

Climate Change Adaptation: A Priorities Plan for Canada

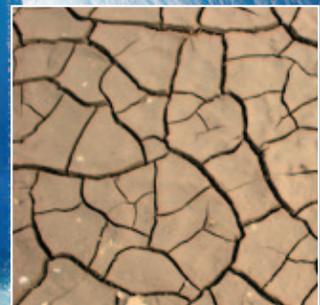
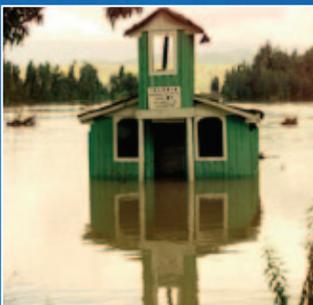
Report of the Climate Change Adaptation Project (Canada)

Dr. Blair Feltmate

Chair

Dr. Jason Thistlethwaite

Director





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Dr. Blair Feltmate

Chair

bfeltmat@uwaterloo.ca

Dr. Jason Thistlethwaite

Director

j2thistl@uwaterloo.ca

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Acknowledgment

We thank Dr. James Lovelock, who inspired and provided insight to the Climate Change Adaptation Project (Canada). We also thank Dr. Neil Comer, Dr. Frank Frantisak, Dr. Jason Grove, and Natalia Moudrak, who contributed substantially to the project's execution.

This project would not have been possible without the support of the Intact Foundation, our partners at Intact Financial Corporation, and the Faculty of Environment, University of Waterloo.





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A. Forward

The continued increase of atmospheric carbon dioxide abundance is as near certain as any properly sceptical scientist would admit. What is less certain are the consequences; climate science has not yet advanced to the point where forecasts of climate, for decades ahead, are as reliable as the weather forecast for weeks ahead. We have to rely on the history of climate, when carbon dioxide levels were as high as they are now, and upon mathematical models that are far from complete. These models, for example, do not include the biosphere as an active participant in climate change. We are obliged to assume, therefore, that high CO₂ levels will be associated with climates inconsistent with our present way of life.

There is no practical way yet to significantly reduce the burden of greenhouse gases. To do so may not be an ineluctable feat, but human reaction is quite slow in times of peace. Consider the time it would take to stop burning fossil fuel for energy, or to reorganise our lifestyles so as to use less fossil fuel for transport. Consider the failure of renewable energy sources so far to make even a dent in the increase of CO₂. Remember, also, that away from the western world, vast populations cannot easily be denied what they see as their just expectation: a lifestyle comparable with that in the developed world.

We must, therefore, learn to adapt to climate change. Geoengineering, such as making clouds at the ocean surface to reflect sunlight, or putting aerosols in the stratosphere has been discussed as a solution, but not yet tried, even on a pilot scale. There is a slight but real chance that this might serve to offset temperature rise. Good evidence exists that the Pinatubo volcanic eruption in 1991 caused a cooling for three years; but like an untried cancer cure, the side effects may be as bad as the disease. I feel that things will have to get a lot worse than they are now before we would dare to use geoengineering.

For these reasons, I am much moved by this report from Dr. Feltmate and Dr. Thistlethwaite on the use of practical and immediately accessible adaptation as a way to live with and survive climate change. We have only to consider modern Singapore. This is an island nation, located in one of the hottest climates of the world, that has adapted so successfully that its interior climate is cool and pleasant while its GDP is among the highest of the world. If they can do it, I feel sure that Canada can do it too.

Sincerely,
Dr. James Lovelock,
Founder of Gaia Theory



B. Executive Overview

The **Climate Change Adaptation Project: Canada** (CCAP) was designed to identify and operationalize practical, meaningful and cost-effective adaptation solutions to the most challenging impacts of climate change facing Canada. Although some Canadian initiatives have profiled the long-term, broad impacts of climate change and the need to embrace adaptation, there has not been an initiative at the national level to identify a short list of priority areas of climate change challenges and solutions that Canada must address immediately.

Why Should Canada Embrace Climate Change Adaptation?

As the title suggests, the focus of this project is climate change adaptation. Adaptation encompasses *adjustments in practices, processes or structures in response to projected or actual climate and extreme weather events*. This approach is different than mitigation, which focuses on *activities that reduce or eliminate the release of greenhouse gases* that contribute to climate change.

The decision to focus the project on adaptation, rather than mitigation, is based on evidence that the climate is already undergoing observable change and will continue to do so. To illustrate this change in terms of temperature and precipitation:

- The 10 warmest years on record have all occurred since 1998. Indeed, between 2001 and 2010, global temperatures averaged 0.46 °C above the 1961-1990 average, and were the highest ever recorded for a 10-year period since the beginning of instrumental climate records.
- Major Canadian cities are experiencing extreme precipitation events with increasing frequency. For example, in Toronto, two 1-in-10-year precipitation events and six 1-in-50-year events

occurred between 1996 and 2011. In Calgary, a single July 2010 hailstorm caused \$400 million in damage, making it the costliest hailstorm in Canadian history. Dry conditions are also more extreme, contributing to drought and even dangerous wildfires, such as the 2003 Kelowna and 2011 Slave Lake fires.

To understand the drivers for adaptation, it might be instructive to visualize Canada as a house with worn shingles, where every time it rains, water drips through to the structure below. We are faced with two choices – do we fix the roof (i.e. adapt), or do we stand by and watch the inside of the house slowly disintegrate (i.e. do nothing)? As the findings presented in this report illustrate, “fixing the roof” is the **cost-effective and risk-adverse** choice that Canada should embrace.

Indeed, the issue of whether Canada should focus on climate adaptation is no longer a question – the answer is “yes”; the imperative now is to prioritize the key adaptation challenges to be addressed in the immediate term, and identify how to best execute solutions to these challenges.

Adaptation and Mitigation. Although the CCAP is focused on adaptation, limiting emissions of greenhouse gases is a mutually important priority and should also be pursued. However, there is an immediate need to address adaptation, given that climate change will continue to occur as atmospheric concentrations of greenhouse gases increase [e.g. as of 2012, global CO₂ concentration equalled 394 parts per million (ppm), which is approximately 100 ppm higher than global concentrations of CO₂ over the past 900,000 years, and this concentration is projected to increase under virtually every modelling projection]. Also, since the mid-1990s, Canadian discussions surrounding climate change have focused disproportionately on mitigating greenhouse gas emissions. A national focus to prioritize key adaptation initiatives is timely, given the recognition that climate change “is here and now.”



Cost-Effective Adaptation Solutions. During the management of the CCAP, it became evident there is a pervasive perception that adaptation to climate change is costly to implement. Although this can be the case, adaptation initiatives can also be relatively inexpensive. For example, the cost to build a new house, transmission line, or mine that is adapted to climate change for its life-cycle, is not materially different than building the structure improperly (i.e. business-as-usual, without adaptive capacity), given that a re-build or retrofit is much more expensive. As a rule of thumb, incorporating adaptation initiatives into the design of a new structure generally adds from zero to five per cent to the front-end building cost.

The installation of a backwater valve into new home construction provides a useful example of cost-effective adaptation (see Chapter 8). In the 1990s, basement flooding replaced fire damage as the most expensive source of home insurance claims. This growing cost is partially linked with an increase in the intensity and duration of rainfall events, which can over-burden sewer lines so that water backs up into basement drains. Indeed, one three hour rainfall in August 2005 of over 160 mm resulted in 13,000 flooded basements in Toronto and caused \$500 million in property damage. A backwater valve (which stops water from backing up through a basement drain) costs \$200 to install in a new home. This investment is a fraction of the cost for retrofitting an existing home, or the cost for repairing a flooded basement. Similar examples of cost-effective adaptation initiatives are discussed throughout the report.

Canada's International Environmental Image. Throughout 2011-2012, the CCAP was presented to approximately 80 audiences within Canada, the United States and England. Senior U.S. audiences included: the Department of Energy (including Secretary of Energy Steven Chu), the Department of Defence (Pentagon), the National

Aeronautics and Space Administration (NASA) and the U.S. Army Corps of Engineers; British audiences included senior politicians and climate scientists. Additionally, the CCAP was presented to the senior administration of the United Nations. Following presentations to all of these audiences, a consistent theme emerged – they all applauded Canada for addressing adaptation to climate change within a framework of prioritized challenges and solutions. Although many countries recognize the value of adapting to climate change, substantive means to operationalize adaptation have often proven elusive, and in many cases, countries have only responded to climate change following a substantial extreme weather event (i.e. management by disaster).

As Canada implements climate change adaptation best practices, and subsequently promulgates its successes internationally, Canada will build a reputation as a leader in the area of adaptation, one that other countries may view favourably. This reputation can help create a positive business environment for Canadian companies, one that facilitates a responsible “license to operate,” thus greatly easing operational start-ups. Conversely, to the degree that Canada might be seen as a laggard on adaptation, this can hurt or impede Canadian businesses in their ability to operate internationally.

To sum up, climate change adaptation, applied properly, is simply “good” and “smart” business for Canada at both the international and national levels.

“Made in Canada” and “Bottom-up process.” Prioritizing actions on climate change adaptation creates an opportunity for Canadians from all regions and backgrounds to have a stake in shaping the way our country responds to climate change. Most adaptation research begins with governments or scientists who choose the project’s priorities. In this study, the CCAP asked Canadian



leaders, of many different backgrounds from across the country, what challenges the project should address. More than 80 representatives from Canadian industry, government, aboriginal communities, non-governmental organizations (NGOs), academe, and the legal community were invited to join in this effort. By sparking a debate on adaptation priorities, Canadians can engage their own perspective and experience to inform our adaptation strategy.

The Purpose for the Climate Change Adaptation Project

The purpose of the CCAP was to identify:

- five key areas and courses of action that Canada must engage to limit current and future impacts to industries and public sectors that will otherwise result due to climate change.
- three key areas and courses of action that Canada must engage to limit current and future property & casualty insurance impacts that will otherwise result due to climate change.

To appreciate the motivation for these objectives, three points merit a brief explanation:

- The CCAP focused on a contracted list of climate change challenges (i.e. five and three areas and courses of action) because the mandate of the project extended beyond producing a report to also include implementing the project's recommendations. Implementing change is a formidable task, so a focused approach was deemed to be optimal rather than diffusing efforts across a range of challenges.
- CCAP considered climate impacts to both industry and public sectors. Industry sectors considered under the CCAP ranged from mining to banking to telecommunications. Public sectors included non-industry areas, such as freshwater resources, biodiversity, and human

health impacts (see Figure A for a list of all sectors considered under the CCAP).

- The property & casualty sector (see Figure B for list of all property & casualty challenges) was treated separately from the focus on industry and public sectors due to the high level of perceived challenge that climate change may present to this sector (e.g. flooding).

The “Five-Step Method” of the Climate Change Adaptation Project

The CCAP consisted of five steps, each briefly described below:

1) Establish Climate Change Projections for Canada. The first step in the CCAP was to run ensemble climate projections for Canada, in reference to changes in temperature and precipitation regimes (relative to an average baseline of 1971-2000), across the four seasons (winter, spring, summer, fall), for the years 2020 and 2050. These projections established the parameters within which adaptation must occur. The ensemble model projections (i.e. a model of 24 global climate projection models “rolled into one”) were developed by the Canadian Climate Change Scenarios Network (CCCSN), Environment Canada (see Climate Model Projections, p. xvii).

2) Primary Subject Matter Experts. Using the CCCSN climate change projections as a framework, primary subject matter experts prepared presentations which identified the key climate change challenges within their core areas of expertise for various industry and public sectors, and recommended actions to address those challenges. They delivered their presentations to the Adaptation Advisory Committee.

3) Adaptation Advisory Committee (AAC). The AAC consists of approximately 80 leaders drawn from across Canada who represent industry, finance, law, academe, aboriginal communities, government,



youth and NGOs (see AAC members, p. xiii). Primary subject matter experts (from step 2) delivered 24 presentations to the AAC (see Figure A for topics). Following each presentation, AAC members scored each sector on a scale from zero (not important) to 100 (highly important), for areas that Canada should address from the perspective of adaptation to climate change.

AAC members next cast their top five votes for sectors that required immediate attention from the perspective of adaptation. Similarly, in reference to property & casualty insurance, eight presentations were delivered, and the AAC members each cast three votes to identify the three areas they considered most important.

Based on the collective vote of the AAC, five sectors and three areas of property & casualty insurance were identified as the key climate challenges to be addressed in Canada

4) Secondary Subject Matter Experts. Nationally recognized subject matter experts (for each of the top five sectors and three insurance areas) were asked to identify specific climate change challenges, and propose three practical, meaningful and cost-effective actions to address those challenges for their area of expertise.

Each subject matter expert produced two reports: (a) a Summary Report, which very concisely presented key findings to stakeholders (i.e. generally three to five pages); and (b) a Detailed Report, for stakeholders requiring more detailed explanations than those presented in the shorter report.

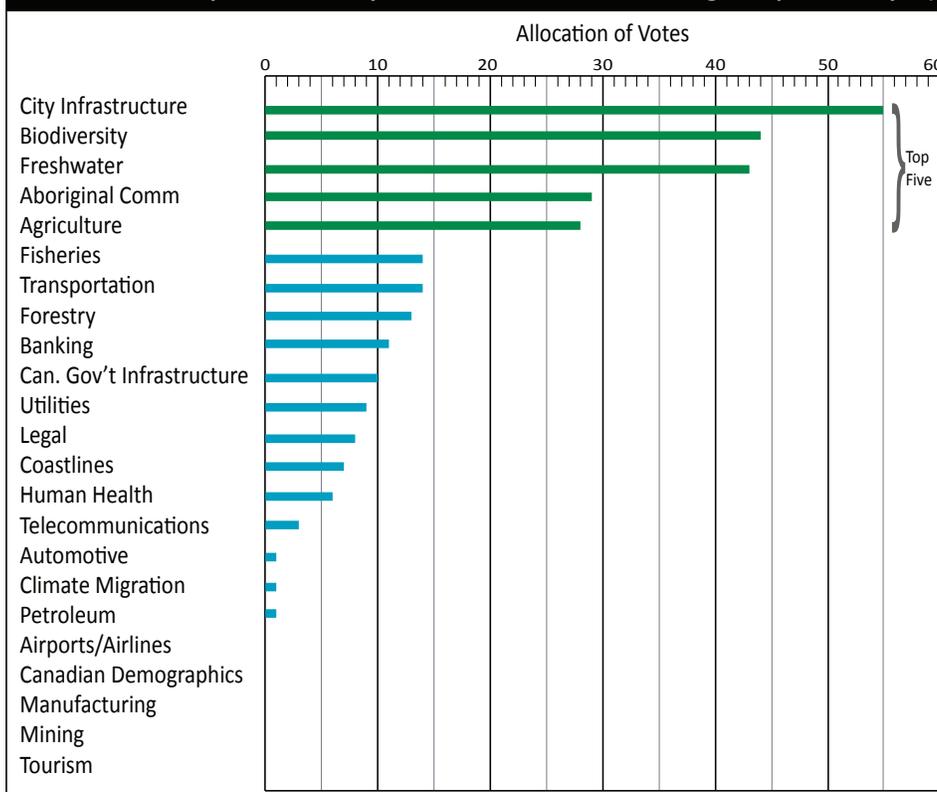
5) Operationalizing Recommendations. Subject matter experts' reports were integrated into a final report, the CCAP, released in spring 2012. The next three years of the project remain dedicated to operationalizing climate adaptation

recommendations presented in the CCAP. This process involves holding meetings with key decision-makers, across industry and public sectors throughout Canada.

Canada's Priority Areas of Focus for Climate Change Adaptation

The AAC reviewed 24 sectors that Canada could potentially address from the perspective of adaptation to climate change. Of these 24 areas of consideration, five received the greatest number of votes by the AAC: (1) City Infrastructure, (2) Biodiversity, (3) Freshwater Resources, (4) Aboriginal Communities, and (5) Agriculture (see Figure A).

Figure A: Prioritization of Climate Change Adaptation Sectors for Canada (determined by the Adaptation Advisory Committee of the Climate Change Adaptation Project)





Based on Figure A, the signal strength (i.e. the number of votes directed towards the top five areas) was definitive.

In reference to property & casualty insurance, the AAC identified the following areas of priority concern: (1) better alignment of insurance coverage and pricing with climate change risk, (2) champion changes in building codes to better reflect climate change risk, and (3) develop tools for insurers to promote climate change adaptation by homeowners (see Figure B).

Subject Matter Experts

The subject matter experts engaged to address the eight priority areas of climate change that challenge Canada are listed below. These experts are identified as “top-tier practitioners” in their respective fields.

City Infrastructure

- *Darrel Danyluk* – Chair, World Federation of Engineering Organizations Committee on Engineering and Environment.

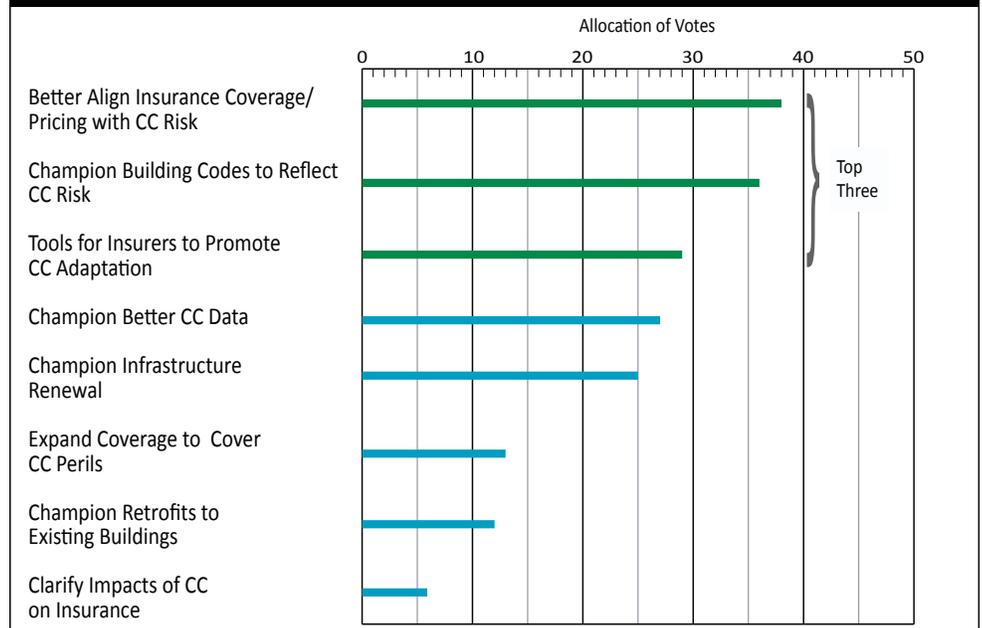
Biodiversity

- *Steve Hounsell* – Director, Board of the Canadian Business and Biodiversity Council; Chair, Board of Trustees, Trees Ontario.

Freshwater Resources

- *Dr. David Schindler* – Killam Memorial Chair and Professor of Ecology, University of Alberta
- *Dr. Jim Bruce* – Former Director of Canada Centre for Inland Waters; Former Assistant Deputy Minister of Environmental Management, Environment Canada.

Figure B: Prioritization of Climate Change Property & Casualty Concerns for Canada (as determined by the Adaptation Advisory Committee of the Climate Change Adaptation Project)



Aboriginal Communities

- *Chris Henderson* – President, Lumos Energy; Chair, Delphi Group; National Coordinator, Aboriginal Clean Energy (ACE) Network
- *Dr. Judith Sayers* – Chief, Hupacasath First Nation, British Columbia (1995-2009); Chief Negotiator for Hupacasath First Nation.

Agriculture

- *Dr. Barry Smit* – Professor and Canada Research Chair in Global Environmental Change, University of Guelph.

Insurance: Adapting Building Codes for Climate Change

- *Grant Kelly* – Director of Climate Change Adaptation Projects, Institute for Catastrophic Loss Reduction (ICLR)
- *Paul Kovacs* – Executive Director, ICLR
- *Dr. Jason Thistlethwaite* – Research Associate, ICLR.



Insurance: Tools to Promote Adaptation by Existing Homeowners

- *Dan Sandink* – Manager, Resilient Communities & Research, ICLR
- *Glenn McGillivray* – Managing Director, ICLR.

Insurance: Aligning the Price of Insurance With the Risk of Damage

- *Paul Kovacs* – Executive Director, ICLR.

Climate Change Adaptation Priorities for Canada

Each of the subject matter experts was charged with explaining each challenge identified by the AAC and to recommend actions to address those challenges. Experts were directed to be aspirational in their recommendations, yet to also focus on actions that are practical, meaningful, and cost-

effective. A summary of their key recommendations follows in section F. Chapter Summaries. For more detailed explanations regarding the rationale in support of their recommendations, please refer to G. Full Chapters.

Tracking Progress on Climate Adaptation

Throughout 2012 and 2013, the CCAP Chair and Director will hold meetings relevant to the implementation of adaptation with key decision-makers across Canada. Additionally, beginning in January 2013, the first annual “Climate Change Adaptation Report” will be issued to document which adaptation recommendations were implemented, and to present actions to address outstanding challenges.

Dr. Blair Feltmate
Chair

Dr. Jason Thistlethwaite
Director





Industry and Public Sector Climate Change (CC) Challenges		
	Adaptation Recommendation	Next Steps
City Infrastructure	Incorporate Adaptation into City Planning Policy	Meet with environmental officers within major Canadian cities to embed CC adaptation into city policy. Job descriptions of managers, engineers and utility personnel should define responsibilities and reporting requirements to adhere to the updated city policy.
	Prioritize Areas of High CC Risk and Implement Adaptation Measures	Meet with environmental officers within Canada's major cities to estimate CC risks to critical infrastructure (using such tools as the Public Infrastructure Engineering Vulnerability Committee – PIEVC – protocol). For critical vulnerabilities, implement adaptation immediately.
Biodiversity	Identify Bioclimatic Zones with Greatest Need of Adaptation Measures	Determine the extent of change in bioclimatic zones caused by CC in comparison to Canada's National Ecological Framework in collaboration with Environment Canada and provincial conservation authorities. Next, undertake vulnerability assessments of key species and community types to climatic changes to establish geographical priorities for adaptation on a national and provincial basis.
	Increase Habitat Connectivity in Human-Dominated Settled Landscapes	Develop and support programs such as Ontario's 50 Million Tree Program to increase habitat connectivity in four key localities in Canada in collaboration with Environment Canada and provincial conservation authorities.
Freshwater Resources	Preserve/Restore Critical Wetlands	Establish a national priority to identify, preserve and/or restore wetlands that are "key capacitors" within watersheds across Canada in cooperation with Environment Canada and Natural Resources Canada.
	Move Population and Water-Intensive Industry to Water (not vice-versa)	Develop and promote policies to encourage new development on the Peace River (where there is ample water supply), rather than the small South Saskatchewan River, in collaboration with multiple government agencies (federal, provincial, municipal) and aboriginal representatives.
Aboriginal Communities	Redesign and Relocation of Climate- Stressed Communities	Design climate vulnerability assessments with aboriginal communities and Aboriginal Affairs and Northern Development Canada (AANDC). These assessments should determine whether communities affected by ongoing spring floods such as Kashechewan, Attawapiskat (Ontario), Tuktoyatuk (Northwest Territories) and Peguis First Nation (Manitoba) require the redesign or potential relocation of key facilities.
	Factor Traditional Knowledge into Adaptation	Work with aboriginal communities and AANDC to ensure that adaptation policy integrates local and culturally specific knowledge about CC. Develop adaptation policies to protect threatened local sources of food.
	Integrate Resiliency into Community Access/ Transportation	Develop a transportation infrastructure assessment program with AANDC to identify aboriginal communities vulnerable to CC induced isolation, and contingency protocols that address vulnerable locales.
Agriculture	Develop CC Information and Dissemination Programs to Engage Agricultural Stakeholders	Engage representatives from agricultural producers, businesses, government agencies and the research community to develop agriculture-relevant CC dialogue, with a focus on factoring CC into decision-making in cooperation with the Canadian Federation of Agriculture (CFA).
	Incorporate CC into Planning Decisions	Work with the CFA to identify cases where decision-making processes within the agricultural industry can include material considerations of CC risks and opportunities.
Property and Casualty Insurance Challenges		
New Homes and Adaptation	Integrate Adaptation into New Home Builds through the National Building Code	(1) promote building durability and resiliency as a core theme for the National Building Code, (2) develop information on future weather extremes relevant to the building code, and (3) pursue building code reforms that support adaptation (i.e. mandatory backwater valves).
Existing Homes and Adaptation	Incorporate Pre- and Post-Disaster Improvements in Infrastructure Design to Mitigate Future Losses	In cooperation with the Insurance Bureau of Canada (IBC): (1) incorporate adaptation into federal and provincial Disaster Financial Assistance Arrangements, and (2) develop and promote insurance programs with incentives for home owners to implement adaptation practices.
Insurance Pricing and Adaptation	Perform Attribution Analysis to Identify Key Variables that Explain Weather-Related Losses	Initiate an extreme-weather attribution study to identify key variables contributing to weather-related losses by working with the Insurance Bureau of Canada, the insurance industry, and Environment Canada.



C. Adaptation Advisory Committee

Dr. Blair Feltmate (Project Chair)

Associate Professor, Faculty of Environment
University of Waterloo

Dr. Jason Thistlethwaite (Project Director)

University of Waterloo and Institute for
Catastrophic Loss Reduction

Dr. James Lovelock

Founder,
Gaia Theory

Dana Atwell

Former Director, Environmental Policy & Programs,
Nova Scotia Power Inc.

Debbie Baxter

Chief Sustainability Officer
LoyaltyOne

Charles Brindamour

Chief Executive Officer
Intact Financial Corporation

Kim Brand

Director, Environmental Affairs Public,
Corporate & Government, Scotiabank

Dr. Jim Bruce OC

Principal
Forum for Leadership on Water

Jim Burpee

President and CEO
Canadian Electricity Association

Robert Campanelli

Vice President
Real Property Association of Canada

Denise Carpenter

President and CEO
Canadian Nuclear Association

Dr. Quentin Chiotti

Co-Lead, The Gateway Project
Association for Canadian Educational Resources

Valerie Chort

National Leader - Sustainability & Climate Change,
Partner, Enterprise Risk Services, Deloitte Canada

Dr. Neil Craik

Director, SEED, Faculty of Environment
University of Waterloo

Dr. Stephen Crawford

Assistant Professor, Dept. of Integrative Biology
University of Guelph

Darrel Danyluk

Principal
J. Danyluk Consulting Inc.

Dr. Ron Dembo

Founder and CEO, Zerofootprint

Julie Desjardins

Principal
Desjardins & Associates Consulting Inc.

Bruce Dudley

Senior Vice President, The Delphi Group

Eugene Ellmen

Executive Director
Social Investment Organization

Ken Elsey

President and CEO
Canadian Energy Efficiency Alliance

Tom Ewart

Former Managing Director
Network for Business Sustainability

Jimena Eyzaguirre

Policy Advisor, NRTEE

**Ted Ferguson**

Vice President, The Delphi Group

Dr. Donald Forbes

Senior Research Scientist
Natural Resources Canada

Dr. Frank Frantisak OC

Corporate Director
Former Senior VP, Noranda Inc.

Dr. Neil Freeman

Vice President, Business Development
Horizon Utilities

Dan Gagnier

Chair, IISD

Mike Gerbis

CEO, The Delphi Group

John Haffner

President
Haffner Consultants

Toby Heaps

President and Editor
Corporate Knights

Chris Henderson

President, Lumos Energy
Chairman, The Delphi Group

Steve Hounsell

Director, Canadian Business and
Biodiversity Council

Peter Johnson

Principal
Poyry Management Consulting

Brian Kelly

Manager of Sustainability
Office of the CAO, Region of Durham

Paul Kovacs

Founder and Executive Director
Institute for Catastrophic Loss Reduction

Pat Koval

Partner
Torys LLP

Karen Kraft Sloan

Founder
EcoNexus

Karen Kun

Director
Waterlution

Dr. Geoffrey Lewis

Assistant Professor, Faculty of Environment
University of Waterloo

Eva Ligeti

Executive Director
Toronto Clean Air Partnership

Matthew McCulloch

Director, Corporate Consulting Services
The Pembina Institute

Michelle McCulloch

Senior Manager, Environment
TD

David MacLeod

Senior Environmental Specialist
Toronto Environment Office

Ian McPherson

Former President
Criterion Investments

Adine Mees

Former President
Canadian Business for Social Responsibility

Manjana Milkoreit

Ph.D. Candidate, Global Governance
University of Waterloo

Mike Morrice

Executive Director
Sustainable Waterloo



Natalia Moudrak
School of Planning
University of Waterloo

Sandra Odendahl
Director, Corporate Environmental Affairs
RBC

Dr. Kenneth Ogilvie
Sustainability Consultant

Tanis Ostermann
Manager, Corporate Environmental Management
Department
Manitoba Hydro

Bob Oliver
Executive Director
Pollution Probe

David Oulton
Former Head
Federal Climate Change Secretariat

Dr. David Pearson
Professor, Department of Earth Sciences
Laurentian University

Channa Perera
Director, Sustainable Development
Canadian Electricity Association

Alex Phillips
Senior Environmental Advisor
Ministry of Environmental Ontario

Kevin Ranney
Global Director, Responsible Investment
Services, Jantzi-Sustainalytics

John Roberts
Vice President, Environment
Aurora Energy Services Inc.

Gregor Robinson
Senior Vice-President, Policy and Chief Economist,
Insurance Bureau of Canada

Gregor Robinson
Senior Vice-President, Policy and Chief Economist,
Insurance Bureau of Canada

Dr. David Runnalls
Chair Emeritus
IISD

Dr. Judith Sayers
Chief Negotiator
Hupacasath First Nation

Kathy Scales
Senior Advisor, Energy and Climate Change
Suncor Energy Inc.

Dr. David Schindler
OC, FRS, FRSC, Killam Memorial Chair and Professor
of Ecology
University of Alberta

Dr. Barry Smit
Canada Research Chair in Global and Environmental
Change, University of Guelph

Dr. Stuart Smith
Former Chair
Science Council of Canada

Erik Sparling
Senior Analyst, Risk Informed Decision Support Risk
Sciences International

Brenda Stasuik
Director, Corporate Social Responsibility
Farm Credit Canada

Melanie Steiner
Markets Leader, Climate Change and Sustainability
Services, Ernst & Young

Sandi Stride
President, EcoStride Group
CEO, Sustainable Hamilton

Melanie Steiner
Market Leader, Climate Change and Sustainability
Services, Ernst & Young



Nelson Switzer

President and Chief Sustainability Officer
Asherleaf Consulting Inc.

Gray Taylor

Chair, Climate Change & Emissions Trading Group,
Partner, Bennett Jones LLP

Bob White

President
BRI International

Dr. John Wiebe

President and CEO
Globe Foundation

Dr. Steven Young

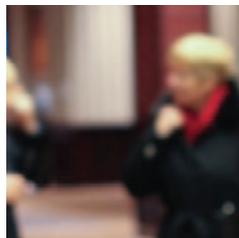
Associate Professor, Faculty of Environment
University of Waterloo

Ron Yachnin

Principal
Yachnin and Associates

Laura Zizzo

Partner, Zizzo Allan Climate Law LLP





D. Ensemble Climate Scenarios

The CCAP used a set of ensemble climate scenarios as a framework to inform subject matter experts on the major climate challenges facing Canada. These projections were developed by the Canadian Climate Change Scenarios Network (CCCSN) by integrating 24 climate models developed by different international modelling centres. By combining the models, individual biases associated with any single model are limited. It is for this reason that recent scientific literature has confirmed that ensemble models are the most likely to “provide the best projected climate change signal.”¹ The models used for the CCAP identify the changes in temperature and precipitation relative to an average baseline between 1971-2000 across four seasons (winter, spring, summer and fall) for the 30-year periods centred in the 2020s and centred in the 2050s.

The ensemble projections used in the CCAP combined 24 “A1B” emissions scenarios. There are several different emission scenarios commonly available, such as A2, which assumes emissions will significantly increase, and B1 which assumes emission levels will decrease as governments implement mitigation regulations. The A1B scenario represents the “medium” projection and assumes that while emissions will increase more than the B1 scenario, mitigation measures will limit these emissions below the significant levels assumed in the A2 scenario.²

¹ Canadian Climate Change Scenarios Network (CCCSN). 2012. Ensemble Scenarios.

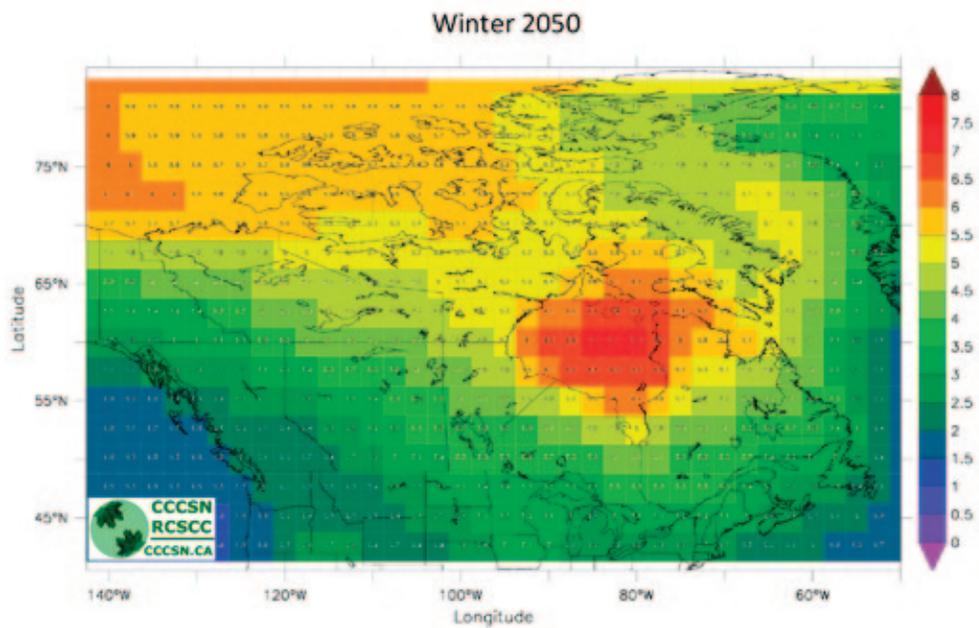
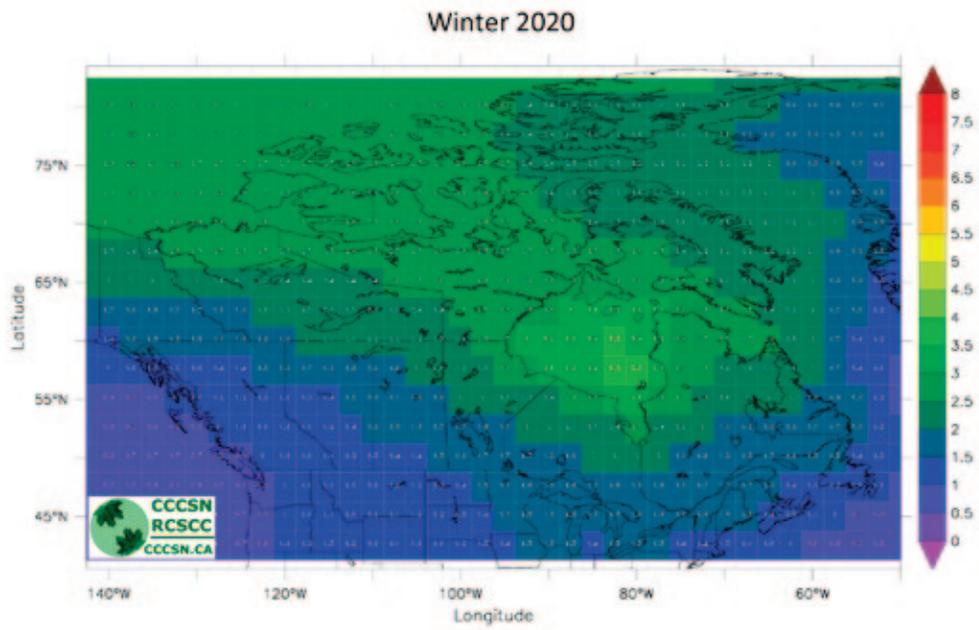
Online: <http://cccsn.ca/?page=enablescenarios>

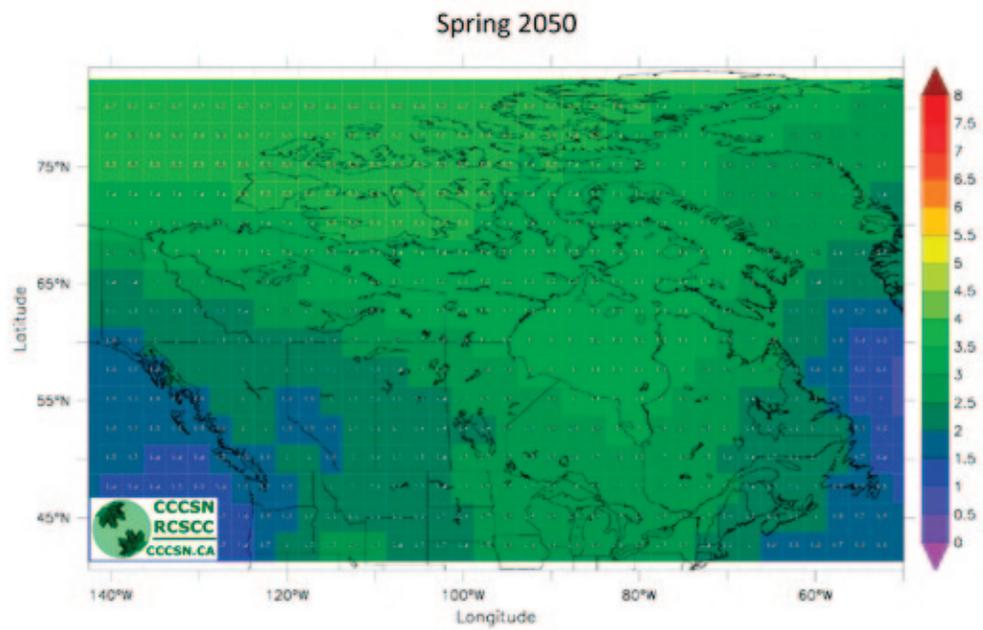
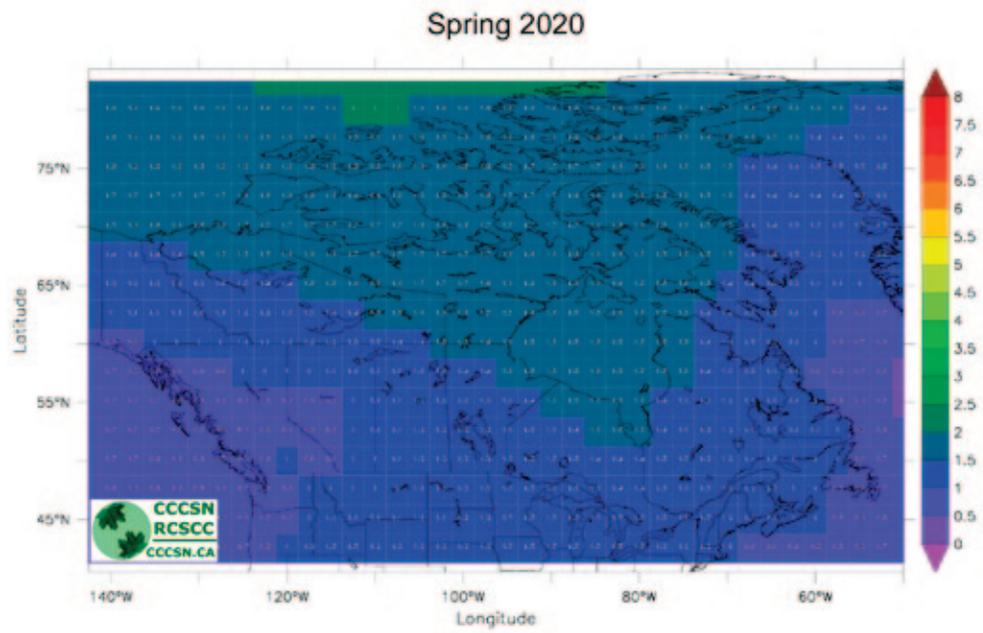
² Canadian Climate Change Scenarios Network (CCCSN). 2012. Which Scenario to Select.

