New Nouveau Brunswick CANADA

Atlantic Region Adaptation Science Activities

Department of Environment

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ATLANTIC REGION ADAPTATION SCIENCE ACTIVITIES

Abstract: On the Atlantic coast of Canada, the predicted effects of climate change, such as sea-level rise and the increased occurrence and intensity of extreme weather events, are compounded in many areas by post-glacial crustal subsidence, leading to increased coastal erosion and flooding. This places dykelands, coastal populations and their infrastructure and industries at risk. Trends in hydrologic data are already beginning to appear in New Brunswick hydrometric records to support the predictions of local climate scenarios developed using statistical downscaling from global models. Ice on lakes, rivers and along the coast is forming later, mid-winter break ups are occurring more often and the dates of spring floods have advanced to earlier in the year. Saltwater intrusion into freshwater aquifers is a growing concern as coastal municipalities and industries work to achieve a balance between changing demands and availability. Impacts to municipal water supplies, agriculture, forestry, fisheries, tourism and energy are also expected as water resources come under increased pressure. The predicted regional impacts of climate change assembled from the general scientific literature and the work presented at jurisdictional expert conferences and workshops held in New Brunswick are summarized. Recognizing the importance and benefits of working collaboratively on regional adaptation issues, the Atlantic Provinces have adopted a Climate Change Adaptation Strategy. Within the framework of this Atlantic Adaptation Strategy, and as part of the Natural Resources Canada Regional Adaptation Collaboration Program, a number of projects, informed by science, are being proposed by the Atlantic Provinces. These projects are intended to develop tools and approaches that will support appropriate adaptation planning and decision making for coastal areas, inland waterways and for related infrastructure.

Keywords: adaptation, climate change, infrastructure, statistical downscaling, Atlantic Canada, sea-level rise, flooding, regional collaboration

1. Introduction

The scientific consensus is that climate change due to human activities is occurring now, and will become more pronounced in the future. The Intergovernmental Panel on Climate Change (IPCC Working Group I, 2007) have deemed the evidence of climate change as “unequivocal” as we observe increasing global air and ocean temperatures, widespread melting of snow and ice and rising sea level. Computer models, used to simulate the changes to the global climate induced by human activities, predict that the climate will become warmer, as global average surface temperatures are predicted to rise between 1.1°C and 6.4 °C over the next hundred years (IPCC Working Group I, 2007). Such changes in the earth’s temperature are unprecedented in the last 10,000 years.

Efforts to decrease greenhouse gas emissions are required, but these efforts will not stop further climate change from occurring. Climate changes have already begun and will continue throughout the 21st century, thereby affecting our natural environment and resources significantly. What may appear to be relatively small changes in temperature are linked to substantial changes in the physical environment. Changes in weather and climate have numerous ancillary effects on other vital aspects of the total environment such as the water cycle, vegetation, pests, diseases, fire risk, floods and droughts, food production, and human health. Therefore, changes induced by climatic change will have a significant effect on the health and economic well-being of all Atlantic Canadians. Adaptation to changing environmental conditions is necessary to lessen the effects of climate change.

In the Atlantic region, unlike other parts of Canada, the predicted effects of climate change, such as sea-level rise and the increased occurrence and intensity of extreme weather events, are compounded in many coastal areas by post-glacial crustal subsidence. This will increase coastal erosion and flooding, placing dykelands, coastal populations and their infrastructure and industries at risk.

Scientific work (including monitoring, research, special investigations, and a review of scientific literature) provides an understanding of the many risks posed by climate change, which natural and human systems are likely to be most vulnerable, and what might be achieved by adaptive responses. This scientific work, commonly referred to as adaptation science, is required in the immediate future to provide a sound basis for policy, planning, and program delivery aimed at offsetting the impacts of climate change.

This report focuses on adaptation science activities previously conducted in Atlantic Canada (the provinces of New Brunswick, Newfoundland and Labrador, Nova Scotia, and Prince Edward Island) and identifies areas in need of future research to identify the consequences of climate change and potential adaptation responses. The following section summarizes climate projections to the end of this century for Atlantic Canada, and more specifically New Brunswick, based on the results of statistical downscaling of global climate models. The subsequent section provides an overview of the changes already being observed in Atlantic Canada based on the examination of historical climate records. This is followed by a summary of the predicted regional impacts of climate change assembled from the general scientific literature and the work presented at jurisdictional expert conferences and workshops. The last two sections of the report present an overview of the Atlantic Canada Climate Change Adaptation Strategy and the project areas being addressed as part of the Natural Resources Canada Regional Adaptation Collaboration Program.

