

CHAPTER 10

Moving Forward on Adaptation

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SUMMARY

The climate change debate has moved from questions about the reality of, and reasons for, change, to consideration of what can be done to address its causes and consequences. While reduction of greenhouse gas emissions is essential to reduce the rate and magnitude of climate change, it cannot prevent significant changes in climate. Therefore, adaptation is also necessary. Because climate will continue to change for many decades, adaptation is an ongoing process that involves building the capacity to undertake continual adjustments in response to changes in climate and other stresses. Adaptation involves a wide range of actors, including individuals, community groups, civil society, the private sector and all orders of government.

Canada has the capacity to adapt to the adverse impacts of climate change and to take advantage of the opportunities that climate change will bring. The effective deployment of this adaptive capacity will be facilitated by increased knowledge and awareness of the impacts of changing climate, and broader understanding of the role of adaptation. Some adaptation actions in the context of climate change are already being undertaken in Canada. Most of these were initiated in response to isolated events or circumstances, as the need became apparent and where the capacity existed. A more anticipatory and strategic approach to adaptation would help reduce social and economic costs, increase efficiency and further reduce vulnerability in Canada.

Moving adaptation forward in Canada involves building on the momentum gained through existing initiatives and considering additional steps to facilitate implementation of adaptation measures and policies. Building on present activities involves:

- maintaining and strengthening the knowledge base;
- synthesizing and sharing knowledge;
- removing barriers to action; and
- reviewing and contributing to international initiatives.

To achieve these goals, all of the actors involved in climate change adaptation will play a role. Possible near-term steps include:

- broadening engagement and collaboration;
- leading by example;
- enhancing institutional capacity; and
- promoting and, where appropriate, mandating adaptation measures.

1 INTRODUCTION

1.1 VISION FOR AN ADAPTIVE SOCIETY

The vision embodied in this chapter is one of an adaptable and adapting Canadian society that is coping well with climate change through both reducing greenhouse gas emissions and adapting, and is profiting and thriving in the process. Such a vision cannot be achieved with only a spontaneous or *laissez-faire* approach. Some deliberate and co-ordinated steps forward are necessary. As Canadians adapt to climate change, they require, as a minimum, access to the best scientific information and expert help and advice regarding the choice of adaptation options (Box 1). Successful future adaptation will depend upon maintenance and strengthening of the knowledge base, as well as mechanisms for sharing information. At the same time, efforts towards overcoming barriers to action are needed to create an environment that is more favourable for adaptation. Progress on these actions requires leadership from the public and private sectors, as well as changes in public attitudes and behaviour, and a greater awareness of the potential for adaptation.

There is every reason to be confident that Canadians are capable of achieving this vision. Canada has the wealth, technology, skills,

social organizations and institutions that are necessary for success, and a strategic approach to adaptation would help to maximize efficiencies and cost-effectiveness. Additionally Canadians understand that we do not face the challenge of climate change alone. Although the climate is likely to change more in Canada, especially in the north, than in many other regions of the world, our adaptive capacity is great. We are therefore in a good position to adapt ourselves and to help others who are less fortunately positioned to cope with climate change. We also have the resourcefulness to learn from the lessons and experiences of other countries.

What could stand in our way? As the following text makes clear, given awareness and the will, existing barriers can be overcome. As climate change unfolds today, tomorrow and over the coming decades, a great deal of adaptation will be needed to complement efforts to reduce the rate of climate change through mitigation. It is important to recognize, however, that understanding of adaptation and the will to adapt come first. This chapter is an effort to contribute to the further development of that understanding and will.

BOX 1

What is adaptation to climate change?

(modified from Chapter 2)

Adaptation to climate change is any activity that reduces the negative impacts of climate change and/or positions us to take advantage of new opportunities that may be presented. There are many different types of adaptation (Table 1). Adaptation includes activities that are taken before impacts are observed (anticipatory) and after impacts have been felt (reactive; Smit et al., 1999). Both anticipatory and reactive adaptation can be planned (i.e. the result of deliberate policy decisions), while reactive adaptation can also occur spontaneously (i.e. autonomous, without planning). In most circumstances, anticipatory planned adaptations will incur lower long-term costs and be more effective than reactive adaptations. Other dimensions of adaptation include temporary or permanent adaptation measures, and reversible or irreversible adaptation.

Adaptation will usually not take place in response to climate change alone, but in consideration of a range of factors with the potential for both synergies and conflicts. Successful adaptation does not mean that negative impacts will not occur, only that they will be less severe than would be experienced had no adaptive action been taken. In deciding what adaptation option is most appropriate for a particular situation, attention must be paid to the feasibility and likelihood of uptake, as well as the mechanisms involved.

TABLE 1: Different types of adaptation (*modified from Smit et al., 1999*).

ADAPTATION			
Based on	Type of adaptation		
Intent <i>In relation to climatic stimulus</i>	Autonomous <i>(e.g. unmanaged natural systems)</i>	Planned <i>(e.g. public agencies)</i>	
Action	Reactive <i>(post)</i> <i>(From observed modification)</i>	Concurrent <i>(during)</i>	Anticipatory <i>(ante)</i> <i>(Prior modification)</i>
Temporal scope	Short term <i>Adjustments, instantaneous, autonomous</i>	Long Term <i>Adaptation, cumulative, policy</i>	
Spatial scope	Localized	Widespread	

1.2 SCOPE OF THIS CHAPTER

This chapter explores how the developing momentum towards adaptation in Canada can be built upon and strengthened. It draws upon the preceding chapters in this assessment, reports of the Intergovernmental Panel on Climate Change (IPCC) and the growing body of research on adaptation, as well as steps being taken elsewhere in the world to move adaptation forward.

Section 2 of this chapter provides a brief summary of the current status and practice of adaptation in Canada; Section 3 focuses on the momentum towards adaptation and additional efforts required to support adaptation decision-making over the next decade or so; and Section 4 identifies some potential next steps.

2 STATUS OF ADAPTATION

2.1 ADAPTATION IMPERATIVE

Reducing greenhouse gas emissions alone is not enough to address the challenges associated with climate change. It is also necessary to adapt. Many impacts of climate change are now being observed across Canada (*see* Chapters 3–8) and around the world (*see* Chapter 9 and Intergovernmental Panel on Climate Change, 2007a, b). Moreover, further change is locked into the climate system — the Earth and its atmosphere are committed to centuries of changing climate, including associated sea level rise (Intergovernmental Panel on Climate Change 2007a).

In anticipation of the impacts of climate change, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 with the fundamental objective of stabilizing greenhouse gas concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system. One of the important criteria for assessing what is ‘dangerous’ is the ability to adapt. The Convention therefore acknowledges that adaptation is necessary and provides for assistance to the most vulnerable countries in meeting costs of adaptation.

The question today is not whether adaptation will occur, but when and how it will occur. Some adaptation will occur spontaneously; examples of this are already apparent in Canada and around the world. In other cases, adaptation requires effective planning, co-operation and co-ordination. A proactive approach is likely to improve the success of adaptation initiatives and reduce the associated costs.

Adaptation and mitigation are complementary responses, and both are essential in addressing climate change. The role of adaptation and its relationship to mitigation have received less

attention than mitigation alone (e.g. Klein et al., 2007), but it is clear that adaptation will be more feasible and effective if the rate of climate change is slower and the magnitude smaller. Although little is known about the costs of adaptation (e.g. Churchill et al. 2006; Stern, 2006), it is clear that the more the climate changes, the more difficult and costly adaptation is likely to become. Eventually there are limits to adaptation.

