land	Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area	No	AMEC
210	132	Eastern Newfoundland	1984	2	8		1984	2	11		3	Winter	Central	1865	Glovertown	Terra Nova River	Ice Jam											An ice jam on the Terra Nova River formed following a mild spell that caused break-up and increased stream-flow. Two houses were seriously damaged in the resulting flood.	Glovertown Flood Study Report, Department of Natural Resources website	142	AMEC
211	133	Codroy Valley	1985	4	N/A		1985	4	N/A		N/A	Spring	Western	1105	Codroy Valley		unknown												Flood Risk Mapping Study of the Codroy Valley Area	No	AMEC
212	134	St. John's	1985	5	24		1985	5	25		1	Spring	Eastern	4400	St. John's	South Brook Tributaries	Rainfall	85										85mm of rain fell in 33 hours causing flooding from Donovans to Kilbride and along a South Brook Tributary	Waterford River Area - Hydro technical Study	No	AMEC
213	135	Stephenville Crossing/Black Duck Siding Area	1986	1	N/A		1986	1	N/A		N/A	Winter	Western	420	Black Duck Siding	Harry's River	Ice Jam											Ice jams caused flooding similar to the flooding in Jan 1985, only this time the flooding was more serious	Hydro technical Study of the Stephenville Crossing and Black Duck Siding Area	No	AMEC
214	136	St. Phillips	1986	2	N/A		1986	2	N/A		N/A	Winter	Eastern	4000	St. Phillips	Broad Cove River	Ice Jam											A combination of a Ice Jam and rainwater caused flooding damages to a residence and surrounding farmland	Flood Risk Mapping Study of Portugal Cove, St. Phillips and Outer Cove	No	AMEC
215	137	Portugal Cove, St. John's	1986	4	11		1986	4	11		1	Spring	Eastern	4000	Portugal Cove		Rainfall											MR: 77mm fell in 11 hours. Snowmelt combined with frozen ground increased the severity of the flooding. An undersized culvert caused flooding and damages to two adjacent properties. 70mm of rain in 22 hours on frozen soil led to flooding at Dunn's and Waterford Road Bridges and other areas.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flood Risk Mapping Study of Portugal Cove, St. Phillips and Outer Cove. Waterford River Area - Hydro technical Study	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
216	137	Portugal Cove, St. John's	1986	4	11		1986	4	11		1	Spring	Eastern	3760	Petty Harbour - Maddox Cove		Rainfall	71										MR: 77mm fell in 11 hours. Snowmelt combined with frozen ground increased the severity of the flooding. An undersized culvert caused flooding and damages to two adjacent properties. 70mm of rain in 22 hours on frozen soil led to flooding at Dunn's and Waterford Road Bridges and other areas.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flood Risk Mapping Study of Portugal Cove, St. Phillips and Outer Cove. Waterford River Area - Hydro technical Study	No	AMEC
217	137	Portugal Cove, St. John's	1986	4	11		1986	4	11		1	Spring	Eastern	4400	St. John's	Waterford River	Rainfall	70										MR: 77mm fell in 11 hours. Snowmelt combined with frozen ground increased the severity of the flooding. An undersized culvert caused flooding and damages to two adjacent properties. 70mm of rain in 22 hours on frozen soil led to flooding at Dunn's and Waterford Road Bridges and other areas.	MR: Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland. Flood Risk Mapping Study of Portugal Cove, St. Phillips and Outer Cove. Waterford River Area - Hydro technical Study	No	AMEC
218	138	Fortune	1986	6	6		1986	6	6		1	Summer	Eastern	1650	Fortune		Rainfall	76.2										MR: The main sewer system was washed away, Bay Street was closed, which is the main street leading to the fish plant. Also some property damage. Several basements and residential properties flooded	Department of Natural Resources website	138	AMEC
219	138	Fortune	1986	6	6		1986	6	6		1	Summer	Eastern	1940	Grand Bank		Rainfall	76.2										MR: The main sewer system was washed away, Bay Street was closed, which is the main street leading to the fish plant. Also some property damage. Several basements and residential properties flooded	Department of Natural Resources website	138	AMEC
220	139	Hant's Harbour	1987	2	2		1987	2	2		1	Winter	Eastern	2095	Hant's Harbour	Halfway Brook	Ice Jam											Ice blocked the brook, then the rain and snowmelt produced runoff which caused the brook to overflow. A summer home was surrounded by water and access to five other homes and two summer cottages were inaccessible	Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour	No	AMEC
221	140	St. John's	1987	2	26		1987	2	27		1	Winter	Eastern	4400	Gould's	Ryan's River	Ice Jam											explosives was used to remove an ice jam behind Avalon Raceway after it caused some basement flooding	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
222	141	St. John's	1987	3	17		1987	3	20		3	Winter	Eastern	4400	Gould's		Rainfall	74										Record snowfalls over the winter left the river channels filled with snow and ice,. During melt period it caused the bands to overflow .	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
223	142	Glovertown	1988	N/A	N/A		1988	N/A	N/A		N/A	Winter	Central	1865	Glovertown	Terra Nova River	Ice Jam											Minor damage was caused by an ice jam at the river mouth	Department of Natural Resources website	142	AMEC
224	143	St. John's	1988	2	26		1988	3	2		6	Winter	Eastern	4400	Gould's	Ryan's River	Ice Jam											Ice Jam on Ryan's river caused flooding to some basements.	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
225	144	St. John's	1988	4	8		1988	4	8		1	Spring	Eastern	4400	St. John's		Rainfall											Heavy rainfall cause damages to several properties/roads to different areas of the city.	The Telegram	No	AMEC
226	145	Placentia	1989	1	5		1989	1	5		1	Winter	Eastern	3800	Placentia		Winds / Tides										20	40-50 homes in the area affected by flooding, some didn't evacuate	The Evening Telegram	145	AMEC
227	146	Ferryland	1989	1	4		1989	1	4		1	Winter	Eastern	1580	Ferryland		Coastal Flooding										2 families	Two families evacuated after a breakwater broke in the community	Flood Risk Mapping Study - Gould's, Petty Harbour and Ferryland	No	AMEC
228	147	St. John's	1989	1	9		1989	1	9		1	Winter	Eastern	4400	Gould's	Raymond River	Ice Jam											Raymond River had overflowed its banks for a week and had flooded one residents septic tank.	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
229	148	Stephenville	1989	8	N/A		1989	8	N/A		N/A	Summer	Western	4945	Stephenville		unknown												Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
230	149	Victoria	1990	1	27		1990	1	27		1	Winter	Eastern	5225	Victoria	Salmon Cove River	Ice Jam											The cover of the river broke and jammed downstream of the bridge, some of the ice and water bypassed the ice jam and flooded the surrounding area	Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour	No	AMEC
231	150	Carbonear, Victoria	1990	2	10		1990	2	11		1	Winter	Eastern	950	Carbonear	Powell's Brook	Rainfall											MR: Heavy rains caused extensive flooding, roads were washed away when ice broke loose. A ice jam occurred in the night time and due to darkness and the ice cover in the area measures to rectify the situation were delayed until daylight and three houses were flooded	Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour	No	AMEC
232	150	Carbonear, Victoria	1990	2	10		1990	2	11		1	Winter	Eastern	5225	Victoria	Salmon Cove River	Ice Jam											MR: Heavy rains caused extensive flooding, roads were washed away when ice broke loose. A ice jam occurred in the night time and due to darkness and the ice cover in the area measures to rectify the situation were delayed until daylight and three houses were flooded	Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour	No	AMEC
233	151	St. John's	1990	3	4		1990	3	4		1	Winter	Eastern	4400	Gould's		Rainfall											Melting snow and rainfall caused flooding of one barn at the Avalon Raceway and several feet of water across the parking lot.	Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
234	152	Stephenville	1990	8	N/A		1990	8	N/A		N/A	Summer	Western	4945	Stephenville	Blanche Brook	unknown											Bridges were damaged and culverts washed out	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
235	153	Stephenville	1990	12	9		1990	12	9		1	Winter	Western	4945	Stephenville	Warm Creek	Rainfall	100										Culverts were washed out and bridges were damaged	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
236	154	Victoria, Winterton, St. John's	1991	2	15		1991	2	15		1	Winter	Eastern	5225	Victoria	Salmon Cove River	Rainfall											MR: Heavy rains combined with snowmelt caused damages to several residences. Rain combined with snowmelt caused flooding conditions, water flowed over the highway and overtopped the river banks. snowmelt and rainfall caused flooding in many areas in the Gould's. Doyles River flooded its banks.	MR: Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour. Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
237	154	Victoria, Winterton, St. John's	1991	2	15		1991	2	15		1	Winter	Eastern	5450	Winterton	Western Pond Brook	Rainfall and Snowmelt	63										MR: Heavy rains combined with snowmelt caused damages to several residences. Rain combined with snowmelt caused flooding conditions, water flowed over the highway and overtopped the river banks. snowmelt and rainfall caused flooding in many areas in the Gould's. Doyles River flooded its banks.	MR: Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour. Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
238	154	Victoria, Winterton, St. John's	1991	2	15		1991	2	16		1	Winter	Eastern	4400	Gould's	Doyle's River	Rainfall	40										MR: Heavy rains combined with snowmelt caused damages to several residences. Rain combined with snowmelt caused flooding conditions, water flowed over the highway and overtopped the river banks. snowmelt and rainfall caused flooding in many areas in the Gould's. Doyles River flooded its banks.	MR: Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour. Flood Risk Mapping Study of Gould's, Petty Harbour and Ferryland	No	AMEC
239	155	Eastern Newfoundland	1991	2	17		1991	2	18		2	Winter	Eastern	4400	St. John's	Mundy Pond	Rainfall	45.6										MR: Rainfall caused flooding to residential property, and some damage to roads in the Shea Heights area. A bridge in Seal Cove was washed out by the rain. Extensive flood damage was reported in Winterton, where ice and water clogged the main brook running through the town causing tremendous overflow. The town had to call a state of emergency when rafting ice in the Shoal Harbour River threatened a bridge and also extensively damaged several houses.	Evening Telegram	155	AMEC
240	155	Eastern Newfoundland	1991	2	17		1991	2	18		2	Winter	Eastern	1145	Conception Bay South		Rainfall	45.6										MR: Rainfall caused flooding to residential property, and some damage to roads in the Shea Heights area. A bridge in Seal Cove was washed out by the rain. Extensive flood damage was reported in Winterton, where ice and water clogged the main brook running through the town causing tremendous overflow. The town had to call a state of emergency when rafting ice in the Shoal Harbour River threatened a bridge and also extensively damaged several houses.	Evening Telegram	155	AMEC
241	155	Eastern Newfoundland	1991	2	17		1991	2	18		2	Winter	Eastern	5450	Winterton		Rainfall	45.6										MR: Rainfall caused flooding to residential property, and some damage to roads in the Shea Heights area. A bridge in Seal Cove was washed out by the rain. Extensive flood damage was reported in Winterton, where ice and water clogged the main brook running through the town causing tremendous overflow. The town had to call a state of emergency when rafting ice in the Shoal Harbour River threatened a bridge and also extensively damaged several houses.	Evening Telegram	155	AMEC
242	155	Eastern Newfoundland	1991	2	17		1991	2	18		2	Winter	Eastern	1055	Shoal Harbour		Rainfall	45.6										MR: Rainfall caused flooding to residential property, and some damage to roads in the Shea Heights area. A bridge in Seal Cove was washed out by the rain. Extensive flood damage was reported in Winterton, where ice and water clogged the main brook running through the town causing tremendous overflow. The town had to call a state of emergency when rafting ice in the Shoal Harbour River threatened a bridge and also extensively damaged several houses.	Evening Telegram	155	AMEC
243	156	Burin Peninsula	1991	10	15		1991	10	15		1	Fall	Eastern		Mooring Cove		Rainfall	65.2										The river created a 50ft cavern which cut off the highway between mooring cove and Spanish Room. It caused isolation of approximately 20,000 people.	Department of Natural Resources Website.	156	AMEC
244	156	Burin Peninsula	1991	10	15		1991	10	15		1	Fall	Eastern	725	Burin		Rainfall	65.2				$300,000	$300,000					65.2mm of rain fell in a few hours, approximately $300,000 to local school.	The Evening Telegram	156	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
245	157	Placentia	1991	12	25		1991	12	25		1	Winter	Eastern	3800	Placentia		Winds / Tides / Rainfall	32.5									10	Flooding caused by winds and tides, many people evacuated from their homes, 1/3 of town under water	The Evening Telegram	157	AMEC
247	158	Conception Bay	1992	10	10		1992	10	10		1	Fall	Eastern	1145	Conception Bay South		Coastal Flooding											A severe storm produced considerable damage to property along much of Conception Bay shore. Considerable damage to property along much of CB shore. Numerous boats sunk/damaged. Rain and high winds caused damages to over a dozen homes. Basements were flooded, sewer backup and eroding problems	Department of Natural Resources Website	158	AMEC
248	275	Grand Bank	1993	10	N/A		1993	10	N/A		N/A	Fall	Eastern	725	Burin Peninsula		Rainfall	76.2										Over a dozen homes experienced flooded basements due to sewer back-ups, and runoff eroding	Department of Natural Resources Website.	275	AMEC
249	159	Hant's Harbour	1995	1	7		1995	1	8		2	Winter	Eastern	2095	Hant's Harbour	Halfway Brook	Rainfall and Snowmelt											Record captured by Dept. Source not found.	Flood Risk Mapping Study of Carbonear, Victoria, Salmon Cove, Whitbourne, Heart's Delight, Winterton, Hant's Harbour	No	AMEC
250	160	Frenchman's Cove Pond	1995	1	N/A		1995	1	N/A		N/A	Winter	Eastern	1710	Frenchman's Cove		Rainfall	50.8										Flooded roads, no cars could pass in any direction.	Department of Natural Resources Website.	160	AMEC
251	161	Stephenville	1995	1	N/A		1995	1	N/A		N/A	Winter	Western	4945	Stephenville	Warm Creek	unknown											Flooding between Noels Pond and Route 460	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
252	162	Stephenville	1995	3	N/A		1995	3	N/A		N/A	Winter	Western	4945	Stephenville	Blanche Brook	Ice Jam											Ice Jam resulting in a section of the road closed to traffic, flooding on Massachusetts Drive	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
253	163	Stephenville	1995	6	N/A		1995	6	N/A		N/A	Summer	Western	4945	Stephenville	Blanche Brook	unknown	118										River bend erosion along Minnesota Drive, erosion and collapse of gabion retaining walls	Flood Risk Mapping Study of Stephenville, Kippens and Cold Brook	No	AMEC
254	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Central	165	Wesleyville		Coastal Waves	116				$2,200,000	$2,200,000					MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC
256	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Eastern	2675	Lamaline		Rainfall	116				$2,200,000						MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC
257	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Eastern		Drake's Cove		Rainfall	116				$2,200,000						MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC
258	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Eastern	1665	Fox Cove-Mortier		Rainfall	116				$2,200,000						MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
259	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Eastern	1545	Epworth	Bugdens Brook	Rainfall	116				$2,200,000						MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC
260	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Eastern	2885	Little St. Lawrence		Rainfall	116				$2,200,000						MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC
261	164	Burin Peninsula	1995	9	11		1995	9	11		1	Summer	Eastern	2745	Lawn		Rainfall	116				$2,200,000						MR: Damages to roads in the community. Hurricane Luis. Two bridges were washed out and at least one home destroyed. A portion of the highway near Lamaline was washed out. Heavy rains and winds caused damages to roads, bridges and several basements were flooded. A half dozen washouts developed in the area. In Epworth the roads were damaged. Bugdens Brook overflowed its bank. A bridge was washed out, several washouts throughout the town. Several washouts throughout the town.	Department of Natural Resources Website	164	AMEC
262	165	Humber Arm Region	1996	2	17		1996	2	18		2	Winter	Western	1200	Corner Brook		Rainfall and Snowmelt	49										Two days of heavy rain and melting snow caused flooding in Corner Brook, Curling and Massey Drive. Washouts and mudslides occurred. In Cox's Cove, a few homes flooded. In Flat Bay many cabins were seriously damaged.	Department of Natural Resources Website	165	WRMD
263	165	Humber Arm Region	1996	2	17		1996	2	18		2	Winter	Western		Curling		Rainfall and Snowmelt	49										Two days of heavy rain and melting snow caused flooding in Corner Brook, Curling and Massey Drive. Washouts and mudslides occurred. In Cox's Cove, a few homes flooded. In Flat Bay many cabins were seriously damaged.	Department of Natural Resources Website	165	WRMD
264	165	Humber Arm Region	1996	2	17		1996	2	18		2	Winter	Western	3167	Massey Drive		Rainfall and Snowmelt	49										Two days of heavy rain and melting snow caused flooding in Corner Brook, Curling and Massey Drive. Washouts and mudslides occurred. In Cox's Cove, a few homes flooded. In Flat Bay many cabins were seriously damaged.	Department of Natural Resources Website	165	WRMD
265	165	Humber Arm Region	1996	2	17		1996	2	18		2	Winter	Western	1235	Cox's Cove		Rainfall and Snowmelt	49										Two days of heavy rain and melting snow caused flooding in Corner Brook, Curling and Massey Drive. Washouts and mudslides occurred. In Cox's Cove, a few homes flooded. In Flat Bay many cabins were seriously damaged.	Department of Natural Resources Website	165	WRMD
266	165	Humber Arm Region	1996	2	17		1996	2	18		2	Winter	Western	1605	Flat Bay		Rainfall and Snowmelt	49										Two days of heavy rain and melting snow caused flooding in Corner Brook, Curling and Massey Drive. Washouts and mudslides occurred. In Cox's Cove, a few homes flooded. In Flat Bay many cabins were seriously damaged.	Department of Natural Resources Website	165	WRMD
267	166	Hermitage - Sandyville	1998	4	14		1998	4	14		1	Spring	Central	2265	Hermitage-Sandyville	Granfer's Pond	Dam Break	40				$3,000,000	$3,000,000					Heavy rainfall. ~40 mm of rain. Hermitage-Sandyville. Estimates of $3,000,000 in damages to the water supply, main highway and the spinoff influences on the fish plant and other businesses and population in general.	Multiple	166	WRMD
268	167	St. John's	1998	4	8		1998	4	8		1	Spring	Eastern	4400	St. John's	Leary's Brook	Rainfall	65.7				$140,000	$140,000			11		Heavy rainfall. 65.7 mm of rain. St. John's. $140,000 in damages including road erosion and 11 claims for property damage.	The Evening Telegram, Internal Site Report	167	WRMD
269	168	King's Point	1998	9	23		1998	9	24		2	Fall	Central	2595	King's Point	Paddy's Brook	Rainfall	31.85										Heavy rainfall. 28-35.7 mm of rain, Springdale to La Scie respectively. King's Point. A culvert had washed out.	Multiple	168	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
270	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Western	2735	La Scie	Morgan's Brook	Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
271	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Western	580	Brent's Cove		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
272	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Western	4605	Seal Cove		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
273	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Central	5390	Wild Cove		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
274	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Central		Birchy Lake		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
275	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Central	1655	Fortune Harbour		Rainfall	84.1				$1,250,000	$1,250,000					Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
276	170	Gould's & Petty Harbour	1998	10	16		1998	10	17		2	Fall	Eastern	4400	St. John's - Gould's	Doyle's River	Rainfall	91.7				$10,000	$10,000			multiple		Heavy rain. 91.7 mm of rain w/ 5 to 10 yr return period. St. John's - Gould's and Petty Harbour. Basements were flooded in Petty Harbour as a power dam overflowed; $3,500 in damages. Roads eroded & washed out in the Gould's; $6,500 in damages.	Multiple	170	WRMD
277	170	Gould's & Petty Harbour	1998	10	16		1998	10	17		2	Fall	Eastern	3760	Petty Harbour - Maddox Cove	Petty Harbour River	Rainfall	70										Heavy rain. 91.7 mm of rain w/ 5 to 10 yr return period. St. John's - Gould's and Petty Harbour. Basements were flooded in Petty Harbour as a power dam overflowed; $3,500 in damages. Roads eroded & washed out in the Gould's; $6,500 in damages.	Multiple	170	WRMD
278	171	St. Phillips	1999	1	10		1999	1	11		2	Winter	Eastern	4000	Portugal Cove-St. Phillips	Broad Cove River	Rainfall and Snowmelt	40								1		Heavy rain & snowmelt. 40 mm of rain. Portugal Cove-St. Phillips. Broad Cove river overflowed its banks and flooded a resident's basement.	Internal Site Report	171	WRMD
279	172	West Coast	1999	1	24		1999	1	25		2	Winter	Western	4945	Stephenville	Noel's Pond	Rainfall	35.6	20									Heavy rainfall and snow. Portion of highway shoulder near Bonne Bay Pond had 30 metres washed away and dropped off by about 10 feet. No major accidents. TCH Deer Lake to Birchy Narrows minor shoulder damage.	Internal Site Report, The Telegram, Environment Canada	172	WRMD
280	172	West Coast	1999	1	24		1999	1	25		2	Winter	Western	1380	Deer Lake	Steady Brook	Rainfall	40.4	118									Heavy rainfall and snow. Portion of highway shoulder near Bonne Bay Pond had 30 metres washed away and dropped off by about 10 feet. No major accidents. TCH Deer Lake to Birchy Narrows minor shoulder damage.	Internal Site Report, The Telegram, Environment Canada	172	WRMD
281	172	West Coast	1999	1	24		1999	1	25		2	Winter	Western	1200	Corner Brook	Bonne Bay Pond	Rainfall	43.4	60									Heavy rainfall and snow. Portion of highway shoulder near Bonne Bay Pond had 30 metres washed away and dropped off by about 10 feet. No major accidents. TCH Deer Lake to Birchy Narrows minor shoulder damage.	Internal Site Report, The Telegram, Environment Canada	172	WRMD
282	172	West Coast	1999	1	24		1999	1	25		2	Winter	Western	3940	Port au Port East		Rainfall											Heavy rainfall and snow. Portion of highway shoulder near Bonne Bay Pond had 30 metres washed away and dropped off by about 10 feet. No major accidents. TCH Deer Lake to Birchy Narrows minor shoulder damage.	Internal Site Report, The Telegram, Environment Canada	172	WRMD
283	173	St. John's	1999	4	13		1999	4	13		1	Spring	Eastern	4400	St. John's	Waterford River	Rainfall and Snowmelt											Heavy rain & snowmelt. St. John's. Waterford river overflowed its banks flooding some backyards of homes.	Multiple	173	WRMD
284	174	St. John's	1999	4	29		1999	4	29		1	Spring	Eastern	4000	Portugal Cove-St. Phillips	Doyle's River	Rainfall											Heavy rain. 70.8 mm or rain in 24 hr period. St. John's & Portugal Cove-St. Phillips. Basement flooding and road shoulder erosion were noted; one lane on Thorburn Rd closed due to cave in.	The Telegram	174	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
285	174	St. John's	1999	4	29		1999	4	29		1	Spring	Eastern	4400	St. John's	Waterford River	Rainfall	70.8								at least 2		Heavy rain. 70.8 mm or rain in 24 hr period. St. John's & Portugal Cove-St. Phillips. Basement flooding and road shoulder erosion were noted; one lane on Thorburn Rd closed due to cave in.	The Telegram	174	WRMD
291	175	South Coast	1999	9	23		1999	9	23		1	Summer	Eastern	4345	St. Brides	Atlantic Ocean	Coastal Waves											Tropical Storm Gert. St. Bride's. Hurricane Gert downgraded to Tropical Storm Gert caused damage to the breakwater, wharf and other Federal property as well as private fishing vessels. 2 dozen fishermen affected with several losing boats and gear and it cut their season short.	VOCM, The Northern Pen	175, 176	AMEC
292	175	South Coast	1999	9	23		1999	9	23		1	Summer	Eastern	3800	Placentia Bay		Rainfall											Tropical Storm Gert. St. Bride's. Hurricane Gert downgraded to Tropical Storm Gert caused damage to the breakwater, wharf and other Federal property as well as private fishing vessels. 2 dozen fishermen affected with several losing boats and gear and it cut their season short.	Department of Natural Resources Website	176	AMEC
294	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	251	Bay de Verde		Storm Surge					$125,000		$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
295	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	5145	Trepassey		Storm Surge					$242,000		$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
296	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	3830	Point aux Gaul		Storm Surge					$310,082		$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
297	178	South Coast	2000	1	22		2000	1	22		1	Winter	Western	1025	Channel-Port aux Basques	Atlantic Ocean	Storm Surge			14		$407,349	$1,291,818	$4,346,283	$4,346,283	multiple		MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
298	178	South Coast	2000	1	22		2000	1	22		1	Winter	Central	315	Belleoram		Storm Surge					$61,000		$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
299	178	South Coast	2000	1	22		2000	1	22		1	Winter	Central	4100	Ramea		Storm Surge					$134,387		$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
300	178	South Coast	2000	1	22		2000	1	22		1	Winter	Western		Channel Head Island		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	WRMD
302	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	615	Brigus		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
304	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	1060	Clarkes Beach		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
305	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	1125	Colliers		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
306	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	1280	Cupids		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
307	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern		Allan's Island		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
308	178	South Coast	2000	1	22		2000	1	22		1	Winter	Central	4385	St. Jacques-Coombs Cove		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
309	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	4990	Sunnyside		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
310	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	2675	Lamaline		Coastal Waves					$12,000		$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails.	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
311	179	Reidville	2000	5	21		2000	5	21		1	Spring	Western	4172	Reidville	Upper Humber River	Rainfall					$143,674	$143,674					Heavy rain & snowmelt. Q=871 m^3/s exceeding Q20=859 m^3/s. Reidville. Damaged a pump house & equipment; shifted the concrete pier of the Humber River bridge, $143,674.10 to replace bridge.	Government News Release, Email	179	WRMD
312	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	4400	St. John's	Atlantic Ocean	Coastal Waves			2.5		$13,800	$13,800			a few		Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
313	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	245	Bay Bulls		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
314	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	2125	Harbour Grace		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
315	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	2320	Holyrood		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
316	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	3760	Petty Harbour - Maddox Cove		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
317	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	4015	Pouch Cove		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
318	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	4215	Riverhead		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
319	180	Northeast Avalon Peninsula	2000	9	25	19:00	2000	9	25	21:00	1	Fall	Eastern	5125	Torbay		Coastal Waves											Storm Surge. 2-3 m high waves. NE Avalon Peninsula. Damage cost reported to be $13,800, including damaged boardwalks, flooded basements, etc.	MR: Multiple, VOCM, CBC	180	WRMD
320	181	St. John's	2001	2	15		2001	2	15		1	Winter	Eastern	4400	St. John's		Rainfall											Heavy rain. St. John's. Homes and roads were flooded when snow clogged drains followed by rain.	CBC	181	WRMD
321	182	St. John's	2001	7	12		2001	7	12		1	Summer	Eastern	4400	St. John's	Leary's Brook	Rainfall											Heavy rain. St. John's. Flash flood near Avalon Mall flooded the parking lot of Woodgate Plaza.	Email and The Telegram	182	WRMD
322	183	St. John's	2001	9	19		2001	9	19		1	Summer	Eastern	4400	St. John's	Quidi Vidi Lake	Rainfall	100				$6,700,000	$6,700,000	$6,083,243	$6,083,243	hundreds		Tropical Storm Gabrielle. 100 mm of rain exceeded the 1:100 year, 12 hour rainfall rate. St. John's. Widespread flooding & washouts flooded streets, houses, & buildings including the Avalon Mall & ~15 schools.	Department of Natural Resources Website, CBC News	183	WRMD
323	184	Shea Heights	2002	2	17		2002	2	17		1	Winter	Eastern	4400	St. John's - Shea Heights		Rainfall and Snowmelt									1		Heavy rain and snowmelt. Hartery Crescent, Shea Heights, St. John's. 1 basement flooded.	VOCM News	184	WRMD
324	185	Corner Brook	2002	2	11		2002	2	11		1	Winter	Western	1200	Corner Brook		Rainfall	30										Heavy rain. ~30 mm of rain. Corner Brook, West Coast. City streets were flooded.	The Western Star, Email, The Weather Network	185	WRMD
325	186	Corner Brook	2002	2	28		2002	2	28		1	Winter	Western	1200	Corner Brook		unknown											The city received 90 distress calls about flooding. Tiny rapids formed gauges in streets. Water was pouring out of manhole covers.	Department of Natural Resources Website	186	AMEC
326	187	Southern Avalon	2002	6	27		2002	6	27		1	Summer	Eastern		Cape Race		Rainfall	47.1										Heavy rain. 47.1 mm of rain. Cape Race, Southern Avalon. Shoulder washouts rumoured.	Email, Environment Canada	187	WRMD
327	188	St. Mary's Bay	2002	7	20		2002	7	20		1	Summer	Eastern	3530	North Harbour		Rainfall	142				$520,000	$520,000			10 or more		Heavy rain. Up to 142 mm of rain. St. Mary's Bay area. Damages cost $520,000 included road & shoulder washouts and flooded basements.	MR: Internet, Multiple	188	WRMD
328	188	St. Mary's Bay	2002	7	20		2002	7	20		1	Summer	Eastern	4415	St. Joseph's		Rainfall											Heavy rain. Up to 142 mm of rain. St. Mary's Bay area. Damages cost $520,000 included road & shoulder washouts and flooded basements.	MR: Internet, Multiple	188	WRMD
329	188	St. Mary's Bay	2002	7	20		2002	7	20		1	Summer	Eastern	2170	Harricott		Rainfall											Heavy rain. Up to 142 mm of rain. St. Mary's Bay area. Damages cost $520,000 included road & shoulder washouts and flooded basements.	MR: Internet, Multiple	188	WRMD
330	188	St. Mary's Bay	2002	7	20		2002	7	20		1	Summer	Eastern	3335	Mount Carmel-Mitchell's Brook-St. Catherine's		Rainfall											Heavy rain. Up to 142 mm of rain. St. Mary's Bay area. Damages cost $520,000 included road & shoulder washouts and flooded basements.	MR: Internet, Multiple	188	WRMD
331	189	Western Newfoundland	2002	9	12		2002	9	12		1	Summer	Western	4945	Stephenville	Deer Lake	Rainfall	18										Post-Tropical Storm Gustav. 40 to 70 mm of rain. Stephenville & Deer Lake. Reports of minor flooding.	MR: Email, Multiple	189	WRMD
332	189	Western Newfoundland	2002	9	12		2002	9	12		1	Summer	Western	1380	Deer Lake		Rainfall	47										Post-Tropical Storm Gustav. 40 to 70 mm of rain. Stephenville & Deer Lake. Reports of minor flooding.	MR: Email, Multiple	189	WRMD
333	190	Irish Town	2002	9	27		2002	9	27		1	Fall	Western	2425	Irish Town-Summerside		Rainfall	30										Heavy Rain. 30 mm of rain. Irishtown-Summerside. Culvert washed out.	Email	190	WRMD
334	191	Baie Verte Peninsula	2002	10	28		2002	10	28		1	Fall	Central	4770	Snook's Arm		Snowmelt		200									Snowmelt. 20 cm of snow. Snook's Arm, Baie Verte Peninsula. Road washed out.	Email	191	WRMD
335	192	St. John's	2002	12	15		2002	12	15		1	Fall	Eastern	4400	St. John's		Rainfall	48.5										Heavy rain. 48.5 mm of rain. Ayres Cove, Downtown, St. John's.	The Telegram, Environment Canada	192	WRMD
336	193	Badger	2003	2	15		2003	2	15		1	Winter	Central	155	Badger	Exploits River	Ice Jam					$2,630,000	$2,630,000	$8,223,258	$8,223,258	340	1100	Ice Jam. 1:100 yr flood water level. Badger. Sever flooding caused $2.63 M in damages including damages to houses, public buildings and water and sewer systems.	The Western Star, The Telegram	193, 276	WRMD
337	194	Flat Bay	2003	2	18		2003	2	18		1	Winter	Western	1605	Flat Bay	Flat Bay Brook	Ice Jam											No Details	Email	194	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
338	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western	1200	Corner Brook		Rainfall and Snowmelt					$1,400,000		$9,589,511				MR: Damage to infrastructure. The Trans Canada Highway is closed because of a flood damaged bridge. Rainfall and snowmelt. West Coast, Stephenville area. Sidewalk section washed away in Stephenville. In Cox's Cove basements were flooded as a result of floodwaters on the Frenchman's Pond watershed. Corner Brook suffered extensive damage	MR: The Western Star. Disaster News Network	195, 287	AMEC
339	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western		Pinchgut Bridge	Pinchgut River	Rainfall and Snowmelt					$1,400,000		$9,589,511				MR: Damage to infrastructure. The Trans Canada Highway is closed because of a flood damaged bridge. Rainfall and snowmelt. West Coast, Stephenville area. Sidewalk section washed away in Stephenville. In Cox's Cove basements were flooded as a result of floodwaters on the Frenchman's Pond watershed. Corner Brook suffered extensive damage	MR: The Western Star. Disaster News Network	195, 287	AMEC
340	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western	4945	Stephenville	Stream running along Minnesota Dr	Rainfall and Snowmelt					$1,400,000		$9,589,511				MR: Damage to infrastructure. The Trans Canada Highway is closed because of a flood damaged bridge. Rainfall and snowmelt. West Coast, Stephenville area. Sidewalk section washed away in Stephenville. In Cox's Cove basements were flooded as a result of floodwaters on the Frenchman's Pond watershed. Corner Brook suffered extensive damage	MR: The Western Star. Disaster News Network	196	AMEC
341	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western	4950	Stephenville Crossing	Pelleys Brook	Rainfall and Snowmelt					$1,400,000		$9,589,511				MR: Damage to infrastructure. The Trans Canada Highway is closed because of a flood damaged bridge. Rainfall and snowmelt. West Coast, Stephenville area. Sidewalk section washed away in Stephenville. In Cox's Cove basements were flooded as a result of floodwaters on the Frenchman's Pond watershed. Corner Brook suffered extensive damage	MR: The Western Star. Disaster News Network	195, 287	AMEC
342	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western		Bay of Islands		Rainfall and Snowmelt					$1,400,000		$9,589,511				Corner Brook suffered extensive damage	MR: The Western Star. Disaster News Network	195, 287	AMEC
343	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western	1235	Cox's Cove	Frenchman's Pond	Rainfall and Snowmelt					$1,400,000	$1,400,000	$9,589,511	$9,589,511	100+	24 families	In Cox's Cove basements were flooded as a result of floodwaters on the Frenchman's Pond watershed	MR: The Western Star. Disaster News Network, Dept of Natural Resources Website	195, 287	AMEC
345	197	Northeast Coast & Central	2003	5	10		2003	5	10		1	Spring	Central	1960	Grand Falls-Windsor	Exploits River	Rainfall	75										Rainfall. 26.8 mm fell on St. John's causing flooding throughout the city. On the same day road washouts were reported on the Baie Verte Highway and in Trinity Bay.	Multiple	197, 283	WRMD
346	197	Northeast Coast & Central	2003	5	10		2003	5	10		1	Spring	Western	740	Burlington	Leary's Brook	Rainfall											Rainfall. 26.8 mm fell on St. John's causing flooding throughout the city. On the same day road washouts were reported on the Baie Verte Highway and in Trinity Bay.	Multiple	197, 283	WRMD
347	197	Northeast Coast & Central	2003	5	10		2003	5	10		1	Spring	Western	4760	Smith's Harbour	Quidi Vidi Lake	Rainfall											Rainfall. 26.8 mm fell on St. John's causing flooding throughout the city. On the same day road washouts were reported on the Baie Verte Highway and in Trinity Bay.	Multiple	197, 283	WRMD
348	197	Northeast Coast & Central	2003	5	10		2003	5	10		1	Spring	Eastern	4400	St. John's	Rennie's River	Rainfall	26.8										Rainfall. 26.8 mm fell on St. John's causing flooding throughout the city. On the same day road washouts were reported on the Baie Verte Highway and in Trinity Bay.	Multiple	197, 283	WRMD
349	198	Fortune Bay	2003	10	19		2003	10	20		1	Fall	Central	2265	Hermitage	Churchill River												Closure of route 360, about one Kilometre south of the Hermitage intersection.	The Telegram, Dept of Natural Resources Website	198, 291	WRMD
350	199	Corner Brook	2003	10	22		2003	10	22		1	Fall	Western	1200	Corner Brook		Rainfall											Heavy rain. Corner Brook. Knocked out retaining wall on high wall interchange.	CBC website	199	WRMD
353	202	The Beaches (White Bay)	2004	1	16	11:00	2004	1	16		1	Winter	Western	270	The Beaches	Atlantic Ocean	Coastal Waves			10							51	Storm surge. 10 m waves. The Beaches. 40 homes were evacuated & main road washed out.	CBC website, news reports, CBC radio interview with Mayor of Ferryland, Dept of Natural Resources Website	202, 280	WRMD
354	203	Burin Peninsula	2004	2	18		2004	2	19		2	Winter	Eastern	2675	Lamaline		Storm Surge											A combination of storm surge and high winds resulted in property damage	Dept Natural Resources Website	203	WRMD
355	204	Ferryland	2004	2	20		2004	2	21		2	Winter	Eastern	1580	Ferryland		Coastal Waves											High winds and waves caused damage in the community. Waves washed away the breakwater protecting the road that runs out to Ferryland lighthouse.	Dept Natural Resources Website	204	WRMD
356	205	Baie Verte Peninsula	2004	4	18		2004	4	20		2	Winter	Eastern	2385	Indian Bay	Indian Bay River	Rapid Snowmelt											The Indian Bay river overflowed surrounding a church in the community. One house was evacuated and several other were put on watch. Rapid snowmelt and flooding in Indian Bay river caused the flooding.	Department of Natural Resources Website, The Telegram, The Beacon	205	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
358	206	Burin Peninsula	2004	4	5		2004	4	5		1	Spring	Eastern	5355	Whitbourne		Rainfall											MR: Road closed on Burin Peninsula between Terrenceville and Goobies. A combination of heavy rain and runoff forced the closure of parts of the highway on the West Coast affecting Burgeo and on the TCH around Whitbourne. Heavy Rain and runoff washed out a section of the road at Top Pond Brook.	Dept Natural Resources Website	206	WRMD
360	207	Glenwood-Appleton	2004	4	17		2004	4	17		1	Spring	Central	1855	Glenwood		Rainfall and Snowmelt											MR: Rapid snowmelt resulted in high waters and flooding in Glenwood and Appleton. Flooded Basements.	The Beacon	207	AMEC
361	207	Glenwood-Appleton	2004	4	17		2004	4	17		1	Spring	Central	85	Appleton	Gander River	Rainfall and Snowmelt											MR: Rapid snowmelt resulted in high waters and flooding in Glenwood and Appleton. Flooded Basements.	The Beacon	207	AMEC
363	209	Corner Brook	2004	8	9		2004	8	9		1	Summer	Western	1200	Corner Brook		Rainfall											Flooding in MacDonald Drive area.	The Western Star	209	AMEC
364	210	Eastern, Central, Southern Shore	2004	9	20		2004	9	20		1	Summer	Eastern	20	Admirals Beach		Rainfall	148										MR: Tropical Storm Ivan. The Beaches evacuated. Tropical Storm Ivan. Up to 148 mm of rain & 10 m high waves. 50 + Basements and the Salvation Army church flooded in King's Point.	Internet (CBC), Dept Natural Resources Website	210	WRMD
366	210	Eastern, Central, Southern Shore	2004	9	20		2004	9	20		1	Summer	Eastern	575	Branch	Atlantic Ocean	Rainfall	148		10								MR: Tropical Storm Ivan. The Beaches evacuated. Tropical Storm Ivan. Up to 148 mm of rain & 10 m high waves. 50 + Basements and the Salvation Army church flooded in King's Point.	Internet (CBC), Dept Natural Resources Website	210	WRMD
367	210	Eastern, Central, Southern Shore	2004	9	20		2004	9	20		1	Summer	Central	610	Brighton		Rainfall	148										MR: Tropical Storm Ivan. The Beaches evacuated. Tropical Storm Ivan. Up to 148 mm of rain & 10 m high waves. 50 + Basements and the Salvation Army church flooded in King's Point.	Internet (CBC), Dept Natural Resources Website	210	WRMD
368	210	Eastern, Central, Southern Shore	2004	9	20		2004	9	20		1	Summer	Central	2595	King's Point		Rainfall	148										MR: Tropical Storm Ivan. The Beaches evacuated. Tropical Storm Ivan. Up to 148 mm of rain & 10 m high waves. 50 + Basements and the Salvation Army church flooded in King's Point.	Internet (CBC), Dept Natural Resources Website	210	WRMD
369	210	Eastern, Central, Southern Shore	2004	9	20		2004	9	20		1	Summer	Western	270	The Beaches		Rainfall	148										MR: Tropical Storm Ivan. The Beaches evacuated. Tropical Storm Ivan. Up to 148 mm of rain & 10 m high waves. 50 + Basements and the Salvation Army church flooded in King's Point.	Internet (CBC), Dept Natural Resources Website	210, 281	WRMD
370	211	Rocky Harbour	2004	9	12		2004	9	12		1	Summer	Western	4245	Rocky Harbour		Rainfall	71.3										Heavy rainfall. 71.3 mm of rain in Deer Lake. Rocky Harbour. A driveway & parking lot washed away. (Hurricane Frances)	The Telegram	211	AMEC
371	212	St. John's	2004	11	16		2004	11	16		1	Fall	Eastern	4400	St. John's		Rainfall	64.3				$25,000	$25,000			1		Heavy Rainfall. 64.3 mm of rain fell in a 10 hr period exceeding the 12 hr 5 yr event. St. John's Area. $25,000 in damage resulted.	The Telegram	212, 305	AMEC
373	214	Avalon Peninsula	2004	8	8		2004	8	8		1	Summer	Eastern	5455	Witless Bay		Coastal Flooding											Heavy Seas damaged or destroyed several fishing boats	VOCM, Telegram	No	AMEC
374	215	St. John's	2005	1	24		2005	1	24		1	Winter	Eastern	3345	Mount Pearl		Rainfall and Snowmelt	50	600									Snowmelt and rain. St. John's & Mount Pearl. Houses & roads were flooded and Power outages affected 5000 residents.	Multiple	213	AMEC
375	215	St. John's	2005	1	24		2005	1	24		1	Winter	Eastern	4400	St. John's		Rainfall and Snowmelt	50	600							2		Snowmelt and rain. St. John's & Mount Pearl. Houses & roads were flooded and Power outages affected 5000 residents.	Multiple	213	AMEC
377	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	990	Cavendish		Storm Surge			15.2								MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	AMEC
379	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	4400	Flat Rock		Storm Surge			35		$2,000,000	$2,000,000					MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
384	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	520	Bristol's Hope		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
385	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	935	Capelin Cove		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
386	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	1460	Duntara, Bonavista Bay		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
388	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	1145	Foxtrap, Conception Bay South		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
389	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	1975	Grates Cove		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
390	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	2095	Hant's Harbour		Coastal Waves									16		MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
391	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	4150	Red Head Cove		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
392	216	Flatrock to Bonavista	2005	3	16		2005	3	17		2	Winter	Eastern	5155	Sibley's Cove , Trinity Bay		Coastal Waves											MR: High winds and high tides resulted in a storm surge, destruction was caused in nine communities. The breakwater at Flatrock was completely destroyed. There were road damages. Damages to other communities included roads, fishing gear. Storm Surge. 35 to 50 feet waves. 9 Eastern communities including Cavendish and Flatrock. Damages of $2,000,000 included a damaged breakwater, road washouts, and boats. Stages, sheds, boats and fishing gear sustained damages. The breakwater was almost completely destroyed. The seawall was destroyed.	Multiple	216, 288	WRMD
395	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	3155	Marystown	Salt Cove Brook	Rainfall	200	620			$100,000	$100,000	$1,340,476		a number		MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
396	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	3930	Port au Bras	Jane's Pond	Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
397	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	4435	St. Lawrence		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
398	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	2885	Little St. Lawrence		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
399	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	2995	Lord's Cove		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
400	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	2495	Jean de Baie		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
401	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	725	Burin	Black Duck Cove	Rainfall		620					$1,340,476	$1,340,476			MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
402	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	4143	Red Harbour		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
403	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	1665	Fox Cove		Rainfall	200	620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
404	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	430	Black Duck Cove		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
405	218	St. John's	2005	4	12		2005	4	12		1	Spring	Eastern	4400	St. John's	Quidi Vidi Lake	Rainfall	69										Heavy rainfall. 69 mm of rain. St. John's. Curb lanes were under 1 ft of water in places, and low-lying areas were flooded. Quidi Vidi Lake overflowed it's banks due to malfunctioned flood control gate. Roads closed near Health Sciences Center.	CBC Website, The Telegram , emails	218	WRMD
406	219	Corner Brook	2005	8	11		2005	8	12		1	Summer	Western	1200	Corner Brook		Rainfall	45										Street Damage and Private Properties damaged.	The Telegram	219	WRMD
407	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	4945	Stephenville	Blanche Brook	Rainfall	151.4				$10,000,000	$10,000,000	$28,283,786	$28,283,786	152	271	Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	The Western Star	220	WRMD
408	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	1750	Gallants		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
409	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	1114	Cold Brook		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
410	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	3485	Noel's Pond		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
411	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	4245	Rocky Harbour	Warm Creek	Rainfall	113.8						$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
412	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	420	Black Duck Siding		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
413	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	4065	Pynn's Brook		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
414	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	4172	Reidville		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
415	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	2615	Kippens		Rainfall							$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
416	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	1380	Deer Lake		Rainfall	65.6						$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
417	220	Stephenville Area	2005	9	27		2005	9	28		2	Fall	Western	1200	Corner Brook		Rainfall	61.4						$28,283,786				Heavy rainfall. 151.4 mm of rain in Stephenville. Stephenville area, affecting 12 communities ~100 km apart. Greater than 1:100 year flood & 1:100 year 12 hour rainfall in Stephenville. EFO declared a State of Emergency in Stephenville & Reidville. 76 homes flooded & 181 people evacuated in Stephenville; 2 bridge washouts and several water main breaks in Stephenville. 90 people evacuated in Reidville.	Multiple	220	WRMD
418	221	St. John's	2005	10	16		2005	10	16		1	Fall	Eastern	4400	St. John's (Kilbride)		Rainfall	60.4										Heavy rainfall. 60.4 mm of rain. Flooding on roads in the Goulds and Kilbride area of St. John's on Sunday, Oct. 17, 2005. No major damage was reported.	Environment Canada, The Telegram	221	WRMD
419	222	Burin Peninsula	2005	12	12		2005	12	12		1	Fall	Eastern	3285	Monkstown		Rainfall	50										Heavy rainfall. 50 mm of rain. Burin Peninsula. Several roads eroded & washed out. Peak flow at Rattle Brook near Boat Harbour was 50.7 m^3/s where Q5 = 49.0 m^3/s and Q10 = 58.0 m^3/s.	VOCM, Environment Canada, Emails	222	WRMD
420	222	Burin Peninsula	2005	12	12		2005	12	12		1	Fall	Eastern	260	Bay L'Argent		Rainfall											Heavy rainfall. 50 mm of rain. Burin Peninsula. Several roads eroded & washed out. Peak flow at Rattle Brook near Boat Harbour was 50.7 m^3/s where Q5 = 49.0 m^3/s and Q10 = 58.0 m^3/s.	VOCM, Environment Canada, Emails	222	WRMD
421	222	Burin Peninsula	2005	12	12		2005	12	12		1	Fall	Eastern	2150	Harbour Mille-Little Harbour East		Rainfall											Heavy rainfall. 50 mm of rain. Burin Peninsula. Several roads eroded & washed out. Peak flow at Rattle Brook near Boat Harbour was 50.7 m^3/s where Q5 = 49.0 m^3/s and Q10 = 58.0 m^3/s.	VOCM, Environment Canada, Emails	222	WRMD
422	223	Burin	2005	N/A	N/A		2005	N/A	N/A		N/A	Spring	Eastern	725	Burin	Riverhead Brook	Rainfall											Road leading to Taylors Bay was flooded, 400m of highway submerged.	Source not recorded	No	WRMD
423	224	Northern Peninsula	2006	1	17		2006	1	18		2	Winter	Western	4095	Raleigh	Atlantic Ocean	Coastal Waves											Storm surge. Raleigh. Cut off access to homes & dumped debris on the roads. The storm surge hammered the shoreline & roadways.	CBC News	224, 300	WRMD
426	227	Conception Bay	2006	2	1		2006	2	1		1	Winter	Eastern	1060	Clarkes Beach		Coastal Flooding											Captured by Department - unable to confirm.	Dept Natural Resources Website	227	WRMD
427	227	Conception Bay	2006	2	1		2006	2	1		1	Winter	Eastern	5145	Trepassey		Coastal Flooding									1		MR: Roads washed out by coastal flooding. One home was flooded and the road to the community closed for a period of time.	Dept Natural Resources Website	227	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
428	227	Conception Bay	2006	2	1		2006	2	1		1	Winter	Eastern	1060	Chapel's Cove		Coastal Flooding									1		MR: Roads washed out by coastal flooding. One home was flooded and the road to the community closed for a period of time.	Dept Natural Resources Website	227	WRMD
429	227	Conception Bay	2006	2	1		2006	2	1		1	Winter	Eastern	265	Coley's Point, Bay Roberts		Coastal Flooding									1		MR: Roads washed out by coastal flooding. One home was flooded and the road to the community closed for a period of time.	Dept Natural Resources Website	227	WRMD
430	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	3210	Middle Arm	Rattling Brook	Rainfall	208				$30,000	$30,000	$4,659,615	$4,659,615	50		MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
431	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2190	Harry's Harbour		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
432	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	740	Burlington		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
433	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	3510	Norris Arm North		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
434	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	170	Baie Verte		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
435	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2360	Horwood		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
436	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	4110	Rattling Brook		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
437	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	1095	Coachman's Cove		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
438	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	4760	Smith's Harbour		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
439	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	4910	Springdale		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
440	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Western	1620	Fleur de Lys		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	WRMD
441	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2040	Greenspond		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
442	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2385	Indian Bay		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
443	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	3860	Point Leamington	Mill River	Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
446	230	St. Mary's Bay	2006	8	10		2006	8	10		1	Summer	Eastern	3335	Mount Carmel-Mitchell's Brook-St. Catherine's	Salmonier River	Rainfall	40				$125,000						Heavy rainfall. 28.2 mm of rain. Salmonier to New Bridge in the St. Mary's Bay area. 1 bridge washed out and another lies on the cusp of ruin.	Dept Natural Resources Website	295	WRMD
448	230	St. Mary's Bay	2006	8	10		2006	8	10		1	Summer	Eastern	1637	Forest Field-New Bridge		Rainfall	40				$125,000	$125,000					Heavy rainfall. 28.2 mm of rain. Salmonier to New Bridge in the St. Mary's Bay area. 1 bridge washed out and another lies on the cusp of ruin.	Dept Natural Resources Website	295	WRMD
449	231	Witless Bay Area	2006	8	29	23:30	2006	8	30		2	Summer	Eastern	5455	Witless Bay	Atlantic Ocean	Coastal Waves			13		$5,000	$5,000					Storm surge. 13 foot waves were reported. Witless Bay and Bauline East Area. Heavy seas damaged 4 boats. Environment Canada reports swells came from a churning low pressure system 200 km offshore on the Grand Banks.	The Telegram	231, 310	WRMD
451	233	Boswarlos	2006	8	8		2006	8	8		1	Summer	Western	546	Boswarlos		Rainfall											Low-lying area flooded, Bridge washed away.	The Georgian	233	AMEC
452	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	1060	Clarkes Beach		Coastal Waves	46										Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
453	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	4400	Flatrock		Coastal Waves											Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
454	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	3865	Point May	Atlantic Ocean	Coastal Waves									1		Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
455	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	4104	Random Island		Coastal Waves											Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
456	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	5145	Trepassey		Coastal Waves											Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
457	235	Northeast Coast	2006	10	25		2006	10	25		1	Fall	Central	830	Campbellton		Rainfall											Storm damage throughout Central.	NTV	235	WRMD
458	235	Northeast Coast	2006	10	25		2006	10	25		1	Fall	Central		Notre Dame Bay		Rainfall											Captured by Department - unable to confirm.	Source not recorded	No	WRMD
459	235	Northeast Coast	2006	10	25		2006	10	25		1	Fall	Western	3210	Middle Arm	Atlantic Ocean	Rainfall	34.3										Storm surge & heavy rain. Notre Dame Bay area & Campbellton. Tides reached dangerous heights combined with rain and high wind causing damage to residents. In Middle Arm several homes were flooded.	NTV	235	WRMD
460	234	Baie Verte, Coast of Bays	2006	9	13		2006	9	14		1	Summer	Western	170	Baie Verte		Rainfall											Florence	The Newfoundland Herald	No	WRMD
461	234	Baie Verte, Coast of Bays	2006	9	13		2006	9	14		1	Summer	Western	4110	Rattling Brook		Rainfall											Florence	The Newfoundland Herald	No	WRMD
462	234	Baie Verte, Coast of Bays	2006	9	13		2006	9	14		1	Summer	Western	3210	Middle Arm		Rainfall											Florence	The Newfoundland Herald	No	WRMD
463	234	Baie Verte, Coast of Bays	2006	9	13		2006	9	14		1	Summer	Western	4305	St. Albans		Rainfall											Florence	The Newfoundland Herald	No	WRMD
464	237	Western Newfoundland	2007	2	6		2007	2	6		1	Winter	Western	1315	Daniels Harbour		Coastal Flooding					$538,000	$3,060,000	$2,960,767	$2,960,767			MR: Major damages to wharf and breakwater. Damages to the wharf and sewer outfall. High Winds and Large waves destroyed parts of the boardwalk at Trout River, minor damages to homes. Some roads were washed out, and houses were threatened.	The Western Star	237, 308	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
465	237	Western Newfoundland	2007	2	6		2007	2	6		1	Winter	Western	4245	Rocky Harbour		Coastal Flooding					$3,000,000		$2,960,767				MR: Major damages to wharf and breakwater. Damages to the wharf and sewer outfall. High Winds and Large waves destroyed parts of the boardwalk at Trout River, minor damages to homes. Some roads were washed out, and houses were threatened.	The Western Star	237, 308	AMEC
466	237	Western Newfoundland	2007	2	6		2007	2	6		1	Winter	Western	5175	Trout River		Coastal Flooding					$422,000		$2,960,767				MR: Major damages to wharf and breakwater. Damages to the wharf and sewer outfall. High Winds and Large waves destroyed parts of the boardwalk at Trout River, minor damages to homes. Some roads were washed out, and houses were threatened.	The Western Star	237, 308	AMEC
467	237	Western Newfoundland	2007	2	6		2007	2	6		1	Winter	Western	1230	Cow Head		Coastal Flooding							$2,960,767				MR: Major damages to wharf and breakwater. Damages to the wharf and sewer outfall. High Winds and Large waves destroyed parts of the boardwalk at Trout River, minor damages to homes. Some roads were washed out, and houses were threatened.	The Western Star	237, 308	AMEC
468	238	West Coast	2007	3	15		2007	3	16		2	Winter	Western	3941	Port au Port West-Aguathuna-Felix Cove	Romaine's River	Rainfall and Snowmelt	70	600									Heavy rainfall & snowmelt & ice blockage. 70 mm of rain & 60 mm of equivalent snowmelt in Stephenville. Stephenville and Port au Port West-Aguathuna-Felix Cove. Road Shoulder erosion, roads & 4 bridges were closed.	The Western Star, Email, other	238	AMEC
469	238	West Coast	2007	3	15		2007	3	16		2	Winter	Western	4945	Stephenville		Rainfall and Snowmelt											Heavy rainfall & snowmelt & ice blockage. 70 mm of rain & 60 mm of equivalent snowmelt in Stephenville. Stephenville and Port au Port West-Aguathuna-Felix Cove. Road Shoulder erosion, roads & 4 bridges were closed.	The Western Star, Email, other	238	AMEC
470	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	1455	Dunville		Rainfall					$5,000,000	$6,000,000	$24,522,325	$24,522,325			MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
471	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	265	Bay Roberts		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
472	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3500	Norman's Cove		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
473	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3600	Old Shop		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
474	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3800	Argentia		Rainfall	85						$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
475	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	2970	Long Harbour		Rainfall	100						$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
476	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	615	Brigus		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
477	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	680	Bryant's Cove		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
478	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	5355	Whitbourne		Rainfall	150						$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
479	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4835	North River		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
480	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4835	South River		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
481	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4345	St. Brides		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
482	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	265	Shearstown		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
483	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4680	Ship Harbour		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
484	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3800	Placentia		Rainfall	85				$1,000,000		$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
485	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	1280	Cupids		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
486	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4400	St. John's		Rainfall	96						$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
487	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	5215	Upper Island Cove		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
488	241	West Coast	2007	8	9		2007	8	9		1	Summer	Western	1380	Deer Lake		Rainfall											100's of thousand's worth of damage to private properties and businesses.	The Telegram	241	WRMD
489	242	West Coast	2007	8	9		2007	8	9		1	Summer	Western	3210	Middle Arm		Rainfall											Private properties damaged. Homes and Businesses flooded.	The Nor'Wester	242	WRMD
490	243	Ship Harbour	2007	10	21		2007	10	23		2	Fall	Eastern	4680	Ship Harbour		Rainfall											Main access road was closed due to flooding.	The Telegram	243	WRMD
491	244	Rushoon	2008	1	30		2008	1	31		1	Winter	Eastern	4295	Rushoon	Rushoon River	Ice Jam										30	Water eroded the ground in an area next to the Rushoon Parish Hall, uncovering an underground pipe. Area's of town under water.	The Southern Gazette	244	WRMD
493	245	Fortune Bay, Burin Peninsula	2008	2	19		2008	2	20		1	Winter	Eastern	3155	Marystown		Rainfall	70										MR: Flooding on Route 360. Some flooded basements and clogged drains	MR: CBC website. Coaster. The Southern Gazette, Dept of Natural Resources Website	245, 278	AMEC
494	245	Fortune Bay, Burin Peninsula	2008	2	19	11:00	2008	2	20	11:00	1	Winter	Eastern	3895	Pool's Cove		Rainfall	65										MR: Flooding on Route 360. Some flooded basements and clogged drains	MR: CBC website. Coaster. The Southern Gazette, Dept of Natural Resources Website	245, 278	AMEC
495	246	King's Point	2008	7	29		2008	7	31		2	Summer	Central	2595	King's Point		Rainfall					$25,000	$25,000					After a two day heavy rain storm, King's point was left with major road damage estimating around $20000-30000	The Nor'Wester	246	WRMD
496	247	Gambo	2008	7	30		2008	7	31		1	Summer	Central	1755	Gambo		Rainfall	65				$1,782,710	$1,782,710	$1,782,710	$1,782,710		20-30	Intense rainfall event (60-70 mm in 9 hours). Damage estimate received from Department of Natural Resources.	The Newfoundland Herald, Dept of Natural Resources Email containing DFAA damage estimate	247	WRMD
497	248	Gambo	2008	8	15		2008	8	16		1	Summer	Central	1755	Gambo		Rainfall	54.4									20	Heavy rains caused flooding to sections of the Trans Canada Highway near Joey's Lookout, Gambo. Government officials were concerned of a landslide resulting in approximately 12 homes, located just below the area, to evacuate	The Beacon, Dept of Natural Resources Website	248	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
498	249	South Coast	2008	9	7		2008	9	7		1	Summer	Central	315	Belleoram		Rainfall					$1,000,000	$1,010,000					Heavy rain from Hurricane Gustav caused extreme flooding to the basement of one home in Port aux Basques. Estimated to be thousands of dollars of damage. In Belleoram, culverts became blocked with debris and several areas flooded.	CBC News, The Gulf News	249	WRMD
499	249	South Coast	2008	9	7		2008	9	7		1	Summer	Western	1025	Channel-Port aux Basques		Rainfall					$10,000				1		Heavy rain from Hurricane Gustav caused extreme flooding to the basement of one home in Port aux Basques. Estimated to be thousands of dollars of damage. In Belleoram, culverts became blocked with debris and several areas flooded.	CBC News, The Gulf News	249	WRMD
500	250	Gambo	2008	11	20		2008	11	20		1	Fall	Central	1755	Gambo		Rainfall											The third flood in three months: A culvert blocked with debris during a heavy rain. The flood caused minor damage to people's property.	The Telegram, Dept of Natural Resources Website	250	AMEC
501	251	St. John's	2008	11	29	17:00	2008	11	29		1	Fall	Eastern	4400	St. John's	Quidi Vidi Lake	Rainfall	100				$500,000	$500,000					Heavy rains caused flooding in the St. John's area, resulting in damage and closure to many roads and major flooding to one soccer pitch	The Telegram, CBC, Dept of Natural Resources Website	251	WRMD
502	252	Corner Brook	2008	12	10	18:00	2008	12	10		1	Fall	Western	1200	Corner Brook	Petries Brook	Rainfall and Snowmelt											Heavy snow and rains caused a flash flood in Corner Brook area. Petries Brook overflowed. A culvert was engulfed and the bank collapsed, sending water, rocks and trees rushing past nearby homes.	The Western Star, CBC News, Dept Natural Resources Website	252	WRMD
504	253	Woody Point	2009	3	3		2009	3	3		1	Winter	Western	5490	Woody Point		Rainfall and Snowmelt											Flooding to Bonne Bay Academy.	The Western Star	253	AMEC
505	254	Dunville	2009	3	9		2009	3	9		1	Winter	Eastern	1455	Dunville		Rainfall											Damages to the property of one household.	The Charter	254	AMEC
506	255	St. John's	2001	9	19		2001	9	19		1	Summer	Eastern	4400	St. John's		Rainfall	100										Hurricane Gabrielle, some roads and parking lots have been washed out. Basements are flooded knee deep as the storm sewers can't handle the water.	The Telegram	255	AMEC
507	256	Gander	2009	8	23		2009	8	24		2	Summer	Central	1760	Gander		Rainfall	71				$50,000	$50,000			1		Tropical Storm Bill	The Beacon	256, 257	AMEC
508	257	Gander	2009	8	30		2009	8	30		1	Summer	Central	1760	Gander		Rainfall	54								1		Tropical Storm Danny	The Beacon	256, 257	AMEC
509	258	Corner Brook	2009	8	19		2009	8	19		1	Summer	Western	1200	Corner Brook		Rainfall											Heavy Rain caused severe flooding, which washed dirt and rocks in the street	The Western Star	258	AMEC
510	259	St. John's	2009	10	19		2009	10	19		1	Fall	Eastern	3345	Mount Pearl	Waterford River	Rainfall											Heavy rainfall caused the Waterford River to flood, damages wasn't extreme	The Telegram	259	AMEC
511	260	Ferryland	2009	12	29		2009	12	29		1	Winter	Eastern	1580	Ferryland		Coastal Waves											High seas washed out a road leading from Ferryland to the lighthouse, damaging property and the breakwater in the area.	Dept Natural Resources Website	260	WRMD
512	261	St. John's	2009	12	22		2009	12	22		1	Winter	Eastern	4400	St. John's		Coastal Waves											Hugh waves damaged wharves, stages and fishing huts.	Dept Natural Resources Website	261	WRMD
513	262	Avalon Region, Bonavista Peninsula	2010	2	5		2010	2	5		1	Winter	Eastern	4400	St. John's		Storm Surge											MR: A storm surge caused property damage. Approx 350m of boardwalk was destroyed a storage shed and wharf was also damaged. Large waves battered property in the Battery and to a lesser extent Quidi Vidi. Several sheds and wharves were destroyed	Dept Natural Resources Website	262	WRMD
514	262	Avalon Region, Bonavista Peninsula	2010	2	5		2010	2	5		1	Winter	Central	2040	Greenspond		Storm Surge					$9,000	$9,000					MR: A storm surge caused property damage. Approx 350m of boardwalk was destroyed a storage shed and wharf was also damaged. Large waves battered property in the Battery and to a lesser extent Quidi Vidi. Several sheds and wharves were destroyed	Dept Natural Resources Website	262	WRMD
515	263	St. John's	2010	3	8		2010	3	8		1	Winter	Eastern	4400	St. John's	Quidi Vidi	Rainfall	118										Heavy rainfall caused flooding in several areas.	The Telegram	263	AMEC
516	264	West Coast	2010	5	4		2010	5	4		1	Spring	Western	2090	Hampden (White Bay)		Rainfall											MR: The main road let go in Hampden, one resident lost two sheds, flooded basements. Heavy rains washed out the bridge and the roads	MR: The Nor'Western. The Western Star	264	AMEC
517	264	West Coast	2010	5	4	7:00	2010	5	4		1	Spring	Western	1195	Cormack		Rainfall											MR: The main road let go in Hampden, one resident lost two sheds, flooded basements. Heavy rains washed out the bridge and the roads	MR: The Nor'Western. The Western Star	264	AMEC
518	265	Trinity South	2010	6	15		2010	6	15		1	Summer	Eastern	5365	Whiteway		Rainfall											Washed out roads, flooded basements	The Compass	265	AMEC
519	266	Southwest Newfoundland	2010	9	7		2010	9	7		1	Summer	Western	1200	Corner Brook		Rainfall											Winds and rain caused trees to fall down on properties in Corner Brook (Earl)	CBC Website	266	AMEC
521	268	Ferryland, Western Newfoundland	2010	12	24		2010	12	24		1	Winter	Eastern	1580	Ferryland		Coastal Flooding											Road washed out leading to the Ferryland lighthouse damaging property in the area.	CBC Website, Northern Pen, Dept of Natural Resources Website	268	WRMD
522	268	Ferryland, Western Newfoundland	2010	12	24		2010	12	24		1	Winter	Western	2050	St. Lunaire-Griquet		Storm Surge									15	14	High winds and tides caused damages to numerous fishing stages and wharves with debris washed into the road.	CBC Website, Northern Pen, Dept of Natural Resources Website	268	AMEC
523	269	The Beaches	2011	1	10		2011	1	10		1	Winter	Eastern	270	The Beaches		Coastal Waves											The community was evacuated due to fears that the transportation link would be broken if the road washed out.	Dept Natural Resources Website	269	AMEC
524	270	Conception Bay	2011	2	18		2011	2	18		1	Winter	Eastern	1145	Conception Bay South		Storm Surge											A storm surge washed the beach between Cherry Lane and the Yacht Club, damages were reported by three residences.	Dept Natural Resources Website	270	AMEC
525	271	Trout River	2011	3	7	3:00	2011	3	7		1	Winter	Western	5175	Trout River	Manuels Brook	Flash Flood / Ice Jam									5		Heavy rains caused a blockage in Manuals Brook which forced water down the roads and caused damages to some homes.	The Western Star, Dept of Natural Resources Website	271, 309	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
526	272	Burin Peninsula, South Coast	2011	10	3	7:00	2011	10	3		1	Fall	Central	315	Belleoram		Rainfall											MR: 5 homes were evacuated, state of emergency called for a short period of time. Some of the homes were badly damaged. Damages to some roads on the Burin Peninsula.	CBC Website, Dept of Natural Resources Website	272, 282	AMEC
527	272	Burin Peninsula, South Coast	2011	10	3	7:00	2011	10	3		1	Fall	Central	525	Bonavista Peninsula		Rainfall											MR: 5 homes were evacuated, state of emergency called for a short period of time. Some of the homes were badly damaged. Damages to some roads on the Burin Peninsula.	CBC Website, Dept of Natural Resources Website	272, 282	AMEC
548	274	Labrador	2006	12	1		2006	12	4		3	Fall	Labrador		Mud Lake	Mud Lake	Ice Jam									at least 2		Ice jam. Bad Weather caused ice build-up in Churchill River flooding in village of Mud Lake. Local school closed and two houses' basements were flooded. Churchill River raised several feet.	Email, Notes, Environment Canada	274	WRMD
549	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Western		Harbour Cove		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
550	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Western	3210	Middle Arm		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
551	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Western	3265	Ming's Bight		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
552	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Central	1860	Glover's Harbour		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
553	169	Central NF - Baie Verte Peninsula	1998	9	6		1998	9	6		1	Fall	Central	2970	Little Bay Islands		Rainfall	84.1				$1,250,000						Tropical Storm Earl caused heavy rain. Rain up to 115.2 mm in 24 hr; may have exceeded the 1:100 yr rainfall event. $1.25M in damages including culvert washouts, road washouts/erosion & basement flooding. 53 to 115.2 mm's of rain.	Internal Site Report	169	WRMD
554	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	1650	Fortune		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
555	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	3155	Marystown		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
556	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern		Peter's River		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
557	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	4600	Seal Cove		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
558	178	South Coast	2000	1	22		2000	1	22		1	Winter	Eastern	4505	St. Vincent's-St. Stephen's-Peter's River		Storm Surge							$4,346,283				MR: The breakwater was completely destroyed, several sections of infrastructure were washed ashore. Costal Waves / Storm Surge. 2 waves of 11-17 m. Channel-Port Aux Basques. $500,000 in damages to homes, a light house, etc. Damages to sewer outfall. To repair damages to a sea wall and two sanitary sewer outfalls to pre-storm conditions. Damages to roads. Major flooding in some areas, Allan's Island roadway cut off by large rocks tossed by storm surge blocking entrance. Damages to sea defence wall and walking trails	MR: Internet, Multiple. The Compass. The Navigator. The Telegram. The Western Star	178	AMEC
559	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	1545	Epworth		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
560	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	1940	Grand Bank		Rainfall		620					$1,340,476		12		MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
560	238	West Coast	2007	3	15		2007	3	16		2	Winter	Western	1114	Cold Brook		Rainfall and Snowmelt											Heavy rainfall & snowmelt & ice blockage. 70 mm of rain & 60 mm of equivalent snowmelt in Stephenville. Stephenville and Port au Port West-Aguathuna-Felix Cove. Road Shoulder erosion, roads & 4 bridges were closed.	The Western Star, Email, other	238	AMEC
561	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	2745	Lawn		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
561	238	West Coast	2007	3	15		2007	3	16		2	Winter	Western	5090	Three Rock Cove		Rainfall and Snowmelt											Heavy rainfall & snowmelt & ice blockage. 70 mm of rain & 60 mm of equivalent snowmelt in Stephenville. Stephenville and Port au Port West-Aguathuna-Felix Cove. Road Shoulder erosion, roads & 4 bridges were closed.	The Western Star, Email, other	238	AMEC
562	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern	3830	Point aux Gaul		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
562	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	575	Branch		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
563	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern		Salt Cove Brook		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
563	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	2250	Brook Heart's Delight-Islington		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
564	217	Burin Peninsula	2005	3	30		2005	3	31		2	Spring	Eastern		Salt Pond		Rainfall		620					$1,340,476				MR: Heavy rainfall. Up to 200 mm of rain in 36 hr. Env. Can estimated 140 mm to 160 mm of rain. Burin Peninsula. Estimated damages of $100,000. Roads washed out, eroded road shoulders and driveways. Grand Bank reports 10 – 12 flooded basements.	Multiple	217	WRMD
564	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern		Cape Shore		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
565	005	Stephenville Crossing	1951	12	18		1951	12	19		1	Fall	Western		Bay of Islands		Coastal Flooding										600	MR: Storm washed out rail bed and 15 telephone poles blown down. Streets were flooded and there was interior damages to several homes. Damage was also reported at Summerside, Bay of Islands and many fisherman lost boats and gear.	MR: Flooding Events in Newfoundland and Labrador - An Historical Perspective. Heritage Newfoundland Website, Department of Natural Resources Website	307	AMEC
565	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	950	Carbonear		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
565	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1885	Goobies							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
566	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	1060	Clarke's Beach		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
566	281	St. John's	1964	N/A	N/A		1964	N/A	N/A		N/A	N/A	Eastern	4400	St. John's		Rainfall											Heavy rains caused the riase of a stream at Goulds, near St. John's; 2-year old swept into the stream and drowned.	Dept Natural Resources Website	304	AMEC
566	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1965	Grand le Pierre							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
567	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	1675	Fox Harbour		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
567	280	Grand Bank	1975	N/A	N/A		1975	N/A	N/A		N/A	Summer	Eastern	1940	Grand Bank		unknown											Flooding	Dept Natural Resources Website	290	AMEC
567	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2125	Harbour Grace							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
568	080	Humber Arm Region	1976	3	21		1976	3	23		3	Spring	Western	1710	Frenchman's Cove		Rainfall											Heavy rain and snowmelt caused flooding on several streets and private property was damaged	Flooding Events in Newfoundland and Labrador - An Historical Perspective, Dept of Natural Resources Website	292	AMEC
568	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	2015	Green's Harbour		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
568	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2150	Harbour Mille-Little Harbour East							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
569	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	2125	Harbour Grace		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
569	282	Placentia	1982	1	1		1982	1	1		1	Winter	Eastern	3800	Placentia		unknown											No Details	Dept Natural Resources Website	299	AMEC
569	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	2165	Hare Bay							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
570	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	2335	Hopeall		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
570	279	Stephenville	1983	1	N/A		1983	1	N/A		N/A	Winter	Western	3485	Stephenville	Warm Creek / Blanche Brook	Rainfall and Snowmelt											Blanche and Warm Creek burst their banks.	Dept Natural Resources Website	289	AMEC
571	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3105	Makinsons		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
571	276	Badger	1985	N/A	N/A		1985	N/A	N/A		N/A	N/A	Central	155	Badger		unknown											No Details	Dept Natural Resources Website	276	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
572	195	West Coast	2003	3	31		2003	4	1		2	Spring	Western	1807	Georges Lake		Rainfall and Snowmelt					$1,400,000		$9,589,511				MR: Damage to infrastructure. The Trans Canada Highway is closed because of a flood damaged bridge. Rainfall and snowmelt. West Coast, Stephenville area. Sidewalk section washed away in Stephenville. In Cox's Cove basements were flooded as a result of floodwaters on the Frenchman's Pond watershed. Corner Brook suffered extensive damage	MR: The Western Star. Disaster News Network	195, 287	AMEC
572	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3165	Marysvale		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
573	197	Northeast Coast & Central	2003	5	10		2003	5	10		1	Spring	Eastern		South Port, Trinity Bay		Rainfall											Rainfall. 26.8 mm fell on St. John's causing flooding throughout the city. On the same day road washouts were reported on the Baie Verte Highway and in Trinity Bay.	Multiple	197, 283	WRMD
573	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	3415	New Harbour		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
574	203	Burin Peninsula	2004	2	18		2004	2	19		2	Winter	Eastern	3830	Point Aux Gaul		Storm Surge											A combination of storm surge and high winds resulted in property damage	Dept Natural Resources Website	203	AMEC
574	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4225	Roche's Line		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
575	205	Baie Verte Peninsula	2004	4	18		2004	4	20		2	Winter	Eastern	1350	Dead Man's Bay		Rapid Snowmelt											The Indian Bay river overflowed surrounding a church in the community. One house was evacuated and several other were put on watch. Rapid snowmelt and flooding in Indian Bay river caused the flooding.	Department of Natural Resources Website, The Telegram, The Beacon	205	AMEC
575	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	4860	Spaniard's Bay		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
576	205	Baie Verte Peninsula	2004	4	18		2004	4	20		2	Winter	Eastern	3040	Lumsden		Rapid Snowmelt											The Indian Bay river overflowed surrounding a church in the community. One house was evacuated and several other were put on watch. Rapid snowmelt and flooding in Indian Bay river caused the flooding.	Department of Natural Resources Website, The Telegram, The Beacon	205	AMEC
576	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern		Tilton		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
577	210	Eastern, Central, Southern Shore	2004	9	20		2004	9	20		1	Summer	Central	20	Admirals Beach		Rainfall	148										MR: Tropical Storm Ivan. The Beaches evacuated. Tropical Storm Ivan. Up to 148 mm of rain & 10 m high waves. 50 + Basements and the Salvation Army church flooded in King's Point.	Internet (CBC), Dept Natural Resources Website	210, 281	WRMD