Online: <http://cccsn.ca/?page=scen-which>

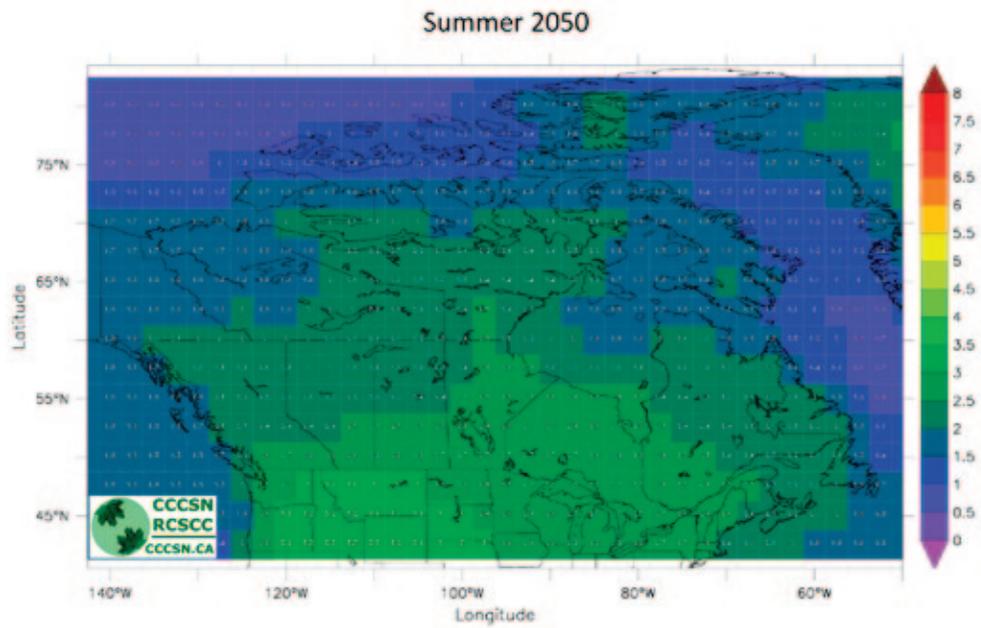
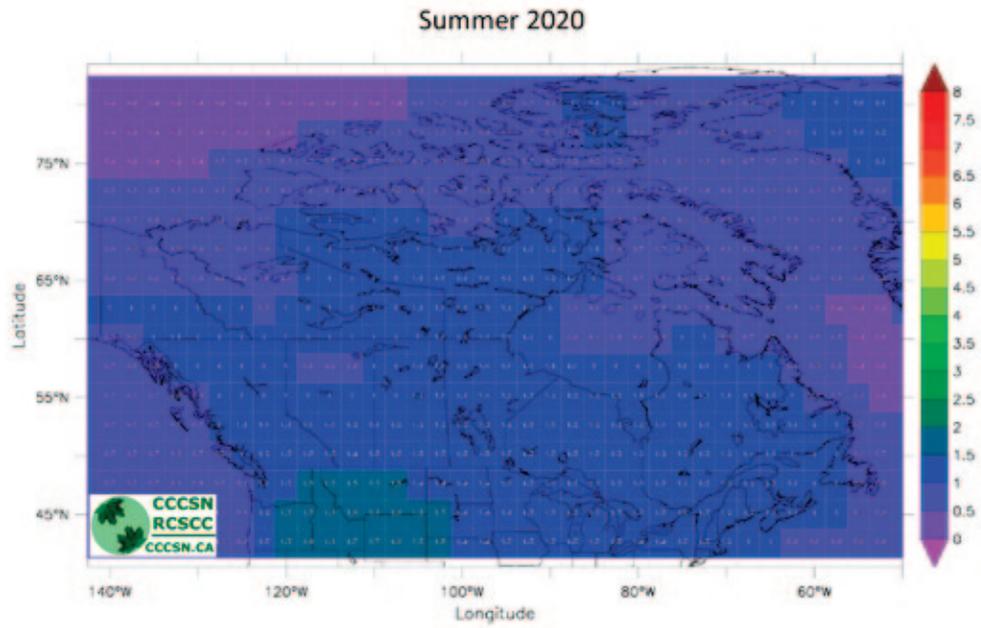


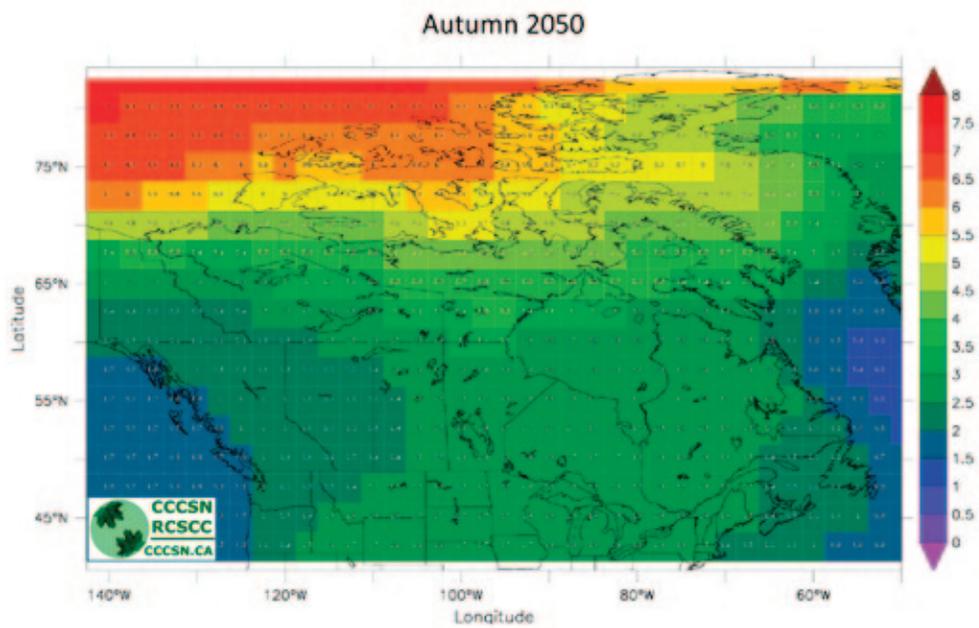
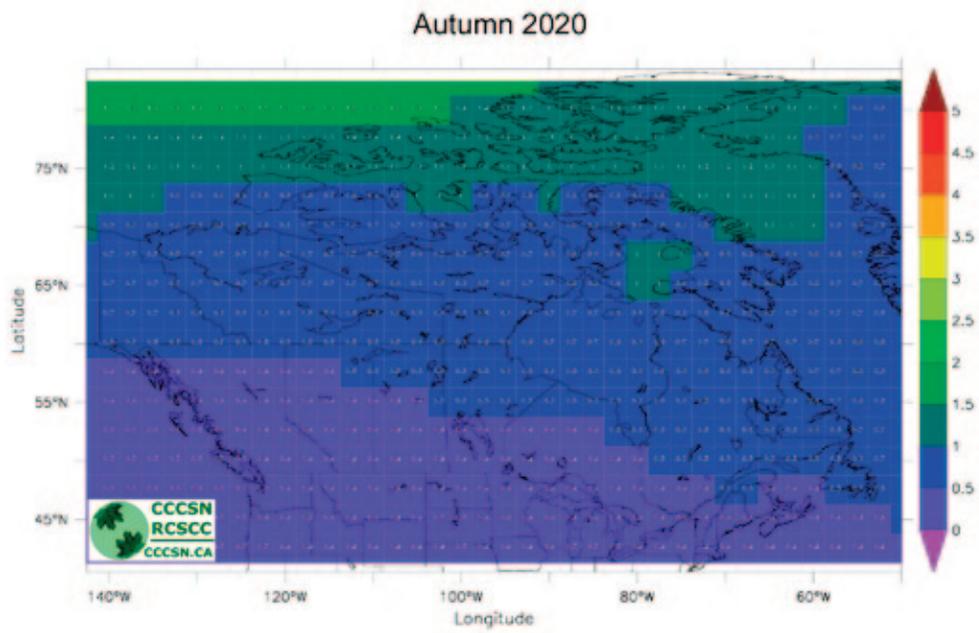
Temperature Scenarios





Change in Air Temperature (°C)

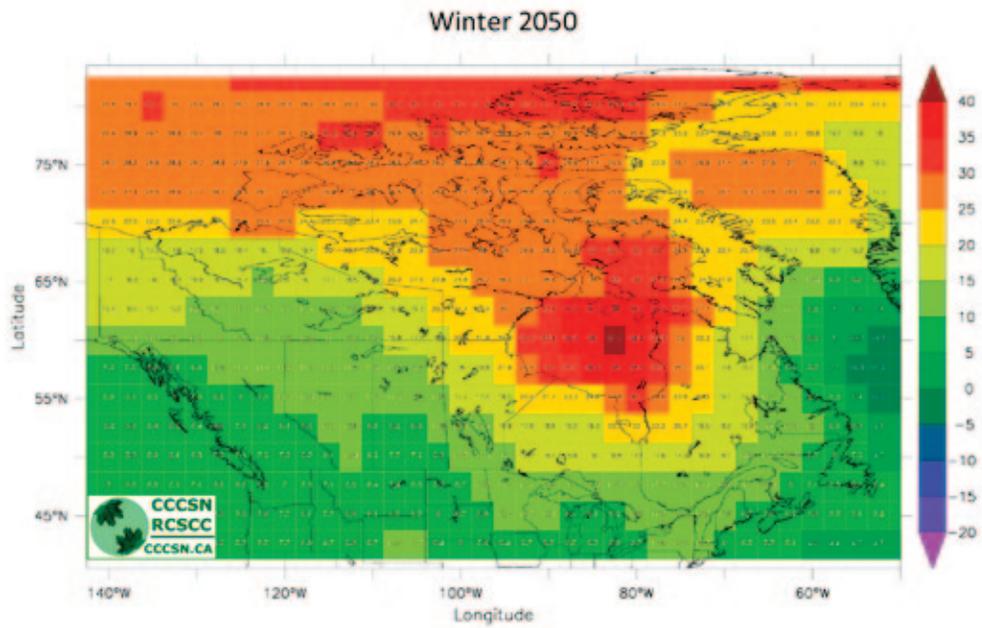
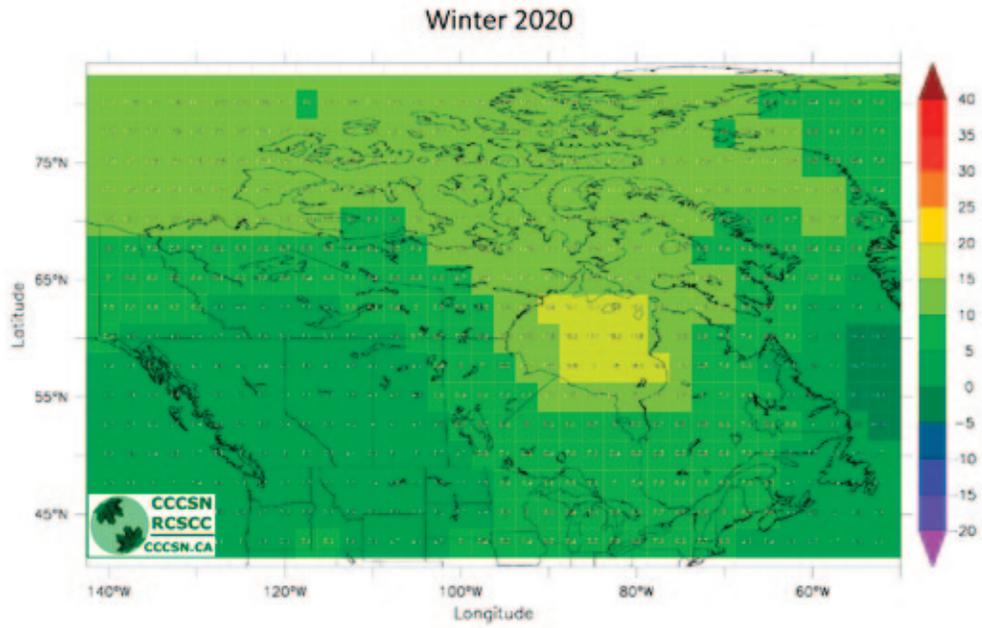




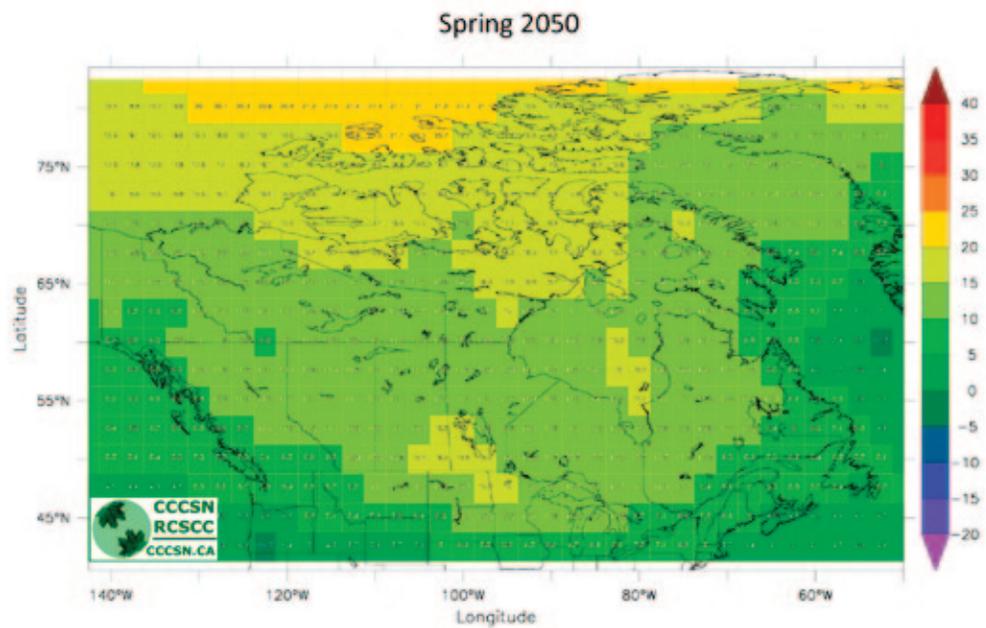
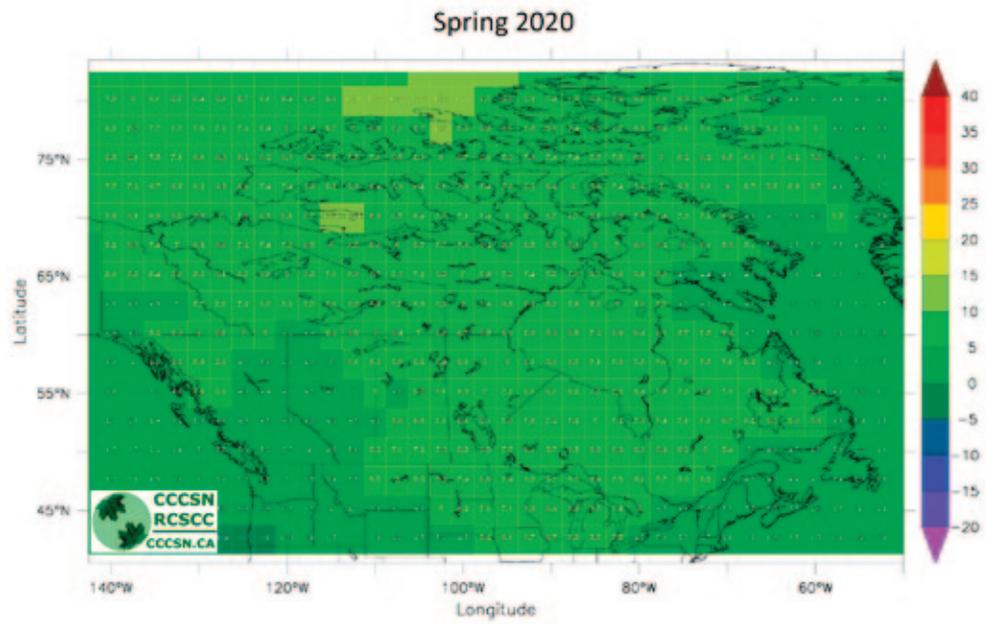
Change in Air Temperature (°C)

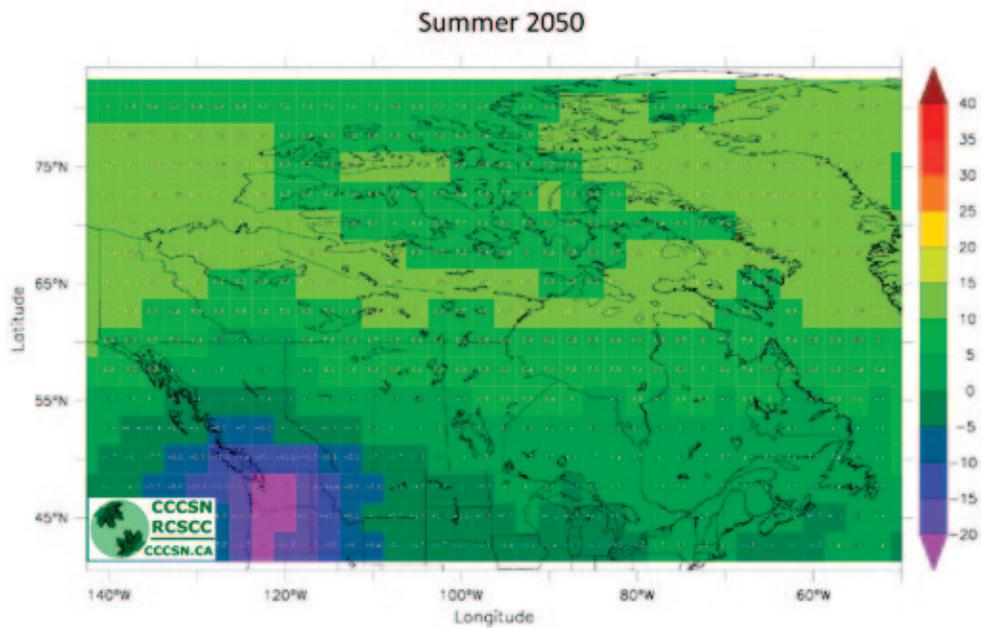
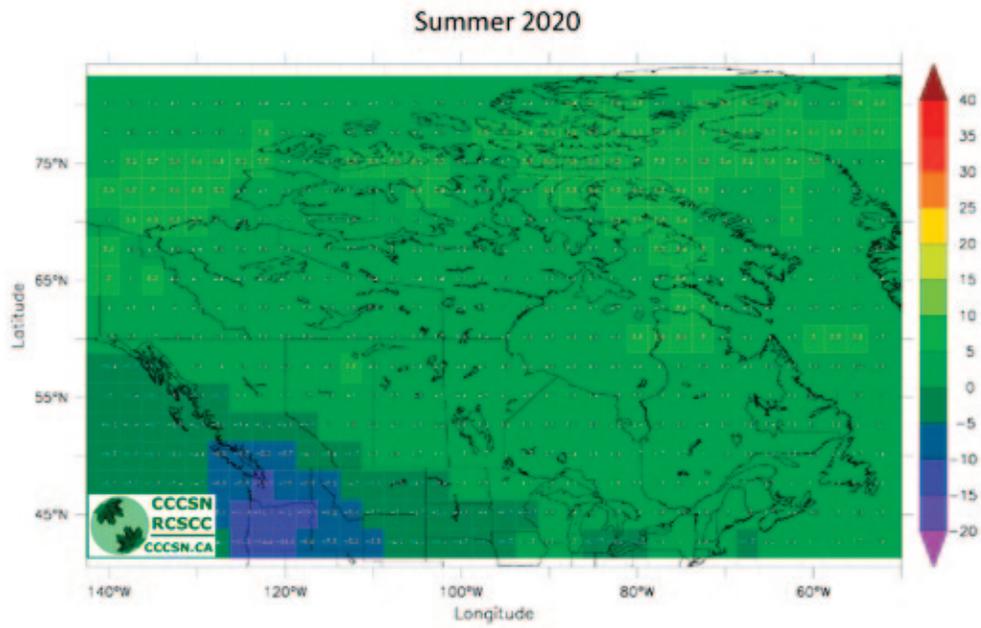


Precipitation Scenarios

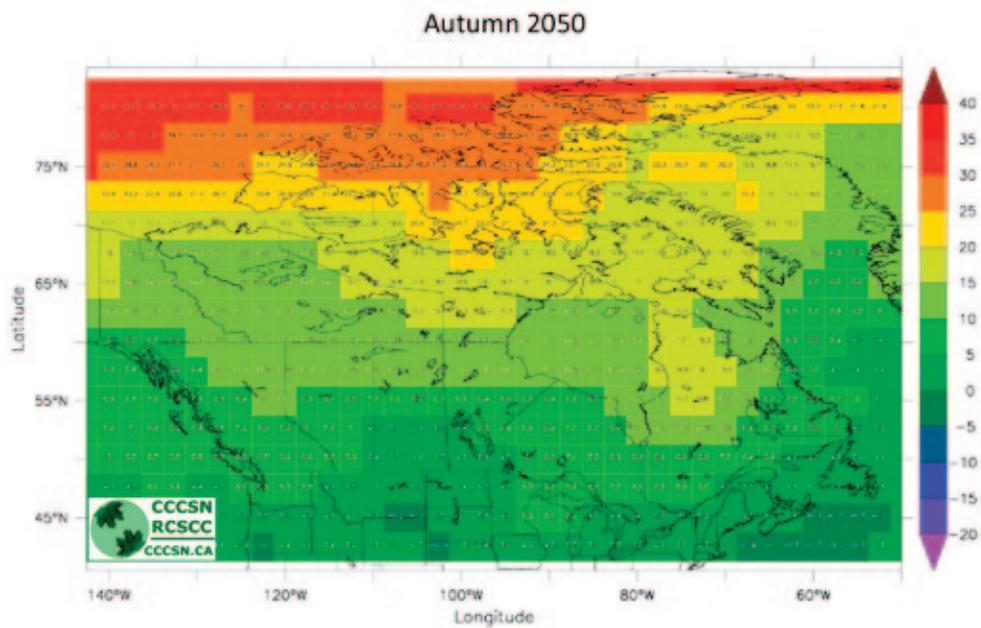
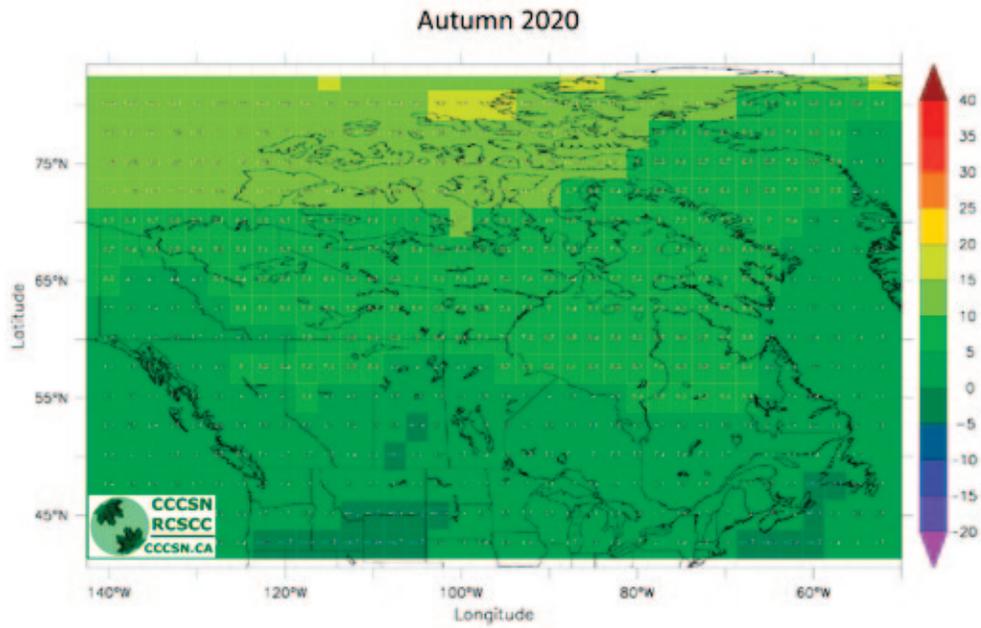


Change in Precipitation (%)





Change in Precipitation (%)



Change in Precipitation (%)



E. Major Climate Trends in Canada

Overview

The following analysis will identify some of the most significant climate trends demonstrated by the ensemble climate models used by the CCAP. Implications of these climate trends for Canadian communities and industry are also discussed. These implications are derived from the expert analysis included in the CCAP report and give a “high-level” introduction of how climate change will affect Canadians. Before elaborating on these temperature and precipitation trends, the table below will highlight expected changes to major Canadian cities by 2050.

Toronto, Montreal, Calgary and Winnipeg, for example, will see the number of heat and humidex advisories increase. This intensive heat places a great deal of strain on city infrastructure, utilities, and health and social services.

Higher summer and spring temperatures across southern regions will significantly increase the frequency and intensity of atmospheric conditions conducive to extreme weather. This warming will also delay cooling and the emergence of ice cover in the Great Lakes. As colder winter weather moves in, during the autumn months, the open and warm lakes will fuel heavy “lake effect” rain and snow events. As extreme weather becomes more frequent, infrastructure decision-making must begin to incorporate more resilient design and construction practices. Ice-free lakes will also generate more evapotranspiration, which could lower lake levels and freshwater availability.

Table A: Summary of Regional Climate Change Scenarios Expected by 2050 (1971-2000 baseline)

Major Regional Cities	Temperature Trend		Precipitation Trend	
	Summer	Winter	Summer	Winter
St. John’s	+1.5 to 2°C	+2 to 2.5°C	0 to +5%	+5 to 10%
Montreal	+2 to 2.5°C	+3.5 to 4°C	0 to +5%	+10 to 15%
Toronto	+2 to 2.5°C	+2.5 to 3°C	0 to +5%	+10 to 15%
Winnipeg	+2 to 2.5°C	+3.5 to 4°C	0 to +5%	+15 to 20%
Calgary	+2 to 2.5°C	+2.5 to 3°C	0 to +5%	+10 to 15%
Vancouver	+1.5 to 2°C	+2 to 2.5°C	-15 to -20%	+5 to 10%

Source: Observations from ensemble climate models developed by CCCSN 2010

Temperature

The models reveal that temperature is warming across the country, but there are important regional variations. For example, the Arctic sees significant warming, between 2 to 4°C by 2020 and 4.5 to 8°C by 2050, whereas the rest of the country will experience a more moderate, but still notable, 0.5 to 2°C increase by 2020 and a 2 to 4°C increase by 2050. As a consequence of these changes, cities that are already exposed to high summer temperatures will see their temperatures increase.

The agricultural industry is, perhaps, most exposed to changes in temperature. Most of Canada’s agricultural community will enjoy a longer season with less frost and freezing days. While this is certainly an important opportunity, seeds and production processes will have to adjust to higher heat thresholds. Warmer temperatures earlier in the year and subsequent cold snaps could also kill off insect populations critical to pollination of crops.



Northern regions will experience a significant 4.5 to 8°C rise in temperature across autumn and winter months. While opening water transportation routes and expanding resource extraction opportunities, unstable and melting permafrost also limit our ability to extract these resources, and threaten the livelihood of many northern and aboriginal communities. Ice roads – a more efficient and critical access route than water transport for supplying northern communities and industries with necessary supplies – are particularly vulnerable.

As with most climatic change, the most significant concern is “positive feedback,” where local climate warming further intensifies the already changing climate. For example, as the climate warms, permafrost could melt and release trapped pockets of greenhouse gas emissions. This release could trigger more intense warming.

Precipitation

Similar to the temperature changes observed by the ensemble models, notable precipitation changes also vary across Canada. The models suggest the Arctic region will see a significant 10 to 20 per cent precipitation increase by 2020 and a 10 to 40 per cent increase by 2050 throughout the winter. During the spring and summer, the Great Lakes will see a zero to five per cent decrease in precipitation, but could see an increase in winter precipitation. During the summer, southern British

Columbia and Alberta are expected to experience a significant five to 15 per cent decrease in precipitation by 2020 and a 10 to 25 per cent decrease by 2050.

Southern Ontario, Quebec and Prairie regions should expect dryer conditions during the summer to continue, which will increase water bans, strain drinking water reservoirs, threaten traditional sources of hydroelectricity and, potentially, lower water levels in the Great Lakes. This drying could, however, be somewhat mitigated by an increase in winter precipitation levels.

Winnipeg and its surrounding region are expected to experience a pronounced increase in winter precipitation. These changes increase the region’s sensitivity to spring flooding, which is already a significant environmental risk. Vancouver and its surrounding region, however, demonstrate a marked decrease in precipitation. This reduction in precipitation across the lower mainland and B.C. interior is the most significant outcome predicted by ensemble climate models. The region is already exposed to forest fire risk, which could substantially increase as precipitation levels drop.

The agricultural industry in the B.C. interior and southern Alberta will struggle to find new sources of freshwater as both winter and summer precipitation levels drop. Oil sands operations, which are dependent on a sufficient supply of freshwater, could also face water shortages.



F. Chapter Summaries





1. City Infrastructure

Darrel Danyluk

Chair, World Federation of Engineering Organizations Committee of Engineering and Environment

Introduction

Canadian cities, large and small, provide their citizens with physical infrastructures that are the foundation to a desirable quality of life. These systems deliver water supply, treatment, storage and distribution; storm water collection and disposal; waste water collection, treatment and disposal, and solid waste management systems; energy generation, supply and distribution; and modes of transport, including roads, rail, bridges, ports, airports and associated structures. In addition, these systems extend to the built environment, including schools, hospitals, public and private buildings. Physical infrastructure systems encompass the human component for management, operations and maintenance, and interlink with social and economic infrastructures. They create a human footprint and impact the natural environment. They were conceived, designed and built over decades, utilizing the codes and standards of the day, which included climate criteria.

Climate change effects have raised concerns over the magnitude, seriousness and implications of their impact on existing infrastructures. The United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) have concluded that it is necessary to assess the relevancy of climate criteria used in the past to design all infrastructures. Such assessments will determine infrastructure vulnerability to climate-induced failure. Since every element within each infrastructure system needs a vulnerability assessment, enormous

numbers of infrastructure components require evaluation.

Besides “hard” infrastructure components, such assessments encompass components supporting infrastructure operation and maintenance, including personnel, laws and regulations, emergency measures, policies and procedures. Where vulnerability exists, it is necessary to establish the severity of the failure, and whether the severity falls within acceptable limits. Where vulnerability falls outside acceptable tolerances, adaptation measures are required and must be supplied by urban municipalities. This requires that all infrastructures be assessed and addressed at the local community level, where adaptation to a changing climate is most effective. This planned approach will allow cities to direct resources to the most vulnerable infrastructures.

Although assessing climate vulnerability is a significant undertaking, there is a strong business case for taking such action. The cost of identifying and addressing infrastructure vulnerability to a future climate during construction is much cheaper than the cost of restoring infrastructure after it has been damaged. This business case represents a significant driver for policymakers to incorporate assessments of climate vulnerability into the design and construction of city infrastructure.

Climate Change Challenges for Cities

The three greatest challenges for adapting city infrastructure to a changing climate are:

1. Uncertainty about the nature and rate of local climate change, and which climate parameters pose the greatest risk to continued safe and cost-effective operation of existing and proposed infrastructure. This uncertainty extends to the design of new infrastructures, where current design values may not take into account future climate changes, particularly extreme climate events.



2. The unknown risks of climate change impacts to individual infrastructure components, and determining the adaptive capacity of these components.
3. The development of effective knowledge and capacity among municipal staff to maintain infrastructure at a sustainable level of service that is resilient to climate change impacts.

Adaptation Solutions

1. Estimate the Probability of Matching or Exceeding Climate Thresholds for the Remaining Service Life of the Infrastructure

In reference to city infrastructure and climate adaptation, the first step is to establish a current profile of relevant climate parameters, using historical recorded/measured data from the past 30 years, which is the normal period of record used by Environment Canada to establish climate norms and climate criteria from existing codes and standards. Because much of Canada's infrastructure is well into its service life, understanding present climate helps provide a current baseline to compare with the original design values, and a means to determine future criteria. Climate projections and climate models should be used to estimate the probability of matching or exceeding climate thresholds for the remaining service life of the infrastructure.

This approach is necessary because existing probability estimations about the service life of infrastructure do not factor in future climate scenarios. Estimates of the magnitude of maximum values above a certain accepted frequency would justify adaptive action. Without linking the estimation of future climate parameters to the service life cycle of the infrastructure, our communities could be exposed to great vulnerability. For existing infrastructure, it is the remaining service life; for new infrastructure, it is the design service life.

2. Conduct Climate Change Related Vulnerability/Risk Assessments to Define Risks

Once infrastructure is identified that is not built to withstand future climate scenarios, a vulnerability assessment represents the logical next step. Engineering vulnerability/risk assessment ensures climate change is effectively considered in the planning, engineering, design, operations and maintenance of civil infrastructures. It is a structured, formalized process based on the well-developed science of risk assessment from which engineers, planners, climatologists and risk managers can identify vulnerabilities (risks), set priorities, and recommend adaptive measures to address vulnerabilities. The Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol developed in Canada outlines a process to systematically review climate information and identify infrastructure vulnerability by considering the infrastructure's embedded adaptive capacity. Designed to be used on all types of infrastructures, it includes a methodology to estimate the severity of climate impacts on infrastructure components in order to identify high-risk components. This information can be used to make informed decisions on the implementation of adaptive measures.

Communities, and their municipal governments, should assess all infrastructures at two levels – initial screening to identify high-risk areas (e.g. flood-prone areas), followed by a more detailed climate risk assessment to identify and define the risks to critical infrastructures. For critical vulnerabilities, adaptation should be implemented in the short term. For “non-critical” vulnerabilities that are beyond acceptable risk levels, a longer-term plan for action should be developed that embeds climate adaptation measures into ongoing operations, maintenance, future capital projects and urban development.



3. Incorporate Adaptation into City Planning Policy

Addressing the changing climate with respect to infrastructure requires a multi-disciplinary approach that includes engineers, planners, managers, operators, climate scientists and other scientific professionals working towards a common goal. To this end, we recommend that cities embed the “no regrets” approach to climate change into city policy, with specific reference to adaptation. A “no regrets” approach to climate policy identifies actions that improve infrastructure resiliency and generates community benefits – whether anticipated climate change materializes, or not. Accordingly, the job descriptions and duties of all managers, engineers and utility personnel should integrate adaptation into defined responsibilities and reporting requirements.

To ensure municipal officials recognize the role of adaptation for their jobs, we recommend

creating an enabling environment where stakeholders work as a team and “learn by doing,” by undertaking case studies of infrastructure risk and adaptation planning. This will build local capacity and teamwork to address this challenge. There is a need to engage civil society, municipal politicians and municipal staff on the importance of considering the impacts of the changing climate. This requires a dedicated and focused awareness campaign geared to ensure acceptance of this issue and implementation of cost-effective measures that will enable infrastructure to withstand climate impacts. This awareness effort must be prolonged and repeated.

To summarize, where vulnerability falls outside acceptable tolerances, adaptation measures are required. Assess and address all infrastructures at the local community level, where adaptation to a changing climate is most effective. This planned approach allows cities to direct resources to the most vulnerable infrastructures.





2. Biodiversity

Steve Hounsell

Director, Board of the Canadian Business and Biodiversity Council; Chair, Board of Trustees, Trees Ontario

Introduction

Biodiversity refers to the variety of life on the Earth. It includes the diversity of ecosystems, the species found within those ecosystems, the genetic diversity found within species and the ecological and evolutionary processes that keep them functioning, yet ever evolving.

Biodiversity also embraces the “goods and services” that ecosystems provide, including clean water to drink, clean air to breathe, healthy food to eat and other renewable raw materials upon which our lives, society and economy depend. Ecosystem services are broadly classified into provisioning services, regulating services, supporting services, and social/cultural services. Climate regulation (natural processes that reduce the greenhouse gas emissions that cause climate change) is but one of several important regulating services that healthy ecosystems provide. Conversely, the loss or degradation of ecosystems further exacerbates the issue of climate change, demonstrating the close interactions between biodiversity and climate regulation. Biodiversity can also be conveniently described as the green infrastructure, or “natural capital” upon which our health and future prosperity as a society and nation depends.

On a global basis, the world’s ecosystems are reaching tipping points beyond which irreversible changes will occur with dire consequences for life on earth, including humans. Canada is not exempt from those global changes. The key drivers for biodiversity losses include habitat loss, invasive species, population growth, pollution,

overharvesting and unsustainable resource consumption, and now, climate change. This report focuses on the key threats and challenges that climate change poses to biodiversity, and offers recommended actions to reduce adverse effects and enhance the resilience of Canada’s ecosystems.

Climate Change Challenges for Biodiversity

1. Changing Bioclimatic Envelopes

Climate variables, including temperature, precipitation and humidity largely determine which species can survive and which cannot. Given the relative stability of climate over the past several millennia, it is not surprising that entire ecosystems and their associated species have evolved to cope with prevailing climatic conditions. Radical shifts in bioclimatic envelopes (i.e. geographical areas of similar climate regimes) will have significant potential impacts on species. Many species will not be able to migrate fast enough to keep pace with changing climates. There will be “winners” and “losers” under such selection pressures, forever changing the structure and composition of many of Canada’s ecosystems and the socio-economic services and functions they provide.

2. Altered Disturbance Regimes (e.g. insect, disease, pathogens, drought, fire, extreme storm events and floods)

Biotic communities have adapted over long periods of time to cope with naturally occurring disturbance regimes, such as fire, drought, flood and insect infestations. Many species and communities are dependent upon such disturbance regimes to complete their life cycles. Climate change is expected to alter the frequency, intensity, scale and geographic scope of disturbance regimes, which may be well beyond the tolerance limits of species and community types, again with cascading adverse socio-economic consequences.



3. Exotic Invasive Species and Eruptive Native Species

The rapid spread of exotic invasive species is considered the second greatest threat to biodiversity, after habitat loss. The removal of thermal barriers to range expansions through climate change is expected to cause the rapid spread of many invasive species. In the absence of natural predators and diseases, populations of invasive species (e.g. emerald ash borer, zebra mussel) can quickly expand to the detriment of native species. Likewise, the removal or alteration of thermal barriers can also cause massive eruptions (population explosions) of even native species into regions where they have been historically absent and where natural predators are absent. The devastating spread of the mountain pine beetle in Western Canada is but one example.

Adaptation Solutions

Canada's arctic ecosystems will be most severely affected by climate change with very limited climate change adaptation potential. Canada's extensive forest systems, the western prairie regions, and the human-dominated settled landscapes of southern Canada will all be adversely affected by climate change impacts. The following recommended actions, if robustly implemented, should serve to limit these effects and enhance the resiliency of those ecosystems.

