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Adapting to Climate Change



An Introduction for
Canadian Municipalities

*Aussi disponible en français sous le titre : S'adapter aux changements climatiques :
Une introduction à l'intention des municipalités canadiennes*

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Preface



The impacts of changing climate are already evident in Canada and globally. Scientific understanding of climate change indicates that Canada will experience significant shifts in weather patterns over the period of a single generation, a trend that will likely continue for several centuries. Communities of all sizes will face many new risks and opportunities. Managing the impacts of a changing climate will require developing local strategies.

The anticipated impacts of climate change include drought; reduced quality of surface waters; a higher incidence of vector-borne diseases; more frequent heat waves resulting in reduced air quality and high human discomfort in urban centres; and an increase in storm surge flooding in coastal regions. For many municipalities, the change in the frequency and severity of extremes in weather – such as intense precipitation, heavy winds or ice storms, as well as seasonal variations in the water supply – are a major concern. The greatest warming is expected to occur in the North. Resource-based and Aboriginal communities, which generally have economies closely tied to the natural environment and local climate variability, are particularly vulnerable.

Anticipating the effects of climate change and taking actions before major impacts occur is an effective strategy to manage climate risk and reduce a community's overall vulnerability. Adaptation involves making changes in decisions, activities and thinking in response to observed or expected changes in climate. Governments, individuals, industry and community groups can all take adaptive actions to reduce potential harm and to take advantage of new opportunities. Possible adaptation actions are tremendously wide ranging and may involve using new technologies, adjusting planning and investment practices, and revising regulations. Adaptation measures can also help achieve other municipal sustainability goals and should not be considered only as stand-alone actions to address climate change.

This book is an update and expansion of the document published in 2006 by the Canadian Climate Impacts and Adaptation Research Network (Mehdi, 2006) under the same title. It provides municipal decision-makers and staff with information to help them understand the need for climate change adaptation and how to put adaptation measures in place. The book also refers to other guides that can help municipalities identify and address risks and opportunities, and to case studies that illustrate how municipalities of varying sizes from across the country are taking action now.

Each case study outlines the impact of changing climate on the community, the catalyst for developing a plan, the plan-making process, measures adopted, next steps and lessons learned. The case studies illustrate the value in collaborating with non-traditional partners and demonstrate practical measures that other municipalities facing similar issues might take to enhance community resilience in the face of a changing climate.

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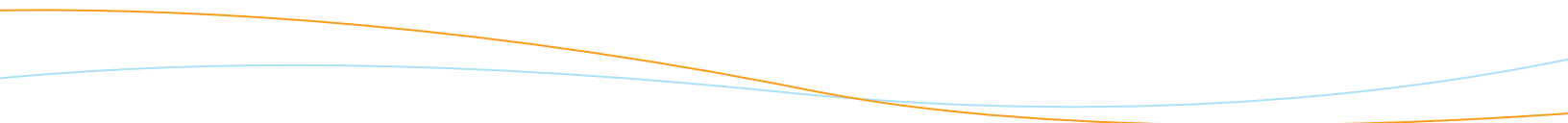
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CHAPTER 1

AN INTRODUCTION TO CLIMATE CHANGE ADAPTATION

The Earth's climate is changing. Some of this change is due to natural variations that have been taking place for millions of years, but increasingly, human activities that release heat-trapping gases into the atmosphere are warming the planet by contributing to the "greenhouse effect."

The Intergovernmental Panel on Climate Change concludes that the best estimate for global average surface air warming over the current century ranges from 1.8°C to 4.0°C (IPCC 2007). This rate of temperature change is without precedent in at least the last 10 000 years. Consequently, historical climate no longer provides an accurate gauge for future climate conditions.

What is climate change adaptation?

Even after introducing significant measures to reduce greenhouse gas (GHG) emissions, some additional degree of climate change is unavoidable and will have significant economic, social and environmental impacts on Canadian communities. To reduce the negative impacts of this change and to take advantage of new opportunities presented, Canadians will need to adapt.



Climate change adaptation refers to actions that reduce the negative impact of climate change, while taking advantage of potential new opportunities. It involves adjusting policies and actions because of observed or expected changes in climate. Adaptation can be reactive, occurring in response to climate impacts, or anticipatory, occurring before impacts of climate change are observed. In most circumstances, anticipatory adaptations will result in lower long-term costs and be more effective than reactive adaptations.

Adaptation is not a new concept: Canadians have developed many approaches to effectively deal with the extremely variable climate. For example, communities in the Prairie provinces have been designed to withstand extreme differences in seasonal temperatures. Nevertheless, the amount and rate of future climate change will pose some new challenges. The fact that science now allows communities to anticipate a range of potential climate conditions, and therefore take action before the worst impacts are incurred, makes adaptation to future climate change different from how Canadians have adapted historically.

Adaptation (responding to climate impacts) and mitigation (reducing GHG emissions) are necessary complements in addressing climate change. The fourth assessment report of

the Intergovernmental Panel on Climate Change states that while neither adaptation nor mitigation actions alone can prevent significant climate change impacts, taken together they can significantly reduce risks. Mitigation is necessary to reduce the rate and magnitude of climate change, while adaptation is essential to reduce the damages from climate change that cannot be avoided.

Single policies and measures can be designed to help tackle both mitigation and adaptation. For example, as the climate changes, a projected higher frequency and intensity of rain storms may increase stormwater runoff and the potential for localised flooding in urban areas. Planting street trees is an initiative that municipalities can implement to both reduce stormwater runoff (adaptation) and increase carbon storage (mitigation).

In other cases, there may be conflicts between adaptation and mitigation goals that can only be addressed in a broader context of community priorities and risk tolerance. For example, increased use of air conditioning can be considered an adaptive measure because it reduces human health problems during heat waves, which are projected to become more frequent in future. However, air conditioning is energy intensive and, depending on the source of the electricity, is likely to increase carbon dioxide emissions. Therefore, in deciding which adaptation action is most appropriate for a particular situation, attention must be paid to its implications for adaptation and mitigation, as well as its cost, efficacy and acceptance by the public.

Why Canadian municipalities need to adapt

Gradual shifts in average conditions (temperature, precipitation and sea level) will be accompanied by changes in climate variability and the frequency of extreme weather and climate events. The impacts of changing climate are already evident in every region of the country, especially in Canada's North where impacts are associated with warming that is taking place at faster rates than those throughout the country as a whole.

Anticipated impacts across Canada include increased frequency and severity of extreme weather events (e.g. heat waves, floods, coastal storm surges and droughts), more smog episodes and disease outbreaks, thawing of permafrost, loss of northern sea ice, and rising sea levels. These impacts will affect municipalities large and small, urban and rural, and have both positive and negative implications on infrastructure (e.g. transportation, water supply, sewage), social and economic systems (e.g. human health, competitiveness, recreation) and natural environments (e.g. biodiversity loss, habitat degradation, invasive species).



LEARN MORE ABOUT CLIMATE CHANGE IMPACTS AND ADAPTATION IN CANADA

From Impacts to Adaptation: Canada in a Changing Climate 2007 presents the current understanding of the ongoing and future impacts of climate change on Canada and the

country's ability to adapt. Regional chapters in the book identify key issues and provide examples of adaptation initiatives in British Columbia, the Prairies, Ontario, Quebec, Atlantic Canada and the North. The "Synthesis" chapter presents 10 key conclusions at the national level.

adaptation.nrcan.gc.ca/assess/2007/index_e.php

Climate change impacts in Canada

Projected rapid changes in the climate system will increasingly pose significant challenges in Canada. Some primary biophysical impacts of concern include

- permafrost thawing, with the associated effects on northern infrastructure
- warming and prolonged drought, making forests more susceptible to fires and insect infestations
- increased drying of the continental interior, reduced snow packs and shrinking glaciers, leading to water shortages for agriculture, hydroelectric facilities, shipping, municipal water supplies and other uses
- increasing frequency of heat waves and smog episodes, causing morbidity and mortality, notably in large cities where heat island effects amplify these events
- increasing severity and frequency of some extreme weather events and associated natural hazards such as floods, impacting economic activities, infrastructure and health
- increasing coastal exposures to storm surges due to increases in the number and intensity of storms, combined with higher sea levels, leading to erosion and infrastructure damage
- damage to habitat for vulnerable species, impacting the local economy and traditional ways of life in some communities



PHOTO COURTESY OF DEBBIE HOLICK

RECENT COSTLY WEATHER EVENTS IN CANADA, EXCLUDING DROUGHT		
WEATHER EVENT	REGION	(\$) COST
1998 Ice storm	Ontario, Quebec, Atlantic Canada	~5.4 billion
1996 Saguenay flood	Quebec	1.7 billion
1991 Calgary hailstorm	Alberta	884 million
1997 Red River flood	Prairies	817 million
2003 British Columbia / Alberta wildfires	British Columbia, Alberta	~700 million
2005 Toronto extreme rain	Ontario	>500 million
2005 Southern Alberta floods	Alberta	400 million
1996 Calgary hailstorm	Alberta	305 million
2003 Hurricane Juan	Atlantic Canada	200 million

Impacts of recent extreme weather events highlight the vulnerability of Canadian communities and critical infrastructure to climate change. The costs resulting from extreme weather events in Canada over the past 15 years have been greater than for all previous years combined. Hundreds of millions and even billions of dollars in property damage and disruptions in the production and flow of goods and services have been associated with flooding, wind, hail and ice storms, hurricanes, tornados and wild fires in all regions of southern Canada. Increases in the frequency and intensity of extreme weather, as is projected to occur with continued climate change, will also affect the cost and availability of insurance and impact governments where they serve as insurers of last resort.

Local governments have a unique and critical role to play in managing the risks of a changing climate. While all levels of government have important adaptation responsibilities, the local nature of many climate impacts means that municipalities are often on the front line to ensure effective management of risks, protect community safety and promote economic sustainability. Municipalities are well positioned to implement adaptive measures, particularly through processes such as land use planning, community energy planning and mechanisms like zoning or permit regulations. For many communities, changes in climate variability, as reflected in less predictable weather events, may represent a greater challenge for planning than will changes in average climatic conditions.

The actions taken today by towns and cities to enhance community resilience to climate change will greatly influence their ability to meet future sustainability goals, as well as to pay for the human and economic costs of climate-related impacts. The case studies in this report provide several examples of relatively low-cost actions, particularly through planning processes, being taken by communities today that are designed to reduce costs of future impacts.



PHOTO COURTESY OF OLE MIKKELSEN

CHAPTER 2

CLIMATE CHANGE ADAPTATION AND MUNICIPAL DECISION MAKING

Planning for climate change impacts

No single approach to climate change adaptation is appropriate for all communities. Each municipality has to contend with unique geography and specific climate-change issues. Legal systems, laws, institutions and cultural traditions differ by region. The resources that a community can dedicate to adaptation planning also vary substantially. Large metropolitan areas may have many planners and policy-makers dedicating at least some of their time directly to adaptation-related issues, whereas a remote hamlet likely will not have any planners. Approaches should build on the communities' land use and capital infrastructure plans and be adjusted to the realities of the local situation.

The adaptation actions presently taken by communities across Canada are diverse. Most climate change adaptation actions are embedded in a municipality's existing plans and strategies. In some communities, municipal staff and community partners have developed plans, policies, regulations or programs specifically for climate-change adaptation. These plans may target one adaptation issue/measure or be wide-ranging by tackling numerous climate issues, cross-cutting various departments and even external organizations. Such planning can target private citizens, including home and business owners, or be focused on a municipality's internal operations and infrastructure.

Key ingredients for successful adaptation planning

UNDERSTANDING VULNERABILITY

Assessing vulnerability is an integral part of most adaptation planning processes. Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.



MAINSTREAMING ADAPTATION INTO EXISTING PROCESSES, POLICIES AND MECHANISMS

Adaptation can often be effectively integrated into existing processes, policies and mechanisms. Rather than developing new plans and strategies, it may be logistically easier and more financially prudent for municipalities to build long-term climate factors into a wide array of municipal operations and services, including infrastructure decisions, capital plans, land use plans and disaster emergency management frameworks.