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
577	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	5155	Trinity Conception		Rainfall							$24,522,325		100		MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
578	239	Western Avalon Peninsula	2007	7	31		2007	8	1		2	Summer	Eastern	5365	Whiteway		Rainfall							$24,522,325				MR: Many streams overflowed their banks washing away roads and culverts and caused property damage. Shearstown Brook burst its bank and the bridge over the river was in danger of failing. Numerous basements were flooded. The access road was washed out meaning the Marine Atlantic ferry couldn't run. The road to the fish plant was washed out. Houses had 4-5 feet of water in them, 4 different sections of the road was washed out.	MR: VOCM. CBC. Telegram. The Charter	239	WRMD
578	277	Bay Roberts	2006	2	1		2006	2	2		2	Winter		265	Bay Roberts		Storm Surge									1		High winds caused storm surge that resulted in coastal flooding	Dept Natural Resources Website	277	AMEC
579	277	Bay Roberts	2006	2	1		2006	2	2		2	Winter		1060	Clarke's Beach		Storm Surge											High winds caused storm surge that resulted in coastal flooding	Dept Natural Resources Website	277	AMEC
579	278	Middle Cove	2008	8	31		2008	8	31		1	Summer			Middle Cove		Wave											Rogue wave washes people out to sea.	Dept Natural Resources Website	294	AMEC
580	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	272	Beachside		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
580	268	Ferryland, Western Newfoundland	2010	12	24		2010	12	24		1	Winter	Western	1985	Great Brehat		Storm Surge											High winds and tides caused damages to numerous fishing stages and wharves with debris washed into the road.	CBC Website, Northern Pen, Dept of Natural Resources Website	268	AMEC
581	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2595	King's Point		Rainfall							$4,659,615		45		MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
581	268	Ferryland, Western Newfoundland	2010	12	24		2010	12	24		1	Winter	Western	4350	St. Carols		Storm Surge											High winds and tides caused damages to numerous fishing stages and wharves with debris washed into the road.	CBC Website, Northern Pen, Dept of Natural Resources Website	268	AMEC
582	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2775	Lewisporte		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
583	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	2970	Little Bay		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
584	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	3475	Nipper's Harbour		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
585	228	Baie Verte Peninsula, Bonavista North, Point Leamington	2006	4	16		2006	4	20		4	Spring	Central	3645	Pacquet		Rainfall							$4,659,615				MR: Flooded Cemetery and Park, many roads still underwater from previous flood. Heavy rainfall and Spring runoff. 108 mm of rainfall. State of Emergency declared in Middle Arm affecting 50 homes; 1 person injured. Washed out roads. Access to community was cut off. Baie Verte's water line damaged & Middle Arm's water and sewer was out of service too. Road closed in Fleur de lys. Noseworthy's Drive residents lost their street, worst flooding in 20 years.	MR: The Beacon. The Telegram. The Nor'Wester. The Pilot, The Advertiser	228	AMEC
586	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	1695	Francois		Coastal Waves									1		Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
587	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	2110	Harbour Breton		Coastal Waves									1		Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
588	234	South Coast	2006	9	13		2006	9	14		2	Summer	Eastern	3740	Petit Forte		Coastal Waves											Tropical Storm Florence. High winds up to 163 km/hr. Coastal communities of Southern and Eastern Newfoundland. Reports of an eroded beach in Point May and damages to a road in Trepassey. Damages to Random Island area was minor.	Multiple	234	WRMD
589	238	West Coast	2007	3	15		2007	3	16		2	Winter	Western	268	Bay St. George		Rainfall and Snowmelt											Heavy rainfall & snowmelt & ice blockage. 70 mm of rain & 60 mm of equivalent snowmelt in Stephenville. Stephenville and Port au Port West-Aguathuna-Felix Cove. Road Shoulder erosion, roads & 4 bridges were closed.	The Western Star, Email, other	238	AMEC
600	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	4104	Random Island		Rainfall					$100,000,000		$72,730,852				Roads washed out, a 80yr old man was swept out to sea.	Multiple	267, 267b	AMEC
601	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	290	Beau Bois		Rainfall					$100,000,000		$72,730,852				Roads washed out	Multiple	267, 267b	AMEC
602	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4435	St. Lawrence		Rainfall	239				$100,000,000		$72,730,852				Winds were so high that it ripped the roof of a hardware store. By 7am some of the roads in the town were already impassable.	Multiple	267, 267b	AMEC
603	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2745	Lawn							$100,000,000		$72,730,852				State of emergency declared, roads in the town were washed out by heavy rain.	Multiple	267, 267b	AMEC
604	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3155	Marystown							$100,000,000		$72,730,852				Roads washed out	Multiple	267, 267b	AMEC
605	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5180	Trouty							$100,000,000		$72,730,852				Houses and Roads were washed away	Multiple	267, 267b	AMEC
606	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	525	Bonavista		Rainfall	200				$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
607	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	1055	Clarenville							$100,000,000		$72,730,852				State of Emergency called to help crews deal with flooding that swamped roads.	Multiple	267, 267b	AMEC
608	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3965	Port Rexton							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
609	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1780	Garnish							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
610	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5155	Trinity							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
611	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4990	Sunnyside							$100,000,000		$72,730,852				A section of the main road was washed out, leaving about half of the Trinity Bay community cut off.	Multiple	267, 267b	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
612	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	1755	Gambo							$100,000,000		$72,730,852				Flooding caused several families to leave their home, forced the town to call a state of emergency	Multiple	267, 267b	AMEC
613	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	1865	Glovertown							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
614	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3500	Norman's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
615	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4335	Jacques Fontaine							$100,000,000		$72,730,852				Residents quickly found themselves stranded by flooding.	Multiple	267, 267b	AMEC
616	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1775	Garden Cove							$100,000,000		$72,730,852				A metre of water pooled over the sole road in the community, no one can get in or out of the community.	Multiple	267, 267b	AMEC
617	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2765	Lethbridge		Rainfall	194				$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
618	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3345	Mount Pearl		Rainfall	134				$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
619	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4400	St. John's		Rainfall	130				$100,000,000		$72,730,852				Roads and properties flooded	Multiple	267, 267b	AMEC
620	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	1760	Gander		Rainfall	124				$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
621	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern		Port Union		Rainfall	79				$100,000,000		$72,730,852				Roads washed out	Multiple	267, 267b	AMEC
622	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2280	Hickman's Harbour							$100,000,000		$72,730,852				Some residents used a boat to get around, Ralph Blundell lost everything in the storm.	Multiple	267, 267b	AMEC
623	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1040	Charleston							$100,000,000		$72,730,852				Bridge/Road washed out	Multiple	267, 267b	AMEC
624	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3945	Port Blandford							$100,000,000		$72,730,852				Town called a state of emergency, washed out roads, flooding and downed power lines.	Multiple	267, 267b	AMEC
625	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5040	Terrenceville							$100,000,000		$72,730,852				The town was cut off from the Burin Peninsula, which was also washed out.	Multiple	267, 267b	AMEC
626	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1940	Grand Bank							$100,000,000		$72,730,852				Many homes were damaged by wind and rain.	Multiple	267, 267b	AMEC
627	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	165	New-wes-valley							$100,000,000	$100,000,000	$72,730,852	$72,730,852			Suffered damages by the wind and rain, the hospital also had to be evacuated due to flooding.	Multiple	267, 267b	AMEC
628	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern		Goose Cove							$100,000,000		$72,730,852				Damages to roads and property	Multiple	267, 267b	AMEC
629	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5175	Trout River	Manuels Brook						$100,000,000		$72,730,852				4 homes were flooded as water ran down the street, the water was caused by a jam that caused	Multiple	267, 267b	AMEC
630	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1455	Dunville							$100,000,000		$72,730,852				Damages to a residence in the town	Multiple	267, 267b	AMEC
631	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4755	Adams Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
632	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2305	Adeytown							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
633	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	180	Baine Harbour							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
634	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	251	Bay de Verde							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
635	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	260	Bay L'Argent							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
636	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	510	Boat Harbour							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
637	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3405	Brownsdale			104				$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
638	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	710	Bunyan's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
639	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	725	Burin							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
640	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	845	Canning's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
641	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	950	Carbonear							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
642	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	990	Cavendish							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
643	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1010	Chance Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
645	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1060	Clarkes Beach							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
646	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1030	Chapel Arm							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
646	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern		Come by Chance							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
647	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	1435	Dover							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
648	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1510	Elliston							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
649	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1530	English Harbour East							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
650	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1545	Epworth-Great Salmonier							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
651	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1650	Fortune							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
652	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1665	Fox Cove-Mortier							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
653	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1675	Fox Harbour							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
654	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	1720	Freshwater							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
655	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3830	Point au Gaul							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
656	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3865	Point May							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
670	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2240	Heart's Content							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
671	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2245	Heart's Delight							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
672	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2315	Hodge's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
673	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2320	Holyrood							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
674	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2585	King's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
675	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2675	Lamaline							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
676	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2770	Lewin's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
677	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	2775	Lewisporte							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
678	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2830	Little Catalina							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC

Flood #	Storm #	General Location	Start Year	Start Month	Start Day	Start Time	End Year	End Month	End Day	End Time	Duration (days)	Season	Region	LGP#	Community Name	Water Bodies	Type of Event	Rainfall Amount	Snowfall amount	Sea Height	Jam Height	Damage Estimate by Community (if known)	Damage Estimate by Storm (once per storm)	DFAA Damage Report	DFAA Damage Report (once per storm)	Homes Flooded	People Displaced	Description	Source	Attachment Number	Data Added By
679	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2885	Little St. Lawrence							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
680	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2945	Logy Bay							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
681	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	2970	Long Harbour							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
682	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Central	3385	Musgravetown							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
683	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3435	New Perlican							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
684	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3595	Old Perlican							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
685	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3665	Parker's Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
686	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	3800	Placentia							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
689	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4104	Random Island West							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
690	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4143	Red Harbour							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
691	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4295	Rushoon							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
692	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4520	Salmon Cove							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
693	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4545	Sandringham							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
694	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4825	South East Bight							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
695	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4835	South River							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
696	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4850	Southern Harbour							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
697	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern		Southwest Arm							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
698	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4505	St. Vincent's							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
699	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	4985	Summerville							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
700	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5005	Swift Current							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
701	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5035	Terra Nova							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
702	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5125	Torbay							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
703	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5155	Trinity Bay North							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
704	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5225	Victoria							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
705	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5245	Wabana							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC
706	283	Southern and Eastern Newfoundland	2010	9	21		2010	9	22		1	Fall	Eastern	5365	Whiteway							$100,000,000		$72,730,852					Multiple	267, 267b	AMEC

11. Appendix D IDF Curves Report

GOVERNMENT OF

NEWFOUNDLAND AND LABRADOR

FLOOD RISK MAPPING PROJECT

CORNER BROOK AND GOULDS/PETTY HARBOUR

Development of Projected Intensity-Duration-Frequency Curves

Submitted to:

Water Resources Management Division

Department of Environment and Conservation

Government of Newfoundland and Labrador

Submitted by:
AMEC Earth & Environmental,
a Division of AMEC Americas Limited
133 Crosbie Road, PO Box 13216
St. John's, Newfoundland & Labrador
Canada, A1B 4A5

May 2012
TA1112735

Table of Contents

LIST OF FIGURES

INDEX OF TABLES

1.0 INTRODUCTION

This report provides an overview of the development of projected intensity-duration-frequency curves (IDF curves) for two areas of Newfoundland, Canada; Corner Brook and Goulds/Petty Harbour. The objective of the work described here is to develop IDF curves that reflect the changes in the characteristics of precipitation that might be caused by projected changes in climate. Three time frames were adopted for projections: 2020, 2050 and 2080.