Momentum for adaptation to climate change is building among a few innovators. Individuals, communities, civil society, the private sector in industry, business, and commerce, and governments at all levels have roles to play in adaptation. The wide range of players highlights that adaptation can be complex, particularly at regional and national scales. Complexity also results from the unequal distribution of climate change impacts, costs and benefits by regions and localities, by economic sectors and by different social groups, as well as differences in the capacity of these players to undertake adaptive actions.

It is broadly recognized that there is a need to give greater attention to adaptation, and a positive start is being made. Understanding of the risks and opportunities arising from climate change, and the processes of adaptation, has been increasing significantly. For Canada, this progress is evident in the research results presented in the preceding chapters of this assessment. Although much of the focus has been on impacts, there are examples of practical on-the-ground adaptation, both in Canada and internationally, that are contributing to enhancing the understanding of adaptation processes.

There remain knowledge gaps. Examples of questions where further insights are needed include:

- How much adaptation can be expected to take place spontaneously by people and industry acting on their own, and in their own self-interest?

- What kind and quality of information about climate change risks is needed, and by whom and how should it be supplied?
- To what extent is guidance and promotion required?
- How can responses be co-ordinated, and how will the responsibilities and the costs be distributed?
- What level of adaptation is required in the interests of public safety?

Answers to such questions would help inform the identification of priorities for adaptation action. While the generation of more knowledge is important, it is also recognized that knowledge must be effectively communicated. Lack of understanding is one of the chief barriers to effective adaptation in Canada today.

2.2 ESTABLISHING THE FOUNDATION

The need for adaptation to ‘normal’ climate has always been present (Burton, 2004) and has a long history of professional and managerial practice in specific disciplines or professions. In the context of climate change, there has been rapid growth in research and writing on the subject of adaptation since the UNFCCC was opened for ratification in 1992 (e.g. Smit et al., 1999, 2000). Policy frameworks for adaptation have been developed (United Nations Development Programme, 2005), the concept of vulnerability has been elaborated upon (*see* Chapter 2), and initial quantitative measures of vulnerability have been proposed (Adger et al., 2004; Downing and Patwardhan, 2005). In addition, compendia of tools and methods for impact and adaptation assessment have been compiled (Feenstra et al., 1998; United Nations Framework Convention on Climate Change, 2005), and the need and potential for technology development and transfer have been explored (Klein et al., 2006). Thus, a strong foundation for the development of adaptation policy and the implementation of adaptation measures has been created.

Canada’s approach to adaptation to climate change, like that of virtually every other developed country, remains in its early stages of development. Canadian experts have contributed substantially to the development of adaptation theory and practice through such organizations as the Intergovernmental Panel on Climate Change. Adaptation actions that make both the present and the future more sustainable, sometimes referred to as ‘no-regrets’ measures, are often cited as the key to moving forward despite uncertainty. Adaptations in building and infrastructure design, water and energy conservation, renewable energy generation, and diversification of economies are win-win strategies that provide useful starting points for communities to increase their adaptive capacity.

Professional, expert and management groups working within sectors are accustomed to using their own institutional processes and tools to manage risk, timing of capital stock turnover and business case presentation. These groups now share the need to factor climate change into their work, and face similar challenges in devising the best ways to achieve this. Past practices (that are still being used in many instances) make the assumption that climate ‘normals’ of the past will also apply to the future, and often rely on empirical analysis of the historical climate record. This assumption can no longer be considered correct, and such analysis therefore no longer provides an adequate basis for decision-making. Increasingly, efforts are being made to incorporate information on climate trends and future climate projections. Expert judgement will be increasingly required, and will be most accepted when trend analysis and climate scenarios point in the same direction. This is the case for most, but not all, climate impacts in Canada. For example, despite historical trends of decreased runoff in much of northern Quebec, climate models consistently project increasing runoff in future (*see* Chapter 5). However, for the foreseeable future, a combination of trend analysis and scenarios seems likely to offer the best strategy for incorporating climate change information into decision-making in many professional fields (Carter et al., 2007).

2.3 EXAMPLES OF CURRENT ADAPTATION ACTIVITIES

Policies and measures to cope with climate variability and extremes have long been used effectively in Canada. Indeed, much of Canadian history can be seen as the successful struggle to thrive within a harsh and varied climate. Adaptation to ongoing and future climate change will involve both a continuation of past initiatives and the introduction of new approaches. Many of the lessons learned from adapting (either successfully or poorly) to past climate, including variability and extremes, will inform future adaptation decisions. What differentiates past adaptation to ‘normal’ climate from adaptation to climate change are the high rate of change that is projected and the associated uncertainties. It needs to be understood that there will be no return to the previous ‘normal’. Instead, we face an ongoing process of change that will continue for decades to centuries. It is therefore not a case of planning for a different stable future climate, but of building the capacity and flexibility to cope with whatever evolving climate may bring in the future.

Both implementation of operational adaptations and the facilitation of future adaptation by increasing adaptive capacity are required (Smit and Wandel, 2006). Ideally, climate change adaptation initiatives will be integrated with other programs

and driven by goals that extend beyond preparing for climate change. This is just the beginning of a process of integrating (mainstreaming) climate risks into decision-making, such that adaptation decisions are based upon understanding of changes in both climatic and non-climatic factors (Klein et al., 2007).

The capacity to undertake adaptation varies greatly across Canada — between and within regions, communities and sectors — owing to a large number of economic, social, institutional and location factors (e.g. Smit and Wandel, 2006). As such, a range of motivations drive adaptation — from protecting health and safety during extreme weather events to making businesses more competitive, efficient and profitable, as well as sustaining economic development in the longer term. The examples presented in Table 2 illustrate that many actors, including individuals, community groups, the private sector and all orders of government, are involved in climate change adaptation and reflect ways that Canadians are now starting to adapt.

As noted by the Conference Board of Canada, there is considerable scope for adaptation in the private sector (Churchill et al., 2006). However, while there are indications of increasing awareness, the Conference Board report concluded that more preparations and precautionary measures are needed (Churchill et al., 2006). Industry and professional organizations, such as the Canadian Council of Professional Engineers and the Canadian Institute of Planners, are working to include climate change adaptation in their professional curriculum. Professional organizations, such as the Air and Waste Management Association and the Canadian Water Resources Association, are also placing climate change adaptation on their agendas. Obstacles to adaptation in the private sector include the perceived costs of innovation and associated competitive disadvantage in the absence of demands for higher standards from consumers or stricter codes and standards set by governments.

The role of governments in adaptation often involves finding a balance between protecting the safety of the public and facilitating and promoting adaptation without discouraging innovation, initiative and enterprise. Recent government program initiatives to facilitate adaptation are summarized in Canada's Fourth National Report on Climate Change (Environment Canada, 2006). There are some circumstances where regulation, such as revisions in the codes and standards for infrastructure, may be necessary in the interests of public safety, to ensure that changing climate risks are factored into design and construction. At the time of writing, initiatives by the Canadian Council of Professional Engineers, the Canadian Standards Association and the National Round Table on Environment and Economy are investigating various aspects of infrastructure adaptation in Canada.

The examples provided in Table 2 of adaptation by different actors are indicative of the types of responses that will be needed on a much larger scale as climate change unfolds. Exactly how such activities can best be expanded in a timely and effective manner is yet to be determined. It is clear, however, that co-operation within and between all levels of government, the private sector and civil society, as well as the research community, is essential. As in other public policy areas, serious consequences can flow from failures of integration and co-operation.

