Protecting your Community from Climate Change

A TRAINING PROGRAM FOR ONTARIO MUNICIPALITIES

Clean Air Partnership

Authors:
Jennifer Penney, Director of Research
Kevin Behan, Program Manager
Erica Pinto, Researcher
Caroline Rodgers, Researcher
Nick Weigeldt, Researcher

Cover Design:
Leena Salem

Cover Image:
By John R. Southern, Toronto. Online at
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Natural Resources Canada Ressources naturelles Canada

Canada

Ontario

For more information, contact
Clean Air Partnership
75 Elizabeth Street
Toronto, Ontario M5G 1P4
Canada
416-392-6672
www.cleanairpartnership.org

About the Clean Air Partnership
Clean Air Partnership's mission is to transform cities into sustainable, vibrant, resilient communities, where the air is clean to breathe and greenhouse gas emissions are minimized. Our applied research on municipal policies strives to broaden and improve access to public policy debate on air pollution and climate change issues. Our social marketing programs focus on energy conservation activities that motivate individuals, government, schools, utilities, businesses and communities to take action to clean the air.

FOREWORD FROM EVA LIGETI
EXECUTIVE DIRECTOR, CLEAN AIR PARTNERSHIP

CAP is pleased to present the Municipal Adaptation Training Program, a part of the Ontario Regional Adaptation Collaborative (ORAC), supported by Natural Resources Canada and the Ontario Ministry of the Environment.

Damage from weather is a fact of life in Ontario. We are familiar with the destructive potential of rainstorms and floods, droughts and heat waves, ice storms and blizzards, tornadoes and windstorms. But scientists tell us that we face additional weather risks because of climate change. These changes will expose us to a growing range of challenges and new costs for protecting our health and our property. Our efforts to reduce emissions must remain the first line of defence, but we need to prepare for the climate change that we cannot avoid. Adaptation is necessary to prepare our communities and economies to deal with the weather disruptions that are becoming more severe and frequent as the planet's climate changes.

> *"Adaptation can no longer be considered the 'Cinderella' of climate change...... while a suggestion 10 years ago that adaptation would be unavoidable was considered defeatist, it is now commonly accepted that immediate investment in adaptation will be essential to buffer the worst climate impacts."* [1]

Ontario's municipal leaders are the front line for protecting lives and property from the impacts of severe weather with their responsibilities for infrastructure and services.

The Municipal Adaptation Training Program has been tailored specifically for municipal decision-makers. Our key objective is to help you to make the transition from awareness of climate change to taking adaptation action. Our focus is on the steps how to initiate a decision-making process, from raising awareness to undertaking assessments and planning leading to the implementation of practical adaptation actions. The program itself will continue to develop as we work with you and other workshop participants. The final version will be available to you and your colleagues as you embark on the adaption planning process in your jurisdiction.

[1] *Source: http://www.ukcip.org.uk/wordpress/wp-content/PDFs/UKCIP_Managing_adaptation.pdf*

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MEET THE INSTRUCTORS

Eva Ligeti
Executive Director, Clean Air Partnership

Eva directs research and social marketing with a focus on urban air quality and climate change mitigation and adaptation for livable, low carbon cities. Ms. Ligeti serves on numerous boards and committees including, Federation of Canadian Municipalities' Green Municipal Fund's Council, Brantford Power Inc. and the Advisory Council of the Nuclear Waste Management Organization. She was a member of the Province of Ontario's Expert Panel on Climate Change Adaptation. She is a co-chair of Civic Action's Green GTA Task Force. She was a member of the Advisory Committee for the Metrolinx Go Electrification study. An adjunct professor at the University of Toronto, Graduate Program in Environmental Science, she teaches environmental law.

Eva was Ontario's first Environmental Commissioner from 1995 until 1999. Prior to her term as Environmental Commissioner, she was the Principal, Sheppard Campus, Seneca College of Applied Arts and Technology and Chair, School of Legal and Public Administration. Eva is a lawyer (LL.B. Windsor, LL.M. Osgoode).

Eva's goal is to build programs, policies and practices that facilitate urban communities making the transition to a low carbon future. She develops market and community-based research and strategies for: healthy, clean air; climate adapted, resilient cities; a sustainable built environment that reflects livable, sustainable urban planning, with convenient, accessible, public transit and active forms of transportation.

Kevin Behan
Director of Research, Clean Air Partnership

Kevin Behan's research interests include GIS and Spatial Analysis and the application of these techniques in the fields of urban forestry, transportation and urban heat island research. He has previously worked in research with both the Centre for Spatial Analysis and McMaster Institute for Transportation and Logistics at McMaster University where he employed simulation modeling to examine emissions produced in various scenarios of land use and urban development and to understanding the relationship between environmental pollution and health. Prior to this, Kevin was employed as a GIS analyst with the Government of Ireland Forestry Department, surveying forest crops and implementing sustainable harvest practices in compliance with Forest Stewardship Council guidelines.

Nick Weigeldt
Researcher, Clean Air Partnership

After an undergraduate degree in Geography and Urban Studies from the University of Winnipeg, it was the emerging imperative of cities responding to climate change that prompted Nick to pursue further education in urban planning. During his time at Ryerson University's Master of Planning program, his GEOIDE-research focused on emerging online methods of civic engagement and public participation in the planning process as well as the land-use planning barriers to urban and near-urban small-scale agriculture. He was the Ryerson recipient of the Canadian Institute of Planners Student Award for Academic Excellence. Subsequently, as a researcher in the academic and professional planning contexts, he returned to cities and climate change where he was involved in a Canada-wide research project that looked at the role of municipalities in Canadian climate change governance and the drivers prompting municipalities to respond to climate change.

Jennifer Penney
Former Director of Research, Clean Air Partnership

Jennifer Penney is the Director of Research for the Clean Air Partnership. Jennifer has a Doctorate in Work Environment Policy. She is the author or co-author of several reports on adapting to climate change including: *Climate Change and Human Health in Cities* (forthcoming),*Climate Change Adaptation in the City of Toronto: Lessons for Great Lakes Communities (2009), Cities Preparing for Climate Change: A Study of Six Urban Regions (2007), Climate Change Adaptation Options for Toronto's Urban Forest (2007), Time to Tackle Toronto's Warming (2007),* and a *Scan of Climate Change Impacts on the City of Toronto (2006).*

Jennifer has also organized workshops for municipal staff on climate change adaptation, worked as a consultant to the City of Toronto in the development of their recent Climate Change Adaptation Strategy, and advised the Federation of Canadian Municipalities on the development of adaptation program. In 2007-2008, Jennifer coordinated the work of Canada's Alliance for Resilient Cities, a network of municipalities and others concerned about preparing for the impacts of climate change.

Before retiring, she instructed the workshops in the GTA and Southwestern Ontario.

INTRODUCTION

It is now unequivocal that climate change is underway and that the consequences could be severe. Towns and cities in Ontario will be directly affected by many of the impacts of climate change, including increased intensity and frequency of extreme weather events, heat waves, flooding from intense precipitation events, increases in the intensity of storms, water shortages and other effects.

The majority of local governments in Ontario have responded to the concerns about climate change by putting into place mitigation programs to reduce greenhouse gas emissions. However, it is becoming clear that communities and municipalities will also have to plan to adapt to some of the changes that are inevitable. Adaptation to climate change means taking action to protect our natural, built and social environments from the impacts of climate change. A number of municipal governments in Ontario have already begun.

This course is intended to help municipalities and municipal departments take action to adapt to climate change. It builds on the experience of some local government leaders in the field, and includes links to reports of their efforts. It also draws on the important work of Canadian and international climate change scientists and adaptation researchers.

The course will be offered in four regions of Ontario in the spring and fall of 2011 in two 2-day sessions in each region. The program consists of 12 modules, each of which has a backgrounder and guide for facilitators:

1. An Introduction to Climate Change, Trends and Projections
2. Impacts on Urban Ontario Municipalities
3. Climate Change Adaptation Planning
4. The Adaptation Team
5. Creating an Initial Assessment of Vulnerabilities
6. Climate Change Risk Assessment
7. Identifying and Choosing Adaptation Options
8. Integrating Adaptation into Municipal Plans
9. Municipal Programs to Implement Adaptation
10. Drivers and Barriers
11. Communicating to and Engaging Stakeholders
12. Indicators of Progress

The Clean Air Partnership will follow up the course with a Train-the-Trainers program so that the course and its modules can be given and adapted by those who wish to replicate it within their municipalities or their regions.

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MODULE 1: OVERVIEW OF CLIMATE CHANGE

Learning Objectives and Outcomes

By the end of the module, participants will have:

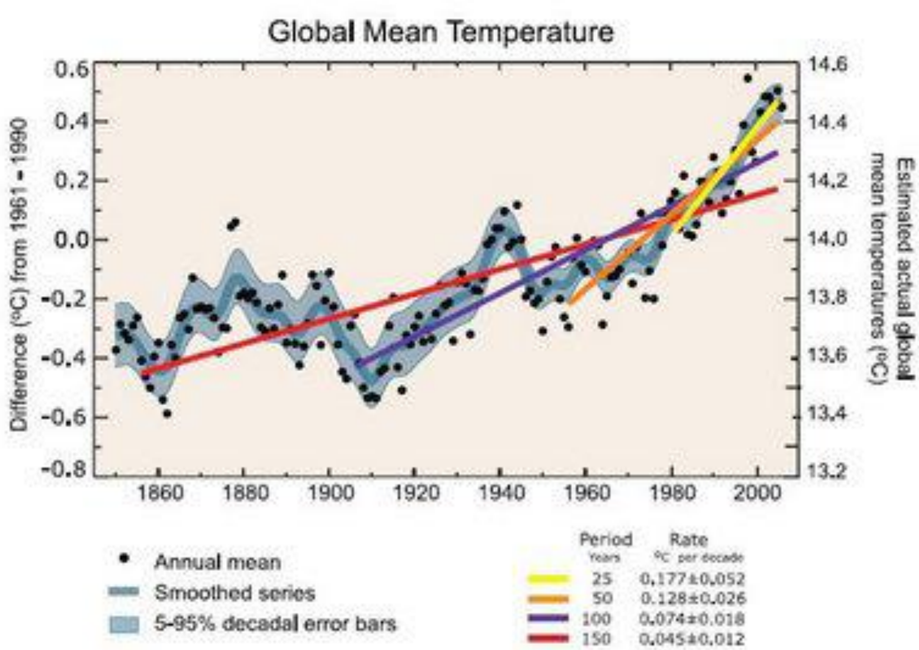
- Reviewed the main features of climate change and how it is expected to manifest in Ontario
- Understood the main features of global and downscaled climate models, and how to get information about local climate trends and projections
- Reviewed and discussed climate trends and projections for a city in their region.

Introduction

The earth is warming. According to the Intergovernmental Panel on Climate Change (IPCC), the mean temperature for the planet as a whole has climbed 0.74˚C in the last 100 years. The World Meteorological Organization has determined that the last decade is the warmest since we began recording temperatures in the 1850's. Scientists from the UK Met Office have recently estimated that, on the basis of current greenhouse gas emissions, average temperatures could increase by 3º to 7ºC by 2090, with best estimates around 5ºC.

Figure 1 shows how global mean temperatures have changed in the last 150 years, and also how the change in temperature is speeding up.

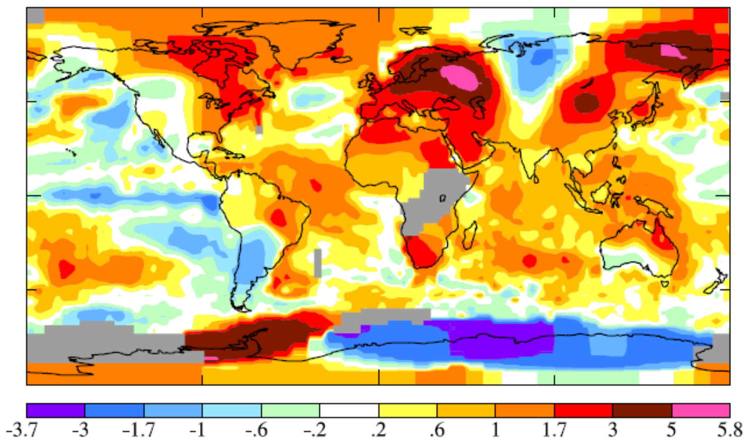
Figure 1: Global Mean Temperature 1860-2000



Source: IPCC Fourth Assessment, Working Group I

Global averages tend to mask variations in temperature from season to season and from place to place. Some parts of the world – mainly in the far north – are warming more quickly than other areas. This variability can be seen in Figure 2, which is a snapshot of temperatures in July of 2010.

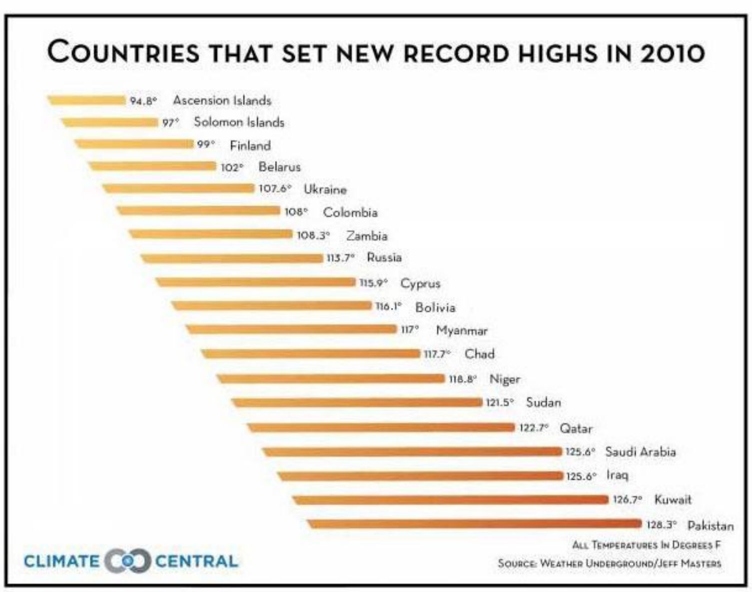
Figure 2: July 2010 Surface Temperature Anomaly (°C) Relative to the Base Period 1951-1980



Source: US National Aeronautics and Space Administration, August 2010

According to the US National Oceanic and Atmospheric Administration (NOAA), the year 2010 tied with 2005 as the hottest year on record. Climate Central recently posted the graphic in Figure 3 below, showing 19 countries that set new heat records in 2010.