Over the last four decades, climate scientists have developed a theoretical framework and have accumulated observational evidence to indicate that the average temperature of the Earth is increasing, and that part of this increase can be attributed to emissions of greenhouse gases generated by human activities (IPCC, 2007). Modern climate simulation models, referred to as global climate models (GCMs, and also referred to as general circulation models), have been used to develop quantitative projections of future changes in temperature, precipitation and other climate variables based on estimates of future emissions of greenhouse gases. These models show a consensus that the global average temperature will increase, though the amount of the projected temperature increase varies with latitude and is not evenly distributed seasonally. Increases in the global average temperature will cause increased evaporation, resulting in an increase in the global average precipitation. However there is a high degree of uncertainty regarding the spatial and temporal distribution of those changes in precipitation, and furthermore, precipitation in some areas of the globe will decrease.

Theory, and analysis of GCM outputs, indicates that warmer temperatures will change the characteristics of precipitation extremes (Kharin, et al., 2007). This scientific information along with recent flood events have motivated infrastructure planners to undertake efforts, like that described herein, to quantify the impact of projected climate change on the IDF curves used as one basis for design of drainage and flood infrastructure.

This work focused on two areas, Corner Brook and Goulds/Petty Harbour, in Newfoundland. Newfoundland is the island portion of the easternmost Canadian province, Newfoundland and Labrador. It is located between the Gulf of St. Lawrence and the Atlantic Ocean, and is one hundred kilometers northeast of Cape Breton Island of Nova Scotia. The climate in Newfoundland has been characterized by observations at a number of weather stations. The climates in the regions of Corner Brook and Petty Harbour were based on the Deer Lake station and the St. John’s A weather station, respectively. Although climate measurements from a third station at Stephenville were studied, Deer Lake and St. John’s A were determined to have the climate that best represented the sites in question.

In 2010, Environment Canada developed updated IDF curves based on historical observations from the stations at Deer Lake (data from 1966 through 2002), St. John's A (data from 1949 through 1996), and Stephenville A(data from 1967 through 2007). The documentation for these historical IDF curves included the record of the intensity of annual extreme precipitation events for nine event durations ranging from 5 minutes to 24 hours. Another historical IDF curve was developed by CBCL Limited based on a combination of data from the St. John's A station and a second station at Windsor Lake, nearby (data provided by WRMD). To obtain projected IDF curves, the precipitation intensities in the historical IDF curves were adjusted to reflect projected changes in climate using a statistical modeling technique that is described briefly in the following paragraph, and in more detail in the following sections of this report.

The approach selected for this work uses a statistical model that derives the sensitivity of extreme precipitation to climate conditions from the historical climate information for a site. In this case the historical climate was characterized by observations of monthly average temperature and monthly total precipitation at the Deer Lake, St. John's A and Stephenville weather stations. The statistical model, which is described in more detail below, was fitted to the local climate data and the historical monthly precipitation maxima using a form of regression. Information about future monthly average temperature and monthly total precipitation was obtained from the output of 48 runs of GCMs. Each GCM run was compared internally to establish a projected future *change* in temperature and precipitation. These changes were used to adjust the historical record of temperature and precipitation to reflect future conditions, which resulted in 48 future climate scenarios that were based on the historical record but which reflected the projected future change in climate. This approach, which is referred to as the *delta* approach, is used to reduce some of the inevitable bias inherent in projections of future climate.

The statistical model of extreme precipitation was then run against each of these adjusted records to obtain estimates of climate-impacted extreme precipitation intensities for each of the nine durations and six return intervals. These estimates reflect the bias in the statistical model, so one more run of the statistical model was made against the average historical climate conditions to provide a baseline set of extreme precipitation intensities. This set of baseline intensities was compared against each of the 48 estimates of climate-impacted intensities to determine the *change* in intensity attributable to the change in climate. These changes were then used to adjust the values in the historical IDF curve to obtain the final projected values of precipitation intensity. (This is another application of the delta approach.)

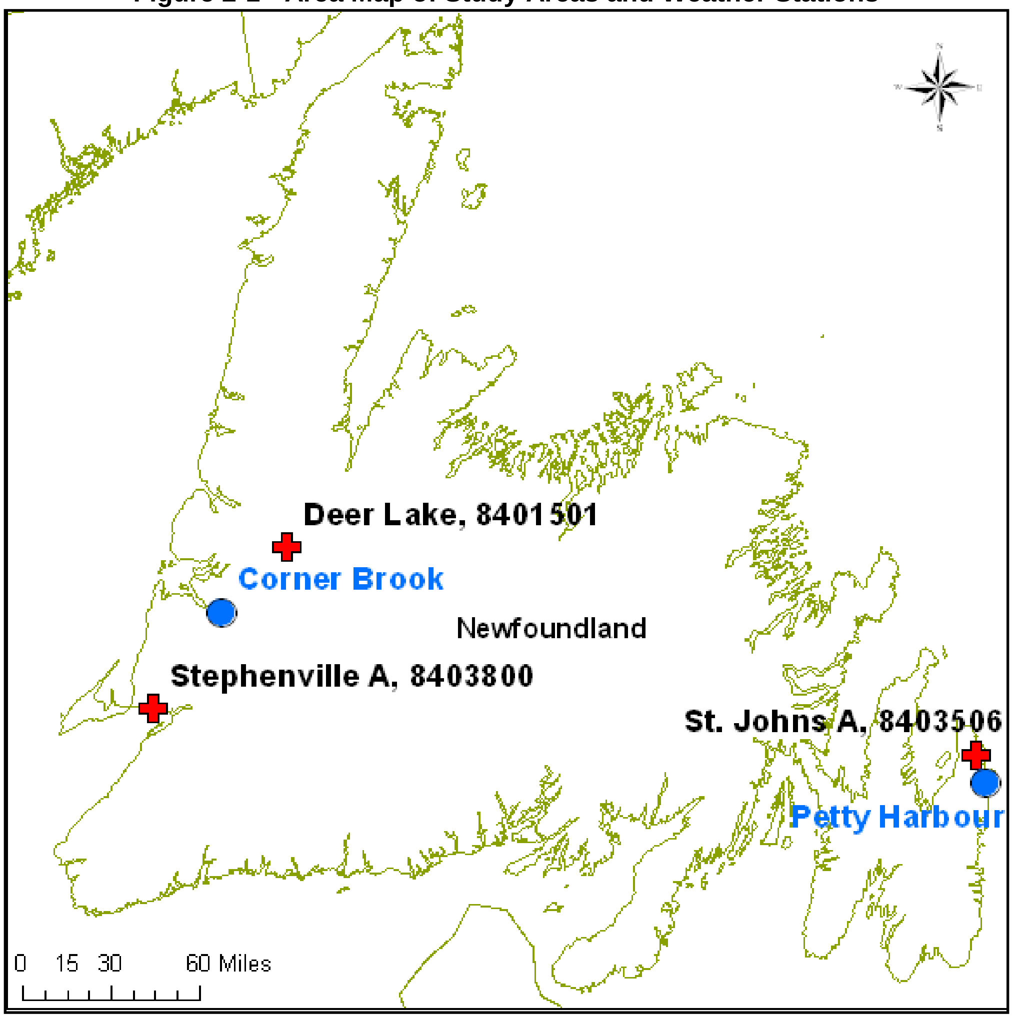
The 48 projections used to characterize future climate conditions produced an equal number of estimates of projected precipitation intensities for each duration and return interval. For reporting purposes, these results were aggregated into the mean, maximum and 90th percentile non-exceedance value of precipitation intensity for each duration and return interval.

This report also includes projected precipitation intensities developed by Lines et al. (2008) and Finnis (data provided by WRMD).

2.0 DATA

This section describes the three data sets used in this work; the local extreme precipitation event data, the local monthly climate data and future projected data from the GCMs. The local conditions were characterized with three weather stations: Deer Lake (8401501), St. John's A (8403506) and Stephenville A (8403800). Figure 2-1 shows the location of the weather stations with respect to the study areas.

Figure 2-1 - Area Map of Study Areas and Weather Stations



2.1 Historical IDF curves

The historical IDF curve and underlying precipitation data were obtained from Environment Canada. Figure 2-2, Figure 2-3 and Figure 2-4 show the historical IDF curves for each of the three stations. Table 2-1, Table 2-3 and Table 2-5 show the historic IDF data in tabular form. Table 2-6 shows the values for the updated version of the historical IDF for the St. John’s A station; this table was developed by combining data from the St. John’s A station with data from a nearby station at Windsor Lake operated by the City of St. John’s (data provided by WRMD). This station is referred to as the St. John’s Composite record. Table 2-2, Table 2-4 and Table 2-7 show the underlying annual maximum precipitation values for the three Environment Canada stations; data for the St. John’s Composite record were not available.

Figure 2-2 - Historical IDF Curve, Deer Lake Station, 8401501

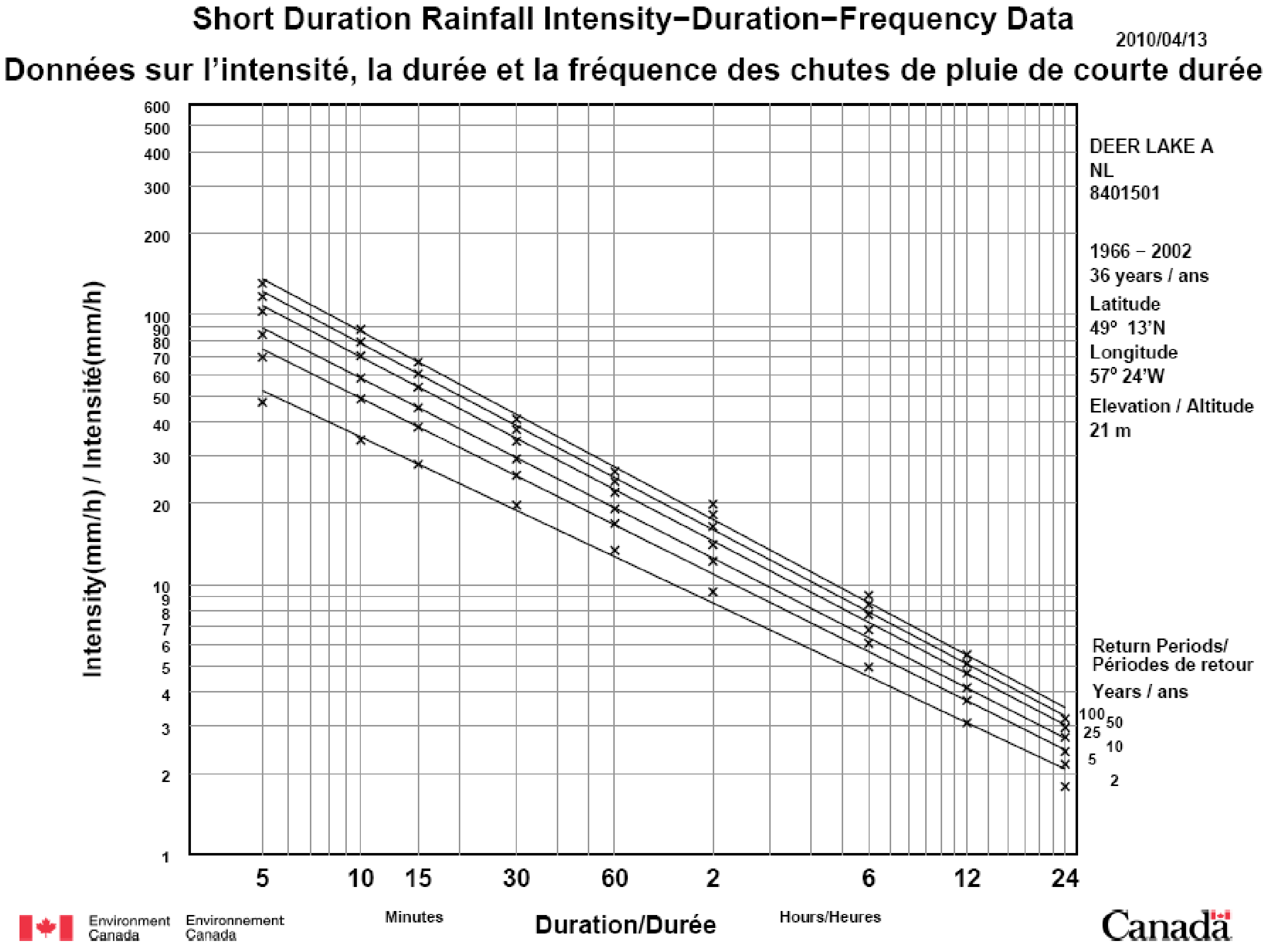


Table 2-1 - Historical IDF Table, Deer Lake Station, 8401501, Precipitation intensities over the specified duration, mm/hr

		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	47.3	69.5	84.1	98.2	102.7	116.4	130.0
	10 min	34.3	48.6	58.2	67.3	70.2	79.1	87.9
	15 min	27.9	38.3	45.1	51.7	53.8	60.2	66.6
	30 min	19.7	25.4	29.2	32.8	33.9	37.5	41.0
	1 hr	13.4	16.8	19.1	21.3	21.9	24.1	26.2
	2 hr	9.4	12.2	14.1	15.8	16.4	18.1	19.9
	6 hr	5.0	6.1	6.8	7.5	7.7	8.4	9.1
	12 hr	3.1	3.7	4.2	4.6	4.7	5.1	5.5
	24 hr	1.8	2.2	2.4	2.6	2.7	3.0	3.2

Table 2-2 - Historical Annual Maximum Precipitation Events Deer Lake Station, 8401501, mm

Year	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
1966	2.8	3	4.6	6.3	9.9	13.7	21.8	25.9	29.2
1967	5.1	5.8	7.1	10.9	14.2	19.3	31.7	37.6	38.6
1968	4.1	6.1	8.9	12.2	13.2	21.3	41.1	52.1	64
1969	3	4.8	6.1	7.4	10.7	14.7	25.9	31	37.8
1970	2.8	3	4.1	6.9	13.2	23.4	38.1	39.6	40.1
1971	3.6	5.6	6.6	8.9	11.2	12.4	22.9	27.7	29.2
1972	4.6	4.8	5.3	7.4	9.7	15.7	27.4	36.6	45
1973	7.1	12.4	13.5	15.2	15.7	23.1	36.6	47	50.3
1974	2.8	5.3	7.4	9.1	13.7	16.8	28.2	32	43.9
1975	7.1	8.9	11.2	15.7	23.9	39.9	44.7	50.8	66.5
1976	3.8	3.8	4.3	6.9	9.7	13.2	25.7	39.1	42.4
1977	3.8	7.4	7.6	15	18.3	18.5	34.3	46.7	47.5
1978	6.9	10.8	13.9	16.5	19.6	36.1	36.1	36.1	45.9
1979	4	6.5	7.7	9.6	9.8	11.9	24.2	33.3	41.2
1980	3.1	4.9	5.8	7.1	10.1	15.3	34.3	55.7	62.7
1981	3.4	4.4	5.1	8.3	14.1	15	24.3	37.9	43.8
1982	1.9	3	4	6.4	12.7	21.5	30	30.2	38.3
1983	4	6.5	7.4	12.1	19.8	28.1	34	36.8	46.3
1984	11.6	12.8	12.8	12.8	12.8	17.8	31.1	33.8	43.3
1985	3.3	4.6	4.8	7.6	10.6	13	18.2	25.7	32.7
1986	2.2	4.3	5.4	7.3	10	13	21.5	28.2	39.9
1987	4	5.7	6.7	10.2	10.9	15.5	25.2	25.7	26.7
1988	8.3	10	11.9	14.1	16.2	18.9	31	39.8	39.8
1989	4	5	6.2	8.5	11.6	17.2	26.4	34.4	40.8
1990	6.2	9.2	11.2	12.5	16	21.9	22.8	37.3	38
1991	2.3	3.7	3.9	6.4	11.2	18.5	38.2	40.4	43
1993	1.8	3.2	4.8	6.7	9.7	17.8	28.7	31.9	40.8
1994	4.7	9.4	10.1	13.5	19.9	25.8	33.9	39.7	51.3
1995	2.8	3.6	4.7	9.2	13.5	23.1	44.9	54	70.1
1996	2.5	3.9	5.1	7.2	10.9	20.1	44.6	59	59.1
1997	3.6	5.1	6.6	10.1	12.4	13.4	21.1	30	35.6
1998	2.6	3.8	4.8	9.6	13.4	19.6	29.4	42.3	53.6
1999	3.3	5	7.5	14.8	21	24.3	25.2	39	41.4
2000	7.8	10.4	10.4	11.5	16.5	28.7	46.9	48.3	48.3
2001	5.2	7.5	9.7	13.3	18.3	24.2	27	31.5	38.2
2002	4.2	7.5	11.1	15.8	19.8	21.5	36.5	44.2	49.2

Figure 2-3 - Historical IDF Curve, Stephenville A Station, 8403800

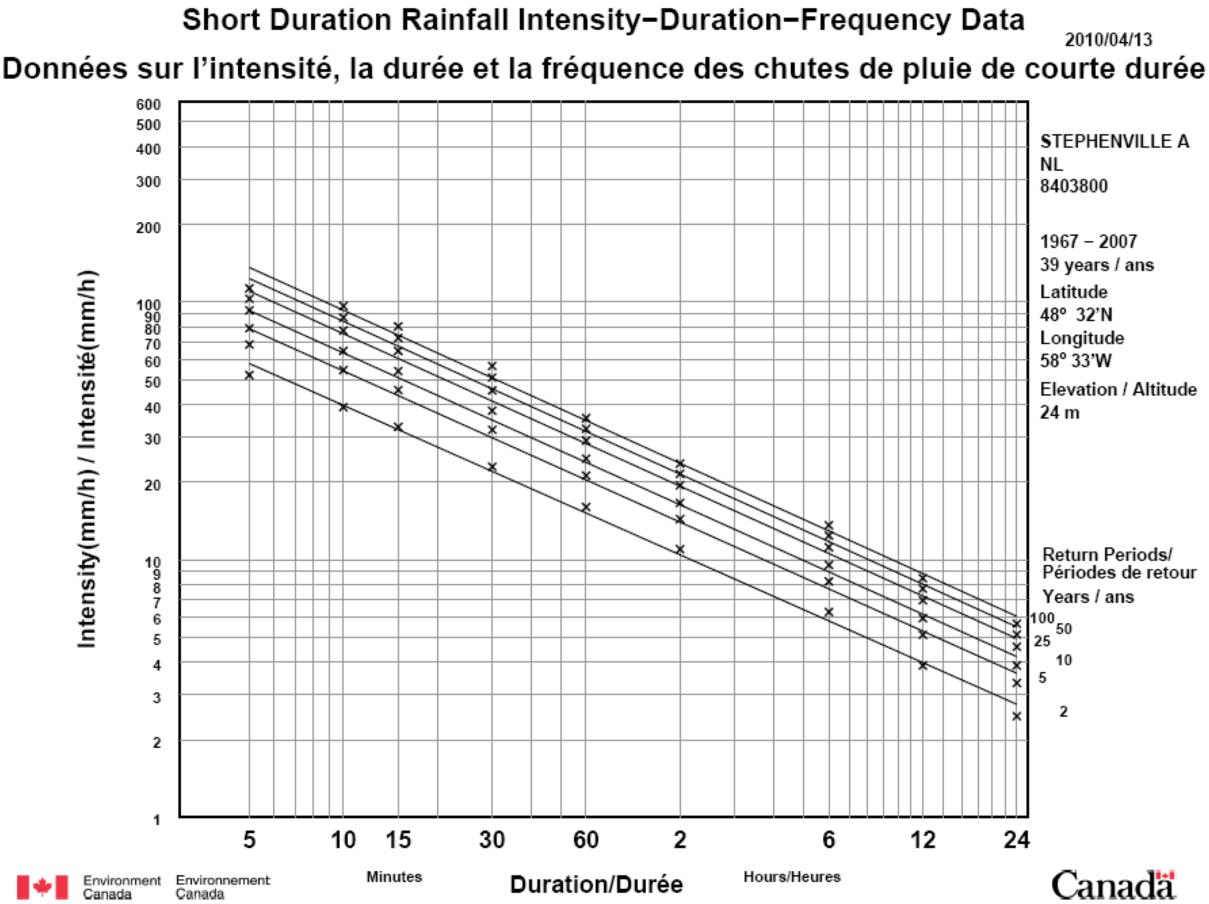


Table 2-3 - Historical IDF Table, Stephenville A Station, 8403800, Precipitation intensities over the specified duration, mm/hr

		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	52.0	68.3	79.1	89.4	92.7	102.8	112.8
	10 min	39.0	54.4	64.5	74.3	77.4	86.9	96.4
	15 min	32.8	45.5	53.9	62.0	64.5	72.4	80.3
	30 min	22.9	31.9	37.8	43.5	45.3	50.9	56.4
	1 hr	16.0	21.2	24.6	27.9	29.0	32.2	35.4
	2 hr	11.0	14.4	16.6	18.7	19.4	21.5	23.6
	6 hr	6.3	8.2	9.5	10.8	11.2	12.4	13.6
	12 hr	3.9	5.1	5.9	6.7	7.0	7.7	8.5
	24 hr	2.5	3.3	3.9	4.4	4.6	5.1	5.6

Table 2-4 - Historical Annual Maximum Precipitation Events Stephenville A Station, 8403800, mm

Year	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
1967	4.3	7.9	8.9	14	18	18.5	25.4	38.6	51.8
1968	4.1	6.9	8.1	8.6	14	17	36.6	52.8	70.6
1969	2.3	3.3	4.1	5.8	7.6	14.5	29.7	48.3	58.4
1970	4.8	8.6	8.6	9.1	14	21.6	39.6	41.4	54.9
1971	3.8	5.6	7.9	11.2	16.8	21.6	37.6	47.5	57.4
1972	6.1	7.4	9.1	12.7	15.7	25.1	40.9	43.4	48.8
1973	2.8	5.3	7.1	10.7	20.6	37.6	49	52.8	89.7
1974	3.3	4.3	6.6	11.4	18.5	25.7	47	60.5	63
1975	5.6	8.6	9.4	9.9	14.5	16.3	32.8	36.3	41.1
1976	3	5.3	6.6	7.9	10.4	13.5	22.9	33.8	36.6
1978	2.3	3.3	4.6	7.9	11.2	17.3	23.5	34.3	42
1979	5.1	10.1	13.6	16.7	22.6	33.5	74.4	87.5	98
1980	4.6	6.4	7.8	11.4	18	19.6	36.3	44.4	59.4
1981	3.1	5	5.5	7.3	10.4	16	31.1	34	52.1
1982	3.3	4	5.4	6.6	11.1	14.2	30	35.7	44.8
1983	3.8	6	7.4	10	14.6	20.9	45.3	52.2	82.4
1984	4.5	5.5	6.8	10.2	13.8	18.2	28.1	41.1	63.2
1985	2.9	5.5	6.4	8	9.9	13.3	23	31.8	32.6
1986	3.6	6.2	7.3	10.4	16.8	22.3	23.7	33.8	46.1
1987	4.6	7.8	9.4	14	18	27.4	41	44	49.9
1988	6.5	10.8	14.2	21.7	22.2	22.4	53.1	56	56
1989	4.4	7.9	9.7	11.5	17.7	29.6	47.1	59.5	97.5
1990	9.4	18.7	23.2	33.2	41.5	46.3	51.5	54.6	88.9
1991	3.8	5.9	6.8	8.8	13.4	23.6	46.4	52.8	55.9
1993	6.8	11.7	14.8	20.7	21.6	25.4	32.4	42.2	56.5
1994	3.8	6.2	6.4	10.6	17.1	18.1	31.5	54.8	69.4
1995	7.9	8.8	10.8	14	26	45.3	82.5	97.6	134.5
1996	3.4	6.4	9.3	17.7	23.1	30.1	47.8	67.1	68.4
1997	6.1	8.8	9.9	13.8	14.5	17.1	24.7	31.4	46
1998	6.8	12.9	16.3	19.9	24.6	30.3	38.2	41.6	52.5
1999	5.1	5.1	6.5	10.8	18.2	25.1	32.8	37.9	40.4
2000	4.2	6.1	8.1	12	14.2	24.2	45.5	48.7	58.8
2001	3.5	4	5	8.5	12.7	18.3	33.5	40.4	57.9
2002	4.4	6.2	8.6	13.8	19.6	25.2	58	59.4	60.5
2003	6.1	7.1	10.7	14.7	16	19.9	36.6	41	52.7
2004	3.4	4.8	6	8.5	13.5	21.8	33.6	39.9	65.3
2005	4.8	6.2	9	13.2	14.6	24.4	60.3	106.6	138.4
2006	5.1	5.9	8.1	11.4	21.2	24.1	35.8	50.6	55.5
2007	5.4	5.8	8.4	11.2	13.6	20.6	43.3	47.9	62.6

Figure 2-4 - Historical IDF Curve, St. John's A Station, 8403506

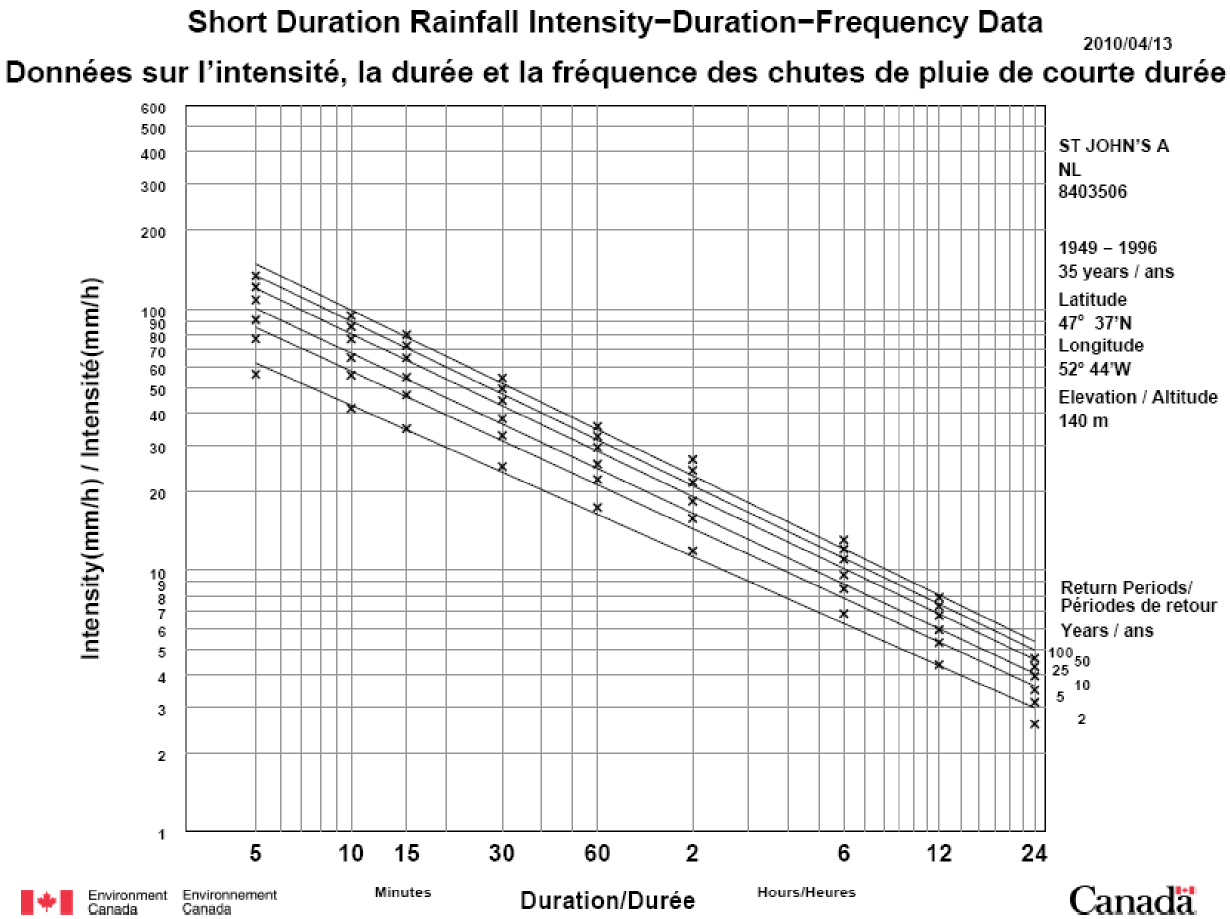


Table 2-5 - Historical IDF Table, St. John's A Station, 8403506, Precipitation intensities over the specified duration, mm/hr

		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	56.2	77.0	90.8	104.0	108.2	121.1	133.9
	10 min	41.6	55.7	65.0	74.0	76.8	85.6	94.2
	15 min	34.9	46.9	54.8	62.4	64.9	72.3	79.7
	30 min	24.9	32.8	38.0	43.0	44.6	49.5	54.4
	1 hr	17.4	22.3	25.5	28.6	29.5	32.5	35.5
	2 hr	11.9	15.8	18.4	20.9	21.7	24.1	26.5
	6 hr	6.8	8.5	9.6	10.7	11.0	12.0	13.1
	12 hr	4.4	5.3	5.9	6.5	6.7	7.3	7.9
	24 hr	2.6	3.1	3.5	3.8	3.9	4.3	4.6

Table 2-6 - Historical IDF Table, St. John's Composite Record, Updated March 2012, Precipitation intensities over the specified duration, mm/hr

		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	55.0	73.7	86.0	97.9	113.3	124.8
	10 min	41.6	54.6	63.0	71.4	82.2	90.0
	15 min	35.7	46.8	54.0	60.8	70.0	76.8
	30 min	26.2	34.4	39.8	45.2	51.8	57.0
	1 hr	18.7	24.7	28.6	32.4	37.3	40.9
	2 hr	12.9	17.5	20.5	23.4	27.1	29.9
	6 hr	7.4	9.6	11.1	12.5	14.3	15.7
	12 hr	4.7	6.1	7.1	8.0	9.2	10.1
	24 hr	2.8	3.6	4.1	4.6	5.2	5.7

Table 2-7 - Historical Annual Maximum Precipitation Events St. John's A Station, 8403506, mm

Year	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
1949	8.9	8.9	10.2	17.5	28.2	52.6	61.7	62	63.5
1961	3	4.3	5.3	6.9	8.6	13.5	25.7	35.6	38.6
1962	2.8	4.6	4.6	8.1	13	20.6	33.8	54.9	59.7
1963	10.2	11.2	11.7	13.7	18.5	23.6	40.9	52.3	57.9
1964	4.3	6.9	7.9	11.2	19.3	28.2	54.9	72.6	77.5
1965	5.3	7.4	9.9	13	17.8	19.6	32.3	51.8	59.7
1966	8.4	13.2	17	25.4	29.7	43.7	48.5	64.5	85.3
1967	2.3	3.8	5.3	9.9	10.9	16.3	29.5	44.4	58.4
1968	6.3	12.7	13.7	14.7	17.5	22.4	41.9	55.1	61.7
1969	5.6	7.1	8.4	8.6	11.7	19	30.7	34.5	48.3
1970	5.6	7.1	10.7	15.2	16.3	19.6	42.4	62.5	87.4
1971	6.3	10.4	14.5	16	19	22.1	34.3	41.1	77.7
1972	4.8	5.3	6.6	10.9	15	20.6	47.8	72.6	89.2
1973	5.3	6.9	7.9	10.4	16.5	30	49.5	65.8	67.1
1974	3.6	5.6	6.3	9.9	16.3	22.4	42.4	53.3	72.9
1975	8.1	10.4	12.2	17.8	19	19.6	46.5	71.9	82.3
1976	3.6	4.8	6.1	8.4	12.7	19	33.8	42.2	53.6
1977	3.8	5.6	7.6	11.7	17.5	23.4	38.6	40.4	41.4
1978	4	5.9	7.4	7.6	12.9	13.1	27.1	37.6	43
1979	3.2	4.2	5.9	10.2	16.2	18.1	29.3	41.9	49.2
1980	3.2	6.1	7.4	12.2	17.4	23.9	33.6	41.6	69.8
1981	N/A	N/A	N/A	N/A	15	22.4	46.7	72.5	82.6
1982	5.1	9	12.9	17.1	24.5	35.9	80.3	82.4	84
1983	1.6	3.2	4.8	9.6	19.2	26.5	47.3	52.8	54.7
1984	5	9.9	13	21.5	27.1	36.6	61	74	75.3
1985	5.2	7.1	9.8	11.3	14.1	18.5	36	54.9	82.9
1986	3.1	4.8	7.2	14.3	23.3	27.9	40.2	58.9	70.6
1987	5.1	7.3	8.6	16.2	23.5	24.2	30.6	36.6	46.8
1988	6.6	10.6	13.2	17.4	23.4	25.9	44.8	45.8	49
1989	2.9	4.5	6.2	8	10.9	19.7	43.4	51.6	51.6
1990	3.7	5.9	6.5	12.6	19.2	28.5	48.1	68.7	85.2
1991	7.8	11.4	15.9	23.3	28.8	29.5	51.2	52.2	59.7
1993	4.4	7	7.6	11.5	20	31.3	47.6	49.4	55.3
1994	6.2	9.1	10.3	12.6	12.8	14.9	N/A	N/A	67.5
1995	5.2	9.8	14.5	16.6	27.6	46.7	55.9	58.8	61.6
1996	4.8	6.2	7.4	10.2	15.4	27.2	40.2	44	48.4

2.2 Local Climate Data

Local climate data were required to establish the sensitivity of extreme precipitation to monthly average precipitation and temperature. Local climate data were obtained from Environment Canada for the 11 elements shown in Table 2-8.

Table 2-8 - Historical Climate Data Elements

Element Description
Mean Max Daily Temp (°C)
Mean Daily Temp (°C)
Mean Min Daily Temp (°C)
Extreme Monthly Max Temp (°C)
Extreme Monthly Min Temp (°C)
Monthly Total Rain (mm)
Monthly Total Snow (cm)
Monthly Total Precip (mm)
Snow on Ground Last Day (cm)
Direction of Max Gust (10's deg)
Speed of Max Gust (km/h)

Data for all elements were available on a daily timestep. Table 2-9 summarizes the period of record, monthly total precipitation and monthly average temperature for the three stations.

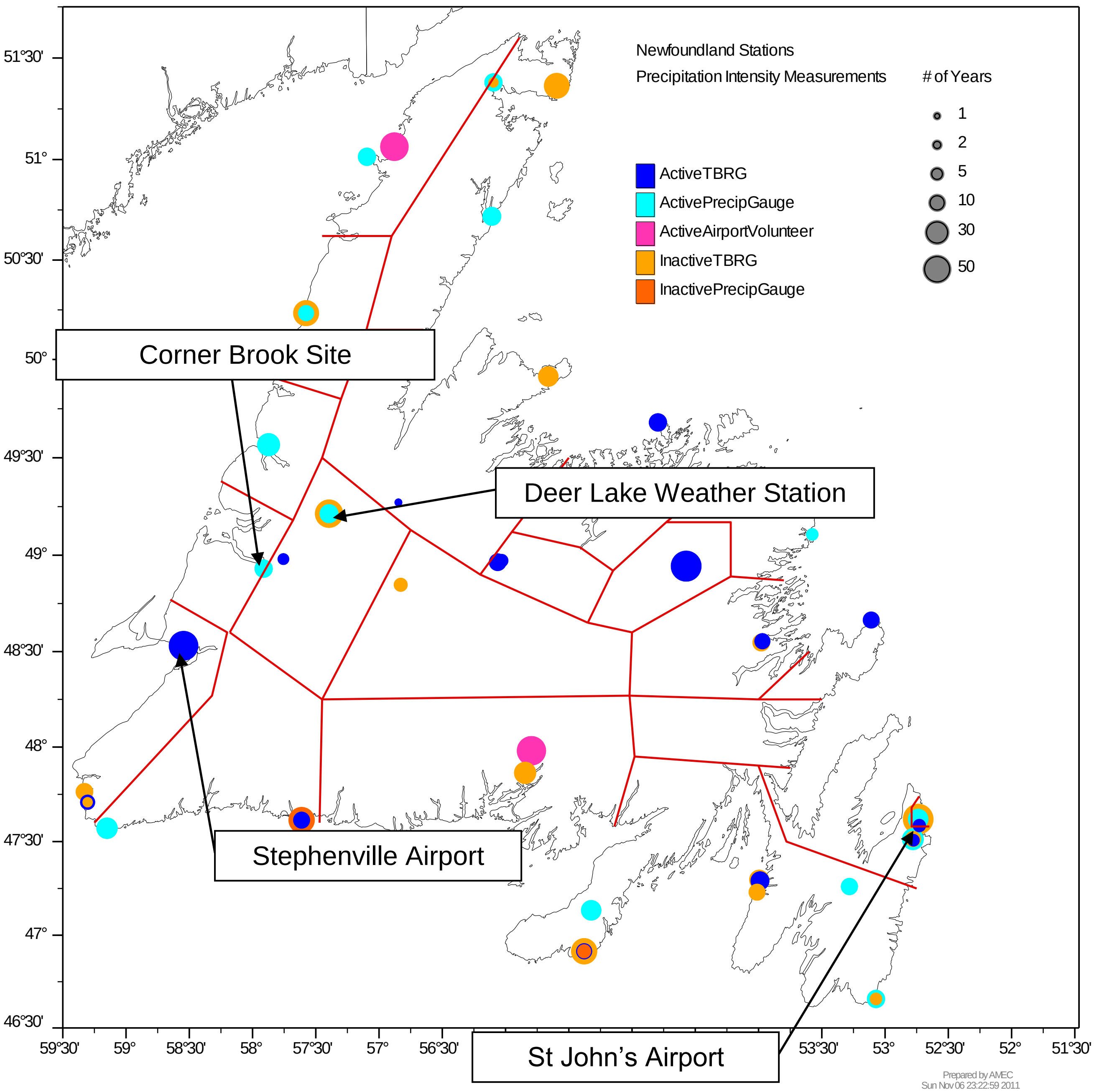
Table 2-9 - Summary of Availability of Historic Monthly Data

Month	Deer Lake, 8401501		Stephenville A, 8403800		St John's A, 8403506	
	Total Precip (count)	Mean Temp (count)	Total Precip (count)	Mean Temp (count)	Total Precip (count)	Mean Temp (count)
Jan	69	72	69	69	70	70
Feb	71	73	69	70	70	70
Mar	71	72	70	70	70	70
Apr	70	72	67	70	69	69
May	**70**	**70**	**67**	**69**	**70**	**70**
Jun	**70**	**72**	**68**	**69**	**69**	**69**
Jul	**72**	**72**	**69**	**69**	**69**	**69**
Aug	**68**	**70**	**69**	**69**	**69**	**69**
Sep	**70**	**70**	**68**	**69**	**69**	**69**
Oct	**69**	**71**	**68**	**69**	**69**	**69**
Nov	70	71	68	69	69	69
Dec	70	73	69	69	69	69
First Year of Data	1933	1933	1942	1942	1942	1942
Last Year of Data	2005	2005	2010	2010	2010	2010

Note: While datapoints are shown for all months, correspondence with Environment Canada staff indicated precipitation data for these stations are only valid from May to October. The stations have not been equipped with heating elements to allow them to measure snowfall water equivalent accurately.