2. Climate Projections for Atlantic Canada

Although future climates cannot be predicted with certainty, confidence in many aspects of climatic prediction is growing as global climate models become more advanced.

At present, the prediction of future climates is largely based on coarsely gridded global climate models that are being developed by researchers around the world for various greenhouse gas emissions scenarios (IPCC Working Group I, 2007). In order for these models to be of use at a regional and local scale, statistical downscaling techniques based on historical climate observations are commonly used. This method enables more detailed local-scale predictions to be elaborated on from relatively coarse global climate models outputs [i.e., the reliability of predictions improve as “predictions” of past climate improve].

Swansburg et al. (2004) and Lines et al. (2006) developed statistical downscaling model outputs of the first version of the Canadian Global Climate Model (CGCM1) in order to generate local climatic scenarios for New Brunswick and the Atlantic region respectively. While their work was based on the first generation of climate change scenarios, these efforts have been major contributions to climate change prediction in Atlantic Canada and have provided some of the most detailed predictions of future climatic conditions for the region to date.

Local climate scenarios for New Brunswick
Swansburg et al. (2004) generated local hydro-climatic scenarios for seven meteorological stations in New Brunswick for the period of 2010 to 2099. Using the CGCM1 with, what was hoped to be a worst-case scenario of tripling of carbon dioxide concentrations over pre-industrial levels by 2100, They predicted that annual and seasonal maximum and minimum air temperature would increase significantly across New Brunswick throughout the 2020's, 2050's and 2080's compared to conditions during the period 1961 to 1990. They estimated that the annual minimum air temperature would increase by approximately 4 to 5°C, while maximum air temperature would increase by approximately 4°C, with larger increases in air temperature at central New Brunswick stations than in northern or southern regions of the Province. Seasonally, increases up to 6°C were estimated in maximum spring air temperature and minimum winter air temperature.

They predicted that, compared to current climate conditions, total annual precipitation would increase from 2010 to 2099 by 25 to 50% by the 2080's at northern and central stations and by 9 to 14% at southern stations. Throughout most of the province, winter precipitation would increase, and, given the warmer temperatures, some of this increase may be in the form of rain rather than snow.

In addition to temperature and precipitation, they performed downscaling of New Brunswick hydrometric records. Using this approach, they projected that average annual discharge would increase by 16 to 45% in New Brunswick by the 2080's compared to average discharge conditions from 1961 to 1990. Winter and spring discharge will increase significantly at all hydrometric stations, with the largest increases likely towards the end of the 21st century. Summer discharge will decrease significantly at all stations, while autumn discharge was predicted to decrease significantly in all rivers except the upper Saint John and Restigouche. An increase in flood magnitude and frequency was predicted for New Brunswick (Swansburg et al., 2004).

Local climate scenarios for the Atlantic region
Statistical downscaling was used by Lines et al. (2006) to generate local climatic scenarios for 14 meteorological stations located across all four Atlantic Provinces. Using the CGCM1, with a less extreme emissions scenario (GHG+A1) than that used by Swansburg et al. (2004), they also developed seasonal and annual projections for the 2020's, 2050's and 2080's. Their projections indicated a consistent rise in maximum and minimum air temperatures across the region, with the exception of Labrador, where temperatures were predicted to decrease slightly. They estimated that in Atlantic Canada the mean annual minimum air temperature would increase by 5°C, while the mean annual maximum air temperature would increase by approximately 4°C.

They projected that by the 2080's, winters will become 4 to 6 % wetter and summers will become 8 to 18 % wetter than the base climate of 1961 to 1990.

Average annual precipitation was projected to rise by 8 to 20% in Atlantic Canada, except over northern Nova Scotia and eastern New Brunswick, where decreases of approximately 5% were projected (Lines et al., 2006).

Recent work
As part of the recent Canada-wide study, *From Impacts to Adaptation: Canada in a Changing Climate 2007*, a summary of climate projections based on a suite of seven global climate models was presented in the chapter on Atlantic Canada by Vasseur and Catto (2008). Largely

due to the work of the Canadian Climate Change Scenarios Network (CCCSN), the outputs of various global climate models developed by researchers around the world are now accessible on-line for use in the development of climate change scenarios for impacts studies of user specified sites (Barrow et al., 2004). The work presented by Vasseur and Catto (2008) illustrates a recent shift towards looking at suites of several climate models rather than focusing on more detailed downscaled projections from just one model (e.g. Swansburg et al., 2004; Lines et al., 2006).