2.4 INTERNATIONAL DIMENSIONS OF IMPACTS AND ADAPTATION

The impacts of changing climate in Canada will have implications for other countries and vice versa (*see* Chapter 9). Some of this is related to competitive advantages and global trade supply-demand dynamics. For example, with a longer and warmer growing season, Canada may require less imported fresh fruits and vegetables. There are also issues associated with the impacts of climate change on human health and migration, and transboundary waters. A detailed discussion of potential direct and indirect effects on Canada arising from climate changes elsewhere in the world is presented in Chapter 9, which concludes that fully understanding the implications of climate change for Canada requires accounting for the international dimensions.

It is also important to consider international dimensions in adaptation decisions. For example, adaptation measures and policies adopted in one country could serve as trade barriers or subsidies, and thus attract attention under international trade agreements. Such possibilities lie in the future and are likely to unfold gradually. It is nevertheless important for policy-makers and industry in Canada to understand these broader economic implications of adaptation to climate change.

Many other nations, particularly those in the developing world, are likely to be more adversely affected by climate change than Canada. The higher frequency and severity of weather-related disasters are already significant obstacles to development, and create more demands for humanitarian aid (Red Cross Climate Centre, 2007). There is a growing need for technical and financial assistance to developing countries to help them adapt to climate change and associated extreme events (*see* Chapter 9). The increasing losses from weather-related disasters world-wide are also having impacts on insurance and reinsurance costs (Linnerooth-Bayer and Mechler, 2006).

TABLE 2: Selected examples of adaptation initiatives undertaken by individuals, community groups, industry and governments in Canada.

Adaptation example	References and/or chapter
INDIVIDUALS	
<ul style="list-style-type: none"> Northerners are more frequently using insect repellents, bug nets and window screens to deal with the increased proliferation of insects. 	Nickels et al. (2002) Chapter 3
<ul style="list-style-type: none"> Hunters in the Arctic have increased the use of the global positioning systems to assist navigation in unpredictable or challenging weather. 	Ford et al. (2006) Chapter 3
<ul style="list-style-type: none"> Homes and cottages are being built farther back from the coast. 	Chapters 4, 8
<ul style="list-style-type: none"> Residents of remote coastal communities are better prepared for shortages (i.e. power, food, transportation) due to recent experience with inclement weather conditions. 	Chapters 4, 8
COMMUNITY GROUPS AND ORGANIZATIONS	
<ul style="list-style-type: none"> The community of Arctic Bay, NU has shifted a portion of its narwhal quota from spring to summer hunts to reduce risks associated with ice break-up conditions, and to increase chances of hunting success. 	Armitage (2005); Community of Arctic Bay et al. (2006) Chapter 3
<ul style="list-style-type: none"> Residents of Pointe-du-Chêne, NB organized an emergency shelter in response to increasing flooding risk, and lobbied elected officials for less vulnerable road access. 	Chapter 4
<ul style="list-style-type: none"> A community group in Annapolis Royal, NS undertook mapping of potential storm surges that has resulted in revision of emergency measures. 	Medhi et al. (2006) Chapter 4
<ul style="list-style-type: none"> The Mississippi Valley Field Naturalists published a report educating residents about the potential impact of climate change on ice safety conditions from year to year 	Egginton et al. (2007) Chapter 6
INDUSTRY	
<ul style="list-style-type: none"> Production barges have been used in the Mackenzie Delta rather than a land-based production facility, in recognition that higher temperatures and rising sea levels are exacerbating flood risk. 	Chapter 3
<ul style="list-style-type: none"> Thermosyphons have been used in the construction of several major infrastructure projects in the North to induce artificial cooling of permafrost under warming conditions. 	EBA Engineering Consultants Ltd. (1995) Chapter 3
<ul style="list-style-type: none"> Agricultural producers are purchasing crop insurance to offset losses caused by inclement weather. 	Witrock and Koshida (2005) Chapters 6, 7, 8
<ul style="list-style-type: none"> Some forestry companies have started using high-flotation tires on their vehicles to help navigate wet or washed-out conditions, allowing them to work in a wider range of weather conditions. 	Cline et al. (2006); Mellgren and Heidersdorf (1984) Chapter 7
<ul style="list-style-type: none"> The forest industry in central BC is seeking to extract as much merchantable timber as possible from forests affected by the mountain pine beetle epidemic. The industry is also attempting to develop alternative markets for beetle-killed wood. 	Pederson (2004)
<ul style="list-style-type: none"> Producers have changed their final product (e.g., from fresh fruit to juice) when the season has not favoured original intentions. 	Risbey et al. (1999); Belliveau et al. (2006)
<ul style="list-style-type: none"> Ski resorts are diversifying activities offered to encompass as many seasons as possible. 	Scott (2003)

Adaptation example	References and/or chapter
GOVERNMENTS	
<ul style="list-style-type: none"> Municipalities along the Quebec eastern North Shore have introduced regulations to limit development in zones vulnerable to coastal erosion and flooding. 	Chapter 5
<ul style="list-style-type: none"> Westbank, BC has included climate change in the Trepanier Landscape Unit Water Management Plan. 	Summit Environmental (2004) Chapter 8
<ul style="list-style-type: none"> The town of Vanderhoof, BC is engaged in a vulnerability assessment pilot project with the Canadian Forest Service, with a specific goal of being able to plan adaptation to climate change. 	Natural Resources Canada (2005) Chapter 8
<ul style="list-style-type: none"> Water meters have been installed in the Southeast Kelowna Irrigation District and several Canadian cities (e.g. Kelowna, BC; Sudbury, ON; Moncton, NB) to reduce water consumption. 	Chapters 4, 6, 8
<ul style="list-style-type: none"> Regina, SK has increased urban water conservation efforts. 	Cecil et al. (2005)
<ul style="list-style-type: none"> Smog and heat-health warning systems have been implemented in Toronto, ON and Montréal, QC. 	Rainham et al.(2005); Ministère de la Santé et des Services sociaux (2006)
<ul style="list-style-type: none"> New Brunswick's Coastal Areas Protection Policy establishes set-backs for permanent structures and could facilitate planned retreat. 	New Brunswick Department of the Environment and Local Government (2002)
<ul style="list-style-type: none"> Alberta's Water for Life Strategy addresses climate change impacts in areas that are currently water-stressed. 	Government of Alberta (2003)
<ul style="list-style-type: none"> British Columbia's Future Forests Ecosystem Initiative incorporates climate change adaptation into forest management. 	BC Ministry of Forests and Range (2007)
<ul style="list-style-type: none"> Research and networking have been supported through a range of federal, provincial and territorial programs. 	Environment Canada (2006)

3 BUILDING THE MOMENTUM

The role and importance of adaptation are becoming more widely recognized among scientists and governments (e.g. Intergovernmental Panel on Climate Change, 2007b; Pielke et al., 2007), and some media reports have cited the necessity for adaptation (e.g. CBC News, 2007; Graham, 2007; Harrison, 2007; Shimo, 2007). This is evident both within Canada and internationally. Current adaptation initiatives in Canada are promising indications of the determination of Canadians, from individuals to community groups, industry and government, to adapt to the changing climate.

Building on the momentum provided by these existing initiatives requires envisioning where we want and need to go. Although specific goals will vary based on their timeframe (e.g. short,

middle and long term) and the groups involved, one of the commonly cited objectives is to have climate change integrated, or 'mainstreamed', into relevant decision-making processes (e.g. Klein et al., 2005, 2007). This means that climate change is not considered in isolation from the numerous other factors that influence decision-making, but rather is considered as one element of integrative analysis and policy development. One example of mainstreaming is the manner in which climate change is addressed in the environmental assessment process for major projects, such as mines and pipelines in northern Canada (see Chapter 3). Although this represents important progress, there are limitations to a project-by-project approach. While such an approach contributes to reducing the vulnerability of the person or agency implementing the action, it also has the potential to

inadvertently increase the vulnerability of others. Therefore, it is important to think about adaptation to climate change in a more collective and strategic way in relation to Canada's future development (Office of the Auditor General of Canada, 2006).