Understanding a municipality's climate vulnerability provides a basis for establishing priorities.

Analysis starts with an assessment of a municipality's vulnerability to the current climate, informed by knowledge of how climate events have impacted the community in the past, the actions that were taken in response to those impacts and how successful those actions were (NRCan 2004). The next phase of analysis examines how climate risks are likely to change in future; these risks are informed by projections of future climate as well as social and economic conditions. Stakeholder input is critical at all stages of a vulnerability assessment.

MANAGING RISK

Adaptation can be seen simply as a way to manage the risks presented by a changing climate. Climate-related risks can be treated similarly to other risks (i.e. financial, political, demographic and engineering) municipalities face. Many municipal decision-makers are familiar with risk management, which is a practical and credible approach to selecting the best course of action in uncertain situations. Risk management helps decision-makers determine, understand, analyze and communicate about risks.

Vulnerability assessments are a common element of risk management approaches. They help identify and classify potential risks to municipal policies, programs, infrastructure and other assets. The process for selecting a community's adaptation plans and measures may be formal or ad hoc. The advantages of a formal approach are its ability to provide clear and structured rationales and to accommodate the uncertainties that are inherent in projections of future climate, social and economic conditions.

For every climate impact, there is a range of possible responses that vary in time, complexity and cost. Many of these options fit into the following broad categories (from Pew Center 2009):

- **“no-regrets”**: actions that provide benefits regardless of impacts incurred from climate change
- **profit/opportunity**: actions that take advantage of a changing climate to yield net benefits
- **“win-win”**: actions that reduce vulnerability to climate change while also contributing to other economic, social or environmental goals (including reduction of greenhouse gas emissions)
- **low-regret**: measures that have relatively low costs and yield high benefits
- **avoiding unsustainable investments**: measures that limit or prevent new investment in areas already at high climate risk and where climate change is likely to exacerbate the impacts
- **averting catastrophic risk**: policies or actions taken to avoid unacceptably high losses as a result of climate events

CLIMATE CHANGE SCENARIOS

Climate change scenarios are one tool that can help raise awareness of climate change risks and, in some cases, help plan to address specific impacts. They present the differences between historic climate conditions and plausible future climate conditions. The scenarios complement projections of socioeconomic changes that many communities routinely use as part of long-term planning processes (see Appendix A). The following are key sources of scenario information in Canada:



PHOTO COURTESY OF NATURAL RESOURCES CANADA

- Canadian Climate Change Scenario Network – www.cccsn.ca
- Ouranos – www.ouranos.ca
- Pacific Climate Impacts Consortium – www.pacificclimate.org

IDENTIFYING SYNERGIES AND OVERCOMING CONFLICT

Adaptation is closely linked with sustainable development. Policies, plans and investments that span more than two decades may not be sustainable if the changing climate is not factored into their development. Understanding the links between climate change actions and sustainability goals helps municipalities make their adaptation actions more effective by strategically allocating resources to achieve multiple outcomes.

Municipal decision-makers also need to be aware of the possible conflicts that can arise when choosing adaptation measures. For example, a sea wall may protect coastal properties from extreme storm damage, but it can also have an adverse affect on the health of the coastal ecosystem (e.g. disturbing sensitive fish- and bird-breeding grounds) and have negative impacts on erosion or sedimentation elsewhere on the coast. Discussion is an important means of resolving conflict and arriving at community consensus. Many Canadian communities that have successfully implemented adaptation plans and measures have held public consultations to openly discuss costs, benefits, strengths and weaknesses of various options, and to give the public an important say in deciding the best way to proceed.

AWARENESS, LEADERSHIP AND PARTNERSHIPS

Awareness of the potential impacts of climate change on communities and of the value of taking early action to reduce negative impacts is critical. Because adaptation often involves proactive investment to prevent future damage, awareness is needed among the public and decision-makers.

Moving from awareness to action frequently requires strong leadership. Foresight, determination and patience are needed to instigate municipal adaptation work and see it through to implementation stages. In many cases, it takes one or more champions (inside or outside the local government) to keep adaptation initiatives alive in the face of the many competing priorities that municipalities face. Communities that have shown initiative and success in climate change mitigation programs and measures may be able to efficiently leverage this leadership to accelerate adaptation efforts.

Also, interdisciplinary partnerships and collaboration can be useful when addressing the complex challenges of climate change. When planning for climate change, particularly in the vulnerability assessment stage, policy-makers and planners will need to draw on external specialists. These partnerships with climate change specialists are particularly important because municipalities will have to clearly explain complex issues to a public faced with many competing priorities.

The case studies in Chapter 3 illustrate the approaches that Canadian communities have taken to build awareness and partnerships, and the actions that resulted.

Adaptation tools and guide books

Various tools exist that can help municipalities integrate climate change adaptation into new and existing plans. These include:

- **guide books** (electronic or hard copies) that include key decision-making steps common to many adaptation plans and strategies
- **risk management processes** for selecting the best course of action in situations where uncertainties are significant
- **case studies** that provide examples of how communities are confronting specific climate challenges

Some important Canadian sources of information are listed below. Additional information and tools can be accessed at the Web sites listed in Appendix B.



Adapting to Climate Change: A Risk-based Guide for Local Governments (Black et al., 2010)

This guide, based on risk-management guidelines from the Canadian Standards Association, uses a simple, practical approach for identifying risks, ranking them and selecting

the best way to reduce those risks. Versions of the guide exist for British Columbia, Alberta, Ontario and northern Canada, while a generic guide with region-specific annexes will be available in 2011.

http://adaptation.nrcan.gc.ca/tools/abosuj_e.php



Changing Climate, Changing Communities: Municipal Climate Adaptation Guide and Workbook (ICLEI Canada)

This guide provides a Canadian-based framework that helps local governments develop an adaptation plan that addresses the most significant climate risks and opportunities for their community. The five-milestone approach to adaptation planning is 1) initiate, 2) research, 3) plan, 4) implement and 5) monitor. The accompanying workbook includes practical tools and exercises to support practitioners during the planning process.

www.iclei.org/index.php?id=11710



A Guide for Quebec Municipalities for Developing a Climate Change Adaptation Plan (Ouranos)

Élaborer un plan d'adaptation aux changements climatiques : Guide destiné au milieu municipal québécois

This French-language guide uses five steps to help municipalities identify climate risks, set adaptation priorities and implement effective adaptation strategies.

http://ouranos.ca/media/publication/111_PlanadaptationCC-Guidemunicipalites-Ouranos.pdf



Municipal Resources for Adapting to Climate Change (Federation of Canadian Municipalities)

This publication features seven municipalities that are considering adaptation in their communities. Scientific resources and planning tools that have been used by other municipalities are also included.

www.sustainablecommunities.ca/files/Capacity_Building_-_PCP/PCP_Resources/Mun-Re-_Adapting-Climate-Change-e.pdf



Infrastructure Climate Risk Protocol (Engineers Canada)

This protocol is intended for users who own, operate or design physical infrastructure. It provides a five-step procedure to assess the vulnerability of infrastructure to climate change from an engineering perspective. The protocol helps users systematically evaluate risks from climatic changes on all components of infrastructure.

www.pievvc.ca



Climate Change Adaptation Framework Manual (Ministry of Sustainable Resource Development, Alberta)

This manual helps organizations anticipate and prepare for the economic and ecological impacts of climate change in a comprehensive and consistent manner.

www.srd.alberta.ca/MapsFormsPublications/Publications/ClimateChangeAdaptationFramework.aspx

CHAPTER 3

CASE STUDIES: INTEGRATING CLIMATE CHANGE CONSIDERATIONS INTO MUNICIPAL DECISION MAKING

The case studies presented here demonstrate how Canadian communities are starting to address climate change adaptation. While they do not claim to represent best practices, they serve to raise awareness of climate change impacts and provide insights as to how these challenges might be addressed by other communities facing similar issues.

Certain case studies reflect actions taken by communities as a specific response to recognized climate change impacts (e.g. Clyde River, Le Goulet and Québec City). Other studies represent actions that reduce vulnerability to climate change

even though this was not the main reason for implementing the initiatives (e.g. Kamloops, Metro Vancouver and Regina). All the case studies exemplify how communities followed a decision-making process that directly or indirectly considered climate change adaptation and improved community capacity for long-term adaptation planning and implementation.

The case studies listed in the following table illustrate a range of climate change impacts and possible adaptations, using municipalities of varying sizes from across Canada. For further information, see the “References” chapter.

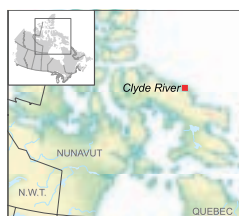
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PHOTO COURTESY OF DAVID MATE

Clyde River's Community Climate Change Adaptation Plan

Planning in remote northern communities presents unique challenges



Canada's North is experiencing rapid changes in climate. Northern residents have noticed thinner sea ice, melting of ground ice, rising sea levels, increases in the frequency and intensity of storm events, and a change in coastal erosion rates due to reduced ice cover. The impact of these changes on communities spurred intergovernmental cooperation and engagement of a professional organization to undertake climate change adaptation planning in Nunavut.

In 2006, a three-day workshop was held in Iqaluit, the territorial capital, to launch a new intergovernmental / interagency climate change adaptation planning initiative for Nunavut. One key recommendation of the workshop was to pilot small-scale, integrated adaptation planning processes in two Nunavut communities. Representatives from the hamlets of Clyde River and Hall Beach offered to be part of the initiative. These pilot projects were designed to be iterative, collaborative processes involving community members (including school students and local decision-makers), scientists and professional planners. Local and traditional knowledge and expertise were recognized to be of paramount importance.

One outcome of the Clyde River pilot project was an action-oriented climate change community adaptation plan. Its development involved the Canadian Institute of Planners, which provided two volunteer professionals to help coordinate the planning process, a science team led by Natural Resources Canada (NRCan) researchers, Ittaq Heritage and Research Centre (an Inuit-run research centre in Clyde River) and the Government of Nunavut. As with all new collaborations, there were a number of challenges to be overcome in achieving an effective working process.

CLIMATE CHANGE IMPACTS

Clyde River is a hamlet of 900 people on the north coast of Clyde Inlet on northeast Baffin Island, Nunavut. The community is surrounded by mountains, dramatic cliffs, deep fjords and rolling tundra. The rapidly warming arctic climate has residents concerned about their safety. Two impacts of particular concern are melting permafrost, which is threatening the integrity of the town's roads, buildings and other critical infrastructure, and unpredictable sea ice, which is making traditional hunting and travelling routes more dangerous.

The planning involved community workshops and in-person interviews, with the Ittaq Heritage and Research Centre playing a key coordination role. The final product was a concise plan listing 38 distinct actions for adapting to specific risks identified by the community. The actions were organized on the basis of which partner (e.g. Hamlet Council, Ittaq Heritage and Research Centre, the Hunters and Trappers Association or other organizations) would be best positioned to implement the action.



SCIENTIFIC FIELDWORK

NRCan is undertaking scientific research in Nunavut that is relevant at the regional and local levels. It includes work on permafrost degradation, landscape hazards, sea-level rise, coastal erosion and freshwater supply. The findings are being integrated with traditional knowledge to improve community planning capacity in Nunavut. This research is being conducted in collaboration with several Canadian universities, the Ittaq Heritage and Research Centre and the Nunavut Research Institute.

The work in Clyde River represents the first attempt at adaptation planning in this small northern community. Many valuable lessons were learned and are being applied to planning processes in other remote northern communities. A summary of these lessons learned can be found on the Canadian Institute of Planners Web site (www.planningforclimatechange.ca). Examples include

- acquiring formal recognition of the project from the Hamlet Council, as well as assigning a senior staff person to the planning work to ensure project continuity and accountability at the local level
- improving the coordination between the science and planning work to allow for better integration
- lengthening the planning cycle to enable the planning teams to spend more time in the community to build relationships and trust
- establishing priorities for recommended actions to help in the implementation phase
- translating all public notification and planning documents into local languages (in this case Inuktitut) before they are released
- enhancing community participation through local culturally appropriate methods, including regular public phone-ins on community radio for contacting local residents and receiving feedback

ADAPTATION ACTION PLAN

A succinct community adaptation plan identified 38 actions, the climate change issue that each addresses, the intended result of the action, and the resources the community could utilize to complete each action. The following is one example.