By examining the projections for the 2080's from a suite of global climate models, Vasseur and Catto (2008) were able to project a change in the average annual temperature of approximately 4°C and an increase in annual precipitation of approximately 7 to 8% above 1961 to 1990 levels for Atlantic Canada. Seasonally, New Brunswick, Nova Scotia and Prince Edward Island are predicted to experience an increase in mean annual temperature of 2 to 4°C in summer and 1.5 to 6°C in winter during the next 50 years compared to observed conditions from 1961 to 1990 (Vasseur and Catto, 2007). Newfoundland and Labrador are also predicted to experience smaller increases than in the other Atlantic Provinces due to the influence of the Labrador Current and the North American Oscillation on climate patterns (Vasseur and Catto, 2007).

3. Observed Impacts of Climatic Changes in Atlantic Canada

At present, we know temperatures have increased over the past century by an average of 1.3°C across Canada (Environment Canada, 2009), extreme precipitation events have become more frequent, and the ice regime on lakes and rivers has changed and will likely continue to change.

Trends are beginning to appear in hydrometric records that support the predictions of local climate scenarios developed using statistical downscaling. Flooding and ice jamming of inland waterways, and sea level rise and storm surges along coastlines, are two key areas where impacts are occurring in Atlantic Canada and where the observed trends are consistent with climate change.

Inland Waters

Climatic change was given serious consideration following the major 1987 ice jam floods along the Saint John River (Beltaos, 1999; Hare et al., 1997). Although no overall trends in mean annual precipitation or stream flow were detected at the time, both appeared to have become more variable since 1950. Freshets had generally started earlier since 1972. There were also several years with high flow, when compared with periods earlier in the century. Only a small rise of spring temperatures was detectable, but snowy or wet winters, coupled with greater variability in temperature, caused earlier thaws and several major flooding and ice-jam events.

Hare et al. (1997) stated that one-day heavy rain or snowfall events had increased in intensity over the Saint John River Basin since 1872. Major precipitation events, not always associated with tropical disturbances crossing the region, occasionally occurred in late summer and fall. A further conclusion was that large amounts of precipitation might also occur during the period of spring ice breakup and flooding in New Brunswick, dramatically exacerbating the resulting flood (Hare et al., 1997), as demonstrated by the flooding of the Saint John River Basin in the spring of 2008.

In 2008, R.V. Anderson Associates Limited examined the records of 13 hydrometric stations in New Brunswick over the period of 1969 to 2006 to ascertain if significant trends in selected hydrologic parameters attributable to climate change could be detected. They found that trends in hydrologic data are beginning to appear in the hydrometric records, with the most significant changes occurring during the past few decades; climate change was surmised to be a plausible explanation for this observation. Statistical analyses confirmed previous observations that the dates of spring flooding had advanced to earlier in the year. Trends in the data also indicated that the number of mid-winter ice breakup events had increased over the period of record, and that ice regimes in New Brunswick are less stable, leading to more uncertainty about ice jamming conditions.

From an engineering perspective, an increased frequency and severity of river ice movement and jamming could increase the possibility of infrastructure being damaged or destroyed by the erosive power of the ice (Beltaos and Burrell, 2003). The apparent increasing instability of ice regimes in New Brunswick, combined with the potential for major storms to occur simultaneously with the spring thaw and the onset of the freshet, confirms a need for adaptation along inland waters to lessen the likelihood and severity of future flood damages.

Further work should be undertaken to compare the hydrometric records in the other Atlantic Provinces to see if similar trends are also occurring there.

Coastal Areas

As detailed in Vasseur and Catto (2008) and Daigle et al. (2006), storm surges have resulted in property destruction and erosion along coastal areas in all four Atlantic Provinces in the past 15 years. The most notable of these was the benchmark Atlantic storm event of January 21, 2000, declared a disaster by the Federal Government of Canada.

Atlantic Canada (with the exception of northern Labrador) is undergoing isostatic subsidence and tilting as a result of glacial loading and unloading at the end of the last glaciation (Daigle et al., 2006). The observed rate of relative sea-level rise is therefore a result of the combined effects of global sea-level rise and subsidence, and is greater for Atlantic Canada than the current global rate of 17 cm per century (Daigle et al., 2006).

Based on current estimates, a relative sea-level rise on the order of 60 cm is expected for Atlantic Canada over the coming century (Daigle et al., 2006; IPCC, 2007). This will result in more frequent flooding of low-lying areas, currently prone to flooding, but also in flooding of higher, previously immune areas that currently host critical infrastructure (Daigle et al., 2006; Vasseur and Catto, 2008).