The following four building blocks for strengthening the momentum to undertake adaptation are addressed in this section:

- maintaining and strengthening the knowledge base
- synthesizing and sharing knowledge
- removing barriers to action
- reviewing and contributing to international initiatives.

3.1 MAINTAINING AND STRENGTHENING THE KNOWLEDGE BASE

To cope effectively with climate change there must be a strong understanding of the issue. This requires knowledge of potential impacts and vulnerabilities, of projected changes in climate and of adaptation processes and decision-making. It is important to recognize key gaps in present knowledge, as well as the need to maintain sources of data.

A large component of the climate change impacts and adaptation literature is devoted to the concept of vulnerability, its assessment and qualitative or quantitative measurement. Vulnerability is a function of exposure, sensitivity and adaptive capacity (*see* Chapter 2), and is therefore influenced by both climatic and non-climatic factors. Vulnerability is generally considered greatest where adaptive capacity is low (due to limited economic resources, poor access to information and technology, or weak social networks; *see also* Chapter 2); where economic activities are highly climate sensitive; where present livelihoods are close to the limits of tolerance or viability; and where ecosystems, social systems and economies are fragile because they lack diversity or have limited resilience (e.g. Burton and van Aalst, 1999; Adger et al., 2004; Downing and Patwardhan 2005). Identifying systems, activities and populations that are currently vulnerable to climate impacts provides one basis for determining short-term priorities for adaptation measures.

Although knowledge of future climate change is based in part upon historical climate trends, it is primarily dependent on analysis using Atmosphere-Ocean General Circulation Models (AOGCMs), Regional Climate Models (RCMs) and statistical downscaling techniques (*see* Chapter 2). There have been significant advances in all of these methods in recent years, which have led to higher confidence in model projections, particularly those of mean temperature. There is, however, less confidence in projections of precipitation and other variables that are relevant to the development and selection of specific adaptation options. There is also less knowledge of likely changes in climate variability and extremes. Uncertainties will always be inherent in climate projections, as analyses are dependent upon assumptions

of future development pathways and associated greenhouse gas emissions (*see* Chapter 2), as well as the relative strengths of positive and negative feedback effects and non-linear changes in biophysical systems. This is not uncertainty regarding whether climate will change, but rather about the speed and magnitude of climate change over time. Adaptation is about how to deal with an uncertain climate as well as a changing climate.

There is an ongoing need for research on climate impacts. While considerable progress has been made in modelling impacts, there remain gaps with respect to the sensitivity of physical, ecological and human systems to critical parameters and thresholds. An important recent development in impacts research is the derivation of probability density functions that capture the continuous distribution of impacts as a function of a range of future climate trends and variability (Carter et al., 2007).

With respect to adaptation decision-making, there are generic reasons to be confident that Canada can adapt well, although analysis of the costs associated with such adaptation remains a major knowledge gap. This confidence stems from the fact that Canada is comparatively well endowed with respect to the broad determinants of adaptive capacity: it is a wealthy society with a highly skilled population and access to technology, and has strong and effective institutions. However, there is a difference between having the capacity to adapt and having the will and motivation to adapt (Burton, 2003). High adaptive capacity does not necessarily translate into strong or effective adaptation (e.g. Field et al., 2007).

In any particular situation, there is a long list of possible adaptive response options (*see* Chapter 3, Table 14 for an example in the forestry sector). Such lists generally include technical, administrative and behavioural actions that could be implemented by different groups, including governments, industry and individuals. Which response, or combination of responses, is chosen depends upon costs, estimates of the risk, available technology, social and institutional constraints and opportunities, and expected benefits. For example, adaptation choices to deal with drought at the farm level are influenced by financial institutions, producers of farm inputs (seeds, fertilizers, machinery and equipment) and several kinds of government programs (e.g. crop insurance). Ultimately, the choices made will reflect the specific circumstances of the decision-makers, including how they perceive the risks and the opportunities.

Dealing with uncertainties and non-specific predictions can present challenges for gaining consensus on adaptation decision-making. Risk management techniques are often used to address decisions under uncertainty (Bruce et al., 2005). Generally speaking, the resolution to these challenges lies in strategies that will be robust against a range of different climate scenarios (e.g. Risbey, 1998; Cohen and Kulkarni, 2001).

3.2 SYNTHESIZING AND SHARING KNOWLEDGE

The rapidly evolving nature of the climate change issue and the large scope and quantity of research on climate change impacts and adaptation necessitate the undertaking of periodic science assessments and the effective transfer of knowledge to decision-makers. This report, *From Impacts to Adaptation: Canada in a Changing Climate 2007*, represents the second national-scale assessment of climate change impacts and adaptation in Canada, the first being the 1998 *Canada Country Study* (Environment Canada, 1998). The spatial scale of national assessments allows demonstration of the breadth and seriousness of the climate change issue, but limits their application to detailed adaptation planning. Therefore, it is also desirable to have assessments at local and regional scales, and assessments that focus on specific sectors. At present, there are ongoing assessments being undertaken in Quebec (Ouranos Consortium, 2007) and Alberta (Sauchyn et al., in press). A sectoral assessment for health (Seguin, in press) is also underway.

Consideration should be given to undertaking specific local and community-based assessments (places, sectors, risks) on a regular basis, with major integrating assessments more widely spaced in time. For example, the European Union (EU) has proposed undertaking semi-decadal syntheses based on results of EU and national research programs (European Commission, 2007a). Ongoing updates of relevant science and observational data and trends are also valuable for monitoring evolving climate and the first-order impacts against the projections that inform adaptation planning. Assessments can provide a foundation for the development of government, business and community adaptation strategies and measures. Assessments also help to direct future research, by identifying knowledge gaps and stimulating new ideas.

Although periodic assessments provide a vehicle for integrating large volumes of scientific information, the transfer of the resulting knowledge to a wide range of decision-makers, including the general public, is also critically important. Raising awareness of risks and opportunities that climate change presents to Canadians, and the role that adaptation can play in responding to climate change, represents the first communication task.

There is also much that can be learned through sharing of information and experiences outside of formal assessment processes. Places that are anticipating water stress in the future can look to places already experiencing such challenges, such as the Okanagan Valley (Cohen and Neale, 2006) or the Prairies, for ideas on how to adapt. Although there are relatively few examples of the effective sharing and transfer of such knowledge, there are considerable opportunities for improving the use of web-based interfaces for information dissemination and exchange.

3.3 REMOVING BARRIERS TO ACTION

Many barriers to adaptation have been identified in the preceding chapters of this assessment, including lack of awareness, regulatory or legislative barriers, and societal expectations. Limitations in access to relevant information, and the lack of tools to facilitate integration of existing knowledge into decision-making, prevent existing information from being used as effectively as possible. The focus of public and media interest on the reduction of greenhouse gas emissions has contributed to a lack of recognition of adaptation and an underestimation of its potential value.