1. Modelling to Prioritize Change and Vulnerability in Bioclimatic Envelopes

The development of models that measure change in bioclimatic envelopes from the historical baselines used to inform Canada's National Ecological Framework is a critical first step for developing adaptation solutions.³ Such model outputs will help to inform climate change adaptation priorities in terms of levels of

climate change threats, species and community vulnerabilities, and risk assessment/management strategies. This type of modelling has been done in Ontario – similar efforts should be broadly expanded to other ecoregions and watersheds across Canada.

Step one would be to get a Canada-wide handle on the extent of change to bioclimatic envelopes caused by climate change in comparison to Canada's National Ecological Framework. Step two would be to undertake vulnerability assessments of key species and community types to such climatic changes. This will serve to inform managers as to geographical priorities for adaptation on a national and provincial basis.

2. Increase Habitat Connectivity in Human-Dominated Settled Landscapes

Habitats found within the human-dominated landscapes of southern Canada can often be characterized as habitat islands in a sea of agriculture or built-up areas. Habitat isolation represents a significant ecological challenge as the climate changes. The survivorship of many species will be dependent upon their ability to disperse to more favourable habitats, as habitats change in response to changing climatic conditions. That implies the need to assist migration by "reconnecting the fragmented landscape" with habitat corridors, and/or increasing habitat density, thereby enabling species to move more effectively through otherwise inhospitable human-dominated landscapes. This is very consistent with the need to develop "natural heritage systems" that are both recognized and protected through land use planning.

Ontario's 50 Million Tree Program is but one example of a program designed to increase habitat connectivity that can and should be strategically replicated elsewhere across Canada. The typical

³ The National Ecological Framework identifies the existing boundaries between different bioclimatic envelopes across Canada.



costs of restoring woodlands in southern Ontario range between \$4,000 - \$5,000 per hectare. These costs need to be juxtaposed against the long-term benefits of sustained ecosystem services and enhanced climate resiliency.

3. Management of Disturbance Regimes

Enhanced modelling is needed at a regional scale to predict the magnitude of change in regional disturbance regimes, including extreme storm events. New or enhanced management approaches, and strengthened capacity to implement those approaches, are needed to predict, manage and limit the adverse effects of more frequent and severe disturbance regimes,

including fire, floods, disease, pathogen and insect outbreaks.

4. Exotic Invasive Species Management

International, national and provincial plans are under way to limit the adverse effects of exotic invasive species, with an emphasis on prevention. Climate change, and the removal or alteration of natural barriers to range expansion will exacerbate present management regimes. For this reason, climate modelling, vulnerability and risk assessments are necessary to update these management regimes in ways that limit future ecological and associated adverse socio-economic impacts of exotic species migration.





3. Freshwater Resources

Dr. David Schindler

Killam Memorial Chair and Professor of Ecology,
University of Alberta

Dr. Jim Bruce

Former Director of Canada Centre for Inland
Waters, and Former Assistant Deputy Minister of
Environmental Management, Environment Canada

Introduction

Water availability and water pollution are the two most significant challenges that Canada must deal with as the climate changes. These challenges are compounded by increasing demands for fresh water for growing population and industrial use. It has been conclusively shown that the global warming trend since 1970 has been driven by greater concentrations of greenhouse gases. The rate of increase of greenhouse gases in the past decade has been alarming, with 20 per cent more emissions per year than in the 1990s. This has resulted in a 30 per cent annual increase in these gases staying in the atmosphere, triggering faster climate changes during this century. With only a few European countries living up to their international obligations to reduce emissions, Asian economies booming, and large emitters per capita lagging in their reductions, greenhouse gas increases will drive even more rapid change in the rest of this century. Thus, the trends in our water systems observed, to date, in response to climate change, are a modest harbinger of things to come. These changes will continue or accelerate in coming decades.

Climate Change Challenges for Fresh Water

The following analysis will break down the climate change challenges for Canada's freshwater

resources by looking at the specific impacts to the Prairie watershed; river systems and the Great Lakes; and the threat of overland flooding.

1. Water Availability and Quality in Alberta and the Prairies

The Canadian "ground zero" for impending water problems under a changing climate is arguably southern Alberta. Alberta represents seven per cent of Canada's land mass, but generates only two per cent of the country's annual flow, largely because it lies in the rain shadow of the Rocky Mountains. At the same time, Alberta hosts critical headwaters for the economically vital Prairie watershed. For this reason, Alberta is an important case to understand the climate change impacts on Canada's freshwater supply.

Water problems are already acute in southern Alberta, where 40 per cent of the province's population (approximately 1.2 million people), 70 per cent of Canada's irrigated agriculture, and much of the province's industry all draw from the South Saskatchewan River system. The South Saskatchewan River represents only three per cent of the average annual flow from the province, and recent studies indicate that withdrawals already exceed the in-stream flow needs for maintaining ecosystem health by 87 per cent.

Climate warming will compound already scarce water supplies in southern Alberta in a number of ways. Much of the area has already warmed by about 2°C. This is almost triple the global average, but is as predicted for mid-continental areas. Ice-free seasons are longer, and evaporation and evapotranspiration are higher as a result. Warmer winters have allowed periodic mid-winter melts, and snow on the ground at the end of winter has declined. Glaciers in the headwaters of the Rocky Mountains are dwindling rapidly, and many of the smaller glaciers will disappear by mid-century.



Climate warming, and growth of human populations and industry will slowly push Alberta toward a water crisis, but recent studies show that another factor will probably make the crisis happen very suddenly. Paleoecological analyses indicate that the 20th century, which we usually think of as normal, was much wetter than the long-term average for the Prairies. In earlier centuries, prolonged droughts, some lasting for decades, were common in southern Alberta and Saskatchewan. Many were much more severe and prolonged than the “Dirty Thirties.” In short, the appearance of a decade-long drought to already increasingly stressed water supplies could quickly bring southern Alberta to the “tipping point” for freshwater supplies stressed by climate warming and increasing human demand.

Climate warming will also bring water stress to northern Alberta, despite the relative abundance of water in that area compared to the southern part of the province. As a result of reduced flows in the Peace and Athabasca Rivers, Lake Athabasca, the fourth largest lake entirely within Canada, has reached record low water levels. Low water on the lake and in the rivers has impeded navigation into the roadless Delta area, so that, in summer, all supplies must be flown into these communities at great cost. Even in winter, due to a shorter season when winter roads can be used for resupplying communities, a warming climate has caused increased costs.

Dwindling lake levels and river flows also affect the quality of remaining water. Many Alberta lakes have had lake levels decrease to where outflow no longer occurs. When this happens, lakes slowly increase in salinity because retention of incoming salts is 100 per cent. As salinity increases, biodiversity generally declines. Eventually, all fishes and most salinity intolerant invertebrates are extirpated, leaving only a handful of salt-tolerant species. Human industry will also intensify the impacts

of climate change on freshwater resources. For example, the rapidly growing oil sands industry (currently doubling every 10 years) makes enormous water demands on the lower Athabasca River and its tributaries, and on the groundwater in the area. After it has been used for processing bitumen, the water is too degraded to be returned to the river, so most of it is stored in huge tailings “ponds,” which have an area of 130 km². Airborne emissions from nearby bitumen Upgraders (a facility where bitumen is “upgraded” into synthetic crude oil) and increasing runoff of chemicals from cleared and mined areas also contribute to declining water quality. Monitoring of the river for industrial impacts has recently been found to be severely flawed in some cases, so that the impacts of more than 40 years of oil sands development on the Athabasca River and on the people downstream are still largely unknown. As climate change puts pressure on water availability and quality, human industry will only add to these impacts.

2. Water Availability and Quality in the Great Lakes and River Systems

The Great Lakes, which Canada shares with the United States, show renewed signs of pollution problems, this time, climate related. Average ice cover in winter has declined from 35 to 10 per cent on Lake Superior since 1973, and a similar trend is evident in all lakes in the system. This changes the energy and water balance, allowing more of the sun’s energy to enter lake waters in winter and warm the surface. With warmer surface waters, the barrier between the upper layers and the cold lower layers gets established earlier and for a longer period. This prevents oxygen from the atmosphere reaching the bottom waters. There, biological decay processes use up bottom water oxygen, causing anoxic or dead zones for fish and bottom fauna. Despite its recovery of health in the 1980s and 1990s under the bilateral Great Lakes Water Quality Agreement (1972), Lake Erie is again



experiencing bottom water anoxia and ecosystem stresses in late summer.

Another manifestation of climate change is more frequent heavy rains. The heavy rains wash more nutrients and toxics into the Great Lakes from both agricultural and urban areas. These particles, plus other contaminants on rural and urban surfaces, are washed into the lakes and their tributaries, in runoff from heavy rain events. All the lakes but Superior show increased algal growth and fouling of beaches in near-shore areas. This effect is made worse by the higher water temperatures, by the intensification of agriculture, and by the growth within cities.

Many river systems face similar challenges related to water quality and availability. For rivers that depend on glacier flows, such as the Columbia and Saskatchewan, these problems are particularly acute. As the climate warms, melt water from glaciers initially contribute more water to rivers, but the amount of melt reaches a tipping point when glaciers have shrunk to the point that their contributions to flow decline. On the other side of the Rocky Mountains, glacier contributions to the Saskatchewan River have been shown to have reached the declining phase. Evidence is not as clear on the Columbia River but there is a hint in the data that the decline is already beginning, with winter and spring temperatures up by 2.5°C since the 1950s and the retreat of glaciers.

3. Overland Flooding

An increase in the frequency of freshwater flooding is another important challenge linked with climate change. “Floods of the century” are becoming increasingly frequent throughout Canada, as moisture from the Gulf of Mexico and United States south travels further north in the winter and spring. Recent 2011 floods in the Red River and its tributaries, and in southern Quebec serve as important examples of the consequences of more moisture travelling further north. Also, there

is a greater frequency of hurricanes in autumn. Strengthened by warming Atlantic Ocean waters, hurricanes are able to travel further north from their southern North Atlantic origins to Atlantic Canada. Flood damage from hurricanes Igor (2010) in Newfoundland and Irene (2011) in Vermont serve as important reminders of this trend.

Adaptation Solutions

Continued failure to adequately address climate change in Canadian activities and development ensures that serious water crises will arise in coming decades. Adaptation measures, such as vigorously pursuing water conservation, restoring wetlands, recognizing water limitations before expanding industries and communities, and improving all aspects of water pollution control, can be immediately beneficial and minimize the adverse impacts of climate change identified above. These actions will enhance Canada’s adaptive capacity to the impacts of climate change on freshwater availability and quality.

1. Protect and Restore Wetlands and Natural Drainage Systems

The restoration of wetlands is an effective means to adapt to the impacts of climate change on water quality and quantity in all regions of Canada. In southern Canada, up to 70 percent of wetlands have been destroyed, usually in order to gain land for agriculture and urban development. Wetlands function as the “capacitors” of watersheds. During snowmelt and after heavy rainstorms, they prevent much of the water from running off immediately to nearby rivers, thus helping to prevent floods. As water stands in wetlands, nutrients and toxic chemicals are removed. The infiltrating water recharges groundwater in the area, buffering against the effect of future drought. Thus, a national initiative to identify, preserve and/or restore wetlands that are “key capacitors” within watersheds across Canada should be set as a priority.



2. Change the Design of Human Infrastructure to Conserve Water Quantity and Quality

Human infrastructure can be adapted in several ways to help conserve water quantity and quality. Improved land conservation measures in agricultural areas are increasingly needed to reduce erosion and diffuse pollution discharges to water bodies. Porous parking and roof systems must be installed in areas facing severe water shortages to mitigate water runoffs and flooding after rain events. These porous surfaces ensure water infiltrates and recharges groundwater. Even with conventional roofs, the addition of rain barrels or cisterns can reduce runoff considerably. Collected water can then be used for lawns, gardens and house plants, reducing demand for expensive tap water that has been treated to human consumption standards.

Other ways to reduce domestic water consumption can be found on many “green” websites. They include such recommendations as metering, mandatory low-flow shower heads and low-flush toilets, which are already becoming common in many water stressed areas. Inverse pricing schemes, where a basic water allocation per capita is inexpensive, but cost rises rapidly as use increases, are another way to encourage water conservation. In particular, pricing and other measures can be used to discourage permanent degradation of water, and to reward returning water in good condition to rivers and aquifers.

Flash flooding with more frequent intense rain events requires several adaptations. Floodplain land mapping and designations to limit development “in harm’s way,” need to be kept up to date, to reflect increasing heavy rains and greater upstream developments. To minimize the now frequent basement flooding, homeowners should install shut-off valves to prevent sewer backup. In very vulnerable areas, municipalities should consider subsidizing these actions.

3. Move Population and Water-Intensive Industry to Water, not Vice-Versa

With the threat of climate change, a growing population and a growing industrial base, it would be wise to take early measures to induce new population and industrial growth to occur in areas with plentiful water. In water-scarce areas, wise cities will choose to support industries that do not have large water demands. For example, rather than continue to put high demands on the small South Saskatchewan River, Alberta could take measures to direct new development to the Peace River watershed, where 70 per cent of the province’s water supply provides an ample water source. At the same time, Alberta will need to be watchful to not deprive the downstream jurisdiction, the Northwest Territories, of needed water. This could be done via tax incentives, water pricing, or other measures. Metering water and using an inverse pricing scheme, as suggested above, are also effective at encouraging conservation in areas where industrial use is high.

4. Integrate Human Water Uses at Watershed Scales

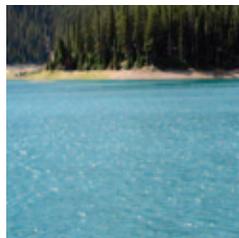
Typically, the water needs of humans are managed piecemeal, via the licensing of individual projects. Often this process results in wasteful uses of water, and ignores the needs of a healthy ecosystem. The integration of human water uses and demands into watershed management represents an important adaptation strategy to improve the efficiency of water use.

Recently, the Bow River Project Consortium in southern Alberta has shown that by integrating water use and needs at a watershed scale, substantial water savings are possible. The Bow River watershed has many demands made from a small river, including supplying about half of Alberta’s water for irrigation, supporting of a city of over one million people (Calgary) and generating



over 90 per cent of Alberta’s hydroelectric capacity. This project has identified a number of recommendations that substantially reduce stress on water availability, and ensure an adequate supply to affected populations. For example,

summer releases from upstream hydroelectric reservoirs have been demonstrated to improve flows and water quality downstream, without compromising generating capacity.





4. Aboriginal Communities

Chris Henderson

President of Lumos Energy, Chair of the Delphi Group, and National Coordinator, Aboriginal Clean Energy (ACE) Network

Dr. Judith Sayers

Chief, Hupacasath First Nation, British Columbia (1995-2009); Chief Negotiator for the Hupacasath First Nation

Introduction

Many First Nations, Métis and Inuit indigenous peoples draw their cultural identity, sustenance, traditional livelihoods and social cohesion from a sense of place; Aboriginal Peoples feel this connection with all of Canada. As the climate changes, so will this connection. In 2006, total aboriginal population was 1.2 million, comprised of First Nations (698,025), Métis (389,700) and Inuit (50,400). These groups are, collectively, growing at a faster rate than any other group across the country. Half the aboriginal population is under 25 years of age and one-third is younger than 14 years. As a consequence, Canada's aboriginal populations will boom in the first half of the 21st century. This population growth and deep connection with the land mean that relative to the present, aboriginal communities will be increasingly impacted by climate change in the years to come.

More than half of Aboriginal Peoples live in one of over 1,900 aboriginal communities spread across Canada. Some are hamlets of a few dozen people, while others are bustling villages of a few thousand of residents. In the last two decades, investment in these communities, and related transportation and energy infrastructure, has exploded. The total value of capital stock directly related to aboriginal communities – including housing, community facilities, airports, ports, roads, bridges and power

capacity – has now reached \$450 to \$700 billion

The vulnerability of Aboriginal Peoples to climate change is defined by three major factors: geography, connectedness to land, and poverty and resource limitations. Communities are often small and, almost always, located close to water in low-lying zones. Aboriginal Peoples are closely tied to the land and its resources. Their way of life is dependent on the land, habitat, wildlife and sea resources, much of which will now be impacted by climate change. The majority of Aboriginal Peoples are among Canada's poor and their overall wealth is limited. As such, aboriginal capacity to respond to climatic impacts is very constrained.

Climate Change Challenges for Aboriginal Communities

Climate change is already impacting aboriginal communities, and the phenomenon will escalate into the future. The physical effects of climate change include: drastic fluctuations to seasonal weather patterns, rising sea level, melting permafrost, ocean and lake storm surges, more frequent and longer duration floods, wildfires and severe weather events. The cumulative impact of these forces creates three major challenges for aboriginal communities across Canada.

1. Dramatic or Continuous Degradation of Community Infrastructure

Climate change will lead to damage and destruction of residences, community facilities, infrastructure and basic services.

2. Diminution of Traditional Livelihoods

Climate change impacts on ecological and wildlife systems will jeopardize harvesting, hunting, fishing, trapping and food security which in turn, will affect the health of Aboriginal Peoples.



3. Catastrophic Disruption to Community Access & Energy Capacity

Climate change will disrupt transportation infrastructure, harbours, airports, roads (including ice roads), bridges and communications systems. These effects will constrain and jeopardize the integrity of community energy systems. A high proportion of these costs are not insured by private commercial and resident property insurance. For this reason, climate change represents a huge potential cost for the Canadian government. Adaptive strategies for aboriginal communities that protect people and property can play a significant role in offsetting these costs.

Adaptation Solutions

The costs of the above realities are already materializing and rising rapidly, which creates a strong imperative to act. To this end, three broad climate change adaptation strategies, described below, are proposed, to be supported through collaborative partnerships between aboriginal communities, governments, NGOs and private industry.

1. Comprehensive Community Capital Planning for Climate Adaptation

Community Redesign and Relocation. Aboriginal communities have not been designed to meet climate change threats. Critical infrastructure within these communities will need to be made more resilient to the changing climate if it is to survive its full life cycle. In extreme situations, this may require community relocation with the consent of the aboriginal groups, including their choice of alternative locations. For example, continued spring flood events could require the redesign and potential relocation of vulnerable facilities in the communities of Kashechewan and Attawapiskat (Ontario), Tuktoyatuk (Northwest Territories) and Peguis First Nation (Manitoba). To facilitate community redesign and relocation,

the development of an aboriginal climate infrastructure assessment is a necessary first step. This assessment can help evaluate potential infrastructure weakness and inform decision-making about redesigns and potential relocations. Aboriginal groups can invoke the assessment voluntarily to explore redesign or relocation options.

Adaptation Community Infrastructure Program. Aboriginal Affairs and Northern Development Canada (AANDC) must integrate climate change adaptation design features into a community infrastructure program. If aboriginal groups choose to implement a climate infrastructure assessment (as suggested above), the AANDC must be ready with new building practices and codes to address potential recommendations that emerge. This program must help facilitate the development of new standards for buildings and facilities to anticipate climate risks, such as melting permafrost, storm surges, and extreme weather.

2. Adaptation Guided by Traditional Knowledge

Traditional Knowledge. Aboriginal Peoples must document climate change in their territories and then find solutions to adapt to the changes. Many changes are based on lived experiences and not written down or fully defined. Documentation and cataloguing of these impacts are critical, if solutions are to be found.

Adaptive Management. Aboriginal communities must determine for themselves whether they see common elements and/or opportunities between adaptive management and their own culturally specific knowledge systems. If so, responsible authorities can offer adaptive management as a viable framework within which indigenous and western science knowledge holders can learn together. Governments must put in place effective and immediate mitigation and adaptation policies and programs, only with the consent of aboriginal groups. Adaptive management should include a



comprehensive sustainability plan that is integrated into a federal and/or provincial plan. This necessarily includes efforts to reduce greenhouse gases.

Food Security. There is a need to ensure current and long-term planning for food. Food security is important for all human beings but in particular for indigenous peoples, who are most impacted by climate change. Aboriginal communities have long relied on the fish, sea resources, wildlife, birds, and the gathering of foodstuffs for their main diet. Measures must be taken by governments, either through legislation or policy, to protect species/foodstuffs used by aboriginal communities threatened by climate change, and to plan for other sources of food.

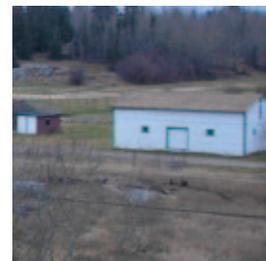
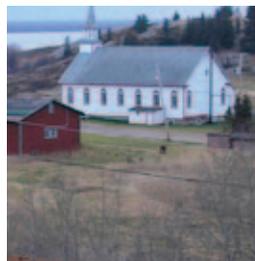
3. Integrate Resiliency into Community Access & Energy Capacity

Emergency Preparedness. The federal government – through its responsibility under s. 91(24) of the Constitution Act, 1867, the Indian Act, treaties and other binding agreements – has an obligation to meet the human needs of communities, needs that may be compromised during times of climate emergency. It is proposed that a climate adaptation emergency measures protocol be developed which would “kick-in” when communities need help from climate impacts. This protocol should establish a climatic emergency measures fund within Aboriginal Affairs and

Northern Development Canada as an internal property insurance mechanism, and a set of guidelines to inform when the protocol should be invoked.

Transport Infrastructure Assessment & Renewal. From the perspective of transportation, climate change will “cut the physical link” between some aboriginal communities and the rest of Canada. Not only will this impact indigenous peoples, but it will also jeopardize Canadian sovereignty and access to natural resources. It is, therefore, proposed that an aboriginal transportation infrastructure renewal mechanism be established to address these key risks.

Renewable Energy Development for Off and On-Grid Communities. It is critical to catalyze all commercially viable sources of renewable energy on aboriginal lands. It is particularly important to try and convert diesel-reliant communities (which have high greenhouse gas emissions) to renewable sources of power. A related action would develop alternatives to energy production that burns black carbon and emits soot by inefficient diesel engines. Research from the Arctic Athabaskan Council, for example, has suggested that soot emissions must be curbed immediately to limit the impacts of climate change. They are making efforts nationally and internationally to have this implemented. Governments should embrace this solution as a viable option.





5. Agriculture

Dr. Barry Smit

Professor and Canada Research Chair in Global Environmental Change, University of Guelph

Introduction

Agriculture in Canada is a significant economic sector, an important component of society, a substantial contributor to trade, and a provider of food, a basic human need. Agriculture is dependent on climate and weather and, hence, it is directly sensitive to climate change.

A changing climate brings both opportunities and challenges to Canadian agriculture, depending on location, production type and individual circumstances.

Globally, agriculture is one of the most widely analyzed areas for climate change impacts, with the focus mostly on yield responses to future climate norms. Work on adaptation has largely been by assumptions about crop shifts over broad spatial scales and long-term time horizons.

Adaptation in agriculture involves decisions by producers, suppliers, processors, marketers, governments at all levels, and researchers.

Climate Change Challenges for Agriculture

1. Denial of Climate Change

A large portion of the agriculture community (producers, businesses, etc.) does not accept the reality of climate change, and/or does not accept that the projections from climate change scenarios are reliable or relevant to agricultural operations. Obviously, this acts as a serious constraint on adaptation to climate change.

2. The Influence of Other Conditions

Decision-makers in agriculture continually adapt to a suite of changing conditions relating to costs, prices, markets, technologies, policies and personal circumstances. In this context, climate change is considered almost inconsequential when making tactical and strategic decisions about enterprises, crops, livestock, resource use, finances, marketing, and so forth.

3. Multiple Decision-Makers

Decisions in agriculture are taken by a very large number of producers (and other businesses and agencies of government), each with its own circumstances, exposures, sensitivities, capacities and propensities. As a result, adaptation needs and options vary considerably, even within a local area, greatly constraining the applicability or validity of so-called best adaptation practices.

Adaptation Solutions

1. Agriculture-Relevant Climate Change Information

In an effort to assist the agricultural community in its understanding of climate change and its potential impact on the sector, it is necessary to identify attributes of climate change that are relevant to agricultural operations and decisions, illustrate the significance of these attributes in terms used by agriculturalists, and then indicate expected changes (or simply direction of changes) in these climate-weather attributes. These are likely to relate to the frequency, magnitude and timing of extremes in droughts, storms, frosts, and other weather events, over five to 15 years. The relationship between longer term conditions (climate) to shorter term conditions (weather) needs to be clarified.



2. Incorporate Climate Change in Planning Decisions

An effort must be made to explore adaptation options relating to climate in the context of the decisions producers and others take in light of a range of other forces (e.g. seed costs, prices, markets, technologies, policies and personal circumstances). Adapting to climate, then, becomes not an additional or competitive task, but rather a factor incorporated (“mainstreamed”) into the regular tactical and strategic decision-making processes.

3. Adaptation Specific to Roles and Situations

It is necessary to recognize that producers, businesses, governments and researchers have

distinct roles to play in adaptation. Among producers, the needs and opportunities for incorporating climate change into decisions will be specific to location, type of enterprise and personal circumstances.

Next steps to elevate the profile of climate adaptation within the agricultural community are to: (1) engage representatives from producers, businesses, government agencies and the research community to develop agriculture-relevant climate change information and dissemination programs, and (2) identify areas within existing decision-making processes to include consideration of climate change risks and opportunities. If successful, climate change adaptation will become a part of ongoing risk management and strategic planning in the sector.





6. Insurance: Adapting Building Codes for Climate Change

Grant Kelly

Director of Climate Change Adaptation Projects,
Institute for Catastrophic Loss Reduction (ICLR)

Paul Kovacs

Executive Director, ICLR

Dr. Jason Thistlethwaite

Research Associate, ICLR

Introduction

Political leadership is required to ensure that the Canadian National Building Code Commission places (NBCC) greater focus on improving building durability and resilience to extreme weather. A new home built in 2011 is expected to provide a family a safe haven from natural disasters for the next 50 years. Given that an estimated nine to 12 million Canadians are expected to live in new homes by 2050 – homes that have yet to be built – it is critical that these homes can provide such a safe haven.

Climate change creates a challenge for new homebuilders and owners as it has been linked with an increase in the frequency and intensity of extreme weather. For this reason, it is important that information about best design and construction practices is made available to protect homes from such weather throughout their 50-year life cycle. Fortunately, considerable research exists about home design and construction practices that can enhance the resilience of new homes to damage from severe weather. Despite this research, homes in Canada still experience more

than \$3.5 billion a year in damage due to severe weather. This damage is likely to increase as the climate changes across Canada.

In the last few decades, the damage generated by natural disasters, specifically those linked with extreme weather, has been increasing. This trend is anticipated to continue over the long-term, as more homes are built in areas exposed to these weather perils. Damage from several 2011 extreme weather events, including the flooding in Manitoba and Quebec, wildfires in Slave Lake, Alberta, and the tornado in Goderich, Ontario, serve as important reminders of this trend.

The National Building Code (NBC) represents an important policy lever in addressing the challenges homeowners face in adapting to climate change. Thankfully, the task of strengthening the building code does not require an expansion of the NBC into new areas. Rather, it is possible to strengthen the code to withstand severe weather within the current code documents.

Climate Change Challenges for the National Building Code

1. Adapting the Code for Climate Risks and Extreme Weather

The existing building code process is informed based on historical baselines for extreme weather. Environment Canada and the NBCC have agreed that these factors should be updated to reflect potential increases in extreme weather. Indeed, they conclude that “almost all of today’s infrastructure has been designed using climatic design values derived from historical climate data, and any changes in future climates will require modifications to how structures are engineered, maintained and operated”.⁴ In order to do this, the building code process must address the challenges

⁴ Environment Canada: Building Codes & Standards. 2010. Climate Information to Inform New Codes and Standards. Online: <http://www.ec.gc.ca/sc-cs/default.asp?lang=En&n=20CD1ADB-1>



involved with integrating future projections for extreme weather into design practices that ensure a home is resilient.

2. Cost-effective Adaptation Through the Building Code

The integration of design practices that protect a home from extreme weather and climate risks represents a significant challenge. The generation of stakeholder support for the integration of new design practices into the building code represents a critical obstacle to resolving this challenge. Stakeholders in the building code process include homebuilders, manufacturers of various building materials, engineers, and academics. For many of these stakeholders, a home becomes much less interesting once someone lives in it. Indeed, the majority of stakeholders tend to be preoccupied on more short-term economic concerns and cost effectiveness. The housing market is extremely competitive, so it is natural that regulators and builders are hesitant to support code changes that increase the costs of construction. The trade-off between code reform that incorporates future weather conditions and cost effectiveness creates a significant challenge for the NBC.

How can the building code process adapt to climate change and protect homeowners from existing and future climate risk given these challenges? The section below develops some adaptation solutions to these challenges.

Adaptation Solutions

1. Incorporate Expectations Regarding Future Climate into the Building Code Process

The federal and provincial governments should support work to incorporate both historic experience with extreme weather and expectations about the future climate into the building code decision-making process. Both governments can

help facilitate this process in two ways. First, they should support research on new construction practices that strengthen the resiliency of new homes to extreme weather linked with future climates. Second, they should formally endorse building durability and resiliency as objectives for the national building code. This endorsement would help mobilize the support necessary to integrate adaptation into the building code. More broadly, political leadership that supports adaptation as a priority for the building code would make Canada an international model for effective adaptation policy.

2. The Insurance and Building Industry Must Identify High-Priority Risks Linked with Future Extreme Weather

To ensure adaptation through the building code is cost effective, the building code process must prioritize risks linked with anticipated future extreme weather. This recommendation for high-priority risks depends on generating accurate data about the frequency and severity of existing extreme weather trends, and how climate change is likely to influence these trends. The insurance industry and federal government, specifically Environment Canada and Infrastructure Canada, can play a pivotal role in addressing this data gap. By linking the frequency and intensity of certain weather trends to damage costs that governments, insurers and homeowners must recoup, insurers and governments can cooperate in playing a vital role to identify high-priority risks that fulfill a cost-benefit analysis. This approach ensures that, while the code takes steps to incorporate resiliency to climate change, this process is informed by scientific research and cost-benefit analysis. To initiate a process that updates the building code to reflect existing and future climate risks, a three-part strategy may be used:

- Promote a discourse focused on climate adaptation with a wide range of stakeholders,



including insurers, homebuilders, building code officials and building researchers. In particular, it is important to develop a relationship between the building community and the insurance industry. A consultation between these stakeholders can identify core concerns about incorporating extreme weather and climate risks into building design.

- Once consensus is established, insurers, builders and scientific researchers can jointly support design practices that promote climate adaptation.
- The federal government can focus attention and resources on this effort to promote adaptation by adopting building durability and disaster resiliency as a theme for upcoming building code renewals.





7. Insurance: Tools to Promote Adaptation by Existing Homeowners

Dan Sandink

Manager, Resilient Communities & Research,
Institute for Catastrophic Loss Reduction (ICLR)

Glenn McGillivray

Managing Director, ICLR

Introduction

The 2006 Statistics Canada census reported 12.5 million residences in Canada, 8.6 million of them built before 1986. Since knowledge on disaster resilience in homes has progressed substantially over the past few decades and changes to building codes that enhance the resilience of new structures do not affect those already built, there is a need to incorporate new knowledge into existing structures and communities.

Climate Change Challenges for Existing Homeowners

Homeowner risk reduction behaviour is inhibited by two key challenges:

- 1. The cost of retrofitting structures**
- 2. A lack of public knowledge of risk-reduction options**

Because extreme climatic events are, by definition, rare events, homeowners often have difficulty appreciating the costs and benefits of retrofitting homes to reduce risk. For these reasons, the integration of adaptation into existing homes represents a significant challenge. This paper outlines three ways to encourage mitigation

against climate-related risks for existing buildings, including: (1) apply insurance tools and government tax-based incentives to encourage risk-reducing behaviour by policy holders, (2) develop and disseminate accurate risk-reduction information, and (3) develop government programs to support mitigation planning in Canada.

Adaptation Solutions

1. Insurance and Government Incentives for Risk Reduction

There are several ways in which insurers can encourage risk-reducing behaviour by homeowners, including: adjusting the price charged for insurance coverage and deductibles, caps on the amount that policy holders will be paid for damage, excluding certain types of damages from insurance coverage, and cancelling insurance policies. Insurers should offer homeowners premium discounts and apply other signals for a wide range of adaptation practices, including the use of superior building products and the use of “better than building code” construction specifications for new builds and major renovations.

Governments can play a significant role in encouraging risk reduction through their ability to set building construction rules, regulations, guidelines and laws. Building codes offer an important lever for integrating adaptation into new homes. Similar to insurance tools, taxation also provides an opportunity to promote risk-reducing behaviour. To date, these options have not been put to use within Canada to encourage adaptation to climate change. However, it is clear that the application of these approaches to reduce climate change risk would be relatively simple in many cases. For example, insurers already use price signals, including limiting how much a policy holder is paid for damages and adjusting premium prices, to encourage risk-reducing behaviour. Thus, better education on how insurance firms price risk



exposure and expansion of these practices to other hazards should not require significant innovation.

2. Adapt the FireSmart Model for Urban Flood and Wind

The communication of knowledge on the most effective strategies for reducing the risk of extreme weather on existing homes remains a challenge for homeowners. The FireSmart program offers an important model to address this challenge. Through the FireSmart program created by Alberta's Partners in Protection, tools aimed at both property and community level wildfire mitigation have been developed and are widely regarded and adopted throughout Canada. Materials developed through the program guide include homeowner risk assessments, vegetation management procedures, and other initiatives homeowners can take on their property to reduce wildfire risk.

Community-level materials guide municipal decision-makers through implementing mitigation measures, including: vegetation management, emergency management, training, public education and land use planning. The FireSmart approach could similarly be used to develop tools to address wind and urban flooding, which present considerable risks to the insurance industry, as well as to Canadian property owners and communities. As climate change increases the frequency and intensity of wind and urban flood events, insurers, governments and property owners will need access to reliable and standardized information on mitigation measures policy holders and communities can adopt to reduce urban flood and wind risk.

A FireSmart-type program for urban flood and wind would allow professionals from across the country to discuss, analyze and identify the most appropriate means of incorporating property-level mitigation options into buildings. The development of risk-reduction materials would require the involvement of a range of government agencies,

including national and provincial environmental and emergency management agencies, as well as researchers and insurance professionals from across Canada. Insurers can provide information on incentives for mitigation and other insurance issues and can play a vital role in distributing information to policy holders.

3. Disaster Mitigation Assistance in Canada

The implementation of disaster mitigation options, including land use planning, building relocation, building retrofits and education – in advance of disaster events – is the most important and effective means of reducing disaster risk. There is strong evidence that supports the positive impacts of mitigation measures. For example, the U.S. Multi-Hazard Mitigation Council has identified that an investment of \$1 in mitigation measures saves \$4 in disaster costs.

Despite the importance of disaster mitigation, emergency management at the national level in Canada has historically focused on the reactive aspects of disaster management, including response and recovery, rather than proactive disaster mitigation and prevention. However, in 2011, there was discussion by the Prime Minister and the Council of the Federation about implementing a federal disaster-mitigation program, following severe flooding in several provinces. This discussion may provide an opportunity to increase the role of risk reduction in emergency management in Canada. Three ways mitigation planning can be improved include: development of a program for pre-disaster mitigation, better incorporation of post-disaster mitigation in government disaster-relief programs, and post-disaster mitigation programs that do not rely on the existence of government disaster-relief payouts.

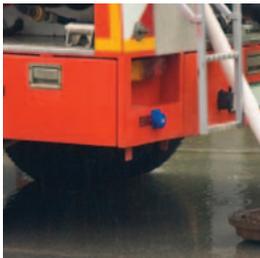
The implementation of disaster-mitigation assistance programs will require a collaborative effort across a range of stakeholders. The



involvement of several national government agencies, including Public Safety Canada, Environment Canada, Natural Resources Canada, and the National Research Council, among others, will be important. Provincial agencies responsible for emergency management should also be involved in the development of national mitigation programs. Municipalities often have the most significant contact with residents, are most involved in aspects of emergency management and, therefore, should be involved in the development of mitigation programs. National professional and industry associations may also prove to be valuable stakeholders in program development, including the Federation of Canadian Municipalities, the

Insurance Bureau of Canada, the Canadian Institute of Planners, and Engineers Canada.

To sum up, there is a strong need to incorporate risk-reduction measures into existing homes and communities, and to promote risk-reducing behaviour. Homeowner risk-reduction behaviour is inhibited by the cost of retrofitting older structures and by the lack of public knowledge of risk-reduction options. Thus, assistance for risk reduction for existing homes is needed. This chapter outlines how government and insurance incentives, improved public education, and funding for disaster mitigation can encourage climate risk reduction for existing buildings





8. Insurance: Aligning the Price of Insurance With the Risk of Damage

Paul Kovacs

Executive Director, Institute for Catastrophic Loss Reduction (ICLR)

Introduction

There has been an alarming increase in severe weather damage over the past three or four decades in Canada. This increase is largely due to an aging infrastructure, population growth and other socio-economic factors. Climate change will likely further increase the risk of damage over the next three to four decades. Insurance has been the primary mechanism used by homeowners and businesses across Canada to mitigate the risk and facilitate recovery from this type of damage. The price of insurance (the price of the risk of damage) plays an important role in maintaining this mechanism as the climate changes.

Insurance pricing is based primarily on the estimation of the risk transferred from the property owner to the insurance company. Insurers use available information to estimate the risk of damage and establish prices for each policyholder. Each policyholder then pays a premium (the price of transferring the risk to an insurer) which creates a “pool” or “reserve” of capital managed by the insurer. When an extreme event occurs, it is the insurer who is responsible for paying out claims to help policyholders recover from potential damage.

An accurate price for insurance serves two critical purposes in mitigating the risk of extreme weather and climate change. First, the price of insurance provides homeowners and businesses with an ongoing measure of their risk of damage. High

prices, or price increases, mean that a property is at a greater risk of damage. These prices should encourage consumers to take actions that reduce their exposure to risk, which will be rewarded by a lower price for insurance coverage. If the insurance price is too low, consumers may be unaware they are exposed to significant risk. If the price is too high, consumers may spend money on unnecessary actions to reduce risk exposure. Second, the price of risk needs to be accurate, so that insurance companies can compensate consumers in the event their property is damaged through extreme weather. If the price of insurance is too low, insurers will not have collected enough capital to compensate all of their clients. In these circumstances, not only is an insurer unable to help their clients recover, but in extreme circumstances, the insurer faces the risk of insolvency. In other words, insurance coverage is no longer available.

Climate Change Challenges for Insurance Pricing

Change in the risk of damage from severe weather linked with climate change challenges the ability of an insurer to assign the correct price to insurance. As the climate changes, so too will the risk of extreme weather damage. Insurers need to understand how climate change will influence extreme weather, to make sure their price is correct. The section below describes policy actions that can help insurers understand how climate change will impact insurance pricing.

Adaptation Solutions

Two key policy options are available to ensure that insurance will continue to help homeowners and businesses recover from severe weather damage, and that insurance prices will encourage Canadians to invest in adaptation to climate change.



1. Educate on the Role of Insurance

Insurance companies across Canada should establish a joint strategy to champion actions by homeowners and businesses to adapt to severe weather. One dimension of the strategy should seek to inform Canadians about the role of insurance to support management of the risk of damage from a broad range of perils, including severe weather. This information will help Canadians understand how to reduce their exposure to extreme-weather risks, and ensure insurance remains affordable as the climate changes.

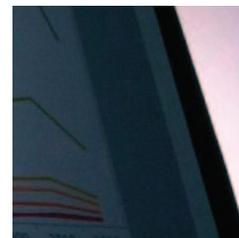
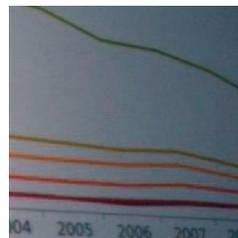
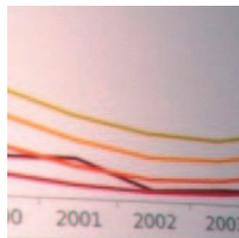
A public education program should:

- inform homeowners how certain adaptation measures, if implemented, can lower insurance prices, but also how inaction could lead to higher rates, or even the cancellation of certain coverage;
- explain to homeowners and businesses how insurance can be used to cover against a range of hazards, including the risk of damage from climate extremes;
- identify insurance prices as a measure of the risk of damage to homes and businesses from perils that include water, wind and other weather hazards.