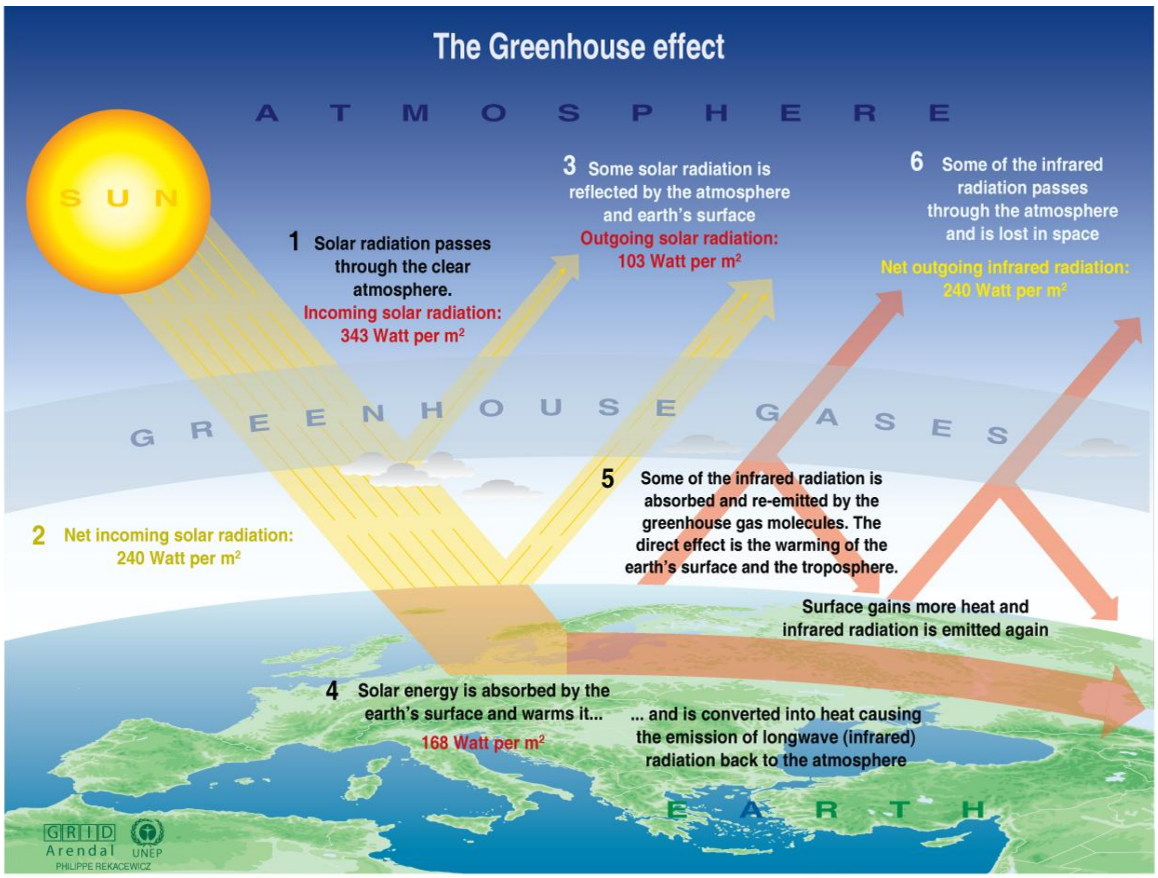
Figure 3: Countries That Set New Record Highs in 2010



The Greenhouse Effect

The global rise in temperature is caused by an increase in greenhouse gases (GHGs), which trap heat in the lower atmosphere. Figure 4, from the United Nations Environment Program, shows how the greenhouse effect works.

Figure 4: The Greenhouse Effect



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Source: United Nations Environmental Program, no date

Though GHGs such as carbon dioxide, methane and nitrous oxide occur naturally, they are increasing in the atmosphere due to human activity such as burning fossil fuels and deforestation. Humans have also invented and released to the atmosphere a number of powerful GHGs such as chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

Key Greenhouse Gases

Though all greenhouse gases contribute to the greenhouse effect, three have greater implications for long-term temperature change than the others.

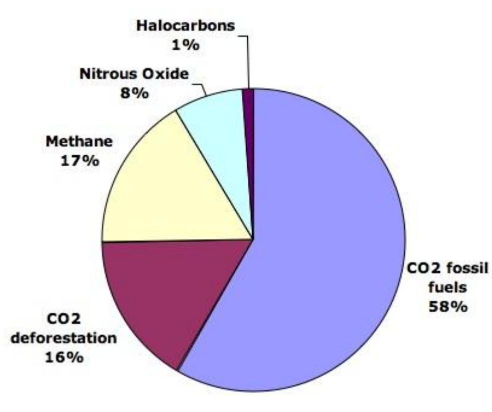
Carbon dioxide is the fifth most common substance found in the atmosphere though it makes up only 0.036% of atmospheric gases. It has a lengthy lifecycle, remaining in the atmosphere for between 50 and 200 years. According to NASA's Earth Observatory, CO_2 levels are higher than any time in the last 750,000 years. Scientists estimate that increases in carbon dioxide levels account for approximately 63% of the recent rise in global temperatures.

Methane has a shorter lifecycle than carbon dioxide (10-12 years), and there is less of it in the atmosphere. However, methane is a major greenhouse gas because it can absorb solar radiation much more efficiently than carbon dioxide. Methane levels in the atmosphere have increased 150% since the 1750s due to increases in rice cultivation, domesticated grazing animals, landfills, coal mining and oil and gas extraction. According to the UK's Hadley Centre for Climate Prediction and Research, methane accounts for approximately 24% of the greenhouse effect.

Nitrous Oxide has an atmospheric lifetime of more than 100 years. Though emitted in much smaller amounts than carbon dioxide or methane, its long lifecycle ensures a build-up in the atmosphere. In 2005, nitrous oxide accounted for approximately 10% of the greenhouse effect.

Other greenhouse gases do not significantly contribute to the greenhouse effect for various reasons. Water vapour, for example, is one of the most abundant substances in the atmosphere, but is not a key factor in long-term climate change because it cycles through the atmosphere in only 8-10 days. Chlorofluorocarbons are very strong greenhouse gases but are emitted in much smaller volumes in part because of controls that have been put on their use to reduce ozone depletion. The relative concentrations of greenhouse gases in the atmosphere are shown in Figure 5.

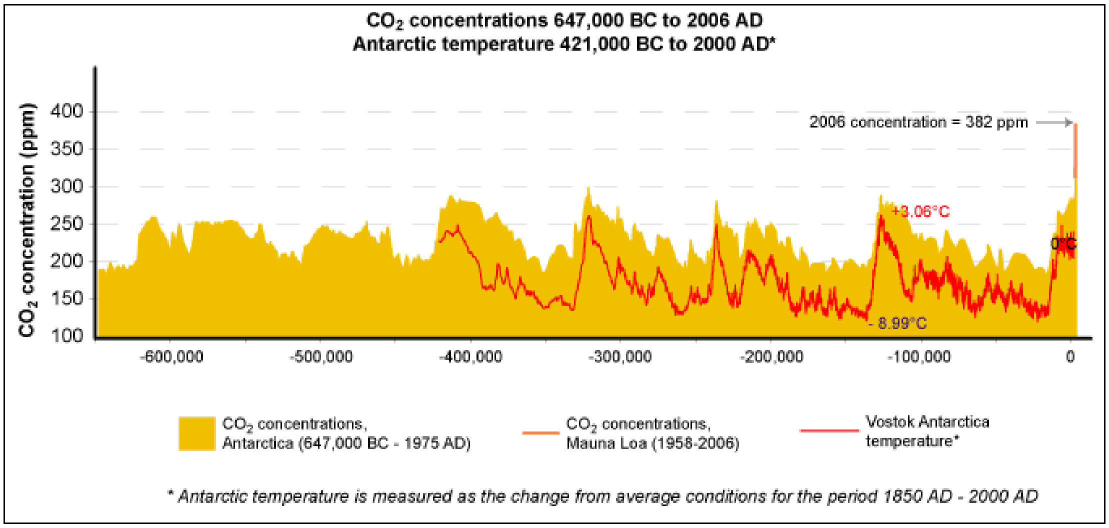
Figure 5: Relative Concentrations of Greenhouse Gases in the Atmosphere



Source: IPCC, 2007

Scientists have studied fluctuations in CO_2 historically by measuring concentrations of the gas trapped in ice core samples taken from the Polar Regions. Temperature changes have been estimated by analyzing tree rings, pollen remains, glaciers and ocean sediments among other things. As a result of these analyses, climate scientists have been able to show a clear relationship between CO_2 concentrations and temperature over more than 600,000 years.[1] This relationship is illustrated in Figure 6.

Figure 6: Relationship between Carbon Dioxide Concentrations and Temperature



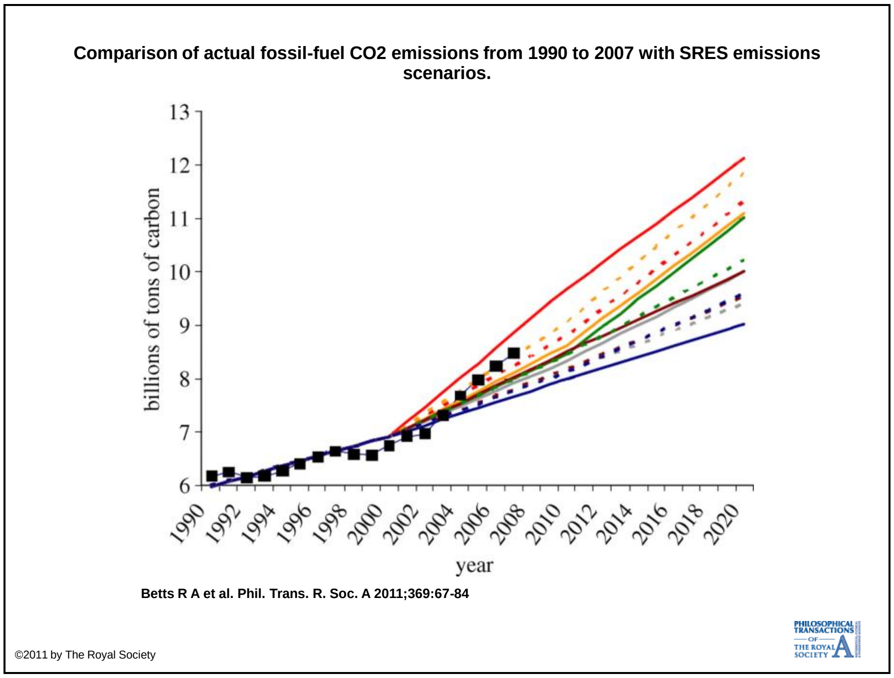
Source: USEPA, 2009

At the time of the Industrial Revolution, the most important greenhouse gas, carbon dioxide (CO_2), was present in the atmosphere at concentrations of about 275 parts per million (ppm). Today, CO_2 has increased to almost 390 ppm, a rise of almost 30%. CO_2 emissions are rising faster today than ever. The IPCC expects CO_2 levels to rise to concentrations of 500 – 1000 ppm by the year 2100, depending on global emissions.

Figure 7 below shows actual emissions since 1990 compared to those projected under several different emissions scenarios that were explored by the IPCC. The figure shows that actual emissions are close to the projections made for the most fossil intensive scenarios. In its reports, the IPCC has tended to focus on climate projections based on mid-range emissions scenarios. However, actual emissions – more than 30 billion tons of CO_2 annually – suggest that more attention should be paid to the potential for more extreme warming and associated impacts.

[1] Higher levels of CO_2 do not initiate the interglacial warming periods, which are due to periodic shifts in the axial tilt of the earth, and in the earth's orbit around the sun. CO_2 is released from the earth's rocks and oceans *after* the start of a warming period, which accelerates the warming, which in turn accelerates the release of CO_2 in a positive feedback effect. The difference today is that humans are adding significantly to the levels of CO_2 that are released naturally, and triggering climatic changes that are occurring many times faster than natural cycles.

Figure 7: Comparison of Actual CO_2 Emissions with IPCC Emission Scenarios



The dashed line represents actual emissions, and the other lines show a variety of emissions scenarios published by the IPCC, from which warming projections were extrapolated.

Source: Betts et al, 2011

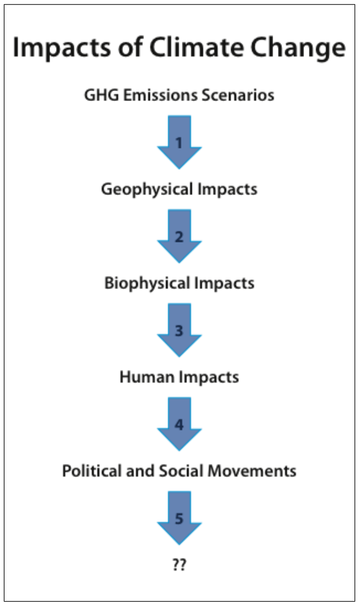
Broad Climatic Changes and First Order (Geophysical) Impacts

A number of worldwide climate features are expected to change as a result of global warming – and many of these are showing up in current trends. These include:

- Warmer average temperatures, with greater warming in the Arctic regions
- Seasonal changes: shorter winters, earlier spring, longer summers and later fall
- Changes in precipitation patterns, with wet regions tending to get wetter and dry regions getting drier
- Increased weather variability
- Increased freeze-thaw cycles in some regions
- Increases in extreme weather events
- Sea level rise and stronger coastal storm surges
- Shrinkage of the polar ice cap and most glaciers
- Reduced snowpack in most mountain ranges
- Increased evaporation from surface waters such as lakes and streams
- Warming and acidification of the oceans.

These geophysical changes will lead in turn to impacts on biophysical systems, human systems, which will influence political and social movements and so on, as illustrated in Figure 8.

Figure 8: Impacts of Climate Change



Source: Adapted from Gilman et al. January 2007

In Module 2, we will describe how some of these impacts will affect municipalities in Ontario, but the remainder of this backgrounder will focus on recent climate trends and climate projections for the province.