Currently, a water level in excess of 3.6 m above Chart Datum (CD), similar to the January 21, 2000 event, occurs approximately once every 100 years in the southern Gulf of St. Lawrence (Daigle et al., 2006). Based on climatic predictions, researchers surmise that the frequency and severity of these events will increase with global warming and the associated sea level rise. At the present rate of relative sea level rise, Daigle et al. (2006) predict that by 2100 a storm-induced water level of 3.6 m above CD could statistically occur every 10 years in the Southern Gulf of St. Lawrence.

Sea level rise threatens not only coastal infrastructure, but also fragile ecosystems and natural resources such as wetlands and freshwater aquifers. Saltwater intrusion of freshwater aquifers is a growing concern as municipalities and industries work to achieve a balance between changing demands and water availability in coastal areas. The impact of sea level rise and a changing hydrology regime on the saltwater/freshwater interface in coastal areas is poorly understood at this time and is an area in need of future research.

4. Summary of Expert Meetings on Climate Change

Since 2003 New Brunswick has hosted a number of meetings and workshops attended by jurisdictional experts from New Brunswick and other Atlantic Provinces dealing with climate change adaptation. These meetings and workshops have increased our understanding of the anticipated impacts of climate change in the region and have helped to identify regional adaptation priorities.

In November 2003, a two-day meeting was held in Fredericton to discuss adaptation to climatic change as it applies to New Brunswick water resources. Attended by more than 30 water resource managers, environmental specialists and experts on climate change, the meeting concluded that New Brunswick (and also Atlantic Canada) faces many challenges to adapt to climate change. This meeting began the process of quantifying the possible impacts of the changing climate on the region.

The principal recommendations from this meeting (Riley Environment Limited, 2004) follow:

- Continue monitoring river, groundwater, and climate-related parameters;
- Development of an accurate inventory of water resources (including supply and usage) to enable effective management;
- Development of provincial water use policies and resource management programs that recognize the value of water;
- Development, as a high priority, of an adaptation strategy, to enable the province to plan for the inevitable and substantial impacts expected from climate change;
- Revision of infrastructure design criteria to reflect changes in climate;
- Coordination of efforts of various federal and provincial government agencies;
- Public education on the expected effects of climate change on water resources; and
- Encouraging better use and conservation of water resources.

A further technical meeting of experts in the areas of water and natural resource management, fisheries, climatology, civil engineering and ecology took place at the Université de Moncton, New Brunswick in 2004. The title of the event was: “Climate Change Impacts and Adaptation: Water Resources and Fisheries in New Brunswick”.

The scientists at this meeting reconfirmed the conclusions and recommendations made at the November 2003 conference. Presentations on science and policy, in particular the reality of having to “plan for uncertainty”, made it clear that decisions have to be made now, bearing in mind what we already know. This was summed up as: “It’s happening, what are we going to do about it?” Integrated planning, taking a whole ecosystem approach, and making decisions on a basis of sound science, were all emphasized.

Based on the information assembled by drawing on the general scientific literature, and the work presented at the New Brunswick expert conferences and workshops held from 2003 to 2008, the sectors predicted to be most affected by climate change in Atlantic Canada are: precipitation and water resources, ecosystems and biodiversity, fisheries and aquaculture, coastal zones, agriculture and horticulture, forestry, air quality, health, and sustainable development. Tables detailing the predicted effects of climatic change in each of these sectors, along with an indication of the relative degree of confidence, are given in Appendix I. Major areas that were not explicitly dealt with included energy production, transportation, manufacturing, and the retail and service industries (including insurance).

During the development of the chapter on Atlantic Canada (Vasseur and Catto, 2008) for the Natural Resources Canada report, *From Impacts to Adaptation: Canada in a Changing Climate 2007*, coastal areas, inland waters and related infrastructure were identified as priority areas for adaptation to climate change in Atlantic Canada. In May 2008 the New Brunswick Department of Environment in collaboration with the three other Atlantic Provinces and in partnership with Natural Resources Canada hosted a Climate Change Adaptation Workshop in Saint John, New Brunswick. The workshop was attended by climate change and adaptation scientists and researchers from the four Atlantic Provinces and all levels of government. The presentations and discussions focused on three priority areas, summarized below.

Coastal Areas

Sea-level rise is expected to increase coastal flooding, storm surge effects, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of our coastal communities. Impacts in the coastal zone are expected to affect local resources, for example through erosion of beaches and salt water intrusion of drinking water wells.

Inland Waters

Later arrival of freeze-up and more mid-winter break-ups of river ice will occur. Spring break-up has advanced to earlier in the year and the number of ice-free days has increased. Inland water resource impacts include fluctuating groundwater recharge and lower summer groundwater levels, plus surface and groundwater quantity and quality changes. Water availability is an example of a critical component which will be impacted by climate change. It is predicted that the Atlantic region will receive more total precipitation; however it is expected to arrive in the form of more intense storm events. The ability to adapt to flood and drought conditions must be developed.