ACTION	Provide broader coverage of communication equipment outside of town for FRS, CB and HF radio.
ISSUE	Uncertain ice and travel conditions. Increased risk to personal safety. Need for quicker and better sharing of information.
RESULTS	Residents able to obtain and pass on information on travel and ice conditions as well as emergency situations. Extend the range of current communication equipment.
RESOURCES	Hamlet with HTA and Search and Rescue Committee

Source: www.planningforclimatechange.ca

The lessons learned from the Clyde River pilot project, combined with similar work in Hall Beach, helped lead to the establishment of the Nunavut Climate Change Partnership. This multi-year collaborative effort, funded by Indian and Northern Affairs Canada, will develop community-based adaptation action plans in five additional communities (Iqaluit, Arviat, Whale Cove, Kugluktuk and Cambridge Bay); prepare a planning workbook/tool for use by other Nunavut communities; produce new scientific information on sea-level change, permafrost landscape hazards and freshwater supply; and create tools to collect, publish, share and communicate knowledge about climate change adaptation.

The Clyde River Adaptation Action Plan, the first of its kind in the Canadian Arctic, provides a useful starting point. The Clyde River Council supports continued efforts for working together to address climate change issues.

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PHOTO COURTESY OF BRIAN AVERY

City of Kamloops' Wildfire Protection Plan

Reducing urban wildfire risk through preventative action



Kamloops, a city of 93 000 people situated in the Thompson River Valley of south-central British Columbia, is particularly vulnerable to wildfires because of its dry climate. Wildfires are one of several risks that are projected to increase in future as a result of a changing climate.

Several factors produce an elevated risk from wildfires to lives and property in Kamloops' wildland-urban interface. These include social factors, such as growing development on the city's perimeter, as well as natural factors such as forest fuel build-up, the impacts of the pine beetle and an increase in the number of hot and dry summers.

During the devastating 2003 wildfire season, Kamloops served as the command and control centre for emergency workers and as a temporary refuge for thousands of evacuees from surrounding municipalities. Three large wildfires reached the city's perimeter that summer, threatening homes and businesses. Fortunately, Kamloops suffered only one minor structural loss when a community waterworks shed burned down. However, the city's close call that summer, as well as the harrowing experiences of other British Columbia municipalities such as Kelowna, spurred Kamloops to take preventative action.

In 1998, the City established a multi-stakeholder committee to coordinate its wildfire response. While it is recognized that it is not possible to eliminate all wildfires (approximately 150 to 170 small wildfires occur within city boundaries each year), actions can be taken to minimize potential home and infrastructure damage.

In 2007, the committee published its comprehensive Community Wildfire Protection Plan, whose overarching goal is "to identify and reduce the risk of life, property and environmental losses due directly or indirectly to wildfire within, or threatening city boundaries through effective

2003 BRITISH COLUMBIA WILDFIRE SEASON

In the hot and dry summer of 2003, more than 2500 wildfires across British Columbia caused unprecedented damage to homes, businesses and public infrastructure. Three pilots lost their lives, 334 homes and businesses were destroyed, and 45 000 people were evacuated from their homes. The total cost of the fires is estimated at \$700 million (Filmon 2003).

pre-planning and preparation." The Plan outlined the City's actions to date and contains further recommendations.

HAZARD ASSESSMENT

In 2004, the City contracted a private firm to conduct a city-wide wildfire hazard assessment to determine the amount and configuration of forest fuel and the ensuing threat to adjacent structures. The resulting map demarcated all public and private lands within the city into the following wildfire risk classes: extreme, high, moderate or low.

FOREST FUEL MANAGEMENT PLAN

A contractor was hired to develop a plan proposing specific actions to reduce the wildfire hazard on the 4036 hectares (ha) of city and crown land that had been assessed as extreme and high hazard. The plan's proposed hazard reduction measures were based on FireSmart hazard reduction guidelines.

FUEL MANAGEMENT OPERATIONS

Based on the management plan described previously, the City undertook extensive forest treatment work on 905 ha of city and crown land. The forest canopy bulk and density were reduced mechanically to decrease the amount of fuel available for combustion to FireSmart guideline levels. The spacing and pruning work was accelerated to be completed by the spring of 2010 because of the seriousness of the pine beetle epidemic, which has killed more than 90 percent of the ponderosa pine trees within city limits.

WILDLAND-URBAN INTERFACE COVENANT

Kamloops' existing Wildland-Urban Interface (WUI) covenant specifies that before a building or subdivision is approved for development, the landowner must agree to wildfire mitigation measures, including fire-resistant roofing materials, fuel buffer dimensions and spark arresters for wood stoves. A more stringent covenant is being developed in 2010. It states that a proposed development situated in the assessed moderate, high or extreme wildfire hazard classes cannot be built upon unless the landowner

- meets a minimum of FireSmart guidelines
- submits a site-specific wildfire hazard assessment to the City

Following negotiations with the City, two new subdivisions have already adhered to the new covenant's more stringent FireSmart guidelines.

PUBLIC AND LANDOWNER EDUCATION AND COMPLIANCE

The City created a wildfire Web site with up-to-date information for area residents. In addition, information and advice is distributed through television commercials, public campaigns, FireSmart seminars and information pamphlets.

The City of Kamloops is balancing public safety with the ecological integrity of surrounding green space. Wildfires are a regular ecological element in this "mountain rain-shadow" region covered by grasslands and forests; the natural burn cycle is between 7 and 30 years. However, most large wildfires have been suppressed in recent decades, and consequently, the land around Kamloops has accumulated dangerous levels of forest fuel material.

Although mechanically thinning thousands of hectares of city forests affects the region's soil, fauna and flora, it can be argued that such operations are bringing the forest closer to its "natural" state by reducing the level of forest fuel by mechanical rather than natural (wildfire) means. The Filmon report (2003), a review of the British Columbia government's response to the fires across the province in

BEST PRACTICE WILDFIRE PLANNING GUIDES

FireSmart: Protecting Your Community From Wildfire (2003), published by Partners in Protection, an Alberta-based non-profit organization, provides individuals and communities with planning tools for mitigating the risk of fire in interface areas.

The City of Langford, British Columbia, received provincial government funding to develop and implement model guidelines for reducing fire risk in the wildland-urban interface. The City published a detailed report in 2002 outlining its experiences, plans, wildland-urban interface covenant and other actions.

2003, argued that controlled forest burns are a good way to replicate the natural ecological integrity of the landscape while also helping to substantially reduce the wildfire threat to the public. The City of Kamloops plans to pilot controlled surface burns in 2011.

Managing wildfires is complex. Although the City of Kamloops has taken action to reduce the risks to human life and property from wildfires, several challenges remain. First, for the current plans and actions to continue to be effective, ongoing active forest management is required (involving either mechanical thinning or controlled burning). Otherwise, the forests will accumulate dangerous levels of forest fuel. Second, the public's perception of fire hazards and what a forest should look like in the Kamloops region has been identified as a major challenge for the City to overcome. Since the wildfires of 2003 and the pine beetle epidemic, public perception is beginning to change; but continued work is needed to fully engage the public and effectively reduce the wildfire risk.

In the aftermath of the 2003 wildfire season, Kamloops quickly mobilized various stakeholders to develop a comprehensive wildfire reduction plan and implement ambitious measures such as forest treatment work and a wildfire hazard covenant. The City's decisive response to the wildfires of 2003 demonstrates the importance of taking concerted action before devastation occurs.

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Metro Vancouver's Stormwater Management Program

Adaptation to climate variability and change can be successfully integrated into existing plans and programs



Metro Vancouver, a regional district comprising 22 municipalities, one electoral area and one treaty First Nation, is home to more than 2 million people. It has experienced very rapid growth over the past decade that is expected to continue. The district's mandate relates primarily to regional planning and delivery of essential utility services. Some Metro Vancouver member municipalities have been addressing climate change adaptation for more than five years.

STORMWATER INTERAGENCY LIAISON GROUP

Under the federal *Fisheries Act*, Metro Vancouver and its member municipalities are not allowed to discharge stormwater and rain runoff that would negatively impact fish and their habitat. The concern is about how changes in stormwater runoff quantity and quality impact the region's many urban and rural salmon and trout streams. Metro Vancouver, its member municipalities, and provincial and federal environmental agencies formed the Stormwater Interagency Liaison Group (SILG) in 2002 under its provincially approved Liquid Waste Management Plan to facilitate the co-ordination and sharing of common research related to stormwater management.

This co-ordinated approach created a template for developing watershed-specific, flexible and adaptive strategies, known as Integrated Stormwater Management Plans (ISMPs). These plans integrate a wide range of water management issues, including watershed health, land use planning, engineering, community values, and climate variability and change. Although the primary drivers in the development of these plans have been expanding urbanization and management of intensive agriculture, climate change has been integrated into the ISMP process and other approaches for managing the health of streams in the region.

A CHANGING CLIMATE

Metro Vancouver has a coastal climate characterized by mild, wet winters and warm, dry summers. Temperature records indicate a clear warming trend of between 0.5°C and 0.8°C over the past century. Also, annual precipitation in the region has increased over the past 50 years. Much of the short-term variability in climate (years to decades) relates to natural climate cycles such as the El Niño-Southern Oscillation.

SEVEN STEPS TO DESIGN AND IMPLEMENT AN ISMP

1. Secure political interest and support.
2. Identify watershed problems and opportunities.
3. Develop objectives and alternative scenarios.
4. Collect meaningful data and refine scenarios.
5. Evaluate alternatives and develop component plans.
6. Develop an implementation program.
7. Refine the plan through adaptive management.

INTEGRATED STORMWATER MANAGEMENT PLANS

The goal of an ISMP is to develop effective stormwater plans that will result in no net loss to environmental quality and protect communities from localized flooding. The process actively seeks input from various stakeholder groups within each watershed and brings together the fields of planning, engineering, ecology and natural hazard protection within an adaptive management methodology. Member municipalities have committed to develop ISMPs for all Vancouver urban and suburban watersheds by 2014.

Within each ISMP process, an advisory group that includes representatives from the development, agricultural and environmental sectors contributes historical knowledge of the watershed and helps to assess the benefits of the ISMP over time. The general public is involved in evaluating alternative management scenarios and reviewing the plan's success. This roundtable approach relies on a combination of knowledge of land use, water resources and engineering from governments, local residents and experts. A widely supported set of final adaptive management rules allows landowners and developers to make long-term investment decisions with confidence, provide government agencies with regulatory certainty and ensure that the investments of municipal governments lead to continuous improvements in stormwater management.

Approximately 25 ISMPs have been completed or are underway in Metro Vancouver – representing about half of the watersheds in the region. Municipalities have adopted such measures as on-site rainfall retention (through infiltration and detention infrastructure) the re-exposure and naturalisation of culverted or buried streams, reduction targets for total impervious area and improved public access to waterways. Some of these measures are driven, in part, by the projected impacts of climate change on the region's watersheds. After the measures are implemented, many municipalities will monitor stream flows and stream health (e.g. benthic and fish studies).

WATERSHED IMPROVEMENT FEATURES

Many Metro Vancouver municipalities have translated the ISMPs into actions. For example, the Corporation of Delta has a landscape architect on staff to assist the engineering design team to construct landscaped watershed improvement features that reduce stormwater runoff and protect stream health. The engineering team has constructed more than 18 watershed improvement projects that include permeable paving and the planting of street trees over renovated portions of roadsides, infiltration tanks, grassy swales and rain gardens.

CLIMATE CHANGE VULNERABILITY ASSESSMENT

In 2006, Metro Vancouver partnered with Engineers Canada to conduct an initial assessment of various components of the region's wastewater system – combined sewers, pump stations and the Iona Island wastewater treatment plant. The final report noted that low-lying wastewater infrastructure (such as the Iona Island wastewater treatment plant, which provides primary treatment services for approximately 600 000 people) was vulnerable to both rising sea levels and possible increases in the frequency and magnitude of storm surges. In addition, the increasing intensity of extreme rain events potentially has significant implications for the capacity of existing sewers and the design of upgraded infrastructure.