2. Develop Better Data to Estimate the Risk of Severe Weather Damage

Insurance companies have demonstrated their skills in anticipating damage claims due to significant Canadian perils like vehicle damage, urban fires and property theft, but only recently has the industry begun to rigorously assess the risk of severe weather damage. Only over the past decade have claims payments for severe weather damage become a significant cost for insurance companies, a cost large enough to justify current efforts to assess the risk of future damage claims.

Governments can serve Canadians by working with insurance companies to ensure appropriate information is available to better anticipate the risk of severe weather damage to homes and businesses. Without this information, insurers face information asymmetries when trying to accurately price the risk associated with climate change. This includes detailed, local data about historic severe weather events, including intense rainfall, severe wind (including hurricanes and tornadoes), winter storms, flooding, and wildland fires. Anticipating the risk of damage also requires reliable data regarding the state of public infrastructure and socio-economic information. Environment Canada, Natural Resources Canada, Infrastructure Canada, Statistic Canada and others have the potential to improve the information available.



G. Full Chapters





1. City Infrastructure

Darrel Danyluk

Chair, World Federation of Engineering Organizations Committee on Engineering and Environment

Introduction

“Because of climate change, Canada’s cities and the country as a whole can anticipate increases in the severity of weather events that will test capacities to maintain and sustain infrastructure.”

Climate change effects have raised concerns over the magnitude, seriousness and implications of their impact on existing infrastructures. The United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) have concluded that it is necessary to assess the relevancy of climate criteria used in the past to design all infrastructures. Such assessment will determine infrastructure vulnerability to climate-induced failure. Since every element within each infrastructure system needs a vulnerability assessment, enormous numbers of infrastructure components require evaluation.

Canada, specifically its cities, can expect increases in severe weather that adversely impact the delivery and sustainability of infrastructure services. All infrastructures were designed and built to the codes and standards existing when they were constructed. These codes and standards are changing to address climate change, so providers of public and private infrastructure face challenges in the delivery of new and retrofitted infrastructure, and in coping with aging and neglected infrastructure.

Life expectancies of public infrastructure are based on present and future climate conditions. Climate change, manifested through changes in

atmospheric and oceanic conditions, will impose increased and new risks on many natural and human systems – notably through changes in climate variability, and in the frequency and magnitude of extreme climatic events. Significantly, not all changes will be detrimental. Nevertheless, infrastructure vulnerabilities must be identified, prioritized, and adaptive actions implemented.

Fortunately, knowledge on climate variables and climate change is improving. Risk-management tools and vulnerability-assessment protocols to identify, prioritize and implement adaptation and mitigation actions are now available. For example, Engineers Canada has developed the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol as a tool that can proactively screen potential infrastructure vulnerabilities. Existing operating and capital budgets already fund some of this work. An approach that embeds PIEVC into all new capital works and infrastructure rehabilitation and upgrades will, over time, reduce vulnerabilities and climate-proof the systems.

It is critical that adaption employing climate vulnerability assessments be applied, using a “no-regrets” framework. A “no regrets” approach to climate policy identifies actions that improve infrastructure resiliency and generate community benefits, whether anticipated climate change materializes or not. This means climate change assessments must be embedded into all new capital works and infrastructure rehabilitation and upgrades. Over time, these actions will reduce vulnerabilities and improve the resiliency of infrastructure to extreme weather and climate risks.

Climate Change Challenges for City Infrastructure

Physical infrastructure in which Canadians have made huge investments, is critical to our quality of life. Water, food, shelter, heat, light,



mobility, communications, access to services, and waste removal depend on the resiliency of this infrastructure. Recent climate-induced failures demonstrate negative impacts on such critical infrastructure. Examples include the Quebec ice storms, Manitoba flooding and the power failures in northeastern Canada and United States. With two-thirds of Canada’s population concentrated in 20 urban areas, the functionality and resilience of infrastructure to a changing climate fundamentally will determine the sustainability of the communities where most Canadians live.

This paper seeks to identify the initial actions needed for the Canadian urban municipalities to adapt to the impacts of a changing climate. At a broad level, these actions support a risk-based approach to manage current and future risks associated with the changing climate, particularly hydro-meteorological hazards.

The three greatest challenges for adapting city infrastructure to a changing climate are:

1. Uncertainty about the nature of local climate change, and which climate parameters pose the greatest risk to continued safe and cost-effective operation of existing and proposed infrastructure. This uncertainty extends to the

design of new infrastructures where current design values may not take into account future climate changes, particularly extreme climate events.

2. The unknown risks of climate change impacts to individual infrastructure components, and determining the adaptive capacity of these components.
3. The development of effective knowledge and capacity among municipal staff and leadership to maintain infrastructure at a sustainable level of service that is resilient to climate change impacts.

Responding actions must be closely linked and coordinated, and not be addressed in isolation. Actions must be sequenced and coordinated to continually inform subsequent decisions and actions that are economically, socially and environmentally responsive, and sustainable.

Assessing Infrastructure Life Cycle

The following analysis will break down the important steps involved in assessing the life cycle of municipal infrastructure for climate resiliency. This process is necessary to resolve the

Table 1.1: Service Life of Selected Infrastructure (years)

Type of Infrastructure	Lifespan	Major Upgrades or Refurbishment	Reconstruction
Houses & Buildings Average Lifespans of Municipal Infrastructure Components	50-100	15-20	50-100
Storm/Sanitary Sewer	100	25-50	100
Dams/Water Supply	50-100	20-30	50
Roads	50-100	10-20	50-100
Bridges	50-100	20-25	50-100



uncertainties in assessing the climate vulnerability of municipal infrastructure. For example, determining how much of the infrastructure’s useful life lies behind it, and how much ahead of it, will demonstrate how far to project the changing climate. There is no value in predicting changes beyond the point when infrastructure rehabilitation, upgrading or replacement is anticipated.

Table 1.1 lists infrastructure categories relative to service life. Lifespan may be defined as the length of time between initial construction and the need for replacement or decommissioning. Replacement becomes the preferred decision when maintaining or upgrading existing infrastructure is not cost effective. Many infrastructures are planned and designed for rehabilitation and upgrade once or more in their lifespan. Climate adaptation measures must recognize the time span between the present and when such action is contemplated.

Infrastructure Component Definition

The infrastructure components being assessed must first be defined by a multi-disciplinary team that includes engineers, city planners, risk professionals, infrastructure managers and operators. This process establishes the boundary conditions between the infrastructure and other systems or processes.

The assessment must consider the degree of granularity in defining the infrastructure components. For example, with a potable water supply, treatment and distribution system, does the assessment need to examine each pump or all pumping stations individually?

“Non-structural” components should also be defined, as a changing climate will impact them. Changes to components cost less to implement and are less disruptive to the public.

Table 1.2: Highway Infrastructure Elements: An Example of the Level of Detail Possible

#	Infrastructure
1	Surface – Asphalt
2	Pavement Marking
3	Shoulders (Including Gravel)
4	Barriers
5	Curb
6	Luminaires
7	Poles
8	Signage – Side Mounted – Over 3.2 m ²
9	Signage – Overhead Guide Signs
10	Overhead Changeable Message Signs
11	Ditches
12	Embankments/Cuts (Constructed)
13	Hillsides (Natural)
14	Engineered Stabilization Works
15	Avalanche (Including Protective Works)
16	Debris Torrents (Including Protective Works)
17	Structures that Cross Streams
18	Structures that Cross Roads
19	River Training Works (Rip Rap)
20	Mechanically Stabilized Earth Walls
21	Pavement Structure Above Sub-Grade
22	Catch Basins
23	Median and Roadway Drainage Appliances
24	Sub-Drains
25	Third-party Utilities
26	Culverts < 3m
27	Culverts > 3m
28	Asphalt Spillway and Associated Piping/Culvert
Environmental Features	
29	In-Stream Habitat Works
30	Off-Channel Habitat Works
31	Wildlife Fence System
32	Wildlife Crossing Structures
33	Vegetation Management
34	Invasive Plants & Pests
Miscellaneous	
35	Administration/Personnel & Engineering

Source: Auld and MacIver, 2005.

Once this multi-disciplinary team defines the infrastructure components, each component should be reviewed for vulnerability to a defined set of climate variables/extremes believed to potentially impact one or more components. Table 1.2 provides examples of infrastructure components for a highway system.



Table 1.3: An Example of Climate Parameter Infrastructure Threshold Indicators

#	Climate Parameter	Infrastructure Threshold Indicator
1	High Temperature	Number of days with max. temp. exceeding 30°C
2	Low Temperature	Days with min. temp. below -24°C
3	Temperature Variability	Daily temperature variation of more than 24°C
4	Freeze / Thaw	17 or more days where max. temp. > 0°C and min. temp. <0°C
5	Frost Penetration	Assessed through empirical analysis of forecast climate conditions
6	Frost	47 or more days where min. temp. <0°C
7	Extreme Rainfall Intensity Over One Day	Determined empirically. PCIC used > 76 mm over 24hrs
8	Magnitude of Severe Storm Driven Peak Flows	Determined empirically. PCIC used directional wind speed, temperature and precipitation all > median values
9	Frequency of Severe Storm Driven Peak Flow Events	Determined empirically. PCIC used directional wind speed, temperature and precipitation all >median values for three consecutive days in autumn
10	Rain on Snow	10 or more days where rain falls on snow
11	Freezing Rain	1 or more days with rain that falls as liquid and freezes on contact
12	Snow Storm / Blizzard	8 or more days with blowing snow
13	Snow (Frequency)	Days with snowfall >10 cm
14	Snow Accumulation	5 or more days with a snow depth >20 cm
15	High Wind/ Downburst	Wind speed > 80.5 km/hr
16	Visibility Due to Fog	Decrease in stopping sight distance <245 m

Source: B.C. Ministry of Transportation and Infrastructure Nodelcorp Consulting Inc., 2010

Climate Parameter Definition

The next task is defining the possible climate parameters that may impact one or more of the infrastructure components. Initially, the list should be extensive and exhaustive to ensure and demonstrate that all parameters were considered. These definitions should be further refined into quantitative descriptors relating more directly to the design and operating condition of the infrastructure component and locality. These descriptors may be documented as design criteria, operating procedures, maintenance efforts or past climate impacts. The quantification of climatic parameters allows analysis of historical climate data and guides future climate projections. Table 1.3 demonstrates the level of detail necessary to define

climate parameters meaningful for vulnerability and risk assessment.

The likelihood of these parameters being exceeded should be defined. Historical data can be analyzed to establish a current baseline, while climate projections are necessary to establish future parameters.

Infrastructure Risk Profile

Once the climate parameters that may impact infrastructure components are defined, probabilities should be assigned to various climate parameters. Similarly, severity scores can be assigned for each interaction. Based on the probability and severity scores, one can calculate outcomes using the equation:



Table 1.4: Summary of Climate Change Risk Assessment Scores

Infrastructure Components	High Temperature	Low Temperature	Temperature Variability	Freeze/Thaw	Frost Penetration	Frost	Extreme Rainfall Intensity over One Day	Magnitude of Severe Storm Driven Peak Flows	Frequency of Severe Storm Driven Peak Flows	Rain on Snow	Freezing Rain	Snow Storm/ Blizzard	Snow (Frequency)	Snow Accumulation	High Wind/ Downburst	Visibility / Fog
Infrastructure																
Surface - Asphalt	18	9	2	6	2	2	30	30	25							
Pavement Marking											9	18	18	18		
Shoulders (Including Gravel)							36	36	35		3	3	3	18		
Barriers				6								3	3	15		
Curb	6			3									9	9		
Luminaires											12	12	3	12		
Poles											3			9		
Signage - Side Mounted - Over 3.2 m2											3	12	3			
Signage - Overhead Guide Signs					8						3	9	3			
Overhead Changeable Message Signs					8						3	9	3			
Ditches				6			30	36	35	3			3	18		
Embankments/Cuts (Constructed)				18	6	2	36	42	35				3	18		
Hillsides (Natural)				15			30	42	35	9			3	3		

Source: B.C. Ministry of Transportation and Infrastructure Nodelcorp Consulting Inc., 2010

Risk = Probability (Likelihood) x Severity

For instance, estimating the probability of the climate parameters, as defined in Table 1.3, and assigning these within a probability scoring system, is the first step to calculating a risk score. The second step involves estimating the severity of the climate impact, again using a severity scoring system that may be quantitatively or qualitatively based. This approach generates a risk profile similar to that in Table 1.4. This table shows a segment of a more comprehensive risk profile and is based on a 0-7 scoring system for probability and severity used in the PIEVC Engineering Protocol.

It is suggested that current and future risk profiles be generated with the difference between them (either positive or negative) attributed to climate change. The current risk profile is based on

historical climate information while the future risk profile is based on climate projections. Once the current and future risk profiles are established and high- and medium-risk components identified based on established risk thresholds, managing these risks can begin.

Disaster Risk-Management Cycle – Implementation

Successful disaster risk management requires implementing many, if not all, of the following steps that may be considered part of a continuous cycle:

- Prevention/Mitigation – measures taken before and after an event to lessen the likelihood and severity of disaster by implementing sustained actions. It includes improved construction practices to reduce or eliminate long-term risk to people and property.



- Preparedness – measures taken before and after an event to lessen the severity of disasters by planning for the disaster event to ensure an effective response and recovery, and training people to implement plans once a disaster occurs. This includes: prediction and warning systems for different disasters; emergency preparedness (e.g. monitoring, alerting and evacuating, immediate disaster assistance to set up medical operations, deployment of search and rescue teams, and distribution of rescue and emergency supplies and equipment); drills, education, training and public awareness.
- Response – measures taken during and immediately after an event, including capability to provide rapid and efficient medical, rescue and emergency supplies, and equipment.
- Recovery/Rehabilitation – implementation of actions to promote sustainable redevelopment following a disaster, including land use planning controls, rebuilding of houses and buildings, financing for rebuilding, repair of roads, bridges, water system, psychological counselling, and long-term assistance to rebuild the community.

Preparing a response plan for each step and performing measures according to the plan are vital. Risk-management planning and its implementation should effectively balance structural and non-structural measures corresponding to provincial and regional conditions, and should avoid overconfidence and exclusive reliance on non-structural measures (e.g. evacuation). The effects should be evaluated using test trials. It is also important to recognize that non-structural measures require structural facilities (e.g. evacuation routes, shelters).

An Example – Disaster Risk Management for Water-Related Climatic Impacts

Water-related disasters involving infrastructure may be mitigated only if policy makers, citizens, administration, and other entities appropriately fulfill their roles, and emphasize the importance of awareness-raising and disaster-prevention education. Awareness and education are vital in gaining public acceptance and in developing and implementing cost-effective adaptive actions. Implementation measures and strategies that integrate climate adaptation with disaster risk management are described below for water-related disasters resulting from extreme climate events.

It is important for water-related parties in each river basin to coordinate management of all natural and physical water infrastructures. The Netherlands National Research Program and Commission of the European Communities (2009) has developed a sophisticated framework that is particularly applicable to Canada. This framework includes the creation of the short-term plan (five to 10 years) and the medium and longer term plan (over 10 years), and implementation on a prioritized basis. Strategies in the short-term plan (identified below) include a focus on low-cost, effective, “no-regrets” action to create or update the flood control program for the regional/local drainage basin and catchment area(s):

- undertake a screening assessment of the natural drainage patterns and the impact of a changing climate on elements within the urban footprint, by considering current and future relevant climate parameters;
- undertake detailed vulnerability assessments on critical facilities with implementation of recommended actions;
- update floodplain boundaries for the 100-year event to help determine appropriate adaptation measures for threatened properties



within the revised boundaries (this will help explain the need for these measures to affected residents);

- assess the underground drainage collection and disposal system for its capacity and resilience to current and future climate extremes;
- assess the secondary overland flow channels to identify flooding patterns for extreme events and calculated return periods;
- review and reinforce the functionality of existing flood-control structures;
- determine and climate-proof the critical transport infrastructure needed for evacuation and hospital access;
- redefine the 100-year floodplain for new development areas and functionality of flood prevention/mitigation (capacities for underground and surface drainage infrastructures);
- review and reinforce historical or traditional flood prevention facilities (ring levees, secondary levees in floodplain, disaster prevention forests).

Strategies for the medium- and longer-term (>10 years) plan:

- develop institutional frameworks that define relationships and locations of organizations and institutions with disaster risk reduction and response responsibilities;
- plan non-structural measures, including education, forecast and warning systems, communications, and periodic drills of evacuation and rescue;

- establish post-event recovery protocols and management systems;
- promote and establish insurance systems for disasters;
- build capacity for relevant personnel in and across city departments for effective system management to enable smooth information-sharing. Routine performance of drills to set the roles and responses of decision-makers and related organizations;
- consider area-wide construction and management of river basins and communities (e.g. on-site detention reservoirs, infiltration facilities, land-use control);
- focus on land use control for undeveloped areas;
- plan and finance strategies for retreat from dangerous areas;
- define reasonable sharing between structural and non-structural measures depending on resources of national/ local governments and the socio-economic importance of a target area;
- use more storage facilities (reservoirs, more room for rivers) than flow facilities (diversion channel, raise levee level).

Adaptation Solutions for City Infrastructure

Because of climate change, Canadian cities and the country as a whole can anticipate increases in the frequency and severity of weather events that will test capacities to maintain and sustain infrastructure. Both short- and long-term projections point toward changes in the average weather pattern across the country. The expected life of infrastructure depends on understanding the impact of existing and future climate change.



Infrastructure vulnerable to such trends must be identified.

Fortunately, knowledge of climatic variability is improving. So, too are the tools and the protocols engineers, climatologists and risk managers use to flag and prioritize vulnerabilities – thereby allowing adaptation and mitigation. Engineers Canada - Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol is a model for such a vulnerability assessment. It can be used to develop a much-improved understanding of climate risks to infrastructure, one that informs and justifies proactive actions to address identified vulnerabilities. Over time, employing an approach that facilitates a PIEVC assessment as infrastructure is being built, rehabilitated or upgraded, will decrease vulnerabilities and climate-proof systems.

Teams that already design, manage, and run the infrastructures provide the essential human resources useful in spotting climate-related challenges and recommending adaptive or remedial actions. These teams can adopt and implement three core adaptation solutions to help deal with the climate change challenges for city infrastructure.

1. Estimate the Probability of Matching or Exceeding Climate Thresholds for the Remaining Service Life of the Infrastructure

The first step is to establish a current profile of relevant climate parameters, using historical recorded/measured data from the past 30 years, which is the normal period of record used by Environment Canada to establish climate norms and climate criteria from existing codes and standards. Because much of Canada's infrastructure is well into its service life, an understanding of the present climate helps provide a current baseline to compare with the original design values, and a means to establish future criteria.

By using climate projections and climate models, we can estimate the probability of matching or exceeding these baseline climate thresholds for the remaining service life of the infrastructure. This approach is necessary because existing probability estimations about the service life of infrastructure do not factor in future climate scenarios. Estimates of the magnitude of maximum values above a certain accepted frequency would justify adaptive action. Without linking the estimation of future climate parameters to the service life cycle of the infrastructure, our communities could be exposed to great vulnerability. For existing infrastructure, it is the remaining service life; for new infrastructure, it is the design service life.

2. Conduct Climate Change Related Vulnerability/Risk Assessments to Define Risks

Engineering vulnerability/risk assessment ensures climate change is effectively considered in the planning, engineering, design, operations, and maintenance of civil infrastructures. These assessments constitute a structured, formalized process based on the well-developed science of risk assessment from which engineers, planners, climatologists and risk managers can identify vulnerabilities and risks, set priorities, and recommend measures to address them. Information generated by these assessments can be used to make informed decisions on the implementation of adaptive measures.

Communities and their municipal governments should assess all infrastructures at two levels – initial screening to identify high-risk areas (e.g. flood-prone areas), followed by a more detailed climate risk assessment to identify and define the risks to critical infrastructures. For critical vulnerabilities, adaptive measures should be implemented over the short term. For “non-critical” vulnerabilities that are beyond acceptable risk levels, a longer-term “no-regrets” plan for



action should be developed that embeds climate adaptation measures into ongoing operations, maintenance, future capital projects and urban development.

3. Incorporate Adaptation into City Planning Policy

Addressing the changing climate with respect to infrastructure requires a multi-disciplinary approach that includes engineers, planners, managers, operators, climate scientists and other scientific professionals working towards a common goal. To this end, we recommend that cities embed the “no-regrets” approach” to climate change into city policy, with specific reference to adaptation, and to revise the job description and duties of all managers, engineers and utility personnel, defining

responsibilities and reporting requirements to adhere to the city policy.

In addition, we recommend creating an enabling environment where stakeholders work as a team, and by undertaking case studies of infrastructure risk and adaptation planning, “learn by doing.” This will build local capacity and support teamwork to address this challenge to engage civil society, municipal politicians and municipal staff on the importance of considering the impacts of the changing climate. The facilitation of an enabling environment requires a dedicated and focused awareness campaign geared to ensure acceptance of the changing climate and implementation of cost-effective measures that will enable infrastructure to withstand climate impacts. This awareness effort must be prolonged and repeated.





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2. Biodiversity

Steve Hounsell

Director, Board of the Canadian Business and Biodiversity Council; Chair, Board of Trustees, Trees Ontario

Introduction

“Climate is a key driver in determining the kinds of biotic communities which can thrive within any given region, landscape and waterscape.”

Biodiversity is formally defined as the variability among living organisms from all sources, including among other things, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems (Convention on Biological Diversity, 1992). It is an embracing concept, referring to the entire ecosphere and all of its ecosystems and component living parts and the ecological and evolutionary processes that keep them functioning, yet ever evolving.

Canada, by virtue of its vast geographical size, has a diverse array of ecosystem types that include: marine and freshwater ecosystems, both lake and riverine; as well as diverse terrestrial ecosystems, ranging from the Arctic tundra in the north, Carolinian woodlands in the extreme south, mountain ecosystems in the west, prairie and wetland ecosystems, and the vast boreal forest which stretches across most of Canada.

Biodiversity also includes all of the “goods and services” that the ecosystems provide. These include such services as clean water to drink, clean air to breathe, healthy food to eat and other renewable raw materials upon which our lives, our society, and economy absolutely depend. Ecosystem services are broadly classified into: provisioning services, which include food, water, timber and fibre; regulating services,

such as climate, flood and disease prevention, waste treatment, and air and water quality; and supporting services, such as soil formation and nutrient cycling, and social/cultural services that provide recreational, spiritual and aesthetic benefits. Biodiversity can also be conveniently described as the green infrastructure, or “natural capital,” upon which our health and future prosperity as a society and nation depends. The degradation of ecosystem goods and services from various means, including climate change, will serve to undermine the future health and prosperity of Canadian society. Climate regulation is one of several important regulating services that healthy ecosystems provide.

Conversely, the loss or degradation of ecosystems further exacerbates the issue of climate change, demonstrating the close interactions between biodiversity and climate regulation. The fundamental importance of large-scale intact ecosystems for climate regulation is summarized well by Dr. James Lovelock (2009, p. 50): “Too easily forgotten is Gaia’s need: we have to leave enough natural ecosystems on land and in the ocean for planetary self-regulation.” Gaia was the Earth goddess in ancient Greek religion, and is Dr. Lovelock’s term for “the living planet.” He goes on to say that “the natural world outside of our farms and cities is not there as a decoration but serves to regulate the chemistry and climate of the Earth, and the ecosystems are the organs of Gaia that enable her to maintain our habitable planet.”

A little more context is offered from the proceedings of the ninth World Wilderness Congress, held in Mexico in November 2009 (Watson et al. 2011). Vice President Harvey Locke of the WILD Foundation stated (Leahy, 2009): “The enormous challenges humanity faces this century – like a warming planet, freshwater shortages, pollution, declining fisheries, desertification and unsustainable food production – cannot be solved without protecting more than 50 per cent of Earth’s land and oceans...We must protect and restore the



systems that drive the living planet and provide us with air, water and food.” Whereas much of Canada is in good shape relative to such targets, the same cannot be said for the human-dominated settled landscapes of southern Canada

On a global basis, the Earth’s ecosystems are experiencing acute losses of biodiversity and continued degradation of ecosystem services, potentially reaching tipping points beyond which recovery is unlikely, precipitating dire consequences to humanity and its future prosperity. This has been driven by unsustainable use and a growing ecological footprint which is well beyond the earth’s biocapacity for renewal. The Global Biodiversity Outlook Report 3 (Secretariat of the Convention on Biological Diversity, 2010) concluded that signatory nations for the Convention on Biological Diversity failed to achieve their international targets of slowing the rate of global biodiversity losses by 2010. Canada, although blessed with vast natural resources, is suffering from similar problems and also failed to achieve its target of reduced biodiversity losses. By way of example, Canada’s grasslands and southern wetlands continue to decline in acute terms. We are losing old-growth forests, experiencing changes in river flows at critical times of the year, and witnessing increases in wildfire and significant shifts in marine, freshwater and terrestrial food webs (Federal, Provincial and Territorial Governments of Canada, 2010).

The underlying root cause for the imperilment of biodiversity is a growing population, coupled with excessive resource consumption on a per capita basis. More specifically, losses to biodiversity are driven by habitat loss, exotic invasive species, human population growth, pollution, overharvesting and unsustainable resource consumption and now, climate change. Although habitat loss continues to be the leading cause of biodiversity losses, it is expected that climate change will, in the coming decades, become the leading cause of biodiversity loss.

Climate Change Challenges for Biodiversity

1. Changing Bioclimatic Envelopes

Biotic communities are shaped and determined by interactions between the biotic and abiotic components of the environment and associated biogeochemical and climatic processes. Climate is a key driver in determining the kinds of biotic communities which can thrive within any given region, landscape and waterscape. Climate variables, including temperature, precipitation and humidity have a profound influence over community type, and largely determine which species can survive and which cannot.

The National Ecological Framework for Canada has utilized the historically stable relationship between climate, bedrock geology, soil and landform to classify ecosystems within a hierarchy of spatial scales (e.g. Wiken, 1986; Crins et al. 2009). That framework has been used for renewable resource management and protected areas management. The biotic communities found in our current ecoregions across Canada have evolved over several thousand years, largely since the last Ice Age, and are well adapted to survive within the climatic constraints of those regions. That is all about to change with the increasing effects of climate change.

Radical shifts in climate envelopes (areas with similar climate regimes) are expected, and have been predicted based on climate modelling in Ontario (McKenney et al. 2010) and elsewhere (Hole et al. 2011). Changing bioclimatic envelopes have the very real potential to have huge impacts on Canada’s biota (the plant and animal life of a particular region and period), with cascading adverse socio-economic effects on people deriving their livelihood from those ecosystems. Under such scenarios of changing bioclimatic envelopes, species with wide climatic tolerances can be expected to persist. Species with narrow climatic



tolerances will need to emigrate to habitats with preferred climatic and edaphic (site/soil) conditions, assuming they have robust dispersal mechanisms and that dispersal “avenues” are available.

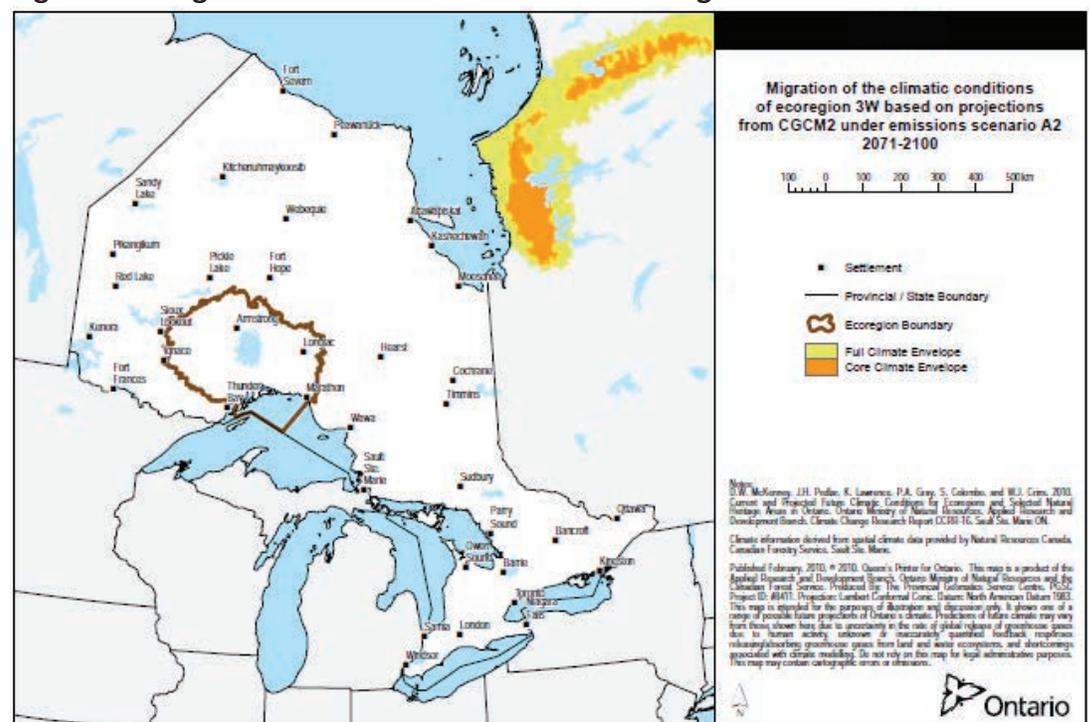
Where this is not the case, population declines and possible local and regional extirpations of such species can be expected. Conversely, new species can be expected to colonize new areas of favourable climatic regimes. This is a dynamic process with both “winners” and “losers.” Habitat generalists and opportunistic species will likely prevail at the expense of habitat specialists with narrow habitat requirements. The effect will be a northward expansion of species with current southern affinities, and the retreat of northern species adapted to colder climates.

Given the rapid predicted shifts of bioclimatic envelopes and the predicted disjunct, non-linear patterns of such changes (see Figure 2.1 from McKenna et al. 2010), it is clear that many species will not be able to migrate fast enough to keep pace with changing climates. They will find themselves in unsuitable climates for their survival, or will be under severe stress through increased vulnerability to other stressors, including disease, parasitism and predation. There will be many losers under such selection pressures and some community types may well collapse. Biotic failure, or even the partial collapse of economically important species, leads to many related problems, including greater

risk of fire and conversely floods. These events translate into significant socio-economic problems for local and regional communities, threatening Canada’s status as a leading producer of renewable resources.

Some species with wide tolerances will continue to survive and will persist under changing climatic conditions. New climatic conditions will also favour the establishment of new species with more southern affinities, assuming there are no barriers to dispersal for their northward expansion and appropriate soil conditions exist. Barriers to dispersal (e.g. major waterbodies, like the Great Lakes, or other biophysical barriers to dispersal, including inhospitable habitats), will have significant adverse effects on both emigrating species and immigrating species (i.e. potential colonists), further simplifying ecosystems. This could render such ecosystems more vulnerable to other forms of perturbations. Ecosystem resilience is typically, although not always, correlated with increasing species diversity. These changing climatic envelopes also “fuel” the other drivers for

Figure 2.1: Migration of Climatic Conditions of Ecoregion 3W



Source: McKenney et al. 2010.



ecosystem change, including altered disturbance regimes (e.g. wildfire, wind, flood events and insect outbreaks) and the establishment of exotic invasive species and eruptive native species.

2. Altered Disturbance Regimes

Many biotic communities are adapted to natural disturbance events and cycles, where it is cycles of annual flooding in floodplain areas or fire disturbance regimes in prairie or jack pine boreal forest ecosystems. Problems arise when disturbance regimes exceed the tolerance limits of the species found within those ecosystems. Climate change is predicted to alter naturally occurring disturbance regimes in terms of increased intensity, duration and/or frequency of events, scale and geographic scope. Any changes to such regimes beyond historical norms and cycles (either more, or less), will cause corresponding shifts to biotic communities. Examples of disturbance regimes are many and include, but are not limited to:

- changing precipitation patterns causing either too much water (extreme flood events) or conversely too little water (drought conditions), beyond the tolerance limits of existing species and biotic communities;
- increased intensity and scale of fire in zones and regions experiencing excessive drought, or regions where an abnormal build-up of fuel has been caused by other disturbances (disease, invasive pests, or eruptive hyper-abundant native species, like the mountain pine beetle);
- extreme storm events (ice, tornados, etc.) beyond the norm for which local and regional communities have adapted;
- warming temperatures (both extreme and average) beyond the tolerance of species for long-term reproductive success.

By way of example, some of our fire-adapted

boreal ecosystems may be rendered highly vulnerable to intense and widespread fires that are expected to be well beyond historical norms (increased intensity and frequency). Other regions may experience more frequent and intense flooding, again beyond historical patterns. One-hundred-year flood events could become 10-year flood events with the new 100-year event being of much greater magnitude. Such intense disturbance regimes can cause significant changes to ecosystems, while posing very serious risks to human settlements and the renewable resources that are supporting local and regional economies. The maxim of “healthy ecosystems supporting healthy people and healthy economies” needs to be invoked. If ecosystems start to fail, or degrade, there will be cascading adverse effects to our future health and prosperity. Conversely, some economic opportunities might occur, depending upon the nature of replacing species and communities. The prudent action would be to limit the magnitude of human-induced ecosystem changes.

The economic cost of ecosystem failures caused by disturbance regimes is already significant. Major efforts are expended on monitoring such things as forest health and limiting the adverse effects of pathogens and insect outbreaks, and extreme fire and flood events. The cost of managing ecosystem health (both aquatic and terrestrial) will rise significantly in the coming decades, due to the added pressures and intensification of disturbance regimes.

3. Exotic Invasive Species and Eruptive Native Species

The rapid spread of exotic invasive species is considered the second greatest threat to biodiversity, after habitat loss. Invasive species are generally defined as harmful alien species whose spread, or introduction, threatens ecosystems, the economy or human health (Government of Canada 2004). Climate change will exacerbate what has already become an acute problem to



biodiversity, globally, and across Canada. The removal of thermal barriers to range expansions is expected to cause the rapid spread of many invasive species already established in Canada's ecosystems, while providing greater opportunities for the ever-increasing threat of new invaders. Such occurrences, should they dominate community structure, will further simplify ecosystems in the near term while rendering them more vulnerable to longer term perturbations.

The economic consequences of invasive species to Canada's economy are enormous, with some provinces, such as Ontario (OMNR, 2011), far more acutely affected than others. The cost of aquatic and terrestrial invasive species to Canada's economy is not precisely known, but for perspective, the Commission for Environmental Cooperation has estimated that the cost of invasive species exceeds \$100 billion annually in the United States. The damage costs from invasive species will increase substantially under climate change.

The removal or alteration of natural thermal barriers can also cause major range expansions and massive population eruptions of native species – with high reproductive outputs and dispersal capabilities – into regions where they have been historically absent, and where natural predators or other limiting factors are absent. The rapid spread of the mountain pine beetle in Western Canada is but one example. The economic devastation to local and regional economies caused by such events is immense and has prompted major coordinated efforts to limit damages and prevent further range expansions.

Mortality losses from such events are exacerbated by other disturbance events, including the possibility of more extreme fire events which can arise from excessive accumulations of fuel (dead standing timber) and more severe and extreme storm events (lightning storms). Such cumulative effects can lead to locally and regionally devastating consequences to ecosystems and associated

human settlements and economies. Significant investments, in the order of tens of millions have been spent by federal and provincial governments to manage and limit the further spread of just the mountain pine beetle. This is but one of many potential native pest species. Future investments will need to substantially increase to offset the added effects of climate change.

The Vulnerability of Canada's Ecosystems to Climate Change

Hudson Bay and Arctic Ecosystems. Based upon the Canadian Climate Change Scenarios Network ensemble models (CCCSN, 2010), it is clear that Canada's arctic ecosystems (both marine and terrestrial) will experience the greatest levels of warming, with acute changes to winter temperature and winter moisture regimes centred over Hudson and James bays and much of the Arctic Ocean. As the period of ice-free conditions increase, positive feedbacks of warming will occur, accelerating and exacerbating effects.

Although Arctic terrestrial ecosystems are largely intact, rapidly changing "climate envelopes" will fundamentally alter terrestrial communities with further positive feedback loops caused by thawing permafrost. The thawing permafrost will release vast quantities of methane, an extremely potent greenhouse gas, further accelerating runaway climate change. These ecological impacts will adversely affect northern human communities and their infrastructure, forever changing a culture and way of life.

Large intact forest ecosystems. Canada's large intact forest ecosystems, which include the vast boreal forest, highly valued for its carbon storage and where much of our industrial forestry takes place, will also be at risk to climate change. The relative acuteness of climate change may not be as great as in the regions of Hudson Bay and the Arctic, but preliminary work from Ontario on changing climatic envelopes (McKenney et



al. 2010) suggests profound changes are likely to occur in Canada's northern forests. The area of climatically favourable and optimal habitat for such boreal species such as black spruce, jack pine, white spruce and balsam fir will likely diminish and retreat further north, where suitable site and soil conditions for growth and reproduction are threatened. The future of our northern forests is also threatened by more frequent and intensifying disturbance regimes (insect, disease, violent storms, floods, fire, tornados and drought). The cascading impacts to forest biodiversity and the goods and services they provide for Canada's economy could be very significant. Likely effects include reduced forest health and increased risk of forest community collapse, with immense socioeconomic consequences, locally, regionally and nationally.

Prairie ecosystems. The availability of water or moisture is a primary determinant, together with temperature and landform, of ecosystem type and community composition. The Prairies are prairies because they are adapted to low moisture regimes. Even prairie ecosystems, which are among the rarest ecosystem types in North America (formerly among the most extensive, covering much of the continental Midwest), are at risk due to predicted lower precipitation rates and the reduced contributions of glacial melt, as glacier-fed streams are further diminished. This region and its vulnerable riverine systems are highly vulnerable to climate change impacts. David Schindler (2011) has summarized the key threats and adaptation needs in this report, which includes sound recommendations for watershed and land use planning.

Human-dominated landscapes. The magnitude of climate change predicted for southern Canada is considerably less than predicted for more northern latitudes. Biodiversity is already imperilled in the more human-dominated settled landscapes that

characterize much of southern Canada, adjacent to the U.S. border. This is largely a function of scant supplies of available habitats and extreme habitat fragmentation in landscapes that are largely under private ownership. Land securement, through land trusts and federal and provincial government protected areas planning, have safeguarded some of the most important remnant habitats. Nevertheless, extensive habitat restoration and recovery is needed on the working landscapes between the protected areas, to conserve biodiversity in these regions. These actions are urgently needed even without the added threat of climate change. Climate change simply exacerbates the threat to biodiversity in fragmented landscapes, as habitats change in response to changing temperature and moisture regimes, beyond the tolerance limits of local species. In the absence of much greater habitat connectivity (interconnected networks of habitats), many of these landscapes will act as barriers to the northward movement of species which possess poor natural dispersal capabilities.

Adaptation Solutions for Biodiversity

1. Modelling to Prioritize Change and Vulnerability in Bioclimatic Envelopes

The development of models that measure change in bioclimatic envelopes from the historical baselines used to inform Canada's National Ecological Framework is a critical first step for developing adaptation solutions. Such model outputs will help to inform climate change adaptation priorities in terms of levels of climate change threats, species and community vulnerabilities, and risk assessment/management strategies. This type of modelling has been done in Ontario (McKenney et al. 2010) and elsewhere (Hole et al. 2011). This work should be broadly expanded to other ecoregions and watersheds across Canada. Issues of appropriate scale



(downscaling to regional models) will need to be addressed in relation to specific regions.