Recent Climate Trends in Ontario

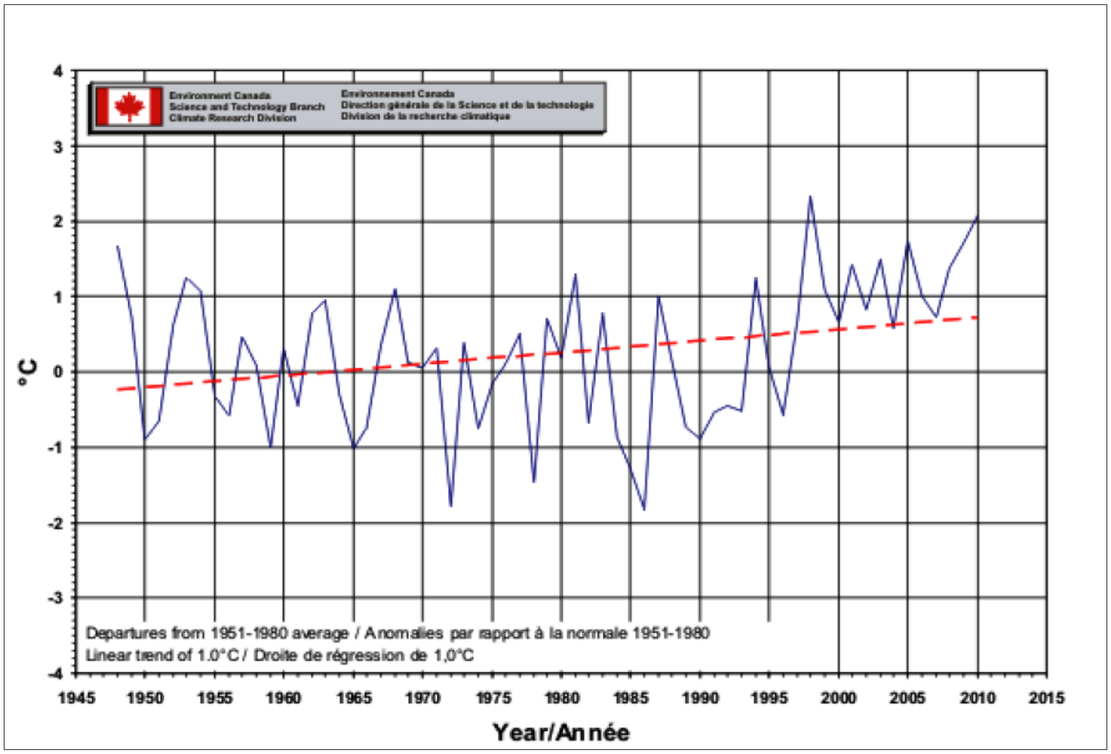
Temperature

In Canada, average temperatures have risen 1.3°C over the past 60 years. However, the temperature increase varies from region to region. In Ontario, the Great Lakes – St. Lawrence Lowlands has warmed 0.6°C over this period and Northern Ontario has seen a 0.8°C average increase.

Environment Canada's on-line *Climate Trends and Variations Bulletin* tracks climate trends for each season and year.

For example, Figure 9, downloaded from the *Bulletin*, shows the long-term trend in autumn temperatures for Canada, which have warmed on average 1.0°C from 1945 to 2010.

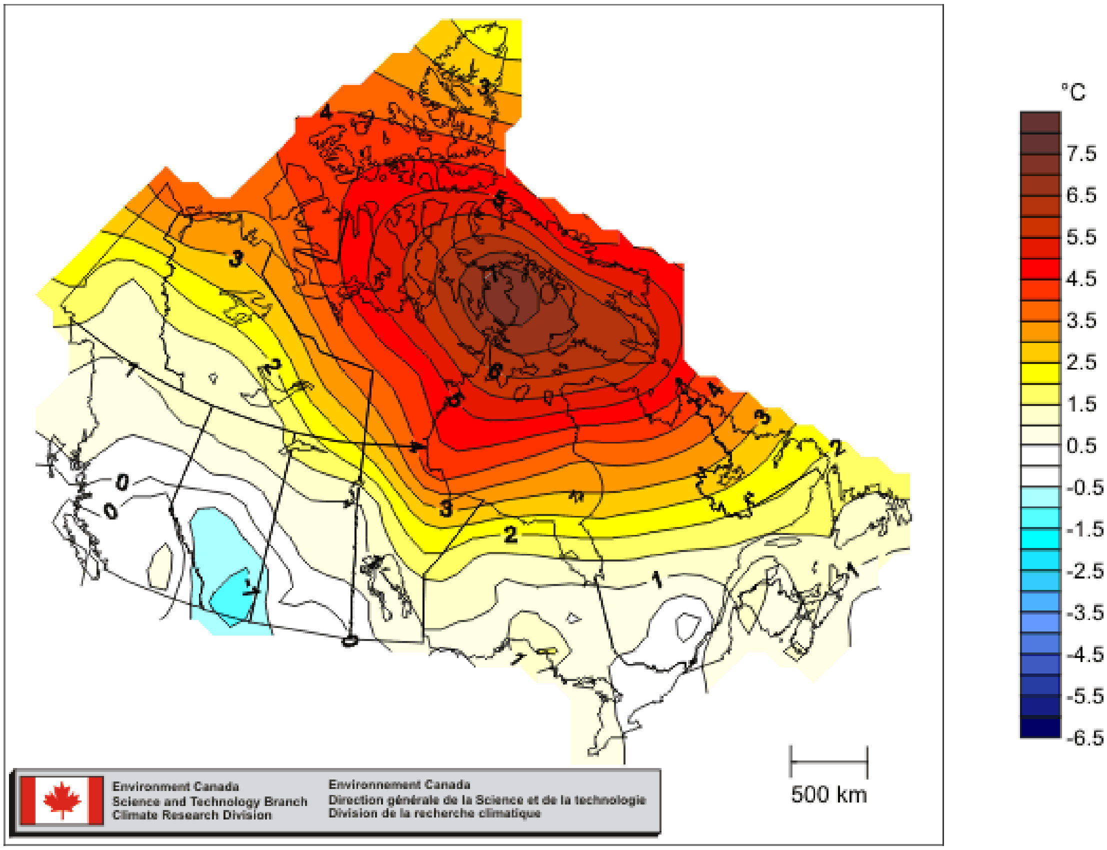
Figure 9: Autumn Temperature Departures and Long-term Trends



Source: Environment Canada, 2010

Figure 10, also downloaded from the *Bulletin*, shows the differences in temperature departures from the 1951-1980 average for the autumn of 2010 for different regions in Canada. The national average temperature for this fall was 2.1ºC higher than the average for 1951-1980. However, as can be seen from the map, Nunavut experienced the largest increase (4.0ºC) in seasonal temperatures, while the Great Lakes – St. Lawrence Lowlands saw a much smaller increase (0.5ºC).

Figure 10: Autumn 2010 Temperature Departures from 1951-1980 Average



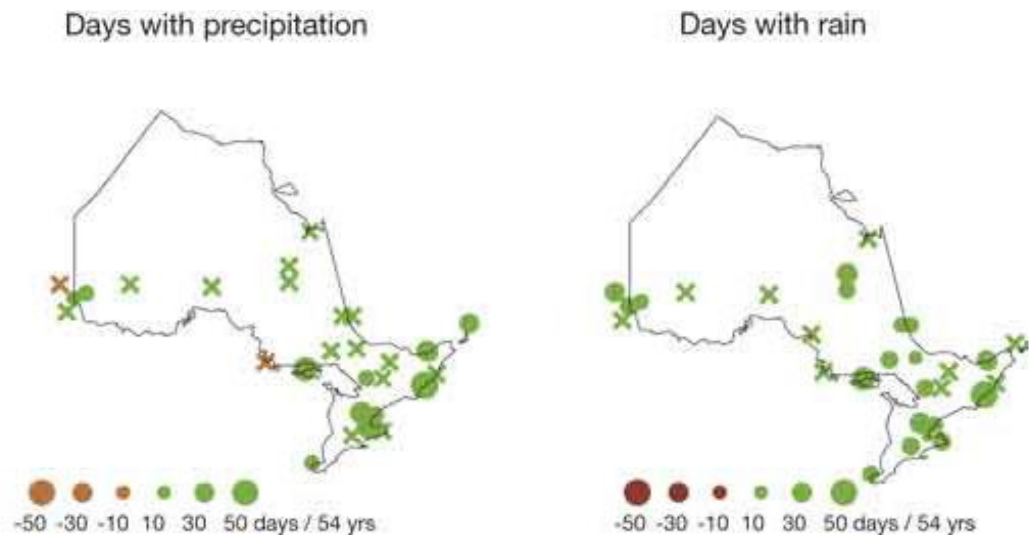
Source: Environment Canada, 2010

Precipitation

In Canada, precipitation trends have also varied greatly by region. While the high Arctic has experienced a drastic increase (between 25-45%) in precipitation, southern Canada has increased by a more modest 5-35%, with some regions observing a reduction. As shown in Figure 11, parts of Ontario are experiencing significant increases in the number of days with rainfall, as well as lake-effect snow[2].

[2] Lake-effect snow results from cold air passing over warmer bodies of water. Water vapour rises from the lakes, freezes and is released as snow in areas downwind.

Figure 11: Trends in Precipitation Indices 1950-2003

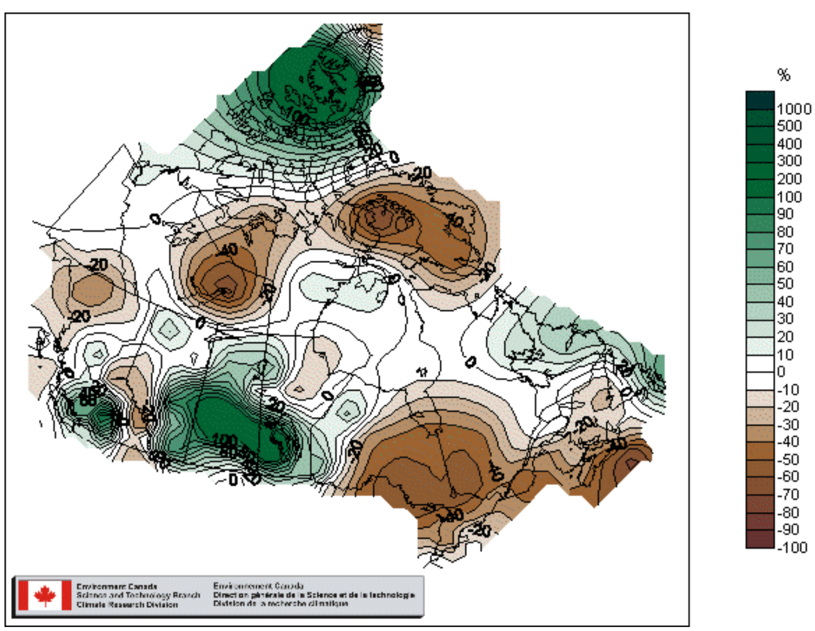


Brown and green dots indicate trends significant at the 5% level, and the size of the dots is proportional to the magnitude of the trend. Crosses denote non-significant trends.

Source: Vincent and Mekis, 2006.

Although precipitation on the whole is increasing in Canada and in Ontario, it remains quite variable. Figure 12 from Environment Canada's Climate Trends website show that the spring of 2010 was much drier in most of Ontario compared to 1951-1980, the second driest spring since records began in the Great Lakes – St. Lawrence region.

Figure 12: Spring (2010) National Precipitation Departures from Normal (1951-1980)



Source: Environment Canada, 2010

Climate Trends Data for Canadian Communities

Environment Canada operates two websites that can provide users with much of the climate data needed to obtain past trends information and future projections of climate for locations across Canada. The Canadian Climate Change Scenarios Network (CCCSN) website is a joint venture of the Adaptation and Impacts Research Section at Environment Canada and several university partners. The website provides data for understanding some historical climate as well as climate projections based on a range of available global climate models and several regional climate models. This information can help municipalities construct future climate scenarios for their locale.

Users are able to view historical climate data collected by 125 weather stations in Ontario from 1961 to 2000, using many different visualization and analysis options. The data, taken as a whole or in two 30-year periods (1961-1990 or 1971-2000) provides the "baseline" for climate change projections. Using this methodology, baseline biases of the climate models can be minimized. It is recognized, however, that the model projections represent grid cell average changes, not point-specific station climate change, so some caution is assumed in the final interpretation. High precision station projections of climate change at a particular station location would likely require a more detailed downscaling technique. The World Meteorological Organization recommends that a 30-year period (long enough to eliminate year-to-year variations) should be used as the climatological baseline period for impact and adaptation assessments. The available baseline data is for specific weather station locations, and does not necessarily capture the weather which can vary between stations, a concern particularly in the northern parts of the province where there may be hundreds of kilometres between stations.

The historical climate data on the CCCSN website is based on what is available on the second website, Environment Canada's Climate Normals and Averages from 1971-2000. This website allows users to select a weather station and obtain the monthly averages, minimums and maximums for dozens of different climatic variables which may be manipulated using a spreadsheet or statistical software.

Appendix A has further information on the CCCSN and Evironment Canada Climate Normals and Averages websites as well as a depiction of the recent climate trends for annual precipitation and temperature for four Ontario communities which Golder Associates has derived from these websites.

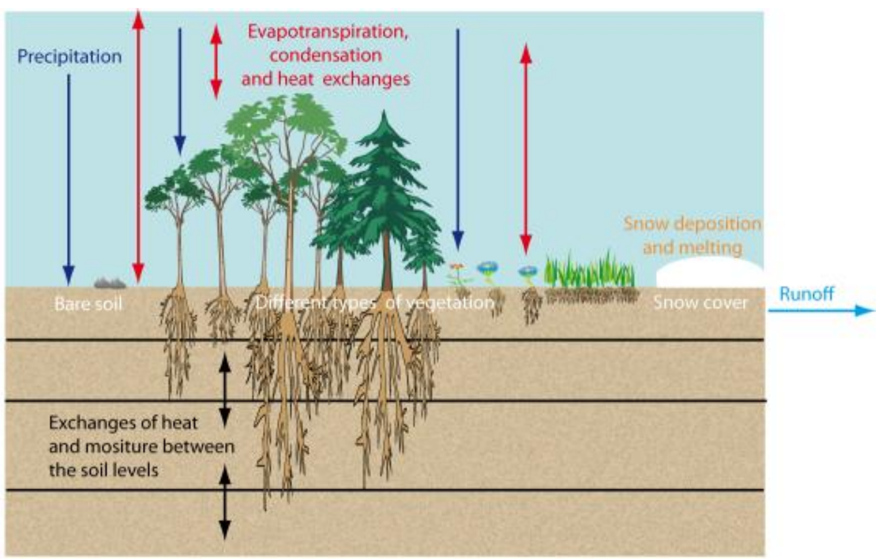
Climate Models and Future Projections

Climate models have been developed to try to understand all the factors that give rise to climate trends. Global Climate Models or General Circulation Models (both abbreviated as GCM) are based largely on the work of scientists who investigate how various atmospheric processes work and who express these workings in a series of mathematical equations. GCMs try to simulate as much as possible about the climate system, including the following processes:

- incoming solar radiation and outgoing terrestrial radiation (energy balance)
- wind patterns and atmospheric chemistry
- how clouds are formed and precipitation falls
- ocean dynamics and currents
- sea ice and ice sheet dynamics (how they grow or shrink)
- land surface – including vegetation – and snow cover
- terrestrial and marine carbon cycles.