A great deal of scientific knowledge about climate change in Canada is held and advanced by government departments and agencies, other government-supported centres and programs, universities, think-tanks, professional organizations and non-government organizations. This information could be made more accessible and user friendly and its use promoted more vigorously. Specific information is needed on potential impacts for localities and sectors, including the timing of expected changes. Interactive discussions on adaptation measures would also facilitate effective and timely choices. As with many other issues, informing key audiences and engaging them in a proactive way would likely lead to an expansion of adaptation. Ensuring widespread access to knowledge and experience, facilitated by different levels of government acting together, would be an effective way of enhancing Canada's resilience to a changing climate. Appropriate institutional mechanisms for making information on climate change available and engaging Canadians in consideration of their adaptation options could be devised.

Access to decision-support tools and data sets to support such analytical methods is also important. Climate scenarios, an area of active research in Canada, represent one important category of data delivery (Climate Change Scenarios Network, 2007; Ouranos Consortium, 2007). A recognized need with respect to scenarios is more detailed information on the probability distribution of impacts. In addition, although compilations of existing adaptation methods and tools at the international level are readily accessible (Feenstra et al., 1998; United Nations Framework Convention on Climate Change, 2005), the majority of these tools are directed towards the measurement and assessment of impacts, rather than facilitating adaptation decision-making.

As noted previously, risk management approaches are the basis for most current adaptation decision-support tools. Efforts highlighted in several of the regional chapters of this assessment (e.g. Chapters 4 and 8) could lead to prototypes for decision-making in communities across the country (Mehdi et al., 2006). Adaptation modelling, a concept that is currently in development by a number of research groups worldwide (Herrod-Julius and Scheraga, 2000; Hope, 2006; Burton, 2007; Dickinson, 2007) may eventually result in formalized, quantitative methods for evaluating potential adaptations for a particular location.

3.4 REVIEWING AND CONTRIBUTING TO INTERNATIONAL INITIATIVES

Much can be gained by reviewing and contributing to international initiatives, and through a conscious effort to draw upon such opportunities. Most of the challenges facing Canada are not unique to our country, and many regions of the world have experience dealing with climate impacts similar to those Canada is expected to see in the future. A 2006 review (Gagnon-Lebrun and Agrawala, 2006) concluded that the United Kingdom, United States, Australia, New Zealand and the Netherlands were the most advanced in implementing adaptation measures.

Workshops and conferences to share research results, experience and tools, and participation in international initiatives are all mechanisms for the transfer of knowledge. Such sharing is one of the primary goals of the Nairobi Work Program on Impacts, Vulnerability and Adaptation to Climate Change under the UNFCCC (United Nations Framework Convention on Climate Change, 2007). In addition, there are growing opportunities for the Canadian business community to play active and constructive roles outside our borders on issues of climate change adaptation (International Institute for Sustainable Development, 2003; Mitchell and Tanner, 2006). The same applies to those engaged in research and development and in technical and social innovation.

Canada also has a responsibility to help other countries (Gardiner, 2004), especially those most severely impacted by climate change and least able to adapt (Burton et al., 2006, *see* Chapter 9). This can take the form of engagement in multilateral negotiations and contributions under the UNFCCC and other forums, as well as direct bilateral assistance, and would complement efforts of multilateral agencies that highlight the importance of incorporating climate change considerations within development policy frameworks and programming (World Bank, 2006).

In addition to research initiatives and experience with implementing adaptation measures, Canadians can also learn from the experiences of other countries as they start to develop policy frameworks and tools to assist adaptation (Box 2).

BOX 2

Learning from others

European countries have generally been the most active with respect to adaptation policy initiatives, and a number now have adaptation plans in place or under development.

The European Union (EU) 'Climate Change Programme II: Impacts and Adaptation' has a mandate of "exploring its role and the scope for a policy strategy to adapt to the impacts of unavoidable climate change and how best to assist local, regional, and national efforts" (European Commission, 2007b). The program published a report entitled *Building National Adaptation Strategies* (European Climate Change Programme, 2006). A green paper examining options for EU actions emphasizes the need to develop a coherent policy response to reduce costs and enable complementary actions based on joint partnerships at the most appropriate level (European Commission, 2007a).

Within the EU, steps are being taken by several member countries, including the following:

France passed a national adaptation strategy in November 2006. The strategy takes a crosscutting approach involving initiatives based on sectors (agriculture, energy and industry, transport, buildings and habitat, tourism, banking and insurance), environment (urban, seashore and oceans, mountain, forest) and resources (water, biodiversity, health, risks). France is now implementing the recommended actions in this strategy.

The *Netherlands* has drafted a 'National Programme for Spatial Adaptation to Climate Change' (ARK) with a strong emphasis on spatial planning and addressing issues associated with sea-level rise. It contains several key elements, including the role of the government, the integration of adaptation decisions into financial processes and instruments, and the design of physical structures.

Finland completed an adaptation strategy in 2005. The strategy identifies impacts and adaptation measures for all key sectors. It identified six priorities for implementation in the period 2006–2015: 1) integrating climate change impacts and adaptation into sectoral planning; 2) improving capacities to address extreme weather events; 3) including climate change aspects into long-term investments; 4) enhancing observation and monitoring systems; 5) strengthening and focusing research and development; and 6) relating this work to the international development agenda.

The *United Kingdom* is developing an 'Adaptation Policy Framework' (APF) that incorporates feedback from public consultations held between November 2005 and January 2006. The APF will set out a structure for the roles and activities of different organizations (from central government to individuals) to ensure a comprehensive and coherent approach to adaptation and to prevent adaptation in one sector from having negative impacts upon another sector. This policy initiative complements work in the United Kingdom on tools to support adaptation decision-making (e.g. Willows and Connell, 2003; Shaw et al., 2007).

Spain has established a Climate Change Policies Co-ordination Commission, which in July 2006 approved a 'National Plan for the Adaptation to Climate Change' (PNACC). The plan provides a general reference framework for evaluation of impacts, vulnerability and adaptation to climate change.

4 NEAR-TERM STEPS

Building on the strong knowledge base summarized in the preceding chapters of this assessment, there are a number of potential steps that could help ensure that adaptation continues to move forward in Canada.

4.1 BROADENING ENGAGEMENT AND COLLABORATION

All chapters of this assessment conclude that a wide range of actors are involved in climate change adaptation (*see also* Table 2). In addition to implementing adaptation actions, community groups, industry and professional organizations, and all orders of government can help strengthen adaptive capacity.

Given the broad range of actors involved, recognition and articulation of the roles and responsibilities of each would facilitate co-operation. There is also likely to be a need for appropriate mechanisms to facilitate effective co-ordination and collaboration. Such steps form part of the development of a strategic approach to adaptation. Where adaptation is built onto existing activities, it will likely be clear who will carry out the adaptation measures or policies in question, under what authority they will act and how the costs will be distributed. Where new initiatives on adaptation are required, the situation might be more complex. Clarification of the responsibilities of individuals, industries and various orders of government will facilitate new and planned action on adaptation. Some evolution of responsibilities may need to occur as the need for adaptation to climate change becomes more apparent and more urgent.

4.2 LEADING BY EXAMPLE

Leaders, innovators and early adopters exist within all segments of Canadian society. With respect to climate change adaptation, federal and provincial governments have provided much of the leadership with respect to research and networking, while some industries, municipalities and professional organizations have led the way in implementation of adaptation measures or at least preparing to adapt. This leadership conveys to others the importance of adaptation and the benefits that can be gained through action.