Infrastructure

Infrastructure-based components of our economies and social networks (transportation, wellness and culture, public services) will be altered by changes to climate. Our understanding of how predicted changes to our climate will affect these infrastructure resources, and therefore, our economy is a critical part of planning our future.

5. Atlantic Climate Change Adaptation Strategy

Coming out of the 2008 workshop, the Council of Atlantic Environment Ministers (CAEM) identified climate change, and especially climate change adaptation, as a key environmental issue for Atlantic Canada. Recognizing the importance and benefits of working collaboratively on regional adaptation issues, and based on the recommendations from previous expert meetings on climate change, the CAEM agreed to collaborate on a Climate Change Adaptation Strategy for Atlantic Canada in June 2008.

Principles and Goals

1. To enhance the resilience and adaptive capacity of Atlantic Canada communities to climate change.
2. To integrate climate change adaptation measures through climate proofing in existing and development activities.
3. To promote meaningful regional collaboration, co-ordination and sharing of good practices on the integration of climate change adaptation in development decisions.

Key Result Areas

Recognizing the complex inter-relationships and linkages among the principles and goals of the strategy, three key result areas for action were identified under the Atlantic Climate Change Adaptation Strategy.

<u>1 - Indentifying Climate Risks</u>

An important first step in adaptation to climate change is the identification and quantification of the risks associated with climate change. Once quantified, it is then possible to begin to build tools to ensure the resilience of both natural and man-made environments to these risks.

<u>2 - Climate Proofing Decisions</u>

Climate proofing decisions in Atlantic Canada refers to assisting partners in their efforts to reduce their risks and vulnerability to climate change. Seeking opportunities from climate variability where they exist is also a component of climate proofing decisions.

<u>3 - Regional Collaboration</u>

Establishing a Regional Adaptation Collaborative with an organizational body to oversee its implementation, and focusing on the common priority Atlantic region issues of: coastal areas, inland waters and infrastructure.

6. Atlantic Regional Adaptation Collaborative Program

In June, 2008 all four Atlantic Ministers of the Environment formally agreed to work collaboratively on adaptation to climate change. The provinces have assembled a team of professionals, scientists and partners in engineering, land use planning and municipal administration interested in helping communities incorporate adaptation in decision making. Within the framework of the Atlantic Adaptation Strategy, and as part of the Natural Resources Canada Regional Adaptation Collaborative Program (RAC), this collaborative will aid in building on the existing and well functioning networks that exist in the Atlantic region, as well as identify opportunities, fill gaps and remove barriers to adaptation. As part of the RAC, a number of projects have been proposed that would develop tools and approaches to enable appropriate adaptation planning and decision making in the three previously identified priority areas of inland waterways, coastal areas and their related infrastructures.

As proposed, the Atlantic RAC will extend collaboration beyond the four Atlantic Departments of Environment to include the Atlantic Planners Institute, the four Atlantic Engineering Associations, the Atlantic Municipal Associations, the Insurance Bureau of Canada and Natural Resources Canada. The aim of the Atlantic RAC is to foster collaborative work which will produce applied solutions to existing problems that relate to environmental change.

The New Brunswick Department of the Environment is the lead agency for climate change adaptation in New Brunswick and has taken on the lead role in the development of the Atlantic RAC. In this capacity the Department has been leading the development of an Atlantic Canada proposal to the Natural Resources Canada Regional Adaptation Collaborative Program.

7. Conclusions

Uncertainties exist about the magnitude and consequences of climatic change, especially at the local scale. However, Atlantic Canada is being, and will continue to be impacted by a changing climate. Coastal communities and habitats, inland water resources in terms of quality and quantity issues, and infrastructure such as transportation and communications networks and water and wastewater infrastructure will be increasingly stressed by climate change impacts.

Approaches to risk and vulnerability management must be developed to protect current and future development, communities, our economy and critical natural features from impacts associated with climate change. Development should be based on principles that consider weather extremes, environmental conditions, and matters of public safety. Decision making at all levels of government and support mechanisms to those processes (e.g. regulation and policy) should seek to guide development to appropriate locations that reduce or remove public risk and increase their resilience to a changing climate.

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APPENDIX I
Predicted Impacts of Climate Change in Atlantic Canada

A list of the effects of climatic change that are expected in Atlantic Canada is given in the following tables. This information has been assembled by drawing on the general scientific literature, and takes into account the work presented at the expert conferences held in New Brunswick from 2003 to 2008. The level of confidence varies considerably between predictions, so where possible, an indication is given of the degree of confidence for each item. This involves professional judgment but is still useful when interpreting the information.