Each of these processes involves a multitude of sub-processes. Figure 13 shows several of the processes that are taken into account in the land surface component of a climate model.

Figure 13: Main Processes Taken into Account in a Land Surface Model

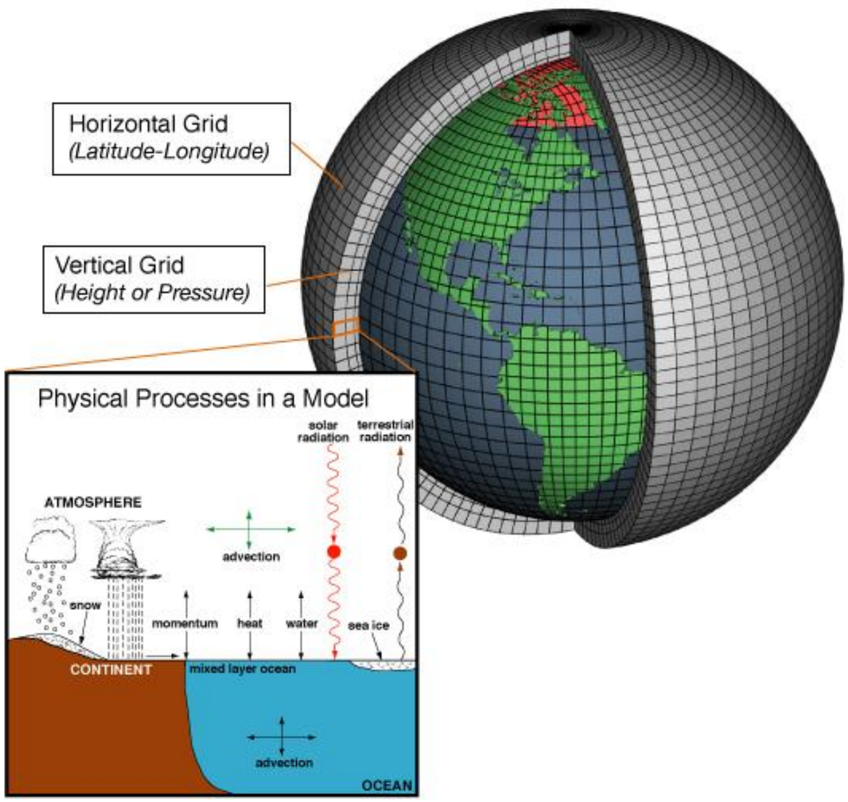


Source: Université Catholique de Louvain 2010

GCMs analyze the interactions and feedbacks among these different parts of the climate. Earth is a complex place and these models are complex too. They include so many math calculations that they must be run on supercomputers. The US National Center for Atmospheric Research recently developed a comprehensive Community Climate System Model that requires about three trillion math calculations to simulate a single day, for example. It takes thousands of hours to run the model. The model output is analyzed by researchers and compared with the results of other models, and with actual weather observations.

To run a model, scientists divide the planet into three-dimensional grid cells, as shown in Figure 14. The model outputs project temperature, precipitation, wind, humidity, and other features of climate for each grid cell. Typical GCM grid cells are about 250 km square, and about 1 km high. (The atmosphere is analyzed in about 20 layers). The results that are reported for each grid cell are averages and do not describe any variation within the three-dimensional cell. This variability could be considerable if, for example, a coastal area, large lake or a mountain is in part of the cell, or if part of the cell covers an urban area and part a forest.

Figure 14: Schematic of a Climate Model



Source: National Oceanic and Atmospheric Administration, 2010

Recent GCMs have been able to achieve much higher resolution (smaller grid cells). The Goddard Earth Observing System Model, Version 5 (GEOS-5) runs at a 28 km resolution, and NASA reported a recent run of the model at a 5 km resolution.

Small scale physical processes that affect local climate but are smaller than the size of the grid cells are not directly modeled. These processes are referred to as “parameters” by climate modellers and their net impact is estimated rather than mathematically modeled and included in the model by a process called parameterization. Examples include cloud formation in the atmosphere and small scale ocean eddies.

The more weather factors and physical processes that a model can represent the better the model can simulate the real climate. Accuracy is determined by “hindcasting” – running the model simulations for past time periods and comparing model outputs to actual climatic measurements and trends. The more accurate a model is in reproducing past and current climate, the more credible its future climate projections. When Mount Pinatubo erupted in 1991, producing a temporary cooling effect, modelers were able to evaluate their models for the effects of volcanic aerosols on climate. Many of the climatic changes that we have seen recently – greater warming in the Arctic, greater warming at night, and stratospheric cooling – were correctly predicted by climate models.

Despite the recent development of models that can accommodate a greater number of parameters and weather-related factors, General Circulation Models are still limited in a number of ways:

- Though modelling of precipitation has improved, the correlations between most GCMs and observed rainfall are still poor;
- Model have difficulties simulating clouds and their response to climate change;
- There remains uncertainty about the rate of heat uptake by the oceans;
- Climate variability and extremes are still very difficult to predict;
- Projections for shorter time periods are less accurate.

It must be noted that some level of uncertainty is always expected in climate projections because complex atmospheric processes are not completely understood, and because of uncertainty about the quantity of greenhouse gases that will be emitted in future.

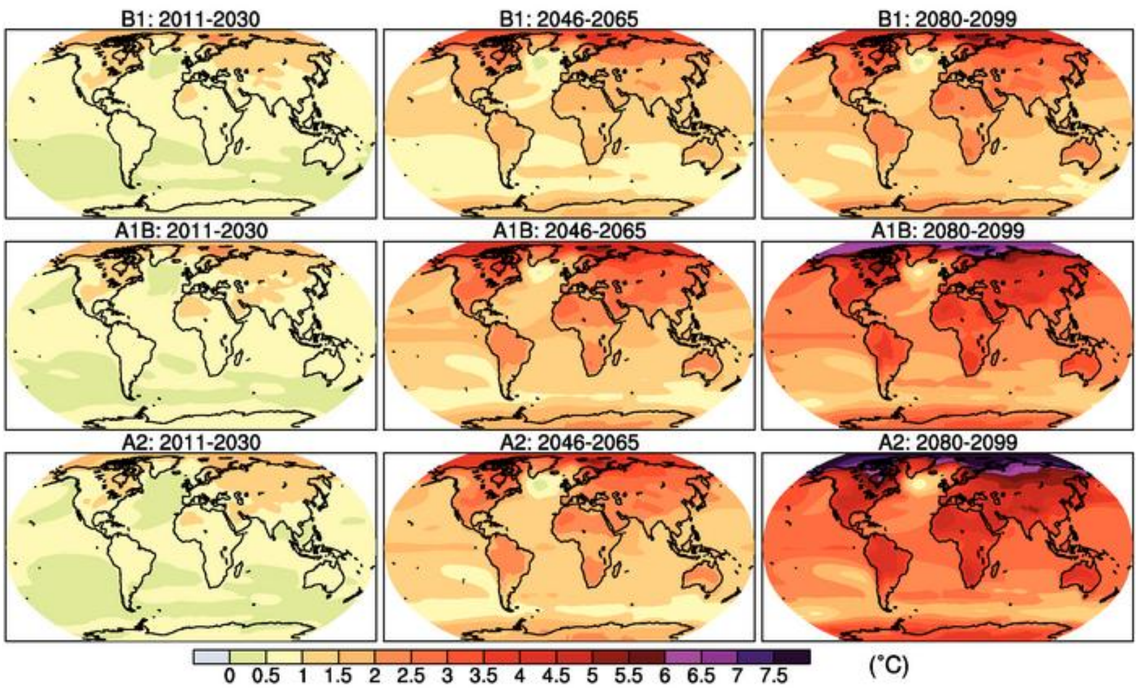
In addition to inputting all the factors that affect weather into a GCM, modellers must estimate future greenhouse gas emissions. For this, the IPCC has developed a standard set of future socio-economic scenarios that are likely to give rise to greater or lesser emissions. The A1 family of scenarios, for example, assumes rapid economic growth, population that peaks in the mid century, and the rapid adoption of new technologies. Three sub-scenarios forecast different fuel and energy sources: fossil-fuel intensive (A1FI), non-fossil fuels (A1T), and a combination (A1B). The A2 scenario assumes a more regional approach to economic growth, continuously increasing population and uneven adoption of technologies. The B1 scenario is similar to A1, but assumes less material intensivity and the introduction of cleaner technologies. Finally, the B2 scenario assumes local approaches to economic, social and environmental sustainability, with intermediate levels of economic development and more uneven technological change. In general, the A1FI and A2 scenarios project the greatest amount of greenhouse gas emissions in the future, with the A1T and B1 scenarios projecting the least.

Using Ensembles of GCMs

There are dozens of GCMs currently in use internationally. Each GCM takes a slightly different approach, especially for parameterization. It is not always easy to choose which GCM to use in developing future climate projections. An **ensemble approach** examines the outputs of a number of model runs (of the same or different GCMs) for future climates under different emission scenarios. Many analysts will use the mean or median of several GCM outputs as the best estimate for future conditions; others will use runs from different models to present a range of probabilities.

In its 2007 report, for example, the IPCC presented mean surface warming projections for three different periods (2011-2030, 2046-2065 and 2080-2099) based on ensembles of GCM's run using three different emissions scenarios that make different assumptions about future population and economic growth.

Figure 15: Global Climate Model Ensemble Showing Annual Mean Surface Warming for B1, A1B and A2 Scenarios in time periods 2011-2030; 2046-2065; and 2080-2099 (Based on normals from 1980-1999)

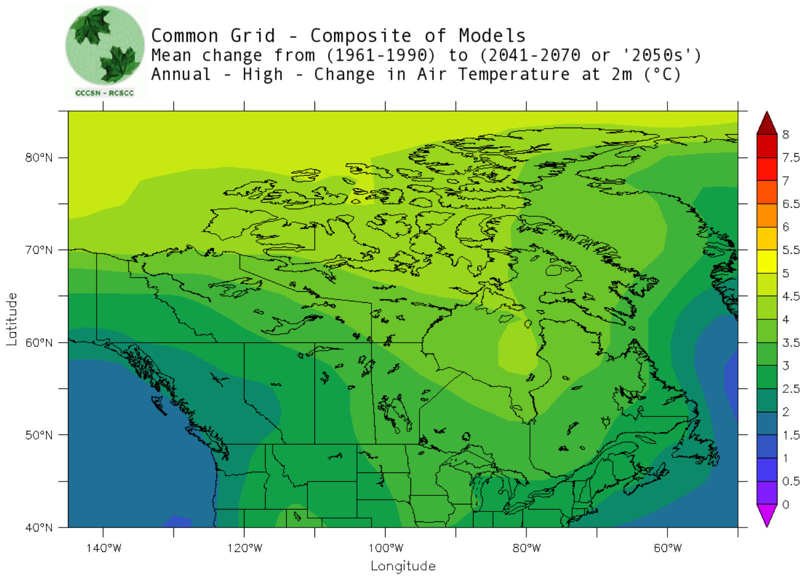


Source: IPCC, 2007

Climate Models and Future Projections for Regions of Ontario

The climate projections derived from the Canadian Regional Climate Model (CRCM) or the Canadian Coupled Global Climate Model depict more severe warming occurring in the northern and eastern regions of the country with the rest of the country experiencing a more muted 2-3 degree change over the next 30 to 60 years. Figure 18 shows the projected temperature changes in Canada for the 2050s.

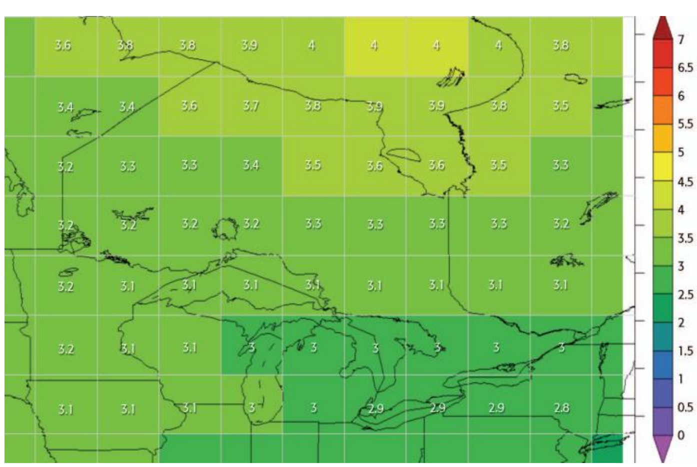
Figure 18: Results from an Ensemble of Models for High Emission Scenarios for 2041-2070, Depicting Mean Annual Change in Air Temperature at 2m (°C) from 1961-1990



Source: CCCSN, 2009

Currently, there are a number of regional projections available for Ontario. These vary by downscaling method, climate model(s) on which they are based, emissions scenarios used, and time period of the projections. Figure 19, derived from an ensemble of 24 GCMs and a relatively high emissions scenario, was downloaded from Environment Canada's Canadian Climate Change Scenarios Network, and projects average temperature increases ranging from 2.9 °C in the southernmost regions of the Ontario, to 3.8°C in most northerly areas of the province in the 2050's, compared to the 1961-1990 baseline.

Figure 19: Projected Increase in Average Annual Temperature (°C) in the 2050s Compared with 1961-1990 using HIGH GHG Emissions (A1B emission scenario)



Source: CCCSN, 2009

Regional projections for seasonal temperatures and precipitation are likely to be more valuable for planning than annual mean temperature. The expectation of a 6% increase in annual precipitation for example, is of limited value for a municipality that may be facing an increase in snow, rain, freezing rain or all three. An increase in rain, especially intense rain, may indicate a need to reinforce bridges and expand stormwater management systems, while an increase in expected snow may lead to planning for greater snow removal capacity.

Using Ensembles of GCMs to Project Local Climate Changes

The ensemble data provided by the CCCSN website comes from model data provided to the Fourth International Panel on Climate Change (IPCC) Assessment Report in 2007. The entire site contains 37 global climate models created by different research centres over 3 separate IPCC assessment periods, including GCMs developed by Environment Canada's Canadian Centre for Climate Modeling and Analysis. (The Canadian models begin with the prefix "CGCM".). By using the tools on CCCSN to examine the output of several models, a user can find a range of projected values for an area for a given time period under different emissions scenarios.