This leadership could be enhanced through a more strategic approach to adaptation. Many governments and non-government organizations would benefit from undertaking reviews of existing

policies and programs to assess their vulnerability to climate change, and their ability to facilitate adaptation. Such analyses have been undertaken in the United Kingdom (e.g. Department of Environment, Food and Rural Affairs, 2003) and could serve as a model for other governments concerned with climate change impacts. Similarly, industry and businesses would benefit from a review of how climate change is likely to influence their operations, planning processes and competitiveness in terms of trade and market share. Such reviews would identify areas for more detailed examination, and ultimately lead to revision of climate-sensitive operations, programs and policies that will enhance their sustainability under a changing climate.

4.3 ENHANCING INSTITUTIONAL CAPACITY

There is now a diffuse and generally unco-ordinated flow of information and advice with respect to climate change adaptation from several government agencies, the scientific community and others. Enhancing institutional capacity could help shape a more coherent and user-friendly process that would allow Canadians to access the most authoritative information about how climate change will affect them in their own businesses and localities, and to engage the appropriate expertise in discussion about adaptation options. Examples of new institutions developed to help address this gap in Canada include the Ouranos Consortium (Quebec), the Prairie Adaptation Research Collaborative and the Pacific Climate Impacts Consortium. There is also significant opportunity to enhance the capacity within existing institutions to provide information and guidance on adaptation. For example, agricultural extension services, public health authorities, water management authorities and many other such services could factor climate change into the guidance they provide.

4.4 PROMOTING AND MANDATING ADAPTATION MEASURES

In some circumstances, more than information and guidance may be required to move forward on adaptation action. This may be especially true where extra costs are involved, or where institutional or other barriers exist. In such circumstances, governments and industries may wish to take further action, such as the provision of incentives or penalties. For example, water rates could be modified for different users, and improvements in

water-use efficiency could be promoted and rewarded. Insurance may also have a role to play in facilitating adaptive behaviour. A range of market-type instruments can be used to promote and persuade people to move towards effective adaptation within various sectors. In circumstances where climate change presents significant risks to the security and safety of Canadians, it may

be appropriate to mandate or require adaptation actions. Prominent among these needs is the importance of ensuring that construction of buildings and other infrastructure is robust to the changes in climate, including extreme weather risks.

5 FROM VISION TO ACTION

This chapter has described current and potential adaptation options, policies and measures in the context of a vision for an adaptive and adapting society. It is intentionally non-prescriptive in the sense that no specific recommendations are directed to any one place or institution. Because adaptation is such a multistakeholder and place-specific process, heavily top-down or structured approaches would risk inhibiting the diversity of

activities and innovations that are required. It is clear that, as more climate impacts are experienced, all sections of Canadian society will need to adapt. Co-operation, co-ordination and social solidarity will help ensure that this will happen, and that barriers and obstacles are removed. Moving from vision to action needs many steps by many motivated actors.

REFERENCES

- Adger, W., Brooks, N., Kelly, M., Bentham, G., Agnew, M., and Eriksen, S. (2004): New indicators of vulnerability and adaptive capacity; Tyndall Centre, Technical Report 7, <http://www.tyndall.ac.uk/research/theme3/final_reports/it1_11.pdf>, [accessed February 19, 2007].
- Armitage, D.R. (2005): Community-based narwhal management in Nunavut, Canada: change, uncertainty and adaptation; *Society and Natural Resources*, v. 18, no. 8, pp. 715–731.
- British Columbia Ministry of Forests and Range (2007): Future forest ecosystems initiative; British Columbia Ministry of Forests and Range, <http://www.for.gov.bc.ca/hts/Future_Forests/>, [accessed November 23, 2007].
- Belliveau, S., Bradshaw, B., Smit, B., Reid, S., Ramsey, D., Tarleton, M., and Sawyer, B. (2006): Farm-level adaptation to multiple risks: climate change and other concerns; University of Guelph, Department of Geography, Occasional Paper 27, <<http://www.multiplerisks.com/results/inc/Farm-level%20adapt.pdf>>, [accessed December 13, 2006].
- Bruce, J., Egener, M. and Noble, D. (2005): An overview of the risk management approach to adaptation to climate change in Canada; report submitted to Natural Resources Canada, Climate Change Impacts and Adaptation Directorate, <http://adaptation.nrcan.gc.ca/pdf/29156ce6051f409990f872d838bcbbb_e.pdf>, [February 19, 2007].
- Burton, I. (2003): Do we have the adaptive capacity to develop and use the adaptive capacity to adapt? *in* Climate Change, Adaptive Capacity, and Development, (ed.) B. Smit, R. Klein, R. and S. Huq, Imperial College Press, London, United Kingdom, p. 137–161.
- Burton, I. (2004): Climate change and the adaptation deficit; *in* Climate Change: Building the Adaptive Capacity, (ed.) A. Fenech, D. MacIver, H. Auld, R. Bing Rong and Y. Yin, Environment Canada, Meteorological Service of Canada.
- Burton, I. (2007): Modelling adaptation? *Tiempo Climate Newswatch*, <<http://www.tiempocyberclimate.org/newswatch/comment070212.htm>>, [accessed March 16, 2007].
- Burton, I. and van Aalst, M. (1999): Come hell or high water — integrating climate change vulnerability and adaptation into bank work; World Bank, Environment Department Papers, Climate Change Series, Paper 72, <http://www.aiaccproject.org/resources/ele_lib_docs/burton_WBreport.pdf>, [accessed November 27, 2007].
- Burton, I., Diringer, E. and Smith, J. (2006): Adaptation to climate change: international policy options; Pew Center on Global Climate Change, Arlington, Virginia, <http://www.pewclimate.com/docUploads/PEW_Adaptation.pdf>, [accessed November 27, 2007].
- Carter, T.R., Jones, R.N., Lu, X., Bhadwal, S., Conde, C., Mearns, L.O., O'Neill, B.C., Rounsevell, M.D.A. and Zurek, M.B. (2007): New assessment methods and the characterisation of future conditions; *in* Climate Change 2007: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson; Cambridge University Press, Cambridge, United Kingdom, p. 133–171.
- CBC News (2007): Adapt policies to climate change, scientists say; Canadian Broadcasting Corporation, April 10, 2007, <<http://www.cbc.ca/technology/story/2007/04/10/science-adaptation.html>>, [accessed November 27, 2007].
- Cecil, B., Diaz, H., Gauthier, D. and Sauchyn, D. (2005): Social dimensions of the impact of climate change on water supply and use in the City of Regina; report prepared by the Social Dimensions of Climate Change Working Group for the Canadian Plains Research Centre, University of Regina, Regina, Saskatchewan, 54 p.
- Churchill, J.L., Iqbal, M. and Roberts, J. (2006): Adapting to climate change: is Canada ready?; Conference Board of Canada Report, 23 p.
- Climate Change Scenarios Network (2007): Canadian Climate Change Scenarios Network (CCCSN); <<http://www.ccsn.ca/index-e.html>>, [accessed November 28, 2007].
- Cline, R., Ragus, J., Hogan, G., Maynard, D., Foster, N., Terry, T. (2006): Policies and practices to sustain soil productivity: Perspectives from the public and private sectors; *Canadian Journal of Forest Research*, 36, 615–625.
- Cohen, S. and Kulkarni, T., editors (2001): Water management and climate change in the Okanagan Basin, BC; Environment Canada and University of British Columbia, Vancouver, BC, 75 p., <http://adaptation.nrcan.gc.ca/projdb/pdf/46_e.pdf>, [accessed November 27, 2007].

