# Climate Change and Water Resource Management in Newfoundland and Labrador: Issues, Challenges and Adaptation Strategies

**September 2010**

Newfoundland Labrador


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# Introduction

“Water is the primary medium through which climate change influences Earth’s ecosystem and thus the livelihood and well-being of societies” (UN Water, 2010). Many of the predicted changes due to climate change such as altered temperatures, precipitation patterns and the increased frequency of storm events could greatly influence the hydrologic cycle. This will in turn impact the amount of available water, water quality, the occurrence of floods and numerous other physical and socio-economic factors in the province.

In Canada, climate change impacts will not be the same across the country (Marbek Resource Consultants, 2009). Owing to its large geographic size and variability, this is also true for Newfoundland and Labrador (NL). What this means, is from region-to-region, the impacts of climate change on local water resources will be different. The issues facing coastal communities may be quite different from inland or northern communities. Regardless of mitigation measures, it appears a number of changes to our environment are coming and communities throughout the province must be prepared to adapt to the inevitable impacts of climate change. UN Water notes that one of the main drivers of water resources management is climate change (2010).

One of the difficulties of developing adaptation plans to deal with climate change is that there remains a great deal of uncertainty in terms of the actual impacts climate change will bring to the earth in general and NL specifically. Many discussions are focused on predictions and theoretical expected impacts. With that said, there have been a few studies completed on actual observed climate change related impacts affecting water resources in NL. For example, the collection of ambient water quality has been ongoing in the province since 1986. A 2003 report on Water Quality Trends in Selected Water Bodies of Newfoundland and Labrador indicated statistically significant trends in water quality parameters even in pristine watersheds where there was little development activity. Decreasing trends were observed in major ions and conductivity, while increasing trends were observed in turbidity and colour. As these trends were observed in all regions of the province, their cause was linked to climate change. Trends in precipitation and stream flow from each region were also examined from 1986 to 2000. From each region there was a noticeable upward trend in precipitation. There was also a distinct upward trend in stream flow observed in Central and Labrador Regions, a slight upward trend in the Western Region and no discernable trend observed in the Eastern Region. Increased precipitation leads to increased runoff, which in turn leads to decreased concentrations of major ions (and conductivity), and increased sediment loads affecting turbidity and possibly colour. As well, in 2009 an update of the flood risk study for Stephenville revealed that the 24 hour – 100 year rainfall intensity has increased by 13 % for that region, indicating extreme precipitation events appear to be on the rise. These studies help illustrate that climate change is more than a theoretical issue and the results of these changes are already evident.

In NL, the Water Resources Management Division (WRMD) of the Department of Environment and Conservation (ENVC) is the lead agency for the management of water resources. As such, its programs and operations will also be influenced by climate change. It is essential for the Division to try and identify the issues and challenges climate change poses to the water resources of the province and their management. It would also be prudent to try and develop strategies to minimize negative impacts and where possible maximize any potential benefits that are foreseen. As the impending effects of climate change on water resources are broad ranging, WRMD faces numerous challenges and must consider how these changes impact many aspects of its programs. Adaptation strategies must consider the range of impacts predicted by climate change scenarios (Vescovi et al., 2009). Some of the more important issues include:

i. Climate Change Predictions
ii. Design of Hydraulic Structures
iii. Flood Risk Mapping
iv. Flood Forecasting
v. River Ice
vi. Snow
vii. Water Quantity
viii. Water Quality and Aquatic Ecosystems
ix. Drinking Water Quality
x. Water and Wastewater Infrastructure
xi. Groundwater

# i. Climate Change Predictions

### Issues and Challenges

In order to develop adaptation plans for water resources management it is important to know what the future climate change scenarios will be at a community or watershed level. Climate change predications are based on a set of climate change scenarios. The scenarios are a function of both the climate change model and greenhouse gas emission scenario used (Vescovi et al., 2009). As each scenario is equally plausible (Conner et al., 2009) it is important to use a range of climate change scenarios to get a holistic climate change prediction.

Unfortunately, the outputs of climate change models cannot be directly used for local water resources adaptation applications. This is because their climatic information resolutions are very coarse or large scaled. The outputs from these models are often geared towards a national, rather than regional or local perspective. For example, one of the most common types of models are General Circulation Models (GCMs). GCMs are mathematical models used to represent the global circulation of the Earth's atmosphere or ocean and are used to simulate the response of climate systems to different emission scenarios (IPCC, 2007). GCMs have very coarse or large scaled resolutions, in the range of 100 to 600 km.

In order to extract information useful for local adaptation planning, the information from climate models has to be downscaled to achieve finer resolutions using climatic downscaling techniques. Climatic downscaling techniques are methods used to derive relevant regional scale (i.e. 10 to 100 km) information of climate change from the outputs of larger-scale models such as the GCMs. Two main techniques are classified as dynamical downscaling (DD) and statistical downscaling (SD) (IPCC, 2007). Additionally, a combination of DD and SD may be used (Dialogue on Water and Climate, n.d.).

Dynamic downscaling techniques consist of using the outputs of a GCM as lateral boundary conditions for more sophisticated models of a limited geographic area and with a higher resolution in space. Dynamic downscaling involves using numerical meteorological modeling to reflect how global patterns affect local weather conditions. Simply put, through DD, outputs from a GCM are input into appropriate regional climate models (RCMs). A challenge in this approach is error propagation from GCM into RCM (Dialogue on Water and Climate, n.d.).

Statistical downscaling techniques consist of establishing empirical relationships between large-scale information and the local climate. That is, SD uses equations to bring global-scale projections down to a regional level. Based on the derived relationships the local climate can be simulated for many years of records at a given time scale (hours, days, months).

A large challenge facing the Province is that very limited climatic downscaling work has been done for NL. This makes the development of local adaptation plans difficult. A further challenge is that for NL, the various climate change models produce differing outputs that need to be taken in consideration in decision making.

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environment Program (UNEP) and the World Meterological Organization (WMO). The IPCC is regarded as the lead agency in the assessment of climate change and with regards to the environment and socio-economic impacts (www.ipcc.ch)

Outputs from 12 climate change models were compared by the IPCC (IPCC, 2007) to gauge their agreement. Where GCM results are not in agreement, there are increased challenges in using DS techniques (Dialogue on Water and Climate, n.d.). As shown in the figure below (IPCC Synthesis Report 4), NL is highlighted as one of the places were the models do not agree with each other. Despite the challenges in using DS techniques for NL, the DS work done has shown there will be increased precipitation and temperature (Lines, 2008).