Figure 2-1 shows the Deer Lake and Stephenville A stations to be approximately equidistant from the Corner Brook site. Further detailed meteorological analysis suggests that the Deer Lake site is considered more representative of the rainfall patterns over the Corner Brook watersheds. As shown in Figure 2-5, the Public Forecast Warning Areas used by Environment Canada place the Deer Lake station within the same Warning Area as Corner Brook while the Stephenville A station falls into another Warning Area. Therefore the Deer Lake station is more representative of precipitation that contributes to flows at Corner Brook. Accordingly, projected IDF curves have been developed only for the Deer Lake and St. John's A Stations.

Figure 2-5 – Public Forecast Warning Areas and Project Sites
Government of Newfoundland and Labrador, (2011)



2.3 Projected Climate Data

The objective of this study is to estimate the sensitivity of extreme precipitation events at the two weather stations of interest (Deer Lake and St. John's A) to projected climate change. Development of information about projected climate conditions involves the following three elements, which are common to most climate impact studies:

- *Emissions scenarios.* Projections of future changes in climate, attributed to human activity, rely on projections of future concentrations of greenhouse gases (GHG), which in turn depend on current concentrations and future rates of GHG emissions. GHG emissions depend, in complex ways, on socio-economic development, technology, demographics and politics. The Intergovernmental Panel on Climate Change (IPCC) has developed a number of "storylines" of future global conditions that are used as the basis for estimates of future GHG emissions. These storylines are documented in the Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000) and are often referred to as SRES scenarios. The IPCC did not assign a likelihood to the SRES scenarios. All are considered equally probable "alternative images of how the future might unfold" (Nakicenovic et al., 2000, Technical Summary). From the four SRES scenario "families" (A1, A2, B1, B2), only the B1, A1B (a member of the A1 family) and A2 scenarios have been used as the basis for projections on many GCMs. These have come to be known, respectively, as the "low", "medium" and "high" emissions scenarios, based on their impact on climate conditions in the year 2100.

- *Global Climate Simulation.* More than 20 GCMs are currently being developed, operated and maintained by national meteorological services, climate research centers and universities around the world. These models have been used to develop quantitative projections of future changes in climate variables, including temperature and precipitation, based on the SRES emissions scenarios. Each GCM is different, but many contain similarities in their conceptual approach and may even share simulation methods and codes. A single GCM will be used to generate many projections, each of which differ by the SRES scenario used to force the GCM, but also by the way in which the model run is initialized and constrained.

- *Downscaled Climate Projections.* GCMs operate on a grid that may range in scale from 100 to 200 miles on a side, and their output is provided at this same resolution. While each GCM grid cell covers from 10,000 to 40,000 square miles, a substantial watershed might cover a few hundred to a several thousand square miles, and many tributaries drain considerably smaller areas. Before GCM output can be used for analysis of local conditions, or for local hydrologic modeling, it must go through a process called downscaling, which relates the large scale GCM data to detailed terrain and observed climate conditions. In addition, GCM projections contain bias, which is exhibited as systematic error in replicating observed conditions. These biases are usually reduced during downscaling with an *ex post* calibration process referred to as *bias correction*.

This project used a set of readily-available downscaled projections from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007) that have been bias-corrected and spatially downscaled and archived by Maurer (2011). These data were downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al., 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003). The archive contains output from 48 model runs, or projections, of monthly precipitation and temperature, with each projection consisting of an overlap period from 1950 through 1999 and a projection period from 2000 through 2099. Each projection is the output from a run of one of 16 GCMs using one of the B1, A1B or A2 emissions scenarios. The GCMs in the archive are listed in Table 2-10.

Table 2-10 - GCMs in Maurer Archive
(after Maurer et al., 2009)

	Modeling Group, Country	IPCC Model I.D.
1	Bjerknes Centre for Climate Research	BCCR-BCM2.0
2	Canadian Centre for Climate Modeling and Analysis	CGCM3.1 (T47)
3	Météo-France/Centre National de Recherches Météorologiques, France	CNRM-CM3
4	CSIRO Atmospheric Research, Australia	CSIRO-Mk3.0
5	US Dept. of Commerce/NOAA/Geophysical Fluid Dynamics Laboratory, USA	GFDL-CM2.0
6	US Dept. of Commerce/NOAA/Geophysical Fluid Dynamics Laboratory, USA	GFDL-CM2.1
7	NASA/Goddard Institute for Space Studies, USA	GISS-ER
8	Institute for Numerical Mathematics, Russia	INM-CM3.0
9	Institut Pierre Simon Laplace, France	IPSL-CM4
10	Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies and Frontier Research Center for Global Change (JAMSTEC), Japan	MIROC3.2 (medres)
11	Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA	ECHO-G
12	Max Planck Institute for Meteorology, Germany	ECHAM5/MPI-OM
13	Meteorological Research Institute, Japan	MRI-CGCM2.3.2
14	National Center for Atmospheric Research, USA	PCM
15	National Center for Atmospheric Research, USA	CCSM3
16	Hadley Centre for Climate Prediction and Research/Met Office	UK UKMO-HadCM3

3.0 TIME FRAMES

Time frames adopted for this work are summarized in Table 3-1.

Table 3-1 - Project Time Frames

Description	Time Frame
Climate simulation overlap period	1950-1999
Climate simulation projection period	2000-2099
2020 projection averaging period	2005-2034
2050 projection averaging period	2035-2064
2080 projection averaging period	2065-2094

4.0 APPROACH

4.1 Candidate Approaches

The Canadian Standards Association (CSA) has published the *Technical Guide, Development interpretation and use of rainfall intensity-duration-frequency information: Guideline for Canadian water resources practitioners* (Technical Guide) (CSA, 2010), which provides background about the methodologies used to develop IDF curves based on current climate, and a discussion about methodologies that are potentially applicable to the development of IDF curves that reflect projected future climate conditions. Appendix 8 of the Technical Guide provides a review of several approaches that, at the time it was compiled, had been applied to estimate the sensitivity of extreme precipitation to projected climate change. For detail on the available methods, the reader is directed to the Technical Guide and the references therein. The methods are summarized below in several categories:

- *Extrapolation of trends.* Linear regression is applied to observed historical data to characterize the trend in short-term precipitation extremes and these statistical models are then used to extend the trend to future periods.

- *Direct interpretation of GCM output.* GCMs provide output at a daily time step and at a grid scale that can range from about 1 to 4 degrees (approximately 100 to 400 km on a side at the equator, with the longitudinal dimension decreasing with increasing latitude). Some studies (e.g. Kharin et al, 2007) have used daily GCM output to characterize daily precipitation extremes. These methods cannot directly address time steps shorter than the time step of the GCM.

- *Direct interpretation of Regional Climate Model Output.* Regional climate models (RCMs) use a finer grid scale than is used by a GCM (e.g. 25 km for an RCM versus 100-400 km for a GCM). Because RCMs are usually "nested", that is, their spatial scope is relatively local and their boundary conditions are set by the results of a GCM run, use of an RCM is sometimes referred to as “dynamical downscaling”. RCMs also run at a finer temporal resolution than GCMs and some RCMs can produce output at 1-hour time steps. These data have been used directly to characterize short-term precipitation, but cannot directly address time steps shorter than the time step of the RCM. Because RCMs are computationally expensive to run and their spatial extent is limited, there are fewer runs available. The results of an RCM run will reflect any biases in the GCM run on which it is based.

- *Applying scale factors to climate model output.* Scale factors relate short-term precipitation to longer-term precipitation, e.g. monthly average to total precipitation.

- *Applying statistical models to climate model output.* Statistical models can be developed to represent a functional relationship between short-term precipitation and a predictor variable, usually at a larger temporal and spatial scale (e.g. monthly total precipitation at a GCM or RCM resolution). The most common statistical model is a linear model developed using regression. Linear models of the parameters of extreme value distributions (e.g. Gumbel, Weibull) have also been used.

- *Conditional weather generators applied to climate model output.* Weather generators are stochastic models that generate time series of weather conditions. These models may be parametric (they rely on classical statistical distributions described by parameters) or they can be non-parametric (they rely on re-sampling analogs of weather from the historical data) or a combination of the two. When applied to investigating climate change impacts, weather generators are usually conditioned on large-scale weather variables using statistical models as described above or using non-parametric techniques like the K-nearest neighbor technique.

In the approaches described above, climate model output may be “raw” output at the native grid scale of the climate model (either a GCM or a RCM) or downscaled output.

Despite the remarkable improvements in the scientific state of knowledge about the processes that drive weather, and ultimately climate, there is considerable uncertainty about the sensitivity of climate to increasing greenhouse gas concentrations. Because of that uncertainty, and because of practical constraints, each of the methods described above have shortcomings. It is fair to say that all of the methods described above rely to some degree on an assumption that the relationships between large-scale and small-scale processes, both in time and space, will continue unchanged into the future. This is true of all approaches that use downscaling, scale factors and statistical models, including weather generators. Climate models simulate climate sensitivity, but even these models contain statistical sub-models and are limited in spatial and temporal resolution. In short, there is no perfect method to project climate impacts, there will be considerable uncertainty regarding those projections, and this uncertainty should always be considered when making long-term decisions about investment, policy or infrastructure.

4.2 Selected Approach

Based on a review of available methods, and considering the objectives and constraints of the current work, an approach employing extreme value statistics was judged to be the best approach for estimating the sensitivity of short-term precipitation to projected climate. This approach, described in Towler, et al., (2010) (published after compilation of the Technical Guide), involves fitting linear models of the parameters of an extreme value distribution of a short-term variable to predictor variables, usually long term variables, referred to as “covariates”. We refer to this statistical model as the “intensity model”. The method, which is sometimes referred to as generalized linear models (GLM) (Furrer and Kaatz, 2007), allows modeling of variables that do not have a normal distribution as well as discrete variables, such as precipitation occurrence.

In the approach described below the climate predictor variables used to force the GLM model of climate sensitivity are developed using a *delta* approach and the final adjusted values of precipitation intensity are in turn calculated by a second application of the delta approach to the output of the GLM model. The delta approach and its application are described below.

4.3 Data Diagnostics

A diagnostic analysis was conducted to determine the strength of available long-term climate variables for predicting short-term precipitation. The available projected climate variables were monthly precipitation depth and monthly average temperature. These variables could also be calculated from the local historical climate record. Three variables, monthly total precipitation, monthly average temperature and the product of those two variables were tested for their strength as a predictor of extreme precipitation. The strength of a predictor was assessed using the coefficient of determination estimated using linear regression. These analyses were made using the statistical package “R” (http://www.r-project.org/).

The results of this analysis revealed that statistically significant predictors could not be found for annual precipitation extremes. However, significant predictors were found for many durations for many months. Table 4-1 and Table 4-2 show the occurrence of extreme precipitation at Deer Lake and St. John’s A respectively: shaded cells indicate a month and duration for which snow was a possibility and, due to the lack of accurate snowfall recording at the stations, extreme precipitation data could not be verified. On this basis we elected to model the occurrence of monthly extremes between May and October, the maximum of which would represent the annual extreme.

In addition, in the set of extreme event data, there were a number of months where more missing values were reported for the 24-hour storm duration than for the other storm durations. For a given month and parameter, if more than 4 days data were missing, that month's data for the 24-hour storm duration were deemed unusable and were not used for the fitting and projection process.

Table 4-1 - Occurrence of Annual Extreme Precipitation, Deer Lake Station

	Occurrence of Annual Extreme Precipitation Event, Deer Lake Station													
Event Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	multiple	SUM
5 Minutes	1	1	-	-	1	-	12	15	4	1	-	-	3	38
10 Minutes	-	-	-	-	-	2	12	15	4	1	1	-	3	38
15 Minutes	-	-	-	-	1	4	14	16	1	1	1	-	-	38
30 Minutes	-	-	-	-	1	5	15	15	1	-	-	-	1	38
1 Hours	-	-	-	-	1	3	15	14	1	2	1	1	-	38
2 Hours	-	-	-	-	2	3	11	12	3	3	4	-	-	38
6 Hours	-	-	-	-	1	5	6	11	5	6	3	1	-	38
12 Hours	-	-	-	-	1	4	6	7	9	7	2	1	1	38
24 hours	-	-	1	-	1	6	5	6	7	8	3	1	-	38
SUM	1	1	1	-	9	32	96	111	35	29	15	4	8	342
%	0.3%	0.3%	0.3%	0.0%	2.6%	9.4%	28.1%	32.5%	10.2%	8.5%	4.4%	1.2%	2.3%	100.0%

Table 4-2 - Occurrence of Annual Extreme Precipitation, St. John's A Station

	Occurrence of Annual Extreme Precipitation Event, St. John's A Station													
Event Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	multiple	SUM
5Minutes	2	-	-	-	-	1	9	12	7	3	2	1	-	37
10Minutes	1	-	-	-	-	1	10	13	7	1	2	1	1	37
15Minutes	1	-	-	-	-	2	10	11	7	3	1	2	-	37
30Minutes	1	-	-	-	-	2	9	11	6	3	3	1	1	37
1Hours	1	-	-	-	-	2	10	13	6	3	1	-	1	37
2Hours	2	-	-	-	-	3	9	9	4	6	2	1	1	37
6Hours	2	-	-	-	1	3	4	7	5	3	7	4	1	37
12Hours	1	1	-	2	2	2	3	7	5	3	7	4	-	37
24hours	1	1	1	2	4	1	2	7	6	5	3	3	1	37
SUM	12	2	1	4	7	17	66	90	53	30	28	17	6	333
%	3.6%	0.6%	0.3%	1.2%	2.1%	5.1%	19.8%	27.0%	15.9%	9.0%	8.4%	5.1%	1.8%	100.0%

4.4 Use of Composite Historical IDF for St. John's Area

A second set of historical IDF curves were used to project IDF values for the St. John's area. This was done to account for a large precipitation event that took place in 2002, after the St. John's A station was taken offline. In order to include the effect of this storm, data from the St. John's A station with data was combined from a station at Windsor Lake, approximately 1.6 kilometer from the St. John's A station (updated data provided by WRMD). The record for the St. John's A station runs from 1949 through 1996, and the record for the Windsor Lake station runs from 1999 through 2010. The combined record from these two stations is referred to as the St. John's Composite.

It is important for any analysis of extreme events that all large storms are taken into account, though any analyst should exercise caution combining data from multiple stations. Without a significant period of overlap in the data record for two gauges, no accurate assumptions can be made about the homogeneity of the data recorded by the gauges. There are a number of reasons that a single gauge with a long record provides much higher-quality data than a composite dataset from multiple gauges:

- If two gauges are placed in separate climatic zones, different elevations or regions with varying land cover, they may not experience the same storms.
- Even if two stations are in close proximity they may return very different results for the same storm because, during precipitation events, rainfall is not deposited in a spatially uniform manner.
- There are many environmental factors that can impact the measurements taken by a precipitation gauge including proximity to buildings, localized wind patterns, and local obstructions.
- Gauges of the same type may not be calibrated in an identical way or maintained to the same standard of operation.

The projected IDFs in this report are developed based on the baseline historical IDFs at both the Environment Canada St. John's A site and for the St. John's Composite record.

4.5 Fitting Models

For this work the generalized extreme value (GEV) distribution was fit to the historical monthly precipitation maxima using potential predictor variables. The GEV distribution can assume three possible distribution types, known as the Gumbel, Fréchet and Weibull. The Gumbel is the distribution used by Environment Canada to estimate IDF curves and it is a relatively "light-tailed" distribution with a fixed shape. Using the Frechet variant of the GEV would allow a model to be fit to the shape parameter, which would affect the "weight" of the tail, which is of the most interest in modeling extreme values. The strength of predictors was evaluated to condition the shape parameter of the Frechet distribution explicitly, but no variables showed appreciable strength. This may be because there are not a sufficiently large number of annual values to derive a significant relationship. Accordingly, the Gumbel distribution was adopted.

The GEV models were fitted using the extRemes package (http://cran.r-project.org/web/packages/extRemes/extRemes.pdf) in the statistical package "R" (http://www.r-project.org/). To allow for possible seasonal shifts in extreme event occurrence, seasonal models were fit for each storm duration. In the seasonal model fitting process, all predictor data across May to October were fit against all the data for each individual storm duration. For each duration, models for three principal predictors were evaluated: average precipitation, average temperature and the product of average temperature and average precipitation. For each duration, models based on different predictors were accepted based on statistical significance at a criterion of 0.05 and the best model was selected based on the Akaike Information Criterion (AIC) (explained in Towler, et al., 2010; referenced from Akaike 1974).

For the 9 different durations, statistically significant models were found for each station. Of these, the best predictor for 5 of the models was total monthly precipitation, for 11 models the best predictor was the product of monthly precipitation and temperature, and for the remaining 2 models the best predictor was average monthly temperature. The final model predictors are provided in Appendix A. The parameter selected as the best predictor for each of the month/duration combinations is shown in Table 4-3.

Table 4-3 - Best Predictor Variables

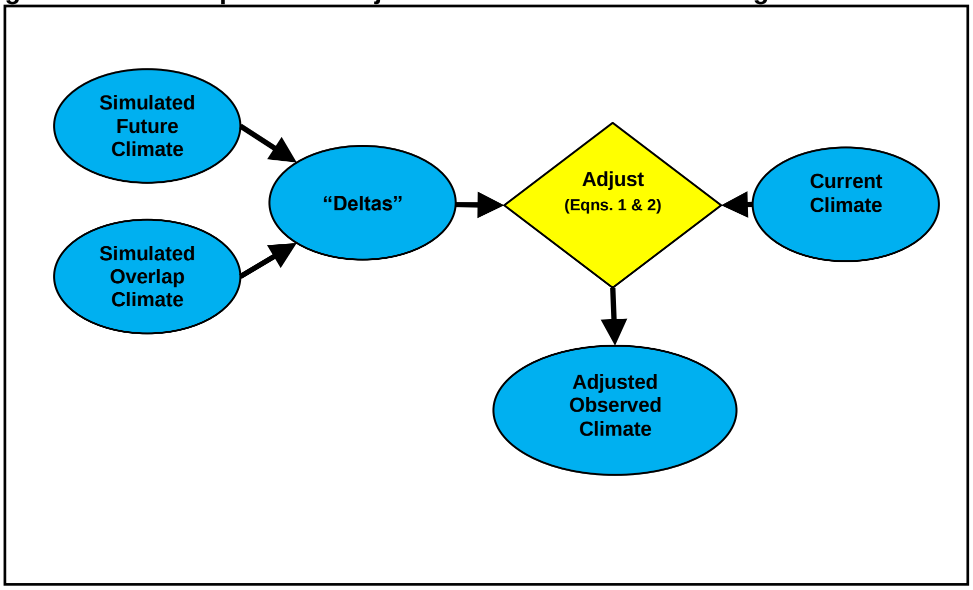
Best Models Chosen (Seasonal Fitting)		
Event Duration	Deer Lake	St John's A
5 min	PxT	T
10 min	T	PxT
15 min	PxT	PxT
30 min	PxT	PxT
1 h	PxT	PxT
2 h	PxT	PxT
6 h	PxT	P
12 h	P	P
24 h	P	P

T = Average Monthly Temperature
P = Total Monthly Precipitation
PxT = Product of P and T

4.6 Developing Projected Precipitation Intensity Values

The projected values of precipitation intensity, which make up the IDF curve, were developed using three applications of the "delta" method (Hamlet and Lettenmaier, 1999; Miller, et al., 2003). In this application, the delta approach is preferred over using climate projections directly, because the delta method reduces the bias inherent in climate simulations. In the delta method, climate projections are used to estimate the *change* in climate variables and this change is then used to adjust the observed record. The projected change is determined for each climate projection by comparing the climate condition during the overlap period from the climate condition at some future point in time. The overlap period is the period of time where the model simulation overlaps the observed climate. In the projections used in this work, the overlap period is 1950 through 1999. In this work, the climate condition during the overlap period is represented as the average for the period 1950 through 1999, and the climate condition at the future point in time is represented as a 30-year average centered on that point in time. The projected IDF curves were based on three future time periods, 2020, 2050 and 2080. The method for adjusting climate variables is illustrated in Figure 4-1.

Figure 4-1 - Development of Adjusted Observed Climate Using the Delta Method



In adjusting precipitation the "delta" is in the form of a ratio as shown in Equation 1.

$$P_p = P_c \frac{P_{sf}}{P_{so}} \quad (1)$$

Where: P_{sf} is the simulated future precipitation, P_{so} is the simulated overlap precipitation, P_c is the current observed precipitation and P_p is the projected future precipitation.

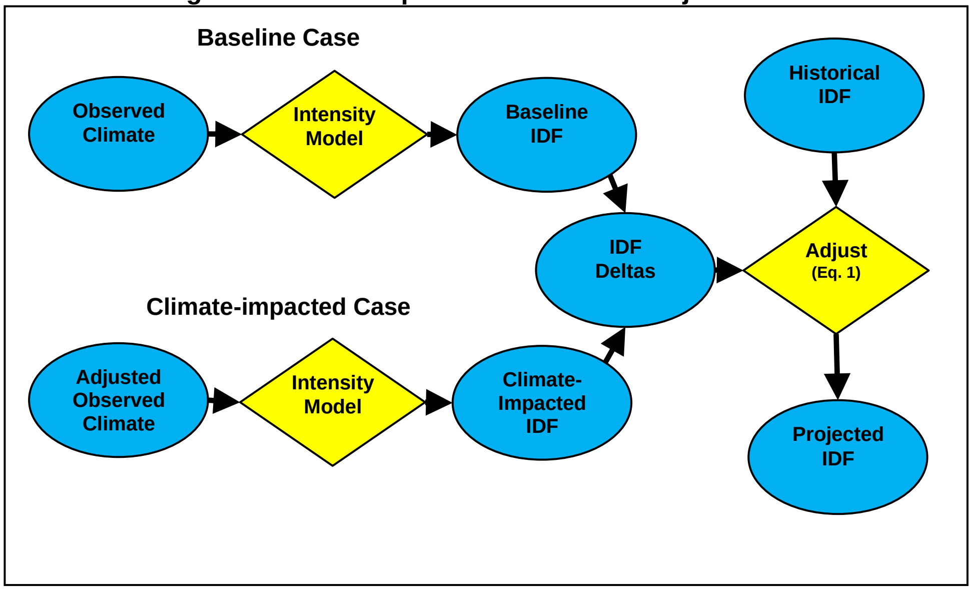
In adjusting temperature, the "delta" was in the form of an offset, as shown in Equation 2.

$$T_p = T_c + (T_{sf} - T_{so}) \quad (2)$$

Where: T_{sf} is the simulated future temperature, T_{so} is the simulated overlap temperature, T_c is the current observed temperature and T_p is the projected future temperature.

The GLM also exhibits inherent bias. In principal every aspect of the method Environment Canada uses to develop IDF curves could be duplicated which would allow for exact replication of the historical precipitation intensities. However, once the distributions are modified in the GLM framework to include covariates, the method and results would deviate from those of Environment Canada. Further, the available GLM fitting routines use different statistical packages and a different method of fitting (maximum likelihood rather than the method of moments) than is used by Environment Canada. Because these differences will introduce bias into the estimates of precipitation intensities, a second application of the delta method was applied to adjust the historical IDF curve. The calculation is done in the same manner as shown in Equations 1 and 2. The method is illustrated in Figure 4-2.

Figure 4-2 - Development of the Final Projected IDF



For each precipitation duration, the intensity model is run once against the observed climate to generate a *baseline* intensity distribution. This distribution is used to develop estimates of baseline intensity for each return interval. The intensity model is then run again for each climate projection, this time using the adjusted observed climate value developed from that projection. This generates, for each projection, a *climate-impacted* probability distribution from which *climate impacted* precipitation intensities are generated for each return interval. The final projected precipitation intensities for each return interval are calculated using Equation 1.

The intensity models are estimated on a seasonal basis, that is, by pooling all data for the months of May through October. This results in a model that captures the sensitivity of precipitation extremes to covariates (temperature, precipitation and the product of precipitation and temperature) exhibited over that season. This is done to increase the size of the data set used to estimate the statistical models, which increases their significance. The models are applied to estimate projected intensities on a monthly basis in order to capture shifts in extreme precipitation caused by projected seasonal shifts in temperature and precipitation.

Projected and observed intensities are first estimated for each month, each duration and each frequency. Then, for each GCM, duration and frequency, the maximum of the monthly intensities is taken as the annual maximum. This process is completed for each duration for both the baseline and the projected case to determine an annual maximum for each case. Then, the ratio of the calculated baseline annual maximum and the calculated projected annual maximum is used as an estimate of the climate sensitivity of the annual extreme precipitation. This calculated climate sensitivity is then used to adjust the historical precipitation intensities in the same manner as is shown in Equation 1.

4.7 Treatment of Uncertainty

All measurements contain uncertainty, and estimates of future conditions are more uncertain than measurements. Each element of a climate impact analysis contains its own degree of uncertainty. These individual uncertainties do not add up in a straightforward way, but they do interact and each added element does increase the overall uncertainty of the final estimate of impact. The approach adopted for this work is intended to make the uncertainty arising from climate models as apparent as possible, so as to allow well-informed judgments regarding future water resources planning.

In North America, the available projections from GCMs show that temperature is highly likely to increase. However, projections of future precipitation are more uncertain; e.g. in some parts of North America model projections disagree on both the sign and magnitude of changes in precipitation. The sources of this uncertainty include the data and structure of the GCMs, the methods used to relate GCM projections to points or small areas on the earth's surface (downscaling), and the projections of future greenhouse gas emissions. Regardless of its source, uncertainty should at least be recognized and ideally should be quantified when climate projections are used for planning purposes.

As a practical matter, uncertainty in climate projections manifests in disagreement between individual projections of future climate conditions and impacts. There are 48 statistically downscaled projections of future climate conditions (monthly average temperature and precipitation) that are readily available for the study area. The most comprehensive picture of uncertainty in future conditions can be obtained by analyzing a large ensemble of projections, as recommended in the CSA Technical Guidelines. Accordingly, all of the available projections have been used to produce, for each duration period and frequency, an ensemble containing 48 estimates of precipitation intensity.

Neither the climate projections nor the results have been broken down according to the SRES emission scenarios because the intention was to represent the uncertainty in climate projections collectively, regardless of source.

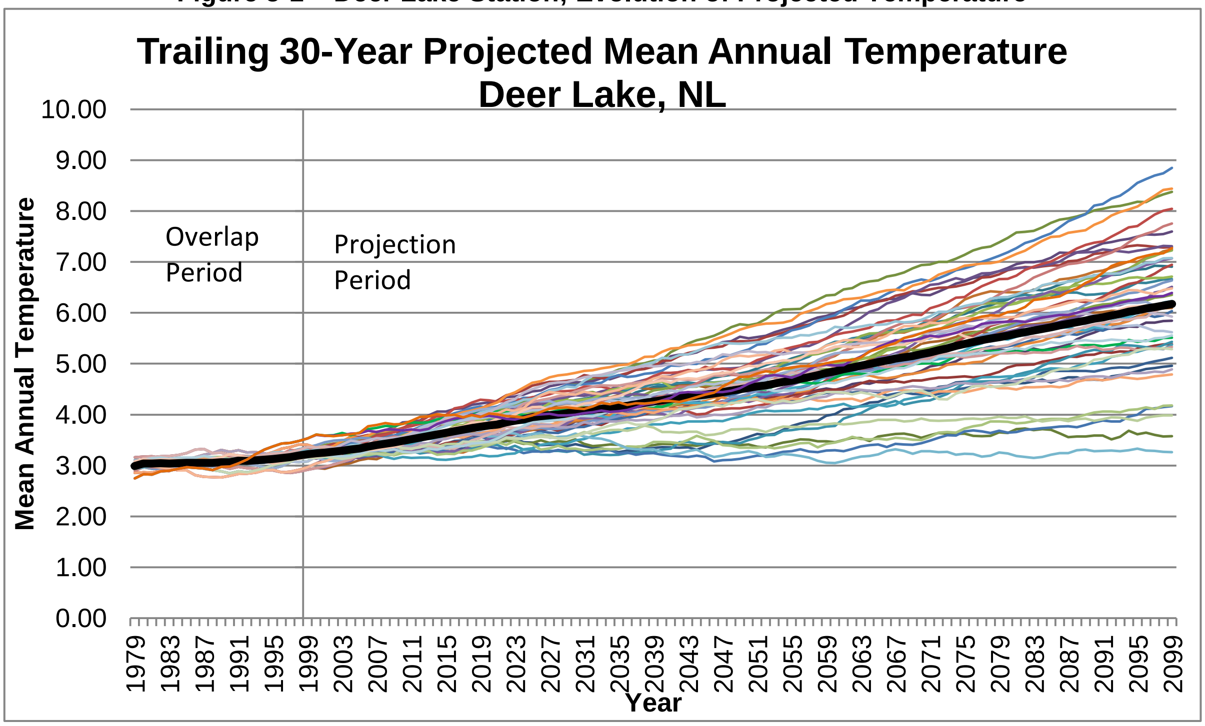
The overall results report the ensemble mean, the ensemble maximum and the 90th percentile non-exceedance value for each intensity estimate. How to interpret the range of projected results is a policy decision; some additional discussion regarding the interpretation of uncertainty is provided in Section 5.3.

5.0 RESULTS AND DISCUSSION

5.1 GCM Projections of Precipitation and Temperature

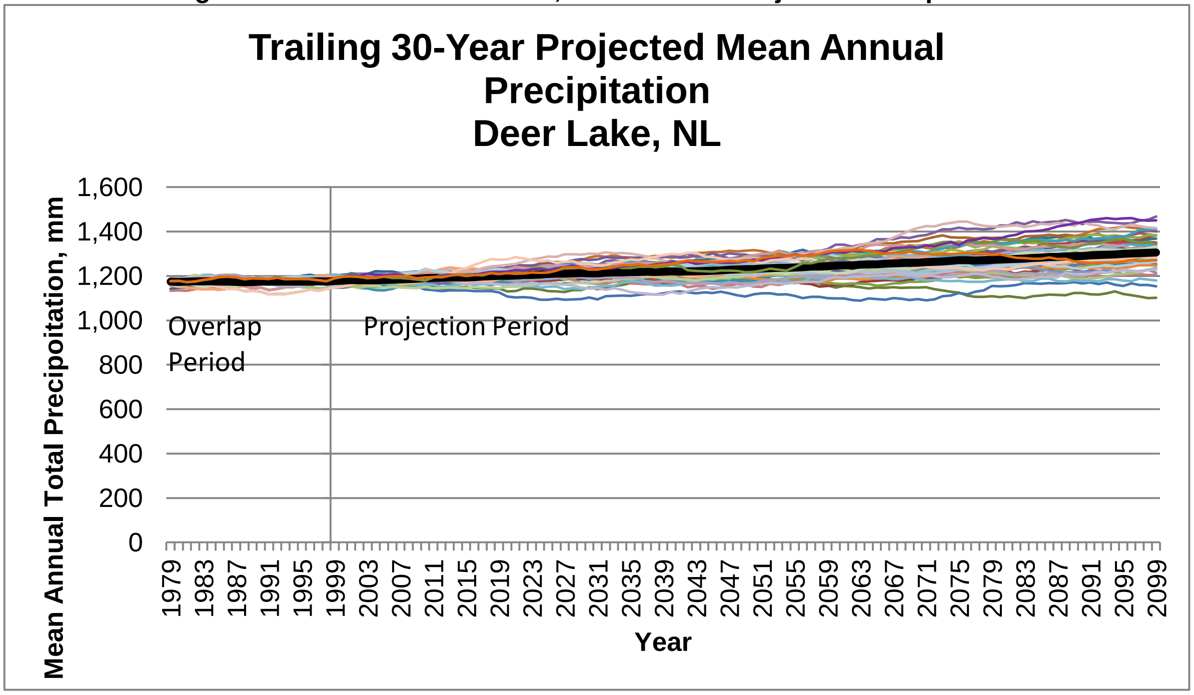
The evolution over time of projected precipitation, temperature and the product of precipitation and temperature for all 48 projections available in the Maurer archive for Deer Lake and St. John's A are shown as 30-year rolling mean values in Figure 5-1 through Figure 5-4.

Figure 5-1 – Deer Lake Station; Evolution of Projected Temperature



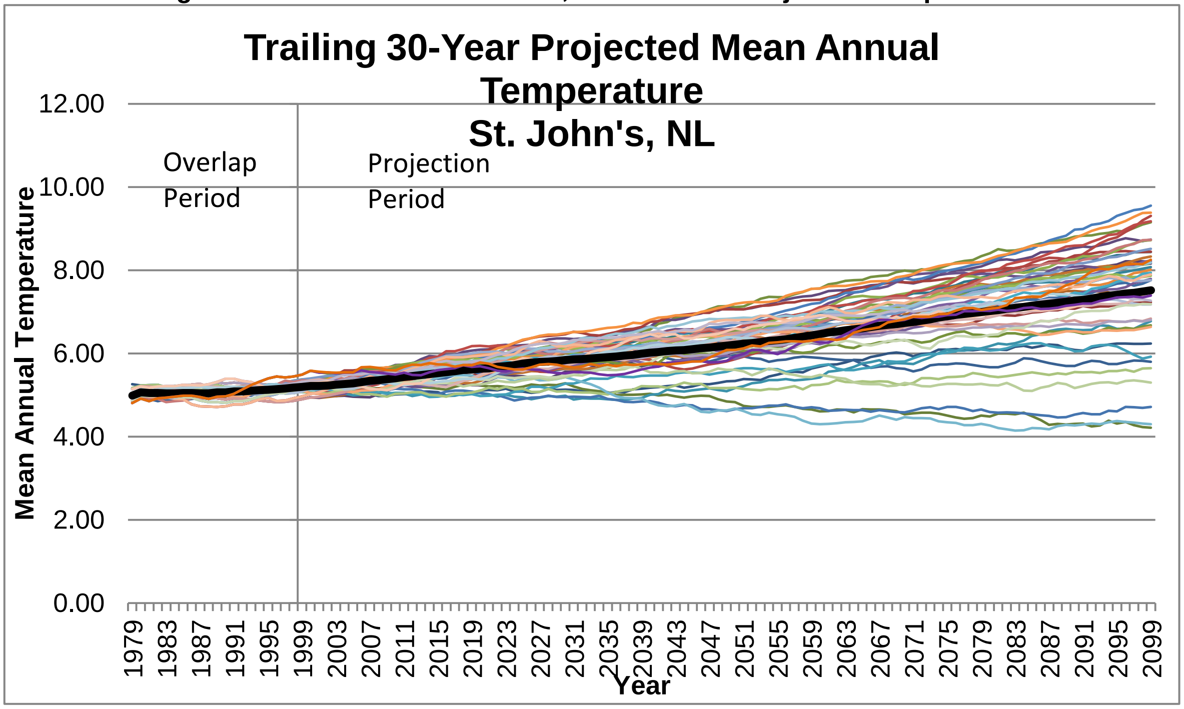
Vertical bar denotes end of overlap period and beginning of projection period. Thin, colored lines represent individual projections. Black line represents mean of all projections.

Figure 5-2 – Deer Lake Station; Evolution of Projected Precipitation



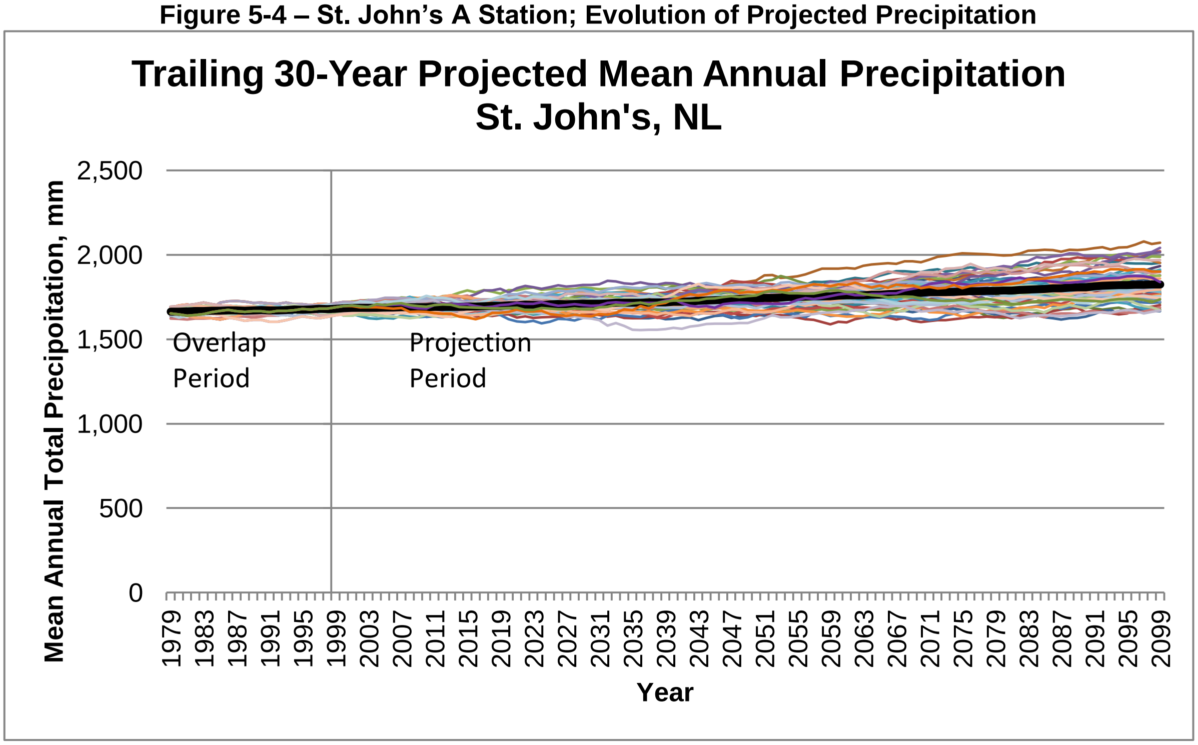
Vertical bar denotes end of overlap period and beginning of projection period. Thin, colored lines represent individual projections. Black line represents mean of all projections.

Figure 5-3 – St. John's A Station; Evolution of Projected Temperature



Vertical bar denotes end of overlap period and beginning of projection period. Thin, colored lines represent individual projections. Black line represents mean of all projections.

Figure 5-4 – St. John's A Station; Evolution of Projected Precipitation



Vertical bar denotes end of overlap period and beginning of projection period. Thin, colored lines represent individual projections. Black line represents mean of all projections.

Table 5-1 - Range of Projected Climate Variables, Deer Lake Site

		Deer Lake Site			
		Time periods			
		1999	2030	2050	2080
30-Year Average Annual Precipitation (mm)	Average	1177	1213	1231	1274
	Min	1148	1103	1117	1105
	Max	1205	1301	1317	1427
30-Year Average Annual Temperature (deg C)	Average	3.22	4.06	4.53	5.55
	Min	2.92	3.30	3.16	3.24
	Max	3.53	4.82	5.76	7.47

Table 5-2 - Range of Projected Climate Variables, St. John's A Site

		St. John's A Site			
		Time periods			
		1999	2030	2050	2080
30-Year Average Annual Precipitation (mm)	Average	1681	1681	1681	1681
	Min	1642	1642	1642	1642
	Max	1716	1716	1716	1716
30-Year Average Annual Temperature (deg C)	Average	5.20	5.84	6.21	7.01
	Min	4.90	4.96	4.66	4.27
	Max	5.49	6.48	7.19	8.41

5.2 Projections of Precipitation Intensities

Table 5-3 through Table 5-5 show the precipitation intensities from the historical IDF curves from Environment Canada for the Deer Lake, St. John's A, and the St. John's Composite record, respectively. These precipitation intensities were adjusted by the projected change, as described in Section 4.6, to obtain the projected precipitation intensities for each of the 2020, 2050 and 2080 time periods. These are shown for the Deer Lake Station in Table 5-6 to Table 5-8, for the St. John's A station in Tables 5-9 to 5-11 and for the St. John's Composite record in Tables 5-12 to 5-14. Projected precipitation intensities are reported as the maximum, mean and 90th percentile of the 48 values estimated.