The CCCSN website offers a way for municipalities to gather all GCM projections quickly and relatively easily. Using data from the 24 models available in the AR4 assessment in 2007, CCCSN provides projected changes for many different climatic variables on a grid-cell basis. Appendix A describes many of these graphic outputs in more detail. Appendix B, contributed by Golder Associates from data available on the CCCSN website, shows the range of projections for annual mean temperature and precipitation for four cities in Ontario.

While the CCCSN website and all of its information are available at no cost as a service from Environment Canada and its academic partners and can provide useful information for municipalities, there are some limitations associated with the CCCSN website. One is that the data they have collected has not been downscaled to the level of a single community or municipality. This task, however, would be a huge undertaking. As GCM grids can be several hundred kilometres square, the data projected for specific locations does not take into account local conditions that can have a significant effect on weather. Another limitation is that of weather station location. Some tools, like the Localizer use data from the nearest Environment Canada weather station but the closest station may not best represent the weather and climate of a given community. A town located inland from the Great Lakes might have more in common with another inland station than one on a major body of water, for example. These limitations, however, should not be a barrier to at least explore the types of impacts climate change may bring to a municipality or region, and offer a good starting-off point for further inquiry and decision-making.

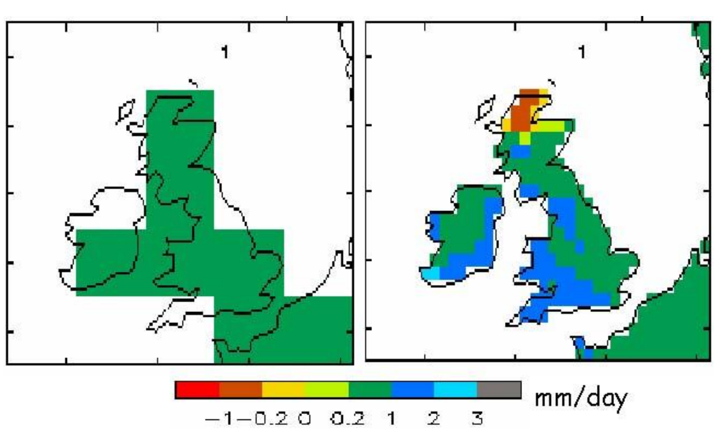
The advantages are that the website presents valuable information customized for Canada from all available international climate models in the form of various visualization tools. The effort to obtain and manipulate all the model data from the IPCC would be a complicated job without CCCSN. The Localizer is a quick and easy way to check a location quickly and produce a small detailed report. Other maps and charts can be produced for a more detailed analysis. There is an ability to also download model data and produce customizable charts. On each regional research page, links to reports produced by the Adaptation and Impacts Research Section and others can be accessed. The site appears to cater to a range of user skill levels, (localizer – beginner, and scatterplot – more advanced). Information on statistical downscaling and data required for this analysis is also available, but this is definitely for the most advanced users.

Downscaling Regional Climate Models

While GCMs provide useful information about potential climate change at a large scale and over long time periods, most decision-makers are more interested in local changes that will help them determine impacts they need to plan for. GCMs cannot directly provide this level of detail. GCMs typically have grid cells of 100 km to 300 km on a side. Climate conditions within this area are averaged to produce projections relevant to the entire grid cell. The UK Met Office's Unified Model, for example, has only six cells that cover most of the country, as shown in Figure 16. A regional model, shown on the right, can provide much smaller grid cells and much more detailed information relevant to local decision-making.

It is important to note that although downscaled regional models provide more detail about potential futures on a local level, they do not decrease the model output uncertainty. Even higher resolution models contain projection uncertainties.

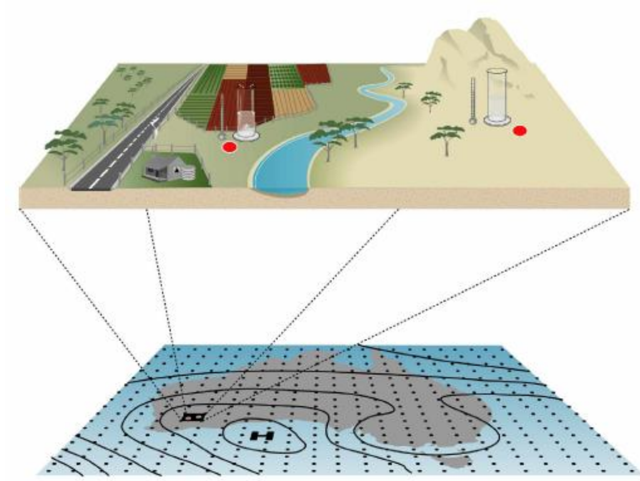
Figure 16: Difference in Resolution for Precipitation between a Global Climate Model and a Regional Model



Source: ClimatePrediction.net – a collaboration of Oxford University and the Met Office (Britain)

In order to effectively incorporate climate projections into their decision-making processes, many municipalities would like to have downscaled climate projections that account for local geographical features such as topography, vegetation, water bodies and land-use patterns known to affect local weather patterns. Regional Climate Models (RCMs) and other downscaled projections can achieve a resolution of 10 – 50 km, thus providing more detailed information about the specific challenges that small regions and individual municipalities may face, but even these are only approximations of reality. Figure 17 shows the relation between large-scale climate projections and the local factors that can significantly affect local climate within a GCM grid cell.

Figure 17: From Global Climate Model to Regionally Specific Downscaled Data



Source: Bureau of Meteorology, Australia

There are several methods that can be used to downscale climate projections to the regional level: simple, dynamical and statistical.

Simple downscaling, used most often as an unofficial estimate of expected climate, involves determining the numerical difference between results from a global climate model for a previous period of time and actual climate observations. This allows the creation of downscaling factors that are then applied to GCM projections, resulting in local projections for the future. The method is appealing as a preliminary analysis of GCM data because it is inexpensive, requires few special skills, and can utilize easily accessible information. However, this method assumes that the relationship between the outputs of the global climate model and local observations will remain constant, which is unknown.

Statistical downscaling (also called empirical downscaling) focuses on the relationship between large-scale climate forces modeled by GCMs or RCMs and local climate station observations. Statistical downscaling analyzes the statistical relationships between the large scale and local climatic conditions and applies these relationships to the outputs of global or regional models. The statistical approach requires less computer time and power than dynamic downscaling and provides the opportunity for testing over many decades. Statistical downscaling can also utilize “ensemble” GCM results, which may match overall observations better than the results from individual models.

In order to achieve accuracy, adjustments are made to GCM outputs for which hindcasts don’t correspond with local observations. The adjustments bring projections more in line with climate trends for factors such as precipitation, which are hard to project. Statistical downscaling techniques assume persistent relationships between large-scale climate trends and local climate. This assumption could lead to accuracy issues in the future, as the climate continues to change and the statistical relationship, therefore may also change.

Statistical downscaling is becoming more common in Canada. The Global Environmental and Climate Change Centre (GEC3), a partnership based at McGill University and collaborating with Environment Canada, has been developing statistical downscaling methods and input data predictors and comparing them to outputs from GCMs and RCMs. A team at the University of Quebec has developed a tool for easy graphical user interface for statistical downscaling. The Pacific Climate Impacts Consortium has also been doing work on statistical downscaling in British Columbia.

Dynamical downscaling is the most complex of the three techniques. Regional Climate Models (RCMs) are produced by increasing the resolution of the climate model in a limited geographical area of interest. This requires major computational power, time and expense. The GCM is used to determine large scale climate conditions such as mean temperature, moisture, circulation (winds), sea-surface temperature and sea ice which serve as "boundary conditions" for the regional model. The regional model incorporates locally specific data (such as elevation and land surface) that modify local climate and which is not available to the GCM. This method allows geographical features specific to smaller regions to be factored into climate analysis; however there are so many computations involved that it is usually too expensive to produce RCM simulations with several GCMs or multiple emissions scenarios.

The Ouranos Consortium in Quebec and more recently Environment Canada based at the Canadian Centre for Climate Modelling and Analysis (CCCma) are involved in the development of dynamical downscaling techniques through Regional Climate Models. The Ministry of Natural Resources and the Ministry of the Environment in Ontario are also developing the capacity to provide regionally downscaled information to communities in the province, but are not yet providing this service.

Table 1 offers more detail on the three methods of downscaling and the advantages and disadvantages of each.

Table 1: Descriptions of Downscaling Techniques with Associated Advantages and Disadvantages

Method	Specifics	Advantages	Disadvantages
Simple	Comparison between data from GCM and recent climate observations and trends; Difference is used to project future trends	▪ Simple ▪ Economical	▪ Possibly less accurate
Dynamical **(Regional climate model)** Methods: ▪ Time Slice ▪ Stretched-grid climate models ▪ Nesting limited area models within GCM	Uses higher resolution Regional Climate Models to simulate finer-scale physical processes consistent with large-scale weather patterns defined by GCM output	▪ Able to include rural landscapes, mountains, differentiate between urban and rural areas thus helpful in areas where land use or topography expected to have a significant effect on local climate ▪ Doesn't assume that statistical relationships will persist ▪ Can better determine realistic position and intensity of storms ▪ Better captures fine structure of climate patterns ▪ Can identify climate conditions and mechanisms not previously observed ▪ Can produce results where there are no observations	▪ Expensive ▪ Time consuming ▪ Based on 1 GCM so biases are amplified ▪ Cannot create large set of possible outcomes
Statistical Methods: ▪ Weather Generation ▪ Regression ▪ Weather Classification	Analyzes the relationships between large scale climate elements (predictors) and local climate variables (predictands) and applies this statistical relationship to the output from global or regional models • Assumes predictor and predictand relationship is stationary • Adjustments are used to make GCM outputs correspond more closely with observations	▪ Faster and cheaper ▪ Uses data from nearby MET stations so can guarantee relevant, local data is incorporated ▪ Can incorporate several GCMs where there is predictor data available ▪ Generates precipitation and temperature time series that are consistent with observed distributions and spatial patterns ▪ Can be tailored for different scales, localities and problems (not always possible with dynamic downscaling)	▪ Assumes that relationship between model and actual observations will hold in the 21st century ▪ Requires long term, reliable observational data ▪ Tends to underestimate variability and extreme events ▪ Observed correlation cannot necessarily be reproduced when using daily data

Sources: International Arctic Science Committee, 2010; Arritt, 2009; Anderson, 2008

The greater levels of detail offered by downscaling allow municipalities the opportunity to make informed decisions regarding city planning; infrastructure upgrades or needs; vulnerable populations; and other concerns. The City of London provides a good example of the use of projections in municipal decision-making.

Case Study: City of London

The City of London suffers from nearly annual flooding of the Thames River which runs through the city. In 2007, the University of Western Ontario conducted a vulnerability study to determine the impacts of climate change on the Thames watershed. The results from this assessment indicated that the Thames River would be much more likely to flood under the changing conditions.

Concerned about infrastructure that suffers from current flooding, the City of London opted to work with the university to develop new intensity, duration and frequency curves and local climate projections. A team from the university examined 26 GCMs and determined a lower and upper boundary for expected precipitation output. Using the weather generator method (a kind of statistical downscaling), regional climate data was downscaled, thus developing a clearer picture of the expected minimum and maximum values for both temperature and precipitation.

The temperature and precipitation projections were then entered into hydrologic models which helped to determine future water levels in the sub-basins within the city. Using an overlay of the city based on the water levels from the hydrologic model, it was possible to identify areas prone to flooding. This information allowed researchers to locate infrastructure within these at-risk areas and determine their vulnerability to future flooding events.

The university research team that was conducting these studies presented its findings to the London City Council in August 2010. The City of London is in the process of evaluating the findings and prioritizing related infrastructure needs. Further analysis of the adequacy of the stormwater system in the face of expected increases in precipitation are planned as a next step.

Using Climate Trends and Projections Information

It is not easy for most municipal staff to understand and use available climate trends and projections information, or to choose among alternative scenarios and methods. Each available method has advantages and disadvantages.

Many municipalities may want to start with the CCCSN website to gather information on recent climate trends and projections for a certain number of climate variables, based on ensembles of global climate models. This information can be supplemented by general information on climate trends from credible scientific sources that is available in reports such as *From Impacts to Adaptation: Canada in a Changing Climate*, or the report of the Ontario's Expert Panel on Climate Change Adaptation, *Adapting to Climate Change in Ontario*.

Depending on the impacts of concern and the departments involved, municipalities may want to work with a local university, or hire a specialist consultant or a non-profit research centre such as Ouranos, to conduct statistical or regional downscaling. This may provide more specific regional information for infrastructure planning, though it doesn't necessarily reduce some uncertainties.

Whatever the initial steps that municipalities take to ascertain local climate trends and projections, it will be important to develop the capacity to track weather patterns locally, to keep up with climate trends and projections information, and to keep an eye on important new findings from climate science.

Resources

For general information on how climate change is likely to proceed in Ontario, access Chapter 6 of *From Impacts to Adaptation: Canada in a Changing Climate 2007*, published by Natural Resources Canada.

To find more detailed information on climate trends in Ontario regions and municipalities check out the following resources:

- Environment Canada Climate Trends and Variations Bulletin – gives up to date information for all regions of Canada on departures from average temperatures for 1961-1990.
- The National Climate Data and Information Archive has information on Climate Normals and Averages 1971-2000 by municipality. Hourly information can be found for many major cities under the Climate Data Online section.
- The Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) has produced climate trends factsheets for several municipalities including Barrie, North Bay, Sault Ste Marie, Sioux Lookout, Sudbury, and Timmins.

The following resources provide information on climate modelling, scenarios and projections for Ontario.