**Projections and model consistency of relative changes in runoff by the end of the 21st century**

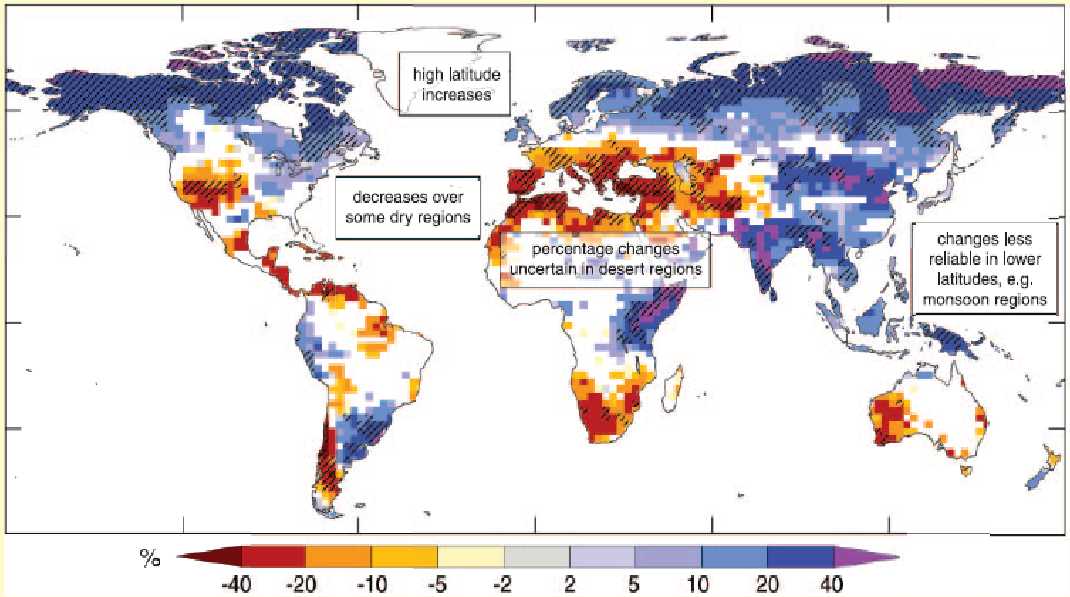



*Figure 3.5. Large-scale relative changes in annual runoff (water availability, in percent) for the period 2090-2099, relative to 1980-1999. Values represent the median of 12 climate models using the SRES A1B scenario. White areas are where less than 66% of the 12 models agree on the sign of change and hatched areas are where more than 90% of models agree on the sign of change. The quality of the simulation of the observed large-scale 20th century runoff is used as a basis for selecting the 12 models from the multi-model ensemble. The global map of annual runoff illustrates a large scale and is not intended to refer to smaller temporal and spatial scales. In areas where rainfall and runoff is very low (e.g. desert areas), small changes in runoff can lead to large percentage changes. In some regions, the sign of projected changes in runoff differs from recently observed trends. In some areas with projected increases in runoff, different seasonal effects are expected, such as increased wet season runoff and decreased dry season runoff. Studies using results from few climate models can be considerably different from the results presented here. {WGII Figure 3.4, adjusted to match the assumptions of Figure SYR 3.3; WGII 3.3.1, 3.4.1, 3.5.1}*

**Solution/Strategy**

The uncertainty involved in predicting the impacts of climate change at a local level in NL make planning and developing adaptation plans difficult. The highly technical and specialized skills involved in climate downscaling mean WRMD does not have the ability to perform the required climate downscaling work in-house. WRMD will need to collaborate with other agencies in order to combat this uncertainty.

WRMD plans to take the following measures to address the current lack of sound data available for predicting the impacts of climate change:

- WRMD will coordinate with Environment Canada's Atlantic Region climate change manager to access more climatic downscaling work.
- WRMD will work with Memorial University faculty to access any climatic downscaling research from a local perspective.
- WRMD will collaborate with the academic community to investigate the development of time series tools and summaries needed by climate

change researchers and policy makers to provide improved ability to access and analyze the data. These will be made available through the Newfoundland and Labrador Water Resources portal.

- WRMD, in conjunction with ENVC's Policy and Planning Division, will coordinate with the Office of Climate Change, Energy Efficiency and Emissions Trading in Executive Council to implement the Province's Climate Change Action Plan.

- WRMD will also collaborate and provide data support to the Office of Climate Change, Energy Efficiency and Emissions Trading in Executive Council and the Policy and Planning Division of ENVC where possible.

- As more downscaling results are made available through academic or federal research, WRMD will work to interpret these results and implement suitable climate change adaptation in its programs.

## ii. Design of Hydraulic Structures

**Issues and Challenges:**

Hydraulic structures are structures used to divert, restrict, stop or otherwise manage the natural flow of water (Coastal and Hydraulics Laboratory). Common examples include dams and culverts. Designing hydraulic structures to adequately handle the changes in precipitation patterns, storm events and the hydraulics of watersheds due to changing climate is a challenge facing the Province. Inadequately designed hydraulic structures can result in threats to the infrastructure, property and residents of NL. Culverts and bridges are often the points on a river or storm water system where flow is constricted. If these structures are not constructed with the capacity to handle peak flows they can essentially act as dams. This can cause water to backup and breach the normal flow channels resulting in flooding. Dams must also be designed, assessed and constructed to account for impending changes to water levels and flows to limit the potential for breaches and failures.

Engineers and planners need the correct data to design and manage drainage systems and related hydraulic structures. One important tool for this process is Intensity Duration Frequency Curves (IDFs). IDFs are graphs and statistics that provide information on the probability of extreme rainfall events for various durations (Atlantic Climate Centre). More specifically, they indicate the rainfall intensity (e.g. mm/hr), rainfall duration (i.e. how long did it rain at that intensity) and rainfall frequency (i.e. how often does a particular rainfall event occur). This information is essential for designing structures to handle peak flows and to prevent flooding and other unwanted occurrences.

The calculation of IDFs requires the collection of precipitation data at the same location over a long period of time. In NL, IDFs are computed from rainfall data recorded at climate stations operated under the Canada - Newfoundland Climate Stations and Programs Agreement. The calculation of IDFs requires precipitation data collected by tipping bucket rain gauges. Other types of rain gauges are not suitable for developing IDFs as they do not record the intensity of precipitation. As climate change will impact the frequency of extreme rainfall events it is necessary to update the IDFs (Vescovi et al., 2009).