Table 5-3 - Historical IDF Table, Deer Lake Station, Precipitation intensities over the specified duration, mm/hr

		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	47.3	69.5	84.1	98.2	102.7	116.4	130.0
	10 min	34.3	48.6	58.2	67.3	70.2	79.1	87.9
	15 min	27.9	38.3	45.1	51.7	53.8	60.2	66.6
	30 min	19.7	25.4	29.2	32.8	33.9	37.5	41.0
	1 hr	13.4	16.8	19.1	21.3	21.9	24.1	26.2
	2 hr	9.4	12.2	14.1	15.8	16.4	18.1	19.9
	6 hr	5.0	6.1	6.8	7.5	7.7	8.4	9.1
	12 hr	3.1	3.7	4.2	4.6	4.7	5.1	5.5
	24 hr	1.8	2.2	2.4	2.6	2.7	3.0	3.2

Table 5-4 - Historical IDF Table, St. John's A Station, Precipitation intensities over the specified duration, mm/hr

		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	56.2	77.0	90.8	104.0	108.2	121.1	133.9
	10 min	41.6	55.7	65.0	74.0	76.8	85.6	94.2
	15 min	34.9	46.9	54.8	62.4	64.9	72.3	79.7
	30 min	24.9	32.8	38.0	43.0	44.6	49.5	54.4
	1 hr	17.4	22.3	25.5	28.6	29.5	32.5	35.5
	2 hr	11.9	15.8	18.4	20.9	21.7	24.1	26.5
	6 hr	6.8	8.5	9.6	10.7	11.0	12.0	13.1
	12 hr	4.4	5.3	5.9	6.5	6.7	7.3	7.9
	24 hr	2.6	3.1	3.5	3.8	3.9	4.3	4.6

Table 5-5 - St. John's Composite Record, Updated March 2012, Precipitation intensities over the specified duration, mm/hr

	Return period (years)					
	2	5	10	20	50	100

Storm Duration	5 min	55.0	73.7	86.0	97.9	113.3	124.8
	10 min	41.6	54.6	63.0	71.4	82.2	90.0
	15 min	35.7	46.8	54.0	60.8	70.0	76.8
	30 min	26.2	34.4	39.8	45.2	51.8	57.0
	1 hr	18.7	24.7	28.6	32.4	37.3	40.9
	2 hr	12.9	17.5	20.5	23.4	27.1	29.9
	6 hr	7.4	9.6	11.1	12.5	14.3	15.7
	12 hr	4.7	6.1	7.1	8.0	9.2	10.1
	24 hr	2.8	3.6	4.1	4.6	5.2	5.7

Table 5-6 - Deer Lake Projected IDF Tables, 2020 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2020 timeframe						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	51.8	73.9	88.1	101.9	106.3	119.6	132.9
	10 min	36.5	50.8	60.3	69.3	72.2	81.0	89.6
	15 min	29.9	40.2	46.9	53.4	55.4	61.7	68.0
	30 min	23.0	28.5	32.2	35.7	36.8	40.2	43.6
	1 hr	15.7	19.0	21.3	23.3	24.0	26.1	28.1
	2 hr	11.1	14.0	16.0	17.7	18.3	20.0	21.9
	6 hr	5.8	6.9	7.6	8.3	8.5	9.2	9.9
	12 hr	3.6	4.2	4.7	5.0	5.2	5.6	6.0
	24 hr	2.1	2.5	2.7	2.9	3.0	3.3	3.5

		90th Percentile, 2020 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	50.3	72.4	86.8	100.6	105.1	118.6	131.9
	10 min	36.1	50.4	59.9	68.9	71.8	80.6	89.3
	15 min	29.3	39.6	46.3	52.8	54.9	61.2	67.5
	30 min	21.9	27.5	31.2	34.7	35.8	39.3	42.8
	1 hr	14.9	18.3	20.6	22.7	23.3	25.4	27.5
	2 hr	10.6	13.4	15.4	17.1	17.7	19.4	21.2
	6 hr	5.6	6.6	7.3	8.0	8.2	8.9	9.6
	12 hr	3.5	4.0	4.5	4.9	5.0	5.4	5.8
	24 hr	2.0	2.4	2.6	2.8	2.9	3.2	3.4

		Mean, 2020 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	48.7	70.8	85.3	99.3	103.8	117.4	130.9
	10 min	35.3	49.6	59.2	68.2	71.1	79.9	88.7
	15 min	28.5	38.9	45.6	52.2	54.3	60.6	67.0
	30 min	20.7	26.3	30.1	33.7	34.8	38.3	41.8
	1 hr	14.1	17.5	19.8	21.9	22.5	24.7	26.8
	2 hr	9.9	12.7	14.7	16.4	17.0	18.7	20.5
	6 hr	5.3	6.3	7.0	7.7	7.9	8.6	9.3
	12 hr	3.2	3.8	4.3	4.7	4.8	5.2	5.6
	24 hr	1.9	2.3	2.5	2.7	2.8	3.1	3.3

Table 5-7 - Deer Lake Projected IDF Tables, 2050 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2050 timeframe						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	52.5	74.5	88.7	102.4	106.8	120.1	133.3
	10 min	38.3	52.5	62.0	70.8	73.7	82.4	91.0
	15 min	30.2	40.5	47.1	53.6	55.6	61.9	68.1
	30 min	23.4	29.0	32.7	36.1	37.2	40.6	44.0
	1 hr	16.0	19.3	21.6	23.6	24.3	26.4	28.4
	2 hr	11.4	14.3	16.2	18.0	18.6	20.3	22.1
	6 hr	6.0	7.0	7.7	8.4	8.6	9.3	10.0
	12 hr	3.7	4.3	4.8	5.1	5.3	5.7	6.1
	24 hr	2.2	2.6	2.7	3.0	3.0	3.3	3.5

		90th Percentile, 2050 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	51.4	73.4	87.8	101.5	105.9	119.3	132.6
	10 min	37.7	51.9	61.4	70.3	73.1	81.9	90.5
	15 min	29.8	40.0	46.7	53.2	55.3	61.5	67.8
	30 min	22.6	28.2	31.9	35.4	36.5	40.0	43.4
	1 hr	15.4	18.8	21.1	23.1	23.8	25.9	27.9
	2 hr	11.0	13.8	15.8	17.5	18.1	19.8	21.7
	6 hr	5.8	6.8	7.5	8.2	8.4	9.1	9.8
	12 hr	3.5	4.1	4.6	4.9	5.1	5.5	5.9
	24 hr	2.0	2.4	2.6	2.9	2.9	3.2	3.4

		Mean, 2050 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	49.4	71.5	85.9	99.8	104.3	117.9	131.3
	10 min	36.4	50.6	60.1	69.1	72.0	80.8	89.5
	15 min	28.8	39.2	45.9	52.5	54.5	60.9	67.2
	30 min	21.2	26.8	30.6	34.1	35.2	38.8	42.2
	1 hr	14.4	17.8	20.1	22.2	22.8	25.0	27.1
	2 hr	10.2	13.0	15.0	16.7	17.3	19.0	20.8
	6 hr	5.4	6.5	7.2	7.9	8.1	8.8	9.5
	12 hr	3.3	3.9	4.4	4.7	4.9	5.3	5.7
	24 hr	1.9	2.3	2.5	2.7	2.8	3.1	3.3

Table 5-8 - Deer Lake Projected IDF Tables, 2080 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2080 timeframe						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	55.8	77.7	91.7	105.1	109.4	122.4	135.4
	10 min	40.8	55.0	64.3	73.1	75.9	84.5	92.9
	15 min	31.8	41.9	48.5	54.8	56.8	63.0	69.1
	30 min	25.8	31.3	34.9	38.3	39.3	42.7	45.9
	1 hr	17.7	21.0	23.2	25.2	25.8	27.8	29.8
	2 hr	12.6	15.6	17.6	19.4	20.0	21.7	23.6
	6 hr	6.6	7.6	8.3	9.0	9.2	9.9	10.6
	12 hr	3.8	4.3	4.8	5.2	5.3	5.7	6.1
	24 hr	2.2	2.6	2.8	3.0	3.1	3.4	3.6

		90th Percentile, 2080 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	53.2	75.2	89.4	103.0	107.4	120.6	133.7
	10 min	39.8	54.0	63.4	72.2	75.0	83.6	92.2
	15 min	30.6	40.8	47.4	53.9	55.9	62.1	68.4
	30 min	24.0	29.5	33.2	36.6	37.6	41.1	44.4
	1 hr	16.3	19.7	21.9	24.0	24.6	26.7	28.7
	2 hr	11.6	14.6	16.5	18.3	18.9	20.6	22.5
	6 hr	6.1	7.2	7.8	8.5	8.7	9.4	10.1
	12 hr	3.6	4.2	4.7	5.0	5.1	5.5	6.0
	24 hr	2.1	2.5	2.7	2.9	3.0	3.3	3.5

		Mean, 2080 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	50.4	72.5	86.9	100.7	105.2	118.6	132.0
	10 min	37.5	51.7	61.2	70.1	73.0	81.7	90.4
	15 min	29.3	39.6	46.3	52.9	54.9	61.2	67.5
	30 min	22.0	27.6	31.3	34.8	35.9	39.4	42.8
	1 hr	15.0	18.3	20.6	22.7	23.3	25.5	27.5
	2 hr	10.6	13.5	15.4	17.1	17.7	19.4	21.3
	6 hr	5.6	6.7	7.4	8.1	8.3	9.0	9.7
	12 hr	3.3	3.9	4.4	4.8	4.9	5.3	5.7
	24 hr	1.9	2.3	2.5	2.8	2.8	3.1	3.3

Table 5-9 - St. John's A Projected IDF Tables, 2020 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2020 timeframe						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	59.1	79.7	93.3	106.4	110.5	123.2	135.9
	10 min	45.5	59.3	68.4	77.2	79.9	88.6	97.0
	15 min	38.3	50.1	57.9	65.5	67.9	75.2	82.5
	30 min	28.2	36.0	41.0	45.9	47.5	52.2	57.0
	1 hr	20.2	25.0	28.1	31.1	32.0	35.0	37.9
	2 hr	13.8	17.7	20.3	22.8	23.6	26.0	28.4
	6 hr	7.6	9.3	10.4	11.4	11.7	12.7	13.8
	12 hr	5.0	5.8	6.4	7.1	7.2	7.8	8.4
	24 hr	3.0	3.5	3.9	4.2	4.2	4.6	4.9

		90th Percentile, 2020 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	58.3	79.0	92.6	105.7	109.9	122.6	135.3
	10 min	44.6	58.5	67.7	76.5	79.3	87.9	96.4
	15 min	37.6	49.5	57.3	64.8	67.3	74.6	81.9
	30 min	27.5	35.3	40.4	45.3	46.9	51.7	56.5
	1 hr	19.6	24.4	27.6	30.6	31.5	34.4	37.4
	2 hr	13.4	17.3	19.9	22.4	23.2	25.6	28.0
	6 hr	7.4	9.0	10.1	11.2	11.5	12.5	13.6
	12 hr	4.8	5.7	6.3	6.9	7.1	7.7	8.3
	24 hr	2.9	3.3	3.7	4.1	4.1	4.5	4.8

		Mean, 2020 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	57.5	78.2	91.9	105.1	109.2	122.0	134.7
	10 min	42.6	56.6	65.9	74.8	77.6	86.4	94.9
	15 min	35.8	47.8	55.6	63.2	65.7	73.1	80.4
	30 min	25.8	33.6	38.8	43.8	45.4	50.2	55.1
	1 hr	18.1	23.0	26.2	29.2	30.2	33.2	36.1
	2 hr	12.4	16.3	18.9	21.4	22.2	24.6	27.0
	6 hr	6.9	8.6	9.7	10.7	11.1	12.1	13.2
	12 hr	4.4	5.3	5.9	6.6	6.7	7.3	7.9
	24 hr	2.6	3.1	3.5	3.9	3.9	4.3	4.6

Table 5-10 - St. John's A Projected IDF Tables, 2050 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2050 timeframe						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	60.9	81.3	94.8	107.8	111.9	124.5	137.0
	10 min	47.2	60.9	69.9	78.6	81.4	89.9	98.3
	15 min	39.9	51.6	59.3	66.8	69.3	76.5	83.8
	30 min	29.7	37.4	42.4	47.2	48.8	53.5	58.2
	1 hr	21.5	26.2	29.3	32.3	33.2	36.1	39.0
	2 hr	14.6	18.5	21.2	23.6	24.5	26.9	29.3
	6 hr	8.0	9.7	10.8	11.8	12.2	13.2	14.3
	12 hr	5.3	6.2	6.7	7.3	7.5	8.1	8.7
	24 hr	3.2	3.6	4.0	4.4	4.4	4.8	5.1

		90th Percentile, 2050 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	60.2	80.7	94.2	107.2	111.3	124.0	136.6
	10 min	45.0	58.9	68.0	76.8	79.6	88.2	96.7
	15 min	37.9	49.8	57.6	65.1	67.6	74.9	82.2
	30 min	27.8	35.6	40.7	45.6	47.1	51.9	56.7
	1 hr	19.9	24.7	27.8	30.8	31.7	34.7	37.6
	2 hr	13.6	17.5	20.1	22.6	23.4	25.8	28.2
	6 hr	7.7	9.3	10.4	11.5	11.8	12.8	13.9
	12 hr	5.0	5.9	6.5	7.1	7.3	7.9	8.5
	24 hr	3.0	3.5	3.9	4.2	4.3	4.7	5.0

		Mean, 2050 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	58.7	79.3	92.9	106.0	110.1	122.9	135.6
	10 min	43.2	57.2	66.4	75.3	78.1	86.8	95.4
	15 min	36.3	48.2	56.1	63.7	66.1	73.5	80.9
	30 min	26.3	34.1	39.3	44.2	45.8	50.6	55.5
	1 hr	18.6	23.4	26.6	29.6	30.6	33.5	36.5
	2 hr	12.7	16.6	19.2	21.7	22.5	24.9	27.3
	6 hr	7.0	8.7	9.8	10.8	11.2	12.2	13.3
	12 hr	4.5	5.4	6.0	6.6	6.8	7.4	8.0
	24 hr	2.7	3.2	3.6	3.9	4.0	4.4	4.7

Table 5-11 - St. John's A Projected IDF Tables, 2080 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2080 timeframe						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	63.7	83.9	97.3	110.1	114.1	126.6	139.0
	10 min	47.4	61.1	70.1	78.8	81.5	90.1	98.4
	15 min	40.0	51.8	59.5	67.0	69.4	76.7	83.9
	30 min	29.8	37.5	42.6	47.4	48.9	53.6	58.3
	1 hr	21.6	26.4	29.5	32.4	33.3	36.2	39.1
	2 hr	14.7	18.6	21.3	23.7	24.6	27.0	29.4
	6 hr	8.6	10.2	11.3	12.4	12.7	13.7	14.8
	12 hr	5.7	6.5	7.1	7.7	7.9	8.5	9.1
	24 hr	3.4	3.9	4.3	4.6	4.7	5.1	5.4

		90th Percentile, 2080 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	62.3	82.6	96.1	109.0	113.0	125.5	138.0
	10 min	46.0	59.8	68.9	77.6	80.4	89.0	97.4
	15 min	38.8	50.6	58.4	65.9	68.3	75.6	82.9
	30 min	28.7	36.4	41.5	46.4	47.9	52.6	57.4
	1 hr	20.6	25.4	28.5	31.5	32.4	35.3	38.2
	2 hr	14.0	18.0	20.6	23.1	23.9	26.3	28.7
	6 hr	7.7	9.4	10.4	11.5	11.8	12.8	13.9
	12 hr	5.0	5.9	6.5	7.1	7.3	7.9	8.5
	24 hr	3.0	3.5	3.9	4.2	4.3	4.7	5.0

		Mean, 2080 Time Period						
		Return period (years)						
		2	5	10	20	25	50	100
Storm Duration	5 min	60.0	80.5	94.0	107.0	111.1	123.8	136.4
	10 min	43.5	57.5	66.7	75.6	78.4	87.1	95.6
	15 min	36.6	48.5	56.4	64.0	66.4	73.8	81.1
	30 min	26.5	34.4	39.5	44.5	46.0	50.9	55.7
	1 hr	18.8	23.7	26.8	29.8	30.8	33.7	36.7
	2 hr	12.8	16.7	19.4	21.8	22.7	25.1	27.5
	6 hr	7.0	8.7	9.8	10.9	11.2	12.2	13.3
	12 hr	4.5	5.4	6.0	6.7	6.8	7.4	8.0
	24 hr	2.7	3.2	3.6	3.9	4.0	4.4	4.7

Table 5-12 - St. John's Composite Record, Updated March 2012 Projected IDF Tables, 2020 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2020 timeframe					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	57.9	76.3	88.4	100.1	115.3	126.6
	10 min	45.5	58.1	66.3	74.5	85.1	92.7
	15 min	39.2	50.0	57.1	63.7	72.8	79.5
	30 min	29.7	37.7	43.0	48.3	54.7	59.7
	1 hr	21.7	27.7	31.6	35.3	40.1	43.6
	2 hr	14.9	19.6	22.6	25.5	29.2	32.1
	6 hr	8.3	10.5	12.0	13.4	15.2	16.6
	12 hr	5.3	6.7	7.7	8.7	9.9	10.8
	24 hr	3.2	4.0	4.5	5.0	5.6	6.1

		90th Percentile, 2020 Time Period					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	57.1	75.6	87.7	99.5	114.7	126.1
	10 min	44.6	57.4	65.6	73.8	84.5	92.1
	15 min	38.5	49.4	56.4	63.1	72.2	78.9
	30 min	28.9	37.0	42.3	47.6	54.1	59.2
	1 hr	21.1	27.1	30.9	34.7	39.5	43.1
	2 hr	14.5	19.1	22.2	25.1	28.8	31.6
	6 hr	8.0	10.2	11.7	13.1	14.9	16.3
	12 hr	5.1	6.5	7.6	8.5	9.7	10.6
	24 hr	3.1	3.9	4.4	4.9	5.5	6.0

		Mean, 2020 Time Period					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	56.2	74.8	87.0	98.9	114.2	125.6
	10 min	42.6	55.5	63.9	72.2	83.0	90.7
	15 min	36.6	47.7	54.8	61.6	70.7	77.5
	30 min	27.1	35.3	40.6	46.0	52.6	57.7
	1 hr	19.5	25.5	29.4	33.2	38.0	41.6
	2 hr	13.4	18.1	21.1	24.0	27.7	30.5
	6 hr	7.5	9.7	11.2	12.6	14.4	15.8
	12 hr	4.7	6.1	7.1	8.0	9.3	10.2
	24 hr	2.8	3.6	4.1	4.6	5.2	5.7

Table 5-13 - St. John's Composite Record, Updated March 2012 Projected IDF Tables, 2050 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2050 timeframe					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	59.6	77.8	89.8	101.4	116.5	127.7
	10 min	47.2	59.7	67.8	75.9	86.3	93.9
	15 min	40.8	51.5	58.5	65.1	74.1	80.7
	30 min	31.2	39.2	44.4	49.6	56.0	61.0
	1 hr	23.1	29.1	32.9	36.6	41.4	44.9
	2 hr	15.8	20.5	23.6	26.5	30.2	33.0
	6 hr	8.7	10.9	12.5	13.9	15.7	17.1
	12 hr	5.7	7.1	8.1	9.0	10.2	11.1
	24 hr	3.4	4.2	4.7	5.2	5.8	6.4

		90th Percentile, 2050 Time Period					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	58.9	77.2	89.2	100.9	116.0	127.3
	10 min	45.0	57.7	65.9	74.1	84.7	92.4
	15 min	38.8	49.7	56.7	63.4	72.5	79.2
	30 min	29.3	37.3	42.6	47.9	54.3	59.4
	1 hr	21.4	27.4	31.2	35.0	39.8	43.3
	2 hr	14.7	19.4	22.4	25.3	29.0	31.8
	6 hr	8.3	10.5	12.1	13.5	15.3	16.7
	12 hr	5.4	6.8	7.8	8.7	9.9	10.8
	24 hr	3.2	4.0	4.5	5.1	5.7	6.2

		Mean, 2050 Time Period					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	57.4	75.9	88.0	99.8	115.0	126.3
	10 min	43.2	56.1	64.4	72.7	83.4	91.1
	15 min	37.1	48.1	55.3	62.0	71.2	77.9
	30 min	27.6	35.8	41.1	46.5	53.0	58.1
	1 hr	19.9	25.9	29.8	33.6	38.5	42.0
	2 hr	13.7	18.4	21.4	24.3	28.0	30.8
	6 hr	7.6	9.8	11.3	12.7	14.5	15.9
	12 hr	4.8	6.2	7.2	8.1	9.4	10.3
	24 hr	2.9	3.7	4.2	4.7	5.3	5.8

Table 5-14 - St. John's Composite Record, Updated March 2012 Projected IDF Tables, 2080 Time Period, Precipitation intensities over the specified duration, mm/hr

		Maximum, 2080 timeframe					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	62.4	80.3	92.1	103.6	118.4	129.5
	10 min	47.4	59.9	67.9	76.0	86.5	94.0
	15 min	40.9	51.7	58.6	65.2	74.2	80.9
	30 min	31.4	39.4	44.6	49.8	56.1	61.1
	1 hr	23.2	29.2	33.0	36.8	41.5	45.0
	2 hr	15.9	20.6	23.7	26.6	30.3	33.1
	6 hr	9.3	11.5	13.1	14.5	16.3	17.7
	12 hr	6.1	7.5	8.6	9.5	10.7	11.6
	24 hr	3.7	4.5	5.0	5.5	6.1	6.7

		90th Percentile, 2080 Time Period					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	61.0	79.1	91.0	102.5	117.5	128.6
	10 min	46.0	58.6	66.8	74.9	85.5	93.1
	15 min	39.7	50.5	57.5	64.2	73.2	79.9
	30 min	30.2	38.2	43.4	48.7	55.1	60.1
	1 hr	22.1	28.1	32.0	35.7	40.5	44.1
	2 hr	15.2	19.9	22.9	25.8	29.6	32.4
	6 hr	8.4	10.6	12.1	13.5	15.3	16.7
	12 hr	5.4	6.8	7.8	8.7	9.9	10.9
	24 hr	3.2	4.1	4.6	5.1	5.7	6.2

		Mean, 2080 Time Period					
		Return period (years)					
		2	5	10	20	50	100
Storm Duration	5 min	58.7	77.0	89.1	100.7	115.8	127.2
	10 min	43.5	56.4	64.6	72.9	83.6	91.3
	15 min	37.5	48.4	55.5	62.3	71.4	78.2
	30 min	27.9	36.1	41.4	46.7	53.2	58.4
	1 hr	20.2	26.2	30.1	33.9	38.7	42.3
	2 hr	13.9	18.5	21.6	24.5	28.2	31.0
	6 hr	7.6	9.8	11.3	12.7	14.5	15.9
	12 hr	4.9	6.3	7.3	8.2	9.4	10.3
	24 hr	2.9	3.7	4.2	4.7	5.3	5.8

In addition to the projections performed using the methodology outlined above, projections from other researchers for St. John's were compiled as well. **Error! Not a valid bookmark self-reference.** presents data for the 2020, 2050 and 2080 timeframes for modeling done by Finnis (as provided by WRMD), HadCM3 Global Climate Modeling downscaling (Lines 2008), and CGCM2 Global Climate Modeling downscaling (Lines 2008). All data are presented as precipitation intensities (mm/hr). Not all sources provided estimates for every time frame and return interval.

Table 5-15 - St. John's A Projected IDF Tables, values from Other Researchers, 2020, 2050, 2080 timeframes, Precipitation Intensities, mm/hr

Historical Baseline							
		Return Interval					
Model Source	Storm Duration	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
Finnis	24hr						
Lines (CGCM2)	24hr			3.2		3.8	4.1
Lines (HadCM3)	24hr			3.2		3.8	4.1
Finnis	12hr						

2020 Timeframe							
		Return Interval					
Model Source	Storm Duration	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
Finnis	24hr						
Lines (CGCM2)	24hr			4.7	5.4	6.2	6.9
Lines (HadCM3)	24hr			4.3	4.8	5.4	5.8
Finnis	12hr						

2050 Timeframe							
		Return Interval					
Model Source	Storm Duration	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
Finnis	24hr	3.2	3.9	4.5	5.0	5.7	6.3
Lines (CGCM2)	24hr			4.9	5.7	6.7	7.4
Lines (HadCM3)	24hr			5.8	6.9	8.3	9.3
Finnis	12hr	5.6	6.9	7.9	8.9	10.2	11.2

2080 Timeframe							
		Return Interval					
Model Source	Storm Duration	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
Finnis	24hr						
Lines (CGCM2)	24hr			4.5	5.0	5.6	6.1
Lines (HadCM3)	24hr			4.6	5.3	6.1	6.8
Finnis	12hr						

5.3 *Interpreting Uncertainty*

Uncertainty reflects imperfection in our state of knowledge, as distinguished from variability, which is the effect of random processes. In practice, such a distinction is not as clear cut, for example, the variability in atmospheric processes leads to considerable uncertainty about tomorrow's weather. Nevertheless, it is important to respect the distinction, because while variability can be addressed in quantitative ways, uncertainty must be addressed, at least in part, by subjective judgment (Vick, 2002). Accordingly, deciding how to use the results of this work in the face of uncertainty will be a policy decision. Some background on the sources of uncertainty and suggestions on how to consider the results herein are provided in the following paragraphs.

Barsugli, et al. (2009) identified the following sources of uncertainty in projections of future climate conditions:

Climate Drivers—The anthropogenic component of climate drivers is greenhouse gas emissions which are formally quantified in emission scenarios. These scenarios in turn depend on projections of future socio-economic, demographic and technical factors.

Climate Sensitivity—This is represented by the climate models themselves. The imperfections in climate models arise from coarse resolution, limitations in simulation of feedback mechanisms, limited knowledge of initial conditions and a number of other factors.

Downscaling—This is required because of the coarse resolution of climate models and the local nature of impact assessments. All downscaling techniques introduce uncertainty.

In addition, there is uncertainty in the models used to assess impact. These can include hydrologic models, statistical models (as is the case in this work), hydraulic models and operations models.

Wilby and Harris (2006) found that the greatest uncertainty in climate impact studies arose from the climate models themselves, followed, in order, by the downscaling method, the hydrology model structure, hydrology model parameters (i.e. the calibration of the model) and finally by the uncertainty in future emissions scenarios.

Uncertainty in climate drivers and climate sensitivity can be represented by using a large number (an *ensemble*) of climate projections. Fortunately, reasonably large ensembles of climate projections are available and can be obtained with a relatively low effort. However, the readily available projections of climate conditions are derived using one downscaling technique, so the uncertainty inherent in downscaling is not represented in the projection ensemble. This uncertainty may be considerable.

The additional uncertainty arising from impact models is not ordinarily evaluated in impact studies, as using multiple hydrologic models, each with multiple calibrations along with multiple hydraulic or operations models, is simply too costly for most agencies. However, it is important to recognize that decision-makers have routinely relied on the results of impact models as the basis for planning and operational decisions, and thus have implicitly accepted the uncertainties in those models.

This work involves a statistical model that, strictly speaking, serves as a second downscaling method. The model takes as inputs projections of climate conditions, downscaled to average conditions over a 1/2 degree grid cell and further downscales those conditions to a single point, in this case the Deer Lake and St. John's A Stations. The model also relates monthly average conditions to monthly, and eventually annual, extreme events. The model assumes that there is a causal relationship between monthly values of the predictor variables (total precipitation and average temperature) and monthly and annual maximum precipitation intensities, and that that relationship will remain unchanged as climate evolves. It can be safely assumed that in strict terms this assumption will not hold up, but it is the basis, at some level, of all estimates of future conditions.

The results presented herein represent one estimate of the range of future extreme precipitation intensity. That range is informed by the range of future projections of monthly average climate conditions, which themselves reflect the range of emissions scenarios and the different degrees of climate sensitivity among the GCMs. However, it is exceedingly important to recognize that an ensemble of projections, such as the one used in this study, may not capture the full range of uncertainty. That is, there is some unknown and unknowable probability that the actual future conditions are not contained in the range of projections in any given ensemble. Further, as noted above, there is additional uncertainty inherent in the downscaling technique and the statistical model that are not reflected in the currently-available ensembles.

Accordingly, the results of this work should be used in combination with all relevant sources of information, including recent experience, and with careful professional judgment.

6.0 REFERENCES

Adam, J. C. and D. P. Lettenmaier (2003). Adjustment of global gridded precipitation for systematic bias, J. Geophys. Res., 108, 1–14, 2003.

Akaike, H. (1974), New look at statistical-model identification, IEEE Trans Automatic Control, 19, 716-723.

Barsugli, J., Anderson, C., Smith, J. and Vogel, J.: Options for Improving Climate Modeling to Assist Water Utility Planning for Climate Change. Water Utility Climate Alliance. San Francisco, California, 2009.

Canadian Standards Association, (2010). Technical Guide. Development, interpretation and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners. Review Draft.

Furrer, E. M. and R. W. Katz, (2007). Generalized linear modeling approach to stochastic weather generators. Climate Research, Vol. 34: 129-144, 2007.

Government of Newfoundland and Labrador, (2011). A Study of Climate Monitoring Capabilities in Newfoundland and Labrador: Parts II and III: User Needs Analysis and Recommendations. Office of Climate Change, Energy Efficiency and Emissions Trading. 7 November 2011.

Hamlet, A.F., and D.P. Lettenmaier (1999). Effects of climate change on hydrology and water resources in the Columbia River Basin. Journal of the American Water Resources Association 35(6):1597–1623.

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kharin, V.V., F.W. Zwiers, X. Zhang and G.C. Hegerl (2007). Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. Journal of Climate, 20 (8), 1419-1444.

Lines, G. S., M. Pancura, C. Lander, L. Titus (2008). Climate Change Scenarios for Atlantic Canada Utilizing a Statistical Downscaling Model Based on Two Global Climate Models. Meteorological Service of Canada, Atlantic Region, Science Report Series 2009-01.

Maurer, E. P. (2011) http://www.engr.scu.edu/~emaurer/global_data/. Accessed January 17, 2011.

Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen. (2002) A long-term hydrologically-based data set of land surface fluxes and states for the conterminous United States, Journal of Climate, 15:3237-3251.

Maurer E. P., Adam J. C. and A. W. Wood (2009). Climate model based consensus on the hydrologic impacts of climate change to the Rio Lempa basin of Central America. Hydrol. Earth Syst. Sci., 13, 183–194.

Maurer, E. P., L. Brekke, T. Pruitt, and P. B. Duffy (2007). 'Fine-resolution climate projections enhance regional climate change impact studies', Eos Trans. AGU, 88(47), 504.

Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor (2007). The WCRP CMIP3 multi-model dataset: A new era in climate change research, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007.

Miller, N.L., K. Bashford, and E. Strem (2003). “Potential Climate Change Impacts on California Hydrology,” Journal of the American Water Resources Association, 39, 771–784.

Nakicenovic, Nebojša, Ogunlade Davidson, G. Davis, A. Grübler, T. Kram, E. Lebre La Rovere, B. Metz, T. Morita, W. Pepper, H. Pitcher, A. Sankovski, P. Shukla, R. Swart, R. Watson, Z. Dadi (eds). Intergovernmental Panel on Climate Change (IPCC) 2000. Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, 599 pp. Available online http://www.grida.no/climate/ipcc/emission/index.htm.

Towler, E., B. Rajagopalan, E. Gilleland, R. S. Summers, D. Yates, R. Katz (2010). Modeling Hydrologic and Water Quality Extremes in a Changing Climate: A Statistical Approach Based on Extreme Value Theory. *Water Resour. Res., 46, W11504*

Vick, S. G. (2002). *Degrees of Belief: Subjective Probability and Engineering Judgment*. Reston Virginia: ASCE Press.

Wilby R. L. and I. Harris (2006). A framework for assessing uncertainties in climate change impacts: Low-flow scenarios for the River Thames, UK, Water Resources Research, Vol. 42, W02419, 2006.

Wood, A. W., Leung, L. R., Sridhar, V., and D. P. Lettenmaier (2004) Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs, Climatic Change, 62, 189–216, 2004.

7.0 APPENDIX A. MODEL PARAMETERS

Table A1. Model Parameter Descriptions

Parameter	Description	Parameter	Description	Parameter	Description	Parameter	Description
Mu0	Location parameter	Xi	Shape parameter	Sigma SE	Standard error sigma	AIC	Akaike Information Criterion
Mu1	Slope of Mu	MU0 SE	Standard Error Mu0	Xi SE	Standard error Xi	p.val	P-value
Sigma	Scale parameter	MU1 SE	Standard Error Mu1	llh	Log likelihood		

Table A2. Deer Lake Model Parameter Values (Seasonal Fitted Model; 5 min, 10 min, 15 min, 30 min, 1 hr, 2 hr, 6 hr, 12 hr, 24 hr)

5_min	No Cov.	P	T	PxT
Mu0	1.41	1.00	0.58	1.06
Mu1		4.27E-03	0.08	3.65E-04
Sigma	0.79	0.75	0.75	0.68
Xi	0.27	0.29	0.16	0.31
MU0 SE	0.06	0.11	0.15	0.06
MU1 SE		1.07E-03	0.01	2.00E-06
Sigma SE	0.05	0.07	0.05	0.07
Xi SE	0.07	0.05	0.05	0.05
llh	-310.99	-304.25	-287.79	-285.04
AIC	623.99	610.51	577.59	572.08
p.val		0.02%	0.00%	0.00%

10_min	No Cov.	P	T	PxT
Mu0	2.08	1.47	0.99	2.03
Mu1		6.37E-03	0.10	4.78E-05
Sigma	1.14	1.07	1.07	1.18
Xi	0.25	0.28	0.18	0.27
MU0 SE	0.09	0.16	0.21	0.09
MU1 SE		1.47E-03	0.02	2.00E-06
Sigma SE	0.07	0.07	0.06	0.07
Xi SE	0.06	0.07	0.07	0.08
llh	-384.70	-376.29	-363.89	-382.56
AIC	771.41	754.58	729.78	767.12
p.val		0.00%	0.00%	3.83%

15_min	No Cov.	P	T	PxT
Mu0	2.67	1.80	1.37	2.20
Mu1		9.33E-03	0.12	5.06E-04
Sigma	1.37	1.28	1.28	1.19
Xi	0.22	0.25	0.18	0.23
MU0 SE	0.11	0.20	0.24	0.10
MU1 SE		1.87E-03	0.02	2.01E-06
Sigma SE	0.09	0.06	0.06	0.06
Xi SE	0.06	0.08	0.08	0.08
llh	-420.16	-409.05	-399.93	-396.36
AIC	842.31	820.11	801.85	794.73
p.val		0.00%	0.00%	0.00%

30_min	No Cov.	P	T	PxT
Mu0	3.95	2.37	2.21	2.11
Mu1		0.02	0.16	2.02E-03
Sigma	1.90	1.69	1.79	1.64
Xi	0.17	0.21	0.12	0.14
MU0 SE	0.15	0.26	0.36	0.12
MU1 SE		2.46E-03	0.03	NA
Sigma SE	0.12	0.06	0.06	NA
Xi SE	0.06	0.11	0.11	0.05
llh	-481.55	-462.75	-464.72	-429.08
AIC	965.10	927.50	931.44	860.16
p.val		0.00%	0.00%	0.00%

1_hr	No Cov.	P	T	PxT
Mu0	5.86	3.24	3.44	3.01
Mu1		0.03	0.22	2.88E-03
Sigma	2.64	2.33	2.54	1.90
Xi	0.09	0.10	0.04	0.14
MU0 SE	0.21	0.39	0.53	0.15
MU1 SE		3.77E-03	0.05	NA
Sigma SE	0.16	0.06	0.05	NA
Xi SE	0.05	0.14	0.15	NA
llh	-541.22	-516.50	-527.04	-479.07
AIC	1084.44	1035.00	1056.07	960.15
p.val		0.00%	0.00%	0.00%

2_hr	No Cov.	P	T	PxT
Mu0	8.46	3.66	5.61	3.91
Mu1		0.05	0.26	4.69E-03
Sigma	3.78	3.28	3.73	2.73
Xi	0.03	-0.03	-0.02	-7.16E-03
MU0 SE	0.30	0.61	0.79	0.39
MU1 SE		6.19E-03	0.07	3.46E-04
Sigma SE	0.22	0.05	0.05	0.07
Xi SE	0.05	0.18	0.21	0.17
llh	-608.40	-571.01	-599.72	-537.11
AIC	1218.80	1144.03	1201.44	1076.23
p.val		0.00%	0.00%	0.00%

6_hr	No Cov.	P	T	PxT
Mu0	14.09	4.62	11.99	7.24
Mu1		0.11	0.19	6.86E-03
Sigma	6.43	5.30	6.44	5.01
Xi	-0.02	-0.09	-0.04	-0.04
MU0 SE	0.50	1.01	1.29	0.70
MU1 SE		0.01	0.11	5.69E-04
Sigma SE	0.36	0.04	0.05	0.05
Xi SE	0.05	0.28	0.37	0.28
llh	-713.12	-662.34	-711.50	-659.46
AIC	1428.24	1326.68	1425.01	1320.93
p.val		0.00%	7.21%	0.00%

12_hr	No Cov.	P	T	PxT
Mu0	17.06	4.34	15.35	8.57
Mu1		0.15	0.15	8.33E-03
Sigma	8.17	6.54	8.17	6.48
Xi	-0.05	-0.12	-0.06	-0.05
MU0 SE	0.63	1.25	1.64	0.91
MU1 SE		0.01	0.13	7.07E-04
Sigma SE	0.45	0.04	0.05	0.04
Xi SE	0.05	0.33	0.45	0.35
llh	-758.95	-702.20	-758.31	-710.28
AIC	1519.91	1406.40	1518.61	1422.56
p.val		0.00%	25.52%	0.00%

24_hr	No Cov.	P	T	PxT
Mu0	19.09	4.97	18.78	10.08
Mu1		0.16	0.03	8.86E-03
Sigma	8.79	6.54	8.79	7.03
Xi	-0.04	-0.08	-0.04	-0.04
MU0 SE	0.68	1.24	1.75	0.98
MU1 SE		0.01	0.14	7.69E-04
Sigma SE	0.49	0.04	0.05	0.04
Xi SE	0.05	0.34	0.49	0.39
llh	-775.59	-706.72	-775.57	-728.59
AIC	1553.17	1415.44	1553.13	1459.18
p.val		0.00%	84.53%	0.00%

**Highlighted p.val cells indicate that the model was found to be statistically significant for that predictor variable. Yellow variable highlights indicate the minimum AIC of the three predictor variables and statistical significance*

Table A3. St John's Model Parameter Values (Seasonal Fitted Model; 5 min, 10 min, 15 min, 30 min, 1 hr, 2 hr, 6 hr, 12 hr, 24 hr)

5_min	No Cov.	P	T	PxT
Mu0	1.86	1.40	1.11	1.93
Mu1		4.10E-03	0.07	-1.95E-19
Sigma	0.97	0.92	0.93	1.26
Xi	0.21	0.24	0.20	0.10
MU0 SE	0.08	0.13	0.18	0.09
MU1 SE		9.55E-04	0.02	5.27E-06
Sigma SE	0.06	0.07	0.07	0.09
Xi SE	0.06	0.06	0.06	0.12
llh	-341.24	-333.34	-329.88	-349.68
AIC	684.49	668.69	661.77	701.36
p.val		0.01%	0.00%	0.00%

10_min	No Cov.	P	T	PxT
Mu0	2.82	2.01	1.55	2.16
Mu1		7.15E-03	0.12	4.28E-04
Sigma	1.44	1.33	1.38	1.16
Xi	0.15	0.21	0.12	0.14
MU0 SE	0.12	0.18	0.28	0.10
MU1 SE		1.37E-03	0.03	3.18E-06
Sigma SE	0.09	0.07	0.06	0.08
Xi SE	0.06	0.09	0.09	0.10
llh	-415.18	-404.73	-401.49	-400.75
AIC	832.35	811.47	804.98	803.51
p.val		0.00%	0.00%	0.00%

15_min	No Cov.	P	T	PxT
Mu0	3.65	2.51	2.09	2.98
Mu1		0.01	0.15	6.33E-04
Sigma	1.80	1.64	1.70	1.60
Xi	0.14	0.20	0.12	0.09
MU0 SE	0.14	0.23	0.33	0.13
MU1 SE		1.76E-03	0.03	7.12E-06
Sigma SE	0.11	0.06	0.05	0.05
Xi SE	0.06	0.10	0.10	0.11
llh	-458.28	-445.89	-444.13	-438.02
AIC	918.55	893.78	890.26	878.04
p.val		0.00%	0.00%	0.00%

30_min	No Cov.	P	T	PxT
Mu0	5.55	3.58	3.51	4.26
Mu1		0.02	0.20	1.37E-03
Sigma	2.56	2.25	2.44	2.18
Xi	0.11	0.18	0.10	0.14
MU0 SE	0.20	0.33	0.48	0.17
MU1 SE		2.50E-03	0.04	5.77E-06
Sigma SE	0.15	0.06	0.05	0.05
Xi SE	0.05	0.14	0.14	0.14
llh	-526.93	-509.23	-516.02	-495.65
AIC	1055.85	1020.46	1034.05	993.31
p.val		0.00%	0.00%	0.00%

1_hr	No Cov.	P	T	PxT
Mu0	8.16	5.08	5.37	5.60
Mu1		0.03	0.26	2.45E-03
Sigma	3.72	3.29	3.57	2.88
Xi	0.06	0.10	0.05	0.09
MU0 SE	0.29	0.50	0.72	0.23
MU1 SE		3.94E-03	0.06	7.39E-05
Sigma SE	0.21	0.05	0.05	0.05
Xi SE	0.05	0.19	0.21	0.16
llh	-596.66	-576.18	-587.73	-559.33
AIC	1195.32	1154.37	1177.47	1120.65
p.val		0.00%	0.00%	0.00%

2_hr	No Cov.	P	T	PxT
Mu0	11.75	6.53	8.76	8.14
Mu1		0.05	0.28	3.44E-03
Sigma	5.40	4.52	5.30	4.38
Xi	-0.01	0.03	-0.01	7.20E-03
MU0 SE	0.42	0.66	1.09	0.42
MU1 SE		5.18E-03	0.09	2.77E-04
Sigma SE	0.30	0.04	0.04	0.05
Xi SE	0.04	0.25	0.29	0.25
llh	-664.00	-632.21	-659.54	-624.97
AIC	1330.01	1266.42	1321.07	1251.94
p.val		0.00%	0.28%	0.00%

6_hr	No Cov.	P	T	PxT
Mu0	18.78	7.39	17.09	10.63
Mu1		0.11	0.15	7.68E-03
Sigma	9.15	6.75	9.12	7.13
Xi	-0.04	-0.01	-0.04	-0.03
MU0 SE	0.71	1.02	1.89	0.80
MU1 SE		8.23E-03	0.16	5.61E-04
Sigma SE	0.50	0.04	0.04	0.05
Xi SE	0.04	0.37	0.50	0.40
llh	-767.45	-709.19	-766.98	-718.62
AIC	1536.90	1420.38	1535.97	1439.24
p.val		0.00%	33.38%	0.00%

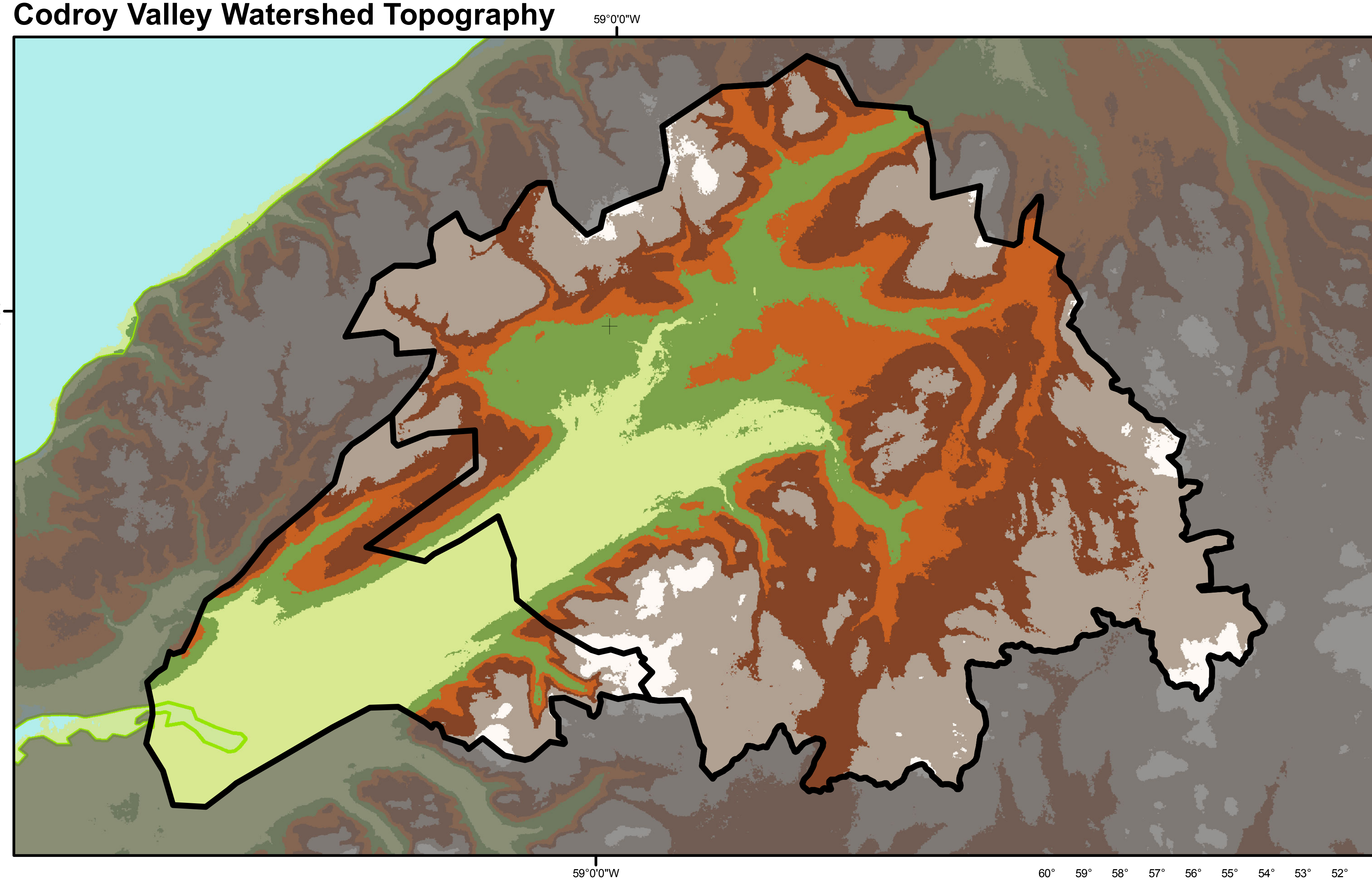
12_hr	No Cov.	P	T	PxT
Mu0	22.01	6.40	21.76	11.11
Mu1		0.15	0.02	0.01
Sigma	11.27	7.96	11.26	9.00
Xi	-0.04	-0.02	-0.04	-0.06
MU0 SE	0.88	1.28	2.34	1.15
MU1 SE		0.01	0.19	8.78E-04
Sigma SE	0.63	0.05	0.05	0.06
Xi SE	0.05	0.44	0.63	0.53
llh	-811.37	-741.87	-811.36	-764.36
AIC	1624.74	1485.73	1624.73	1530.73
p.val		0.00%	91.07%	0.00%

24_hr	No Cov.	P	T	PxT
Mu0	24.49	5.63	25.24	10.92
Mu1		0.19	-0.07	0.01
Sigma	12.37	7.96	12.38	9.14
Xi	-0.03	-1.24E-03	-0.03	-2.41E-03
MU0 SE	0.98	1.34	2.58	1.13
MU1 SE		0.01	0.21	8.21E-04
Sigma SE	0.72	0.06	0.05	0.06
Xi SE	0.06	0.48	0.72	0.56
llh	-832.60	-745.43	-832.55	-774.26
AIC	1667.20	1492.86	1667.10	1550.52
p.val		0.00%	75.24%	0.00%

**Highlighted p.val cells indicate that the model was found to be statistically significant for that predictor variable. Yellow variable highlights indicate the minimum AIC of the three predictor variables and statistical significance*

12. Appendix E Watershed Topography Maps

Codroy Valley Watershed Topography

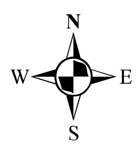


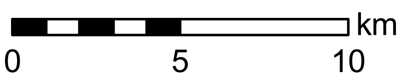
Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

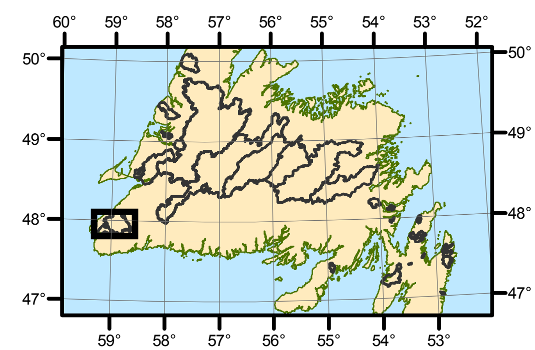
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).