- Cohen, S. and Neale, T., editors (2006): Participatory integrated assessment of water management and climate change in the Okanagan Basin, British Columbia; Environment Canada and University of British Columbia, Vancouver, BC, 189 p., <http://adaptation.nrcan.gc.ca/projdb/pdf/a846_summary_e.pdf>, [accessed November 27, 2007].
- Community of Arctic Bay, Nickels, S., Furgal, C., Akumilik, J. and Barnes, B.J. (2006): Unikkaaqatigiit: putting the human face on climate change — perspectives from Arctic Bay, Nunavut; joint publication of the Inuit Tapiriit Kanatimi, the Nasivvik Centre for Inuit Health and Changing Environments at Université Laval and the Ajunnginiq Centre at the National Aboriginal Health Organization, Ottawa, Ontario, 26 p.
- Department for Environment, Food and Rural Affairs (2003): The impacts of climate change: implications for DEFRA; Department for Environment, Food and Rural Affairs, London, United Kingdom, 31 p., <<http://www.defra.gov.uk/environment/climatechange/pubs/impacts/index.htm>>, [accessed November 27, 2007].
- Dickinson, T. (2007): The Compendium of Adaptation Models for Climate Change: First Edition; Environment Canada, Adaptation and Impacts Research Division, 41 p.
- Downing, T. and Patwardhan, A. (2005): Assessing vulnerability for climate adaptation; *in* United Nations Development Programme, Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures, Cambridge University Press, New York, New York, <http://www.undp.org/gef/undpgef_publications/publications/apf%20technical%20paper03.pdf>, [accessed November 27, 2007].
- EBA Engineering Consultants Ltd. (1995): Tailings management plan and preliminary design of retention structures; report submitted to BHP Diamonds, December 1995.
- Egginton, P., Lehman, P., Casselman, J. and Demuth, M. (2007): On thinning ice: changing ice conditions and safety considerations for the Mississippi watershed, eastern Ontario; Mississippi Valley Field Naturalists, Almonte, Ontario, <<http://www.mvfn.ca/content/climatechange/On%20thinning%20Ice.pdf>>, [accessed March 16, 2007].
- Environment Canada (1998): The Canada Country Study (CCS) — climate change impacts and adaptation in Canada: highlights for Canadians; Environment Canada, 8 volumes.
- Environment Canada (2006): Vulnerability assessment, climate change impacts and adaptation measures; *in* Canada's Fourth National Report on Climate Change, Environment Canada, p. 153–168.
- European Climate Change Programme (2006): European Climate Change Programme: Working Group II Impacts and Adaptation: Building National Adaptation Strategies Sectoral Report, <<http://ec.europa.eu/environment/climat/pdf/eccp/impactsadaptation/natstrategies.pdf>>, [accessed December 10, 2007].
- European Commission (2007a): Adapting to climate change in Europe — options for EU action; green paper prepared by the European Commission for the Council, the European Parliament, the European Economic and Social Committee, and the Committee of the Regions, Brussels, Belgium, 27 p.
- European Commission (2007b): European Climate Change Programme II: Impacts and Adaptation; European Commission, <http://ec.europa.eu/environment/climat/eccp_impacts.htm>, [accessed November 27, 2007].
- Feenstra, J., Burton, I., Smith, J. and Tol, R., editors (1998): Handbook on methods for climate change impact assessment and adaptation strategies (version 2); United Nations Environment Programme, Nairobi, Kenya.
- Field, C.B., Mortsch, L.D., Brklacich, M., Forbes, D.L., Kovacs, P., Patz, J.A., Running, S.W. and Scott, M.J. (2007): North America; *in* Climate Change 2007: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson; Cambridge University Press, Cambridge, United Kingdom, p. 617–652.
- Ford, J.D., Smit, B. and Wandel, J. (2006): Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada; *Global Environmental Change*, v. 16, p. 145–160.
- Gardiner, S. (2004): Ethics and global climate change; *Ethics*, v. 114, no. 3, p. 555–600.
- Government of Alberta (2003): Water for Life: Alberta's strategy for sustainability; Government of Alberta, <<http://www.waterforlife.gov.ab.ca/docs/strategyNov03.pdf>>, [accessed June 1, 2007].
- Graham, S. and Revkin, A.C. (2007): The climate divide; *New York Times*, April 3, 2007, <http://www.nytimes.com/packages/html/science/20070403_CLIMATE_FEATURER/blocker.html?th&emc=th>, [accessed November 27, 2007].
- Harrison, M. (2007): Road stories: ready or not — The National looks at adapting to climate change; Canadian Broadcasting Corporation, The National, <<http://www.cbc.ca/news/background/climatechange/roadstories.html>>, [accessed November 27, 2007].
- Herrod-Julius, S. and Scheraga, J.D. (2000): The team model for evaluating alternative adaptation strategies; *in* Research and Practice in Multiple Criteria Decision Making, (ed.) Y.Y. Haimes and R.E. Steuer; Springer-Verlag, New York, p. 319–330.
- Hope, C. (2006): The marginal impact of CO₂ from PAGE2002: an integrated assessment model incorporating the IPCC's five reasons for concern; *The Integrated Assessment Journal- Bridging Sciences and Policy*; v. 6, no. 1, p. 19–56.
- Intergovernmental Panel on Climate Change (2007a): Summary for policymakers; *in* Climate Change 2007: The Physical Science Basis (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) S. Solomon; D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignot and H.L. Miller, Cambridge University Press, Cambridge, United Kingdom and New York, New York, p. 1–18 <<http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf>>, [accessed November 28, 2007].
- Intergovernmental Panel on Climate Change (2007b): Summary for policymakers; *in* Climate Change 2007: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson; Cambridge University Press, Cambridge, United Kingdom, p. 7–22, <<http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf>>, [accessed November 28, 2007].
- International Institute for Sustainable Development (2003): Livelihoods and climate change: combining disaster risk reduction, natural resource management and climate change adaptation in a new approach to the reduction of vulnerability and poverty; International Institute for Sustainable Development, conceptual framework paper prepared by the Task Force on Climate Change, Vulnerable Communities and Adaptation, <http://www.iisd.org/pdf/2003/natres_livelihoods_cc.pdf>, [accessed March 16, 2007].
- Klein, R.J.T., Alam, M., Burton, I., Dougherty, W.W., Ebi, K.L., Fernandes, M., Huber-Lee, A., Rahman, A.A. and Swartz, C. (2006): Application of environmentally sound technologies for adaptation to climate change: a technical paper commissioned by the United Nations Framework Convention on Climate Change, Expert Group on Technology Transfer; United Nations Framework Convention on Climate Change Secretariat, Bonn, Germany, Technical Paper FCCC/TP/2006/2, 107 p.
- Klein, R.J.T., Huq, S., Denton, F., Downing, T.E., Richels, R.G., Robinson, J.B. and Toth, E.L. (2007): Inter-relationships between adaptation and mitigation; *in* Climate Change 2007: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change), (ed.) M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson; Cambridge University Press, Cambridge, United Kingdom, p. 745–777.
- Klein, R.J.T., Schipper, E.L. and Dessai, S. (2005): Integrating mitigation and adaptation into climate and development policy: three research questions; *Environmental Science and Policy*, v. 8, p. 579–588.
- Linnerooth-Bayer J. and Mechler, R. (2006): Insurance for assisting adaptation to climate change in developing countries: a proposed strategy; *Climate Policy*, v. 6, no. 6, p. 621–636.
- Mehdi, B., editor (2006): Adapting to climate change: an introduction for Canadian municipalities; Canadian Climate Impacts and Adaptation Research Network, 36 p., <http://www.c-ciarn.ca/pdf/adaptations_e.pdf>, [accessed December 13, 2006].
- Mellgren, P.G. and Heidersdorf, E. (1984): The use of high floatation tires for skidding in wet and/or steep terrain; Forest Engineering Research Institute of Canada, Vancouver, BC, Technical Report No. TR-57, 47 p.
- Ministère de la Santé et des Services sociaux du Québec (2006): Chaleur accablante; Ministère de la Santé et des Services sociaux du Québec, <http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?chaleur_accablante_rayons_uv>, [accessed May 2, 2007].
- Mitchell, T. and Tanner, T. (2006): Adapting to climate change: challenges and opportunities for the development community; Institute of Development Studies, 40 p., <<http://www.tearfund.org/webdocs/website/Campaigning/policy%20and%20research/Adapting%20to%20climate%20change%20discussion%20paper.pdf>>, [accessed December 20, 2006].
- Natural Resources Canada (2005): Vanderhoof climate change impacts study; Natural Resources Canada, <http://nofc.cfs.nrcan.gc.ca/climate/en/factsheets/factsheet21_e.html>, [accessed November 26, 2007].
- New Brunswick Department of the Environment and Local Government (2002): A coastal areas protection policy for New Brunswick; New Brunswick Department of the Environment and Local Government, 18 p., <<http://www.gnb.ca/0009/0371/0002/Coastal-E.pdf>>, [accessed January 23, 2007].
- Nickels, S., Furgal, C., Castelden, J., Moss-Davies, P., Buell, M., Armstrong, B., Dillon, D. and Fongerm, R. (2002): Putting the human face on climate change through community workshops; *in* The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change, (ed.) I. Krupnik and D. Jolly, Arctic Research Consortium of the United States, Arctic Studies Centre, Smithsonian Institution, Washington, DC, p. 301–333.
- Office of the Auditor General of Canada (2006): Report of the Commissioner of the Environment and Sustainable Development to the House of Commons: Chapter 2 – adapting to the impacts of climate change; Public Works and Government Services Canada, 36 p., <[http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c20060902ce.html/\\$file/c20060902ce.pdf](http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c20060902ce.html/$file/c20060902ce.pdf)>, [accessed January 18, 2007].