WRMD relies on Environment Canada (EC) to produce IDFs as the province has not developed the in-house statistical capacity to compute them. Cutbacks in the Federal climate monitoring network in recent years have resulted in a shortage of the type of climate monitoring stations and data to provide IDFs. IDFs were once updated every ten years to ensure hydraulic infrastructure reflected the latest climate knowledge. The most recent large scale update of IDFs in Canada was

1990. An update planned in 2000 did not occur due to in large part to changing priorities at EC which also resulted in the removal of tipping bucket rain gauges. In 2009 EC did provide an update to IDFs but only five locations in NL had data after the year 2000. In the absence of more information from EC, one might suspect that these are the only locations with tipping bucket rain gauges that are left on the network in the province.

Table 1 below lists the stations / IDFs that were updated by EC in 2009. The five stations highlighted in red are the only stations with data more recent than 2000. It is interesting to note that despite the concentration of population and high level of development in St. John's, the most recent data available for those designing structures to be used in this area is 1996. It should also be noted that some of these locations in the table are probably redundant as they are too close to each other.

Table 1: List of IDFs in NL released in 2009 by Environment Canada

| **Intensity-Duration Frequency** | |
|---|---|
| **Station** | **Year** |
| Battle Harbour | 1983 |
| Burgeo | 1994 |
| Churchill Falls Airport | 1992 |
| Comfort Cove | 1995 |
| Daniels Harbour | 1995 |
| Deer Lake Airport | 2002 |
| Gander International Airport | 1990 |
| Goose Airport | 2007 |
| La Scie | 1995 |
| Mary's Harbour | 1995 |
| Nain | 2007 |
| Port Aux Basques | 1995 |
| St. Alban's | 1983 |
| St. Anthony | 1995 |
| St. John's Airport | 1996 |
| St. Lawrence | 1996 |
| Stephenville Airport | 2007 |
| Wabush Lake Airport | 2003 |

Climate change scenarios point towards an increase in precipitation (Dialogue on Water and Climate, n.d.). A comparison of the 1990 and 2007 IDFs for Stephenville was conducted during a recent update of the flood risk study for this area. This study revealed that the 24 hour – 100 year rainfall intensity has increased by 13 %. If a similar trend is occurring throughout the province this would suggest much of the infrastructure of the province is now under capacity due to climate change. It also indicates that IDFs that are not using recent data may not be adequate for determining the required capacity for hydraulic structures. The cost to the Province to replace storm damaged, improperly designed infrastructure is already considerable and can be expect to increase.

**Solution/Strategy:**

Despite the expanding number of climate change initiatives from the federal government in recent years, cutbacks to the climate monitoring network have degraded the quality and reliability of the data produced by the network for analyzing climate change patterns. As noted by Marbek Resource Consultants, improved hydrologic monitoring networks are necessary to assess climate change and to develop adaptive capacity (2009). Current reliance on the federal climate programs and products has hampered the Province's efforts to monitor and plan for adapting to climate change. The development of the capacity of the Province to ensure all provincial stakeholders are provided the required climate data for climate change analysis and other activities is essential to adapting to any future climate change scenarios. In order to effectively develop adaptation plans, WRMD could implement some of the following:

- The province may need to institute an independent climate monitoring network to supplement the federal system. In recent years WRMD has developed in house capacity to set up and operate real time automated climate stations with tipping bucket rain gauges.

- In order to provide the essential data for those designing hydraulic structures, WRMD should at minimum reinstate real time automated climate stations at the 18 locations that have had tipping bucket rain gauges in previous years. This would enable the use of historic data from these sites to be used in calculating IDFs.

- It would also be very beneficial to commission a network analysis to determine if additional climate stations are required.

- While ideally IDFs would be updated after every major storm event, they should be updated at least every 10 years.

- The operation of an independent climate monitoring network can be a very technical and challenging endeavor and will require dedicated resources. As an alternative to a totally independent network, WRMD could partner with the Department of Transportation to put additional sensors on their weather stations for the Road Weather Information System (RWIS). RWIS currently has 20 stations and is expected to expand to approximately 28 stations. These stations are generally well distributed through the province.

- The RWIS data is collected by AMEC. WRMD could work on developing tools for acquiring and displaying this data from AMEC.