Metro Vancouver has been proactive in integrating climate change adaptation into the region's wastewater planning processes since 2002. In 2006, Metro Vancouver and Engineers Canada jointly funded an initial assessment of the vulnerability of the region's wastewater infrastructure to climate change. Subsequently, Metro Vancouver undertook actions supporting improving infrastructure resilience, many of which were incorporated directly into the Integrated Liquid Waste and Resource Management Plan, adopted in May 2010. This plan specifically addresses the impacts of climate change and climatic cycles on local water resources.

Although it is not driven directly by concerns about the impacts of climate change, the ISMP process provides Metro Vancouver and its members with an inclusive and comprehensive tool for managing complex risk-management issues that improve the region's capacity to deal with environmental risks, including those related to climate variability and change.

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PHOTO COURTESY OF CATHY TALARICO

Edmonton's Urban Forest Management Plan

Managing urban forests in a changing climate



Edmonton, Alberta, has 299 000 landscape trees on City property, including boulevards and parks. These trees provide a plethora of valuable ecological services to the City. They keep neighbourhoods cool, improve air quality, provide wildlife habitat, remove carbon dioxide from the atmosphere, retain stormwater run off and prevent erosion. In addition, trees add substantial aesthetic, recreational and economic value to communities. However, this valuable asset is at risk because recent drought, insect infestations, disease and storms are taking a heavy toll on Edmonton's extensive urban tree canopy.

In the last decade, more than 30 000 trees (an average of 4300 annually) died because of drought conditions and secondary pests, compared with a previously more typical number of losses of between 600 and 900 annually. The scale and intensity of the drought-related tree deaths are a major challenge for the City. Even with a capital infusion of \$2.75 million to augment replanting efforts in 2003–2004 and the City's desire to replace every felled tree, the City has been unable to keep pace with the recent losses.

Climate change is expected to further increase the threats to the health and viability of Edmonton's urban tree canopy. If summer drought conditions continue, the City will need to intensify replanting efforts and reconsider which tree species to plant to reduce losses. Edmonton is also preparing for a wave from the south of invasive pests and diseases, including the Emerald Ash Borer and Dutch Elm Disease. These are major threats to the urban tree canopy because green ash and American elms comprise approximately 46 percent and 32 percent, respectively, of the City's street trees.

These threats to the urban forest spurred the City to create a plan that would guide its future management over a 10-year period. In 2006, council approved the creation of a new staff position to lead the development of the City's first Urban Forest Management Plan (UFMP). The plan, due in 2010, includes a vision statement, three main objectives, associated strategies and specific actions. The plan's vision is "to have a diverse and sustainable

TREE LOSSES IN EDMONTON		
YEAR	LOST	PLANTED
2002	4300	1000
2003	5200	1800
2004	6200	1600
2005	4300	800
2006	3000	2050
2007	3400	1400
2008	4100	2450
2009	2977	2600

urban forest that enhances the beauty of Edmonton and contributes to the well-being and quality of life for future generations."

Each action has been assigned to a project partner and has a prioritized timeline: short (0 to 3 years), medium (4 to 7 years) and long (8 to 10 years). The following are examples of the key actions:

- Create an inventory of the urban forest (completed 2009).
- Develop a replacement strategy for dead or dying plant material.
- Review existing planting strategies.

THREE MAIN OBJECTIVES OF THE URBAN FOREST MANAGEMENT PLAN

1. To provide Edmonton with a comprehensive plan for effectively managing, sustaining and ensuring the growth of the City's urban forest
2. To educate the general public, other city agencies, neighbouring communities and community partners about the importance of the urban forest, forestry issues and management best practices
3. To protect native forest and tree stands in conjunction with the city's Office of Natural Areas, which is responsible for the natural areas and the Natural Connections Strategic Plan

- Create fire and disaster management plans.
- Develop a disease control plan.
- Assess staffing levels and staff training.
- Develop potential tree planting partnerships.
- Create public education opportunities.
- Perform an Urban Forest Effects Model and a Street Tree Resource Analysis for Urban Forest managers (completed).

The plan was developed with regular input and direction from a multi-stakeholder advisory group that included members of the public and affected interest groups, such as the City's transportation and drainage personnel. An outcomes-based systems approach was used to define measures to assess progress toward the vision and the objectives. Forestry staff began the planning process by conducting an extensive review of best practice urban forest management plans from across North America. At various points in the process, the public was consulted through surveys, online information sharing and focus groups.

An inventory of the urban forest, encompassing both private and public lands, is a key component of the UFMP. In 2009, extensive field observations combined



with meteorological and pollution records were used to calculate the species composition of the urban forest as well as its economic and ecological value. This database provides an accurate baseline for the management of various threats to the urban canopy, including those related to a changing climate.

Edmonton's Forestry Unit is actively testing different strategies and techniques to minimize the threats from climate change as well as take advantage of new opportunities. The City's Old Man Creek Nursery, in partnership with a local private nursery, is conducting tree hardiness trials to test species such as red maples, crabapples, oaks and pears that are not usually planted in Edmonton but have increasing survival potential because of warming climate conditions. In addition, the Forestry Unit is testing alternative maintenance techniques to minimize losses from drought. These include watering methods such as the installation of water bags that slowly release water to the base of trees.

City officials note that a key strength of the UFMP plan-making process has been the Forestry Unit's collaborative approach with other municipal departments and the public. Collaborative computer software has been an important tool for coordinating meetings, sharing data and distributing draft plans. However, the successful implementation of the plan's actions rests on the continued engagement of stakeholders.

Half of Edmonton's trees are on private property. To encourage a healthy tree canopy while also minimizing costs to the City, municipal officials will need to provide ongoing education and other services to the public. In addition, coordination between municipal departments is critical in responding to evolving climate and pest conditions. One example is a joint project between the Forestry Division and Public Works that is studying the feasibility of storing stormwater for use by trees during drought periods.

Edmonton's tree canopy is seriously threatened by climate change, natural disasters, pests and disease. While the UFMP is still in its final draft stage, it has already enabled the City to develop a comprehensive and integrated approach to managing the urban forest. City officials look forward to continuing the work with various public and private stakeholders to implement best practice solutions to minimize, and hopefully reverse, the trend of high tree losses observed over the last decade.

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Regina's Water Conservation Program

Demand management of scarce resources can be critical in enhancing climate resilience



Regina, Saskatchewan, is a city of 200 000 situated in the middle of the vast southern prairies, the driest major region of Canada. The city has very little local access to water. The only body of water running through the city is Wascana Creek, a formerly ephemeral stream that was dammed in 1883 to create an artificial lake that today acts as a downtown landmark.

To meet local demand, Regina draws its potable water from Buffalo Pound Lake (57 kilometres [km] northwest of the city), which itself is fed from Lake Diefenbaker, a large reservoir formed in 1967 by damming the South Saskatchewan and Qu'Appelle rivers.

In the early 1980s, Regina was struggling to meet demand with its existing water supply system. Per capita water usage was increasing annually, and if unchecked, the City would have had to undertake costly infrastructure upgrades to increase potable water and wastewater supply capacity. Although water conservation was a fairly new concept in the 1980s, the City thoroughly explored its options and in 1985 implemented a Water Conservation Program. While not designed as a climate change adaptation measure,

ENHANCED WATER CONSERVATION PROGRAM GOALS

In 1991, Regina City Council implemented strict new targets and expanded the water consumption program to delay infrastructure expansion costs. Since 1991, the program's goals have been to

- reduce the average day and peak day water consumption per capita by 15 percent by 2011
- continue to encourage the wise use of water by customers
- inform the public of the City's plan for water conservation

WATER SCARCITY AND CLIMATE CHANGE

For the Canadian prairies, increases in water scarcity and drought are the most serious risks presented by future climate changes. These impacts will be particularly significant for Regina because much of its water supply comes from the South Saskatchewan River. For this river, rising demand for water by industrial, agricultural and community users in southern Alberta and southwest Saskatchewan will need to be reconciled with projected decreases in mean annual flows due to climate variability and change. Demand management will be a critical tool in addressing water scarcity challenges.

the program has had a profound impact on enhancing the city's climate resilience.

The program involves several components that have been developed incrementally over the last 25 years. These include

- a pricing structure to encourage water conservation
Prior to implementing its conservation program, Regina operated a full-cost recovery, user pay system that charged a fixed price for the first 28 cubic metres of water consumed per household, plus a metered charge for any use above that amount. In 1985, the City replaced the fixed price with a fee for each cubic metre of water consumed. The underlying concept was that by paying for all water

consumed, customers would limit water consumption. This, in turn, would delay the need for system-wide infrastructure upgrades and allow costs to be spread over a greater time period.

- **communication**

Communication has been a central component of Regina’s water conservation efforts. The City has disseminated information and advice – that emphasize the message “save water, save money” – through brochures, Web sites, school visits, local trade shows, xeriscape landscaping workshops, as well as through advertising campaigns using local radio, television, newspapers and billboards.

- **water meter replacement**

In 2002, the City began replacing the approximately 50 000 meters installed before 1992 with the goal of improving metering accuracy – the old meters typically undermeasured water consumption. The new meters have radio transmitters that relay consumption data to a city-operated vehicle each month. Accurate registration of water flows on a monthly basis promotes conservation because customers can quickly and accurately make the connection between changing water conservation habits and their bill.



XERISCAPE

Xeriscape is an alternate form of landscaping that relies on drought-tolerant plants to reduce outdoor watering requirements during the summer. In 1993, the City produced a xeriscape workbook that it distributes annually at free workshops in the spring and fall and on the City’s Web site. In the late 1990s, the City partnered with a local school (collaboration between city staff, teachers, parents and school children) to create a xeriscape educational and demonstration site. The garden features 45 plant types, a false creek and an amphitheatre with a teacher’s rock for outdoor classes and lessons.

UPPER QU’APPELLE RIVER AND WASCANA CREEK WATERSHED PLANNING

The City of Regina has provided strong support to community-based planning in the Upper Qu’Appelle River and Wascana Creek watersheds. In 2002, the newly created Saskatchewan Watershed Authority invited local people to participate in watershed and aquifer planning with the goal of protecting water quality and quantity. A diverse group of stakeholders that included farmers, rural and urban municipalities, environmental organizations and industry oversaw the creation of comprehensive plan. The final plan included 82 initiatives within 10 broad categories. Many proposed actions dealt with climate change adaptation. For example, Action 61 states that “all stakeholders . . . consider climate change an integral part of source water protection decisions.”

Regina’s Water Conservation Program has been extremely successful. The city’s annual water consumption decreased from a high of 39 billion litres (L) in 1988 to 28.5 billion L in 2007. This enabled the City to delay the upgrade to the water supply system.

In 2005, Regina completed construction of a second 57-km pipe from the Buffalo Pound Water Treatment Plant, with the primary goal of improving supply security. The redundancy offered by the second pipe, wherein disruption of one does not impact the entire water supply to the city, is a good example of a measure that enhances resilience in the face of climate change.

Regina has significantly reduced per capita water consumption through a series of incremental changes. In recent years, water consumption for the city as a whole has remained stable despite modest population growth. The modification to the pricing structure, which charges users for every cubic metre of water used, is the flagship feature of this successful program. It demonstrates that financial incentives, in conjunction with effective communication, can help manage demand for scarce resources. While not initially designed as a climate change adaptation measure, improved water management has helped increase the city’s resilience to climate impacts. Recognizing its role as a key water user, the City is lending its experience and support to broader watershed planning initiatives that are addressing water supplies and climate change impacts.

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London, Ontario's, Climate Change Adaptation Strategy

Reducing flood risk through proactive design



Two tributaries of the Thames River meet in London, a city in southwestern Ontario with a population of 350 000. The Thames River has experienced several extreme floods since records began in 1791. Dikes and dams completed in the 1950s have since saved London from major flooding.