- Gagnon-Lebrun, F. and Agrawala, S. (2006): Progress on adaptation to climate change in developed countries: an analysis of broad trends; Report to the Organisation for Economic Co-operation and Development, <<http://www.oecd.org/dataoecd/49/18/37178873.pdf>>, [accessed November 28, 2007].
- Ouranos Consortium (2007): Ouranos scientific program; Ouranos Consortium, <http://www.ouranos.ca/programmation/prog_e.html>, [accessed November 27, 2007].
- Pederson, L. (2004): Prince George timber supply area: rationale for allowable annual cut AAC determination; BC Ministry of Forests, Forest Analysis and Inventory Branch, Victoria, BC, <<http://www.for.gov.bc.ca/hts/tsr1/ration/tsa/tsa24/httoc.htm>>, [accessed May 20, 2007].
- Pielke, R., Jr., Prins, G., Rayner, S. and Sarewitz, D. (2007): Climate change 2007: lifting the taboo on adaptation; *Nature*, no. 445 (February 8, 2007), p. 597–598, <<http://www.nature.com/nature/journal/v445/n7128/full/445597a.html>>, [accessed November 27, 2007].
- Rainham, D.G.C., Smoyer-Tomic, K.E., Sheridan, S.C. and Burnett, R.T. (2005): Synoptic weather patterns and modification of the association between air pollution and human mortality; *International Journal of Environmental Health Research*, v. 15, no. 5, p. 347–360.
- Red Cross Climate Centre (2007): Addressing the consequences of climate change; Annual Report 2006: Addressing the humanitarian consequences of climate change, <<http://www.climatecentre.org/downloads/File/reports/annual%20report%202006.pdf>>, [accessed December 10, 2007].
- Risbey, J. (1998): Sensitivities of water supply planning decisions to streamflow and climate scenario uncertainties; *Water Policy*, v. 1, p. 321–340.
- Risbey, J., Kandlikar, M. and Dowlatabadi, H. (1999): Scale, context, and decision making in agricultural adaptation to climate variability and change; *Mitigation and Adaptation Strategies for Global Change*, v. 4, p. 137–165.
- Sauchyn, D., Byrne, J., Henderson, N., Johnson, D., Johnston, M., Keinzle, S. and Wheaton, E. (in press): Assessment of Biophysical Vulnerability; Final report to Alberta Environment, Alberta Vulnerability Assessment Project, 79 p.
- Scott, D. (2003): Climate change and tourism in the mountain regions of North America; 1st International Conference on Climate Change and Tourism, April 9–11, 2003, Djerba, Tunisia, 9 p., <<http://www.world-tourism.org/sustainable/climate/pres/daniel-scott.pdf>>, [accessed January 22, 2007].
- Seguin, J. (in press): Human health in a changing climate: a Canadian assessment of vulnerabilities and adaptive capacity; Health Canada, Ottawa, Ontario.
- Shaw, R., Colley, M. and Connell, R. (2007): Climate change adaptation by design; Town and Country Planning Association, London, United Kingdom, <http://www.tcpa.org.uk/downloads/20070523_CCA_lowres.pdf>, [accessed November 27, 2007].
- Shimo, A. (2007): Nicer wines, a bit of malaria; *Maclean's*, February 26, 2007, p. 18–20.
- Smit, B. and Wandel, J. (2006): Adaptation, adaptive capacity and vulnerability; *Global Environmental Change*, v. 16, p. 282–292.
- Smit, B., Burton, I., Klein, R. and Street, R. (1999): The science of adaptation: a framework for assessment; *Mitigation and Adaptation Strategies for Global Change*, v. 4, p. 199–213.
- Smit, B., Burton, I., Klein, R. and Wandel, J. (2000): An anatomy of adaptation to climate change and variability; *Climatic Change*, v. 45, no. 1, p. 223–251.
- Stern, N. (2006): *The economics of climate change: the Stern review*; Cambridge University Press, New York, New York, 712 p.
- Summit Environmental (2004): Trepanier Landscape Unit Water Management Plan; Regional District of Central Okanagan, Kelowna, BC, 256 p., <http://www.regionaldistrict.com/docs/planning/Final_Report_Text.pdf>, [accessed May 20, 2007].
- United Nations Development Programme (2005): *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*; Cambridge University Press, New York, New York.
- United Nations Framework Convention on Climate Change (2005): *Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change*; United Nations Framework Convention on Climate Change Secretariat, 155 p., <http://62.225.2.52/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/consolidated_version_updated_021204.pdf>, [accessed February 20, 2007].
- United Nations Framework Convention on Climate Change (2007): *The Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change*; United Nations Framework Convention on Climate Change Secretariat, Bonn, Germany, 12 p.
- Willows, R. and Connell, R. (2003): *Climate adaptation: risk, uncertainty and decision-making*; United Kingdom Climate Impacts Program, Technical Report, 162 p., <http://environment.msu.edu/climatechange/UK_CC_Decisions_Report.pdf>, [accessed November 27, 2007].
- Wittrock, V. and Koshida, G. (2005): *Canadian droughts of 2001 and 2002: government response and safety net programs — agriculture sector*; Saskatchewan Research Council, Saskatoon, Saskatchewan, Publication 11602-2E03, 24 p.
- World Bank (2006): *Managing climate risk: integrating adaptation into World Bank Group operations*; World Bank Group, Global Environment Facility Program, 42 p., <<http://siteresources.worldbank.org/GLOBALENVIRONMENT/FACILITY/GEFOPERATIONS/Resources/Publications-Presentations/GEFAdaptationAug06.pdf>>, [accessed November 27, 2007].