# iii. Flood Risk Mapping

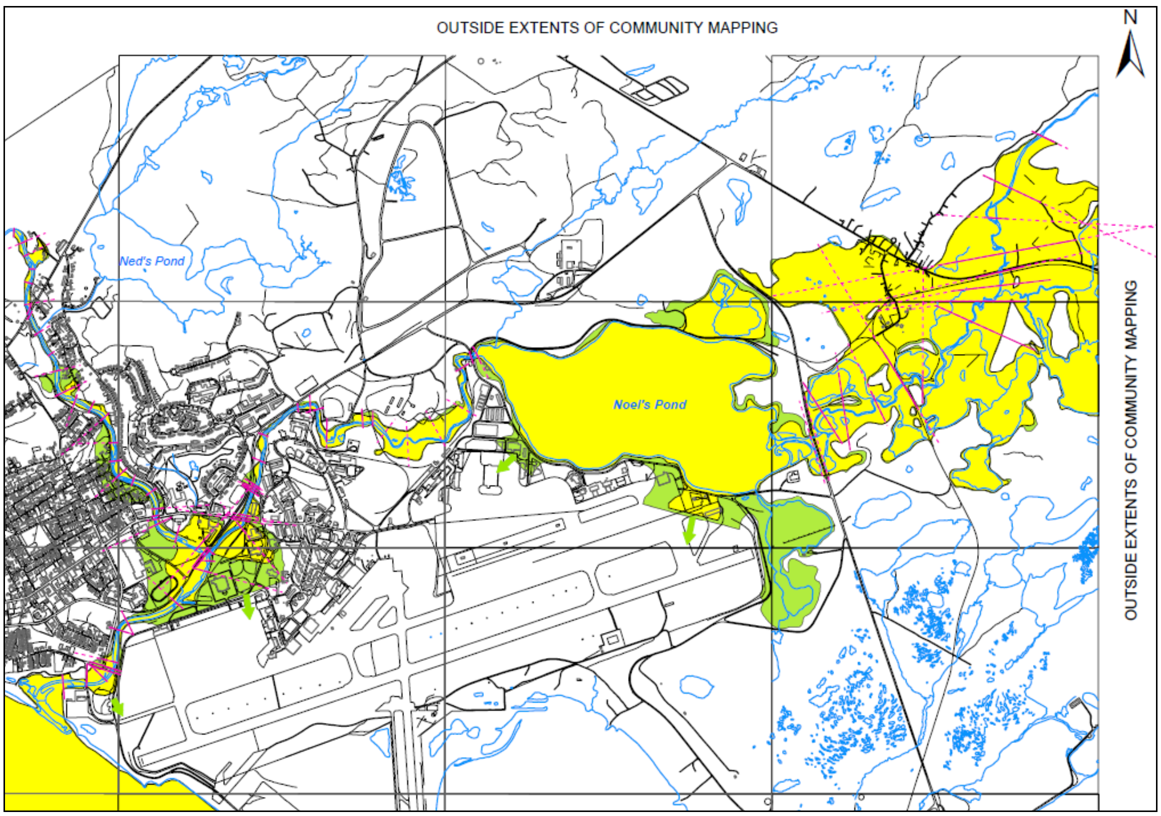
### Issue and Challenges

Floods are one of the most common natural hazards in NL and are often the most costly. The province experiences an average of six floods per year with an average cost greater than $3.2 million a year (Rogers, 2008). Flooding and erosion processes are quite difficult to control and avoid. As such, the best and most cost effective method of minimizing their impact is proper management and planning of mapped floodplains. Floodplain management usually involves the adoption of land use regulations that limit human exposure to areas prone to flooding events.

The province, in cooperation with the federal government, undertook hydrotechnical studies and mapping of flood risk areas in the 1980s and 1990s. There are 38 areas for which floodplains have been identified, studied and mapped using hydro technical studies and flood risk mapping (see Appendix 1 for a list of areas with flood risk mapping and year completed). The flood risk mapping for these areas is subdivided into two zones – the floodway and the flood fringe. The floodway is the portion of the floodplain where the risk of flooding is greatest and flood waters are deepest and most destructive. This is the area where floods have a return period of 20 years (5% chance in any year). The outer portion of the flood zone, the flood fringe, is the area where the risk of flooding is lower and water is generally slower and less hazardous than the floodway. The risk of flooding in the floodway is considered once in 100 years (1% chance in any year). These hydrotechnical studies and associated flood risk maps are critical for public safety, public information, municipal planning, development planning, the setting of structural design criteria, flood response and screening of compensation recipients under the Disaster Financial Assistance Arrangements. All proposed developments in flood risk zones are evaluated against potential impacts on water resources, the structures themselves, and the surrounding areas.

An anticipated impact of climate change is an increase in the occurrence of extreme precipitation events that result in flooding. Climate change in general is expected to result in warmer weather in winter and summer with an increase in total precipitation falling in fewer, but more intense events. Increase in precipitation, especially in intensity of precipitation events, will result in increased flooding events as capacities of natural streams and channels are exceeded and the water over flows the banks to flood homes, institutions, roads and other infrastructure. Not only will flood magnitude and flood frequency increase as a result of climate change but so will the seasonality (Dialogue on Water and Climate). For example, spring runoff will occur earlier (Vescovi et al., 2009). In addition to the extreme precipitation events, it is predicted that sea-level rise will also increase flooding for at-risk coastal communities (e.g. Placentia, Ferryland) (Batterson and Liverman, 2010).

As stated by the IPCC, extreme precipitation events will become more frequent due to climate change (2008). An analysis of the change in IDFs for Stephenville over the past several decades helps illustrate this issue. Between 1990 and 2007 the 24 hour hundred year rainfall intensity for Stephenville has gone up 13%. As well, based on downscaled results from two climate change models (Lines, 2008) the flows in Stephenville could potentially increase by 35 % (Hatch, 2009a) by 2040. The increase in flood area due to climate change is shown in the figure below (Hatch, 2009b).




The changes in precipitation patterns and associated high flows means most, if not all, of the old flood risk hydrotechnical studies and associated flood risk mapping have become outdated. There is an urgent public safety need to update this mapping. Without climate change adaptation, the damages that flooding will have on communities is predicted to double by the end of the century (Bates, 2008). In addition to these communities requiring updated flood risk mapping there are approximately 10 new communities (Conception Bay area, Corner Brook, Petty Harbour, and Springdale) that have requested and need new flood risk mapping.

**Solution/Strategy**

The province has pioneered a new method for incorporating climate change in flood risk mapping studies that was implemented for 2008-2009 Stephenville flood risk study. The 2008-09 Stephenville flood risk study adopted an approach reflecting new practices in flood risk mapping, which included predicting the effect of climate change. In this study, traditional 1:20 and 1:100 year flood lines were produced, as well as a 1:100 year climate change flood line. The study showed that the area flooded during a 1:100 year flood event will increase by approximately 20% due to climate change.

WRMD has recently initiated several projects to assist in incorporating climate change into the flood risk mapping process and has plans for more in the future. These include:

- Following up on the Stephenville flood risk study the Flood Plain Management policy has been amended to add a 1:100 year climate change category to the existing 20 and 100 year flood categories.

- All future flood risk studies will consider climate change scenarios. The 2008-09 Stephenville flood risk study is the template for future flood risk studies.

- In 2010-11, two new flood studies were undertaken by WRMD to address climate change impacts. The first study will produce flood risk maps for the communities of Stephenville Crossing, Black Duck Siding, and Shearstown (Bay Roberts). The maps in this study will include flood lines based on various climate change scenarios. The second study will identify communities that are vulnerable to flooding due to climate change and are in need of climate change adaptation work.

- In order to assist in identifying communities in need of updated flood risk mapping, WRMD is working on developing a satellite based land cover inventory of all communities that have reported major flooding. This will be used to track adverse changes in land cover that might increase the need for flood risk studies.

- The climate change flood lines are based on downscaled global climate change models and serve as an early warning of the potential flood zones. Since these are based on worst case scenarios they should be tracked/updated on a regular basis, at least once every 10 years.

- To ensure that flood risk studies are updated at least once every 10 years, at least four flood risk studies should be updated every year.

# iv. Flood Forecasting

### Issue and Challenges

Flood forecasting is an essential public safety function WRMD performs. Staff use climatic, stream flow, and other relevant data in conjunction with mathematical models to predict water levels and the risk of a river overflowing its banks. Flood forecasts and warnings are produced for areas that have a history of regular flooding. WRMD currently conducts flood forecasting for the community of Badger on the Exploits River and the Humber River valley communities of Steady Brook and Deer Lake.

"The key impact from climate change on water will come in the form of extreme events such as droughts and flooding, seasonal shifts in flow regimes, and reduced winter ice coverage" (National Round Table on the Environment and the Economy, 2009). As well, altered precipitation patterns could result in new communities experiencing regular floods and therefore requiring flood forecasting to protect public life.