Step one would be to get a Canada-wide handle on the extent of change to bioclimatic envelopes caused by climate change in comparison to Canada's National Ecological Framework. That will also serve to inform managers as to geographical priorities for adaptation on a national and provincial basis. Step two would be to undertake vulnerability assessments of key species and community types to such climatic changes.⁵ This will serve to inform managers as to geographical priorities for adaptation on a national and provincial basis. Gleeson et al. (2011) have developed an excellent practitioner's guide to assist resource managers in integrating climate change vulnerabilities and risks into adaptation action plans, strategies and policies.

2. Increase Habitat Connectivity in Human Dominated Settled Landscapes

The shifting of bioclimatic envelopes will also occur to the ecosystems associated with the human dominated landscapes of southern Canada and, most notably, southern Ontario. The fragmented nature of these landscapes poses special problems to species dispersal, as the habitat mosaics shift in response to changing temperature and moisture regimes. Under such scenarios, many of our protected areas will be rendered ineffective for the biodiversity protection purposes for which they were established. To assist native species dispersal to more favourable habitats, we must "reconnect the fragmented landscape." Indeed the United Nation's International Panel on Climate Change has stated that 20 to 30 per cent of the Earth's plants and animals may face extinction without the establishment of interconnected natural areas.

Enhancing habitat connectivity on the landscape is a fundamental tenet of conservation biology

and landscape ecology. It has become even more important under scenarios of climate change. Assisting natural migration of species to more favourable habitat conditions is the top priority action for conserving species in an era of rapidly changing climatic regimes. That implies many things, including: creating more protected areas to strategically enhance connectivity; identifying and protecting (future) climate refugia (large areas of safe haven for biodiversity where climate shifts are expected to be minimal), which can serve as source areas for populating future favourable habitats; restoring habitat linkages and corridors on "working landscapes" and developing supportive economic incentives and policy frameworks to encourage such work on private lands. Enhancing habitat connectivity must be undertaken in a strategic manner and at multiple scales.

In terms of scale, neither climate nor biodiversity recognize political boundaries. Given the nature of the problem and the shifting of more southerly climates northward, a continental framework for enhancing species movement and migration is needed. Considerable work has been done by the Wildlands Network to identify key continental corridors needed to conserve North America's biodiversity. The threat of climate change to species dispersal provides further support and urgency for these tri-national partnership efforts (Dugelby, 2009). It also serves to provide geographical focus for national prioritization of efforts. At the continental level, the Wildlands Network proposes four "Continental Wildways," which may be regarded as large contiguous landscapes for wildlife movement, comprised of a mix of protected areas and restored "working landscapes and waterways" that are "permeable" for wildlife (biodiversity) movement (see Figure 2.2). These "wildways" are also home to our greatest Canadian and North American natural heritage treasures, including national, provincial and state parks, and other protected areas:

⁵ Issues of appropriate scale (downscaling to regional models) will need to be addressed in relation to specific regions.



- The Eastern Wildway extends northwards from the Everglades along the Appalachians to the Arctic, and includes the Algonquin to Adirondack (the “A2A project”) wildlife corridor project, which is a priority habitat corridor bridging New York State and Ontario.
- The Western Wildway spans the continent from Mexico, through the Rockies, to Alaska, and includes the Yukon to Yellowstone (“Y to Y”) wildlife corridor project.
- The Pacific Wildway spans the continent from Baja to Alaska.
- The Boreal Wildway runs from west to east, from Alaska to Canada’s east coast, across the forest roof of North America.

In terms of the Boreal Wildway, much of it remains relatively intact. Considerable efforts have been appropriately devoted to the boreal, and notable partnerships achieved (the Canadian Boreal Forest Agreement) between industry and environmental organizations to maintain the integrity of the boreal forest. Those efforts need to continue. Regardless, the composition of the boreal forest will likely fundamentally change in the coming decades, due to climate change. The challenge will be to manage and reduce the adverse effects of more severe disturbance regimes (weather and biotic) and to integrate plant hardiness considerations into reforestation efforts, relative to changing climates.

The threats posed by climate change have increased the need to “think big” and to undertake levels of habitat protection and restoration at a scale never before undertaken. It is critical to start strategically enhancing connectivity in the southern Canadian portions of the eastern, western and pacific “wildways.” There is a clear role for land trusts (e.g. Nature Conservancy of Canada, and many others) to help increase the extent of protected areas in these landscapes, while complementing their own goals and the international goals emerging from the Convention on Biological Diversity’s Strategic Plan for Biodiversity 2011-2020 to achieve a target of 17 per cent protected areas (Aichi Target 11). In terms of land stewardship and habitat restoration work, Canada is blessed with a robust provincial and national network of land stewards with credible grassroots connections for undertaking meaningful work (See Stewardship Canada, 2012). Climate change simply makes their mission and role more urgent. These organizations and people could be quickly mobilized with appropriate funding support to advance recommended actions on the ground.

The preceding continental scale “wildways” (or habitat corridors) should be complemented at more regional and local scales with watershed-level habitat protection and restoration work. For example:

Figure 2.2: Proposed Continental Corridors to Conserve North America’s Biodiversity (Wildlands Network 2012)



Source: Degelby, 2009



- Merge integrated watershed management with “natural heritage systems” to create interconnected habitat systems of habitat “cores and corridors” along natural drainage systems. It would benefit both terrestrial and aquatic ecosystems. This system should capture representative ecosystem types and gradients and is consistent with the recommendations of Schindler (2011) pertaining to water management.
- Increase “natural cover” (often forest cover, depending upon landscape) to a minimum of 30 per cent, and preferably 50 per cent or more, of watershed areas, to conserve biodiversity (Environment Canada, 2004, forthcoming 2012).
- Implement assisted migration management of vulnerable native species, as well as the management of exotic invasive species, eruptive natives and disturbance regimes, as needed.

Increasing the size of “core habitats” to 100 hectares or more is needed for sensitive species and to enhance ecosystem resilience to extreme storm events. In the case extreme storm events, larger habitat patches are inherently more resilient than small isolated habitat patches, which can be virtually eliminated by such events. A portion of an intact ecosystem can experience great disruption, but will often recover, provided source populations are available from surrounding undisturbed habitats to facilitate succession and re-colonization of local species.

The provinces have an important role to play through land use planning mechanisms and through watershed planning. Land use planning should incorporate the preceding concepts (i.e. integrated watershed management with natural heritage systems) to ensure a resilient landscape capable of delivering key ecosystem services to sustain healthy resilient human communities in the face of climate change (Ontario Biodiversity Council, 2011). A convergence of market

mechanisms, incentives, as well as regulations and policy for land use planning is needed to invest in and promote ecologically resilient landscapes capable of coping with a changing climate.

Given the extensive nature of private land ownership in the settled landscapes of Canada, more work will be needed to monetize the values of ecosystem services and to develop market mechanisms to pay for the delivery of ecosystem services (OBS, 2011; Kenny et al. 2011). Work on ecosystem service valuation is rapidly gaining momentum and has been undertaken globally, nationally and provincially (TEEB, 2010; Kenny et al. 2011; Troy and Bagstad, 2009). Organizations, like Ducks Unlimited Canada and others, have been undertaking research to monetize the ecosystem service values of wetlands and other “natural capital” (Olewiler, 2004). They see such research and the associated development of economic instruments as a means to build support for the delivery of conservation and restoration programs (see Ducks Unlimited, 2012).

Unfortunately, the development of economic instruments for the payment of ecosystem services is still lagging. The Alternative Land Use Service Program is one example that is working well in Prince Edward Island for the payment of ecosystem services to rural landowners (Government of Prince Edward Island and Government of Canada, 2012). Similar pilot programs also exist in Ontario (Norfolk County), Manitoba and Alberta. These and other programs need to rapidly evolve if we are to achieve the scale of habitat restoration needed to enhance ecosystem resilience on private lands in a future of climate change.

The costs of restoring habitats can be significant and vary depending upon habitat types and local site conditions. By way of example, the costs of converting marginal farmland to woodland habitat typically ranges from \$4,000-5,000 per hectare in southern Ontario. The collateral benefits of enhancing habitat connectivity are many and



include linkages to climate change mitigation (carbon sequestration), and the enhanced delivery of ecosystem services, including flood attenuation, and enhanced water quality and quantity. These multiple benefits should make such efforts a “no regrets policy,” meaning they are implemented. Those benefits also include significant job creation. It takes skilled labour of many disciplines to make this happen on the landscape. Ontario’s 50 Million Tree Program is but one example. That effort needs to be greatly expanded within Ontario and notionally replicated across other vulnerable landscapes in Canada (with the caveat of restoring locally and regionally appropriate native habitats). Organizations like Trees Ontario, Tree Canada and provincial stewardship organizations, including the conservation authorities of Ontario, are well positioned for the strategic delivery of such programs on the landscape.

Assisted Migration

Specific work is needed on “assisted migration” to reduce impacts and to assist selected species in relocating to favourable habitats, as a key adaptation strategy (see McLachlan et al. 2007; Hewitt et al. 2011). Assisted migration is generally defined as the intentional translocation or movement of species outside of their historic ranges in order to reduce biodiversity losses, either caused, or predicted, by climate change (Hewitt et al. 2011). It is particularly relevant for species whose dispersal capabilities are limited, relative to the speed of climate change, to overcome and compensate for various barriers to natural dispersal.

Assisted migration is considered a last resort approach, in cases where natural dispersal is simply inadequate to keep pace with changing climate envelopes. Species at risk with poor natural dispersal capabilities that exist in isolated, protected (or unprotected) areas, should likely be the first candidates to be considered for assisted

migration. These species are at greater risk of extirpation or extinction because of changing climatic envelopes. Assisted migration to more favourable habitats may be necessary for their survival. Survivorship of these species is not just dependent upon favourable climatic envelopes, but also upon suitable edaphic conditions (soil, moisture and microclimate). Existing work on species at risk should identify the most vulnerable to climate change, and recommend strategies for dealing with rapidly changing climates in formal recovery plans at the federal (Species at Risk Act) and provincial levels (e.g. Ontario’s Endangered Species Act). It is another factor that should be more rigorously addressed in recovery plans.

The scope of work that is urgently required ranges from basic research to policy development to controlled experiments to practical management action under an applied system of adaptive management – intended to ensure long-term survivorship of key species and community types. Vulnerability assessments for species at risk – ecologically important species, such as keystone species, and economically important species – will be needed to define species in need of assisted migration. Risk assessments and risk management will be required as there are many unknowns. Although controversial, it is believed that the risk of doing nothing far outweighs the risks of proceeding with assisted migration under well-conceived and controlled management efforts. Hewitt et al. (2011), in their manuscript “Taking Stock of the Assisted Migration Debate,” have undertaken a thorough review of the risks and benefits. A proactive and innovative approach is needed, supported by field research. This needs to quickly move from debate and discussion to controlled application.

Relative to the debate on assisted migration, we should consider the fact that major efforts are being undertaken in terms of afforestation, reforestation and other forms of habitat restoration



across Canada. The questions that need to be asked include:

- Are we planting the right species in the right locations relative to a future of changing climate?
- Will the species that are currently being planted and established survive to maturity, successfully reproduce and remain viable communities?
- Are we setting ourselves up for future failure and collapse because we have not taken into consideration changing climates and changing bioclimatic envelopes?

It is suggested that most, if not all, current planting regimes are based on historical norms and well-established protocols for what has been successful in the past. The effect of future climates remains academic and a subject of debate. It needs to rapidly mature into applied practice under adaptive management protocols.

In terms of afforestation and other forms of habitat restoration work, it is recommended that practitioners consider data on plant hardiness, relative to projected climatic changes. The species mix used for planting should ideally be tolerant of the expected new climate. Where projected climatic conditions are no longer favourable for survivorship, controlled experiments on the landscape of planting species with more southerly genotypes, where the appropriate edaphic conditions exist, should be encouraged and monitored for survivorship and reproductive success. Such adaptive management prescriptions can be used for informing more robust larger-scale plantings.

Many southerly species will experience range expansions, although like any range expansions, species along the edge of the range are typically in less than optimum climates, with ranges fluctuating with annual variations in climate. The greater

concern is for northerly species, whose range is contracting without other favourable habitats emerging for their survivorship. In Ontario, for example, the favoured climate for several boreal tree species (e.g. black spruce, jack pine, white spruce, balsam fir, and trembling aspen) is expected to recede and will largely migrate out of the province. This is perhaps most notable for the black spruce, whose favoured (optimal) climate is predicted to exist only along the James Bay and Hudson Bay coastal region (vicinity of Polar Bear Provincial Park) by the end of this century (see: McKenney et al. 2010). Where appropriate edaphic and site conditions exist, assisted migration may well be needed for these economically important species to simply keep pace with changing climate envelopes.

3. Management of Disturbance Regimes

Enhanced modelling is needed at a regional scale to predict the magnitude of change in regional disturbance regimes and the frequency of extreme storm events. The management of disturbance regimes is well established for fire, flooding, insect infestation and various diseases and pathogens. The issue is not so much creating management regimes, but rather assessing whether Canada, and hence the provinces, have the capacity to predict, prevent, or respond to increasing intensities and frequencies of these disturbance regimes. It is expected that new management approaches and enhanced capacity will be needed to limit the adverse effects of more frequent and severe disturbance regimes, including fire, floods, tornados, ice storms, disease, pathogen and insect outbreaks. Do we have the capacity to deal with these threats? If not, do we have a plan to develop the capacity to limit future damages to an acceptable level?

4. Exotic Invasive Species Management

International, national (Government of Canada, 2004) and provincial strategies and plans (see:



OMNR, 2011) have been developed, or are underway, to limit the adverse effects of exotic invasive species, with an emphasis on prevention. Climate change, and the removal or alteration of natural barriers to range expansion, will exacerbate present management regimes. For this reason, climate modelling and associated vulnerability and risk assessments are necessary to update these management regimes in ways that limit future ecological and associated adverse socio-economic impacts of exotic species migration. Proactive and pre-emptive management is needed. Once natural and thermal barriers to dispersal are breached, it is virtually impossible, or prohibitively expensive to control. Accordingly, enhanced capacity to rapidly respond to the threats of range expansions of invasive species is needed to reduce future biodiversity losses.

5. Geoengineering

Canada's Arctic is extremely vulnerable to climate change. Although the preceding actions (notably assisted migration and the enhanced management of disturbance regimes and eruptive and invasive species) have relevance to ecosystems, Canada's Arctic will remain extremely vulnerable. Should tipping points be exceeded, and it is very likely they will, massive releases of methane will accelerate climate change with potentially devastating effects. Extreme vulnerabilities call for potentially extreme actions to limit impacts (see Brand, 2010). Canada and other arctic nations need to identify, assess and potentially implement geoengineering actions to limit adverse effects and "buy time," as more options are considered. Such options need to be carefully controlled experiments that are adaptive and reversible.





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3. Freshwater Resources

Dr. David Schindler

Killam Memorial Chair and Professor of Ecology,
University of Alberta

Dr. Jim Bruce

Former Director of Canada Centre for Inland
Waters, and Assistant Deputy Minister of
Environmental Management, Environment Canada

Introduction

“If climate change is the shark, then water is its teeth.” Paul Dickenson, CEO of Carbon Disclosure Project, 2012

Water availability and water pollution in Canada are growing problems due to the warming climate, in addition to more water demand from an increasing population and industrial use. It has been conclusively shown that the global warming trend since 1970 has been driven by increasing concentrations of greenhouse gases. The rate of increase of greenhouse gases in the past decade has been alarming, with 20 per cent more emissions per year than in the 1990s. This results in a 30 per cent annual increase in these gases staying in the atmosphere, triggering faster climate changes in this century.

With only a few European countries living up to their international obligations to reduce emissions, Asian economies booming, and large emitters per capita lagging in their reductions, greenhouse gas increases will drive even more rapid change in the rest of this century. Thus, the trends in our water systems observed, to date, in response to climate change, are a modest harbinger of things to come. These changes will continue or accelerate in coming decades. The following analysis breaks down the climate change challenges for Canada’s freshwater resources by looking at the specific impacts to

the prairie watershed, the Great Lakes and river systems, and the threat of overland flooding.

Climate Change Challenges for Freshwater Resources

The Prairie Watershed

The western prairies lie in the rain shadow of the Rocky Mountains, resulting in a generally dry climate. Southwestern parts of the prairies are also visited frequently in summer by hot, dry air masses from the deserts of the American southwest, which tend to slide northward along the eastern slopes of the Rockies. As a result, the lowlands of southern Alberta and adjacent Saskatchewan generally have a semi-arid climate. In contrast, the southeastern prairies are much wetter, due primarily to air masses that originate over the Gulf of Mexico. Their climate is generally considered to be sub humid.

Outside of the Arctic, some of the most extreme impacts of climate change in Canada are predicted for the Prairie provinces. Analyses of records from 10 meteorological stations in Alberta and Saskatchewan that do not have urban “heat island” effects indicate that annual average temperatures have already increased by 1 to 4°C, mostly since 1970. Snowpacks have tended to decrease, and fewer days have snow on the ground. Evaporation has increased. The result is that river flows in May to August, when water is in most demand for both human use and ecosystem requirements, have declined (Schindler and Donahue, 2006; Dibike et al. in press). The result has been several years of drought since the late 20th century. In contrast, the eastern prairies have had more precipitation, the result of an increasing frequency of moist air masses that originate over the Gulf of Mexico (Sauchyn et al. 2010).

The decline in winter snowpacks in the Alberta and Saskatchewan parts of the Saskatchewan River Basin has averaged about 30 per cent (Dibike et



al. in press). This appears to be partly the result of more winter precipitation falling as rain, and increasing periodic winter melts, which allow water to seep away rather than accumulate in snowpacks that replenish surface waters and soils just before the growing seasons begin. Because about 80 per cent of the stream flow in the prairies results from melting of winter snows, this is bad news for prairie rivers and their biotic communities. Spring snowmelt also replenishes soil water. It is slowly taken up by plants early in the growing season. Summer rains are seldom high enough to generate any runoff, and are, typically, scarcely enough to maintain growth in the plants started by snowmelt water. Changes are also predicted to the timing of precipitation. Spring melts are occurring about a month earlier, on average, than in the past. These trends are expected to continue, and together, they spell increasing summer water scarcity in the years ahead.

An exception to the general water scarcity is the occurrence of summer thunderstorms, which can generate intense rainfalls over relatively small areas. In such cases, intense flooding can occur. For example, in 2004, a single thunderstorm dropped 150 mm of rain on Edmonton, in under an hour. The resulting flooding caused losses of \$175 million. Such events are difficult to predict, and do little to change the general increase in water scarcity. While it is impossible to attribute the occurrence of a single extreme event to climate warming, a general increase in the frequency and intensity of extreme events such as droughts and heavy rains is predicted, as climate continues to warm (IPCC, 2007; Sauchyn et al. 2010).

Projections based on climate models indicate that by mid-century, the western prairies will have increased by an additional 2 to 4°C. By 2100, the increase would be 4 to 6°C, well outside the range of temperatures that have occurred in the region during the Holocene period, so that major changes to ecosystems must be expected. Increased variability in climate is also predicted (IPCC, 2007;

Sauchyn et al. 2010). Because all ecosystems rely on water, changes to water supplies will affect the entire prairie landscape, including anthropogenic activities. The northern boundaries of grassland and parkland ecosystems can be expected to advance to the north, and the amount of boreal ecosystem in the Prairie provinces will dwindle (Sauchyn et al. 2010).

Increasingly rapid melting of glaciers on the eastern slopes of the Rocky Mountains has also been observed. While the current lack of detailed measurements of ice thickness do not allow precise estimates to be made, it is estimated that an average of 25 per cent of glacial ice has disappeared since the first measurements were made in the early 20th century. Smaller glaciers, such as the Bow Glacier at the headwaters of the Bow River, are predicted to disappear by mid-century. Larger glaciers, such as the Saskatchewan Glacier at the headwaters of the North Saskatchewan River, and the Athabasca Glacier, will be almost gone by the end of the century, if projected temperature increases occur. Together, these two glaciers represent more than 75 per cent of the current ice mass in Alberta. While the glacial contribution to annual river flows in Alberta is only a few per cent, it can be as high as seven per cent of flows in July to September, when annual snow in the mountains is depleted and there is little runoff from lowland watersheds (Marshall and White, 2010). This glacial contribution in late summer is probably critical for the cold stenothermic trout and whitefish species that occur in southern Alberta, which are generally stressed by high water temperatures and low oxygen in late summer and early autumn.

Southeastern Alberta and adjacent southwestern Saskatchewan, where average conditions are dry at best, are particularly vulnerable to climate warming. Even in the 20th century, now recognized as the wettest of the past several centuries, in most years there was less than 10 mm of runoff generated in the area. The area was hard-hit



by droughts of the “Dirty Thirties,” when many rural communities declined in population, and in 1999-2004, when several years of below-average precipitation caused a major agricultural crisis. The worst years were 2001 and 2002, when successive crop losses caused the GDP of the region to decline by \$4.5 billion. Almost 28,000 jobs were lost, and many farms had zero or negative net income. Soils were damaged by wind erosion, grasslands deteriorated, and farmers were forced to reduce their cattle herds because of lack of forage (Sauchyn et al. 2010).

Unfortunately, this same area in Alberta is home to almost 70 per cent of Canada’s irrigated agriculture, about six million cattle and two million hogs, and a third of Alberta’s 3.5 million human population, with over a million people in Calgary alone. The human population of Alberta is projected to increase by about 40 per cent in the next 20 years, placing even more stress on Alberta and the prairie water supply. Given these population and agricultural pressures, Alberta and the prairie watershed should be considered the “ground zero” for water problems as the climate changes.

The Great Lakes and River Systems

To illustrate the far-reaching implications of climate change for water management and governance, several important transboundary river and lake basins will be examined: the Laurentian Great Lakes, the Mackenzie River system, and the Columbia River.

The Laurentian Great Lakes are experiencing the effects of climate change through issues related to both water quality, and lake levels. Both aspects are dealt with, at least partially, under the 1909 Boundary Waters Treaty (Canada-U.S.A), including the Great Lakes Water Quality Agreement (1972, 1978, 1987). This agreement is being revisited in 2011-2012. Adapting to climate change is bound to be one focus of a renegotiated agreement. Impacts of climate change on water quality are due to two

main aspects of the changes, higher temperatures and more frequent heavy rain events. The most obvious evidence of the warming trend has been the gradual shrinking of the average winter ice cover. On Lake Superior, for example, the ice cover has decreased from 35 per cent (1973) to 10 per cent, with similar trends on the other lakes (IJC, 2010). Of course, fluctuations in this trend occur from year to year.

A reduction in ice cover produces major changes in the lakes’ energy budgets. The dark water absorbs more solar energy than highly reflective ice and snow, warming surface layers. This, in turn, increases wind speeds and evaporation, especially in fall and winter months, tending to drive lake levels lower, especially on Superior, Michigan, and Huron. Some of that additional evaporated moisture in the atmosphere falls out as increased lake-effect snows in the lee of the lakes (mostly south and east). The Ontario region, south and east of Lake Huron and Georgian Bay, has experienced increases in winter precipitation of as much as 2 cm per decade since 1970. In strong storm events, snow squalls, it results in serious traffic and snow removal problems, and a greater winter/spring runoff.

Another consequence of declining ice cover is earlier seasonal stratification with the warming surface waters separated from the cold bottom waters. This prevents oxygen from the atmosphere from reaching the bottom waters. There, biological decay processes use up bottom water oxygen, causing anoxic or dead zones for fish and bottom fauna. This had been a chronic problem in Lake Erie in the 1960s and 1970s and was largely overcome by aggressive bilateral phosphorus control under the 1972 Water Quality Agreement. But now, anoxic zones are returning to Lake Erie. This is due not only to the longer period of stratification, but also to the increased frequency of intense rains. Over much of the Great Lakes basin, heavy precipitation events greater than those experienced in only one per cent of rain



intensities increased 27 per cent from 1958 to 2007 (Karl et al. 2009) and, the frequency of such events is projected, by climate models, to double in this century.

Intense rain events cause the erosion of cropland in the Great Lakes basin, along with their toxic chemicals and nutrients (Bruce et al. 2006). These particles, plus other contaminants on rural and urban surfaces, are washed into the lakes and their tributaries in runoff from heavy rain events. On the largely agricultural Maumee River basin on the southwest side of Lake Erie, continuous measurements have shown that most of the phosphorous is discharged to Lake Erie in short episodes immediately after heavy rain events (Soil and Water Conservation Society, 2003). While such measurements are not available on the Canadian side, this is likely the case throughout the basin. More intensive agriculture and animal feed lots contribute to the pollution loads. It is not surprising that intensive algal growth is clogging all Great Lakes shorelines except Superior, where populations and agricultural activities are low. It is imperative that renegotiations ensure that a revised Great Lakes Water Quality Agreement contains stronger provisions to control these diffuse sources of pollution from both urban and rural areas.

The Mackenzie River Basin is also facing issues induced by climate change. High flows and levels on the main stream of the Mackenzie system in summer are important to the northern communities in the Northwest Territories (NWT) that receive supplies by barge traffic. Since 1970, winter and spring temperatures have risen 3°C at Yellowknife, and 3.5°C at Inuvik which is further north. In addition, spring freshets are earlier and trends in summer flows are downward. Water quality and fish contamination is another concern of aboriginal communities in the basin. Lower summer and autumn flows are evident in the three main tributaries: the Liard, the Peace and the Athabasca.

These headwater tributary rivers arise and flow through other jurisdictions than the Northwest Territories, Yukon Territory, British Columbia and Alberta. Only the Yukon has a specific water agreement with the Northwest Territories. British Columbia has a large dam which forms the Williston reservoir on the Peace River, and is proposing a further site “C” dam for hydropower production. This has changed the ice regime downstream, and the timing and magnitude of the spring flood which is important to ecosystems, especially in the Peace-Athabasca Delta. The Athabasca River is the main source for the water-hungry oil sands projects near Fort McMurray, Alberta. On the Athabasca, with climate change, the declining lowest flows are not in summer, but in winter, with gradually less water to dilute pollutants. It has also been shown (Schindler, 2010) that emissions to the atmosphere from oil sands activities are transported downwind. Some contaminants are deposited on snow, tree needles and land, and subsequently washed into waterways some distance from the source. Indeed, a number of persistent toxic compounds are now appearing in aquatic ecosystems of the Mackenzie basin. These may have been transported mainly from sources more distant than the oil sands, but the latter have contributed.

The Mackenzie Delta is increasingly subject to damaging storm surges and salt water intrusion from the Beaufort Sea. Four climate-related factors are at work: reduced protective ice cover near shore, increasing rates of sea level rise, increased numbers of severe winter storms, and increased thawing of permafrost on shorelines. More frequent erosion and flooding episodes are occurring, requiring the retreat of settlements inland. Productive estuary ecosystems on which local populations depend, are also being significantly changed. The thawing of permafrost results in land slumps in the Mackenzie Basin, which re-route streams, drain perched lakes and affect groundwater movement, as well as damage pipelines and buildings.



The Northwest Territories government, in collaboration with its aboriginal population, has developed an ambitious strategy called “Northern Voices – Northern Waters,” to use and protect the waters within its borders, especially the main stem of the Mackenzie River. The changing climate must be fully taken into account in pursuing this strategy. However, it is clear that without firm agreements on water sharing and water quality (and air pollution) with British Columbia and Alberta, achievement of the Northwest Territories’ goals in the context of both headwaters’ industrial development and climate change will not be possible.

As a third example of the need to adapt to climate change impacts in connection with transboundary water issues, consider the Columbia River. Under the Columbia River Treaty of 1961, a series of dams and reservoirs were constructed in Canada for storage of about 31 per cent of the runoff from the Canadian part of the basin. This was to provide for hydropower shared between the two countries, and for a measure of flood control and water supply for ecosystems and fisheries downstream in the United States.

From 1970 to 2009, the mean annual flow at the International Boundary first increased, on average, until the 1990s, but has declined slightly (from about 2,910m³/sec to about 2,800m³/sec to 2009). Minimum flows had similar trends but greater recent declines (from about 2,000m³/sec in late 1990s to about 1,200m³/sec in 2008 and 2009). On the other hand, maximum flows declined from 1970 to 1995, and have since increased to early 1970s levels. The flows at the border are influenced, of course, by operation of the reservoirs in Canada. However, climate change and variability play major roles. Columbia River flows reflect substantially the melting of mountain snow packs and glaciers in the basin. The water from the snow packs tends to influence the maximum discharges in May and June, becoming gradually earlier, and

often augmented by increasing spring rains in the warming climate. Glacier melt tends to be slower and is reflected more in minimum flows, which rose to the end of the last century, but have been generally declining since then. This suggests, but does not conclusively prove, that the Columbia has moved to the declining phase of glacier contributions.

As the climate warms, melt water from glaciers initially contributes more water to rivers, but the amount of melt reaches a tipping point when glaciers have shrunk to the point that their contributions to flow declines. On the other side of the Rocky Mountains, glacier contributions to the Saskatchewan River have been shown to have reached the declining phase. Evidence is not as clear on the Columbia River, but there is a hint in the data that the decline is already beginning, with winter and spring temperatures up by 2.5°C since the 1950s, and glaciers retreating (Demuth, et al., 2008). A small portion of this temperature rise is attributable to fluctuations in Pacific Ocean temperatures which induce the Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO) – modes of natural variability of the climate system. Years with a positive (warm) PDO and El Niño tend to be drier than negative PDO and La Niña periods, with these fluctuating Pacific climate modes (Fleming and Whitfield, 2010). They bring year-to-year variation in the general climate trends. However, it is estimated that most of the temperature increase since 1970 is due to greenhouse gas forcing (Bonfils et al. 2008).

There is a danger in renegotiation of the Columbia River Treaty (by 2024) in that the extra minimum and mean flows from glaciers up to the 1990s will be used as a basis for sharing the waters and its benefits. However, with continuing climate warming, declining minimum and mean flows are to be expected, not only from declining glacier contributions but also from increased evaporation from reservoirs in Canada with higher water



temperatures. Thus, without taking climate change into account, Canada could be lulled into trading away more water and benefits than will occur in its future.

Overland Flooding

In spite of the general decline in annual flow volumes, climate change factors are conspiring to increase short-term flash flooding, mostly on small watersheds and urban areas, and major floods on large basins in central and eastern Canada. For flash floods, the frequency and intensity of heavy rain events is on the rise. This is occurring because as the atmosphere warms, it holds more water vapour, or precipitable water. In theory, for each degree Celsius increase, the atmosphere holds seven per cent more water vapour. Thus, when atmospheric mechanisms get ready to rain, it doesn't just rain, it often pours. It has been shown that in coming decades, over most of Canada, the frequency of rainfalls of high intensities will double. For example, intensities that have been equalled, or exceeded only once in 20 years, will occur every decade on average (Kharin et al. 2007). This trend is already evident, and intense rains have recently caused serious infrastructure damage from Toronto and Peterborough in the south, to Pangnirtung in the Far North.

The behaviour of watersheds is influenced by its vegetation. Wildfires and insect infestations are increasingly affecting such vegetation, especially in the vast boreal forest and in interior British Columbia. For every degree Celsius rise in temperature from 1970 to 2000, an additional 100,000 square kilometres of forest was burned (Flannigan et al. 2005). Warmer winters have also permitted flourishing of mountain pine beetles which have killed trees in more than nine million hectares in British Columbia. These beetles are now invading Alberta. The resulting forest devastation makes watersheds more prone to flash flooding. That is, the heavy rain events run off faster, causing higher flood peaks, with less water retained for low

season flows. An important consequence of the heavier rain events has been a national epidemic of basement flooding from overtaxed sewer and drainage systems. Indeed, insurance industry data now show losses due to water damage outstripping the previously largest hazard – fire.

In both Canada and the United States, it has been found that two-thirds of all disease outbreaks from water occur after intense rain events, inexorably increasing in frequency and amounts. Such intense events result in erosion of, and contaminated runoff from agricultural lands, unintended street washing in urban areas, and in older cities with combined sewers, the overflow of storm waters into sanitary sewage and discharge of this heavily polluted mixture to the nearest water body or well. It is no wonder that health hazards increase after such events and, at times, serious ecosystem impacts occur. Summer, on many rivers and lakes, increasingly brings lower average levels and flows, punctuated by short high-flow events. Higher water temperatures are reducing the range of cold water fish species, but increasing habitat for warm water fish in, for example, the St. Lawrence River (Hudon, 2009).

“Floods of the century” are becoming increasingly frequent on the Red River and its tributaries. Climate change, forced by ever-increasing greenhouse gases, is strengthening the low level transport of moisture from the Gulf of Mexico to the Great Plains in late winter and spring (Cook, 2008). This results in more precipitation, first snow then rain, especially in the more southerly parts of the Red, Souris and Assiniboine basins, which produce more frequent severe spring flooding in eastern Saskatchewan and Manitoba. Eastern Canada – from southeastern Quebec to Atlantic Canada – is also expected to experience flooding on larger river systems. This is a response to more intense winter storms (Lambert, 2004). Also, a greater frequency of hurricanes in autumn, strengthened by warming Atlantic ocean waters, are able to travel further from southern North



Atlantic origins, northward to Atlantic Canada (Emmanuel, 2005).

An increase in the intensity of storm events brings other types of flooding hazards from the sea to the Atlantic region, including the Quebec North Shore. Flooding from the sea is also a problem in coastal British Columbia and Northwest Territories. Sea level rise is accelerating, due to both thermal expansion of the warming waters, and to more rapid melting of ice on land, including that in the Canadian Arctic Archipelago and Greenland. This rise is combined with stronger wind storms, resulting in storm surges.

On the shores of the Gulf of St. Lawrence, damage from strong winds and storm surges is increasing. Storm surges are expected to reach four metres in height, once every decade, by the end of this century. Similar problems are occurring in low lying areas on the west coast, such as southern Vancouver Island and the Fraser River Delta. Heavy rain accompanying severe storms is, at times, blocked from draining to the sea by the higher sea levels. In the vicinity of Tuktoyuktuk, on the Beaufort Sea, thawing of permafrost along the shoreline, more frequent severe storms, and loss of protective shore ice combine to result in shoreline retreat due to erosion, as well as flooding. These events often require the movement of buildings and facilities to higher ground. Sea level rise and storm surges can also result in salt water intrusion into groundwater and further into estuaries, changing aquatic ecosystems and making fresh water supplies more saline.

Adaptation Solutions for Freshwater Resources

Continued failure to adequately address climate change in Canadian activities and development ensures that serious water crises will arise in coming decades. Some of the changes caused to water abundance, distribution and quality will be affected by climate warming, regardless of what

humans do. But much can be done to mitigate some of the effects, or adapt to them to minimize or delaying the adverse impacts of climate change.

A good start would be to simply reduce water consumption. Canadians use roughly three times the water per capita of many European countries, without any improvement in sanitation. They also have done much to destroy the “ecosystem services” provided by watersheds in protecting the quality and quantity of freshwater. Below are some of the adaptation measures that could help to protect and conserve water, without imposing undue hardship on human populations.

1. Protect and Restore Wetlands and Natural Drainage Patterns

In southern Canada, up to 70 per cent of wetlands have been destroyed, usually in order to gain land for agriculture and urban development, or to control mosquitoes. The ecosystem purposes that they provide are generally unrecognized. Wetlands function as the “capacitors” of watersheds. During rapid snowmelt and after heavy rainstorms, they prevent much of the water from running off immediately to nearby rivers, and help to prevent floods following rapid snowmelt or heavy thunderstorms. They make this water available during dry periods, as the infiltrating water recharges aquifers in the area, buffering against the effect of future drought. Wetlands and vegetated soils are also important at removing suspended particles from water, and retaining pesticides, nutrients and other chemicals, preventing them from reaching surface waters or aquifers.

Drainage modification is an important reason for the increased floods observed in many areas, such as the Red River Valley of Manitoba and three Midwestern U.S. states. We need to regard watersheds, and particularly wetlands, as important features in hydrological systems, acting much as capacitors do in electrical systems, evening out the flows from watersheds to lakes and rivers.



Unfortunately, policies to protect and restore wetlands in Western Canada are poorly developed. Alberta has had a stakeholders' committee studying wetland policies for several years. But, in general, overtures from the powerful industrial interests have been heeded, rather than the advice of other stakeholders. While no policy has yet been forthcoming, in Alberta, there is strong pressure to have mining in the oil sands exempted from any wetland replacement policy. Similar pressures are coming from agriculture. Restoration of wetlands is an effective adaptation to climate change, and policies requiring their restoration must be rapidly developed.

Another simple way to increase water on the prairie landscape is to protect beaver populations. Hood and Bayley (2008) showed that the restoration of beaver to Elk Island National Park in the 1950s caused the area of open water in the park in 2002 to be 61 per cent greater than in 1950, even though 2002 was the driest year on record. They found a near linear correlation between the number of active beaver lodges and the area of open water in the park. However, beavers are currently poorly protected, and where flooding of roads or damage to trees become problems, they are generally exterminated.

2. Change the Design of Human Infrastructure to Conserve Water Quantity and Quality

Impervious roads, parking lots and roofs also act as conduits to deliver water, falling as precipitation, rapidly to lakes and rivers. They play important roles in cities, where flash floods and overloaded storm sewers commonly follow thunderstorms. These impervious surfaces also prevent water from recharging groundwater aquifers. In a few areas, such as the lower Fraser River watershed, porous parking lot surfaces and uncurbed roads are beginning to be used to mitigate runoff, to ensure that infiltration recharges ground water.

Runoff from roofs can also be mitigated. In some

areas, sod roofs have successfully been used to reduce runoff, while also providing summer cooling by evaporation. Some flat roofed commercial buildings have even been used as gardens to produce food or flowers. The increasingly frequent large-scale flooding in the Red-Assiniboine basins is likely related to greater transport of moisture from the Gulf of Mexico in the greenhouse gas influenced climate. Adaptations are difficult in the flat land areas, but floodplain mapping and flood proofing of all facilities in the floodplain can reduce losses and personal stress.

Even with conventional roofs, the addition of rain barrels or cisterns can reduce runoff considerably. This water can then be used for lawns, gardens and house plants, reducing demand for expensive tap water that has been treated to human consumption standards. They also reduce the probability of storm drains being overloaded following thunderstorms. In some water-scarce areas, rainwater is also used for flushing toilets, which again do not require water treated to drinking standards.

Other ways to reduce domestic water consumption can be found on many "green" websites. They include such recommendations as metering and mandatory low-flow shower heads and low-flush toilets, which are already becoming common in many water stressed areas. Inverse pricing schemes, where a basic water allocation per capita is quite inexpensive, but cost rises rapidly as use increases, are another way to encourage water conservation. In particular, pricing and other measures can be used to discourage permanent degradation of water, and to reward returning water in good condition to rivers and aquifers.

There are other helpful measures that can help to mitigate the effects of extreme precipitation events. Floodplain land mapping, and designations to limit development in harm's way, need to be kept up to date to reflect increasing heavy rains and greater upstream developments.



Such developments should be built with more permeable surfaces to permit infiltration to groundwater. To minimize the now frequent basement flooding, homeowners should install backwater valves to prevent sewer backup. In very vulnerable areas, municipalities should consider subsidizing these actions. Unknown to many, much treated water is also lost in the distribution systems of older cities. Losses of 30 per cent and more are quite common. Many large western cities have already undertaken programs to reduce water losses via leaky distribution systems.