The categories "high", "medium" and "low" can be equated with "very likely", "likely" and "possible" probabilities of occurrence.

Table 1. Predicted effects and implications of climatic change on weather and climate in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

WEATHER AND CLIMATE	
Predicted Effects	**Implications**
Temperatures will continue to increase on average, with a more pronounced upward trend in inland districts and in summer. **H**	Sustained or increased need for public advisories of heat-stress conditions.
The ice-free season will lengthen in most areas. **M**	Examine implications for recreation, public safety and flood risk.
The frost-free season will lengthen. **H-M**	Potential benefit, but plan for associated increased risk of new/exotic diseases affecting plants, wildlife, domestic animals and humans.
	Basic climatological monitoring at key trend sites must continue, and be protected for the long- term.
Snowfall and duration of snow cover likely to decrease, affecting winter recreation including skiing and snowmobiling **M**	Build climate change considerations into planning for future winter sporting developments.
"Surprise" changes **H**	A need exists for more detailed studies by federal climatic specialists to refine predictions of climatic change in eastern Canada. This is especially true for New Brunswick where competing continental and marine influences complicate predictions.

Table 2. Predicted effects and implications of climatic change on precipitation and water resources in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

PRECIPITATION AND WATER RESOURCES	
Predicted Effects	**Implications**
The precipitation distribution through the year will change. Water supply will diminish, especially in inland districts, due to higher temperatures. **M-H**	Assess groundwater and surface water reserves in terms of sustainable yields.
	Promote water conservation in all use sectors, especially industry and agriculture.
Hydrological processes / water cycle will change. **H**	Ensure adequate data collection and evaluation on all components of the hydrologic cycle, including evaporation and infiltration.
The duration of dry spells between rainfall events is expected to increase, with an associated increase in drought frequency, duration, and severity. **M-H**	Carry out studies that may lead to better techniques for prediction of atmospheric or hydrologic drought.
Precipitation patterns will become more erratic, with an increased frequency of intense storm events, such as summer convective storms (thunderstorms, hailstorms and tornadoes). Associated impacts from erosion and siltation. **M-H**	Ensure appropriate agencies maintain adequate forecasting capability and emergency preparedness.
River flows will become more variable. Spring peak flows will occur earlier and be reduced in duration. Summer minimum flows will be lower. Periods of very low or zero flow are expected to become more frequent. **H**	Carry out updated hydrological modelling for NB, to examine the details of the altered hydrological regime.
Flooding may become more frequent and more severe. Mid-winter thaws and ice breakups, with the potential for ice-jam flooding, will become more widespread and frequent, resulting in more ice jam floods during the winter months. If the mid-winter jams re-consolidate, then spring ice breakup is likely to have more severe impacts. **M-H**	Using an updated hydrological analysis, produce updated flood hazard mapping for the province to assess critical areas at risk. **Note**: existing hydrologic relationships based largely upon the assumption of a homogeneous period of record may underestimate peak flows used for bridge and culvert design. A safety factor may have to be added during design to take into account the hydrologic uncertainties caused by climatic change.
Aquatic ecosystems will change as water levels become lower and water temperatures become higher during the summer months. Algal blooms and eutrophication expected to increase. **M-H**	Ensure continued monitoring; identify critical habitats; continuously evaluate effectiveness of nutrient management activities.

Table 3. Predicted effects and implications of climatic change on ecosystems and biodiversity in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

ECOSYSTEMS AND BIODIVERSITY	
Predicted Effects	**Implications**
Altered ecosystem characteristics and productivity. Some species and ecosystems may be reduced or disappear altogether, causing a loss of biodiversity. **H**	Critical species and habitats need to be identified and plans put in place for protection.
Cold-water species such as salmonids will become increasingly stressed as water levels become lower and water temperatures become higher during the summer months. Suitable freshwater habitat for some aquatic species, such as salmonids, may be lost. Increased water temperatures and reduced dissolved oxygen is expected to harm cold water fish species. **M-H**	Ensure continued monitoring; identify critical habitats.
Shrinkage of boreal/alpine zones with reduction in associated habitat, threats to survival of associated biota. **H**	
Invasion of new (”exotic”) plants and animals extending their ranges into NB. **H**	Plan for appropriate surveillance and management.
Increased fire hazard expected to threaten key habitats and associated species. **M-H**	Examine options for enhanced protection of critical habitats.
Low river flows in summer and increased water temperatures will threaten cold water aquatic life. **H**	Consider greater management efforts on species that can better tolerate warmer water.
Increased frequency of extreme weather events (especially windstorms, droughts, and increased winter freeze-thaw activity) expected to pose significantly increased stress on forest and other ecosystems. **M-H**	Examine options for enhanced protection of critical habitats (also, see under forests).