Accurate flood forecasts rely on well calibrated complex mathematical models. As precipitation patterns change with time due to climate change there will be a need to update and recalibrate the models WRMD uses for flood forecasting.

### Solution/Strategy

Some of the plans WRMD has for addressing climate change in the flood forecasting process are:

- Flood forecasting models should be updated at least once every 10 years to account for changing precipitation patterns.
- Flooding events will be monitored continuously to identify any additional communities that would benefit from flood forecasting.
- WRMD will also try to obtain funding to automate the flood forecasting models it currently uses to make them more efficient and accurate.
- All future flood risk studies should investigate the feasibility of flood forecasting for the relevant areas.

## v. River Ice

### Issue and Challenges

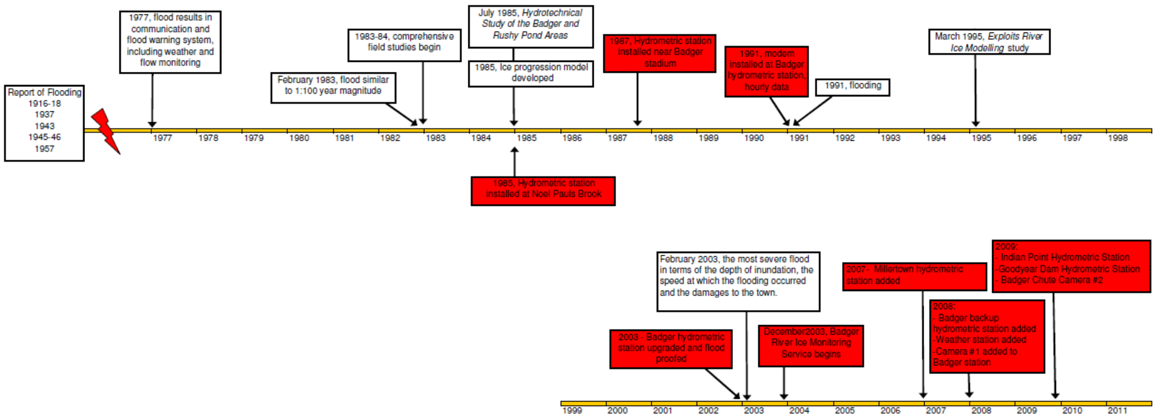
In 2003 there was a massive river ice break up flood in Badger unlike anything ever experienced before at the town. The river ice breakup process is greatly influenced by weather conditions and therefore will be impacted by climate change. Changing temperatures and increased weather variability will change river ice formation, reducing river ice coverage and duration (Marbek Resource Consultants, 2009; National Round Table on the Environment and the Economy, 2010) and breakup patterns resulting in more ice jams (Vescovi et al., 2009). There is currently no local research available on this topic in NL.

River ice behavior is complex and adapting to changes in river ice behavior requires having a means to monitor ice conditions in near real time. Following the 2003 flood WRMD enhanced the flood forecasting system for Badger. WRMD implemented an innovative satellite based river ice service in conjunction with an ice progression model. It also established a network of water monitoring stations, a weather station and two web cameras. The Badger river ice service was the first of its kind in the world and was developed in conjunction with the European Space Agency and local company C-CORE. Similar ice service systems derived from the Badger River Ice Service are now used nationally and internationally.

The Badger River Ice Service is gaining national and international recognition as a climate change adaptation tool and was featured as a climate change adaptation tool by the European Space Agency at the 2008 United Nations Climate Change Conference in Poland.

The evolution of the Badger Flood Forecasting System is shown in the below time line. The data for all water monitoring stations, the weather station, the web camera and the satellite imagery is available to the public, through the ENVC web page and is automatically updated.

## Badger Flood Forecasting System Timeline




### Solution/Strategy

The Badger Flood Forecasting System has received much national and international recognition especially for the River Ice Service. Over the last six years, the Badger River Ice Service has been presented at international meetings and workshops in Cambridge, England; Frascati, Italy; and Innsbruck, Austria. Building upon this success, WRMD will try to institute the following:

- The Badger River Ice Service will be used to continually adapt to climate change induced changes in ice behavior.
- A similar river ice service is being tested in the Churchill River and similar ice services will be developed as needed for smaller rivers (e.g. Rushoon) in the province as high resolution RADAR is made available from the various space agencies.

# vi. Snow

### Issue and Challenges

As stated by the Dialogue on Water and Climate, "the most important effect of climate change is the timing of streamflow. There will be more runoff during winter because less precipitation falls as snow".

Changes to average temperatures and the variability of temperatures will change the form and distribution of precipitation in NL. This is expected to have an impact on the distribution of snow cover in the province. It is very likely that more precipitation will fall as rain rather than snow (Bates, 2008) and more frequent rain-on-snow events (Marbek Resource Consultants, 2009). The change of snow to rain will impact seasonal flow patterns (UN Water, 2010). It is also expected that snowpack will develop later, will not accumulate to same depths and will melt earlier than currently experienced.

Snowpack is very important as it serves as a form of natural water storage. Changes in snowpack have implications for:

- hydro power generation
- drinking water supplies
- decrease in groundwater resources
- increased likelihood of flooding during winter months
- wildlife such as caribou
- recreational activities such as snowmobiling, skiing etc
- increased chance of low flows and drought
- altered flow patterns; spring runoff will likely be earlier and summer flows will be lower leading to water shortages in summer for recreational users and fish populations.

There is very limited snow monitoring in the province. Snow monitoring provides information on snow cover extent (SE), which is the area covered by snow, and on snow water equivalent (SWE), which is the amount of water that would be released by the melting snow. This information is critical for flood forecasting (Humber Valley and Exploits River), hydropower generation, wildlife studies, drinking water reservoir operation, and climate change adaptation in the province. Canada has no national snow monitoring and mapping program. Snow monitoring is undertaken by various agencies on an ad hoc basis without any national coordination or shared standards. In this province, hydro companies do snow surveys but there is a lack of consistency between the companies.

**Solution/Strategy**

WRMD is seeking to implement a state of the art provincial snow monitoring and mapping program that will utilize a combination of ground sensors with space satellite based sensors to create regular SE and SWE maps of the province. WRMD has started preliminary collaboration with Nalcor Energy, Deer Lake Power and other interested provincial agencies on this project. Using technology acquired through previous collaboration products with the European Space Agency (ESA), a snow mapping service was developed for the Humber Valley in 2007 to help with flood forecasting for the communities of Deer Lake and Steady Brook. ESA has offered to help create a space satellite based snow monitoring service for the Humber Valley under the international GlobSnow Project. NL is the only province in Canada to be invited to participate as a user in this project.