3. Change Patterns of Lakeshore Development to Protect Water Quality

Lakes throughout the central and southern parts of Canada have increasing water quality problems in mid-to-late summer that result from excessive inputs of nutrients and pathogens. In most cases, watersheds have been cleared for agriculture, and shorelines are rimmed with hundreds of seasonal cottages. In some cases, communities are built right on the shores of lakes and rivers. Most prairie lakes and streams are naturally very nutrient rich, and the watershed modifications since the mid-20th century have doubled and tripled nutrient input to most.

Phosphorus is usually the nutrient of greatest concern. If it increases disproportionately to the other nutrient in most demand, nitrogen, Cyanobacteria species capable of fixing atmospheric nitrogen become dominant in summer algal populations. Most of these have long filaments or gelatinous sheaths, making them unsuitable as food for most aquatic herbivores. They also produce potent hepato and neuro toxins, and compounds that cause taste and odour problems. As a result, large algal blooms, sometimes accompanied by rotting algal masses on shorelines, have become common on developed lakes. Fish kills resulting from low oxygen conditions as the algae rot on the bottoms of lakes are also becoming more frequent complaints

(Schindler and Vallentyne, 2008).

The development of large blooms of nuisance algae and associated problems increase, as lake levels decline to the point where outflow is near zero (a point already reached in many western lakes). Retention of phosphorus, the main cause of eutrophication, becomes 100 per cent because there are no losses to the atmosphere, as for other major nutrients. However, flooding following snowmelt and extreme thunderstorm events can also release large amounts of phosphorus from watersheds.

For example, flooding in the Red River Valley near Lake Winnipeg causes manure piles, hog lagoons and phosphorus-saturated soils to be covered with or surrounded by water, sometimes for periods of several weeks. Eventually, the water, with its burden of nutrients, pesticides and other chemicals, drains to the lake. As a result of increased nutrient inputs, algal blooms have increased greatly in the last 20 years (McCullough et al. 2012).

The increasingly frequent large-scale flooding in the Red-Assiniboine basins, in addition to more localized urban flooding throughout central Canada, is likely related to greater transport of moisture from the Gulf of Mexico in the greenhouse gas influenced climate. Adaptations are difficult in the flat land areas, but floodplain mapping and flood proofing of all facilities in the floodplain can reduce losses and personal stress.

The solutions for protecting lakes across Canada from development across Canada are simple. Keep development in the catchments of valuable lakes as low as possible. Restrict use of fertilizers and use of land for feedlots. Require that human development is well set back from lake shores. Retain natural vegetation along lake shores. Restrict the use of lawn and garden fertilizers. Pump out sewage and transport it out of the watershed, or use composting or combustion toilets, followed by



disposal of the remains outside the watershed.

4. Move Population and Water-Intensive Industry to Water, not Vice-Versa

Humans have a long tradition of using canals and diversions to move water to exactly where we want it. But recent science has shown us that the disruption of flow patterns has important biological consequences, as biota from one watershed gets transferred to another. Also, the engineering costs of dams and diversions are high and increasing, so that the return for investment is low. A better strategy would be to plan population, agricultural and industrial growth for areas where water is plentiful, perhaps even offering incentives to encourage such population movements.

For example, in Alberta, the Peace River carries about 70 per cent of the water leaving the province, but the watershed is developed only lightly, despite an abundance of fertile agricultural land. It would be worth considering moving some of the irrigation that now occurs in the South Saskatchewan system northward, where the crops are cattle forage or other products not directly used as human food. The saved water in the South Saskatchewan could then be used for more immediate needs, such as growing fresh produce for people, as described below.

5. Integrating Human Water Uses at Watershed Scales

Typically, the water needs of humans are managed piecemeal, via the licensing of individual projects. Often this results in wasteful uses of water, and ignoring the needs of a healthy ecosystem. There are already several efforts underway in Canada to integrate human water uses at watershed scales that offer important information on how this process works.

Ontario has started the process of integrating adaptation into wetland protection through

municipally based river basin conservation authorities. The conservation authorities are required to monitor and ensure that instream flow is adequate for ecosystems, provide source water protection for human uses, and develop flood plain designation and management. For example, the Toronto Region Conservation Authority has already modified its design flood criteria in light of climate trends and projections.

Recently, the Bow River Project Research Consortium in southern Alberta has shown that by integrating water use and needs at a watershed scale, substantial water savings are possible. The Bow River watershed has many demands made from a small river. The river provides about half of Alberta's water for irrigation, the water needs of a city of over one million people (Calgary), and more than 90 per cent of Alberta's hydroelectric generation. It also contains five species of trout, and is regarded as one of the world's premier trout fisheries. Integrating the demands of 14 stakeholders groups, including the Alberta Water Research Institute, irrigation districts, city and county governments, and conservation groups, has led to the following results (Bow River Project Research Consortium, 2010):

- summer releases from upstream hydroelectric reservoirs can improve flows and water quality downstream without compromising hydroelectric generating capacity;
- changes to the management of flows from dams in the Kananaskis River can greatly improve the downstream fishery and other ecological values;
- stabilized water levels in Kananaskis Lake can improve the fishery and create new recreational and tourism experiences;
- the water demands of Calgary, the First Nations in the basin, and other communities can be accommodated;



- irrigation can be expanded with the improvements, without impacting the river.

The Spray Lakes Reservoir can be restored to its original design capacity, significantly increasing water storage in the entire Bow watershed. The Consortium has plans to refine its integrated management model, with the objective of having an integrated adaptive management plan. The model could be emulated in other watersheds with similar efficiencies.

In addition to adaptive management planning, as outlined above, cities and industrial centers should not be planned for flood-prone areas because of the difficulty in protecting and evacuating them during floods.

6. Protect Water Needs for Canadian Food Security

Recently, there has been increasing attention paid to exports of “virtual water,” defined as the water used to produce goods for export, such as grain, meat or hydroelectric power. While such exports are lucrative, they leave behind damage to water quality, water quantity and aquatic biodiversity. At present, Western Canada exports much more “virtual water” in the form of wheat, beef, and other commodities than it imports (Liu and Zeng, 2010). Many of these agricultural products are exported to countries where water is even more scarce, such as Japan, China and the United States. In the future, it will be necessary to keep a close eye on the uses of virtual water. In water scarce areas, water must increasingly be reserved for the needs of residents.

For example, it is clear that the waters of the South Saskatchewan River need to be used for more important purposes than irrigating grain and raising livestock. The human population in the Alberta part of the basin has been increasing rapidly. At present, the majority of the fresh fruits and vegetables

consumed in Canada during the winter and spring months are grown in the southern United States or in the southern hemisphere, while local water is used to irrigate commodities for export.

One major supplier of fresh vegetables is the Imperial Valley of California, which supplies 90 per cent of the winter produce for U.S. markets and is an important source for Canada as well. The Imperial Valley was once an arid area, but has been turned into a major supplier of food by using irrigation water from the Colorado River. The water is trapped by the Hoover Dam to form Lake Mead, a reservoir. From there, the water is transported across 80 km of desert, by the American Canal to the Imperial Valley. The area supplying water to Lake Mead has been subject to 11 consecutive years of drought, and water levels in the reservoir are about 30 m below average. Water is already scarce in the area, and approaching critical scarcity. In addition, high demands for water in growing urban areas like Los Angeles and San Diego are causing the price of water to increase dramatically. This situation is predicted to become much worse with a warming climate. Present predictions are that Lake Mead will be unable to meet water demands by mid-century.

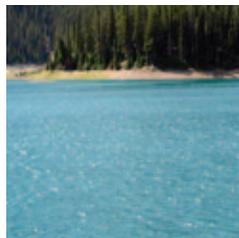
The rapidly increasing price of fuel and the need to cut greenhouse emissions, will greatly increase the costs of transporting fresh produce to Canada. As production in the Imperial Valley dwindles, there will be increasing demand for its produce from U.S. customers, which will drive prices up for Canadians. In short, it is time that we begin adapting to future problems of food shortages. One way to do this might be to convert under utilized sources of freshwater, such as the South Saskatchewan basin, into a supplier of produce. Initially, this might require huge greenhouses, which would require solar, wind and geothermal heating sources for winter operations. Greenhouse produce can be irrigated much more efficiently than field crops, and the scarce waters of the system could be used much more efficiently. Reduced transportation



costs, and increased Canadian food security would be other benefits. As the climate continues to warm, heating costs should decline, and the season when crops can be grown outdoors should increase in length.

The above are but a small start on the adaptations that will be needed to cope with changes in climate

as predicted under “business as usual” climate scenarios. There is no question that changes to the western Prairies, the Great Lakes and Canada’s river systems will be both ecologically and socially devastating (Sauchyn et al. 2010), and adaptation will require robust and quickly adaptable policies, as many surprises are certain to occur.





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4. Aboriginal Communities

Chris Henderson

President of Lumos Energy, Chair of the Delphi Group, and National Coordinator, Aboriginal Clean Energy (ACE) Network

Dr. Judith Sayers

Chief, Hupacasath First Nation, British Columbia (1995-2009); Chief Negotiator for the Hupacasath First Nation

Susan Aglukark is an Inuk musician. Born in Churchill, Manitoba, and raised in Arviat, Nunavut, her songs sing of hope and community. Her banner piece, O Siem, speaks to the communal life of Canada's indigenous people: "O Siem, We are all family, O Siem, We're all the same."

Susan Aglukark's words reflect the spirit of communalism within First Nations, Métis and Inuit communities, a spirit that defines the place of the First Peoples of Canada. Many First Nations, Métis and Inuit indigenous peoples draw their cultural identity, sustenance, traditional livelihoods and social cohesion from a sense of place; Aboriginal Peoples feel this connection with all of Canada. As the climate changes, so will this connection.

In 2006, the total aboriginal population was 1.2 million, comprised of First Nations (698,025), Métis (389,700) and Inuit (50,400). Collectively, these groups are growing at a faster rate than any other group across the country. Half the population is under 25 years of age and one-third is younger than 14 years. For this reason, we know that Canada's aboriginal populations will boom in the first half of the 21st century.

Climate Change Challenges for Aboriginal Communities

The vulnerability of Aboriginal Peoples to climate change is defined by three major factors:

geography, connectedness to land, and poverty and resource limitations. Communities are often small and, almost always, located close to water in low-lying zones. In fact, over half of Aboriginal Peoples live in one of 1,900 aboriginal communities spread across Canada. Some are hamlets with a few dozen people, while others are bustling villages with thousands of residents. These communities and the livelihoods of Aboriginal Peoples are dependent on land, habitat, wildlife and sea resources - much of which will now be impacted by climate change. The majority of Aboriginal Peoples are among Canada's poor and their overall wealth is very limited. As such, aboriginal capacity to respond to climatic impacts is very constrained.

Climate change is already impacting aboriginal communities, and the phenomenon will escalate into the future. The physical effects of climate change include: drastic fluctuations to seasonal weather patterns, rising sea level, ocean and lake storm surges, melting permafrost, more frequent and longer duration floods, wildfires and severe weather events. The cumulative impact of these forces creates three major challenges for aboriginal communities across Canada.

1. Dramatic and Continuous Degradation of Community Infrastructure

In Northern Canada, climate change is melting the permafrost that supports important community infrastructure. Homes and community structures are already beginning to shift and collapse. Most communities do not have the money to prevent complete destruction of their homes and communities and are now looking for methods on how to adapt to melting permafrost (AANDC 2007).

Many aboriginal communities are located along water bodies. Due to increased rainfall and temperature fluctuations that generate intense snowmelts, these water bodies are increasingly overflowing their banks, leading to significant damage. The Ontario communities of Kashechewan



and Fort Albany, for example, are consistently threatened by flooding. The 2012 spring flood in Kashechewan was its fifth related experience in eight years (D'Alieso, 2012). In addition, many communities located near these bodies of water are starting to experience more severe storms. As the ice cap melts, storm systems can draw more moisture and energy from the open ocean.

Droughts will also become more frequent for some aboriginal communities. As precipitation levels drop below historical averages, wildfires become more probable and a significant threat for isolated communities (AANDC 2007, p. 62). For some communities, this threat is conflated by the emergence of the mountain pine beetle. In British Columbia, this invasion of the pine beetle has killed most of the pine trees and the standing tinder dry wood is a huge risk for fire. Many aboriginal communities are surrounded by these high-risk wildfire forests.

2. Diminution of Traditional Livelihoods

Climate change has drastically changed the way of life of many aboriginal people throughout Canada (Crawford, Wehkamp and Smith, 2010). Many traditional sources of food have shifted their migratory patterns in response to warmer temperatures (CIER 2006b, p. 36). There is evidence that these patterns have shifted for a range of animals, including: seals, walruses, polar bears; beluga, fin, bowhead, and minke whales; land mammals, such as, caribou, reindeer, moose, and muskox; fish, such as, salmon, Arctic char, and northern pike; and a variety of birds, including ducks, geese, and ptarmigan. Warmer ocean temperatures have affected the viability of many sea resources, like salmon on the West Coast and other species on the East Coast. For people who have relied on the land, on wildlife, fish and other seafood, this has been devastating and caused cultural dislocation.

Extreme and variable weather events are also

a significant threat to the livelihood of these communities. Variable rain events have led to an increase in coastal erosion and landslides that cut off access to traditional hunting grounds. Conversely, decreased rainfall in some areas has led to droughts and wildfires that shift the traditional hunting populations. Often, these weather events have led to forced evacuations of communities from their traditional territories.

Along with hunting, trapping and fishing for personal use, Aboriginal Peoples have also relied on these activities for economic purposes, such as selling meat, fish, furs and other byproducts. Artists, artisans and other crafters rely on wildlife, birds and plants and other materials to produce works to generate important economic activity. It is critical that aboriginal communities maintain the capacity to generate alternative sources of income through the arts. These important markets are threatened as migratory patterns change in response to climate change.

Eco-tourism – another valuable new source of economic growth for aboriginal communities – is also threatened by shifting migratory patterns (CIER, 2006c). Eco-tourism relies on consistent access to wildlife that may be viewed on tours, waterways to use for canoe tours, and the preservation of traditional ecosystems and plant life. Without these important attractions, aboriginal groups lose important links to their history, which represents the central appeal for eco-tourists.

Gathering, is and has been, a way of life since time immemorial for Aboriginal Peoples. Gathering medicinal plants, foodstuffs, materials for cultural regalia, (barks, feathers, furs, antlers, roots, shells, woods, etc.) materials for basketry (grass, needles, cedar barks and various roots), and other cultural imperatives continues to be done by Aboriginal Peoples (CIER 2006c, p. 14). Climate change is affecting the ecosystems which support the growth of many of these things that Aboriginal Peoples rely on. Areas where plants, trees and other living



organisms once thrived are experiencing significant and dynamic change. Biospheres are evolving and moving north. As a consequence, aboriginal communities are no longer able to access traditional materials.

The way of life of Aboriginal Peoples is also negatively affected by health concerns for elders and other vulnerable people who cannot tolerate heat, or excessive moisture or cold. The health of Aboriginal Peoples shifts with the climate and affects the most vulnerable.

3. Catastrophic Disruption to Community Access and Energy Capacity

As climate change leads to shorter ice-in seasons, higher water levels, floods, permafrost melting, strata weakness, and other severe weather events, important transportation routes – including roads, harbours and airports – will face significant disruptions. Important communications technologies that rely on stable transportation routes are also at risk, including the destruction of towers/satellites, fibre-optic cables, and other technologies.

Ice roads, which serve as a critical lifeline for remote aboriginal communities are particularly exposed to the changing northern climate. The Centre for Indigenous Environmental Resources argues that the implications of climate change will be significant for remote communities dependent on ice roads, including those that host major mining, energy, and timber operations (CIER, 2006a). To preserve these ice roads, long-term strategic planning will be necessary.

The cumulative effect of the above factors produces a simple and devastating conclusion: climate change will have a hugely negative impact on aboriginal communities and livelihoods, food security, and health. These communities will be amongst those most impacted by climatic consequences, with constrained ability to adapt

effectively. As Canadians, we must recognize that it is just and equitable for national climate change adaptation efforts to fully integrate First Nation, Metis, and Inuit communities in the processes of understanding how climate change will affect the country, and how to devise adaptive strategies.

Adaptation Solutions for Aboriginal Communities

The costs of the above realities are already material and rising rapidly. It is imperative to act. Three climate change adaptation strategies are proposed. These strategies are designed to be supported through collaborative partnerships between aboriginal communities, governments, NGOs, and private industry (see Indigenous People's Global Summit on Climate Change 2009 for a broader overview of the link between climate change and First Nations peoples).

1. Comprehensive Community Capital Planning for Climate Adaptation

The *dramatic and continuous degradation of community infrastructure* linked with climate change requires comprehensive community capital planning. Such planning must integrate several key policy principles to be effective.

Community Redesign and Relocation. Aboriginal communities have not been designed to meet climate change threats. Critical infrastructure within these communities will need to be made more resilient to the changing climate, if it is to survive its full life cycle. In extreme situations, this may require community relocation with the consent of the aboriginal groups, including their choice of alternative locations. For example, continued spring flood events could require the redesign and potential relocation of vulnerable facilities in the communities of Kashechewan and Attawapiskat (Ontario), Tuktoyatuk (Northwest Territories), and Peguis First Nation (Manitoba). To facilitate community redesign and relocation,



the development of an aboriginal climate infrastructure assessment is a necessary first step. This assessment can help evaluate potential infrastructure weakness, and inform decision-makers about redesigns and potential relocations. Aboriginal groups can choose to implement the assessment to better evaluate their exposure to climate change and potential options to strengthen resiliency.

Adaptation Community Infrastructure Program.

Aboriginal Affairs and Northern Development Canada (AANDC) must integrate climate change adaptation design features into a community infrastructure program. If aboriginal groups choose to implement a climate infrastructure assessment (as suggested above), then AANDC must be ready with new building practices and codes that can address potential recommendations that emerge. This program must help facilitate the development of new standards for buildings and facilities that anticipate climate risks, such as melting permafrost, storm surges, and extreme weather.

2. Adaptation Guided by Traditional Knowledge

The diminution of traditional livelihoods is a significant outcome as the climate changes for aboriginal communities. Simply integrating this knowledge and experience into adaptation planning represents a critical step in preserving traditional livelihoods.

Traditional Knowledge. Aboriginal Peoples must document climate change in their territories and then find solutions to adapt to the changes. Many changes are based on lived experiences and are not written down or fully defined. Documentation and cataloguing of these impacts is critical, if solutions are to be found.

Adaptive Management. Aboriginal communities must determine, for themselves, whether they see common elements and/or opportunities between adaptive management and their own culturally

specific knowledge systems. If so, then responsible authorities can offer adaptive management as a viable framework within which indigenous and western science knowledge holders can learn together. Governments must put in place effective and immediate mitigation and adaptation policies and programs, only with the consent of and joint development with aboriginal groups. Adaptive management should include a comprehensive sustainability plan that is integrated into a federal and/or provincial plan. This necessarily includes efforts to reduce greenhouse gases.

Food Security. There is a need to ensure current and long-term planning for food. Food security is important for all human beings, but in particular for indigenous peoples who are most impacted by climate change. Aboriginal Peoples have long relied on the fish, sea resources, wildlife, birds, and the gathering of foodstuffs for their main diets. Measures must be taken by governments, either through legislation or policy, to protect species/foodstuffs used by aboriginal communities that are threatened by climate change, and to plan for other sources of food.

While these principles offer an important framework for integrating traditional knowledge into adaptation solutions, there are some specific steps that could help in the process of implementation.

- the preparation of a primer on the impact of climate change on habitats, wildlife, fisheries, traditional livelihoods, foodstuffs and medicinal plants;
- legislation in the Northwest Territories and northern British Columbia to protect caribou herds and habitats, with precedence over other provincial/territorial legislation;
- amendments to the Fisheries Act, to give more authority for Aboriginal Peoples to exercise their economic rights while taking into consideration climate change.



3. Integrate Resiliency into Community Access & Energy Capacity

As this report suggested, aboriginal communities are often located in geographically isolated locations and face significant transportation and energy challenges. Climate change will continue to intensify these challenges. The following recommendations outline some practical steps for addressing these critical challenges.

Emergency Preparedness. The federal government – through its responsibility under s. 91(24) of the Constitution Act, 1867, the Indian Act, treaties and other binding agreements – has an obligation to meet the human needs of communities, needs that may be compromised during times of climate emergency. It is proposed that a climate adaptation energy measures protocol be developed, which would “kick-in” when communities need help from climate impacts. This protocol should establish a climatic emergency measures fund within Aboriginal Affairs and Northern Development Canada as an internal property insurance mechanism, and a set of guidelines to inform when the protocol should be invoked.

Provide aboriginal communities with the resources to prepare for floods, rapidly rising water, fires, severe weather events and increasing winds. Notably, it is necessary to establish funding mechanisms for community and emergency planning. In times of crisis, governments must also be committed to react and assist in a timely manner – to provide essential services, and restore the community to livable conditions. Insurance markets can also be leveraged to provide coverage for these risks.

Transport Infrastructure Assessment & Renewal. From the perspective of transportation, climate change will “cut the physical link” between some aboriginal communities and the rest of Canada. Not only will this impact indigenous peoples, but it

also jeopardizes Canadian sovereignty and access to natural resources. It is therefore proposed that an aboriginal transportation infrastructure renewal mechanism be established to address these key risks. This mechanism should include two important elements:

1. National analysis of transportation infrastructure and aboriginal communities at risk, and the subsequent development of a long-term strategy and funding capacity to ensure that critical transport infrastructure is renewed, accounting for climate change impacts.
2. Inclusion of traditional knowledge and climate change science in the Canadian Environmental Assessment Act relative to new infrastructure construction, such as roads and bridges. The Canadian Environmental Assessment Agency could develop new standards on environmental assessment, informed by traditional knowledge.

Renewable Energy Development for Off- and On-Grid Communities. It is critical to catalyze all commercially viable sources of renewable energy on aboriginal lands. It is particularly important to try and convert diesel-reliant communities (which produce greenhouse gas emissions) to more renewable sources of power. A related action would develop alternatives to energy production by inefficient diesel engines that burn black carbon and emit soot. Research from the Arctic Athabaskan Council has suggested that soot emissions must be curbed immediately, to limit the impacts of climate change (AAC 2009). They are making efforts nationally and internationally to have this implemented. Governments should embrace this solution as a viable option.

While the above mentioned policy recommendations apply to all aboriginal communities, several “clusters” of off-grid aboriginal communities in the country should have priority for implementing these actions. These clusters include:



- 13 Quebec Inuit communities of the Nunavik Region of Northern Quebec and seven First Nation communities;
- 23 communities in Northern Ontario;
- 35 remote communities in the eastern (Nunavut) and the western (Northwest Territories) Arctic;
- 25 remote and off-grid communities of northern and coastal British Columbia;
- eight communities in Labrador.

Conclusion: Taking the Next Steps

Kashtin is a musical duo of two artists from northern Quebec who made a name singing in their native tongue. The group's name means "Tornado" in Innu-aiman. They sing: "Self-awareness is respecting, and protecting our Mother Earth."

Aboriginal Peoples in Canada have already been negatively impacted by climate change and the impacts are growing exponentially, as climate change affects the temperature, water, land, ecosystems, plants, animals, birds, and other aspects of nature that Aboriginal Peoples have relied on since time immemorial.

Immediate measures need to be taken to reverse or slow down the impacts of climate change on aboriginal people. The federal government needs to make Aboriginal Peoples a priority in its

actions, budgets and planning. The retiring Auditor General of Canada Sheila Fraser has said that "If the First Nations and the federal government don't find new ways of working together to solve the innumerable problems, the living conditions in reserves will remain worse off than everywhere else in Canada, and this will prevail for generations to come" (Office of the Auditor General of Canada, 2009). Add to this the staggering impacts of climate change, and there can only be disaster for Canada's vulnerable Aboriginal Peoples and their communities.

To succeed in making positive changes to mitigate climate change requires the total involvement and consent of aboriginal people in the proposed laws, policies, measures, and implementation of solutions. It is a time for governments to be brave and embrace innovation and change:

- utilize aboriginal traditional ecological knowledge;
- share decision-making and management with Aboriginal Peoples;
- provide funds to assist in aboriginal involvement, preparation, planning and implementation of measures to reduce and mitigate the effects of climate change on their community and traditional lifestyle.

These are the keys to successful innovation and change.





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5. Agriculture

Dr. Barry Smit

Professor and Canada Research Chair in Global Environmental Change, University of Guelph

Introduction

“A changing climate brings both opportunities and challenges to Canadian agriculture, depending on location, production type and individual circumstances.”

Agriculture in Canada is a significant economic sector, directly providing one in eight Canadian jobs and eight per cent of Canada’s GDP (2005). It is an important component of society, providing livelihoods for 700,000 Canadians (2006). Agriculture is a substantial contributor to international trade, with exports worth \$28 billion (2006), and it is also a provider of a basic human need – food.

Agriculture is directly dependent on climate and weather, as these affect the conditions required for the growth of plants and animals. Agriculture across Canada is constrained to certain, mainly southern, regions, largely by the availability of heat and moisture. Agricultural production and returns are also influenced by inter-annual variations in growing season conditions, particularly droughts, excessive precipitation and untimely temperature extremes. Canadian agriculture is clearly sensitive to climate change, through changes in norms and extremes (Easterling, 1996; CCIAD, 2002; Weber and Hauser, 2003).

A changing climate brings both opportunities and challenges to Canadian agriculture, depending on location, production type, and individual circumstances. In most regions, an increase in the length of the growing season, or an increase in the heat available for production, would be a benefit for agriculture. However, most regions are also

vulnerable to reductions in available moisture, and to increases in the frequency or severity of extremes (Bryant et al. 2000; Lemmen et al. 2008). Indirect impacts of climate change include changes in the effects of pests, diseases and weeds (Charron et al. 2003; Smit, 2011) and changes in international comparative trade (Lemmen et al. 2008).

Globally, agriculture is one of the most widely analyzed areas for climate change impacts. Most of the work has focused on estimating crop yield responses to future climate norms (Brklacich and Smit, 1992; McKenney et al. 2001; Singh et al. 1998). Adaptations have been addressed largely by assumptions about crop changes over broad spatial scales and long-term horizons (Schneider et al. 2000; Chiotti and Johnston, 1995). There has been less attention to the processes through which producers and others make decisions about crop choice or other adaptations to changing conditions. Analyses of decision-making in agriculture indicate that adjustments are made in an incremental fashion, in light of numerous external economic factors and personal circumstances (Reid et al. 2007; Smit et al. 1996; Risbey et al. 1999).

Adaptation in agriculture involves decisions by producers, suppliers, processors, marketers, governments at all levels, and researchers (Wall et al. 2007). These decisions range from very short term or tactical choices to deal with immediate stresses, threats or opportunities, to more strategic planning for longer term considerations. Decisions by these stakeholder groups are interconnected. For example, a change in demand for a product will affect market prices, influence producers’ crop choices, and processors. A change in a government water policy or insurance program will likely be reflected in producers’ resource use plans and risk management strategies.

Adaptations to climate change in Canadian agriculture can take many forms, initiated by any of the stakeholder groups, to address risks and



opportunities over a range of time scales. Some of the main types of adaptations are summarized in Table 5.1.

Table 5.1: Types and Selected Examples of Adaptation Options in Canadian Agriculture

TECHNOLOGICAL DEVELOPMENTS

Crop Development

New crop varieties, including hybrids to increase the tolerance and suitability.

Weather and Climate Information Systems

Early warning systems that provide weather predictions and seasonal forecasts.

Resource Management Innovations

Water management innovations, including irrigation, to address risk of moisture deficiencies

Farm-level land management innovations to address risk associated with changing climatic conditions.

GOVERNMENT PROGRAMS AND INSURANCE

Agricultural Subsidy and Support Programs

Modify crop insurance programs to influence farm-level risk management strategies.

Change investment in income stabilization programs to influence farm-level risk management strategies.

Modify subsidy, support and incentive programs to influence farm-level production practices and financial management.

Change ad hoc compensation and assistance programs to publicly share the risk of farm-level income losses.

Private Insurance

Develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income.

Resource Management Programs

Develop, implement policies to influence farm-level land and water resource use and management practices.

FARM PRODUCTION PRACTICES

Farm Production

Diversify crop types and varieties, crop substitution, to address environmental changes and economic risks.

Diversify livestock types and varieties to address environmental and economic variations.

Change the intensification of production to address environmental change and economic risks.

Land Use

Change location of crop and livestock production to address environmental changes and economic risks.

Use alternative fallow and tillage practices to address climate-related moisture and nutrient deficiencies.

Land Topography

Change land topography to address moisture deficiencies and reduce risk of farm land degradation.

Irrigation

Implement irrigation practices to address moisture deficiencies, risk of income loss.

Timing of Operations

Change timing of farm operations to address changes in growing seasons and conditions.



FARM FINANCIAL MANAGEMENT

Crop Insurance

Purchase crop insurance to reduce risks of climate-related income loss.

Crop Shares and Futures

Invest in crop shares and futures to reduce risks of climate-related income loss.

Income Stabilization Programs

Participate in income stabilization programs to reduce risk of income loss.

Household Income

Diversify source of household income in order to address risk of climate-related income loss.

Source: Adapted from Smit and Skinner, 2002

Climate Change Challenges for Agriculture

While there are impediments to developing and implementing the specific measures (see Table 5.1), the key challenges to adaptation to climate change in Canadian agriculture are systemic. The challenges noted here apply not to specific adaptation measures, technologies or tools, but to the basic process of adaptation.

1. Denial of Climate Change

A large portion of the agriculture community (producers, businesses, etc.) does not accept that reality of climate change, and /or does not accept the projections from climate change scenarios are reliable or relevant to their operations (Smit et al. 1997; 2000; Wall and Marcell, 2006). Obviously, this acts as a serious constraint on adaptation to climate change.

Analyses of farmers' views on climate change have consistently demonstrated wide skepticism (C-CIARN, 2002; 2003). Representatives from agricultural businesses have also shown limited confidence and interest in "global warming," especially as it relates to their operations. This wide non-acceptance of climate change is evident in agricultural communities that might be expected to benefit from climate change (e.g. wine producers, heat constrained grain growers), and in areas expected to be harmed by climate change (e.g.

drought-prone Prairie crop producers) (C-CIARN, 2003).

The reluctance to accept the reality of climate change seems to be related to two aspects of the message. First, the most commonly disseminated piece of information about climate change is that average global temperature will increase by 1°C or 2°C, over 50 to 100 years, due to human greenhouse gas emissions. Quite apart from the effectiveness of climate change deniers in rural communities, farmers observe that they deal with far greater changes in temperature from day to day, week to week and year to year than 2°C, and 50 to 100 years is beyond their planning horizon.

Second, farmers point out long-term average temperature is not really relevant to their decision making. They are more interested in agro-climatic information that applies to their situations (Bootsma et al. 2005; Belliveau et al. 2006; Wall et al. 2007). Crop specific conditions such as growing season length, or frost-free period, or accumulated heat above growth thresholds are more relevant to farmers, but they do not see these as associated with long-term "global warming."

The key point is that, the form in which climate change information is presented to agriculturalists (mainly long-term temperature norms) has resulted in widespread disillusionment with the issue. More sector acceptance of the issue occurs when



aspects of farmers' operations sensitive to climate and weather are identified, then interpolated with climate change scenarios affecting these farmer-relevant climate attributes. Unless farmers and other agricultural stakeholders accept that climate change is real and has relevance to them, there will be little or no interest in adaptation.

2. Influence of Other Conditions

Decision-makers in agriculture continually adapt to a suite of changing conditions, related to costs, prices, markets, technologies, policies, and personal circumstances. In this context, climate change is considered almost inconsequential when making tactical and strategic decisions about enterprises, crops, livestock, resource use, finances, marketing, etc. Whereas most decisions in the sector are motivated largely by concerns over business economics and financial viability, climate change adaptation is seen as a separate "environmental" issue, marginalized and rarely addressed (Bryant et al. 2004; Belliveau et al. 2006; Wall et al. 2007).

Conventional climate change impact and adaptation studies are founded on the premise that climate change has significant implications for agricultural production, and that producers and others will adjust their practices in consequence of the expected changes in climate. Even for agriculturalists who accept climate change, decisions to modify practices are rarely directed exclusively (or mostly) at climatic stimuli, let alone climate change. Producers are constantly considering the implications of input costs, prices, land use, water use, enterprise mix, personnel, government programs, and policies, etc. These variable conditions directly affect economic returns and livelihoods (NFU 2003; 2005). Hence, the effect of a possible change in some aspect of future temperature or precipitation is unlikely to be addressed separately, or in any manner that might compromise economic returns or financial viability.

Similarly, for other stakeholders, climate is usually a minor factor relative to the other forces of change. Plant breeding, to develop varieties or hybrids better suited to a future climate, is often touted as a clear adaptation opportunity (Smit and Skinner, 2002). Analyses of plant breeding programs show that the focus on non-climate attributes (oil content, herbicide resistance, harvestability, etc.) overwhelms climate change as a target for breeding. Future climate or climate extremes are rarely addressed, and sometimes specifically excluded in the selection processes (Smithers and Blay-Palmer, 2000). Governments also are unlikely to have programs specifically for climate change adaptation. Even in policy areas closely related to climate change adaptation, such as water management or ad hoc compensation programs, the inputs from powerful interests on equity, costs, finances, and other matters, limit the consideration of climate change (Lac, 2004; Wandel et al. 2010).

3. Multiple Decision-Makers

Decisions in agriculture are taken by a very large number of producers (and other businesses and agencies of government), each with its own circumstances, exposures, sensitivities, capacities and propensities. As a result, adaptation needs and options vary considerably, even within a local area, greatly constraining the applicability or validity of so-called best adaptation practices (AAFC, 2003; Bradshaw et al. 2004; C-CIARN, 2003; Reid et al. 2007; Smit and Skinner, 2002; Wheaton et al. 2007).

Given projected increases in temperature, it is often expected that an adaptation in Canadian agriculture would mean farmers expand crop production northward and adopt higher yielding varieties that are viable under longer and warmer growing seasons. A "best adaptation practice" would require the engagement of several stakeholders: researchers, to contribute through identifying crop suitability areas, varietal tolerances, moisture requirements, etc.;



governments, to promote crop development, disseminate information and manage land tenure and land use conversion processes; businesses, to develop, test and market new crops and varieties, supply necessary inputs, and purchase, process, transport and market products; farmer organizations, for information dissemination, field trials and lobbying; and individual producers, to make individual choices, such as to change crops or varieties, land use and other resource use strategies, and possibly, to change locations.

This interplay of numerous interests and stakeholders applies to many of the potential adaptations included in Table 5.1. Irrigation and other water management schemes, insurance and support programs all involve multiple stakeholders, and (as with challenge 2 above) they involve numerous interests and forces which tend to minimize or negate the consideration of climate change.

Adaptation Solutions for Agriculture

1. Agriculture-Relevant Climate Change Information

A necessary requirement for adaptation in Canadian agriculture is that producers and others in the sector appreciate that climate change has relevance to their operations and businesses – that it brings economic risks and opportunities in the immediate and longer terms. Several actions can help facilitate their support:

- identify attributes of climate change that are relevant to farmers' operations and decisions;
- illustrate the significance of these attributes in terms used by agriculturalists;
- indicate expected changes (or simply direction of changes) in agriculture-relevant climate attributes.

Agriculture-relevant climate change attributes of interest to the farming sector are the frequency, magnitude and timing of weather extremes, such as droughts, storms or frosts, over five to 15 years. The notion that shorter term conditions (weather) are somehow separate from longer term norms (climate) needs to be corrected, by showing that weather (including variations and extremes) is part of climate, and climate change will bring changes in variations and extremes as part of the changes in norms.

Achieving recognition of the reality and relevance of climate change for producers and others in the sector requires resources and expertise dedicated to involving farmers; an exchange of ideas and information, particularly from the sector interests to the climate science community; and the development of farmer-relevant information on past and expected future conditions.

2. Incorporate Climate Change in Planning Decisions

The nature of decision-making in agriculture means that the practical, and probably only effective approach to climate change adaptation, is to incorporate consideration of climate risks and opportunities into ongoing risk management and strategic planning processes. Adaptation options relating to climate would be considered as part of decisions producers and others take in light of a range of other forces. Adapting to climate is not an additional or competitive task, but something incorporated (“mainstreamed”) into the regular tactical and strategic decision processes in the sector.

This process of incorporating climate change into established management processes – rather than attempting to develop separate climate-specific adaptation actions – is now widely recognized internationally as the most effective route for reducing climate change vulnerabilities and realizing potential benefits. Rather than dealing



with adaptation in isolation from other factors, integrating (mainstreaming) climate change into ongoing planning and policy decision-making can provide efficiencies in the use of both financial and human resources (Adger et al. 2007; Klein et al. 2007, Smit and Wandel, 2006).

Mainstreaming is also the approach adopted in several Canadian adaptation initiatives. The Government of Canada's report "From Impacts to Adaptation" (Lemmen et al. 2008) notes that "integrating climate change into existing planning processes is an effective approach to adaptation." The foundation of Ontario's (2011) adaptation strategy is mainstreaming adaptation, which "means making sure that legislations, policies and programs are modified to consider climate change adaptation when necessary." British Columbia's (2010) adaptation strategy is based on the principle that "climate change adaptation will be integrated government-wide into planning and program implementation." Mainstreaming is widely recognized as the effective approach in agriculture (Belliveau et al. 2006; Wall et al. 2007; Wheaton et al. 2007; Holland and Smit, 2010).

Opportunities for integrating climate change into existing programs and decisions are numerous, and many can be accomplished quite readily. Drawing from types of adaptation in table 5.1, examples of integrating include:

- crop development programs that include climate resilience;
- water management policies and operations that consider climate change;
- crop insurance program providers incorporating changing climate risks;
- subsidy and support programs that consider climate change;

- private insurance companies that recognize changing climate regimes;
- land development and land use plans that factor in climate change;
- risk management strategies that include changing climate as a factor;
- producer enterprise choices that include consideration of changing climate;
- crop and livestock selections that recognize changing climate;
- land tillage practices that consider climate change;
- users of crop insurance who consider effects of climate change;
- participation in income stabilization programs that consider climate change;
- financial management plans that recognize a changing climate.

The effective route for adapting to climate change in Canadian agriculture is to identify those policies, programs, strategies and practices in which climate change considerations are pertinent and can be incorporated. In this way, it is not necessary to develop new and independent measures specifically to adapt to climate change, but rather to have climate considered, along with other factors, in resource management, financial management, risk management, and other decision processes.

3. Adaptations Specific to Roles and Situations

Producers, businesses, governments and researchers have distinct interests and roles to play in adaptation. To be practical, adaptation



options (including those to be integrated into ongoing programs and plans) need to relate to the responsibilities and mandates of specific stakeholders.

For governments, consideration of climate change would be incorporated into program responsibilities such as: crop insurance, income stabilization, subsidy and incentive, ad hoc compensation, resource management, irrigation, and crop development. Researchers, particularly in the policy field, have an important support role in these areas to identify, develop, and disseminate agriculture-relevant climate and weather information.

Among producers and businesses, the needs and opportunities for incorporating climate change into decisions will be specific to location, type of enterprise, and personal circumstances. Producers make decisions continuously, covering time periods from hours to decades. Climate change can be incorporated into many of these decisions, such

as: enterprise choice or diversification, crop or livestock selection, land allocation and land use, input use, tillage and harvesting practices, drainage, irrigation, timing of operations, marketing, insurance use, futures, participation in income stabilization programs, and income diversification.

Next Steps

The key steps are:

- engage representatives from producers, businesses, government agencies and the research community to develop agriculture-relevant climate change information and dissemination programs;
- identify areas within existing programs and decision-making processes to include consideration of climate change risks and opportunities.