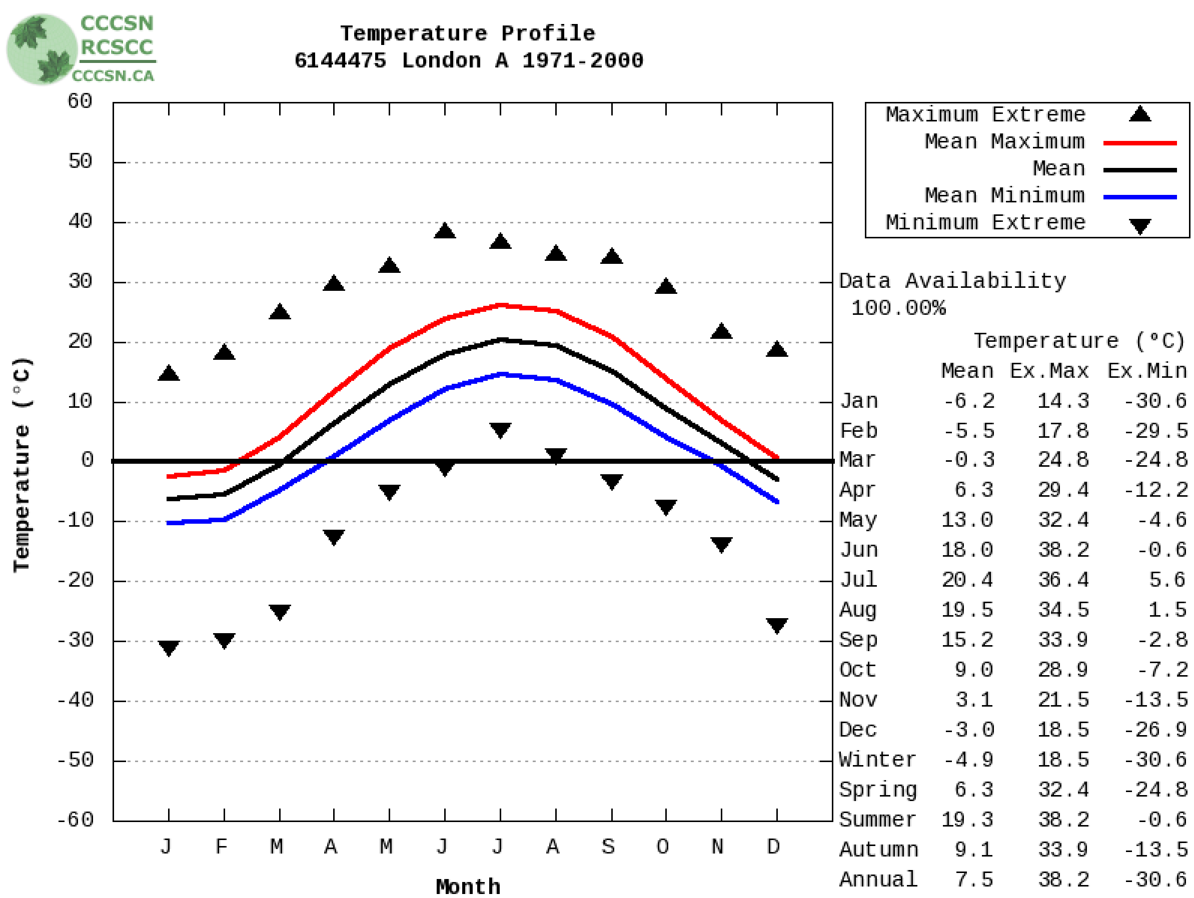
- The Canadian Climate Change Scenarios Network website provides information on models, scenarios and downscaling techniques. It also offers downscaling tools that can be used from the website.
- Environment Canada's Canadian Centre for Climate Modelling and Analysis offers important information on modelling and the models that are used in Canadian projections.
- Environment Canada also offers Adjusted and Homogenized Canadian Climate Data that address discrepancies due to changes in instruments and observing procedures.
- Electric Power Resources Institute has a Climate Science Newsletter that reviews general circulation models and downscaling techniques
- The UN Framework Convention on Climate Change has a comprehensive set of guidelines for the use of statistical downscaling. It offers information on each type of downscaling as well as advantages and disadvantages for each.
- The Ouranos Consortium on Regional Climatology and Adaptation to Climate Change offers a number of services including regional climate simulations, hydroclimatic analyses and climate scenarios.
- The Ministry of Natural Resources report on Climate Projections in Ontario: Practical Information for Policymakers and Planners is designed to deliver climate information to both planners and policymakers for use in strategic planning.
- The Report of the Expert Panel on Climate Change Adaptation, Adapting to Climate Change in Ontario provides recent projections for Ontario.

APPENDIX A: Historical Weather Information and Climate Trends Using CCCSN and Environment Canada's Climate Normals and Averages Websites

The CCCSN website provides users with a wealth of climate information on past trends and future projections. Although all the data on the website is available to the public, navigating the site and extracting useful data is not intuitive. It requires patience and persistence. Some basic knowledge about climate models and ability to interpret complex graphs is also helpful. However, municipalities could benefit from investing staff time in learning to use the website to identify past weather trends and anticipated changes for climate in the future. To this end, Environment Canada staff have provided some training sessions across Canada on the use of the site, but these are infrequent. Questions submitted to feedback are always answered.

The CCCSN website, for example, allows users to find out mean values over a 30-year time period for different climate variables for a specific weather station, using the CCCSN's Bioclimate Profile Analysis tool (located in the Visualization section of the website). Users select a variable for a given Environment Canada weather station, then a baseline period (such as 1971-2000), and a graph similar to Figure 1 is produced, which shows mean monthly and annual temperatures for the London International Airport weather station for the period.

Figure 1: Bioclimate Temperature Profile for London International Airport



The Bioclimate Temperature Profile is a graphical representation of what is available at the Environment Canada Climate Normals and Averages, 1971-2000 website. Figure 2 shows the type of historical weather data captured for a particular weather station in a tabular form. This information is useful for gaining an initial insight into a municipality's climate trends and variability.

Figure 2: Climate Normals and Averages 1971-2000 for London International Airport

Water Data
Weather Winners +
Proactive Disclosure

LONDON INT'L AIRPORT *
ONTARIO

Latitude: 43°01'59.000" N Longitude: 81°09'04.000" W Elevation: 278.00 m
Climate ID: 6144475 WMO ID: 71623 TC ID: YXU

* This station meets WMO standards for temperature and precipitation.

Normals from January to Year View

January-June January-December+Year July-December

Back to station list Another location

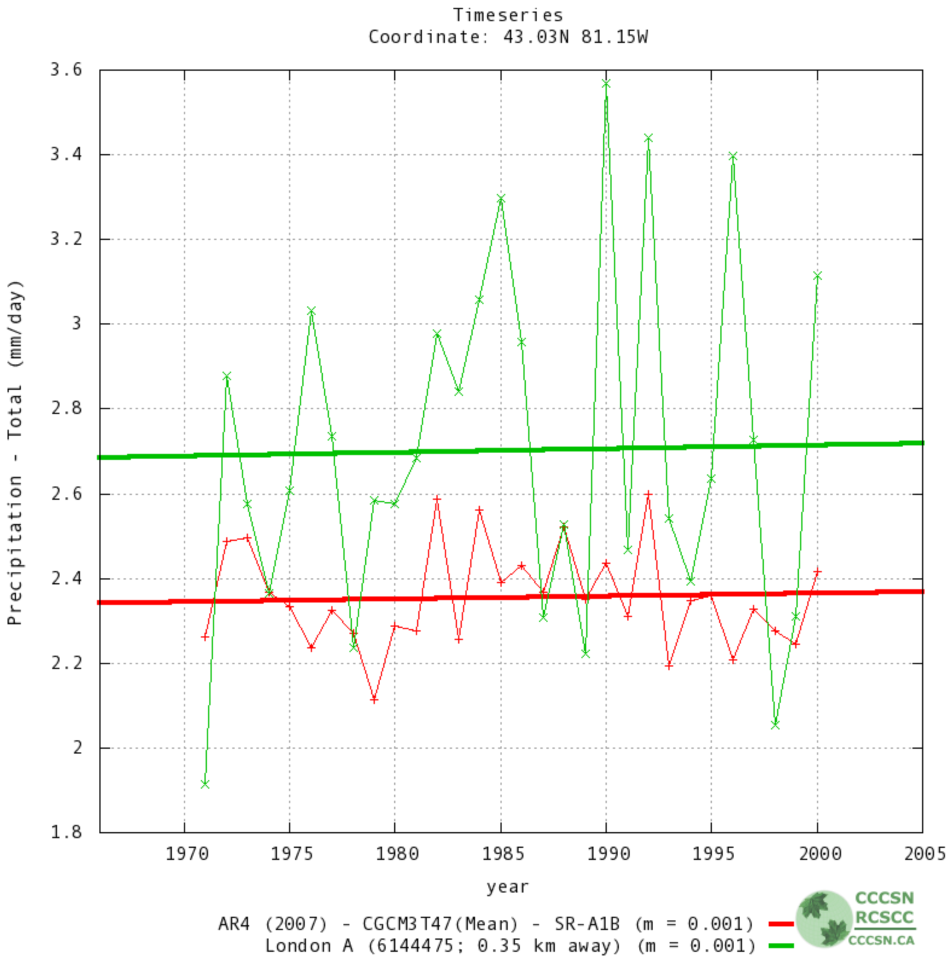
Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-6.3	-5.5	-0.3	6.3	13	18	20.5	19.5	15.3	9	3.1	-3	7.5	A
Standard Deviation	2.8	2.9	2.3	1.7	2.1	1.4	1.1	1.2	1.1	1.7	1.6	2.7	0.8	A
Daily Maximum (°C)	-2.4	-1.4	4.2	11.6	19	23.8	26.3	25.2	20.9	14	6.9	0.6	12.4	A
Daily Minimum (°C)	-10.1	-9.7	-4.7	1	7	12.1	14.6	13.7	9.6	4	-0.7	-6.5	2.5	A
Extreme Maximum (°C)	16.7	17.8	24.8	29.4	32.4	**38.2**	36.7	37	34.4	30	24.4	18.5		
Date (yyyy/dd)	1950/25	2000/26	1998/30+	1990/25	1987/30	**1988/25**	1941/27	2001/08	1953/01+	1946/06	1950/01	1982/03		
Extreme Minimum (°C)	**-31.7**	-29.5	-24.8	-12.2	-5	-0.6	5	1.5	-3.3	-11.1	-18.3	-26.9		
Date (yyyy/dd)	**1970/24**	1978/04	1978/02	1965/03+	1947/10+	1972/11	1963/09+	1982/29	1965/27	1969/23	1951/06	1977/11		
Precipitation:														
Rainfall (mm)	31.1	29.1	53.8	73.8	82.6	86.8	82.2	85.3	97.7	74.9	73.7	47	817.9	A
Snowfall (cm)	52.6	38.1	28.6	9.2	0.3	0	0	0	0	2.7	19.7	51.1	202.4	A
Precipitation (mm)	74.2	60	78.4	82.2	82.9	86.8	82.2	85.3	97.7	77.6	91.1	88.6	987.1	A
Average Snow Depth (cm)	11	12	3	0	0	0	0	0	0	0	1	5	3	A
Median Snow Depth (cm)	11	11	2	0	0	0	0	0	0	0	0	4	2	A

Past annual, seasonal or monthly weather data can also be visualized over many years to give a clearer snapshot of the trends for many different climatic events and the variability from year to year. The Timeseries visualization tool (explained in more detail below), provides users with the ability to analyze past weather trends and to compare these trends to the results of GCM models that have been hindcasted to cover the same historical period. It is important to realize, however, that model values represent grid cell averages and not exact station location values.

The user chooses a location, a weather variable, a GCM model and run (e.g. the CGCM3T47 model chosen here) and a future scenario (such as A1B). In the case of Figure 3, below, the actual annual precipitation (green line) was higher and more variable than that predicted by the

GCM (red line) for the same period. It is expected that model grid cell values will show less variability than a point location. Both the observed measurements and the model show a slightly increasing trend for annual precipitation, but this third generation Coupled Global Climate Model (CGCM3) climate model appears to be a "drier" model, that is, one that generally predicts a future climate with less precipitation for this location.

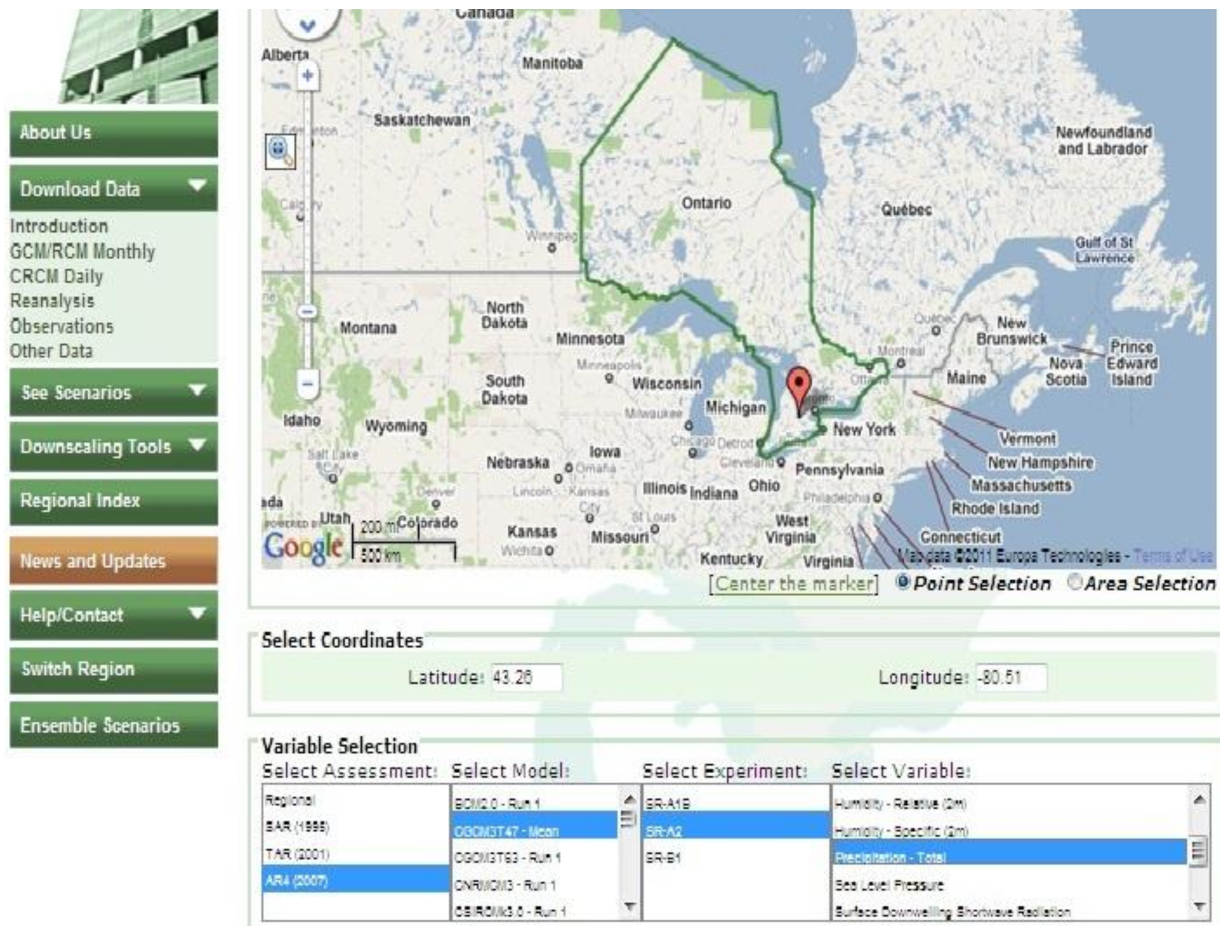
Figure 3: 1971-2000 Observed Precipitation Trend for London, ON, Compared to a GCM Simulation for the Same Period



GCM/RCM Monthly Data

The CCCSN website allows users to download raw data of monthly totals of past climate categories (such as precipitation or temperature) and future data projections for any location in Ontario through its GCM/RCM Monthly Data tool. Users select a location using a Google Map tool, the IPCC Assessment, GCM and run, and an experiment (future scenario). Then a date range is chosen – from 1961 to 2100 – and raw data is output that shows both past values and future projections. Figure 4 shows a screenshot of the CCCSN Monthly Data online interface.