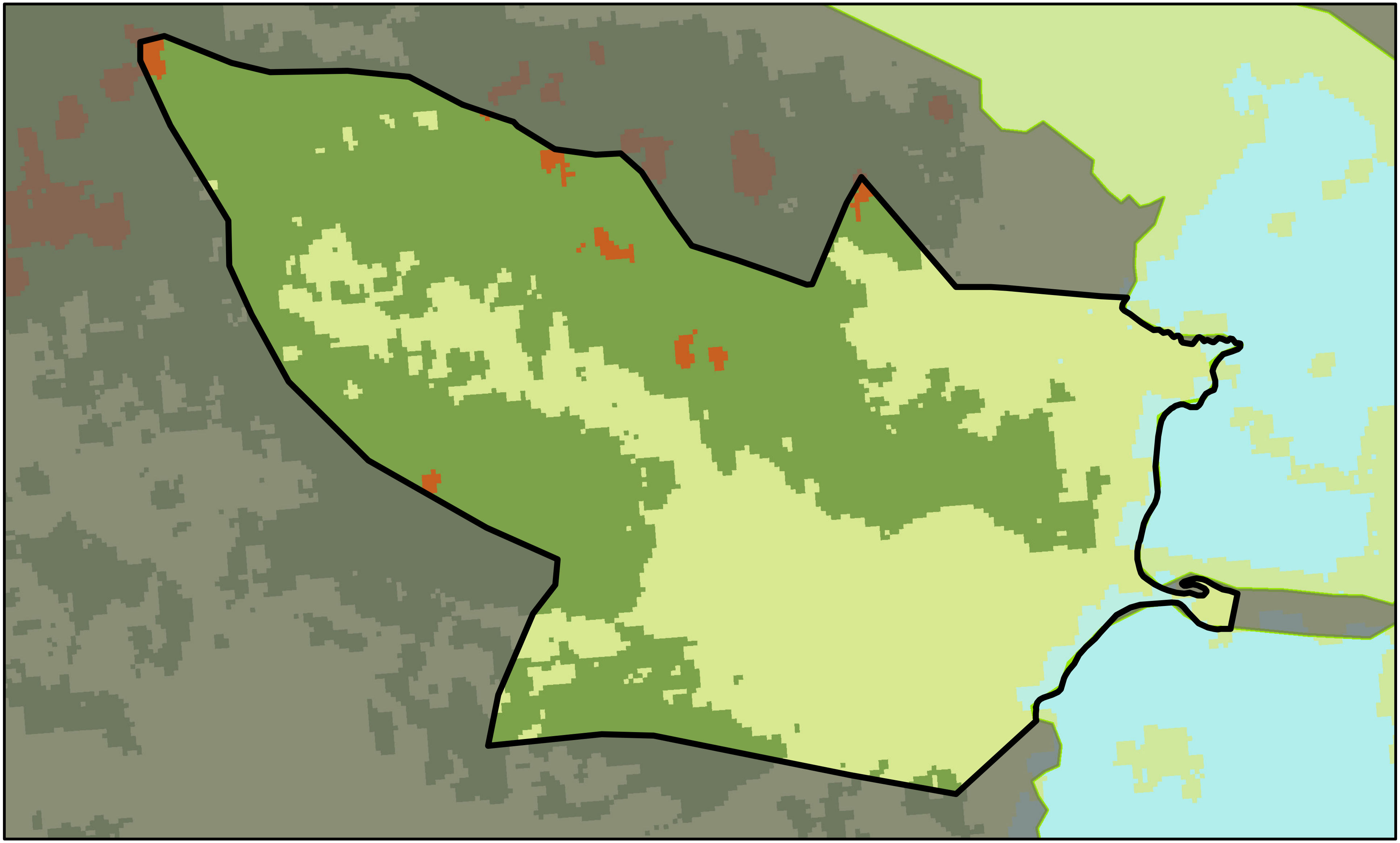


1:225,000

1 cm = 2 km



Ferryland Watershed Land Cover

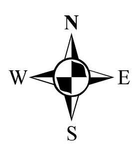


Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).

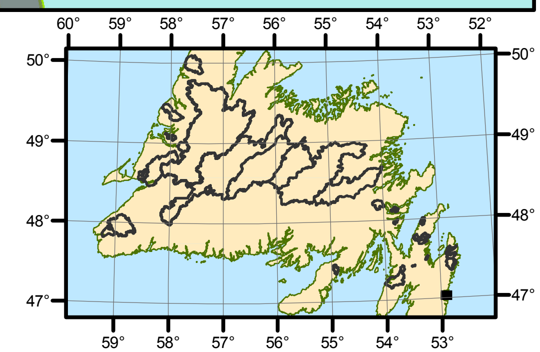


km

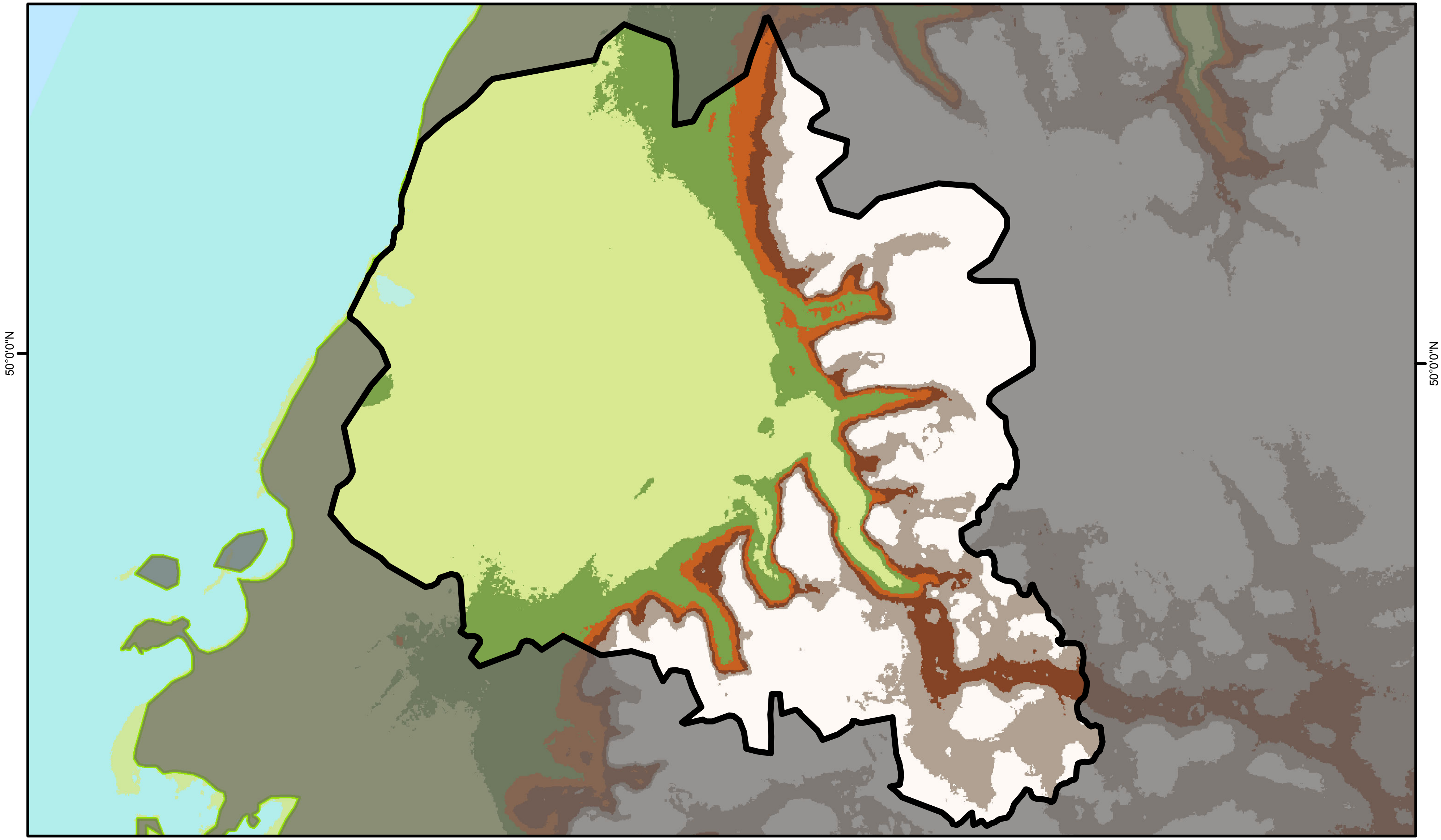
0 1

1:30,000

1 cm = 0 km



Parson's Pond Watershed Topography

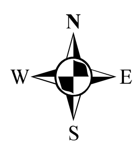


Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

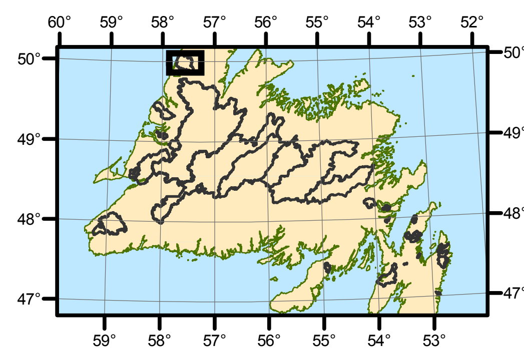
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).



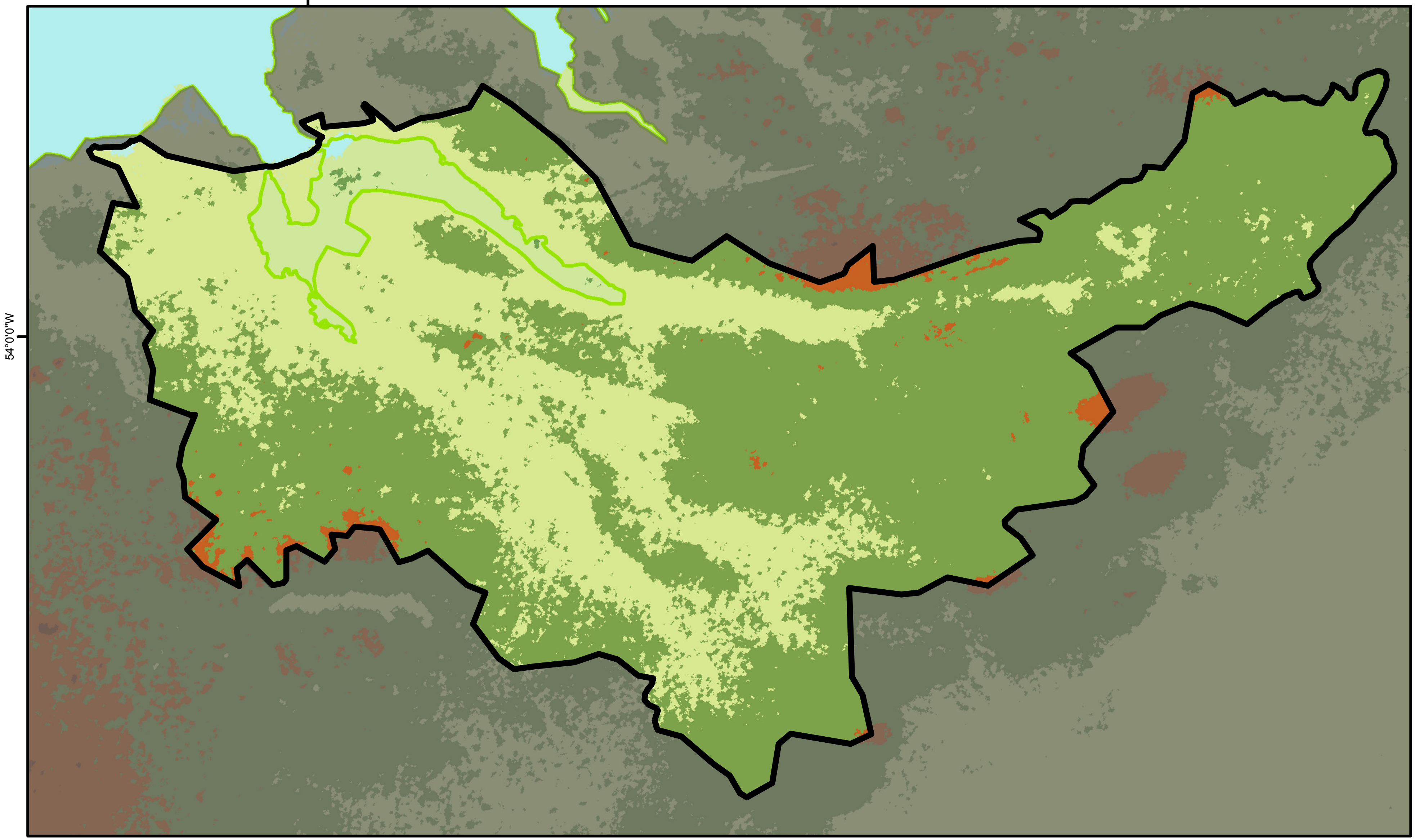
0 5 10 km

1:175,000

1 cm = 2 km



Placentia Watershed Topography

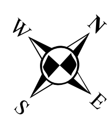


Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

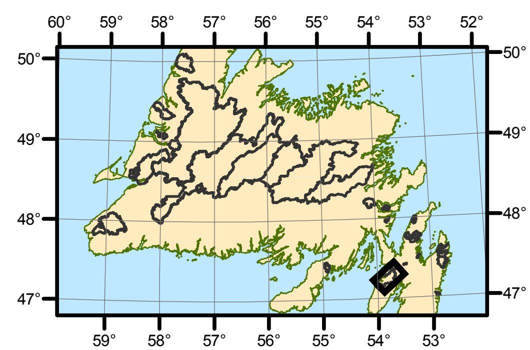
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).



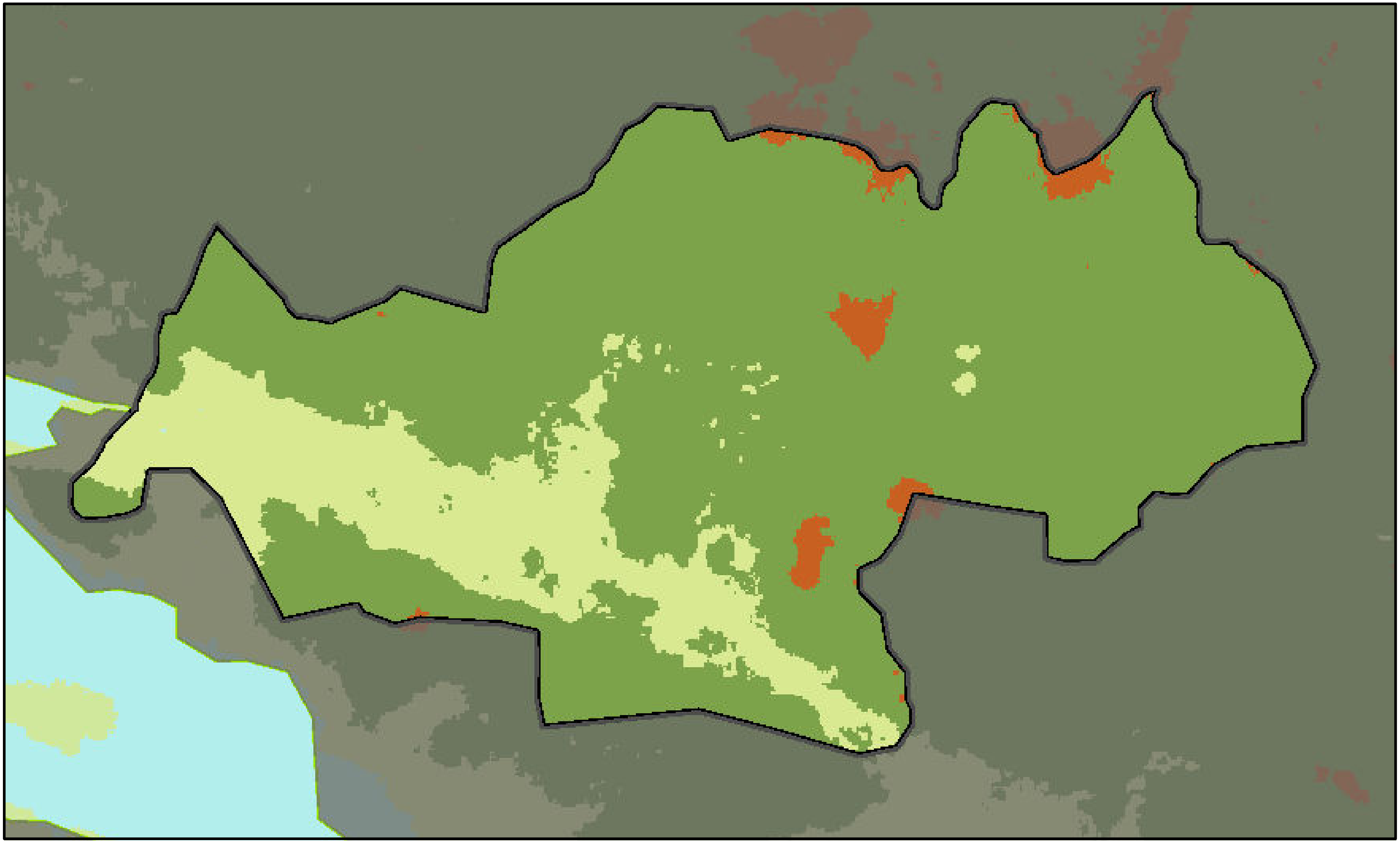
0 5 km

1:150,000

1 cm = 2 km



Rushoon Watershed: Topography



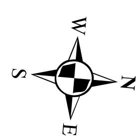
Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

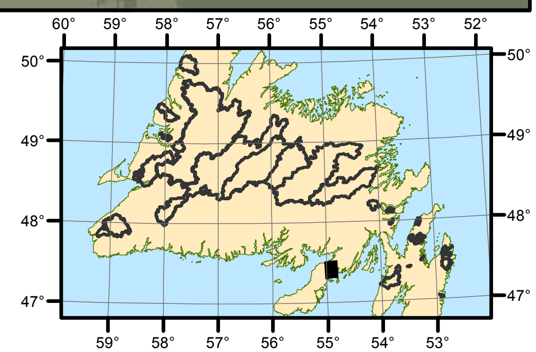
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).

0 2 4 km

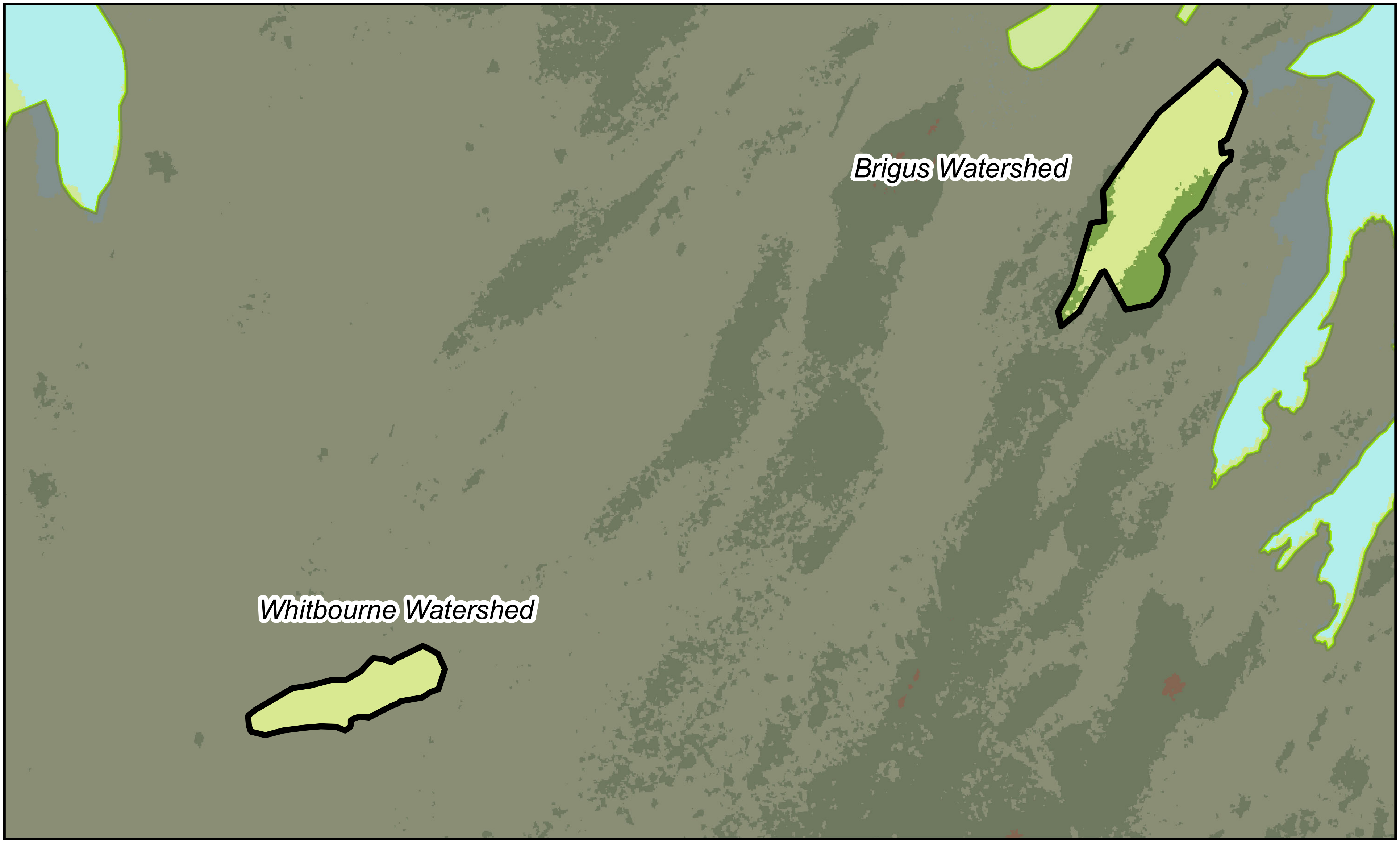


1:60,000

1 cm = 1 km



Whitbourne and Brigus Watersheds Topography

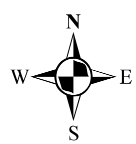


Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

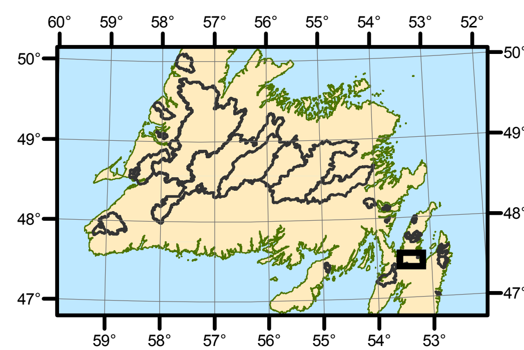
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).



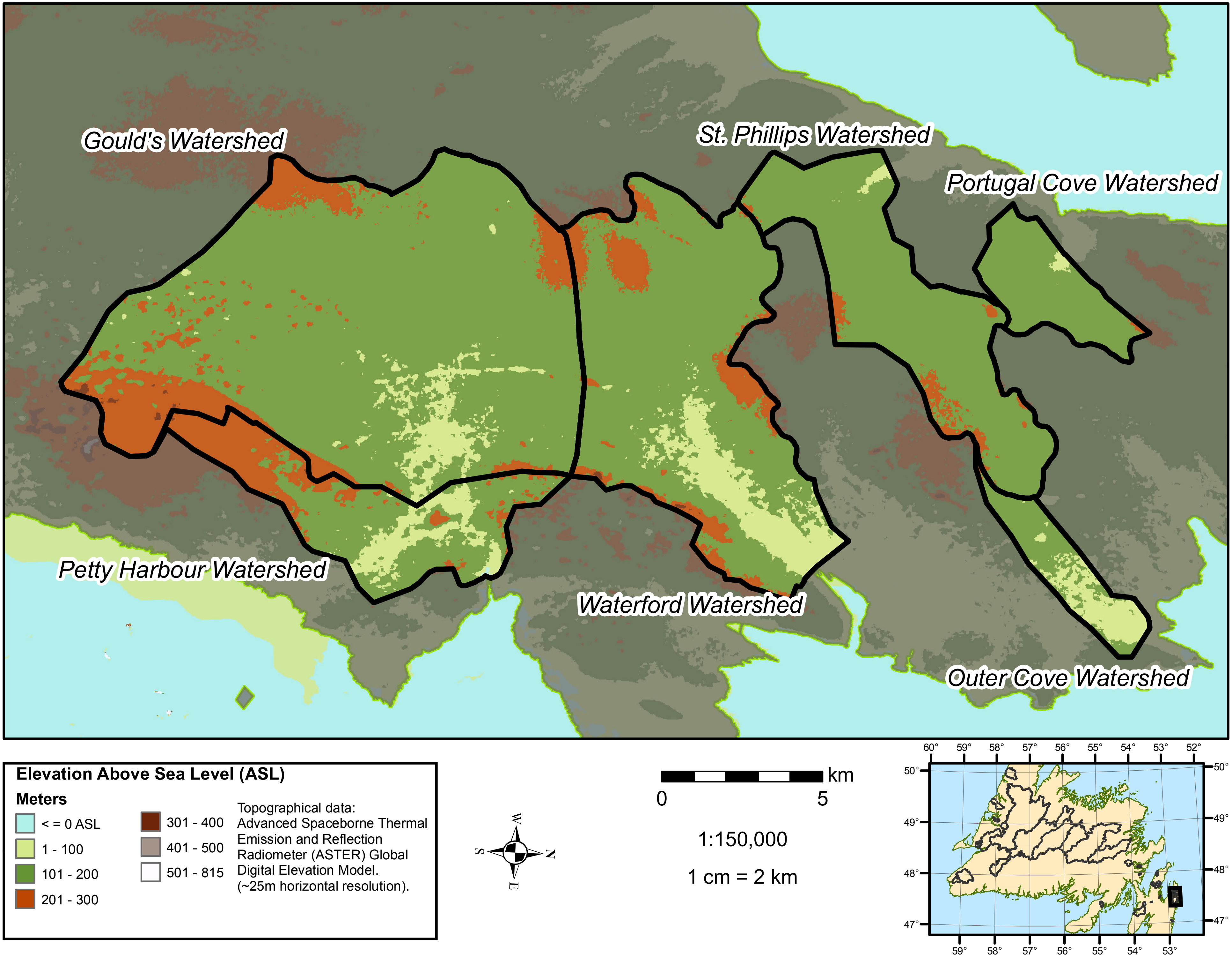
0 5 km

1:125,000

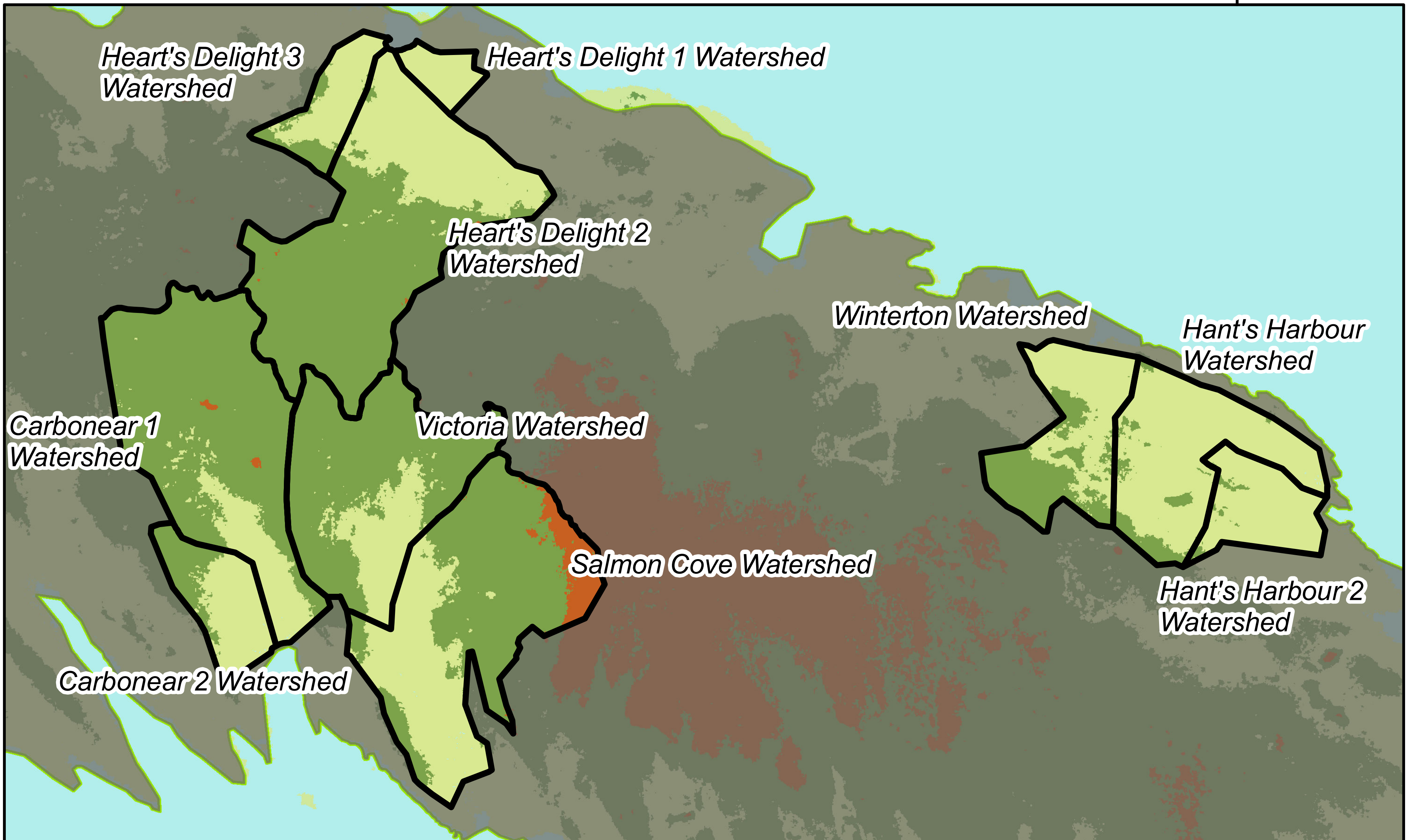
1 cm = 1 km



Eastern Watersheds, East Topography



Eastern Watersheds, North Topography

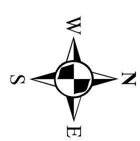


Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

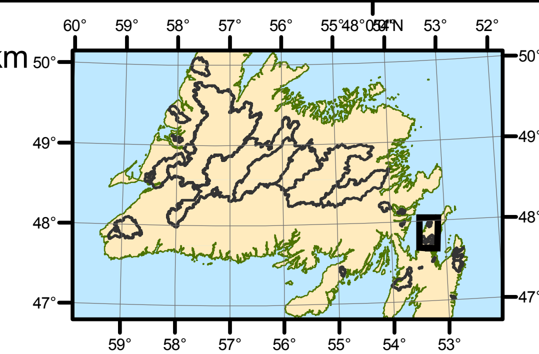
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).



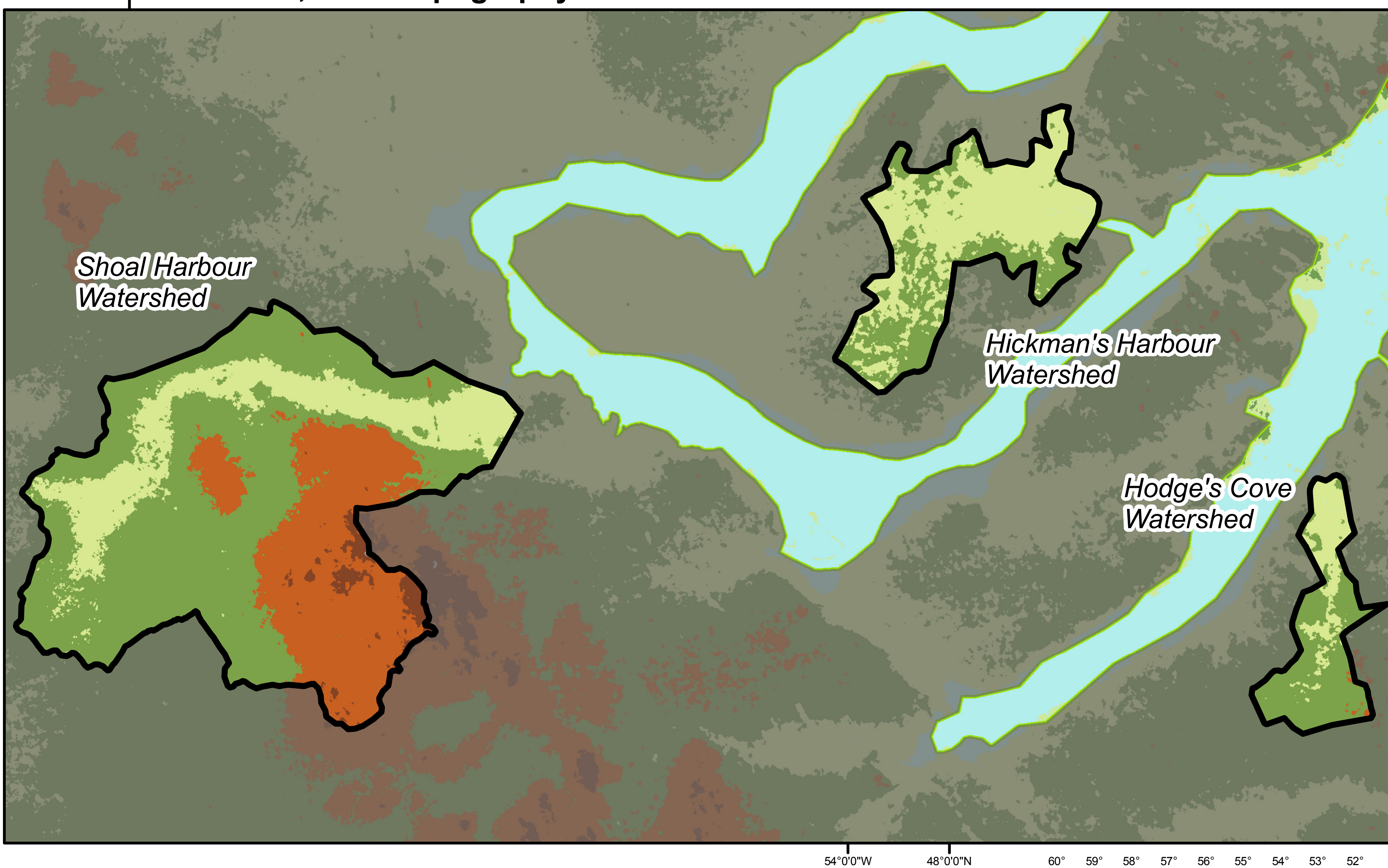
km
0 5 10

1:165,000

1 cm = 2 km



Eastern Watersheds, West Topography



Elevation Above Sea Level (ASL)

Meters

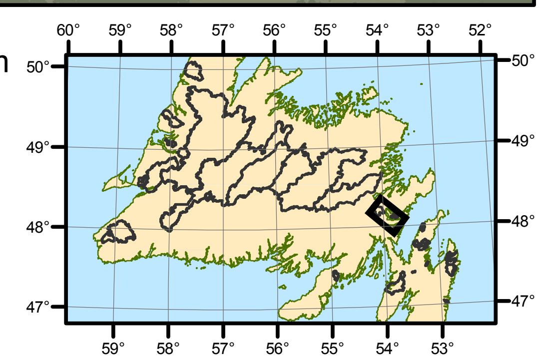
- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).