Moving forward, WRMD will investigate the feasibility of the following:

- The department intends to extend coverage of the snow products to the Exploits River basin to augment the Badger river ice service.
- WRMD will continue to work with the ESA on the GlobSnow project to develop satellite based snow water equivalent (SWE) mapping for the Humber River Valley, Exploits Valley, Churchill River and other sites of interest to Nalcor Energy and wildlife studies.
- The Division will also strive to expand its own snow monitoring network to allow the development and calibration of these SE and SWE products.
- These snow monitoring services could also be extended to important drinking water supply watersheds to help municipalities forecast water availability.
- The satellite based snow cover extent mapping will be made available to the public through the department's webpage and Newfoundland and Labrador Water Resources Portal for use by a wide variety of stakeholders and climate change researchers.
- WRMD could also look into the possibility of installing snow sensors on the Department of Transportation's weather stations for the Road Weather Information System.

## vii. Water Quantity

### Issue and Challenges

As outlined in previous sections, climate change will impact all aspects of the hydrological cycle particularly water levels, stream flows and the distribution of water in NL (Catto, 2010). Changes to the amount, type (i.e. snow vs. rain) and timing of precipitation will impact water quantity in the province. Although extreme precipitation events will increase, as noted by Catto, this may be offset by increased evaporation through increased temperatures and actually result in decreased water levels (2010). As with many ecosystem processes, prediction of water quantities can be complex and is interrelated with other physical and anthropogenic functions. Factors such as altered temperatures, changes to land cover (e.g. loss of wetlands) and land use practices (e.g. urbanization, clear cutting) will all play a role in the amount and timing of available water. Given the large size and geographic variability of NL it is quite likely that changes to water quantity will not be uniform throughout the province.

There is some uncertainty of the impacts that climate change will have on precipitation (Vescovi et al., 2009) and resultantly water resources. WRMD will face challenges managing the water resources of the province given the expected changes to water quantities and the uncertainty surrounding these changes. Changes to the hydrologic cycles and thus the timing of water amounts could lead to both increased flooding and water shortages. It is predicted that increasing severity of precipitation events could lead a greater number of spring floods. In addition to decreasing snow pack and spring runoff, "increased rates of evapotranspiration are anticipated to exacerbate existing water scarcity challenges" (Marbek Resource Consultants, 2009), leading to water shortages during the summer. Water scarcity challenges and low flow events will lead to water use conflicts between various sectors such as industrial, agricultural and municipal (UN Water, 2010). This is compounded by the fact that there is a lack of sound knowledge on the extent of water uses by various sectors as well as a general lack of water conservation and efficiency measures by these sectors. Due to their ability to retain water, wetlands will mitigate some of the impacts of climate change on water resources (Marbek Resource Consultants, 2009).

### Solution/Strategy

WRMD has for a number of years invested significant resources into the monitoring of water quantity in NL. The province currently operates a hydrometric network as part of the Canada - Newfoundland Water Quantity Surveys Agreement and a real time water quantity and quality network as part of the Canada - Newfoundland Water Quality Monitoring Agreement. The Division can implement a number of measures to continue to assess any impacts climate change may have on water quantities such as:

- WRMD will continue to participate in the hydrometric and real-time programs and analyze the resulting data to monitor changes to the amount and timing water levels.

- The hydrometric and real-time networks will be expanded as needed to address any climate change impacts.

- The water quality and quantity collected by the provincial networks is currently, and will continue to be, available to a wide variety of stakeholders and climate change researchers for climate change analysis and studies.

- WRMD may have to play a role in anticipating and resolving water use conflicts that could arise.

- The Department will promote multi-use concepts of water use, conducting studies to advance water conservation and efficiency measures and encourage their implementation to ensure the conservation and appreciation of the value of water resources.

- WRMD can also enhance water use monitoring to acquire sound knowledge on the extent of water uses by new and existing users.

## viii. Water Quality and Aquatic Ecosystems

### Issue and Challenges

In addition to water quantity, climate change is expected to have an impact on water quality. Impacts of climate change such as decreased water levels and stream flows, as well as increased water temperatures, will result in a degraded water quality (World Meteorological Organization et al., 2009). The resulting changes to hydrologic characteristics and fundamental ecosystem processes will impact all organisms that live in or around aquatic environments. As the water chemistry of a water body changes, the aquatic ecology is also impacted. There will likely be a substantial shift in the habitats and associated benthic populations (i.e. organisms living at the bottom of water bodies), fish populations and algal populations that inhabit the provinces waters. Some probable impacts include:

- Increased water temperatures may decrease ecosystem biodiversity and increase algae and toxic cyanobacteria blooms (UN Water, 2010). For example, current aquatic species may not be able to tolerate a warming water temperature trend leading to mass migrations.

- Many aquatic species have optimal water temperatures needed for hatching, growth and other essential functions and have adapted to current conditions. Many fish species will be affected by climate change (Catto, 2009). Changing water temperature may impact the life cycles of aquatic organisms.

- Changing hydrology, in the form of seasonally higher or lower flows, may result in a significant alteration in biological assemblages of benthic invertebrates (e.g. organisms that attach to substrate may not be able to tolerate increased flows).

- Increased water temperatures will lead to increasing eutrophication - the increased plant growth in and around water bodies (Dialogue on Water and Climate, n.d.). This will lead to higher oxygen consumption rates causing stress to these aquatic ecosystems

- Changing hydrology will likely impact the various zones of the water bodies thus leading to changes in available “living space” for aquatic organisms.

- “Higher water temperatures, increased precipitation intensity, and longer periods of low flows are projected to exacerbate many forms of water pollution, including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution” (Bates, 2008).

- Changes in certain water quality parameters (e.g. water temperature; pH; etc.) may have toxicity modifying effects on other compounds in the aquatic ecosystem. For example, the increasing toxicity of certain compounds will lead to a change in certain organisms presence due to varying degrees of tolerability.

- Sea level rise will alter the chemistry of water bodies and wetlands near the coastal environment through the intrusion of salt water again altering the aquatic ecology and beneficial uses.

- Water residence times, and routes in the hydrologic cycle will be impacted, which may negatively impact the quality (Dialogue on Water and Climate, n.d.).