In 2007, a University of Western Ontario (UWO) research team published a report that assessed the vulnerability of the Thames River watershed to changing climate. The study concluded that “climate change is expected to intensify flooding in the [river] basin, thus bringing flows in higher magnitude with more frequent occurrence.”

To act upon the study’s findings, the City engaged UWO researchers from the Department of Civil and Environmental Engineering to conduct a preliminary analysis of the city’s rainfall intensity, duration and frequency curves (IDF curves) in the context of a changing climate. These rainfall trends help define key design criteria for municipal water resource management infrastructure, such as storm sewers, overland drainage, street curbs, gutters, culverts, dikes and bridges.

Analysis of the IDF curves demonstrated that “rainfall intensity and frequency in the Thames River watershed had increased on the basis of historical observations (1965 to 2001) and is anticipated to continue to increase.” The research predicted that peak flow estimates for a small storm lasting fewer than 90 minutes would be increased by 10 to 15 percent, while peak flow estimates for a storm exceeding 90 minutes would be up to 30 percent greater than in the past.

For existing stormwater management systems, this would likely lead to more flooding and overflows. The report



PHOTO COURTESY OF THE UNIVERSITY OF WESTERN ONTARIO ARCHIVES

LONDON'S FLOODING HISTORY

The floods of 1883 caused extensive damage to homes and businesses and killed 17 people, prompting the City to construct protective dikes. The floods of 1937 were the most severe in the city’s history (see above image). River water rose 7 m, overflowing dikes and destroying 1100 homes and killing five people. After the 1937 and 1947 floods, the City constructed three dams along the Thames River to protect the community. Together, the dikes and dams have been effective defensive measures. Although the Thames River flooded its banks in 1977, 1986, 1997 and 2000, no water breached the dikes during these events.

concluded that the City should consider developing significantly larger stormwater management facilities and drawing new flood lines within the Thames River watershed. The latter measure would potentially lead to changes in the City’s Official Plan and other environmental and water resource policies.

In response to the preliminary IDF curves analysis, the City’s Environmental and Engineering Services Department recommended the development of a comprehensive climate change adaptation strategy for London, with a focus on the impacts from flooding. This two-phase strategy, which was passed by City Council in December 2007, includes comprehensive engineering and scientific assessments to more clearly determine the risks to the level of municipal services that can be provided.

While still in its early stages, the adaptation strategy is progressing well. The City plans to move to Phase 2 following completion of the General Risk and Consequences Analysis in February 2011. In addition, based on a recommendation from a Blue Ribbon Panel tasked with reviewing London’s

PHASE 1 – CLIMATE CHANGE ADAPTION TRANSITION STRATEGY	
ACTION	COMPLETION DATE
Undertake detailed analysis and update of the city’s current IDF curves.	May 2010
Investigate increasing the short-term capacity of the stormwater management system by 15 to 20 percent to account for climate change.	July 2010
Engage experts to undertake a general risk and consequences analysis associated with impacts of storm events on the following city-owned and maintained infrastructure: buildings, floodways, streets, culverts, dikes, bridges and sewer design.	February 2011

PHASE 2 – CLIMATE CHANGE ADAPTION LONG-TERM STRATEGY	
ACTION	COMPLETION DATE
Amend the City’s Stormwater Management Strategy and Subwatershed Study upon completion of the general risk assessment and updated IDF curves.	~2013
Consider developing a green infrastructure plan that incorporates an environmental/ecological approach to water resource management.	
Formalize a long-term Climate Change Adaptation Strategy for protection of municipal infrastructure and public and private property.	

STONEY CREEK RESTORATION

This project demonstrates the City moving toward an ecological/systems approach to stormwater management, as stated in the long-term strategy (Phase II). In the spring of 2009, the City undertook channel restoration and remediation on a 1.8-km stretch of Stoney Creek. It also created an adjacent wetland, with a total drainage area of 3600 ha. One goal of the remediation was to ensure that the creek could support the stormwater runoff from a nearby 360-ha residential/commercial development. The remediation work is minimizing bank erosion and stormwater runoff volumes by restoring the creek’s geomorphological and ecological functions.

property development charges, the City has transferred responsibility for the construction of all stormwater management infrastructure from property developers to the City. This transfer of responsibility, which is unique among Ontario municipalities, allows the City to take an integrated systems approach to stormwater management. For example, when a new subdivision is constructed, the City, not the developer, will be responsible for designing and implementing stormwater infrastructure.

High-quality local climate data were a crucial component of this project. However, municipal officials note that relevant local-scale data (such as historical rainfall records) were incomplete and substantially lengthened the data gathering and analysis process undertaken in Phase I. Much of the City’s climate change strategy work would not have been possible without the City dedicating significant funds (\$1.3 million was approved in 2008) to conduct research to examine the impacts of climate change on London’s infrastructure and to update the IDF curves.

London’s Adaptation Strategy demonstrates the importance of collaborative partnerships between climate change specialists and municipal staff. UWO’s rainfall projections will form the basis for revised engineering standards for the City’s stormwater management system. These changes will allow the City to make proactive incremental changes to its flood management program that should help avoid costly, disruptive and dangerous flooding in the future.

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Toronto's Heat Health Alert System

Proactive adaptation can help save lives now and prepare for future climate change



The City of Toronto has developed and implemented two extreme weather alert systems: Extreme-Cold Weather Alerts (in 1996), and Heat Health Alerts (in 2001). These systems are designed to protect the city's most vulnerable populations – the elderly, children, medically at-risk persons, and the homeless – from extremes of heat and cold. The Heat Health Alert System was developed proactively, in part as a response to the disastrous heat waves in Chicago (1995) and Philadelphia (1993), both of which killed hundreds of urban residents.

Environment Canada projects that by the latter part of this century, Toronto will average 65 days per year where the temperature exceeds 30°C, more than four times the historic average between 1961 and 1990. This represents a critical concern that will disproportionately impact the health and wellbeing of the city's more vulnerable populations.

Toronto has had a heat warning system since 1999. The first heat warning system used a threshold of a one-day forecast of humidex over 40°C. Since 2001, Toronto Public Health has adopted the Heat Health Alert System as the basis for declaring alerts. This system is based on a synoptic approach that assesses the historical relationship between mortality levels and weather conditions.

Toronto's Heat Health Alert System includes a three-day forecast outlook. This synoptic-based approach starts with an air mass categorization for each forecast day based on weather conditions (temperature, humidex, dew point, wind speed and direction, air pressure and cloud cover). Then an algorithm is run to predict the likelihood of excess mortality under these air mass conditions; it is this likelihood that determines whether the Heat Health Alert System forecasts an Extreme Heat Alert, a Heat Alert or neither.

The Toronto Medical Officer of Health issues a "Heat Alert" when the likelihood of excess weather-related mortality exceeds 65 percent and an "Extreme Heat Alert" when

POPULATIONS AT RISK FROM EXTREME HEAT

The health risks increase substantially when people experience prolonged exposure to heat without significant cooling intervals. Socially isolated seniors are at highest risk of heat-related illness and death. Other at-risk groups include children, people with chronic and pre-existing illnesses including mental illness, low-income households, and adults who are marginally housed or homeless.

the likelihood of excess weather-related mortality exceeds 90 percent.

At the beginning of the summer, the City of Toronto and its partners provide the public with targeted information on the risks of extreme heat and on precautions to prevent heat-related illness and death. Various brochures are distributed and are available on the City's Web site. Declaration of an alert by Toronto's Medical Officer of Health activates specific responses under the City of Toronto Hot Weather Response Plan, which includes

- contacting local media to inform the public that a heat alert has been issued
- notifying community agencies and other response partners of the alert status, in order for them to implement agency specific protocols

- operating, through the Canadian Red Cross, a heat information line from 9 a.m. to 9 p.m. for those in need of assistance or with heat-related inquiries
- distributing bottled water through the Canadian Red Cross, targeting vulnerable people and providing water to agencies that work with vulnerable groups
- distributing Toronto Transit Commission (TTC) tokens through selected drop-in centres to the homeless so they can reach cooling centres
- opening seven designated cooling centres (one open for 24 hours) at public locations, such as community centres and civic centres, during an Extreme Heat Alert

Toronto Public Health (TPH) conducts an annual review of the City's hot weather response. Recent changes to the plan include an increase in the number of cooling centres and an increase in the number of transit tokens distributed to people in need of transportation to a cool place. TPH also received funding from NRCan in 2010 to develop a map-based decision support tool for public health staff and community partners to improve the delivery of health-protective services to the most vulnerable populations during extreme heat events.

In addition to the Heat Health Alert System, the City has implemented various programs that include measures aimed at reducing the effects of heat waves by implementing tools aimed at cooling the city over the long term. These programs include a Green Roof Bylaw, the Toronto Green Standard, an Eco-Roof Incentive Program, Doubling the Tree Canopy Initiative, and "Greening" Surface Parking Lot guidelines. Many of these actions will help reduce the urban heat island effect, which occurs in urban areas where dark surfaces such as asphalt and roofing absorb the sun's energy and radiate it out, thereby further warming the local ambient air.



PHOTO COURTESY OF STEFAN POWELL

HEAT VULNERABILITY MAPPING TOOL

Toronto Public Health (TPH) is developing a mapping tool to visualize human vulnerability to extreme heat. The maps will incorporate numerous indicators of vulnerability, including surface temperatures, green space coverage, housing and social characteristics of at-risk populations, access to air conditioning, and the location of cool places. Due to be completed in 2011, the tool will help TPH and community partners identify and prioritize geographic hot spots for delivering resources during a heat alert. The City of Toronto also plans to use the tool for long-term climate adaptation planning.

Toronto's Hot Weather Response Plan has increased awareness of problems related to extreme heat, contributed to the development of new programs and measures to combat the urban heat island effect, and helped facilitate the partnering of various City departments, non-governmental organizations and other local groups. The City is now developing a Climate Change Risk Assessment process and electronic tool to be used in a variety of City Divisions. The process will include consideration of many extreme weather indicators, including extreme heat. The results of the risk assessment will enable staff to prioritize climate change risks and prepare appropriate adaptive actions.

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Québec City's Environmental Services Adaptation Plan

Leadership and teamwork are key when developing adaptation plans



Québec City (population 491 000) is located on the north shore of the St. Lawrence River in eastern Quebec. It is expected that climate change will result in the city being impacted by more severe weather events, including more intense snow storms, wind storms, heat waves and torrential rain.

In 2006, a presentation to City staff by Ouranos, a Quebec-based consortium on regional climatology and adaptation to climate change, spurred work to develop an adaptation plan. The City decided that, despite uncertainties in the magnitude of future climate changes, it was judicious to create an adaptation plan by examining past trends, climate projections, vulnerable operations and possible adaptive actions.

By being proactive, the City hoped to reduce the costs and negative effects of a changing climate on the City's operations and infrastructure. The goal was to develop an adaptation plan for the City's Environmental Services Department and then, based on the results of this small-scale trial, to produce an adaptation plan for the entire metropolitan area.

Environmental Services was chosen to develop the first adaptation plan because the department is responsible for managing the city's natural resources in a sustainable manner and already had a good knowledge of climate change. Environmental Services has three main responsibilities:

- managing air, water and soil quality at facilities operated by public works – wastewater treatment plants, landfill sites, snow depots and stormwater management facilities
- managing the City's trees and horticulture
- evaluating water quality (drinking and wastewater) in city-run laboratory facilities

An Environmental Services staff member led the process and wrote the plan. During the process, it was recognized that many actions already provided for in existing management plans could be considered adaptation measures because they serve to reduce vulnerability to climate hazards. Therefore, throughout the consultation process, staff were encouraged to identify both existing and new adaptation measures.

The process proceeded in four main steps over six months.

1. Climate change projections

To prepare for the consultations, a request was made to Ouranos to obtain regional climate modelling data for the 2020s, 2050s and 2080s.

2. Literature review

A literature review, encompassing scientific journal articles and government reports, was conducted to determine the likely impacts of climate change on the city's physical infrastructure and natural environment, and to help create a methodology for developing the plan.