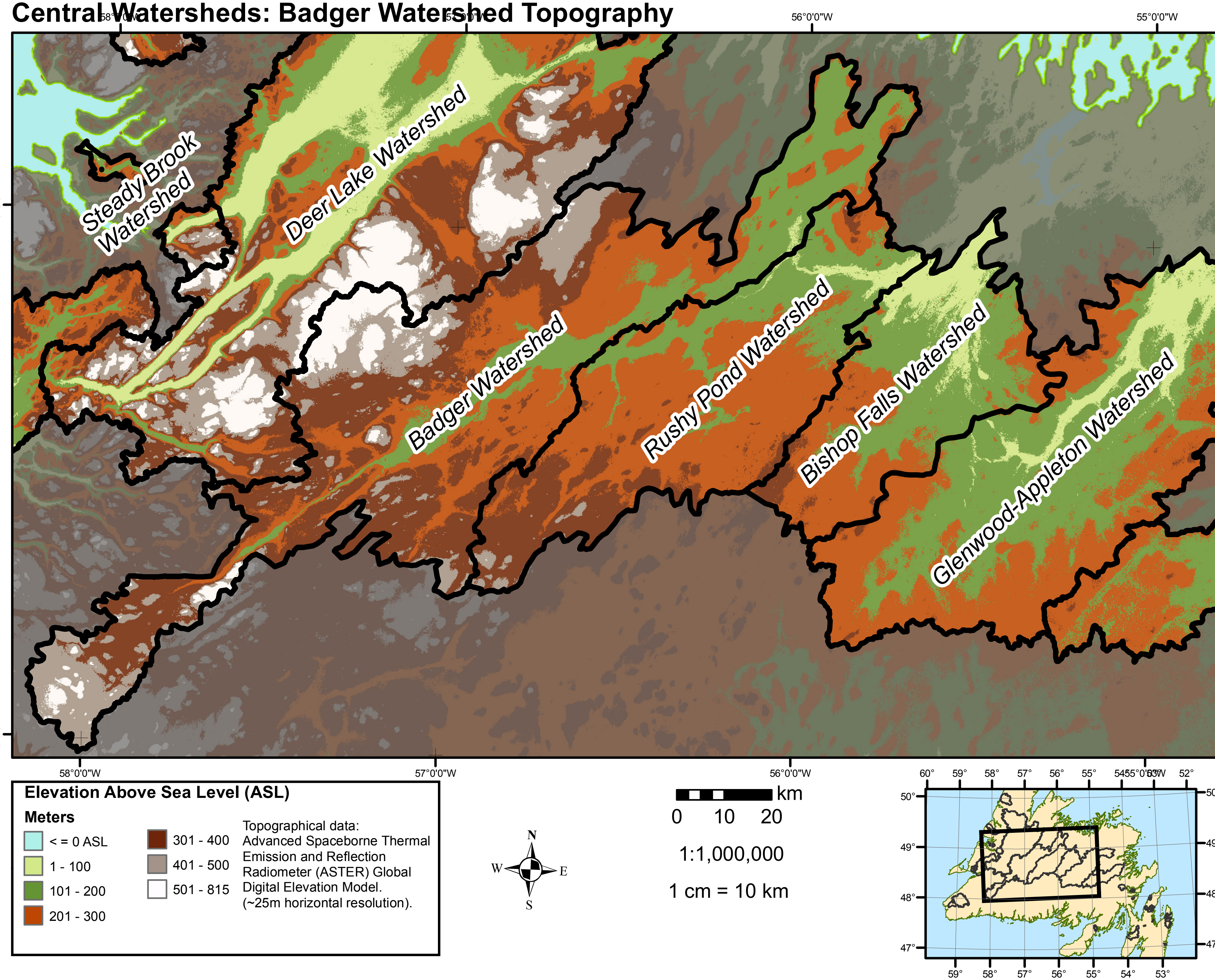
0 5 10 km

1:175,000

1 cm = 2 km



Central Watersheds: Badger Watershed Topography



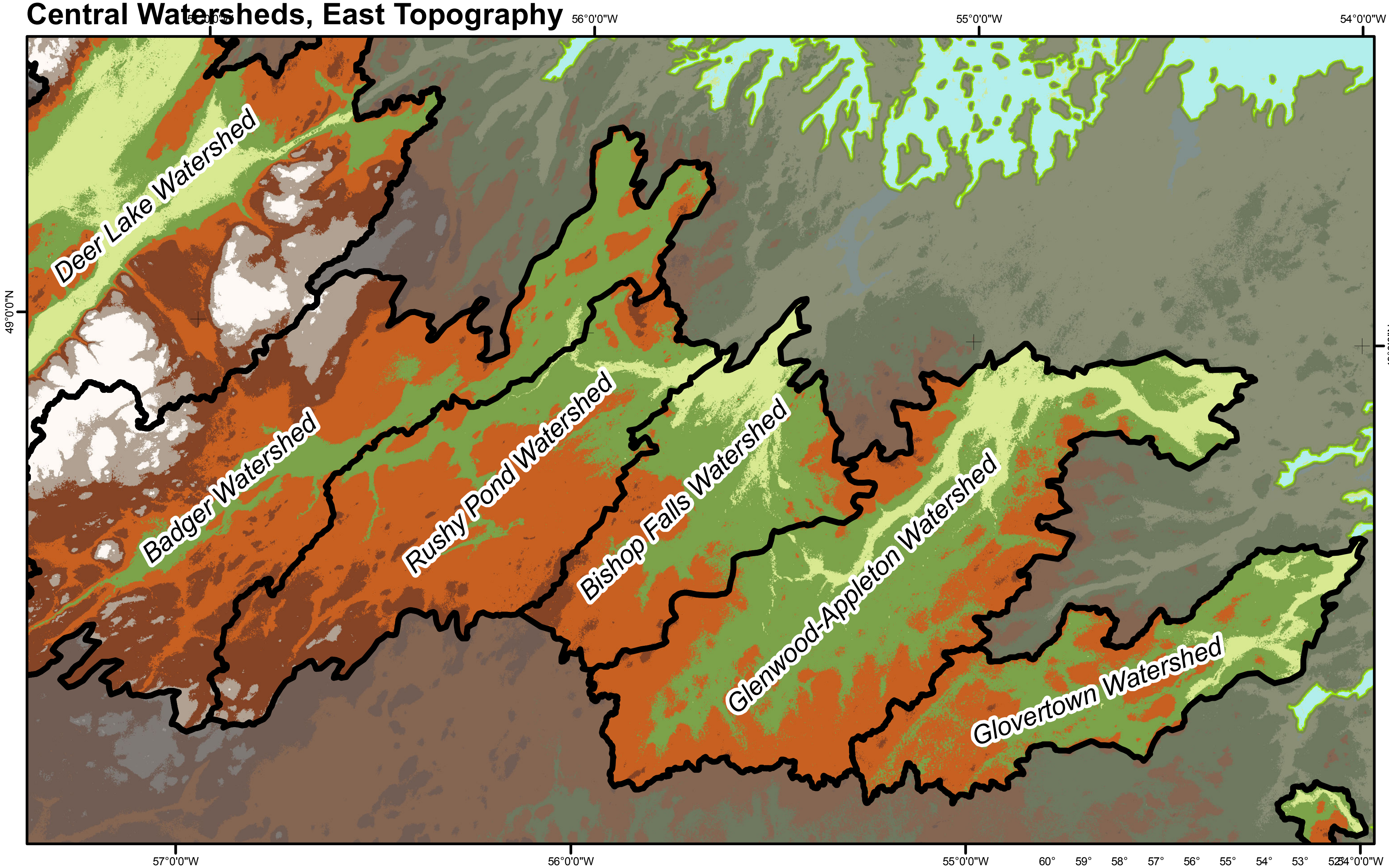
Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).

Central Watersheds, East Topography



Elevation Above Sea Level (ASL)

Meters

- < = 0 ASL
- 1 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 815

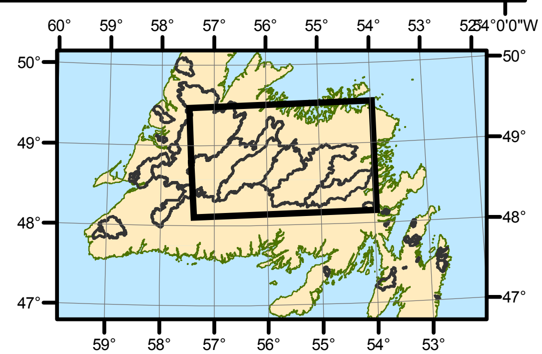
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).

N W E S

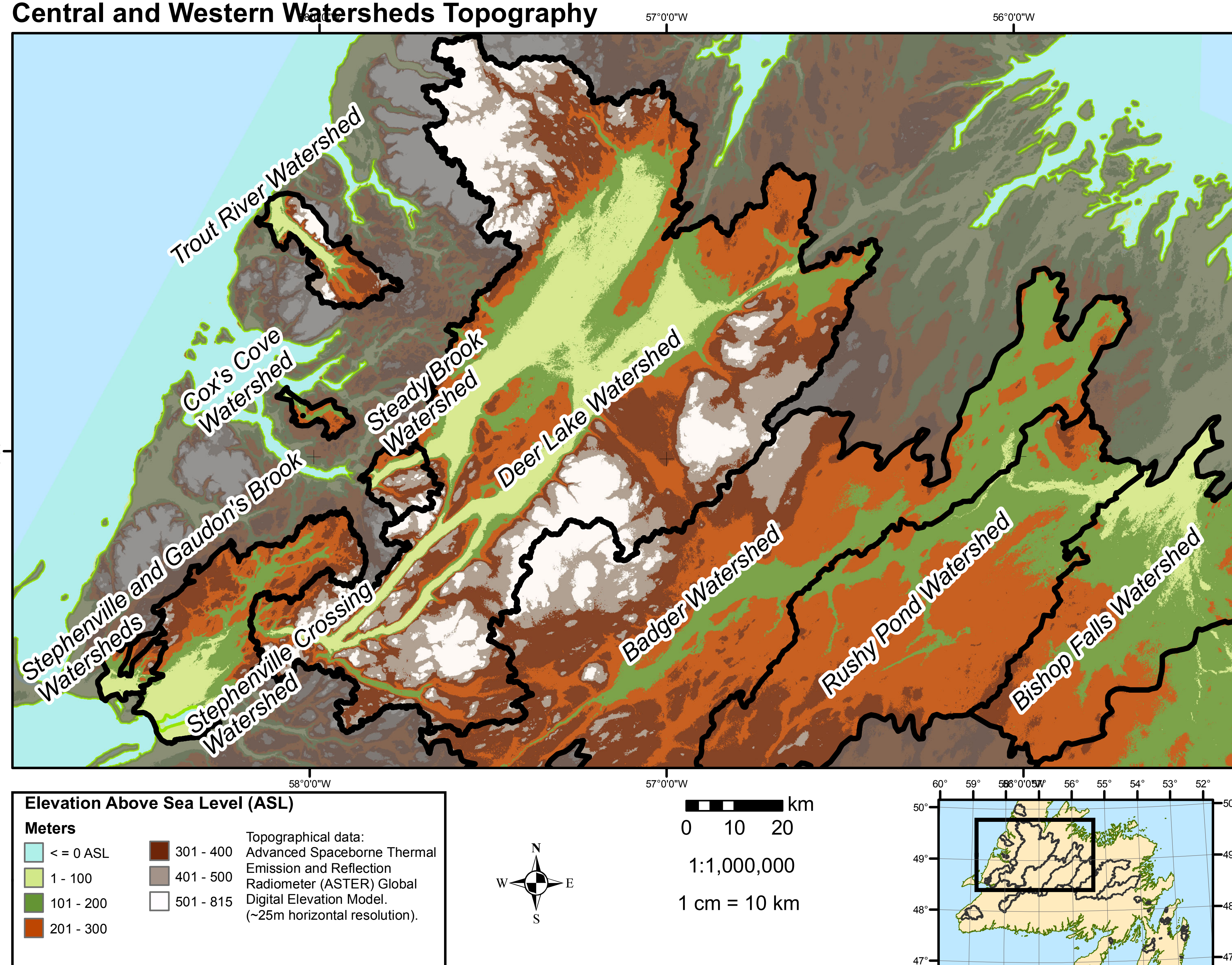
km
0 10 20

1:1,000,000

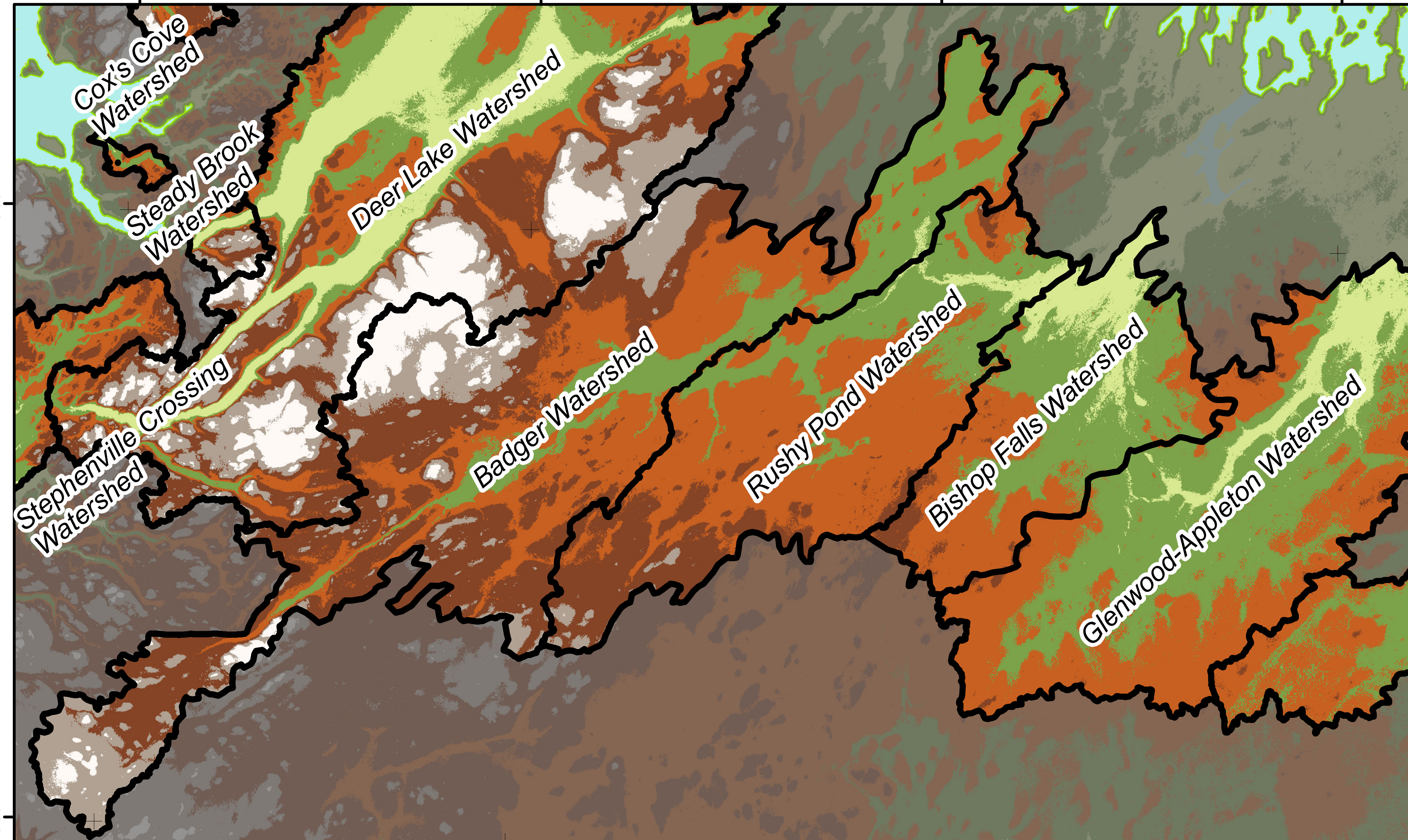
1 cm = 10 km



Central and Western Watersheds Topography



Central and Western Watersheds Topography 2



Elevation Above Sea Level (ASL)

Meters

< = 0 ASL	301 - 400
1 - 100	401 - 500
101 - 200	501 - 815
201 - 300	

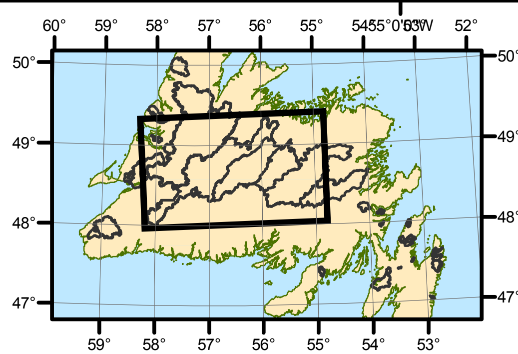
Topographical data: Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model. (~25m horizontal resolution).

N W E S

km
0 10 20

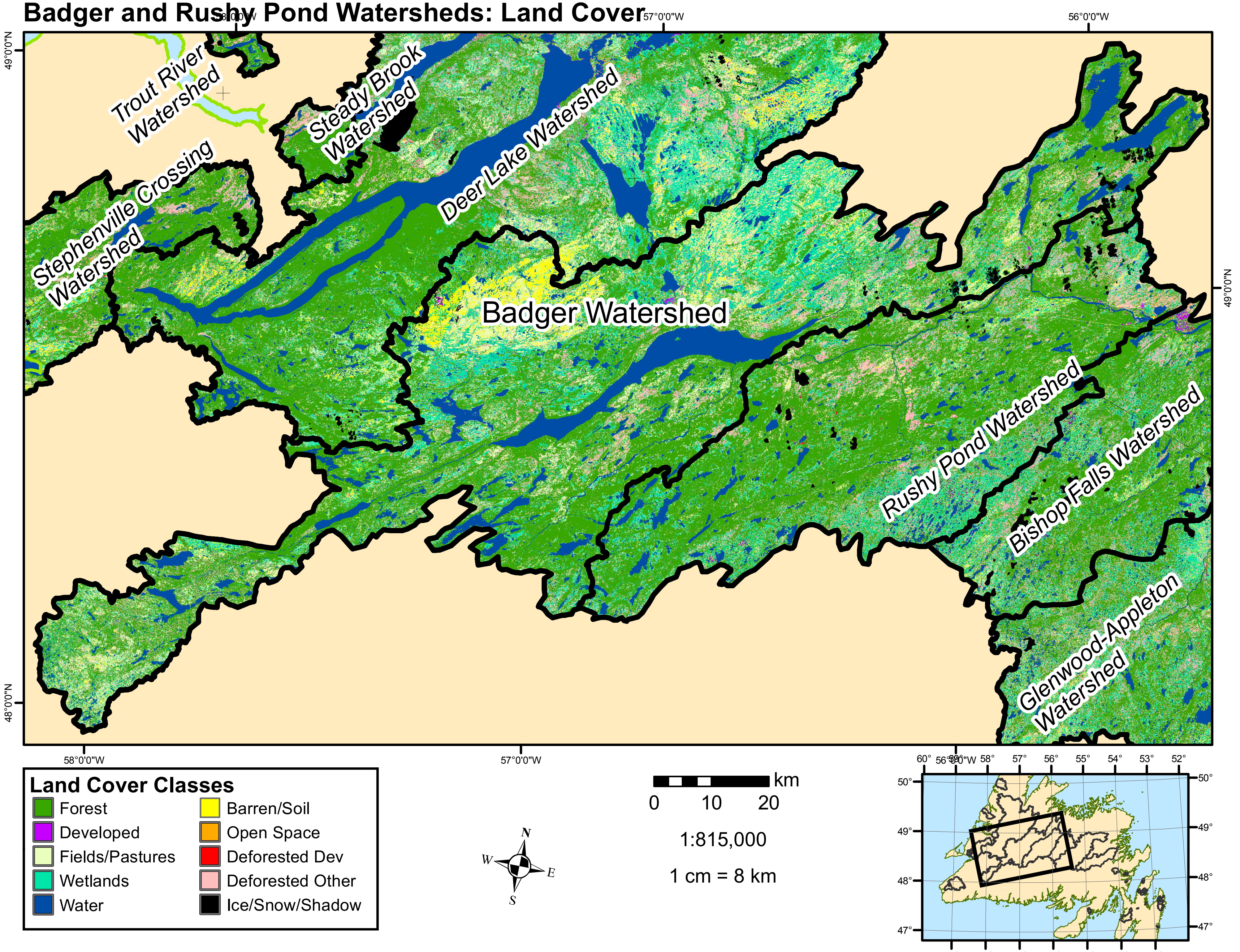
1:1,000,000

1 cm = 10 km

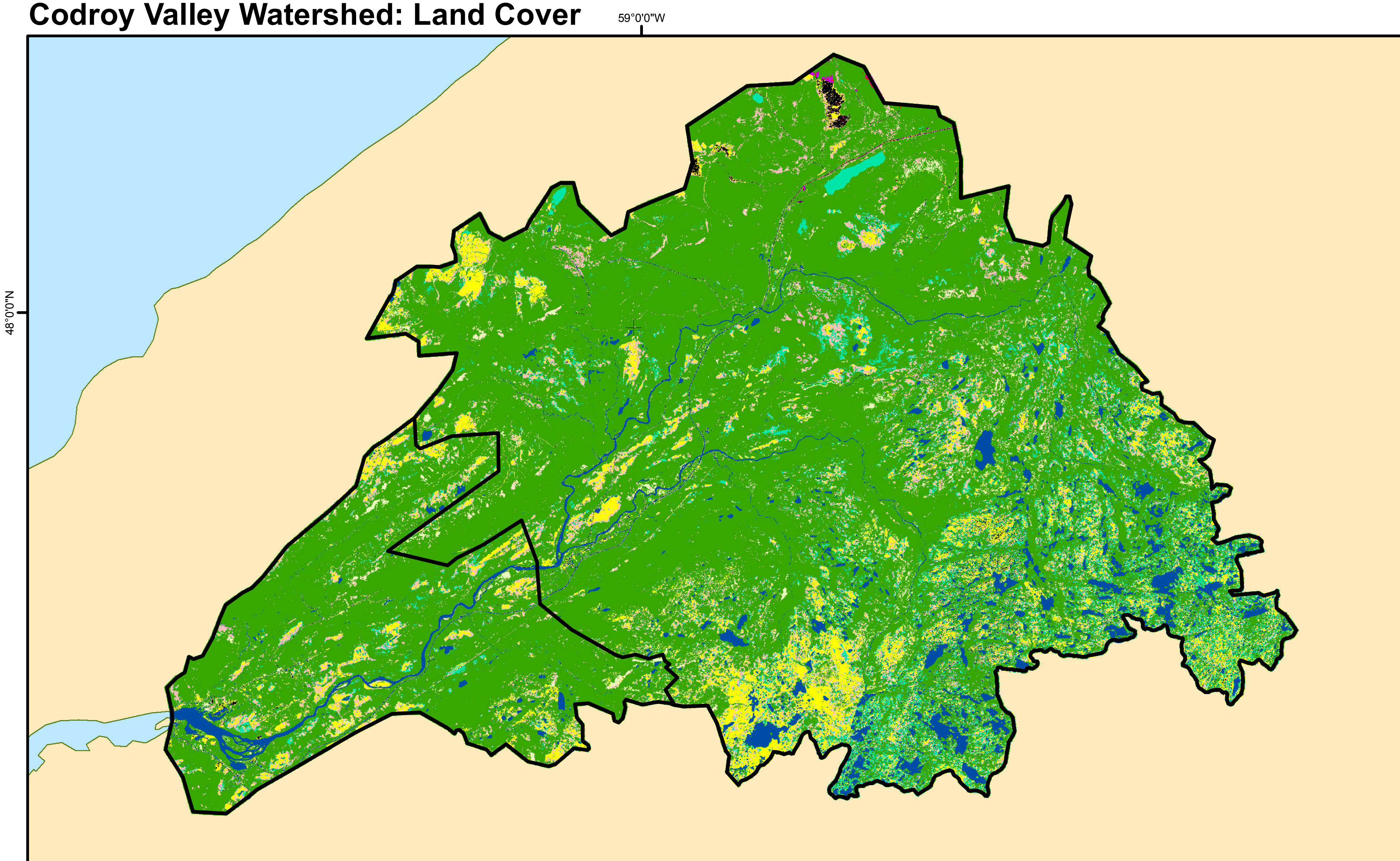


13. Appendix F Watershed Land Cover Maps

Badger and Rushy Pond Watersheds: Land Cover



Codroy Valley Watershed: Land Cover



Land Cover Classes

- Forest
- Developed
- Fields/Pastures
- Wetlands
- Water
- Barren/Soil
- Open Space
- Deforested Dev
- Deforested Other
- Ice/Snow/Shadow

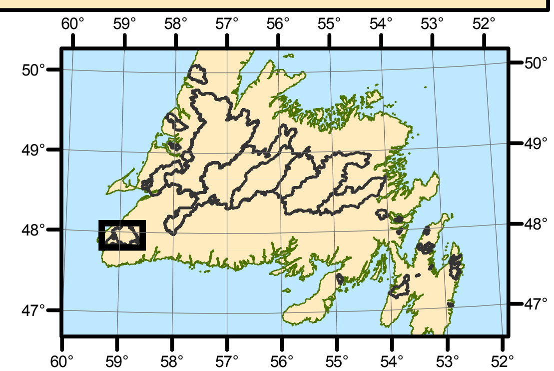
N
W E
S

0 2.5 5 10 km

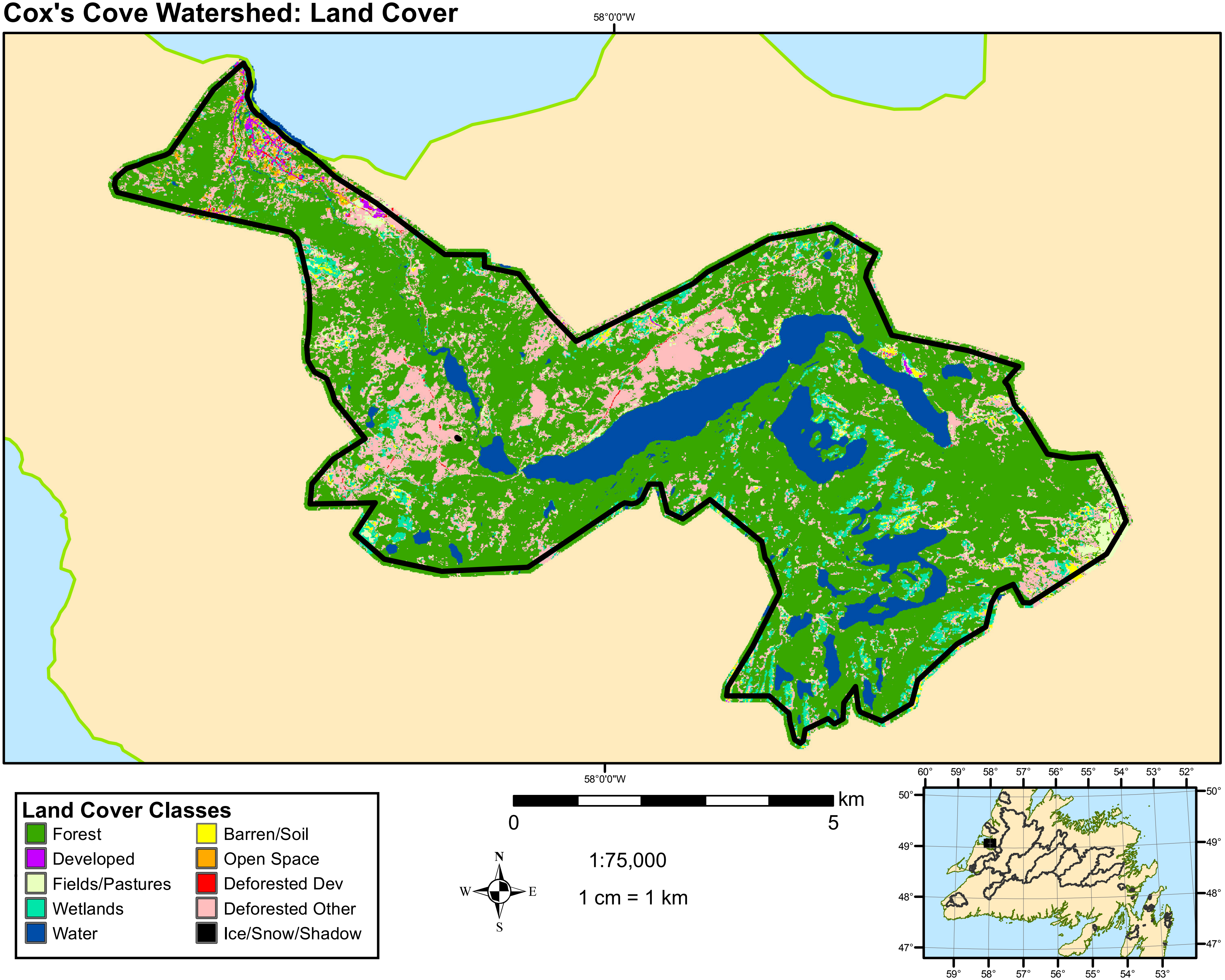
1:225,000

1 cm = 2 km

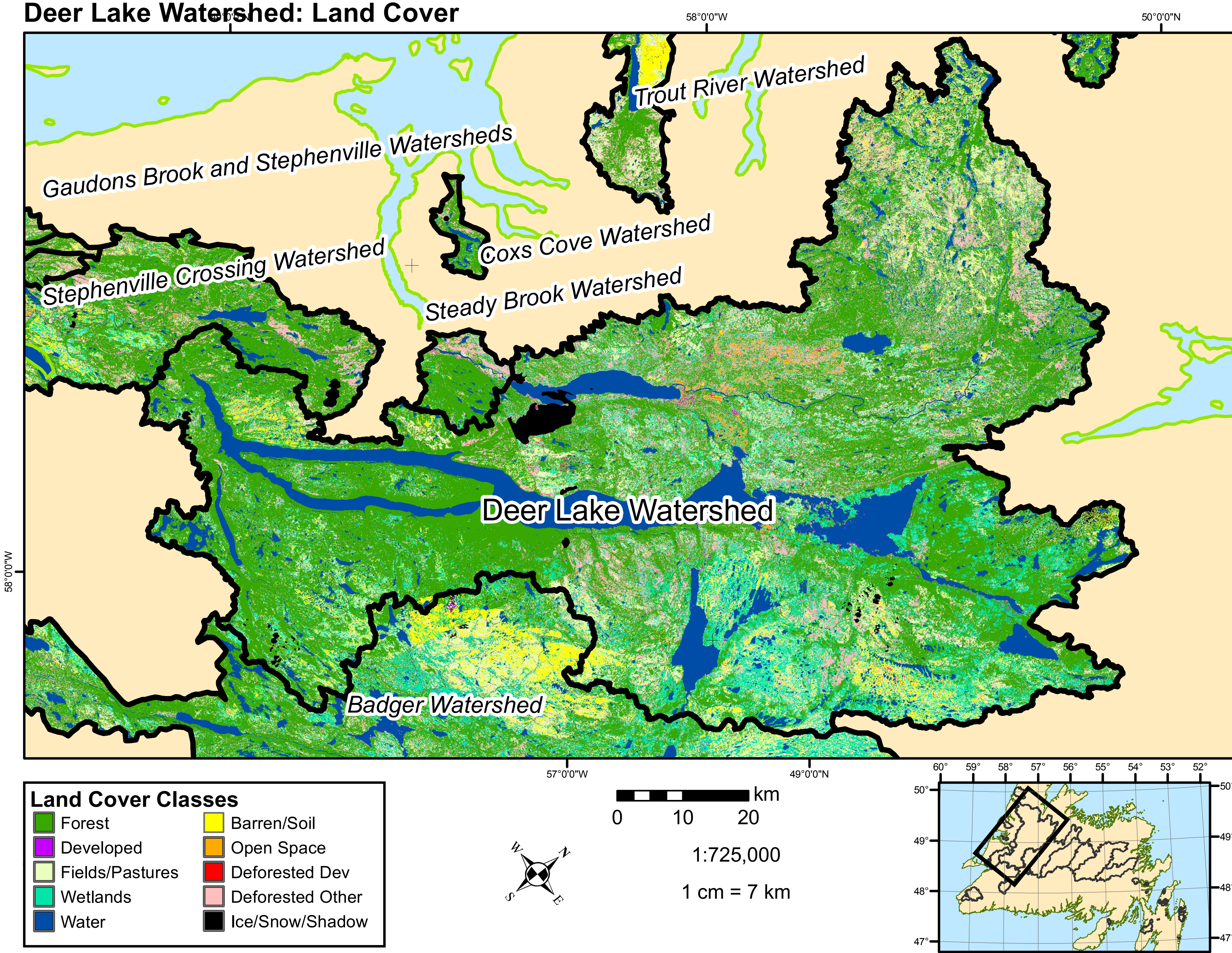
Codroy Valley contains two watersheds reported in this study: Codroy Valley is in the north, and Codroy Valley 2 is in the south.



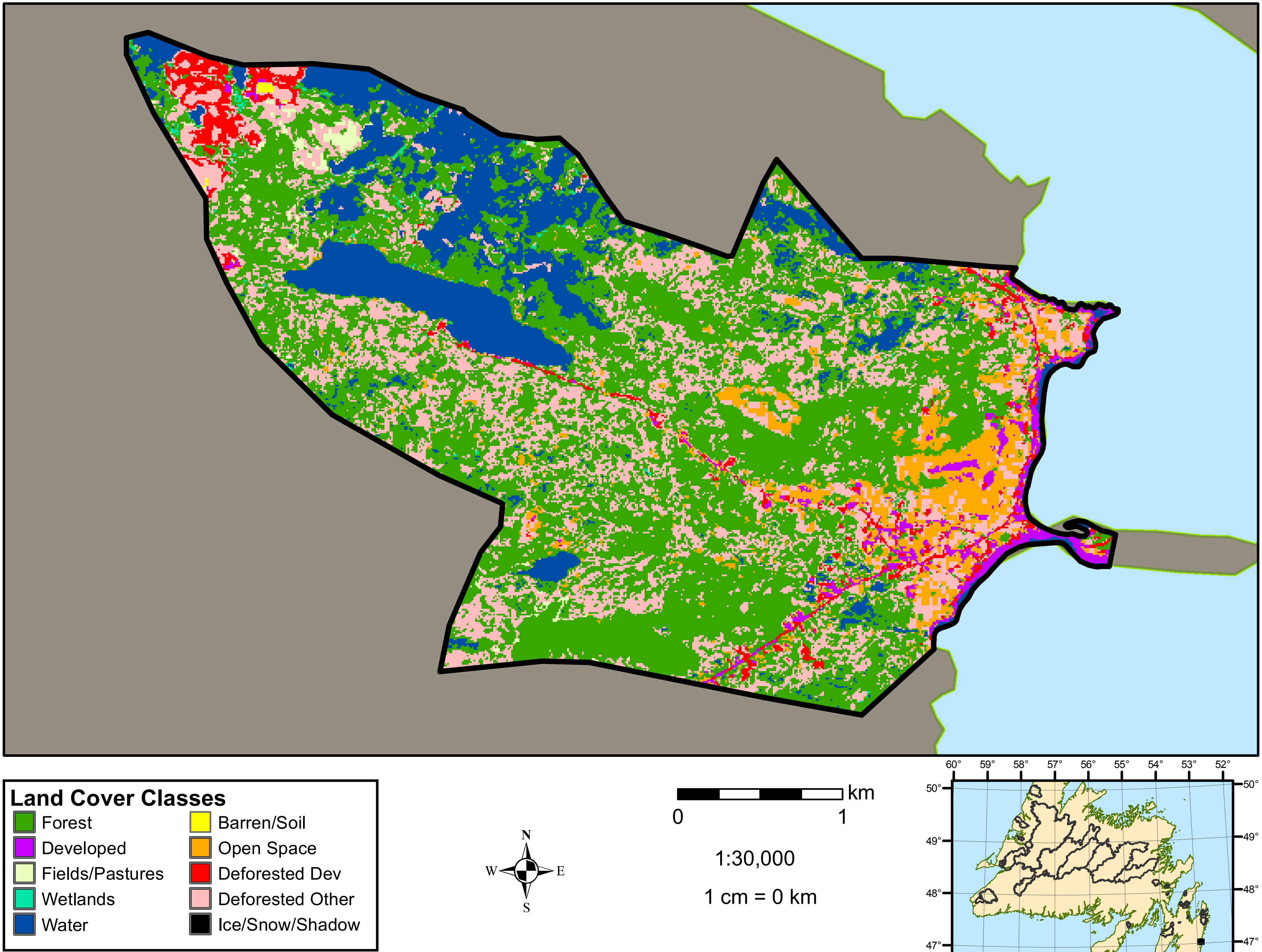
Cox's Cove Watershed: Land Cover



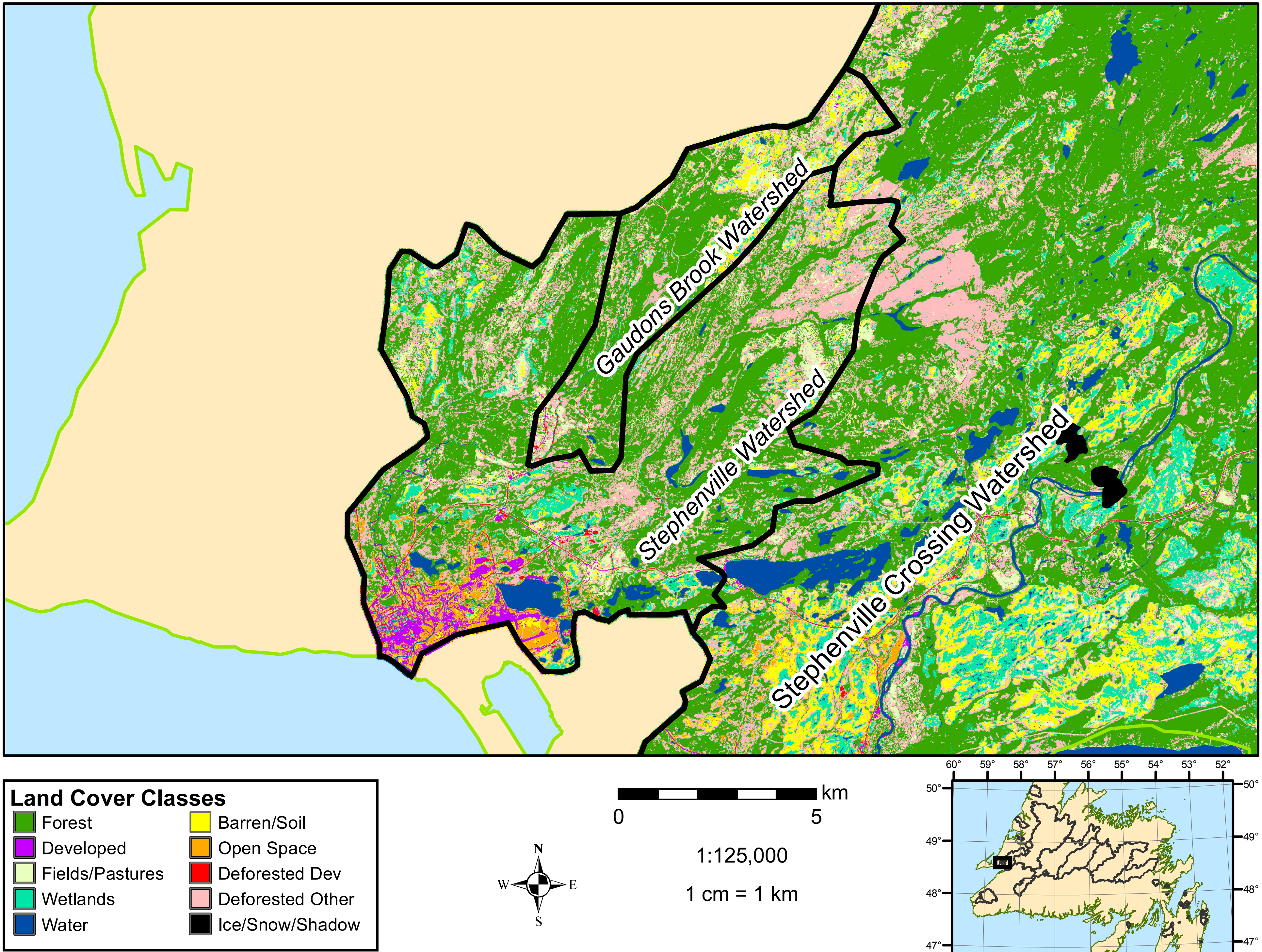
Deer Lake Watershed: Land Cover



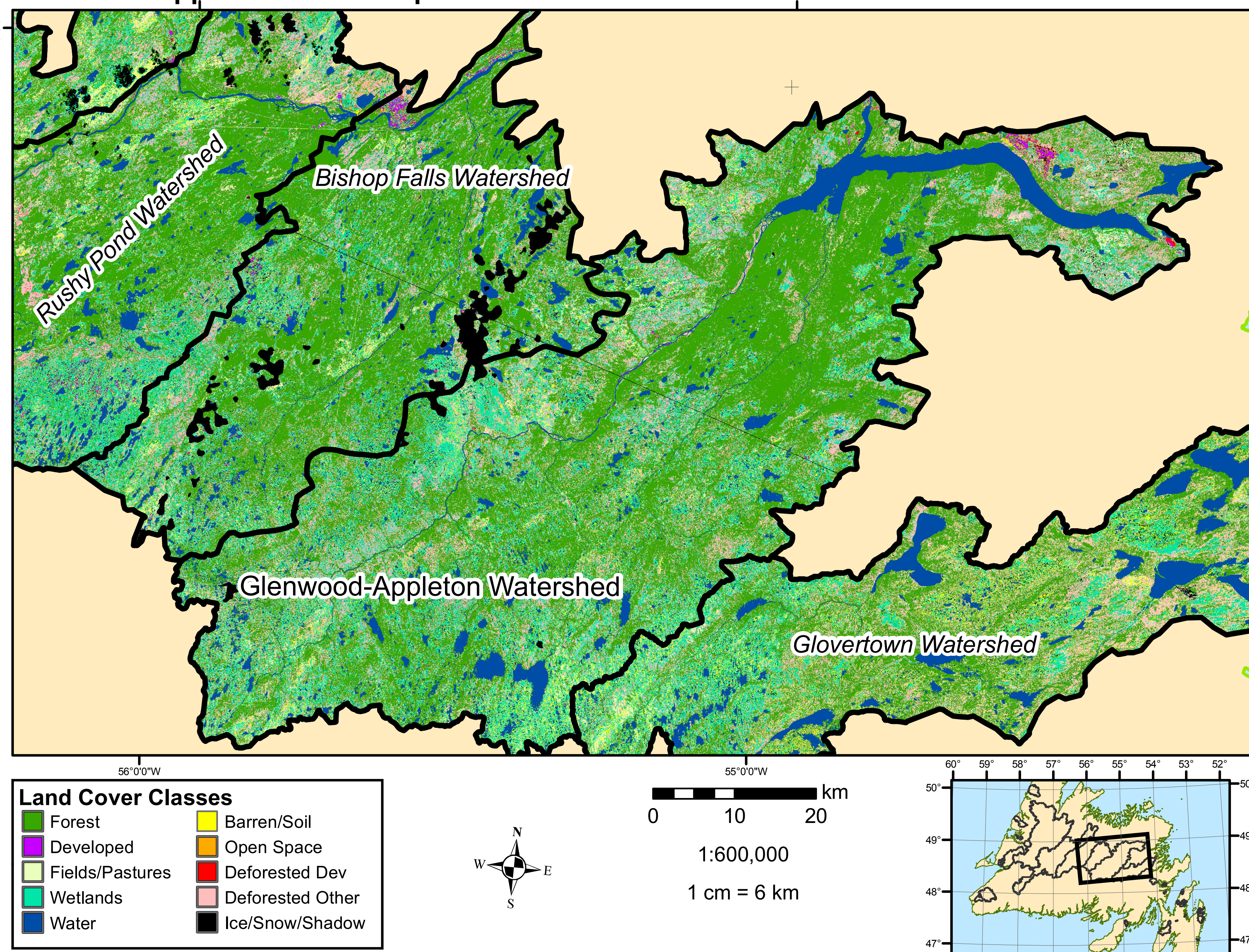
Ferryland Watershed Land Cover



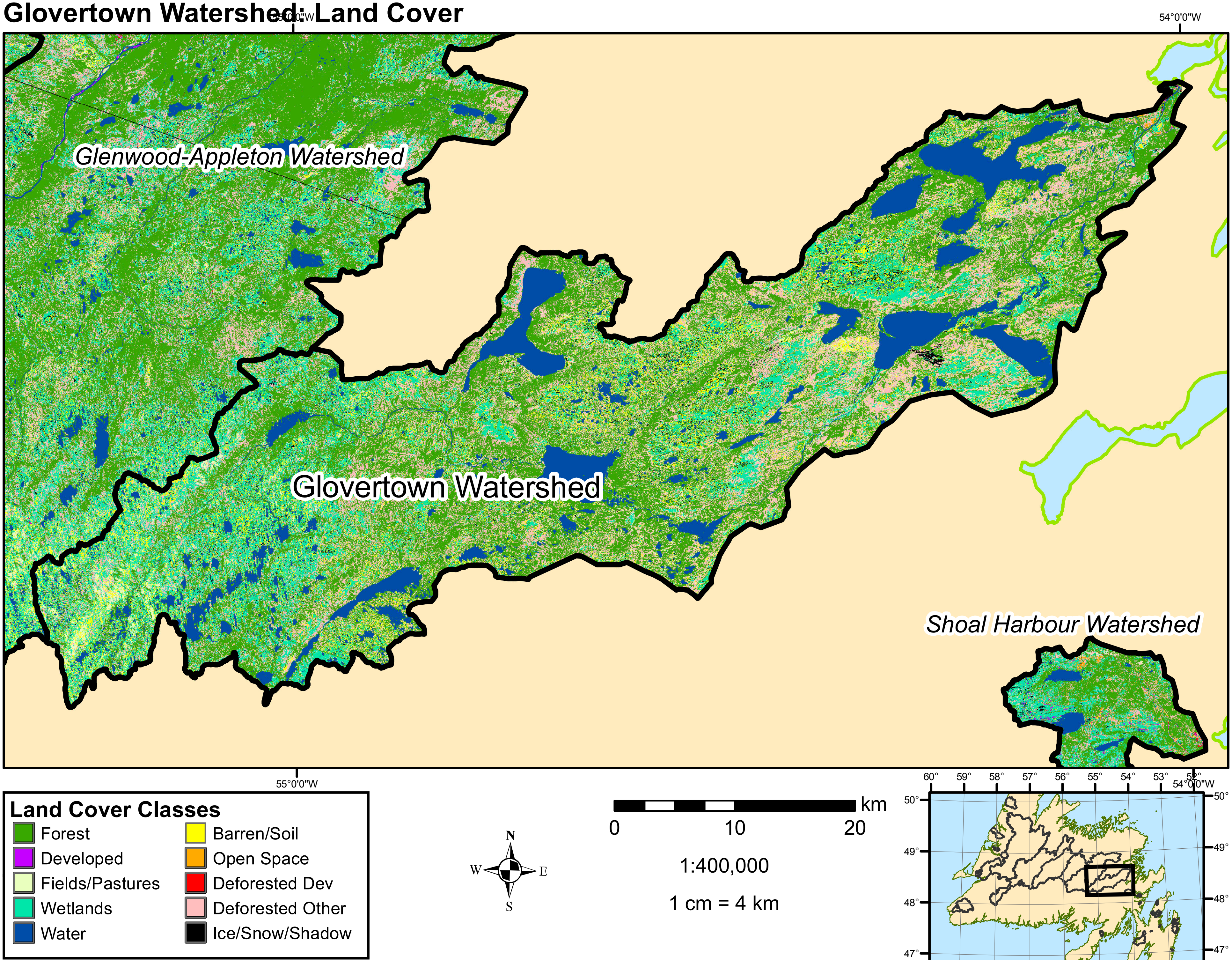
Stephenville and Gaudon's Brook Watersheds: Land Cover