**Solution/Strategy**

The issues facing aquatic ecosystems due to changing water quantity and quality are extensive and complex. Improving WRMD's knowledge of these ecosystems and finding effective means of sharing this information with interested stakeholders will help develop adaptive means of dealing with this uncertainty. A number of strategies can be implemented to best face these challenges including:

- WRMD can improve the Environmental Monitoring Networks to gather baseline information. There is an inherent need to fill the knowledge gap that exists in the understanding of the interaction between the environment and ecosystems. Much remains unknown as to how water quantity and quality impact various aquatic ecosystems and what adaptations are needed to minimize the impacts to these sensitive ecosystems. Improved monitoring of water quality and quantity through the following programs will provide much needed information to better assess the current aquatic ecosystems and to be able to make predictions about future impacts:

    i. Hydrometric Monitoring (water quantity)
    ii. Water Quality Monitoring (grab samples)
    iii. Real-time Water Quality Monitoring
    iv. Aquatic Benthic Bio-monitoring – WRMD has participated in the Canadian Aquatic Biomonitoring Network (CABIN), an aquatic biological monitoring program for assessing the health of freshwater ecosystems in Canada.
    v. Climate Monitoring

- WRMD will aim to update the Trend Analysis Report. A report entitled Water Quality Trends in Selected Water Bodies of Newfoundland & Labrador was prepared in 2003. The Trend Analysis Report examines trends in 36 different water quality parameters from 65 different water quality monitoring stations located on representative rivers throughout the province of NL. There is an inherent need to update the Trend Analysis Report using the grab sample data collected under the Water Quality Monitoring Agreement as well as the inclusion of real-time water quality data. This will help determine how the chemistry of water bodies has been changing overtime.

- WRMD will continue to conduct Intensive Surveys on various water bodies throughout NL to provide useful information to better assess aquatic health. The intensive surveys integrate a variety of monitoring including water, sediment and fish tissue chemistry as well as benthic invertebrate assessment. These intensive surveys will continue to provide important data to better understand the impact of climate change.

- WRMD will continue to research and develop new methods and innovative technologies for assessing the overall health of the aquatic ecosystems and the factors that influence it. Some examples include the use of remote sensing technology to predict water quality, the development of site-specific objectives and real-time monitoring for Blue-Green Algae

- The Division will continue to partner with the federal government and industry in order to avail of the knowledge, expertise and resources that will allow programs/projects to move forward.

- WRMD will continue to develop methods and products that will convert information into knowledge. The citizens of NL need a clear understanding of the impacts that climate change are having and will continue to have on the Province's water resources. Products such as technical reports, GIS-based tools and fact sheets should continue to be developed and made easily available to interested parties.

## ix. Drinking Water Quality

### Issue and Challenges

WRMD is committed to ensuring the residents of NL have access to safe and clean drinking water. The provision of safe drinking water is a multi-faceted process that includes, among other aspects, the protection of drinking water sources, effective treatment of source water and suitable distribution systems. While the impacts climate change will have on the supply of drinking water are uncertain, the potential threats it poses to all aspects of this process are widespread and include:

- Typically, an increase in nutrient and contaminant loading is an issue due to climate change. For example, as water levels decrease the general trend of water quality is to decrease as well. This is due to the dilution of compounds in the water column with the same quantity of contaminants or aesthetic parameters in a smaller quantity of water.

- An increase in frequency and intensity of precipitation events increases the runoff in both rural and urban areas which contribute to the deterioration of the drinking water source quality due to excess contaminants (Bates, 2008). The concentrations of these parameters will have to be monitored to ensure that values do not exceed the Guidelines for Canadian Drinking Water Quality.

- Increased water temperature is an established threat of climate change and can decrease the effectiveness of chlorination and increase the risk of bacteriological re-growth.

- There is normally a risk of increased rates of waterborne diseases due to increased precipitation events.

- As water temperatures rise and nutrient levels increase there may be an increase in algae growth that release toxins that would impact public health (Bates, 2008). NL has had little issue with algae growth in public water supplies to date but indicators seem to point to increased algae growth in non-drinking water bodies that could extend to the drinking water supplies depending on climate change factors.

- As sea levels rise there will be an increased risk of saltwater intrusion into groundwater public and private drinking water wells. NL, with an abundance of coastline with the majority of communities situated on the coastline will be at risk of increased sodium and chloride levels in these drinking water supplies.

**Solution/Strategy**

Ensuring clean and safe drinking water is a challenge as outlined above. Building on the Division's strong existing programs and policies will be essential. Some of the measures WRMD plans to take are:

- The Protection of Public Water Supplies is to be strengthened by replacing the Policy for Land and Water Related Developments in Protected Public Water Supply Areas (WR 95-01) by Regulations. This will strengthen the regulatory framework of the protection status for public drinking water supplies. Through the new regulations, more stringent conditions for Permits for Development can be administered in relation to both water and land uses in Protected Public Water Supply Areas.

- The drinking water quality monitoring program is an evolving program that is modified when required to address the issues that arise in drinking water safety. The monitoring program is flexible in data collection, review of results, reporting and identification of emerging issues to address the additional requirements that may be essential to address drinking water quality safety introduced to NL's drinking water supplies due to climate change.

- The Operator Education, Training and Certification (OETC) program has a mandate to provide job competency training to municipal water and wastewater operators throughout the province. The program will need to be available to provide instruction and training on changes in operation and maintenance techniques and related technology as it relates to climate change impacts on the operation and maintenance of water and wastewater systems. The OETC Program is constantly under review in terms of education/training curriculum content. The program is flexible to the needs of municipal water and wastewater system operators and will customize the training opportunities offered through our program to deal with the above issues and challenges.

## x. Water and Wastewater Infrastructure

### Issue and Challenges

The management of wastewater, storm water and drinking water as well as the infrastructure related to these utilities will also face challenges due to climate change. Many of the impacts discussed previously, such as changes in the amount and timing of precipitation, have implications for the planning, management and design of these utilities. Some of the most serious issues include:

- Increasing coastal storm surge events are a concern, particularly given the large number of coastal communities in the Province. Such events frequently destroy water and sewer infrastructure, including washing out water and sewer pipes along coastal roads, destroying sewage outfalls, flooding septic tanks, and surcharging the sewage collection system. Wastewater treatment plants are usually located in low lying coastal areas and are particularly vulnerable to rising sea level effects.