Table 4. Predicted effects and implications of climatic change on coastal zones in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

COASTAL ZONES	
Predicted Effects	**Implications**
Mean sea level will continue to rise, increasing the likelihood of (a) coastal flooding, (b) drainage problems with urban infrastructure draining to tidal estuaries. **H**	Ensure coastal development proceeds taking into consideration projected environmental changes.
Increased rates of coastal flooding and erosion due to more extreme weather events, higher water levels (including storm surges), and less protection against waves being provided by sea ice. Associated effects on coastal infrastructure. **M-H**	Consider planning for managed retreat or engineered protection of critical areas prone to erosion.
Sea-level rise and changes in precipitation could alter coastal marshes and cause detrimental changes to coastal ecosystems. **M**	Evaluate coastal areas of potential risk based on projected sea level rise, topographical information (e.g., existing mapping), and ecological assessments.
Increased risk of salt intrusion and contamination of coastal aquifers, due to increasing sea levels and increased pumping from inland aquifers for irrigation. **H**	Evaluate sustainability of coastal drinking water aquifers and plan for future new supplies as required.

Table 5. Predicted effects and implications of climatic change on fisheries and aquaculture in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

FISHERIES AND AQUACULTURE	
Predicted Effects	**Implications**
Inland aquaculture may suffer from reduced water quantity and quality due to lower summer flows, reduced water availability and higher water temperatures. **M-H**	Evaluate water resource availability using updated hydrological analyses.
	Develop a strategy for reducing water use in aquaculture.
Increased pest and disease problems, affecting inland and coastal fisheries (including shellfish). **M**	Plan and operate operations to minimise potential effects of new or increased pests/diseases.
	Improve fish/shellfish health monitoring programs.
Recreational angling likely to be affected by low summer river flows, changes in the ice season and changes in species abundance. Fishing seasons may change (timing, duration). **M-H**	Plan additional protection measures as required to maximise the potential for the survival of desired species.
	Develop alternative recreation and tourism strategies (e.g. to account for reduction of recreational fishery).
Salmonids increasingly vulnerable due to higher water temperatures and lower summer flows. **M-H**	Identify critical salmonid habitat for protection, emphasizing stream vegetation buffers and protection of water resources.

Table 6. Predicted effects and implications of climatic change on forestry in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

FORESTRY	
Predicted Effects	**Implications**
Increased fire hazard. **H**	Promote appropriate forest fire risk prevention and mitigation measures.
Increased risk of wind damage. **M-L**	Strategic planning to anticipate and mitigate effects of wind damage.
Increased risk of destructive pests and diseases. **M-H**	Ongoing monitoring and scientific studies of destructive pests and diseases.
	Development of forest management practices to lessen or adapt to higher pest damages.
Longer growing season and higher CO2 may stimulate growth, but limited overall benefit due to poor soils and increased drought stress. **H**	Ongoing trials required of species or varieties with potentially improved adaptation to drought, higher temperatures, or higher CO2.
Changes in regeneration, reproduction, and fitness for some species, and a potentially changing species mix. **M-H**	Ongoing scientific studies required to assess the probable impact of changing atmospheric conditions on regeneration, growth, reproduction, and survival.
Increased incidence of freeze-thaw winter injury. **M**	Ongoing scientific studies required to assess the probable impact of freeze-thaw winter injury on tree survival and associated forest decline.

Table 7. Predicted effects and implications of climatic change on agriculture and horticulture in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

AGRICULTURE AND HORTICULTURE	
Predicted Effects	**Implications**
Probability of summer water shortages will increase, creating a greater need for irrigation in New Brunswick's potato belt and possibly in other areas. **H**	Evaluate groundwater resources in agricultural areas and the potential impacts of long-term irrigation.
Increased irrigation may be problematic in some areas due to local water chemistry.	Plan for additional water testing for irrigation suitability (e.g. sodium absorption ratio testing).
More summer rainfall is expected to fall in high intensity rainfall events. This means an increased probability of soil erosion. **H**	Promote conservation practices in agriculture, forestry and horticulture that protect against soil erosion.
Longer frost-free season and higher mean temperatures (most likely in inland districts, less certain in coastal areas) may allow new crops to be grown or increased productivity of some existing crops. **M-L**	Evaluate options for trial or introductions of new crop species or varieties.
Potential for increases in pests and diseases, including novel or exotic varieties. **M-H**	Planning required to anticipate and mitigate the impacts of new pests, diseases.
Increased heat stress for livestock, especially in intensive operations. **M**	Anticipate and mitigate the impacts of higher heat stress.