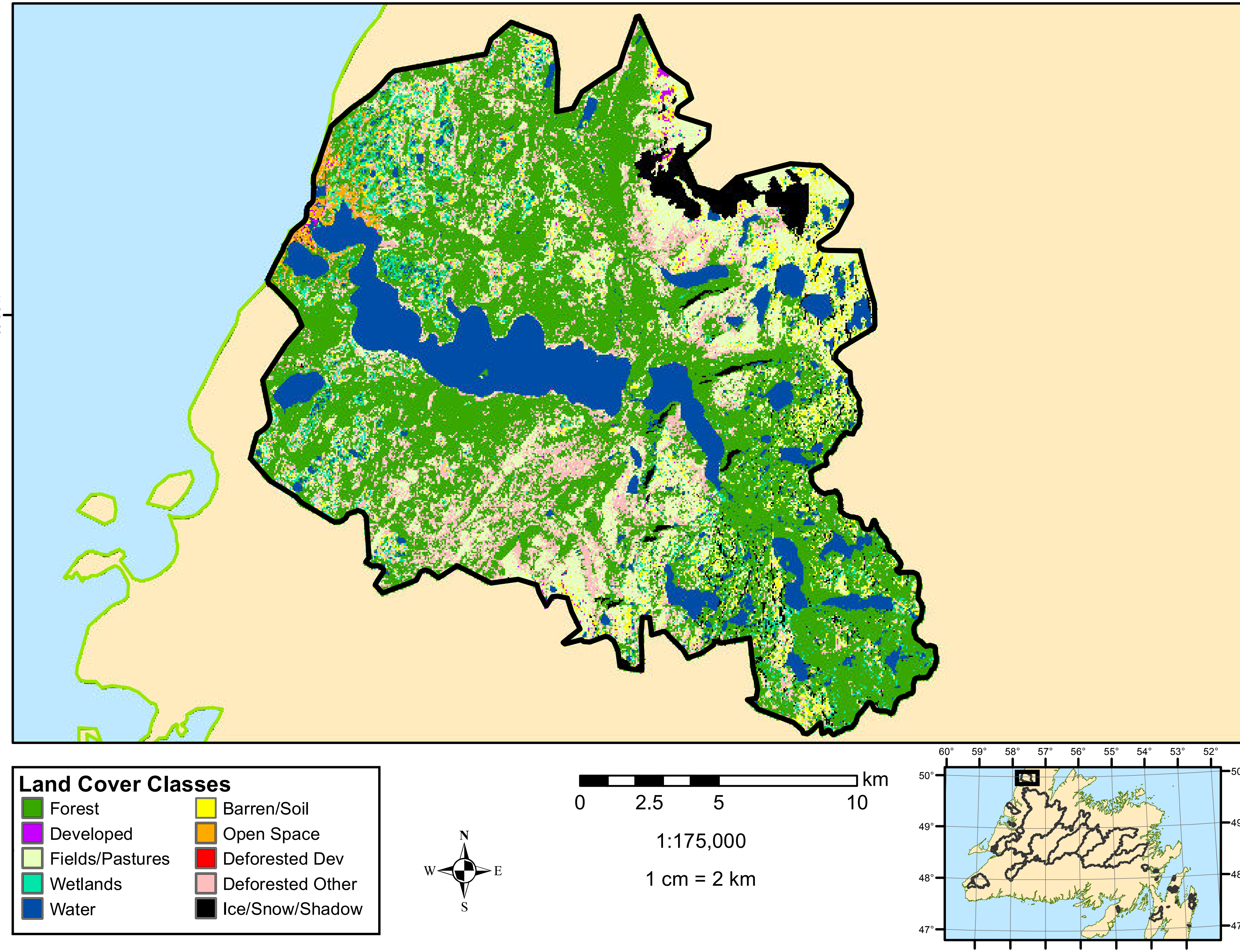
Glenwood-Appleton and Bishop Falls Watersheds: Land Cover



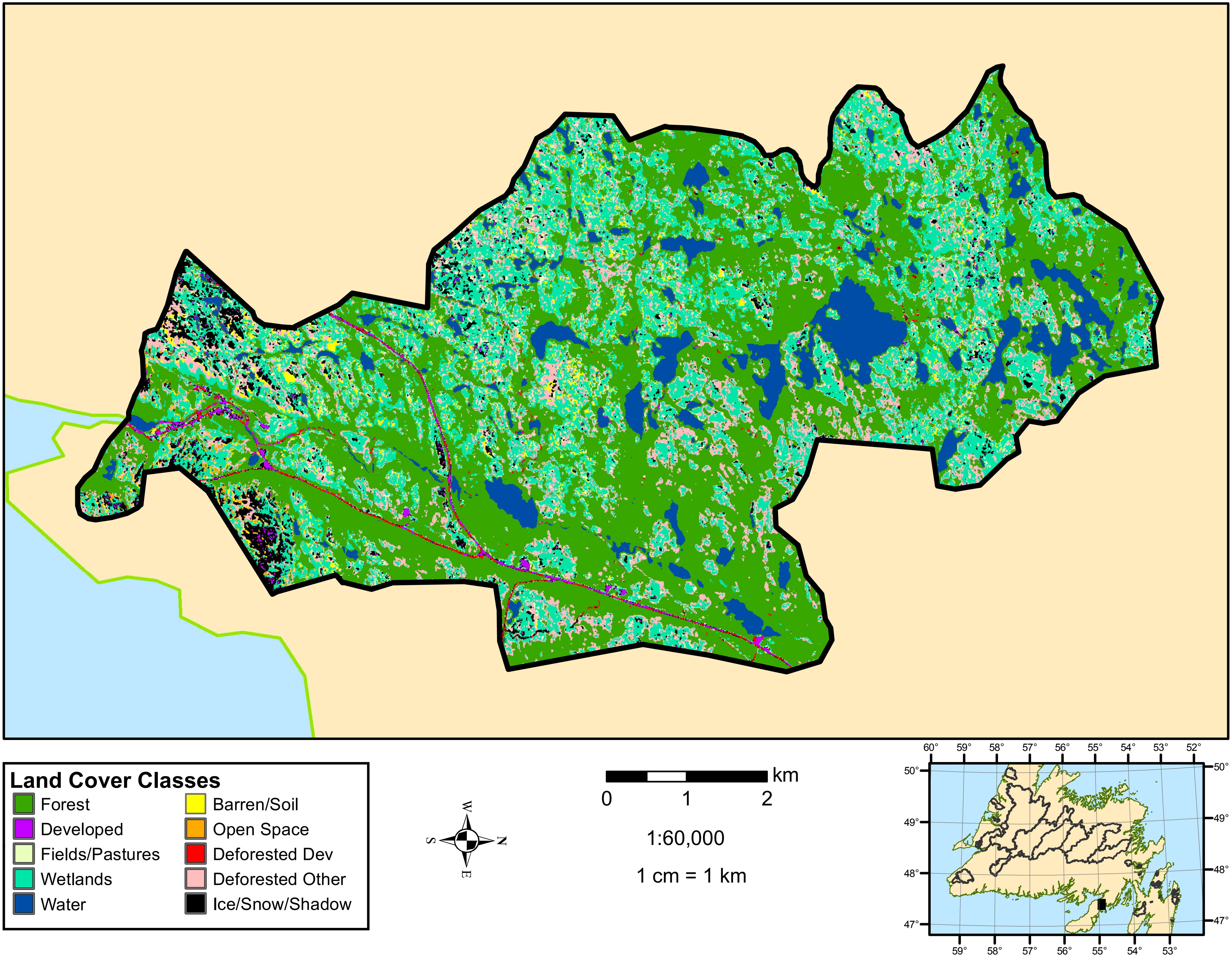
Glovertown Watershed: Land Cover



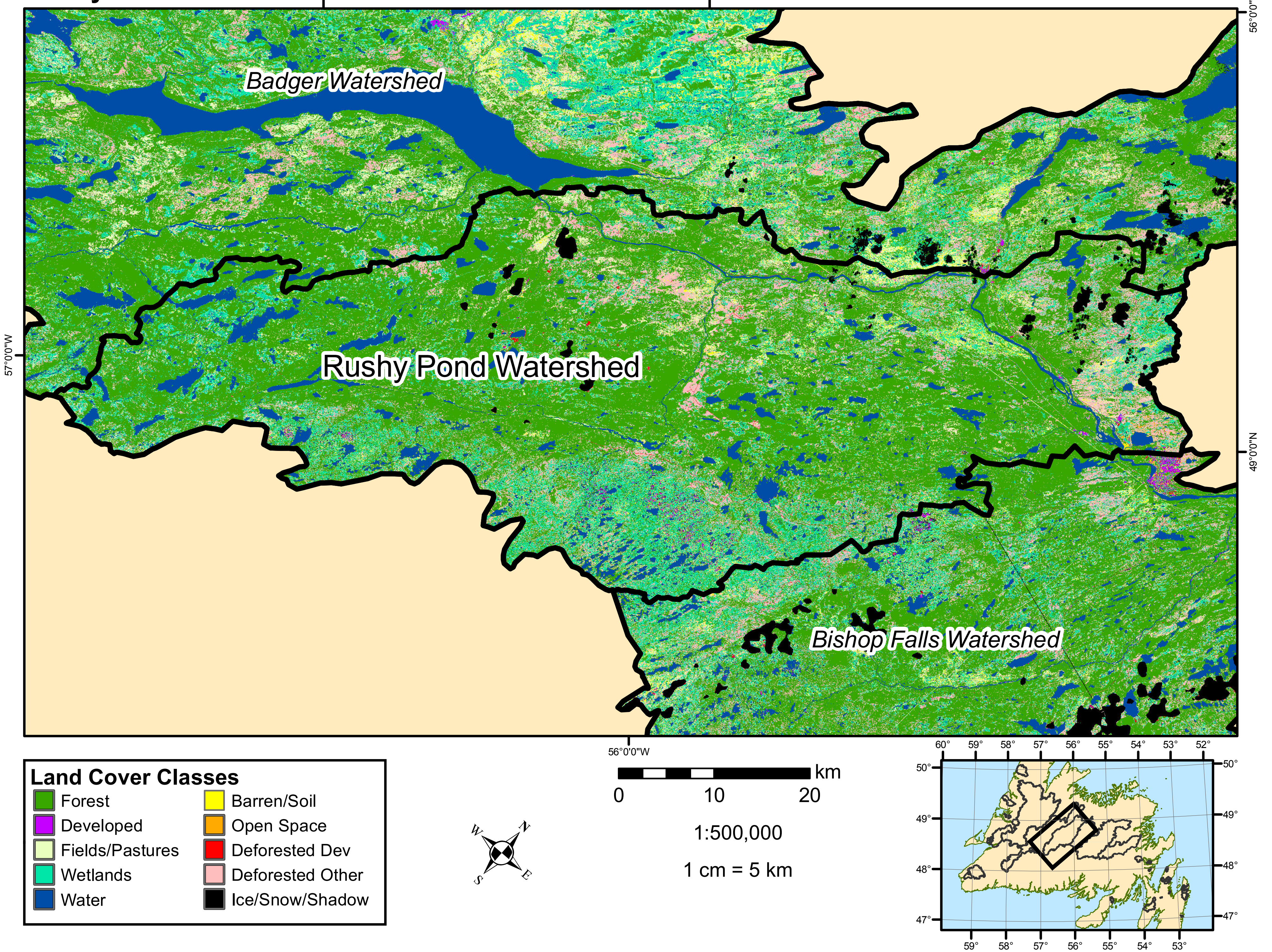
Parson's Pond Watershed: Land Cover



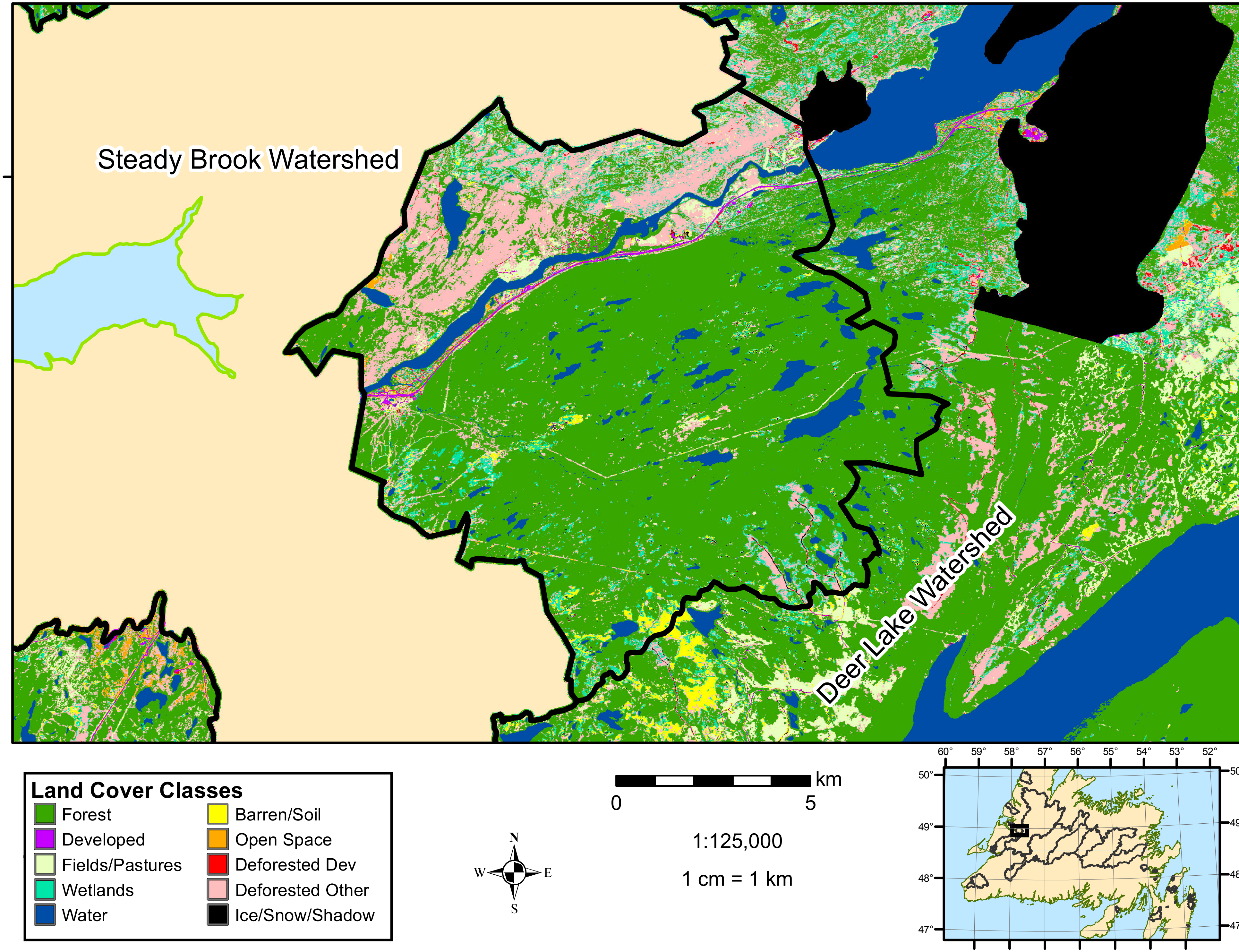
Rushoon Watershed: Land Cover



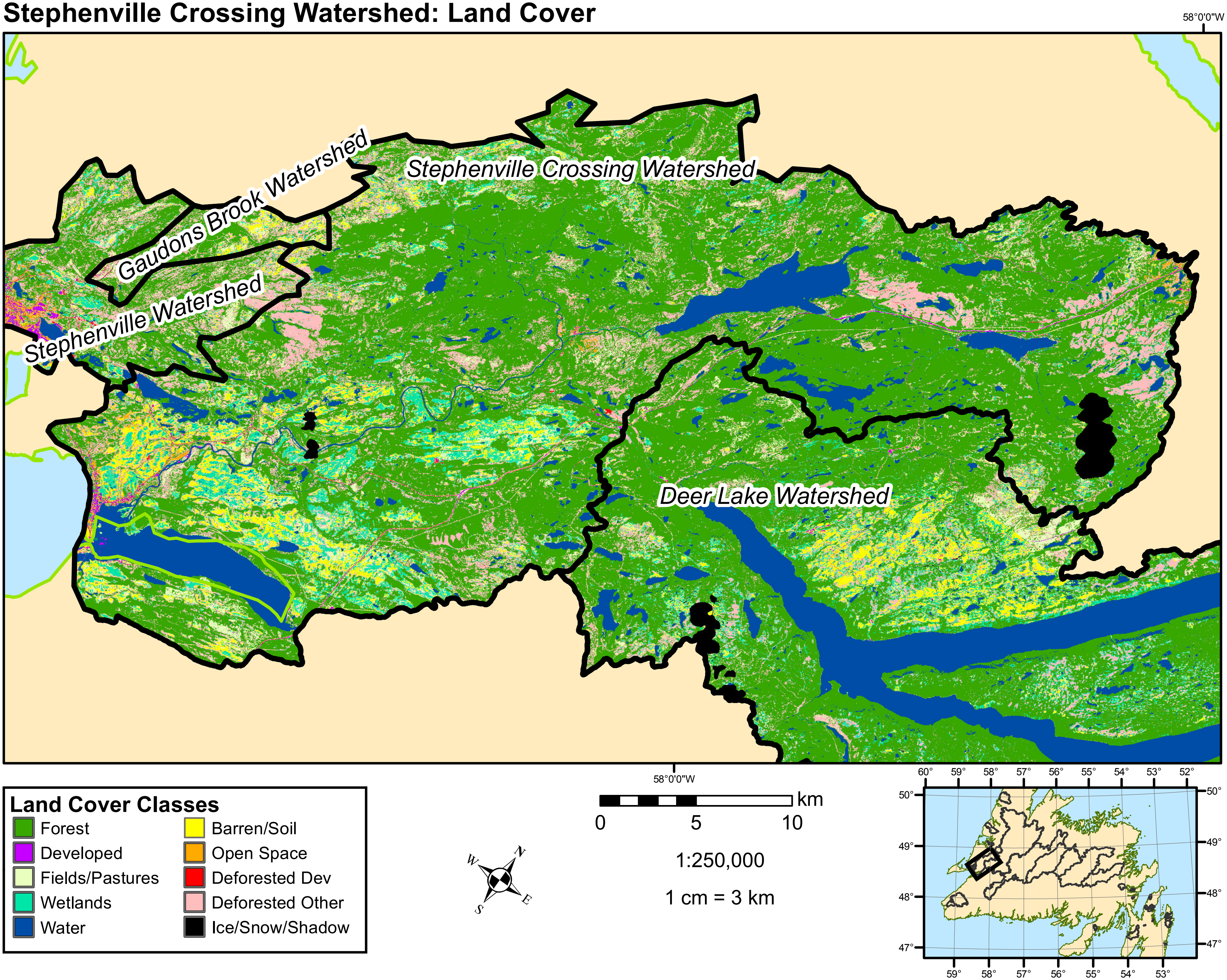
Rushy Pond Watershed: Land Cover



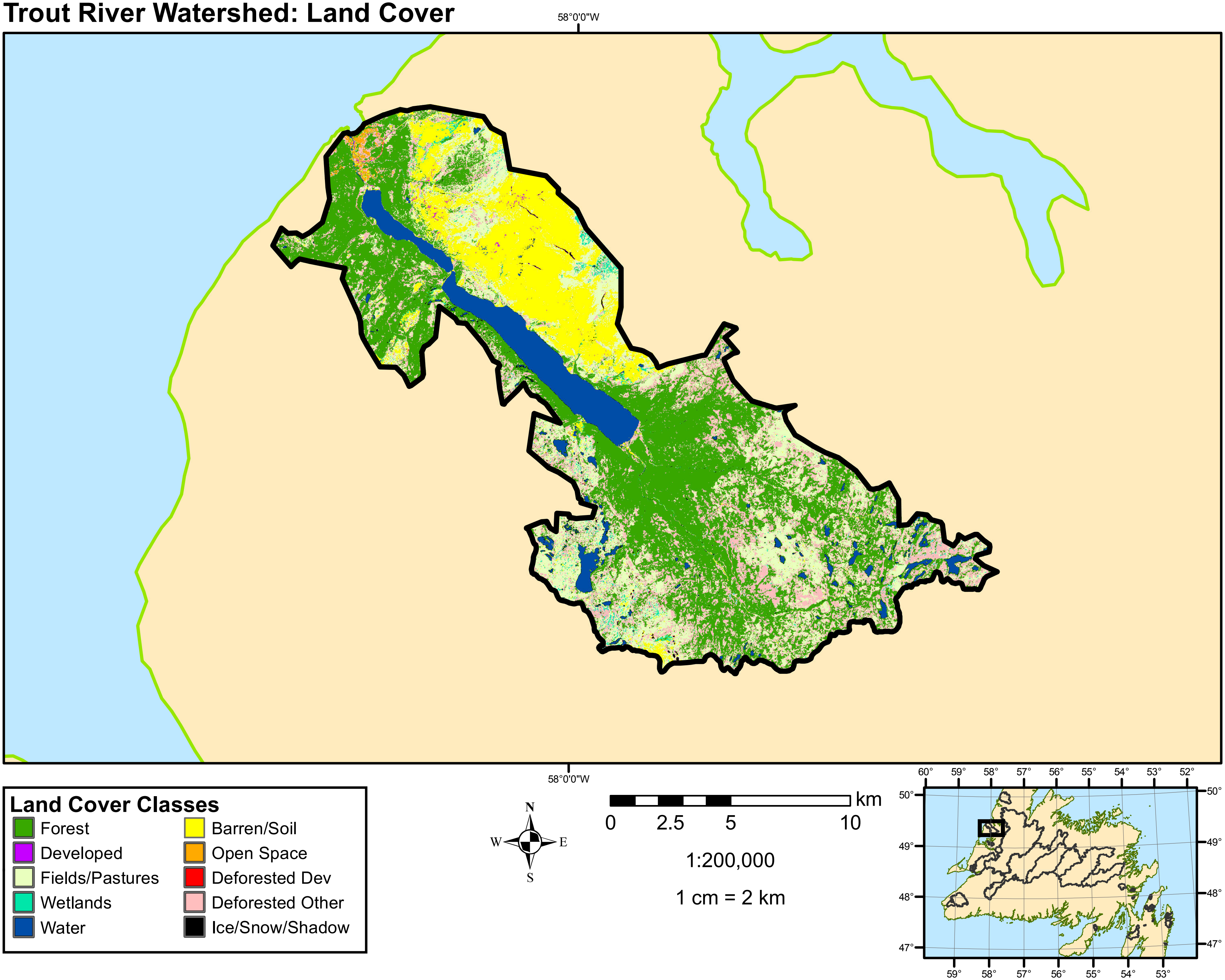
Steady Brook Watershed: Land Cover



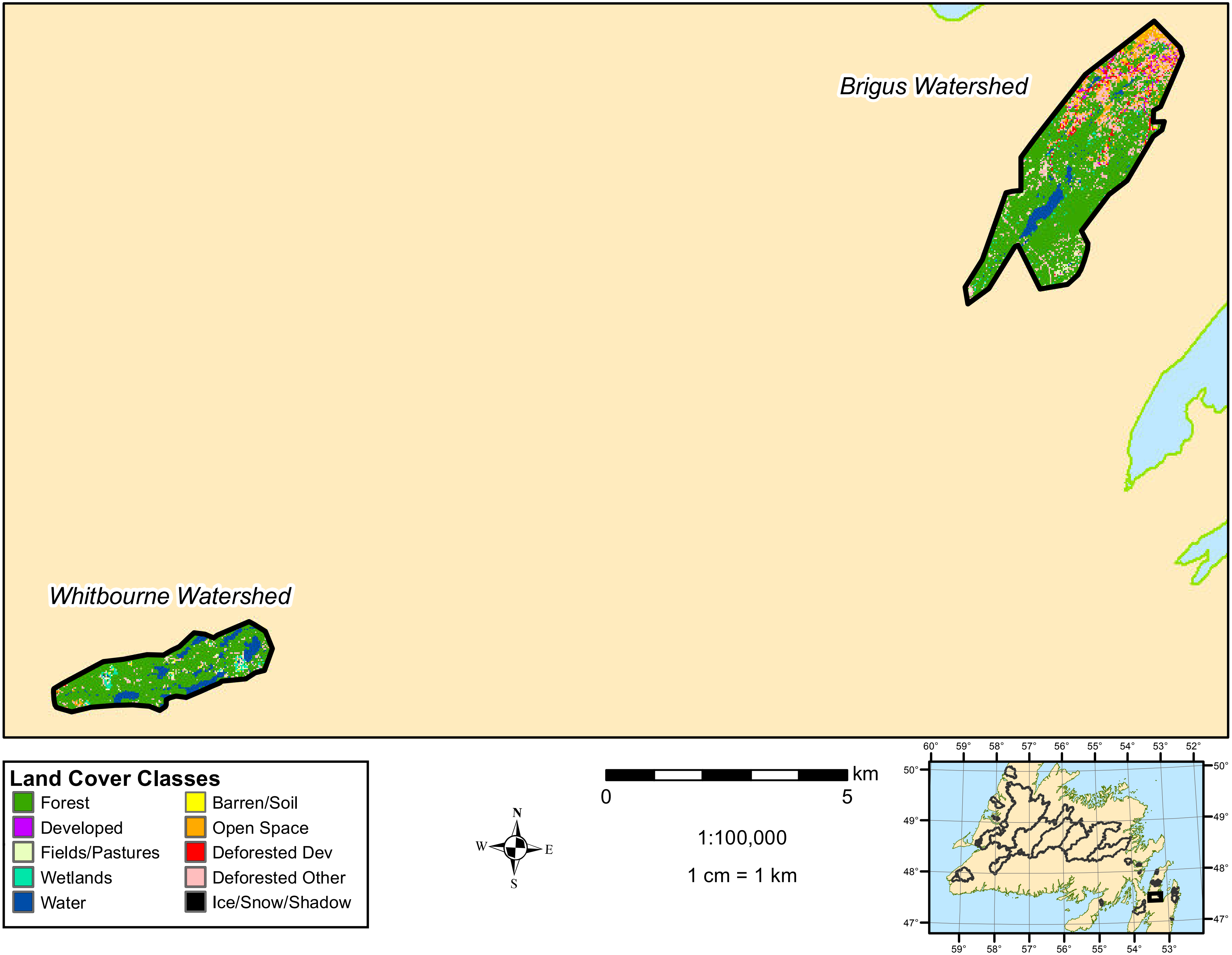
Stephenville Crossing Watershed: Land Cover



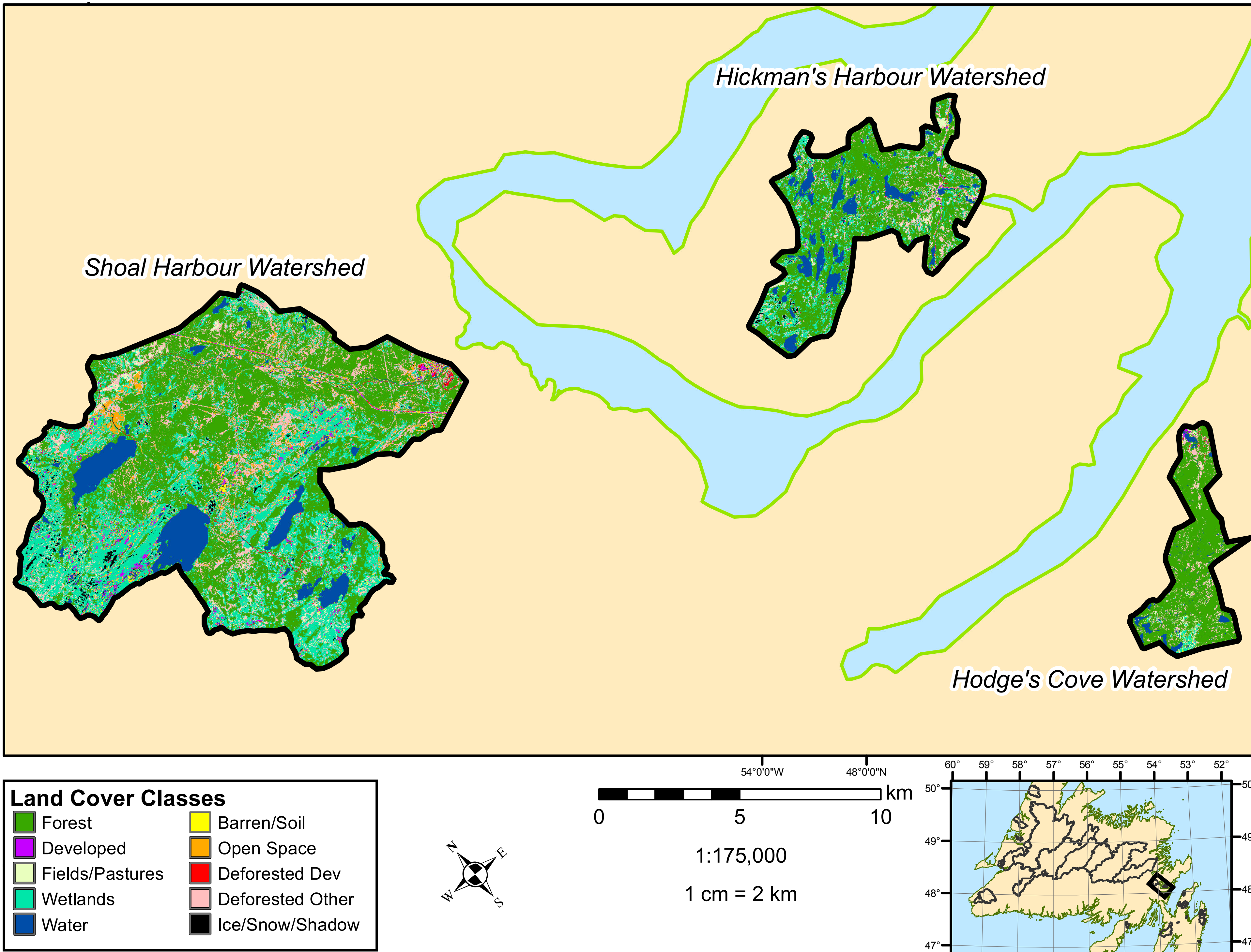
Trout River Watershed: Land Cover



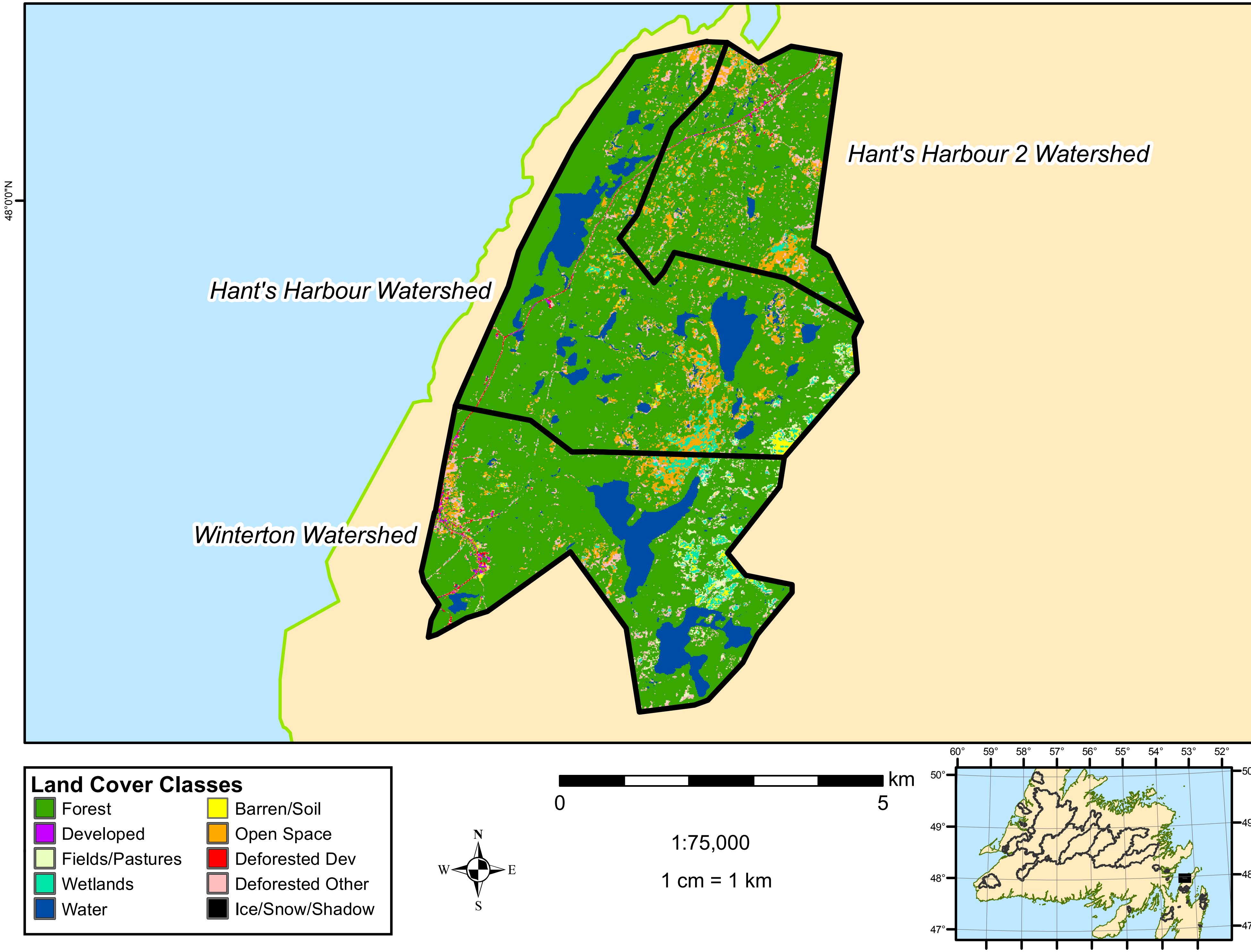
Whitbourne and Brigus Watersheds: Land Cover



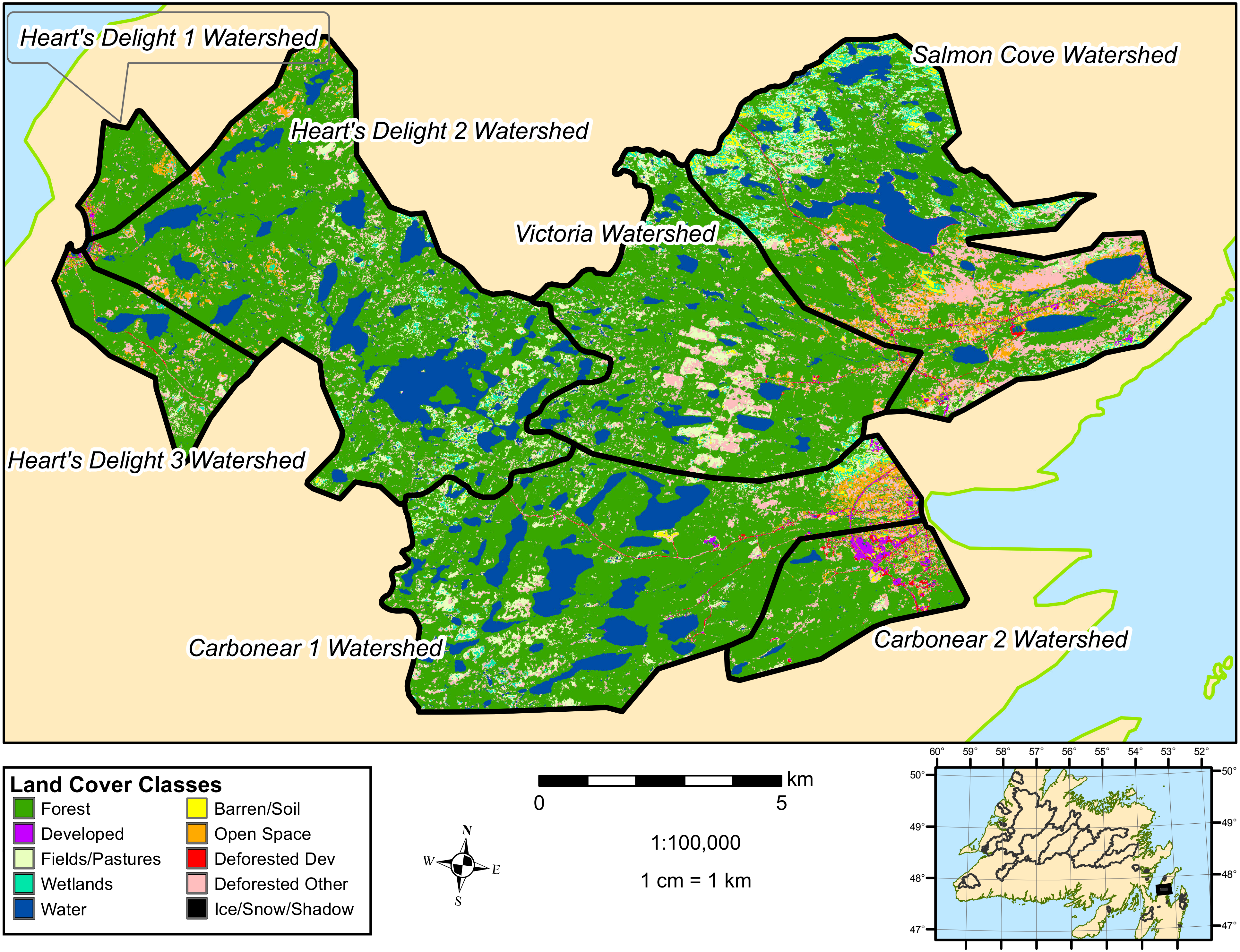
Eastern Watersheds 1: Land Cover



Eastern Watersheds 2: Land Cover



Eastern Watersheds: Land Cover



Eastern Watersheds, East: Land Cover