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6. Insurance: Adapting Building Codes for Climate Change

Grant Kelly

Director of Climate Change Adaptation Projects,
Institute for Catastrophic Loss Reduction (ICLR)

Paul Kovacs

Executive Director, ICLR

Dr. Jason Thistlethwaite

Research Associate, ICLR

Introduction

“Because infrastructure built in current times is intended to survive for decades to come, it is important that adaptation options for the changing climate be developed today and that future climate changes be incorporated into infrastructure design whenever possible.” (Environment Canada, 2010)

Political leadership is required to ensure that the Canadian National Building Code Commission places (NBCC) greater focus on improving building durability and resilience to extreme weather. A new home built in 2012 is expected to provide a family a safe haven from natural disasters for the next 50 years. Given that an estimated nine to 12 million Canadians are expected to live in new homes by 2050 – homes that have yet to be built – it is critical these homes provide such a safe haven.

For new homebuilders and owners, climate change creates a challenge, as it has been linked with an increase in the frequency and intensity of extreme weather. For this reason, it is important that best design and construction practices be available to homeowners and the home construction industry, so they can better protect homes from extreme weather events throughout a home’s 50-year life cycle. Fortunately, considerable information exists,

and is constantly emerging, about home design and construction practices that can enhance the resilience of new homes to damage from severe weather. Nevertheless, homes in Canada still experience more than \$3.5 billion a year in damage due to severe weather. This damage is likely to increase as the climate changes across Canada (ICLR, 2010).

In the last few decades, the damage generated by natural disasters, specifically those linked with extreme weather, has been increasing. This trend is anticipated to continue over the long term, as more homes are built in areas exposed to these weather perils. Damage from several 2011 extreme weather events, including the flooding in Manitoba and Quebec, wildfires in Slave Lake, Alberta and the tornado in Goderich, Ontario serve as important reminders of this trend.

The National Building Code (NBC) represents an important policy lever in addressing the challenges new homeowners face in adapting to climate change. Thankfully, the task of strengthening the building code does not require an expansion of the NBC into new areas. Rather, it is possible to strengthen the code to withstand severe weather within the current code documents.

This report will begin by explaining the structure of building codes in Canada, and the process that is used to update the building codes. It will identify who are the key stakeholders, and how the code incorporates concerns about extreme weather. It will then focus on the specific challenges that must be addressed to leverage building codes as tools for promoting climate adaptation among new homeowners. The report will conclude with the recommendations necessary to address these challenges.

Canadian Building Codes

The building code outlines the minimum level of quality under which a new structure may be legally



built in Canada. We are very fortunate that Canada has strong and well enforced building codes that promote public safety. Canadians enjoy a high degree of uniformity in building construction and fire safety across the country. In fact, the Canadian National Building Code is internationally recognized as one of the best standards of construction in the world.

Canada has (at least) 13 different building codes currently in force across the country. The federal government produces a model code called the National Building Code of Canada (NBC). This document has no legal status outside of land owned by the federal government, unless it is adopted by a province, territory, or municipal government. The NBC is prepared by the Canadian Commission on Building and Fire Codes (Commission) and is published by the National Research Council of Canada.

The NBC was first published in 1941. Prior to that, municipalities established building codes for their cities. Since 1960, the NBC has been revised about every five years, up to 1995. The 2000 edition of the building code was supposed to be an objective, or performance-based, building code. However, this took considerably longer to write than anticipated, and the next edition of the National Building Code of Canada was not published until 2005. An update was published in November 2010.

The NBC outlines standards for the construction, renovation and demolition of buildings. It also covers change-of-use projects where the change would result in increased hazard and/or maintenance and operation in the existing building. The code sets out technical requirements for the aforementioned project types and does not pertain to existing buildings.

The NBC is split into nine parts.

- Part 1 Scope and Definitions;
- Part 2 General Requirements;

- Part 3 Fire Protection, Occupant Safety and Accessibility;
- Part 4 Structural Design;
- Part 5 Environmental Separation;
- Part 6 Heating, Ventilating and Air-Conditioning;
- Part 7 Plumbing Services;
- Part 8 Safety Measures at Construction and Demolition Sites;
- Part 9 Housing and Small Buildings.

Under the building code, there are two types of buildings. These buildings have substantially different requirements:

- Houses and certain other small buildings (less than three storeys high and 600 m²) are considered “Part 9 Buildings” and only parts 1, 2, 4, 5, 6, 7, 8 and 9 apply. Part 9 is very prescriptive and is intended to be applied by contractors.
- Larger buildings are considered “Part 3 buildings” and parts 1 through 8 apply. Part 3 is the largest and most complicated part of the building code. It is intended to be used by engineers and architects.

Under Part 3, architects and engineers problem solve the best design and construction materials needed to meet building code objectives when designing large public (Part 9) buildings. For example, it requires that a building in downtown Toronto be able to withstand the most extreme wind pressures that have been recorded over the last 50 years (“a 1-in-50-year wind event”). Architects and engineers are allowed significant freedom to determine which materials and building design they use to achieve this objective.

There are very different, and much more prescriptive, requirements for the homes most Canadians live in. As an example, the NBC specifies that roof panels on a new home must be attached every 12 inches. The code also specifies the materials builders can use. Although the code



outlines minimum levels, or the worst home that builders are legally able to build, they often exceed these code requirements.

The Role of the Provinces

The National Code has little impact until it is legally adopted by a province. Under Canada’s constitution, provinces and territories regulate the design and construction of new houses and buildings, and the maintenance and operation of fire safety systems in existing buildings. While the Model National Building, Fire and Plumbing Codes are prepared centrally under the direction of the Canadian Commission on Building and Fire Codes, adoption and enforcement of the codes are the responsibilities of the provincial and territorial

authorities having jurisdiction.

Table 6.1 lists the provinces and territories which have adopted the national code, or incorporate its major components.

It is important to note that Vancouver has adopted its own set of codes based on the national model. Vancouver is currently the only municipality in Canada that enacts its own building codes. Other cities instead use the National Building Code of Canada and provincial codes that are derived from it. Vancouver’s code is also derived from these, but includes some local changes. The current code was enacted on January 30, 2007 (Building By-law No. 9419).

Table 6.1: Provincial Adoption of National Building Code

New Brunswick, Nova Scotia, Manitoba and Saskatchewan	Province-wide adoption of the National Building Code, National Fire Code and National Plumbing Code with some modifications and additions.
Newfoundland and Labrador	Province-wide adoption of the National Fire Code and the National Building Code, except aspects pertaining to means of egress and to one- and two-family dwellings within Group C in Part 9. There is no province-wide plumbing code.
Northwest Territories, Nunavut and Yukon	Territory-wide adoption of the National Building Code and National Fire Code with some modifications and additions. Yukon adopts the National Plumbing Code.
Prince Edward Island	Province-wide adoption of the National Plumbing Code. Province-wide fire code not based on the National Fire Code. Major municipalities adopt the National Building Code.
The following provinces publish their own codes based on the National Model Codes:	
Alberta and British Columbia	Province-wide building, fire, and plumbing codes that are substantially the same as National Model Codes, with variations that are primarily additions.
Ontario	Province-wide building, fire and plumbing codes based on the National Model Codes, but with significant variations in content and scope. The Ontario Fire Code, in particular, is significantly different from the National Fire Code. Ontario also references the Model National Energy Code for Buildings in its building code.
Quebec	Province-wide building and plumbing codes that are substantially the same as the National Building Code and National Plumbing Code, but with variations that are primarily additions. Major municipalities adopt the National Fire Code.

Source: National Research Council 2012



Climatic and Seismic Information for Building Design

The NBC recognizes that weather varies across Canada. To reflect this variation, the building code includes a “Supplementary Standard,” called “Climatic and Seismic Information for Building Design.” This standard is based on climatic design values derived from historical climate data provided by Environment Canada. In addition, this standard only applies to Part 3 buildings, which are designed by architects and engineers. Most Canadians live in homes covered by Part 9 of the code, which are designed by builders, and not covered by the supplementary standard on climate design values. This distinction in the application of the standard is unfortunate. But a quick review of its components does demonstrate how the code can be used to strengthen the resiliency of building design to extreme weather and climate risks.

Under the standard, architects and engineers must consider:

- 1. January Design Temperature** – The building should be designed to maintain the inside temperature at a pre-determined level. Buildings and infrastructure constructed in colder climates require greater insulation.
- 2. July Design Temperature** – The building must be designed to maintain the inside temperature at a pre-determined level.
- 3. Heating Degree-Days** – A measure of rate of consumption of energy required to keep the interior of a small building at 21°C when outside temperature is below 18°C.
- 4. Snow loads** – The roof of a building should be able to support the greatest weight of snow that is likely to accumulate on it.
- 5. Annual rainfall** – The amount of total rainfall that normally falls in one year is used as a

general indication of the wetness of a climate.

- 6. Rainfall intensity** – Roof drainage systems are designed to carry off rainfall from the most intense rainfall likely to occur. In the Building Code, this is the 15-minute rainfall that will probably be exceeded once every 10 years.
- 7. One-day rainfall** – Roofs must be designed to withstand the weight of the volume of water from a 1-in-50-year storm.
- 8. Driving rain wind pressure** – This is used to minimize the chance that water will enter the building envelope.
- 9. Wind Effects** - All structures need to be designed to ensure that the structural and secondary components, such as cladding and appurtenances, will withstand the pressures and suctions caused by the strongest wind conditions to blow at that location. Strongest winds are defined as a 1-in-50-year wind.

Both Environment Canada and the Canadian Commission on Building Codes have agreed that these factors should be updated to reflect the impact of climate change on extreme events, “because infrastructure built in current times is intended to survive for decades to come, it is important that adaptation options for the changing climate be developed today and that future climate changes be incorporated into infrastructure design whenever possible” (Environment Canada, 2010).

The goal is to produce revised estimates in time for the 2015 version of the Building Code. While this sounds positive, budget cuts at Environment Canada have limited the capacity of staff working on this project. As a consequence, there is significant uncertainty that this change in policy will be implemented. Even if such a reform is accomplished, the supplementary climate standard does not apply to new homes bought by Canadians. Nevertheless, the standard does demonstrate the



potential of the code as a useful tool for promoting adaptation in Canada's built environment. Potential reforms to Part 9 of the code (which applies to residential homes) could build on the experience of using the supplementary climate standard.

Building Code Reform

The process to make changes to the NBC is very complicated and political. There are two distinct levels of discussions. They are:

1. Changes to the code itself;
2. Changes to the supporting materials referred to within the code.

Changes to the Code Itself

Any change to the code is managed by the Commission. Part 9 of the NBC details the regulatory process required to build and how buildings are put together. All suggested changes are judged relative to the Commission's mission to establish the minimum provisions acceptable to maintain the safety of buildings, with specific regard to public health, fire protection, accessibility and structural sufficiency. The process is open to the public and all discussions are on the public record.

Changes to Supporting Materials

The building code references hundreds of other construction documents that are legally incorporated by reference and, thus, are part of the enforceable code. This includes many design, material testing, installation, and commissioning documents produced by private organizations. Most prominent among these are the Canadian Standards Association, Canadian Electrical Code, Underwriters Laboratories of Canada (a subsidiary of Underwriters Laboratories), documents on

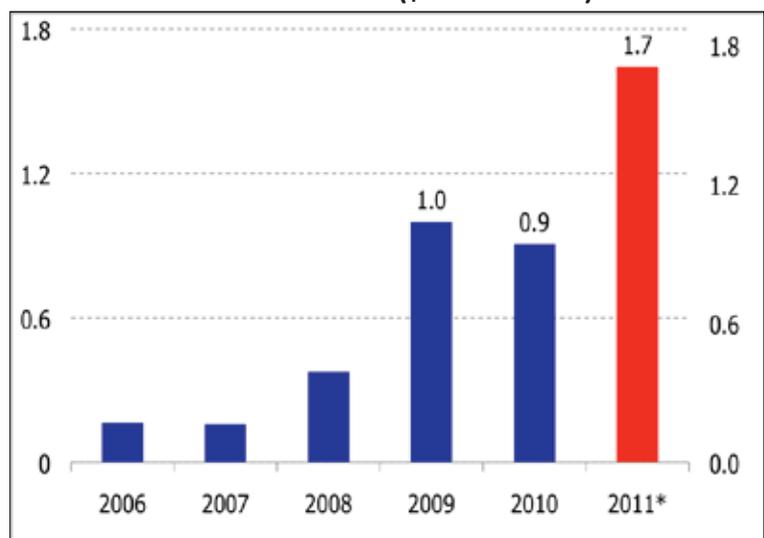
fire-alarm design, and a number of National Fire Protection Association documents. These discussions are not open to the public and are very political.

Climate Change Challenges for the National Building Code

1. Adapting the Code for Climate Risks and Extreme Weather

In the last few decades, the damage generated by natural disasters, specifically those linked with extreme weather, has been increasing. This trend is anticipated to continue over the long-term as more homes are built in areas exposed to weather perils. Below, the Institute for Catastrophic Loss Reduction (ICLR) has provided information on the insured losses linked with a range of Canadian natural disasters (Table 6.1), and the Insurance Bureau of Canada has provided information on the rising costs linked with these disasters (Figure 6.2).

Figure 6.1: Catastrophic Insurance Losses in Canada from 2006 to 2011 (\$ Cdn billions)



* Estimated catastrophic losses

Source: Insurance Bureau of Canada, 2011.



Table 6.2: Canadian Insured Losses Natural Disasters by Type (1983-2006)

Event	No. of Events	Cost in Millions (\$ Cdn 2006)
Icestorm	2	1,961,658
Flooding	27	1,382,153
Storm	26	1,037,023
Hailstorm	13	714,691
Tornado	7	544,122
Wind	8	306,388

Source: ICLR, 2010.

The NBC must adapt to these increasing and costly extreme weather events. Fortunately, it is possible to strengthen the code to withstand severe weather within the current code documents. There is a well-defined process managed by the Commission to discuss code changes. The incorporation of future weather considerations into a code process, however, remains a significant obstacle. Stakeholders who participate in code decisions have a great deal of expertise that can be used to inform such a reform, but reform is unlikely to occur without a mandate that focuses this expertise on the incorporation of future climate conditions into the code process.

2. Cost-effective Adaptation Through the Building Code

Although the NBCC must begin to incorporate future climate and weather conditions into the code process, it must ensure that these decisions are cost effective, and informed using scientific research. In the event the code requires the adoption of new techniques that prove too costly or lack scientific consensus, builders and other stakeholders are unlikely to implement the changes, and are more likely to oppose such reform in the first place. Code reform that incorporates future weather conditions, cost effectiveness, and scientific consensus creates a significant challenge for the NBC. How can the building code process adapt to climate change given these cost concerns?

Adaptation Solutions for the National Building Code

To ensure the building code promotes adaptation to extreme weather and climate risks for residential homes, political leadership is required.

1. Incorporate Expectations Regarding Future Climate into the Building Code Process

The federal and provincial governments should support work to incorporate both historic experience with extreme weather and expectations about the future climate into the building code decision-making process. Both governments can help facilitate this process in two ways.

First, they should support research on new construction practices that are resilient to future climates and extreme weather data relevant for the building code. These practices must be developed through thorough research on existing best practices and scientific testing, to make sure new designs and technologies are adequate for current and future climate and weather patterns. Extreme weather data should be used to update the climatic values used to inform construction practices for residential homes.

Second, both governments should formally endorse building durability and resiliency as objectives



for the national building code. This endorsement would help mobilize the support necessary to integrate adaptation into the building code. More broadly, political leadership that supports adaptation as a priority for the building code would make Canada an international model for effective adaptation policy.

2. The Insurance and Building Industry Must Identify High-Priority Risks Linked with Future Extreme Weather

The building code process must prioritize the most significant risks linked with anticipated future extreme weather, to ensure the integration of adaptation into the building code is cost effective. This recommendation depends on generating accurate data about the frequency and severity of existing extreme weather trends, and how climate change is likely to influence these trends. The insurance industry and federal government, specifically Environment Canada and Infrastructure Canada, can play a pivotal role in addressing this data gap. Insurers, in particular, should more readily allow researchers access to claims data.

By linking the frequency and intensity of certain weather trends to damage costs that governments, insurers and homeowners must recoup, insurers and governments can cooperate and play a vital role to identify high-priority risks that fulfill a

cost-benefit analysis. This approach ensures that, while the code takes steps to incorporate resiliency to climate change, this process is informed by scientific research and cost-benefit analysis. To initiate a process that updates the building code to reflect existing and future climate risks, a three-part strategy may be used:

1. Promote discourse that focuses on climate adaptation with a wide range of stakeholders, including insurers, homebuilders, building code officials and building researchers. In particular, it is important to develop a relationship between the building community, the insurance industry and building science researchers. A consultation between these stakeholders can identify core concerns about incorporating extreme weather and climate risks into building design.
2. Once a consensus is established, insurers, builders and scientific researchers can jointly support design practices that promote climate adaptation.
3. The federal government can focus attention and resources on this effort to promote adaptation by adopting building durability and disaster resiliency as a theme for upcoming building code renewals.





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7. Insurance: Tools to Promote Adaptation by Existing Homeowners

Dan Sandink

Manager, Resilient Communities & Research,
Institute for Catastrophic Loss Reduction (ICLR)

Glenn McGillivray

Managing Director, ICLR

Introduction

“Most of the recent severe weather losses in Canada could have been prevented through the application of current and emerging knowledge about disaster resilient home design and construction.”

The risk of death or injury due to flood, windstorm, lightning or other natural hazards is low and falling in Canada and most affluent countries. However, in almost every country, including Canada, property damage and economic losses due to severe weather have been increasing at an alarming rate for several decades. Over the past decade, the World Disaster Report identified more than 4,000 disasters worldwide that resulted in more than one million fatalities, largely in developing countries, and almost \$1 trillion in economic losses, largely in affluent countries. Moreover, much of the property damage was preventable. Several factors affect this international trend, including more people and property located in areas of high risk, aging infrastructure, and the increasing frequency and severity of extreme weather events.

There are 12.5 million dwellings in Canada, including over eight million detached, semi-detached or row houses (Statistics Canada, 2006). Two-thirds of the homes in Canada were built

more than 25 years ago. In other words, all of the knowledge about disaster-resilient homes that has emerged over the past 25 years was not available for the initial design and construction of two-thirds of the homes in Canada. Nevertheless, many of these safety elements can and should now be added as part of the ongoing maintenance or renovations of homes.

Promoting safety investments is of interest to homeowners seeking to reduce the risk of injury or property damage due to severe weather; governments responsible for public safety; and a number of other stakeholders, including home builders, the renovation industry, insurance companies, banks, and companies that provide lumber and other supplies.

This paper outlines three strategies to increase risk reducing behaviour at the homeowner and community levels:

First, there is a substantial need to increase homeowner and community awareness of severe weather risk and risk reduction options. The Government of Canada should build on existing public and community education practices, including those developed through Partners in Protection in Alberta and some aspects of the Regional Adaptation Collaborative (RAC), to develop nation-wide outreach programs.

Second, the Government of Canada should partner with stakeholders in the private sector, to encourage investments in risk reduction by homeowners and communities. Ultimately, this should include a broad range of partners from the construction, finance and manufacturing industries; however, initially, the government could work with the insurance industry to develop tax- and insurance-based financial incentives promoting homeowner investments in disaster safety.

Third, the government should invest in public infrastructure to better protect homeowners and



homes from the risk of damage due to severe weather. Specifically, this paper recommends the development of a national program to: (1) encourage and assist in the implementation of pre-disaster mitigation options, (2) further incorporate post-disaster mitigation into federal and provincial disaster assistance programs; and, (3) develop post-disaster mitigation assistance programs that are triggered automatically, even when private insurance has provided payouts.

Investments in disaster resilience save lives, prevent injuries, and reduce the risk of property damage. They also result in a reduced need for governments to pay for disaster relief, protect jobs and tax bases, and they make a region, province or country more attractive to domestic and foreign investment.

Climate Change Challenges for Existing Homeowners

1. Public Awareness About Risk Reduction

There is a significant gap in public awareness about the actions that can be taken to reduce a property's exposure to extreme weather risk. The FireSmart program initiated by Partners in Protection represents a model that can be used to address this gap in awareness. Partners in Protection is an Alberta-based partnership of national, provincial and municipal professionals involved in emergency services, land use planning, forest and park management, and research (Partners in Protection, 2007). Partners was formed in 1990 by a task force representing eight Government of Alberta departments and Alberta municipal associations concerned with wildfire risk in the wildland-urban interface (Partners in Protection, 2007).

Incorporated as a non-profit in 1993, the mandate of Partners was to “increase the level of interagency cooperation and promote public awareness [for] reducing the risk of loss of life and property from hazards in the wildland/urban

interface” (Partners in Protection, 2007). Partners in Protection's foundation is based on several intersecting disciplines related to the management of risks in the wildland-urban interface, including vegetation management, physical development, public education, legislation, interagency cooperation, cross training and emergency planning.

Through the FireSmart program, tools aimed at both property and community level wildfire mitigation have been developed and are widely regarded and adopted throughout Canada. Governments in several provinces and territories outside of Alberta, including British Columbia, Saskatchewan, Manitoba, Ontario, Nova Scotia, the Yukon and the Northwest Territories, have adopted FireSmart materials. Furthermore, through the Institute for Catastrophic Loss Reduction, the insurance industry has begun to adopt and disseminate materials developed through the FireSmart program. For its work on the development and distribution of wildfire risk reduction resources, Partners has won awards from Alberta Environment, the Alberta Association of the Canadian Institute of Planners, and the Department of Natural Resources of Canada.

Wildfires have not been viewed as a significant risk by the Canadian insurance industry. The severe fire season in British Columbia in 2003 resulted in approximately \$200 million in insurance payouts (ICLR 2010, p. 45) and initial estimates indicate \$700 million in insurance claims will be paid as a result of the Slave Lake wildfire event in May 2011. However, other climatic events, including wind and urban flooding, present considerable risks to the insurance industry as well as to Canadian property owners and communities. Indeed, data collected by the Insurance Bureau of Canada between 1983 and 2006 indicated, out of a total of 115 large payout events, 27 per cent were caused by flood and rainstorm and 22 per cent were caused by wind and tornado. Furthermore, there is evidence to indicate extreme rainfall, which



often leads to urban flooding and associated sewer backup, and high wind events, may be affected by climate change (Bruce, 2011). As climate change increases conditions conducive to more frequent and intense wind and urban flood events, insurers, governments and property owners will need access to reliable and standardized information on mitigation measures that can be adopted by policy holders and communities.

Program need for urban flood and wind

Urban flooding presents one of the most significant risks facing many of Canada's urban municipalities. Moreover, urban flood events are likely to worsen in the future due to a combination of the impacts of increasing urbanization, aging storm and sanitary sewer infrastructure, and, the increasing value of property and use of basements as living spaces. Heavy rainfall events, often the cause of widespread urban flood events, are also expected to increase in frequency and severity as a result of climate change. Urban flooding related impacts, specifically sewer backups, have become one of the most significant risks facing the insurance industry, with several large events over the past few years resulting in multi-million dollar payouts. The most expensive single urban flooding event was the August 2005 heavy rainfall event in Southern Ontario, which resulted in approximately \$247 million in sewer backup payouts, and total payouts of more than \$500 million.

Homeowners and residents can play a substantial role in the mitigation of the impacts of urban flooding. They can take action to reduce risk in two important ways: by limiting the risk of water and sewage entering homes, and by reducing the amount of water that individual properties contribute to the municipal sewer system (Sandink, 2009). The approach of municipalities across Canada in addressing urban flooding has been highly varied, especially in the case of sewer backup risk reduction. For example, there has

been inconsistency across Canada regarding interpretation of wording related to backwater valves in the National Plumbing Code. The Code states "where a building drain or a branch may be subject to backflow, a backwater valve shall be installed on every fixture drain connected to them when the fixture is located below the level of the adjoining street" (NRC, 2010). A key factor in implementation of this section of the Code is the interpretation of whether or not a lateral "may" be subject to backflow. Municipalities may consider only new development in areas that have had historical sewer backup problems, as those that "may" be subject to backflow events. However, other municipalities may consider any home serviced by the municipal sewer system as potentially vulnerable to sewer backup.

There is also inconsistency across the country about which backwater valves should be installed in homes, where some municipalities require the installation of "inline" backwater valves and others require the "mainline" backwater valve.⁶ A FireSmart type program for urban flood would allow professionals from across the country to discuss, analyze and identify the most appropriate means of incorporating backwater valves and other property-level mitigation options into buildings. There is also a strong need to identify actions that can be effectively and efficiently employed to reduce urban flood risk, including methods to increase the capacity of sewer systems and accommodate overland flows in densely developed urban areas.

Wind represents one of the most substantial climate-related risks faced by the insurance industry. Although the Canadian Hurricane Centre has produced resources relevant to reducing wind-related risks for homes, and governments in Australia have produced valuable homeowner resources for risk reduction from cyclones, there are no widely adopted tools or resources for Canadian property owners and communities

⁶ *Inline valves are placed in branch lines, mainline valves are placed in the main sewer line*



(Environment Canada, 2010; Queensland Government, 2008). Compared to actions that can be taken by individual home and property owners for wildfire and urban flood risk reduction, property-level options for wind may seem limited.

There are, however, several important measures that can be taken to reduce wind risk at the property level, including maintenance procedures (e.g. identification and correction of corrosion, rotten building materials, loose fixing, and termite damage) and retrofitting to increase building resistance to wind damage (including installing garage doors resistant to high wind and impact-resistant screens on windows). Education programs developed through the FireSmart approach can focus on communicating results of new research on wind risk reduction and can “debunk” myths such as, opening all windows in the home to help relieve pressure during a tornado event—an action that can actually increase risk.

Developing programs for urban flood and wind

The primary purposes of FireSmart type education programs for urban flooding and wind should be to develop and disseminate standardized best practices for the mitigation of risks at the property and community levels. However, several other aspects of property-level risk mitigation should also be included in education programs. For example, property owners should be made aware of what is, and what is not, covered by insurance and public disaster relief programs. Communicating that insurable risks (e.g. sewer backup) will not be covered under disaster assistance programs will help increase uptake of sewer backup coverage. Further, in the case of urban flooding, homeowners and municipal leaders should be made aware of the types of water damages covered under homeowner insurance policies. Informing community leaders that damages caused by overland flooding will not receive insurance compensation may serve as a driver to address overland flood risks.

To establish a FireSmart type program for urban flooding, a wide range of professionals should be involved. Effective implementation of public education programs will require partnerships between government (federal, provincial, and municipal) and the insurance industry. Representatives from municipal governments, especially municipal professionals responsible for urban drainage and sanitary sewer management, should participate in the development of urban flood mitigation resources.

The development of wind risk reduction materials would require the involvement of a range of government agencies, including: provincial, environmental, and emergency management agencies; Environment Canada (including the Meteorological Service of Canada and the Canadian Hurricane Centre); as well as researchers and insurance professionals from across Canada. Considerable expertise in wind risk reduction is also available at the University of Western Ontario, where several large projects (e.g. the Insurance Research Lab for Better Homes, the Boundary Layer Wind Tunnel Laboratory) have amassed a considerable body of research on wind risk reduction. Insurers are another good source for providing information on incentives for mitigation and other insurance issues regarding urban flooding and wind risk reduction, and they can play a vital role in distributing information to policy holders. To identify existing mitigation resources for property owners and communities, national and international surveys should be undertaken. Existing best practices should be leveraged for the development of new materials, and adapted for the Canadian context. Development of wind resources and information distribution methods may require more effort than urban flooding, as municipalities across Canada have been implementing urban flood education programs for many years and, in some cases, for several decades.

The Government of Ontario, through the Ontario Regional Adaptation Collaborative, is currently



working with the Institute for Catastrophic Loss Reduction to develop and disseminate materials on a variety of climatic hazards, including urban flooding and wind. These materials are being developed with the assistance of researchers, engineers, and insurance professionals. The Institute has also developed a comprehensive homeowner urban flood reduction handbook, and a construction guide for builders, designed to increase the disaster resilience of new homes. These existing resources could be readily leveraged to create nationwide programs for climatic hazards. To further develop content and strategies for FireSmart type programs for wind and flood, ICLR could conduct workshops across Canada for researchers, engineers, municipal and provincial staff, and other stakeholders, to discuss appropriate measures for lot-level and community-level risk reduction. Through its experience in developing tools, the Institute for Catastrophic Loss Reduction would serve as a valuable partner for further developing a nationwide FireSmart type program.

2. Generating Financial Incentives for Reducing Risks

For more than 50 years, the insurance industry has been accepting the transfer of homeowners' risk of severe weather damage for many perils, including the risk of damage from hail, lightning, tornado, hurricane, severe snowfall, and water. The only major peril not covered by home insurance in Canada is flood. The risk associated with these perils is increasing. Insurers and governments can help reduce them through financial incentives to encourage homeowners to invest in severe weather protection.

Insurance-based incentives for adaptation

With traditional insurance, companies measure and put a price on individual risks, such as the risk of property damage to a specific building from fire, theft, or an extreme weather event, and charge the insured a premium against indemnification.

Insurance is an agreement where, for a stipulated payment called the premium, one party (the insurer) agrees to pay to the other (the policyholder) a defined amount, upon the occurrence of a specific loss. This defined claim payment amount can be a fixed amount, or can reimburse all, or a part of, the loss that occurred. The insurer considers the losses expected for the insurance pool, and the potential for variation, in order to charge premiums that, in total, will be sufficient to cover all of the expected claim payments for the insurance pool. The premium charged to each of the pool participants is that participant's share of the total premium for the pool. Each premium may be adjusted to reflect any special characteristics of the policy. The larger the policy pool, the more predictable its results (Anderson and Brown, 2005).

In insurance, the higher the risk, the higher the premium; the lower the risk, the lower the premium. Pricing is one way insurers incentivize good risk-taking behaviour and disincentivize bad risk-taking behaviour. Hand in hand with pricing is the insurance deductible, that portion of the loss paid out of pocket by the policyholder before reimbursement from the insurance policy comes into effect. If the total loss is less than the deductible, there is no reimbursement paid by the insurance policy. Generally, the higher the deductible is, the lower the premium, and the lower the deductible, the higher the premium.

Deductibles exist, at least in part, to ensure that normal, everyday damage, such as wear-and-tear, is not claimed frivolously by the insured, and to encourage good risk-taking behaviour and dampen moral hazard. Insurers may, therefore, utilize deductibles as a means to communicate poor loss experience for a customer, or risk, by increasing both the premium and the deductible, or just the deductible.

In the event a category of loss grows to become a disproportionate share of a company's overall



claims burden or a common source of claims for a policyholder, or from a particular geographic region, insurers may implement caps or limits on indemnification. For example, in recent years, auto insurers offering coverage in certain Canadian provinces have implemented monetary caps on soft tissue injuries. On the property side, caps have commonly been placed on insured individuals who have made multiple sewer backup claims in a given period. Often such caps are increased (and sometimes lifted) when the insured puts mitigative measures into place, such as backwater valves and sump pumps.

When claims experience for a type of claim (such as sewer backup) becomes too common for a customer, or a geographic area has become a 'hot spot' for a particular type of claim, an insurer may opt to exclude a portion of coverage in a policy. If, for example, an insured makes too many sewer backup claims, just the sewer backup provision in the policy may, in effect, be cancelled. Similarly, if a particular neighbourhood in a city experiences excessive sewer backups on a regular basis, indemnification for that hazard may be excluded, only for that area.

Finally, when an insured files too many claims in a given period, the insurer may opt to cancel the policy altogether. While this often happens in Canada on an individual policy-by-policy basis, it is possible that such cancellations may be implemented on a geographic basis as well, though this is not as common in Canada as elsewhere. In the United States, such blanket, geographic-based cancellations often take place after a major loss event, such as a hurricane, when a company may discover that it is over concentrated in a given area or that a particular region is no longer a desirable place in which to do business.

Essentially, pricing, deductibles, caps/limits, exclusions and cancellations, serve as tools that insurers may use to encourage healthy risk-taking behaviour.

How Insurers may Leverage Pricing as a Tool to Encourage Adaptation

Price-based incentivizing is likely the best understood method insurers may use to promote good risk-taking behaviour and discourage bad behaviour, largely because insurance is a highly commoditized product, with buyers paying more attention to price than to the fine print in the contract.

On the auto insurance side, insurers have long been known to offer premium discounts for drivers that fall within a certain age group and for drivers who have completed a recognized drivers' education program. To promote environmentally friendly "green" behaviour, many insurers now also offer discounts to drivers of hybrid vehicles.

On the property side, insurers regularly provide premium discounts for burglar alarms and sprinkler systems, for example. With regard to basement flooding, some insurers offer discounts if an insured installs a backwater valve and sump pit and pump.

Insurers could offer premium discounts for a wider range of mitigation/adaptation practices, assuming, they are, in fact, pricing for the particular hazard in question. For example, anecdotal evidence suggests that many (or perhaps most) insurers in Canada do not load their pricing models for wildfire risk. These insurers view wildfires as a minor hazard because they have not historically been a big problem for Canadian property insurers. An insurer could, therefore, not offer a premium discount to a property owner who implements FireSmart on his or her property to mitigate against wildfire risk, if the insurer was not charging the homeowner for the risk in the first place.

Nevertheless, there are a range of other measures that could warrant a property premium discount, including the use of superior building products (such as roof shingles designed for high winds, hurricane clips for roof joists, and windows that are



resilient to debris impact) and the use of “better than building code” construction specifications for new builds and major renovations. On the basement flood side, along with the installation of backwater valves and sump pits/pumps, premiums may also be reduced for those who choose not to finish their basements.

Government-based Incentives for Adaptation

Governments at all levels can choose to provide tax-based incentives or establish regulatory requirements, in order to encourage positive actions and/or discourage negative actions.

In a bid to spur economic recovery, the federal government recently offered a temporary 15 per cent tax credit to eligible home renovation expenditures for work performed, or goods acquired, during a set period of time. The plan was to “provide an immediate incentive for Canadians to undertake new renovations or accelerate planned projects.” “The 15 per cent credit may be claimed on the portion of eligible expenditures exceeding \$1,000, but not more than \$10,000, meaning that the maximum tax credit that can be received is \$1,350.” (Government of Canada, 2009). The Canadian government has also offered grants to homeowners who retrofit their homes to make them more energy efficient. The grants were available for specified retrofits, with post-retrofit evaluations conducted to ensure compliance with the program. Most provinces and territories have complementary programs to encourage energy-minded housing improvements (Natural Resources Canada, 2011).

While similar forms of incentivizing can encourage homeowners to put into place measures for adaptation to climate change, none have yet been established by the federal or provincial/territorial governments in Canada, at least, not under the formal banner of “adaptation to climate change.”

In some American states, homeowners are

encouraged to take steps to protect against injury, loss of life and property damage cause by extreme weather. However, it appears that none have been formally positioned as “climate change adaptation,” per se. Examples include the tornado Safe Room Rebate Program, unveiled by the state of Oklahoma after a major outbreak of tornadoes in May 1999. In response, the governor “announced that the state would provide a US\$2,000 rebate for installing a safe room when rebuilding or repairing storm-damaged homes.” (McGillivray and Castaldi, 2000).

For one week in May, the state of Virginia’s Hurricane Preparedness Sales Tax Holiday gives residents the opportunity to purchase a specified list of goods tax free, prior to the start of hurricane season (Virginia Government, 2012). States, such as Florida, Texas and Louisiana also provide for such a tax holiday for hurricane preparedness, and a number provide for income tax deductions for mitigation measures, including Louisiana and South Carolina. The state of Colorado allows a tax deduction up to US\$2,500 for homeowners who undertake wildfire mitigation measures (Colorado General Assembly, 2008).

On a municipal level, several local governments in Canada provide grants and subsidies to homeowners willing to take measures to guard against basement flooding. However, none of these programs are positioned specifically or outwardly as “climate change adaptation.” Several municipalities across Canada have developed homeowner-level flood mitigation programs which offer financial assistance through partial subsidies for homeowner-level urban flood reduction. Subsidy programs have been developed by some municipalities with the goals of increasing homeowner uptake of measures including downspout and foundation drain disconnection, backwater valve installation, and repair to sewer laterals.

Since 1991, the City of Edmonton has offered an assistance program to homeowners affected



by flooding. It provides \$975 for the installation of a backwater valve, and up to \$1,400 for sump pump installation, if necessary. The City of London's program provides 75 per cent of the costs of installation of plumbing devices or alteration of plumbing, and includes up to \$1,875 for disconnection of foundation drains when the connection is inside of the home, and up to \$575 for a backwater valve. The City of Ottawa's program provides up to \$4,000 for the installation of protective plumbing devices when the home is flooded by a sewer backup, and 50 per cent of the cost of installation of protective plumbing – up to \$2,500, if measures are installed in a home that has not experienced flooding, but is in an area that is considered at risk of flooding. The City of Saskatoon provides up to \$2,500 for protective plumbing to homeowners who have been affected by past flooding events. Subsidy programs may be available to everyone; in a city, such as in Toronto; to individuals who have experienced basement flooding, such as residents of St. Catharines; or to homeowners who are in an area vulnerable to basement flooding, such as in London and Ottawa.

Governments have, at their disposal the tools needed to ensure individuals and communities as a whole take the steps necessary to protect against the impacts of a changing climate. These tools include: the ability to set rules, regulations, guidelines and laws; establish and institutionalize building codes, building code enforcement and inspection; and, incentives to promote good risk-taking behaviour through taxation.

3. Improving the Resiliency of Public Infrastructure

The implementation of disaster mitigation options in advance of disaster events is the most important and effective means of reducing disaster risk. Disaster mitigation is closely related to climate change adaptation as both disaster mitigation and adaptation apply risk management principles to identify risks and vulnerabilities, and seek to

increase resilience to future hazard events. Despite the importance of disaster mitigation, emergency management at the national level in Canada has historically focused on the reactive aspects of disaster management, including response and recovery, rather than proactive disaster mitigation and prevention (Henstra and McBean, 2005). Thus, mitigation/prevention has been referred to as the “least developed component of Canada's emergency management system” (Hwacha 2005). Mitigation planning can be improved in Canada in three ways: develop a program for pre-disaster mitigation, better incorporate post-disaster mitigation in government disaster relief programs, and implement post-disaster mitigation programs that do not rely on government disaster relief payouts.

Disaster mitigation serves numerous benefits. It reduces: loss of life and injuries, reliance on insurance payouts and government assistance programs, business interruption, and the unquantifiable social and emotional impacts of disaster events. There is strong evidence that supports the positive impacts of mitigation measures. For example, the U.S. Multi-Hazard Mitigation Council has identified that an investment of \$1 in mitigation measures saves \$4 in disaster costs. However, there are many barriers to the implementation of disaster mitigation measures, and mitigation planning in Canada is relatively rare. For example, a 2003 survey of representatives from 94 Ontario municipalities revealed that only 14 per cent had implemented a hazard mitigation plan and the majority of respondents had not considered hazard mitigation in municipal planning (Newton, 2003).

Due to the localized nature of natural hazards and the importance of municipal governments in emergency management, it is often at the municipal level where the most effective mitigation measures are adopted. Municipalities have authority over some of the most important disaster mitigation tools, including land use



planning, building code enforcement, by-laws and infrastructure design and construction, and municipal officials are often most knowledgeable about local hazards and vulnerabilities. The importance of municipalities in disaster mitigation is reflected by their primary role across Canada in developing and implementing climate change adaptation plans and urban flood reduction programs (see City of Edmonton, 2012; City of Toronto, 2012; Natural Resources Canada, 2010; 2007).

However, local governments deal with a plethora of issues on a day-to-day basis, each with varying levels of urgency that can divert resources away from needed adaptation efforts. The existence of, and reliance on government disaster assistance programs and insurance also serves to inhibit investment in disaster mitigation, as “moral hazard” reduces the willingness of individuals and communities to mitigate risk (Parsons, 2003; Lamond and Proverbs, 2008). However, assistance for mitigation measures from higher levels of government can increase the ability of local authorities to implement mitigation measures.