3. Internal consultations

Internal consultations were conducted with 10 Environmental Services staff members to identify existing and proposed adaptation measures. The outcome was a summary table capturing key actions for each of the department's 20 subactivities.

4. Prioritizing adaptation strategies

Following revisions by the project lead, the summary tables were examined in individual meetings between the project lead and the consulted staff to arrive at a consensus on the final text and the priority level of each proposed measure.

The resulting adaptation plan, which was approved by council in April 2009, commits Environmental Services to consider the impacts of a changing climate in all of its operations, projects, plans and bylaws. In addition, the results from the consultations – including priority level, deadlines – and funding requirements – were presented in tables that clearly and concisely disseminate the key findings.

Eighty-eight adaptation measures have been targeted for all of Québec City’s Environmental Services operations. The majority of these (54) target the aquatic environment and drinking water, areas of high vulnerability to climate change. Twenty-six measures have been defined as priorities, including 12 that had been planned but not yet implemented and 14 that are new strategies.



The adaptation plan places highest priority on measures affecting the quality and availability of water, a vital resource that is particularly sensitive to changes in temperature and precipitation. The City is concerned about the projected increases in summer drought, which could make drinking water scarcer. Another concern is that rising sea levels, along with flow reductions in the St. Lawrence River, would result in salt-water intrusion impacting drinking water supplies in some parts of the city. While some of these issues may be already included in other City plans, the adaptation plan gives priority status to these issues.

The process that led to the development of the Environmental Services Adaptation Plan helped build support for the production of a city-wide adaptation plan. Following a clear presentation of some key climate change impacts and adaptation actions, the City’s Executive Committee approved (in April 2009) an expansion of the adaptation initiative to all of the City’s operations. Development of the expanded plan is possible through funding from the programme Climat municipalités of Québec’s Ministère du Développement durable, de l’Environnement et des Parcs.

The consultation process and adaptation plan developed by Environmental Services is based on the understanding that proactive adaptation measures are generally more cost effective than reactive measures implemented after a significant climate impact has occurred. This example demonstrates the effectiveness of using a consultation mechanism to identify and prioritize adaptation measures and to develop broad-based support and ownership of adaptation initiatives.

ADAPTATION CONSULTATION

A table was distributed to 10 staff members working on different subactivities within Environmental Services. The project lead filled in the climate change projections section based on research findings from Ouranos. The 10 staff members then completed the impacts and adaptation strategies sections. Below is an example of a completed table.

EXAMPLE: DRINKING WATER	
CLIMATE CHANGE PROJECTIONS	<ul style="list-style-type: none"> • increasing temperatures and evapotranspiration rates • absence of precipitation over long periods
IMPACTS	<ul style="list-style-type: none"> • Fresh water supplies may be compromised during the summer because of reduced flow levels. • Possible water shortages could require water restriction measures.
PROPOSED/ EXISTING ADAPTATION STRATEGIES	<ol style="list-style-type: none"> 1. Reserve funds for purchasing municipal water conservation equipment. 2. Install rainwater collection cisterns on selected municipal buildings. 3. Develop a communication program to educate the public on how to increase efficiency of water usage.

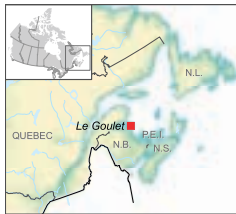
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Le Goulet's Climate Change Adaptation Plan

Planned relocation as an option to address sea-level rise



Le Goulet is a small fishing community with a population of 950 located on the Acadian Peninsula in northeast New Brunswick. The village is low-lying and relatively flat, two features that make it particularly vulnerable to the impacts of a changing climate and rising sea levels.

Local residents have noticed an increase in the frequency and intensity of extreme weather, including storm surges and flooding, and are worried about future impacts on their homes and livelihoods. For example, in the last 15 years, four major floods resulting from coastal storm surges have affected up to 30 homes in the village. These floods contaminated drinking water supplies (salt-water intrusion), caused septic tanks to overflow and flooded access roads, hampering emergency procedures. Contaminated drinking water and mould issues continue to be problems for many homes.

Le Goulet is separated from the Gulf of Saint Lawrence by sand dunes and salt marshes, both of which act as important natural buffers from storm events. Human extraction of dune sand in the 1980s (now illegal), combined with greater-than-normal coastal erosion rates (associated with reduced winter ice cover) and the four major storm surge events have resulted in erosion of the dune sand from a maximum height of 2 m above sea level to a height of just half a metre today. The lower dune levels leave residents increasingly concerned about the impact of future storm surges.

In 2002, engineering consultants hired by the village recommended that a 3.8-km sea wall be constructed just seaward of the sand dunes to protect against the worst impacts of storm surges, at an estimated cost of \$3.3 million. In 2004, community leaders asked University of Moncton climate change specialists to assist the village in producing a comprehensive local plan to adapt to the impacts of climate change and rising sea levels. The development of the plan included three phases.

THREE PRINCIPAL COASTAL ADAPTATION METHODS

Retreat – Relocate human settlement (homes, roads, etc.) away from areas of potential flooding, allowing the rising sea to advance inland.

Accommodate – Engage in actions that compensate for climate-related changes (e.g. constructing raised homes on pilings to accommodate rising sea levels).

Protect – Safeguard existing coastal land uses by implementing measures such as sea walls, dikes, beach nourishment and wetland restoration.

PHASE I – RAISING AWARENESS

In 2007, climate change specialists made three presentations in Le Goulet on different aspects of climate change, storm surges and coastal erosion. The presentations provided local residents with a sound scientific base from which to make informed adaptation and planning decisions. Three principal coastal adaptation methods were presented: retreat, accommodate and protect.

PHASE II – FOCUS GROUPS

Researchers organized discussion groups with 10 to 12 interested residents, living both inside and outside the at-risk zone, and local leaders (including the mayor and councillors). The goal of these group discussions was to arrive at adaptation options to be included in the draft

plan. This collaborative exercise led to, among other things, public consensus on the geographic definition of the area at risk.

PHASE III – ADAPTATION OPTIONS

The discussion groups decided on two principal adaptation options:

Option A: The voluntary retreat of homes most at risk

It was decided that relocating homes at risk from flooding (retreat) to a higher elevation is the most desirable and cost-effective means to reduce the multiple health and safety issues stemming from storm surge flooding. While the retreat option received consensus support within the discussion groups, it remains controversial for many villagers.

For example, the logistics of relocation would be complicated, as funds would have to be made available to compensate for relocation costs and help persuade residents to make the move. Option A also includes sand dune restoration efforts, and modification of the municipal zoning bylaw to ensure only approved adaptive development occurs in flood-prone areas.

Option B: The construction of a 3.8-km sea wall

For some residents, the construction of a sea wall is the most viable option for protecting the community from storm surges and flooding. However, during the group discussions, residents raised doubts as to the efficacy of the sea wall in preventing flooding and contamination of drinking water wells for low-lying homes. If a sea wall cannot prevent these risks, an expensive municipal water and sewage system (estimated at \$14 million) would have to be constructed to provide safe drinking water and sewage disposal.

The group discussions identified several important studies to conduct before moving forward with either option: (1) the development of a digital risk map that superimposes various climate change scenarios (flooding and erosion) with existing topographical features and infrastructure; (2) a modelling study of the impacts of a sea wall on coastal erosion and salt-water intrusion; and (3) a detailed cost analysis for the various adaptation measures.

The university-community partnership successfully initiated an important debate about the future of the community and spurred the following actions. First, in 2009 the Commission d'aménagement de la Péninsule acadienne (local planning commission) modified the village's zoning bylaw to prevent unsuitable development in flood-prone areas. Second, New Brunswick's Department of Natural Resources agreed to produce a high-resolution digital elevation map of the coastline, information needed to inform all possible adaptation options. Data collection for the map took place in the summer of 2010.



INNOVATIVE ZONING BYLAW

Rather than prohibiting all development projects in flood-prone areas of Le Goulet, the local planning commission took a more targeted approach. Using results from the discussion groups, the commission identified a zone where climate change impacts are considered a major risk that developers must consider in their plans. The zoning bylaw provides an opportunity to educate developers about the climate change related risks to people and infrastructure, and ensures that appropriate, but not prescriptive, measures are taken to accommodate those risks. The commission is working with the New Brunswick Department of Environment to develop criteria for adaptation that developers should consider when presenting a development proposal.

Many small communities lack the resources to develop and implement a comprehensive climate change adaptation plan. In Le Goulet, policy-makers were able to rely on nearby researchers from the University of Moncton to provide impartial impacts and adaptation information, to facilitate a discussion process and to draft a plan based on the outcomes from the discussions. This example demonstrates the importance of collaboration between local residents and climate change specialists when producing a climate change adaptation plan for a small community.

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PHOTO COURTESY OF HALIFAX REGIONAL MUNICIPALITY

Planning for Sea-level Rise in Halifax Harbour

Adaptation measures can be incrementally adjusted as new information becomes available



Halifax Regional Municipality (HRM), the capital of Nova Scotia, is Atlantic Canada’s largest city. The municipality covers more than 5500 km² and has a population of more than 390 000. Halifax Harbour, at the heart of HRM, is a major seaport with significant industrial, military and municipal infrastructure.

Rising sea level, along with increased storm intensity and associated waves and storm surges, presents risks to residents, property and infrastructure in coastal areas of HRM. Following extreme weather events in September 2003 and February 2004, HRM launched ClimateSMART (Sustainable Mitigation & Adaptation Risk Toolkit) to help mainstream climate change mitigation and adaptation into municipal planning and decision making. ClimateSMART initiated discussion of climate change and spurred further adaptation action.

In August 2006, the HRM Council adopted the Regional Municipal Planning Strategy, an integrated land use planning guide for future development. The Strategy explicitly included policies to address climate change impacts. It recognized the need to gather scientific data on sea-level rise, storm surges and vulnerability to inform development of an area-specific land use plan for Halifax Harbour.

To deliver the information needed for effective adaptation planning, a partnership was formed between HRM planners and scientists from Natural Resources Canada, provincial agencies, Dalhousie University and Nova Scotia Community College. The process also involved consultation with major harbour stakeholders. The scientists developed scenarios for sea-level rise and extreme water levels to guide adaptation planning. There were several steps in the process to arrive at these scenarios:

DAMAGING STORMS

In recent years, Halifax has experienced frequent extreme weather, including several major storms that caused extensive erosion and flood damage. Most notable was Hurricane Juan in September 2003, a “once-in-a-century” event. This Category 2 hurricane made landfall just west of Halifax and tracked across central Nova Scotia and Prince Edward Island, leaving a trail of damage to property, infrastructure and the environment (cost estimated at \$200 million). A few months later, in February 2004, the severe winter blizzard that became known as “White Juan” dumped nearly 90 cm of snow on Halifax in one day (\$5 million in snow removal and damage costs). These events increased public concern about the potential impacts of climate change.

Analysis of historical sea-level rise, showing that water levels relative to the land have risen by 32 centimetres (cm) over the last century, a combination of land subsidence (-16 cm) and local sea-level rise (16 cm). The figures were derived from the Halifax tide gauge (since 1920) and crustal vertical motion GPS data (since 2002).

Documentation of stormwater levels and impacts on coastal areas. Scientists analysed 90 years of Halifax tide gauge data to determine the frequency and maximum water levels reached during extreme storms.

Hurricane Juan, an exceptional storm with record water levels, was recognized as a benchmark for flooding.

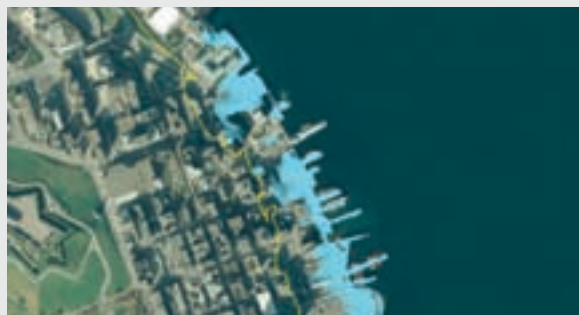
Projections of future sea levels and stormwater levels in Halifax Harbour under three scenarios for 2000–2100: (1) 16 cm – a continuation of the historical rate of change; (2) 57 cm – the upper-limit projection for mean sea-level rise from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (2007); and (3) 1.3 m – a projection based on more recent scientific literature. All of the above were combined with the measured rate of subsidence to give local rates of relative sea-level rise.