Figure 4: Screenshot of CCCSN Monthly Data Interface

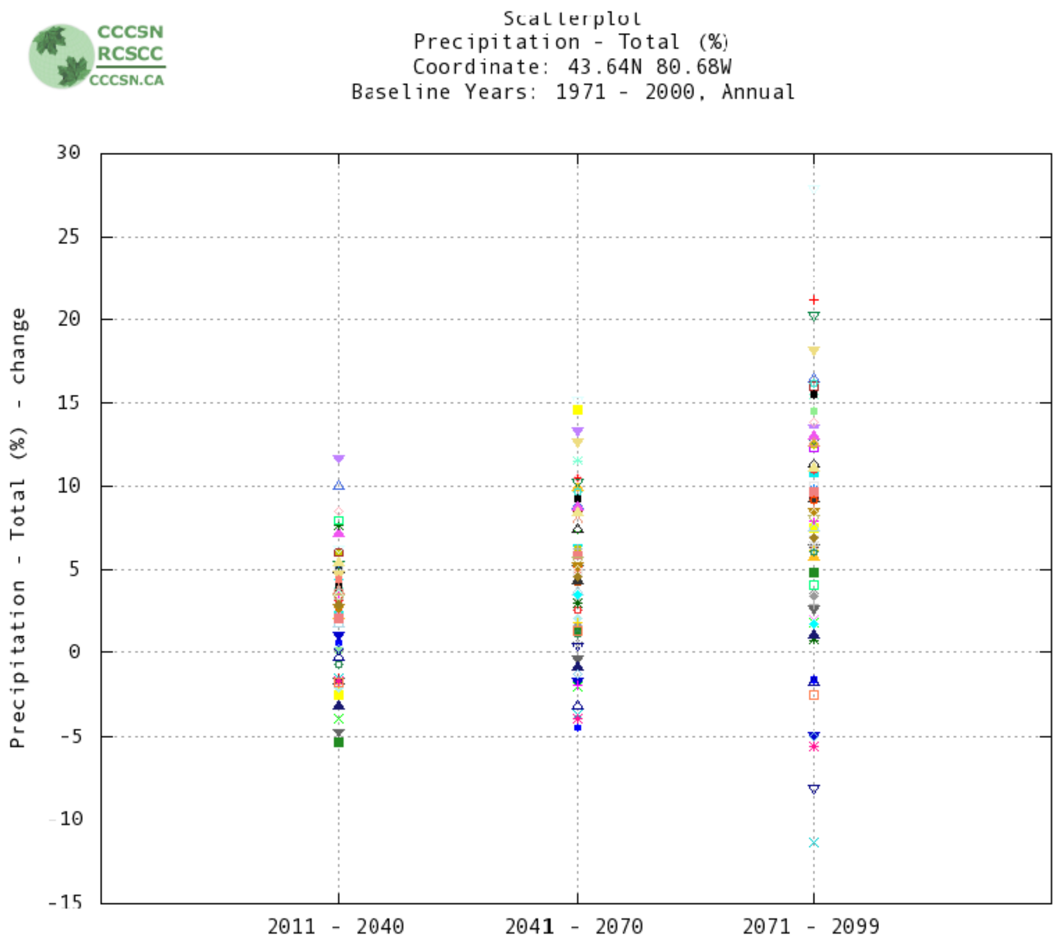


Data Visualization – Scatterplots

The Scatterplots tool allows a user to determine a range of projections for a given location over a series of time periods in the future. They plot the change or percentage change from the baseline data for temperature, precipitation, duration, or many other types of climate data over the next century. This can be done annually, seasonally, or by month. If the user is concerned about increased snowfall under climate change, for example, then the winter months can be selected and he or she can see the range of projections by different climate models.

Figure 5 shows a scatterplot of 24 GCM projections using a mix of scenarios for change in total annual precipitation compared to a baseline of 1971-2000 for a location near Elmira, Ontario. The majority of the GCM's predict increasing annual precipitation for this location. For the period of 2011-2040 (2020's), most of the GCM's project changes range from -3 to +5% in total precipitation. One outlier (the Centre National de Recherches Météorologiques in France, using an A1B scenario) projects an increase of 13%.

Figure 5: Scatterplot of GCM projections for Total Annual Precipitation Change



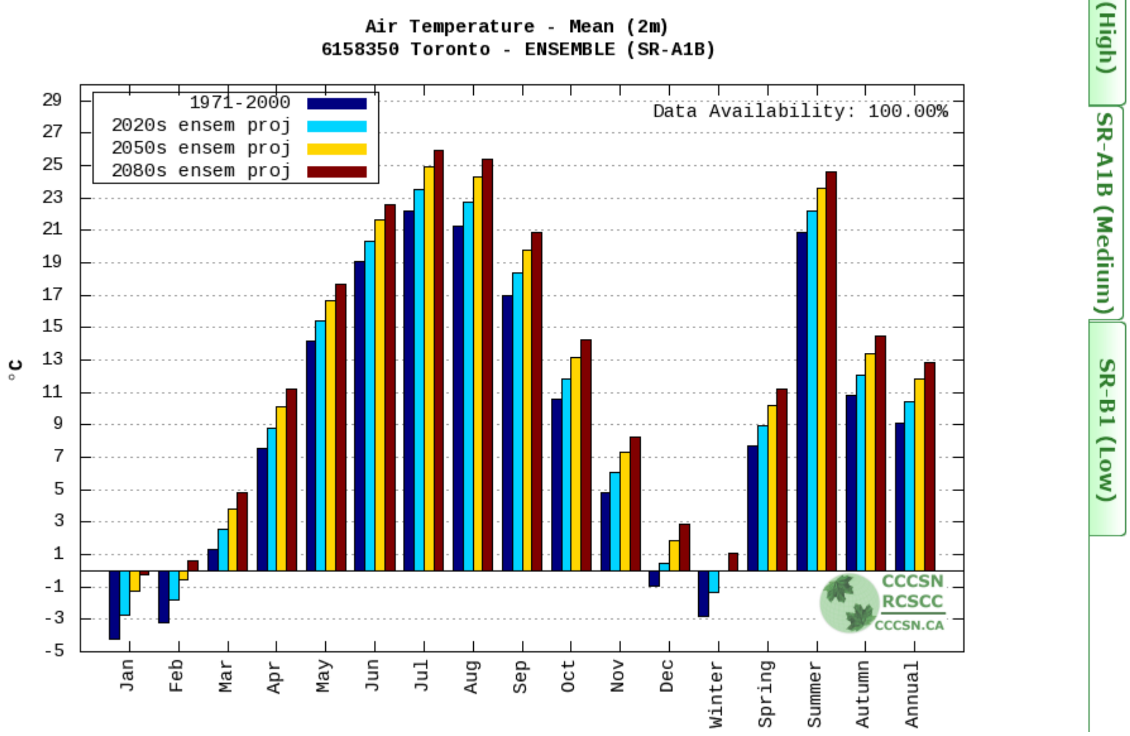
Data Visualization – Localizer

With the recently added Localizer tool, users can easily and quickly obtain values of projected monthly, seasonal and annual temperatures and precipitation calculated by an ensemble of models for a specific postal code location. The tool automatically assigns that postal code to the nearest weather station that tracks the required weather data, and projects future climates (using the ensemble GCM approach) for the 2020s, 2050s, and 2080s using 1971-2000 baseline data. Figure 6 shows the air temperature ensemble projections for a location in downtown Toronto at future time periods and throughout the year for the A1B scenario (other scenarios can be selected). The chart output also indicates the range of model outputs from the ensemble by displaying the standard deviation after each value. The output is explained in detail in the output file which can be saved as a PDF report.

Figure 6: Ensemble projections for a downtown Toronto location

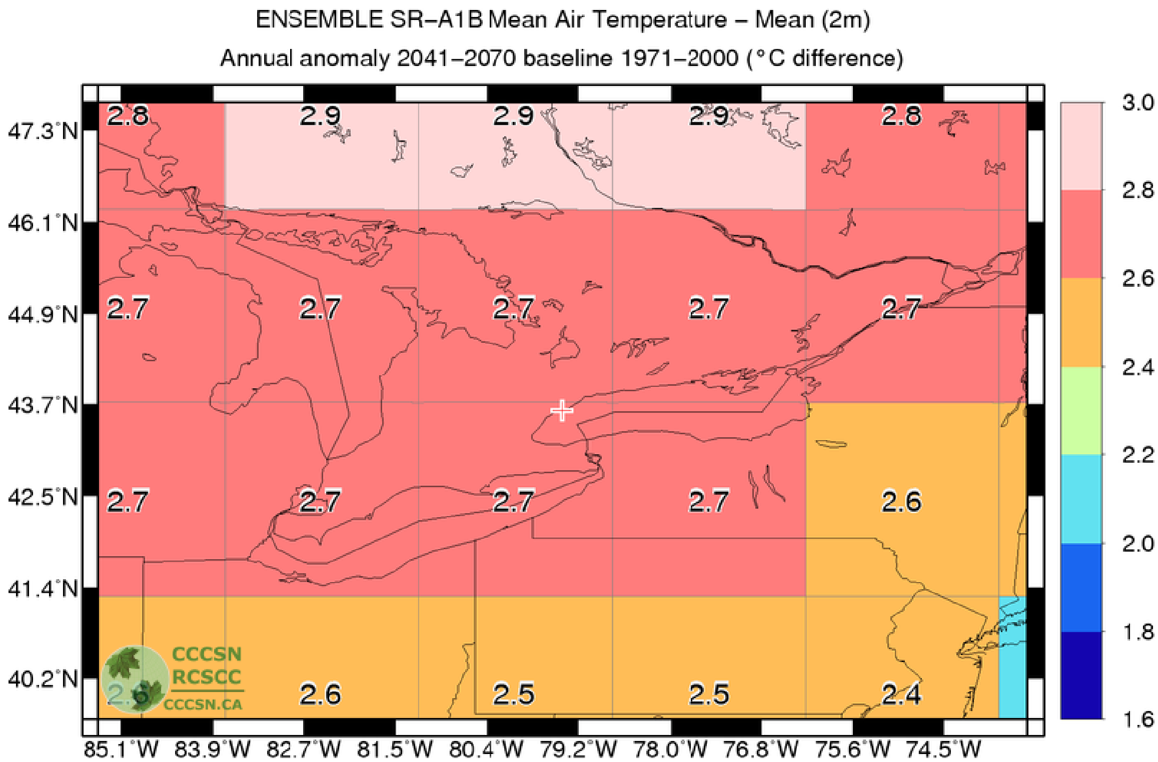
Air Temperature - Mean (2m)

°C	annual	winter	spring	summer	autumn
1971-2000	9.2	-2.8	7.7	20.9	10.8
2020s	10.5 ± 0.3	-1.3 ± 0.5	8.9 ± 0.4	22.2 ± 0.5	12.1 ± 0.3
2050s	11.9 ± 0.7	0.1 ± 0.7	10.2 ± 0.8	23.7 ± 0.9	13.4 ± 0.8
2080s	12.9 ± 1.0	1.1 ± 1.1	11.2 ± 1.0	24.7 ± 1.2	14.4 ± 1.0



From the same Localizer tool output, Figure 7 plots the specific location on the GCM grid, which shows the mean annual temperature increase for each grid cell for 2041-2070 (2050s), compared to baseline temperatures for 1971-2000.

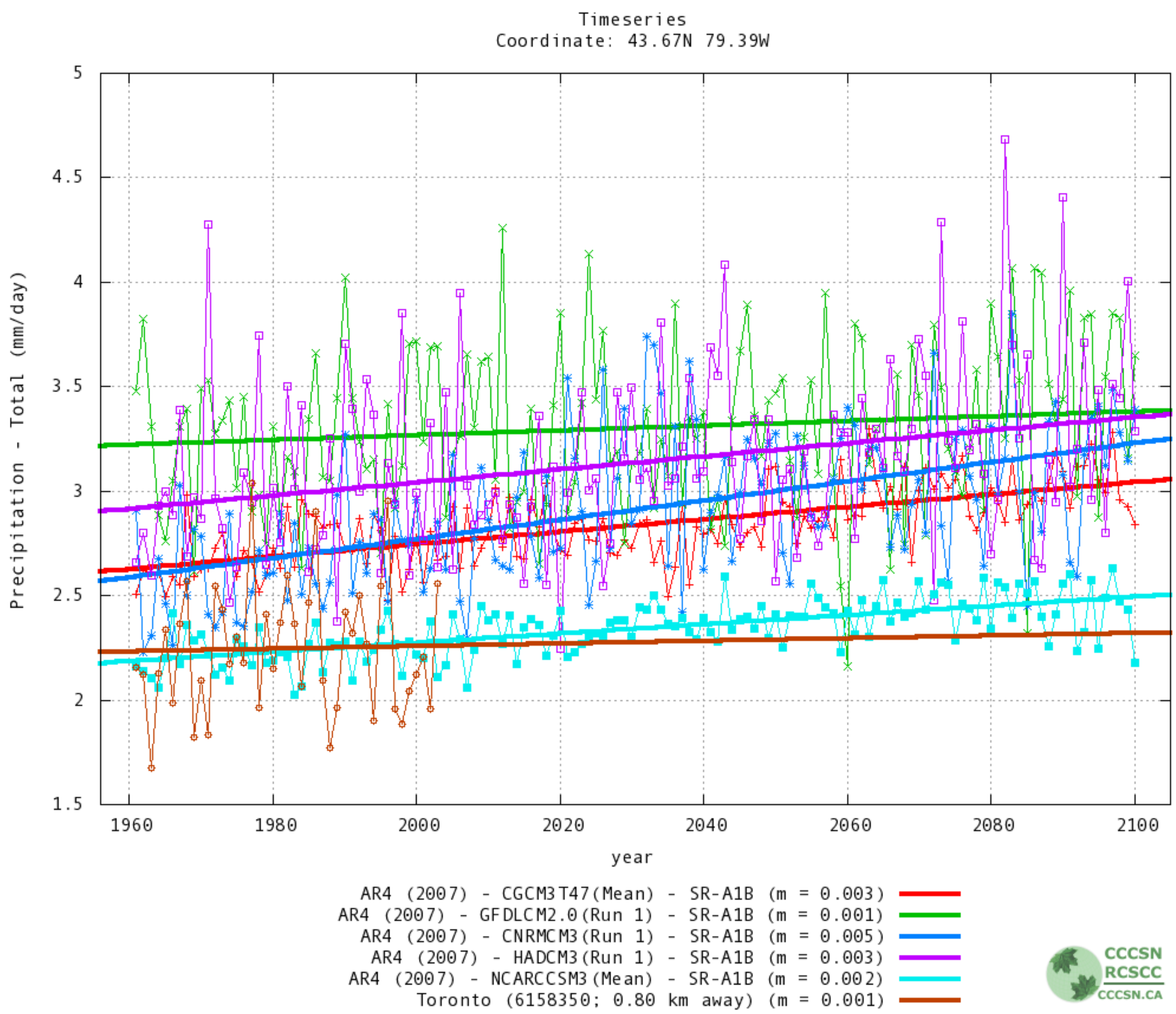
Figure 7: Ensemble projection of changes in air temperature between 2041-2070 from 1971-2000 baseline



Data Visualization – Timeseries

The Timeseries plots annual, seasonal or monthly climate data on a line graph to allow for the visualization of climatic data, past and projected, for one or more GCM models and/or scenarios. Figure 8 helps show the variability of the projected precipitation amounts (measured in millimetres/day) for five different GCM models for a location in downtown Toronto for the period 1960 to 2100. It also shows the actual observed data for the nearest weather station for 1961-2000, and plots a trendline based on that information. The GCM hindcast values for 1961-2000 were derived from the models and show averages for the grid cell within which Toronto falls.   All the GCMs selected here show higher average rainfall than actually occurred at the Toronto observation station in the 1961- 2000 period.