Table 8. Predicted effects and implications of climatic change on air quality in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

AIR QUALITY	
Predicted Effects	**Implications**
Hotter summers are expected, with an increased frequency of smog episodes. **H**	Maintain focus on NOx and VOC controls, plus public advisories of poor air quality episodes.
Increasing temperatures will lead to an increased flux of VOCs in to the atmosphere from natural and other sources (approx 20% increase per degree Celsius). **H**	Maintain priority on effective VOC controls (industries and transportation) and promote cleaner energy sources.
Changes may occur in atmospheric circulation that influence the long-range transport of air pollutants. **M-L**	Maintain monitoring programs to detect and understand changes.
The emission of air pollutants associated with electrical generation may change as heating and cooling demands change (increased demand in summer, lessening demand in winter). **M-H**	Additional potential for exacerbation of summertime smog episodes: maintain monitoring and assessment networks, promote energy smart buildings to offset increased summer demands.
Forest fires expected to be more frequent and larger, increasing the associated emissions of VOCs and particulate matter. **M-H**	Maintain air quality tracking and advisory programs; need for health studies to understand the significance of additional risks and their effects.
Changes in the nature of pollen, dust and spore concentrations are expected in response to warmer weather, possibly synergised by higher CO_2 and humidity. **M**	Maintain monitoring of key indicators to track and understand the nature of changes, and provide input to health management.

Table 9. Predicted effects and implications of climatic change on human health in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

HUMAN HEALTH	
Predicted Effects	**Implications**
Increase in conditions relating to heat stress, possible exacerbation of air pollution related stresses. **M-H**	Provide adequate advisories and mitigation.
Increase in probability of bacteriological contamination of food and water. **M**	Increased need for surveillance and inspection programs.
Increase of vector-borne diseases. **M**	Increased surveillance and testing of swimming areas and wildlife vectors.
Possible decrease in cold-related conditions, frostbite, hypothermia (complicated by changes in activities and behaviour). **M-L**	Uncertain; anticipate shifts in recreational activity patterns.

Table 10. Predicted effects and implications of climatic change on sustainable development in Atlantic Canada (degree of confidence: **H** = highest, **M** = intermediate, **L** = least).

SUSTAINABLE DEVELOPMENT	
Predicted Impacts	**Implications**
Changes in climatic conditions (such as rainfall intensity, duration and frequency) might make some land (e.g. flood plains, steep sites) unsuitable for some types of development, and might require changes in development patterns and the types of development. **M-H**	Carry out the studies necessary to identify and evaluate potential hazards.
	Use community planning and landscape design tools to lessen the exposure and susceptibility of future development to potential natural hazards created or enhanced by climatic change.
	Promote land stewardship for critical areas and areas subject to erosion.
	Place special attention in terms of land use planning on appropriate development in areas prone to riverine or river ice flooding.
Drinking water quality will likely be affected by the change in the quantity and quality of water at the source, as well as from the problems of old water infrastructure. **H**	Examine the adequacy of drinking water supplies and supply systems in terms of quantity and quality.
	Review source water protection programs for effectiveness.
Urban drainage infrastructure will be overloaded more often. Associated risk of contamination from sewage. **M**	Review basic municipal drainage infrastructure.
	Assess the risk of urban flooding, and associated water contamination, due to urban drainage infrastructure becoming over-loaded more often.
	Promote design of urban development that minimizes runoff and maximizes natural infiltration so as to replenish aquifers.
Due to changing climatic conditions, municipal or coastal infrastructure designed to have long life spans might be damaged or become incapable of functioning properly **M**	Assess existing infrastructure with remaining long service lives and renovate/ repair if necessary.
	Design new infrastructure considering potential hydroclimatic changes. Develop and promote design criteria to minimize susceptibility of future.
	Priority should be given be given to areas such as major municipal or coastal infrastructure or other areas where the planning horizons are long and structures are designed to have long life spans.
Increased temperatures may change requirements for heating and air conditioning. **M**	Promote site layouts and building materials, designs and technologies that lessen indoor extremes of temperature.
Resource availability might change as commodity supplies and markets respond to changing environmental conditions. **L**	Carry out basic studies of the energy and material (resource) inputs and outputs to define the economic footprints of the province's urban areas, and develop appropriate conservation measures as needed.