High-resolution mapping of possible future flood levels for each scenario. In 2007, HRM and partners commissioned a LiDAR survey to provide baseline elevation data to a precision of about 15 cm. GIS software was then used to simulate the extent and depth of flooding on harbour-front properties in the year 2100 for various storm events coupled with projected rise in sea level for each of the three scenarios.

In early 2010, following a presentation by scientists and city staff, HRM Council agreed to the use of Scenario 2c as an interim basis for action. This set a policy reference point from which planners can move forward in developing an adaptation plan.

Maps of projected sea-level rise are a powerful visual tool for communicating potential flood impacts to policy-makers, land owners and the general public.

SCENARIO 2C



Relative sea-level rise 2000–2100	=	0.73 m above 2000 level (still water)
Add 1 in 50-year stormwater level	=	1.74 m (tide plus storm surge)
Stormwater level in 2100 relative to geodetic datum	=	2.67 ±0.17 m
Add wave run-up	=	+1 to +2 m

Source: http://geopub.nrcan.gc.ca/moreinfo_e.php?id=248196

Next steps include

- further consultation with property owners and other stakeholders to obtain feedback on options and strategies
- a modelling exercise to accurately predict the impact of heavy wave action on harbour-front properties
- development of a risk assessment database containing information on the vulnerability of harbour-front properties
- the creation of measures that could include minimum ground elevation for new development, engineered solutions such as raising sea wall heights, and land use and development regulations for flood-prone areas

Together, these will lead to the development of a comprehensive adaptation strategy to be presented to Council.

As an interim measure, a recently approved Municipal Planning Strategy and Land Use By-law for the downtown Halifax waterfront area prescribes that any development (ground floor elevation) must be a minimum of 2.5 m above the ordinary high-water mark. This figure may be adjusted based on ongoing sea-level rise monitoring and analysis.

Halifax has taken a pragmatic approach in adapting to the impacts of rising sea level. It partnered with scientific and technical experts to obtain data to develop scenarios that speak to the concerns of stakeholders. Recognizing that time is needed to complete the planning process, HRM staff have used development agreements – bilateral contracts between the municipality and the landowner – for a number of waterfront parcels to encourage appropriate development while the formal adaptation plan is being formulated.

Staff have also noted that the 100-year period allows for inclusion of adaptation measures when infrastructure is due for renewal. In this way, there is recognition that adaptation is an incremental process and that initial useful measures can be taken despite uncertainties in the magnitude of long-term changes.

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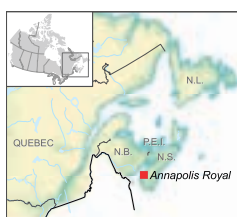
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PHOTO COURTESY OF PAUL ILLSLEY

Preparing for Storm Surges in Annapolis Royal, Nova Scotia

Small communities can take practical steps to reduce their climate vulnerability



Annapolis Royal, Nova Scotia, is a coastal community with a population of approximately 500 located on the southern shore of the Bay of Fundy. A significant area of the town is low-lying, an attribute that, along with rising sea levels and the fact that land has been sinking for thousands of years, makes it increasingly vulnerable to flooding.

FINDING CRITICAL DATA WITH LIMITED RESOURCES

The Clean Annapolis River Project (CARP) searched records from museums, newspapers and historical societies to discover the types of events that occurred in the past and to estimate changes in climatic and tidal factors. The most severe event, the Saxby Gale of October 4–5, 1869, was used as a model for flood predictions.

Finding precise terrain elevation data was also crucial to the Tidal Surge Project. The standard contour interval in the 1:10 000 digital maps is 5 m. This is insufficient when a few centimetres can be the difference between a disastrous flood and a non-event. Instead, CARP obtained paper maps from 1980 at a 1:2000 scale with 2 m contours and spot elevations of 10 cm. With this more detailed information, it was able to determine the locations most at risk from tidal surge flows and the areas most in danger of flooding. Further studies have added yet a higher level of detail (see next inset box).

Climate change will cause coastal communities to experience a rise in sea level and likely increases in the frequency and intensity of storm surges and coastal erosion. Annapolis Royal residents wanted to know whether the risk of flooding would increase in the future and what infrastructure, such as roads, bridges and buildings, would be vulnerable. Of particular concern was the large number of heritage buildings of national significance in the Fundy region.

A citizens-based group, CARP, undertook the Tidal Surge Project in 1998 to assess the town's vulnerability to storm surges. The goal was to identify and gather information on potential threats, including floods during times of extreme tides and storm surges, so the community could put appropriate emergency-response plans and procedures in place.

CARP discovered that a tidal surge during a severe storm was a rare but real threat to coastal zones in their region, particularly if it occurred concurrently with an unusually high tide (the latter happens several times each year). Using future climate change scenarios and resulting sea-level rise predictions, storm surge floods were mapped. With the information gathered, CARP was able to identify wide potential risk zones for tidal surge flooding and possible implications for people in the region.

The results of the project were presented to citizens in a series of public forums. These were followed in the spring of 1999 by a mock disaster scenario that engaged local fire, medical and emergency response teams. The public was also involved, allowing citizens to observe the potential effects that a flood might have on their lives and enabling them to explore how to minimize property damage and harm during a real disaster.

CONTINUED IMPROVEMENT: 2008 FLOODING SCENARIO MAPS



The Groundhog Day storm with 50 years of projected sea-level rise.

To develop improved flooding maps, the Applied Geomatics Research Group conducted a LiDAR survey that used an airborne laser to scan the ground to obtain elevation data to an accuracy of ± 15 cm. The team then created flood risk maps with these data, GIS and software developed in-house, called “the Water Modeller.” The 1976 Groundhog Day storm, during which a high tide coincided with a storm surge, was used as benchmark for flooding. An accurate record of water levels achieved during the Groundhog Day storm was obtained from the tide gauge in Saint John, New Brunswick, which lies across the Bay of Fundy from Annapolis Royal. Future sea-level rise from climate change was then incorporated into the risk statistics and the final maps. To calculate sea levels, the following factors were considered:

- **projected global sea-level rise** – 50 cm in the next century, from the Intergovernmental Panel on Climate Change (2007).
- **crustal motion (uplift or subsistence)** – The Fundy region of Nova Scotia is sinking at a rate of 20 cm per century.
- **tidal range** – The Bay of Fundy tidal range is expected to increase by 10 cm over the next century with increasing sea levels.

The resulting flooding maps can be readily updated to reflect improved estimates of global sea-level rise.

In response, various adaptive planning measures were taken. These include a renewed focus on the need to both raise and properly maintain dikes, issues which have been acknowledged by the provincial government. The maps revealed that during a major flooding event, the fire hall, which is situated on a small rise, would become an island separated from the rest of the community. Subsequently, the Fire Department acquired a boat and modified its emergency response plans, including the relocation of much of the rescue equipment (previously stored solely at the station). One homeowner particularly at risk decided to raise his home by more than half a metre.

CARP’s original Tidal Surge Project led to an important spinoff. In 2005 a team of scientists from the Applied Geomatics Research Group (AGRG) at the Centre of Geographic Sciences (COGS) in nearby Lawrencetown set out to develop high-resolution maps that more accurately visualize future flooding scenarios for the Fundy region of Nova Scotia. The resulting maps, published in 2008, allow Annapolis Royal and other coastal communities in the region to better plan for the future.

Municipal staff in Annapolis Royal use the AGRG maps to inform potential developers of risks from storm surges. In addition, staff have been actively engaging various stakeholders in the Fundy region to develop a coordinated regional approach to tackling future flooding problems. CARP’s work demonstrates that even with limited resources, communities can reduce the uncertainty of climate change effects and find ways to adapt. Actions taken by the town serve to reduce current vulnerability to storm surge flooding and will continue to be built upon, as estimates of future sea-level rise improve.

Annapolis Royal municipal staff look forward to continuing to work with partners and various stakeholders to place the impacts of climate change, and associated storm surge flooding, higher on the regional agenda.

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CHAPTER 4

MOVING FORWARD WITH PLANNED ADAPTATION

Adaptation involves a wide range of actors: individuals, community groups, civil society, the private sector and all orders of government. A proactive adaptation approach – which involves consideration of climate change impacts in planning processes – reduces short- and long-term risks and avoids the significantly higher costs associated with reactive measures. Collective approaches can help achieve multiple policy goals for various orders of government. The implementation of adaptation measures is essential for municipal governments to protect the well-being of citizens and to manage public resources effectively.

Successful adaptation actions require planning and appropriately resourced strategies. Mainstreaming adaptation into existing and new municipal plans, policies and regulations – including capital, infrastructure, land use and emergency response plans – may be the most efficient means of reducing vulnerability to climate change while also contributing to other sustainable development goals. Nevertheless, some communities facing acute impacts may choose to develop detailed climate change adaptation plans to address local priorities.

Information resources are available to help municipalities, whether they are just starting to think about adaptation, conducting a vulnerability assessment or preparing to plan and implement discreet adaptation measures. As a start, Appendix B includes Web sites and resources on climate change impacts and adaptation, ranging from material created for a general audience to resources intended for the scientific community. General information is readily accessible, and regionally specific resources are constantly evolving.



Appendix A: Climate models

Climate models and scenarios: Tools to glimpse the future

The scientific understanding and projection of anticipated changes in our future climate (and its associated variability) is a rapidly evolving research field. Nonetheless, a clear picture of the expected changes in global climate is emerging, and there is increasing confidence in the prediction of climate trends at the regional level. Climate models are the primary tools used to assess future climate.

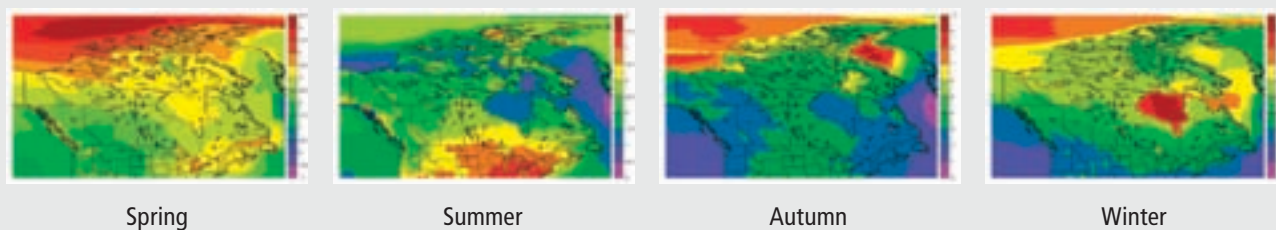
Climate models are computer programs that simulate the climate system's behaviour based on the fundamental laws of physics. Although they are the best available representation of the planet's climate, they are only a simplified version of natural processes. There are two types of models: global climate models (GCMs), which simulate coarse planet climate dynamics with a horizontal spatial resolution of 250 kilometres (km) × 250 km, and regional climate models (RCMs), which cover a limited area with a finer resolution of approximately 50 km × 50 km.

Figures 1 and 2 provide examples of the type of information on future climate that can be accessed through the Canadian Climate Change Scenarios Network (CCCSN). These figures show mean differences in annual temperature and precipitation patterns of the future period (2041–2070 – a.k.a. 2050s) compared with the historical period (1961–1990). The figures are an

ensemble of two versions (4.2.0 and 4.2.3) of the Canadian Regional Climate Model (CRCM), with boundary conditions established by output of the third generation of the Canadian Global Coupled Circulation Model. The output from the two versions are averaged during the historical period and again for the future period. The differences between the two periods are presented in the figures. The future projections are based on a high-level of global socio-economic growth and no change in the relative consumption of renewable versus non-renewable energy resources (SRES-A2 scenario, IPCC 2000).