Examples of Mitigation Efforts in Canada and the United States

Though there has been limited emphasis on disaster mitigation in the Canadian emergency management system, there are several examples of mitigation planning at the provincial and municipal government levels. For example, the Province of Manitoba has partnered with some municipalities, including Winnipeg and Brandon, to provide financial assistance to homeowners to mitigate urban flood risk. Mitigation and prevention of disasters are incorporated into emergency management processes in Ontario through Ontario’s Emergency Management Doctrine and Ontario’s conservation authorities have been strongly involved in flood risk reduction for many decades. All provincial governments have primary roles in flood mitigation, including flood mapping

and structural flood management measures. As discussed above, many municipal governments are engaging in climate change adaptation planning, and have developed and implemented programs to reduce urban flood risk.

Significant disaster mitigation planning has also occurred in British Columbia. In September 2007, the British Columbia Flood Protection Program began providing \$100 million in flood protection assistance over a 10-year period. Quebec’s Civil Protection Act also requires that municipalities undertake hazard identification and risk assessments and adopt disaster mitigation measures (Hwacha, 2005). The Red River Floodway, with a cost of approximately \$60 million for construction, has been used to reduce flood damage along the Red River numerous times and has saved multiples of its construction cost in damages. During the 1997 Red River flood alone, the floodway was estimated to have prevented \$6 billion in damages (OCIPEP, 2002). Though discontinued by the early 2000s, the national Flood Damage Reduction Program (FDRP) provides a further example of successful mitigation planning in Canada. The FDRP, with a focus on identifying flood risk areas to reduce risk through land use planning, and in assisting provinces and municipalities in flood damage reduction, has been shown to be an extremely effective national disaster mitigation program (Brown et al. 1997; de Loë and Wojtanowski, 2001).

The National Disaster Mitigation Strategy (NDMS), released in 2008, was developed in 1998 as a result of a round of national consultations held by the national agency responsible for emergency management (now represented by Public Safety Canada) and the Insurance Bureau of Canada. It was further developed with another round of discussions in 2002, which resulted in the identification of several requirements to reduce disaster losses in Canada, including a need to: reorient Canada’s emergency management focus on response and recovery, support piecemeal



mitigation initiatives occurring at the municipal and provincial level, have pre-disaster mitigation planning, and incorporate disaster mitigation into disaster relief funding (Hwacha, 2005). In January 2008, the guidelines of the national disaster recovery assistance program, the Disaster Financial Assistance Arrangements (DFAA), were revised to include an additional payout for mitigation, limited to 15 per cent of estimated costs of repairing or rebuilding specific projects to pre-disaster condition (Public Safety Canada, 2012). Mitigation measures funded through the DFAA mitigation supplement have included elevation of structures, locating home utilities (e.g. furnaces) above flood water levels, and installing backflow prevention devices and sump pumps.

Mitigation assistance programs in the United States provide further precedent for the creation of programs in Canada. The U.S. Federal Emergency Management Agency (FEMA) has operated several disaster mitigation assistance programs over a number of years (Table 7.1). The Hazard Mitigation Grant Program provides partial assistance for the implementation of disaster mitigation measures during the disaster recovery period, while the Pre-Disaster Mitigation Program provides assistance for mitigation during the pre-event period. The Flood Mitigation Assistance, Repetitive Flood Claims and Severe Repetitive Loss programs are focused on reducing flood risk for properties insured under the U.S. National Flood Insurance Program. Although nothing resembling the National Flood Insurance

Table 7.1: Mitigation Grant Programs in the United States

Program	Description
Hazard Mitigation Grant Program	<ul style="list-style-type: none"> • Assistance for implementation of mitigation measures during disaster recovery phase; • Funds are available based on up to 15% for amounts no more than \$2 billion of the total of Public and Individual Assistance funds authorized for the disaster; • A sliding scale of assistance is provided for mitigation costs above \$2 billion; • Grant pays up to 75% of eligible project costs.
Pre-Disaster Mitigation	<ul style="list-style-type: none"> • Assistance for mitigation planning and implementation of mitigation projects prior to disaster events; • Grant pays up to 75% of eligible project costs; • Small and impoverished communities may be eligible for 90% federal cost-share.
Flood Mitigation Assistance	<ul style="list-style-type: none"> • Assistance for reduction or elimination of long-term flood risk for structures insured under National Flood Insurance Program (NFIP); • Grant pays up to 75% of eligible project costs; • 90% available if previous mitigation measures implemented.
Repetitive Flood Claims	<ul style="list-style-type: none"> • Assistance for reduction or elimination of long-term flood risk to structures insured under NFIP and that have received one or more NFIP payouts; • Grant pays up to 100% of eligible project costs.
Severe Repetitive Loss	<ul style="list-style-type: none"> • Assistance for reduction or elimination of long-term flood risk damage to residential structures insured under the NFIP that have experienced severe repetitive losses; • Grant pays up to 75% of eligible project costs; • 90% available if previous mitigation measures implemented.

Source: Adapted from FEMA, 2008.



Program exists in Canada, these programs provide an indication of the variety and types of mitigation assistance programs currently operating in the United States.

Mitigation grant programs in the United States have been highly successful. Between 1993 and 2003, FEMA spent \$3.5 billion on individual disaster mitigation grants through three disaster mitigation programs, including the Hazard Mitigation Grant Program and Flood Mitigation Assistance programs. A cost-benefit analysis conducted by the U.S. Multi-Hazard Mitigation Council found that for each \$1 spent on disaster mitigation through these programs, \$4 was saved in future damages (Multi-Hazard Mitigation Council, 2005; Godschalk et al. 2009).

Developing Mitigation Programs for Canada

While there has been some success in mitigation planning in Canada to date, more comprehensive and expedient action will be required to develop and implement disaster mitigation programs to offset existing disaster risk and the impacts of climate change. Although the incorporation of mitigation assistance in the DFAA is a positive step toward mitigation planning in Canada, it may not be sufficient to ensure all relevant mitigation measures are implemented. Many provinces have no consideration of mitigation in their disaster relief programs (Durvan, 2011).

Disaster mitigation programs should have a strong emphasis on reducing risk at the local level, and should support mitigation work by municipal governments. Disaster mitigation programs should also build on existing mitigation work carried out by municipalities and provinces across Canada. Similar to the U.S. Pre Disaster Mitigation Program, mitigation programs should emphasize risk reduction during the pre-disaster period. However, incorporating mitigation into post-disaster recovery periods should be included as part of comprehensive mitigation planning. Mitigation

during the post-disaster period can be facilitated through the incorporation of mitigation assistance and requirements in disaster relief programs. All provinces employ disaster assistance programs similar to the national DFAA, which focuses on disaster recovery. In this way, coordination at the provincial government level for post-disaster mitigation will be important.

The DFAA mitigation supplement relies on the payment of disaster assistance for mitigation. However, large loss events do not always result in DFAA payments, such as the August 19, 2005 storm in southern Ontario which resulted in at least \$500 million in insured losses. Thus, post-disaster mitigation assistance should not be limited to situations where there are large government disaster relief payouts, but should also apply to situations where there have been large insurance payouts and where neither insurance nor government assistance has been provided.

Mitigation programs in other countries should be reviewed, and Canada-specific programs should be developed in conjunction with provinces and municipalities. Current mitigation efforts at the municipal government level throughout Canada should also be identified and built upon for national mitigation programs. To ensure that proper mitigation methods are applied, development of hazard identification and risk assessment protocols will be necessary, especially for pre-disaster mitigation programs. There is also a strong need to develop programs to inform the public of disaster risk and the importance of disaster mitigation, to ensure mitigation efforts are not resisted.

Adaptation Solutions for Existing Homeowners

1. Adapt the FireSmart Model for Urban Flood and Wind

Through the FireSmart program created by Alberta's Partners in Protection, tools aimed



at both property and community level wildfire mitigation have been developed and are widely regarded and adopted throughout Canada. The program guide includes homeowner risk assessments, vegetation management procedures, and other initiatives homeowners can take on their property to reduce wildfire risk. Community-level materials guide municipal decision-makers through implementing mitigation measures including vegetation management, emergency management, training, public education and land use planning. The FireSmart approach could similarly be used to develop tools to address wind and urban flooding, which present considerable risks to the insurance industry, as well as to Canadian property owners and communities. As climate change increases the frequency and intensity of wind and urban flood events, insurers, governments and property owners will need access to reliable and standardized information on mitigation measures to reduce urban flood and wind risk.

A FireSmart-type program for urban flood and wind would allow professionals from across the country to discuss, analyze and identify the most appropriate means of incorporating property-level mitigation options into buildings. The development of risk reduction materials would require the involvement of a range of government agencies, including national and provincial environmental and emergency management agencies, as well as researchers and insurance professionals from across Canada. Insurers can provide information on incentives for mitigation and other insurance issues, and can play a vital role in distributing information to policy holders.

2. Insurance and Government Incentives for Risk Reduction

There are several ways in which insurers can encourage risk reducing behaviour by homeowners, including: adjustments to the price charged for insurance coverage and deductibles, caps on the amount policy holders will be paid for damage,

exclusions on certain types of damages from insurance coverage, and cancellations of insurance policies. Insurers could offer homeowners premium discounts and apply other signals for a wide range of adaptation practices, including the use of superior building products and the use of “better than building code” construction specifications for new builds and major renovations.

Governments can play a significant role in encouraging risk reduction through their ability to set building construction rules, regulations, guidelines and laws. Their ability to establish and institutionalize building codes and building code enforcement and inspection can increase the resilience of buildings. Similar to insurance tools, taxation also provides an opportunity to promote risk reduction behaviour. To date, these options have not been used within Canada to encourage adaptation to climate change. However, it is clear the application of these approaches to reduce climate change risk would be relatively simple in many cases. For example, insurers already use price signals, including limiting how much a policy holder is paid for damages and adjusting premium prices, to encourage risk reducing behaviour. Expansion of these practices to other groups should not require significant innovation.

3. Disaster Mitigation Assistance in Canada

The implementation of disaster mitigation options, including land use planning, building relocation, building retrofits, and education – in advance of disaster events – is the most important and effective means of reducing disaster risk. Strong evidence supports the positive impacts of mitigation measures. For example, the U.S. Multi-Hazard Mitigation Council has identified that an investment of \$1 dollar in mitigation measures saves \$4 in disaster costs. Despite the importance of disaster mitigation, emergency management at the national level in Canada has historically focused on the reactive aspects of disaster management, including response and recovery, rather than



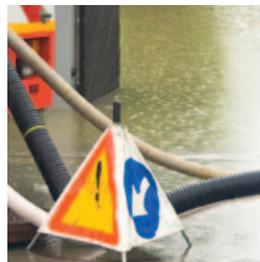
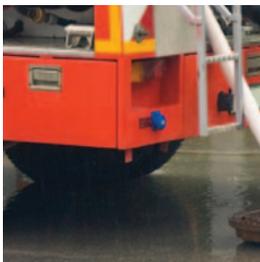
proactive disaster mitigation and prevention.

In 2011, following severe flooding in several provinces there was discussion by the prime minister and the Council of the Federation about implementing a federal disaster mitigation program. This discussion may provide an opportunity to increase the role of risk reduction in emergency management in Canada. Three ways mitigation planning can be improved include: development of a program for pre-disaster mitigation; better incorporation of post-disaster mitigation in government disaster relief programs; and post-disaster mitigation programs that are triggered automatically, even when private insurance has provided payouts.⁷

The implementation of disaster mitigation assistance programs will require a collaborative effort across a range of stakeholders. The involvement of several national government agencies, including Public Safety Canada, Environment Canada, Natural Resources Canada, the National Research Council, among others, will be important. Provincial agencies responsible for emergency management should also be involved in

the development of national mitigation programs. Municipalities often have the most significant contact with residents, are involved in aspects of emergency management, and, therefore, should also participate in the development of mitigation programs. National, professional and industry associations may also prove to be valuable stakeholders in program development, including the Federation of Canadian Municipalities, the Insurance Bureau of Canada, the Canadian Institute of Planners, and Engineers Canada.

To sum up, there is a strong need to incorporate risk reduction measures into existing homes and communities and to promote risk reducing behaviour. Homeowner risk reduction behaviour is inhibited by the cost of retrofitting older structures and by the lack of public knowledge of risk reduction options. Thus, assistance for risk reduction for existing homes is needed. This chapter outlines, how the government and the insurance industry, through incentives and improved public education and funding for disaster mitigation, can encourage climate risk reduction for existing buildings.



⁷Sometimes post-disaster mitigation funding does not occur when there is evidence private insurance has covered some losses.



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8. Insurance: Aligning the Price of Insurance With Risk of Damage

Paul Kovacs

Executive Director, Institute for Catastrophic Loss Reduction (ICLR)

Introduction

“Climate change will likely further increase the risk of damage over the next three to four decades. Insurance has been the primary mechanism used by homeowners and businesses across Canada to mitigate the risk and recover from this type of damage.”

There has been an alarming increase in property damage due to water, wind, wildfire and other weather-related perils over the past three or four decades. This is largely due to an aging infrastructure, population growth, and other socio-economic factors. Climate change will likely further increase the risk of damage (IPCC, 2012). In Canada, insurance is the primary mechanism used by homeowners and businesses to recover after most severe weather events. The price of insurance (or the price of the risk of damage) plays an important role in maintaining this mechanism as the climate changes.

Insurance pricing is based primarily on the estimation of the risk transferred from the property owner to the insurance company. Insurers use available information to estimate the risk of damage and establish prices for each policyholder. Each policyholder then pays a premium (the price of transferring the risk to an insurer) which creates a “pool” or “reserve” of capital managed by the insurer. When an extreme event occurs, the insurer

is responsible for paying out claims to help policy holders recover from potential damage.

Those living with a high risk of damage can buy insurance but the price will be high. Those with a low risk of damage will pay a lower price for insurance. Prices aligned with the risk of loss are an essential foundation for a successful insurance market. Risk-based pricing ensures that all property owners have the opportunity to participate in the insurance pool. It also ensures that sufficient funds will be in the pool to pay the expected damage claims of participants. Policy options to support risk-based pricing by insurance companies are consistent with efforts to ensure that insurance remains available to pay the damage claims of Canadians. Moreover, risk-based insurance prices provide information and incentives to promote adaptation.

An accurate price for insurance serves two critical purposes in mitigating the risk of extreme weather and climate change. First, the price of insurance provides homeowners and businesses with an ongoing measure of their risk of damage from extreme weather, information that can and should be used to encourage appropriate investments in climate adaptation. If the price of risk is too low, policy holders could go unaware that their property is exposed to significant risk. If the price is too high, policy holders might take unnecessary mitigation actions. Second, the price of risk needs to be accurate so that the reserves managed by insurance companies will be large enough to pay damage claims linked with extreme weather and climate risk. If the price is too low, the reserve may not be sufficient to cover the cost of damage. This could lead to the erosion of capital and, perhaps, even insolvency for the insurer. If the price is too high, insurers may charge too much and lose customers to competitors better able to strike the right balance between the price of insurance and a sufficient capital reserve.



Change in the risk of damage from severe weather linked with climate change challenges the ability of an insurer to manage the risk transfer mechanism and maintain its role in recovery and prevention. As the climate changes, with more extreme weather events taking place, so will the risk of extreme weather damage. An accurate estimation of risk will incorporate these changes in extreme weather risks to ensure insurance remains available at affordable and fair levels, and can sustainably support society's management of future extreme weather events. As the climate changes, insurers must adapt and reflect the influence of the changing climate in the prices they charge. This paper identifies two policy options to enhance successful risk-based pricing by insurance companies as a means to manage the risk of damage from severe weather for homeowners.

First, insurance companies across Canada should establish a joint strategy to champion actions by homeowners and businesses to adapt to severe weather. One dimension of the strategy should seek to inform Canadians about the role of insurance to support management of the risk of damage from a broad range of perils, including severe weather. This information will help Canadians understand how to reduce their exposure to extreme weather risks, and ensure insurance remains affordable as the climate changes.

Second, and perhaps most importantly, the Government of Canada should actively work with the insurance industry and other stakeholders to provide better data about the risk of severe weather events that may result in injury or property damage. Insurance companies need better data about the risk of loss if they are to best serve Canadians – data that often can only be provided by the Government of Canada.

Property Insurance in Canada

Insurance is the most competitive financial industry in Canada, with more than 200 companies providing coverage. There is a mix of: small, mid-sized and large insurers; Canadian and foreign owned; focused on local risks, active across the country, participating in markets around the world; specializing in specific kinds of coverage; and, providing a full range of insurance protection. Healthy competition is evident in the modest, but relatively consistent profits earned by the insurance industry, when contrasted to the high but more volatile earnings for banking and other financial services (Kovacs, 2006). Moreover, healthy competition eliminates the scope for intentional cross subsidization of consumers or markets.

Property insurance is available in Canada to provide coverage for homeowners and businesses against loss from a broad range of climate perils – water damage, winter storms, lightning, wildland fire, hail, and severe wind, including hurricanes and tornadoes. Flood insurance is available to businesses but not to homeowners. It represents the most significant climate peril where insurance is not available to homeowners.

More than 95 per cent of property owners in Canada buy insurance for their home or business. Insurance generally represents less than two per cent of overall spending by homeowners and businesses. Indeed, homeowners in Canada pay less than \$3 a day, on average, for insurance that covers the risk of loss from many climate perils, as well as the risk of loss from fire and theft. The price paid by homeowners and businesses includes several taxes, fees and levies assessed by governments on property owners who purchase insurance. The provincial and territorial governments assess many of these taxes.



Typically, consumers pay a price established at the beginning of the contract term in return for the promise that an insurance company will pay for damage due to accidental losses. Most insurance policies cover a period of 12 months, so new information about the risk of damage can be introduced by consumers or insurance companies when a policy is renewed. More than 10 per cent of policy holders change insurance companies each year, seeking coverage that best suits their specific needs.

Property owners use insurance to buy a promise that funds will be provided to restore and rebuild their property if an accidental loss occurs. Usually, less than five per cent of property owners experience a loss in any given year, but those losses can be large, perhaps even catastrophic in the event of a total loss. Pooling the modest premiums paid by many vulnerable property owners provides the funds to prefund the relatively large losses that are incurred by a few (Kovacs, 2006). This pooling concept has been the foundation of insurance in Canada for more than 200 years, with the price of coverage based primarily on the estimated risk of damage.

Climate Change and the Impact of Large Storms

The 1998 ice storm was Canada's most costly disaster. Insurance companies paid \$2 billion in damage claims to homeowners and businesses as a result of a large storm affecting eastern Ontario, southern Quebec and Atlantic Canada. Until recently, this was the largest loss event in the world, when measured by the number of homeowners and businesses receiving an insurance claim payment (700,000 in Canada and more than 100,000 in the United States), and most were fully restored soon after the storm. Moreover, as the recovery needs of homeowners and businesses were addressed by insurance, government agencies were able to focus their efforts on rebuilding

damaged infrastructure and restoring public services (Kovacs, 2006).

After the storm, there was little change in the price of insurance. The ice storm was a large loss, but an analysis of the storm indicated that risk of winter storm damage in the future was largely unchanged. Some insurance companies did adjust the terms and conditions of coverage for the risk of food spoiling in a freezer after a power failure because they discovered that these claims were higher than anticipated but, generally, insurance prices, terms and conditions were unchanged.

However, there have been events in other countries around the world where insurance practices shifted considerably after a large event because of a new understanding of the risk of damage (Kunreuther and Roth Sr., 1998). This was particularly evident in the United States following large hurricanes making landfall in 1992, 2004 and 2005. Insurance markets also adjusted in California and Australia following large wildland fires, and in Europe after major floods, where it became evident that the risk of loss differed from expectations. While Canadian insurance markets have been stable, international experience demonstrates that severe weather events have the potential to disrupt insurance markets if the damage claims they produce were not anticipated. For this reason, insurance prices must begin to reflect the risks of extreme weather damage linked with climate change. To accurately price the risk that must be transferred to a pool to protect Canadians from climate risks, insurers must overcome several obstacles. These are explained in more detail in the following sections.

Why Insurance Prices May Differ from Risk Transferred

There are two factors that may cause insurance prices to differ from the actual risk transferred as the climate changes. First, insurance companies



may attempt keep their prices above or below the rates they estimate as the expected risk of damage. Second, an absence of quality information may increase the difficulty of securing accurate estimates of the risk of loss.

Actions by Insurance Companies

Insurance companies are private businesses. They could choose to charge prices lower or higher than determined by their estimation of the risk of damage. However, the discipline of the insurance market does not allow this strategy to be sustained. For example, if an insurance company sought to charge a price higher than that required to cover the expected damage claims, its customers would soon transfer their business to one of the many other insurance companies participating in this highly competitive market. Independent insurance brokers work to serve homeowners and businesses, to help them identify the insurance coverage best for their specific needs. It would not be possible for an insurer to sustain excessive pricing (Dorfman, 2002; Vaughn and Vaughn, 2001).

If an insurance company chooses deliberately to undercharge for the risks assumed, this would, over time, erode their capital base, as losses regularly exceed the pool of funds collected. This approach is also unsustainable, and in the extreme, could force insurance regulators to close the insurer because of the risk they would not have sufficient capital to pay claims. Prices may temporarily differ somewhat from the expected damage claims for a specific insurance company. However, the discipline of an intensely competitive market will not sustain this as a strategy for a company, or for the industry. Insurance companies are driven to apply available information to estimate expected losses, and, in turn, expected damage losses are the primary factor used to determine prices.

Incomplete Information

The most significant reason why insurance prices differ from the actual risk transferred is likely due to the absence of quality and complete information (Chiappori, 2000). This factor is likely more significant than the potential for deliberate actions by insurance companies, or taxation by governments.

There is little quality information about historic severe weather events in Canada, and this information is essential to quantify the risk that similar events will occur in the future. Because climate change is anticipated to influence the frequency of extreme weather events, missing information on extreme weather patterns constitutes a significant information asymmetry for the insurance industry. Weather records retained by Environment Canada focus on long-term trends in average temperature and precipitation; unusual and extreme events are often ignored or deleted from the record to provide a sense of trends in the mean, while these rare events are typically of considerable interest to insurers. The absence of quality historic weather information imposes a cost on society, including a reduced capability of insurance companies to accurately anticipate future damage claims.

Insurance companies estimate the risk of damage through an assessment of local weather trends, but they also require information about a number of other risk factors. The risk of water damage to homes, for example, appears to be highly dependent on the state of municipal storm and sanitary sewer systems. Insurance companies, through the Insurance Bureau of Canada, have recently launched a pilot project with some communities, to determine if this information can be acquired in a form useful for insurance companies to better anticipate the risk of



losses in the future. Municipal governments are cooperating in this project, with the expectation that this information will better direct scarce public resources toward investments that provide the largest benefits for taxpayers.

Climate Change Challenges for Setting Insurance Prices

While actions by insurance companies can lead to inaccurate risk prices, incomplete information represents the most significant obstacle insurers must address to price climate risks. Incomplete information limits an insurer's ability to address several specific challenges linked with assigning a price to the influence of climate change on extreme weather. These challenges include adverse selection, moral hazard, the inverse production function, and low probability/high consequence perils.

Adverse Selection

Insurance companies and consumers do not have the same information about the risk of loss. If other factors are held constant, like the price of insurance, consumers who know they are subject to greater risk of loss are more likely to buy insurance than those who know they are less likely to experience loss. Insurance companies may not be aware of differences in the risk of loss, so the price, terms and conditions to buy insurance coverage may be the same, even if consumers know they face a risk of loss that is higher or lower than what is anticipated by the insurance company. In circumstances where it is difficult to obtain information about the risk of loss, insurance companies are concerned they may experience a large number of high-risk consumers seeking to buy coverage. This concern is called "adverse selection" (Eisenhauer, 2004; Dahlby, 1983).

In the context of climate change, adverse selection occurs when insurers are unable to accurately understand differences in climate risk exposure between different consumers. Without accurate information on exposure to these risks, insurers will be hesitant to offer any coverage. Flood insurance for homeowners is an example where adverse selection has contributed to a severe disruption in the Canadian market. Homeowners who experience overland or coastal flooding regularly seek to buy flood insurance, while homeowners who know they are unlikely to experience flood damage show little interest in flood insurance (Browne and Robert, 2000). One of the reasons why insurance companies are unwilling to offer flood insurance to homeowners in Canada is due to the difficulty in obtaining quality flood maps and other information to measure the risk of flood damage to individual homes. Concern about adverse selection is one of the reasons why flood insurance is not available for homeowners in Canada. Insurers believe homeowners have more information about the risk of flood damage than is available to insurers, so companies are unable to establish a fair price to charge if they were to accept this risk.

Adverse selection can also lead to the unintended cross subsidization of those living at high risk by those with low risk. For example, new research by the Institute for Catastrophic Loss Reduction indicates that homeowners can reduce the likelihood of basement flooding and other water damage from sewers that back up during intense rainfall events by installing backwater valves, sump pumps, disconnecting their downspouts and appropriate landscaping (Sandink, 2009). Insurance companies have recently begun to apply this research, their damage claims experience, and other emerging information, to differentiate their assessment of the risk of damage. However, before insurance companies had the information needed to introduce these reforms, homeowners



with a low risk of loss were facing similar prices and coverage terms as those with a higher risk of loss. Low risk consumers had been subsidizing high-risk property owners.

Research and analysis is the primary means insurance companies use to manage the risk of adverse selection. Insurers acquire information from potential consumers and from public agencies in order to estimate the risk of future damage claims. These data are combined with information, when it is available, about insurance claims experience. The combined data is then assessed by actuaries. The greatest effort is directed to assess risks with the potential to result in significant damage claims. For example, 30 years ago, insurance damage claims due to severe weather accounted for less than 10 per cent of insurers' costs and relatively little effort was invested to anticipate future costs. Today, severe weather damage claims account for 40 to 50 per cent of most property insurers' damage claims, so a significantly greater investment is made to understand and measure this risk. This trend is anticipated to increase as the climate changes.

Moral Hazard

Moral hazard is introduced if the presence of insurance coverage changes the behaviour of homeowners and businesses so they are less involved in the ongoing care and maintenance of their property and this behaviour increases the likelihood and magnitude of the damage expected. Insurance companies are concerned the cost of damage claims may increase because insurance is purchased. In the context of climate change, moral hazard can occur if the insured is unaware of potential exposure to significant loss through climate-related events.

Insurance has been designed to ensure that a pool of funds is available to pay for accidental losses. If, however, the purchase of insurance leads some

property owners to reduce their efforts to care for their property, then overall damage losses will grow, and increase the cost of insurance. Insurance companies have been concerned about moral hazard in Canada for more than 200 years. Insurers use two mechanisms to manage this risk. First, insurance protection includes deductibles. And second, insurance companies regularly communicate with policy holders.

Property insurance policies in Canada include a deductible set out in the terms and conditions of coverage. The value of the deductible may differ, with \$500 being a common value in Canada, although a growing number of policies have shifted to \$1,000. The reduction in the claim payment by \$500 or \$1,000 has little impact on consumers or insurers for moderate or catastrophic losses, but is most evident for small loss events. Indeed, if the damage is less than the deductible, there will be no payment by insurance companies.

Many decades ago, insurance companies introduced deductibles to encourage homeowners and businesses to remain actively engaged in managing the risk of damage. Customers retain full responsibility for small losses, and share part of the responsibility for moderate or large events. The importance of deductibles for insurers is also evident in the pricing of coverage. Companies lower the cost of buying insurance if homeowners and businesses are willing to accept a higher deductible and increased responsibility for loss prevention.

Insurance companies also actively communicate with policy holders about the actions they can take to reduce the risk of damage. This includes direct communication with customers and joint public education programs by the industry, or working in partnership with public agencies. For many years, the insurance industry has been aggressive in promoting fire safety, crime prevention, and road safety, with the overall message that everyone can contribute to reducing the risk of loss. It is expected



that, over time, insurance companies will become as active in promoting actions to reduce the risk of severe weather damage, now that weather damage has grown to exceed that from fire and theft. Greater safety knowledge is expected to result in increased homeowner and business participation in loss prevention, reduced moral hazard and lower expected damage claims that, in turn, can potentially reduce the price of insurance.

Inverse Production Function

Insurance differs considerably from most other businesses, in that insurance companies must decide what price to charge before they know most of the costs they will eventually pay. This approach is described as an inverse production function. Not knowing the actual costs increases the challenge of determining appropriate pricing, terms and conditions for coverage (Dorfman, 2002; Vaughn and Vaughn, 2001). Climate change intensifies the challenge associated with the inverse production function because insurers need to know how to price the risk of extreme weather linked with future-oriented climate scenarios to cover potential claims and help in recovery.

In contrast, manufacturing companies typically have paid more than 80 per cent of the costs they will incur when they set the prices they charge. In the banking industry, more than 90 per cent of costs are fully known when prices are set. The largest cost for insurance companies is the payment of damage claims, and insurance will only be sold to customers to cover the potential of accidental damage in the future, so damage claims costs are unknown when insurance prices, terms and conditions are established.

Over the past 200 years, insurance companies in Canada have developed rigorous processes for estimating claims that will be incurred. Insurance companies have several decades of experience applying actuarial underwriting methods to

anticipate damage claims from fire, theft, and vehicle collisions. These methods, however, have only recently been applied by most companies to anticipate water, wind and other weather-related damage claims, and are not yet proven. This uncertainty is important, because it is these types of perils that are anticipated to increase as the climate changes.

Weather-related damage claims were a small part of overall damage claims paid until the late 1990s. Insurance companies, however, did collect some data on water and wind damage claims paid over the past 40 years, in addition to some information about the losses linked with extreme weather. This information revealed that water and wind damage claims consistently comprised 10 to 20 per cent of overall damage claims paid until the 1990s. This was much smaller than urban fire damage claims and, typically, smaller than theft claims. Recently, however, there has been an alarming and sustained increase in water damage claims paid, and a steady increase in wind damage claims paid by insurers. Over the past five years, water and wind damage claims have surpassed fire claims and emerged as the largest cost for most insurance companies in Canada.

It is unlikely that traditional actuarial underwriting analysis was applied to weather-related risks until recently, because of this relatively low cost of claims. Insurance companies have only now begun to identify and search for a full range of information to assess weather-related risks. For example, over time, insurance companies have established sources of information about local fire prevention, crime, and road safety information to assess the risks facing each potential customer. This includes developing relationships with government agencies to access information about collision history and driving records.

With time, insurance companies are expected to become as proficient in anticipating severe weather



damage as they have been in anticipating the risk of damage from fire, theft and collisions. The development of this expertise will be critical to better understanding the impact of climate change on the frequency and intensity of extreme weather patterns, and its costs.

Low Probability/High Consequence Events

Traditional pricing and planning activities in insurance are well tested for frequent, but relatively low-cost perils like urban fires, theft and vehicle collisions. Worldwide, this approach has been tested over the past two decades by a number of unlikely, but high-impact, events. This includes major earthquakes, and a number of weather-related perils, such as hurricanes, flooding and wildland fires – which are the same perils likely to be influenced by climate change. The risk of a low probability, high-impact event linked with climate change has the potential to overwhelm an insurance company, if it were to set its prices based exclusively on a rigorous assessment of recent loss experience. Accordingly, over the past decade, insurance companies in Canada, and elsewhere around the world, have begun investing in climate models to better understand the impact of climate change on low probability/high consequence events.

Canadian insurance companies supported the building of earthquake models in the early 1990s, and recently have started to support the development of models for weather perils like severe wind. Over time, tools will emerge to help insurance companies manage a variety of risks that may include water damage, severe wind, wildland fire, winter storm and hail.

The experience with earthquake models indicates that this information will initially focus on support for decision-makers to manage solvency risks, including the purchase of reinsurance (insurance for insurance companies). Over time, these tools

will likely also support decisions about pricing. Because the primary focus for insurance pricing is expected to always be based upon the rigorous actuarial assessment of historic losses, climate models are likely to evolve into an additional support tool, particularly for low probability, high-consequence events.

The difficulty for insurers in creating useful climate models primarily involves the absence of quality data. Historic weather information is difficult to access and was largely designed to follow long-term averages and remove information about the extreme events of concern to insurers. Moreover, these models require considerable information beyond weather data, which are also difficult to acquire. This would include information about the state of Canada's building stock and public infrastructure.

Adaptation Solutions for Aligning the Price of Insurance with the Risk of Damage

1. Educate on the Role of Insurance

Insurance companies across Canada should establish a joint strategy to champion actions by homeowners and businesses to adapt to severe weather. This program can help homeowners take an active role in adapting to extreme weather and climate impacts in ways that mitigate the risk of property damage. These actions mitigate the interference in establishing an insurance price caused by: adverse selection, moral hazard, the inverse production function, and low probability/high consequence events. One dimension of the strategy can inform Canadians about the role of insurance to support society's management of the risk of damage due a broad range of perils, including severe weather and the potential impact of climate change.

A public education program should:



- inform property owners about the role of insurance to prefund specific types of expected weather damage;
- encourage homeowners and businesses to buy insurance against a range of hazards, including the risk of damage from climate extremes;
- identify insurance prices as a measure of the risk of damage to homes and businesses from perils that include water, wind and other weather hazards.

Most homeowners and businesses in Canada buy coverage, so there is a strong foundation for joint outreach. However, many who rent do not buy insurance, and this includes Canadians with lower incomes concerned about the cost of coverage. Insurance companies seek to charge prices that reflect the risk of damage transferred from the property owner to the insurer. Those with lower incomes typically have less property, so the risk transferred and price of insurance will be low: nevertheless, these families may still have difficulty to pay for coverage. Appropriate government agencies should consider the importance of insurance to achieve their policy goals.

Disaster assistance is an example where policy makers actively consider insurance issues. Disaster relief payments, for example, are not paid to homeowners and businesses with insurance coverage, and are not to be paid to property owners who could have purchased insurance but decided not to buy coverage. Disaster assistance is to be directed to re-establish public services, and rebuild public infrastructure, with funds provided to private property owners only when insurance is not available in the local market, and commonly involves flood damage to homes. A joint public outreach program can further reinforce this established policy, because many Canadians only learn about these issues after disaster strikes.

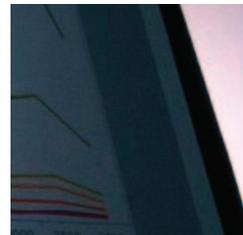
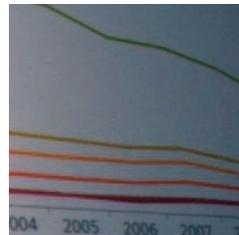
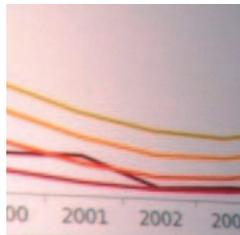
2. Develop Better Data to Estimate the Risk of Severe Weather Damage

The estimation of the risk of damage requires quality information. This includes information about high-impact storms that can damage a home or business, but also information about public infrastructure and socio-economic factors. Without this information, insurers face a significant information asymmetry when trying to estimate the risk of future extreme weather and climate impacts. Adverse selection, moral hazard, the inverse production function, and the challenges linked with low-probability high consequence events, cannot be addressed, as long as this asymmetry disrupts the risk pricing process. For example, how frequently will the storm water sewer system be overwhelmed by a downburst? Will the risk of backup from the sanitary sewer system increase if the town population grows?

Broad national trends are not sufficient to guide homebuilders, local municipal officials responsible for public infrastructure, or insurance companies. A special challenge is the need for data that includes information about local risks. The more detailed the data, the better. Insurance companies have initiated a pilot project to generate data on the basement flooding risks linked with municipal infrastructure through the Insurance Bureau of Canada. This Municipal Risk Assessment Tool (MRAT) will help insurers and municipalities identify the most vulnerable areas for basement flooding. While an important first step, this project should be expanded for other types of risks. The Government of Canada in collaboration with the insurance industry, can play a pivotal role in supporting this type of research. Below are several opportunities for the government and the insurance industry to generate better information on the risk of severe weather damage.



- fund Environment Canada to assess information available concerning the most significant historic high-impact weather events across Canada, and to develop climate models to anticipate future risks;
- establish national inventory of public infrastructure, including municipal, provincial and territorial systems of critical interest to determining the risk of severe weather damage, including storm and sanitary sewer systems.
- revise the national building code to require that new buildings and structures are designed and built to withstand the risk of damage for the severe weather perils expected during the lifetime of the structures rather than historic events;





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H. Glossary





H. Glossary

Below are several key definitions and concepts used in the CCAP report that describe climate-proofing decision-making. The terms help define a common language familiar to climate adaptation professionals. Internationally accepted definitions have been used wherever possible, to ensure this issue is discussed in a common language.

acceptable risk – the level of potential losses that a society or community considers acceptable, given existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures needed to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or “accepted practice,” which are based on known probabilities of hazards and other factors. The concept of acceptable risk, for example, should apply to vulnerability assessments of critical facilities (UNISDR, 2009a).

adaptation – adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Adaptation Advisory Committee (AAC) – a standing body of 80 high-profile representatives from industry, academia, aboriginal communities, NGOs, and the legal community, charged with identifying the key climate change challenges prioritized by the CCAP. The AAC will continue to provide guidance and advice as the CCAP moves to implement its recommendations.

assessing critical infrastructure systems – critical facilities are the primary physical structures, technical facilities and systems that are socially, economically or operationally essential to the routine functioning of a society or community, and

during an emergency. They must be the foremost focus of adaptation planning and implementation of adaptation actions.

climate-proofing -- adaptive actions taken to increase the capacity and resilience of an infrastructure system to enable its functionality and reliability in response to a changing climate. It does not mean the elimination of all risk.

critical facilities -- primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency. Critical facilities are elements of the infrastructure that support essential services in a society (e.g. transport systems, air and sea ports, electricity, water and communications systems, hospitals and health clinics, and centres for fire, police and public administration services) (UNISDR, 2009a).

non-structural measures – any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, through policies and laws, public-awareness raising, training and education (e.g. building codes, land use planning laws and enforcement, research and assessment, information resources, and public-awareness programs.)

primary subject matter expert – the experts chosen to present on a broad range of climate change challenges facing Canadians.

residual risk – risk that remains in an unmanaged form, even when effective Disaster Risk Management (DRM) and Climate Change Adaptation (CCA) strategies, plans and actions are in place, and for which early warning systems (EWS), and emergency response and recovery capacities must exist. The presence of residual risk implies a continuing need to develop and support



effective capacities for early warning systems, emergency services, preparedness, response and recovery; together with risk transfer mechanisms and socio-economic policies, such as safety nets (UNISDR, 2009a).

resilience – capability of infrastructure to respond to, and recover from, the threats of a changing climate with minimum damage/impact to a society’s social fabric, its economy, and the natural environment.

risk management – includes risk identification, risk analysis and risk evaluation. It is the core of the disaster risk management cycle and is an essential element of the ensuing decision-making process.

socio-natural hazard – the increased occurrence of certain geophysical and hydro-meteorological hazards, such as landslides, flooding, land subsidence and drought, that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources. This term is used for the circumstances where human activity is increasing the occurrence of

certain hazards beyond their natural probabilities. Socio-natural hazards can be reduced and avoided through good management of land and environmental resources (Highland and Bobrowsky, 2008; UNISDR, 2009a).

secondary subject matter expert – the experts for each challenge area identified by the Adaptation Advisory Committee who wrote detailed reports outlining each challenge and potential solutions.

structural measures – any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems (e.g. dams, flood levees, ocean wave barriers, earthquake resistant construction, and evacuation shelters).

vulnerability – degree to which the elements within an infrastructure system are susceptible to, and not able to withstand, the adverse impacts of extreme events of greater intensity and duration than provided for in current codes and standards.