- Increased potential for flood events has multiple implications. It can lead to poor source water quality and operational issues, such as capacity overload (Bates, 2008), with water treatment plants thus poor drinking water quality. It can also result in the failure of drinking water reservoir dams, washed out water and sewer pipes, increased infiltration into sanitary sewers, sanitary/combined/storm sewer overflows, bypassing of wastewater treatment plants and surcharging of wastewater treatment plants.

- Low flow events will result in water shortages and decrease the effectiveness of drinking water quality treatment (Catto 2010; Dialogue on Water and Climate, n.d.). Additionally, this can result in more concentrated sewage effluent discharged to inland water bodies, threatening public health.

- Design of water treatment and wastewater treatment plants is based on historical water quantity and quality data. Climate change will have impacts on water quantity and quality over the typical 25 year design life of such facilities resulting in reduced performance of such plants (UN Water, 2010).

- The province currently has no guidelines for stormwater management.

- Climate change effects will result in more regulatory violations, increased infrastructure spending and more issuing of permits to reconstruct destroyed water and sewer infrastructure.

**Solution/Strategy**

WRMD also has a number of potential strategies it hopes to put in place to address pending impacts to water and wastewater infrastructure. These strategies focus on improving monitoring, planning and collaboration and include:

- WRMD can develop relevant climate change indicators for monitoring (including number of sewer overflows per year, number of permits for infrastructure re-construction issued, etc.). More study should be undertaken on the effects of climate change on water and sewer systems in the province.

- The Province can move forward with developing a phased plan to address stormwater management.

- ENVC design guidelines should include a section on how to deal with climate change issues for water and sewage systems. Design tools for flood and low flow analysis should include the most recent data available. OETC section will assist Operators in adjusting practices as required.

- WRMD can undertake water and wastewater system modeling to better understand likely effects of climate change in the province.

- WRMD can promote an integrated watershed management approach.

- WRMD can promote a water conservation approach.

## xi. Groundwater

### Issue and Challenges

Groundwater monitoring is important for effective water management. Information, including movement, availability and quality of groundwater collected through monitoring, provides water resource managers with key data and knowledge to enable sustainable use and long term planning. As well, groundwater is an important source of drinking water for many residents of NL.

Climate change can lead to a number of impacts on groundwater including changes to rates of recharge, groundwater levels and groundwater quality.
The IPCC state that despite heavier precipitation events the rate of groundwater recharge will be reduced by longer dry periods (2008). The heavier precipitation events may actually pose a threat, through contamination, to the quality of the groundwater (Marbek Resource Consultants, 2009; UN Water, 2010). Coastal groundwater sources can also be at risk for sea water intrusion due to rising sea levels (Batterson and Liverman, 2010; World Meteorological Organization et al., 2009) In particular, shallow groundwater sources are most at risk (Dialogue on Water and Climate).

### Solution/Strategy

WRMD has plans to monitor the impacts of climate change on groundwater resources in the province such as:

- WRMD plans to implement an enhanced monitoring network in order to characterize the location, quality and sustainable yield of the groundwater resource and to describe where, how and why this resource may be changing.

- WRMD will attempt to locate monitoring wells in hydrostratigraphic units with the greatest water use and areas identified as “at risk” due to potential effects of climate change, including changes in recharge (i.e. drought) or changes in quality (i.e. sea-water intrusion). Information collected at these sites will provide benefits by improving understanding of the response of this resource to such stresses as droughts and changes in water supply and demand.

- Ideally, sites will be identified that could be coupled with surface-water monitoring sites, in order to address groundwater-surface water interactions and enhance the understanding of effects of climate change on both.

## Summary

"Managing water has always been about managing naturally occurring variability. Climate change threatens to make this variability greater, shifting and intensifying the extremes, and introduces greater uncertainty in the quantity and quality of supply over the long term" (Conner et al., 2009). Current predictions indicate the impact of climate change on water resources will be widespread. Increased occurrences of flooding, water shortages and degraded water quality are all potential issues the province may have to face. Unfortunately, the uncertainty surrounding future climate change scenarios and how they will play out on a local level makes it especially difficult to develop effective management and adaptation plans. Despite this there are a number of strategies WRMD can employ to assist water resource management in NL.

WRMD will continue to find innovative means to monitor the impact climate change is having on the provinces water resources. Given the broad scope of climate change impacts, WRMD will partner with other agencies to share expertise and resources where possible. The Division will adapt existing standards, practices and guidelines as conditions necessitate. As well, WRMD will use the strength and flexibility of its existing programs, and develop new initiatives as required, to assist the communities of the province to adapt to our changing environment.

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## Appendix 1 – Areas with Existing Flood Risk Mapping

| Community | Year of Study |
|---|---|
| Appleton | 1989 |
| Badger | 1985 |
| Bishops Falls | 1990 |
| Black Duck Siding | 1988 |
| Brigus | |
| Carbonear | 1996 |
| Codroy Valley | 1990 |
| Cold Brook | 1996 |
| Cox's Cove | 1988 |
| Deer Lake | 1987 |
| Ferryland | 1996 |
| Gaudon's Brook | 1996 |
| Glenwood | 1989 |
| Glovertown | 1989 |
| Goulds | 1996 |
| Hant's Harbour | 1996 |
| Heart's Delight | 1996 |
| Hickman's Harbour | 1995 |
| Hodges Cove | 1995 |
| Kippens | 1996 |
| Outer Cove | 1996 |
| Parson's Pond | 1988 |
| Petty Harbour | 1996 |
| Placentia | 1985 |
| Portugal Cove | 1996 |
| Rushoon | 1986 |
| Rushy Pond | 1985 |
| Salmon Cove | 1996 |
| Shoal Harbour | 1995 |
| St. Philips | 1996 |
| Steady Brook | 1984 |
| Stephenville | 2009 |
| Stephenville Crossing | 1988 |
| Trout River | 1990 |
| Victoria | 1996 |
| Waterford River | 1988 |
| Whitbourne | 1996 |
| Winterton | 1996 |

# Appendix 2 – Communities which have Requested New or Updated Flood Risk Mapping

1. Carbonear, Conception Bay area, added March 10, 2010
2. Victoria, Conception Bay area, added March 10, 2010
3. Salmon Cove, Conception Bay area, added March 10, 2010
4. Whitbourne, Conception Bay Area, added March 10, 2010
5. Heart's Delight, Conception Bay area, added March 10, 2010
6. Winterton, Conception Bay area, added March 10, 2010
7. Hant's Harbour, Conception Bay area, added March 10, 2010
8. Corner Brook added March 10, 2010
9. Petty Harbour added March 10, 2010
10. Springdale added July 29, 2010