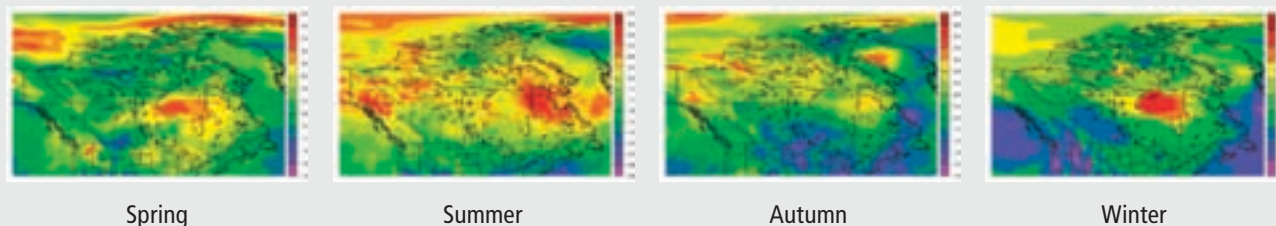
Figures 1 and 2 represent only one possible future Canadian climate as analysed by the CRCM. Simulations from other RCMs, which may use different nesting data (GCMs), different time periods or different greenhouse gas emission scenarios, will produce different results from those shown here. Also, each climate model contains inherent uncertainties

FIGURE 1: CHANGE IN MEAN TEMPERATURE (°C) OVER CANADA IN THE 2050s FROM THE 1961–1990 HISTORICAL BASELINE



Ensemble of two versions of CRCM (see text), courtesy of the Canadian Climate Change Scenarios Network (www.cccsn.ca). Please note that the legends differ for each map.

FIGURE 2: CHANGE IN MEAN PRECIPITATION (%) OVER CANADA IN THE 2050s FROM THE 1961–1990 HISTORICAL BASELINE



Ensemble of two versions of CRCM (see text), courtesy of the Canadian Climate Change Scenarios Network (www.cccsn.ca). Please note that the legends differ for each map.

related to the hypotheses and the simplifications of the real world on which it is based. Consequently, municipal governments are strongly encouraged to use several climate models and scenarios to evaluate and compare climate change outcomes for their region. An “ensemble approach,” in which the projections from many models are averaged, is useful because individual model biases are removed. The CCCSN recently produced an ensemble projection of seasonal temperature and precipitation change across Canada by using all available GCMs from the Intergovernmental Panel on Climate Change’s Fourth Assessment Report (IPCC 2007).

Climate models are not yet at the spatial and temporal scales of resolution that correspond to many extreme weather events such as thunderstorms and extreme rainfall. Note also that changes in average seasonal rainfall are insufficient to assess changes in drought or flood conditions for a specific area.

Climate models provide the virtual meteorological data that feed into the construction of climate scenarios. Climate models and climate scenarios are part of a suite of tools that can be used to determine likely impacts of climate changes for a region.

LEARN MORE

Canada is a world leader in the development of climate models and climate scenarios. The following resources provide information on the understanding of future climate change, the work started and future research directions.

The **Canadian Centre for Climate Modelling and Analysis** develops numerous versions of the Canadian global climate model, provides climate data for these models and distributes data for the Canadian Regional Climate Model (CRCM).

www.cccma.bc.ec.gc.ca

The **Canadian Climate Change Scenarios Network** (CCCSN) is Environment Canada’s interface for distributing information about climate change scenarios and adaptation research.

www.cccsn.ca

The **Ouranos** consortium climate simulations team developed the CRCM and uses multiple versions of the same model to provide regional climate projections.

www.ouranos.ca

Appendix B: Information and resources

Useful climate change Web sites

The following Web sites provide general information on climate change science, greenhouse gases and emissions, and taking action on climate change.

NATIONAL

Climate Change Impacts and Adaptation Division, Natural Resources Canada (NRCan), facilitates the generation and sharing of knowledge, tools and mechanisms to integrate adaptation into policy, plans and projects.

www.adaptation.nrcan.gc.ca

Canadian Climate Change Scenarios Network (CCCSN) is Environment Canada's vehicle for distributing climate change scenarios and adaptation research from national and regional perspectives.

<http://www.cccsn.ca>

Climate Change and Health is Health Canada's resource for researchers and decision-makers to better understand how a changing climate will affect human health and to determine the best ways to prepare for these changes.

http://www.hc-sc.gc.ca/ewh-semt/climat/index_e.html

Climate Change Geoscience Program, Natural Resources Canada, provides planners, decision-makers and the general public with access to a source of credible scientific information on the risks and opportunities faced by Canadian communities and industries as a result of a changing climate.

http://ess.nrcan.gc.ca/ercc-rrcc/index_e.php

Canada's Action on Climate Change is the Government of Canada's Web site on action on climate change across domestic, continental and international fronts.

<http://www.climatechange.gc.ca>

The **Partners for Climate Protection program of the Federation of Canadian Municipalities** is a network of Canadian municipal governments that have committed to reducing greenhouse gases and acting on climate change. www.sustainablecommunities.fcm.ca/partners-for-climate-protection.

ICLEI Canada – Local Governments for Sustainability is part of an international association of local governments that have made a commitment to sustainable development.

<http://www.iclei.org/index.php?id=611>

Planning for Climate Change is a Web site maintained by the Canadian Institute of Planners for disseminating urban planning-related climate change information to its members and the public.

www.planningforclimatechange.ca

REGIONAL

ArcticNet is part of the Networks of Centres of Excellence of Canada, which bring together scientists and managers in the natural, human health and social sciences with their partners in Inuit organizations, northern communities, federal and provincial agencies and the private sector to study the impacts of climate change in the coastal Canadian Arctic.

www.arcticnet.ulaval.ca

Managing the Risks of Climate Change – A Guide for Arctic and Northern Communities was developed by the Centre for Indigenous Environmental Resources (a national, First Nations-directed environmental non-profit organization) to provide northern communities with a simple and practical risk management process.

www.ccrm.cier.ca

Ouranos is a Quebec-based consortium on regional climatology and adaptation to climate change. Ouranos develops and adapts the necessary tools to provide decision makers with detailed climate change scenarios on a regional scale. It also performs evaluations of expected sectoral impacts to optimize adaptation strategies. The Climate Simulations team at Ouranos develops and uses Canadian Regional Climate Model (CRCM) to provide regional climate data.

<http://www.ouranos.ca>

Plan2Adapt (a site developed by the Pacific Climate Impacts Consortium) features a tool designed to help communities assess the impacts of climate change in their region through the generation of high-resolution maps, graphs and data tables.

<http://www.plan2adapt.ca>

The **Northern Climate ExChange (NCE)** is a source of climate change information for Northern Canada. NCE's mandate is to provide independent information, develop shared understanding and promote action on climate change.

<http://www.taiga.net/nce>

The **Pacific Climate Impacts Consortium** is dedicated to stimulating collaboration to produce practical climate information for education, policy and decision making in the Pacific Northwest.

www.pacificclimate.org

The **Prairie Adaptation Research Collaborative** is a multijurisdictional partnership that pursues climate change impacts and adaptation research in the Prairie provinces.

www.parc.ca

INTERNATIONAL

The **Intergovernmental Panel on Climate Change** is the leading body for the assessment of climate change, established by the United Nations Environment Programme and the World Meteorological Organization to provide the world with a clear, scientific view on the state of climate change and its potential environmental and socio-economic consequences.

www.ipcc.ch

The **United Nations Framework Convention on Climate Change** is the international treaty whose ultimate objective is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

www.unfccc.int/adaptation/items/4159.php

weADAPT is a collaborative platform for climate adaptation that draws together a wide range of partners to share experience, tools and case studies to create a dynamic community and knowledge base for adaptation.

www.weadapt.org



Natural Resource Canada's Climate Change Impacts and Adaptation Division provides a comprehensive and up-to-date list of Canadian and international adaptation-related Web sites:

http://adaptation.nrcan.gc.ca/li_e.php

Appendix C: Climate change terminology

Adapted from Intergovernmental Panel on Climate Change (2007)

Adaptation: Adjustment in natural or human systems in response to actual or expected climate stimuli and their effects, which moderates harm or exploits beneficial opportunities. There are various types of adaptation, including anticipatory, autonomous and planned adaptation.

Adaptive capacity: The whole of capabilities, resources and institutions of a country, region, community or group to implement effective adaptation measures.

Climate: Climate in a narrow sense is usually defined as the average weather or, more rigorously, as the statistical description in terms of the mean and variability of relevant variables over a period of time ranging from months to thousands or millions of years. Variables taken into account most often include surface temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing factors, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate projection: The calculated response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Because climate projections are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized, they are therefore subject to substantial uncertainty.

Climate scenario: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships

and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A “climate change scenario” is the difference between a climate scenario and the current climate.

Climate variability: Variations in the mean and other statistics (e.g. standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system or to variations in natural or anthropogenic external forcing.

Extreme weather event: An event that is rare within its statistical reference distribution at a particular place. Definitions of “rare” vary, but an extreme weather event would normally be as rare as, or rarer than, the 10th or 90th percentile. By definition, the characteristics of what is called “extreme weather” may vary from place to place.

Greenhouse gas: Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth’s surface, by the atmosphere itself and by clouds. Water vapour (H₂O), carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄) and ozone (O₃) are the primary greenhouse gases in the Earth’s atmosphere. In addition, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances.

(climate change) Impacts: The adverse and beneficial effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts.

Intergovernmental Panel on Climate Change

(IPCC): A panel established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 to assess scientific, technical and socioeconomic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation.

Mainstreaming: In the context of adaptation, mainstreaming refers to the integration of adaptation considerations (or climate risks) such that they become part of policies, programs and operations at all levels of decision making. The goal is to make the adaptation process a component of existing decision-making and planning frameworks.

Mitigation: In the context of climate change, mitigation is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks.

“No regrets” policy/measure: A policy or measure that would generate net social and/or economic benefits irrespective of whether or not climate change occurs.

Permafrost: Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years.

Precautionary principle: It absorbs notions of risk prevention, cost effectiveness, ethical responsibilities toward maintaining the integrity of human and natural systems, and the fallibility of human understanding. The application of the precautionary principle or approach recognizes that the absence of full scientific certainty shall not be used to postpone decisions where there is a risk of serious or irreversible harm.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the same capacity for self-organization and the same capacity to adapt to stress and change.

Risk: A combination of the likelihood (probability of occurrence) and the consequences of an adverse event (e.g. climate-related hazard).

Risk management: A systematic approach to setting the best course of action under uncertainty, by applying management policies, procedures and practices to the tasks of analysing, evaluating, controlling and communicating about risk issues.

Salt-water intrusion: Displacement of fresh surface water or groundwater by the advance of salt water due to its greater density. This usually occurs in coastal and estuarine areas due to reducing land-based influence (e.g. either from reduced runoff and associated groundwater recharge, or from excessive water withdrawals from aquifers) or increasing marine influence (e.g. relative sea-level rise).

Sea ice: Any form of ice found at sea that has originated from the freezing of sea water. Sea ice may be discontinuous pieces (ice floes) moved on the ocean surface by wind and currents (pack ice) or a motionless sheet attached to the coast (land-fast ice). Sea ice less than one year old is called first-year ice. Multiyear ice is sea ice that has survived at least one summer melt season.

Sea-level rise: An increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land-level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall.

Sensitivity: Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damage caused by an increase in the frequency of coastal flooding due to sea-level rise).

Stakeholder: A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular action or policy.

Storm surge: Generally used to refer to a temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place. Negative storm surges also occur and can present significant problems for navigation.

Tools (for adaptation): Methodologies, guidelines and processes that enable stakeholders to assess the implications of climate change impacts and relevant adaptation options in the context of their operating environment. Tools may occur in a variety of formats and have diverse applications: crosscutting or multidisciplinary (e.g. climate models, scenario-building methods, stakeholder analysis, decision-support tools, decision-analytical tools) to specific sectoral applications (e.g. crop or vegetation models, methods for coastal-zone vulnerability assessment).

Traditional knowledge: A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.

Vulnerability: Vulnerability is the susceptibility to be harmed. Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.

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