Figure 8: Timeseries of past and future rainfall projections in downtown Toronto



APPENDIX B: Historic Climate Trends and Projections for Four Ontario Cities

Prepared by and contributed to the Municipal Adaptation Training Program by:

Golder Associates

2390 Argentia Road, Mississauga, Ontario, Canada L5N 5Z7
www.golder.com

(For more information contact Sean Capstick at
905-567-6100 x1145 or scapstick@golder.com)

The following series of tables and graphs depict weather data and climate trends from 1971 to 2000 for four Ontario municipalities: Windsor, Toronto, Ottawa and Sudbury. They also show what climate models are projecting for annual temperature and precipitation for the 2041-2070 period.

The Historic Climate Tables

The Tables that follow show historic climate changes for the 1971-2000 period for one of four cities in Ontario (Toronto, Windsor, Sudbury and Ottawa). The tables summarize data for 23 different weather variables. The first climate data column provides the mean or average value for each variable for the 30-year period. So, for example, the historic climate table for Ottawa shows that the mean total precipitation for the city during the 1971-2000 period was 937.6 (rain and snow). These means are referred to as "climate normals" for the period.[1]

The second column for the same variable shows an average decrease in annual precipitation of 1.85 mm per year, compared to the climate normal. And the third column shows an average decrease in annual precipitation of 18.5 mm per decade, also compared to the climate normal.

Golder Associates assessed the statistical significance of each of these trends. Statistical significance is not a direct measure of the probability that the trend will occur in the future. It indicates confidence in the trend. For example, if a trend is statistically significant in the 95th percentile, it means that there is 95% chance that the trend falls within the confidence interval.

[1] **Climate normals** are averages of observed climate values for a given location over a specified time period. The World Meteorological Organization (WMO) considers thirty years long enough to smooth year-to-year variations. At the end of each decade, Environment Canada updates its climate normals for as many locations and as many climatic characteristics as possible. Data are not yet publically available for the most recent decade (2001-2010).

Only the 90th, 95th, 99th and 99.9th confidence intervals are tested. A trend with no statistical significance can mean a number of things:

- No change is occurring for this variable;
- There is a large variability in the data (no significant trend can be determined).
- Confidence is less than 90% but may not be low (e.g. 85%);
- There is not enough data to properly capture the trend (a longer data set might show statistically significant trend).

Trends that are not statistically significant in these tables may still be important to watch, such as the total spring precipitation for Ottawa, which declined by almost 6% per decade in the same period, though this was not assessed as statistically significant.

The Historic Climate Trend Graphs

The graphs showing recent climate trends for each city have been prepared for two variables, total annual precipitation and average annual temperature. The upper graph shows the variation in year to year observations, along with the climate normal (i.e., the average of the 30 years of observations).

The second graph in each pair shows the year to year observations, the climate normal, and the trend derived from the observed data (the orange line). If there is a significant change in the climate trend, then the trend line will have a larger slope, positive or negative. For example, the slope of the trend line for temperature from 1971 to 2000 indicates a significant increase for annual temperature in Windsor, Toronto and Ottawa, though this trend is not as marked in Sudbury. It is reasonable to think that this trend will continue in the future. However the trend lines for precipitation are less clear. Windsor has become wetter; Toronto and Ottawa slightly drier; and Sudbury is wetter in some seasons and drier in others. Snowfall has decreased in all four cities.

The Scatter Plots

The scatter plots included in this appendix show the rate of change per decade projected by a number of climate models, each run with three different emissions scenarios. Each model provides a projection for the change in average temperature and precipitation from the baseline period of 1971-2000. For example, a point that lines up with +0.50 on the vertical axis of one of the scatter plots is projecting a temperature increase of 0.5ºC per decade from the 1971-2000 average to the 2041-2070 period. Over seven decades, this change would result in a 3.5ºC average increase in temperature. Similarly, a point that lines up with +2.0% on the horizontal axis is projecting a 2% increase in precipitation per decade over the same period, for a total average increase of 14% over seven decades.

Each forecast falls into one of four quadrants. The upper right quadrant represents a warmer and wetter climate, the lower right quadrant represents a cooler and wetter climate, the lower left quadrant represents a cooler and drier climate, and the upper left quadrant represents a warmer and drier climate.

The scatter plots show that all models forecast that annual temperatures will increase. Most of the forecasts indicate precipitation will increase; however, a number of forecasts predict decreases in precipitation. There does not appear to be an obvious pattern associated with the emission scenarios. That is to say, the forecasts for each of the three emission scenarios overlap and cover much of the forecast range.

When looking at these graphs the distance of the points from the center of the graph and the spread of the data should be noted. Points further from the center indicate a greater predicted decadal rate of change over the observed period. If there is little spread in the data points along either axis, it indicates the models are in relative agreement on how that variable will behave in the future. Likewise, a large spread in the data points along an axis indicates significant differences among the models.

The Histograms

The histograms show how average annual temperatures may be distributed in the 2041-2070 period and how this compares to the 1971-2000 period. Projected average annual temperatures for 2041-2070 may vary in Sudbury from a low of 5.0ºC to a high of about 11.5ºC. Windsor would vary from a low of 9.0ºC to 15.5ºC (a very hot year). As can be seen on the graphs, the temperature distribution for 1971-2000 is significantly cooler. All the histograms show qualitatively that there will be an increase in mean temperature (peak of the curves) and in the maximum and minimum temperatures (curve shape remains the same).

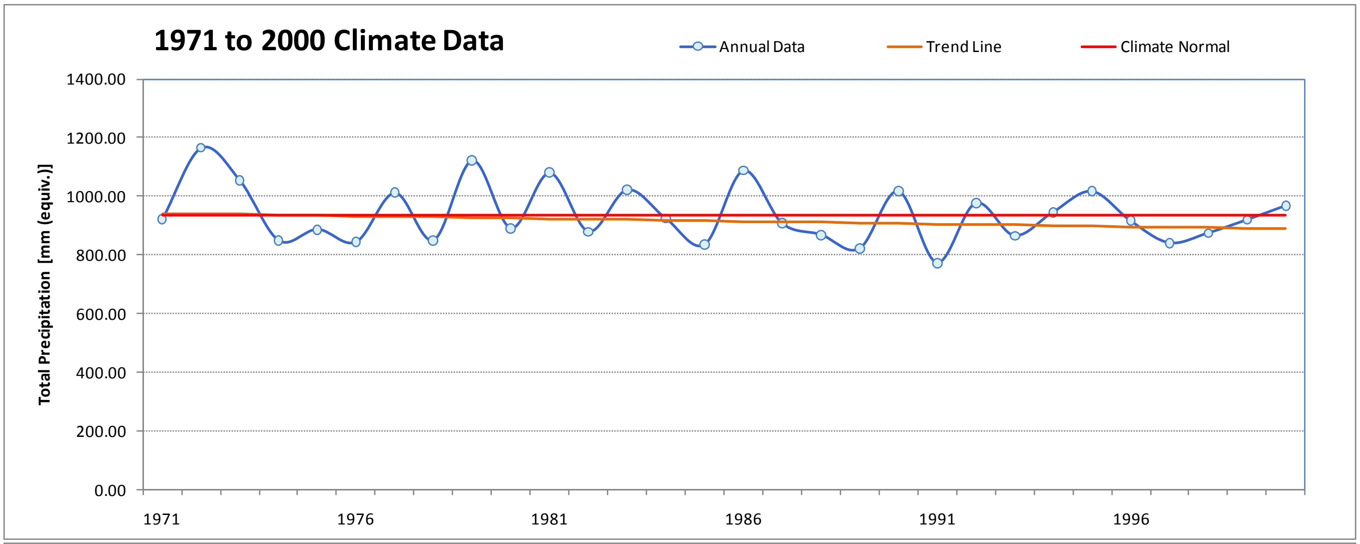
To prepare these histograms, data for average annual temperature and precipitation was extracted from 65 model runs for each of the 30 years in the 2041-2070 period. The highest bars on the graph show the most frequent results; the lowest bars, the least frequent.

Historic Climate Analysis for Ottawa

Parameters	1971 – 2000 Normals	1971 – 2000 Trend (Change per year)	1971 – 2000 Trend (Change per decade)
Total Precipitation [mm (equiv.)]	937.6	-1.85	-18.5
Spring Total Precipitation [mm (equiv.)]	220.3	-1.30	-13.0
Summer Total Precipitation [mm (equiv.)]	265.3	-0.08	-0.8
Fall Total Precipitation [mm (equiv.)]	244.9	+0.38	+3.8
Winter Total Precipitation [mm (equiv.)]	207.0	-1.61	-16.1
Total Snowfall [cm]	230.8	-0.02	-0.2
Total Rainfall [mm]	729.8	+0.82	+8.2
End of Winter (March 21) Snowpack [cm]	21.9	-0.20	-2.0
Number of Period of More Than 10 Days With No Rain [#]	1.3	+0.00	+0.0
Length of Dry Spells [days]	13.0	+0.00	+0.0
Number of Days With >20mm Rainfall [#]	8.0	+0.00	+0.0
Number of Days With >15cm Snowfall [#]	2.3	+0.00	+0.0
Average Annual Temperature [°C]	6.1	+0.04	+0.4*
Average Spring Temperature [°C]	5.3	+0.03	+0.3
Average Summer Temperature [°C]	19.6	+0.03	+0.3
Average Fall Temperature [°C]	7.9	+0.02	+0.2
Average Winter Temperature [°C]	-8.8	+0.05	+0.5
Number of Period of More Than 3 Days With Tmax > 30°C [#]	1.4	+0.00	+0.0
Length of Heat Waves [days]	4.0	+0.00	+0.0
Maximum Daily Temperature [°C]	26.8	-0.01	-0.1
Number of Days with Freeze-Thaw Cycle [#]	36.4	+0.17	+1.7
Number of Period of More Than 3 Days With Tmin < -15°C [#]	5.7	-0.04	-0.4
Length of Cold Spells [days]	10.8	+0.00	+0.0

* significant at the 90th percentile

Total Precipitation [mm (equiv.)] for Ottawa



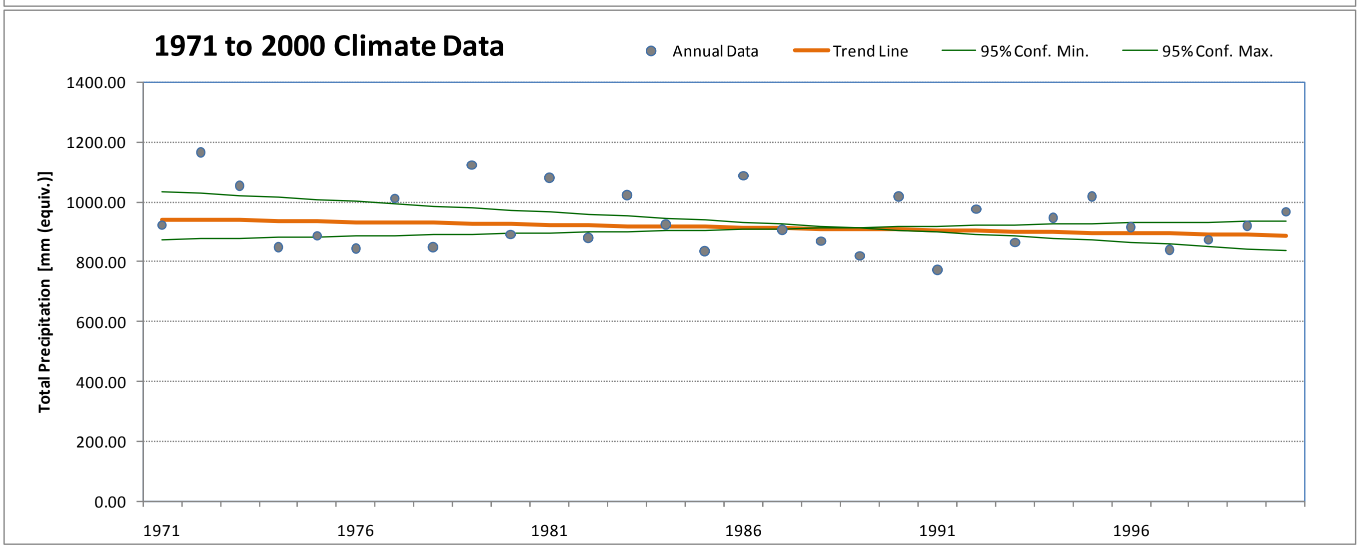
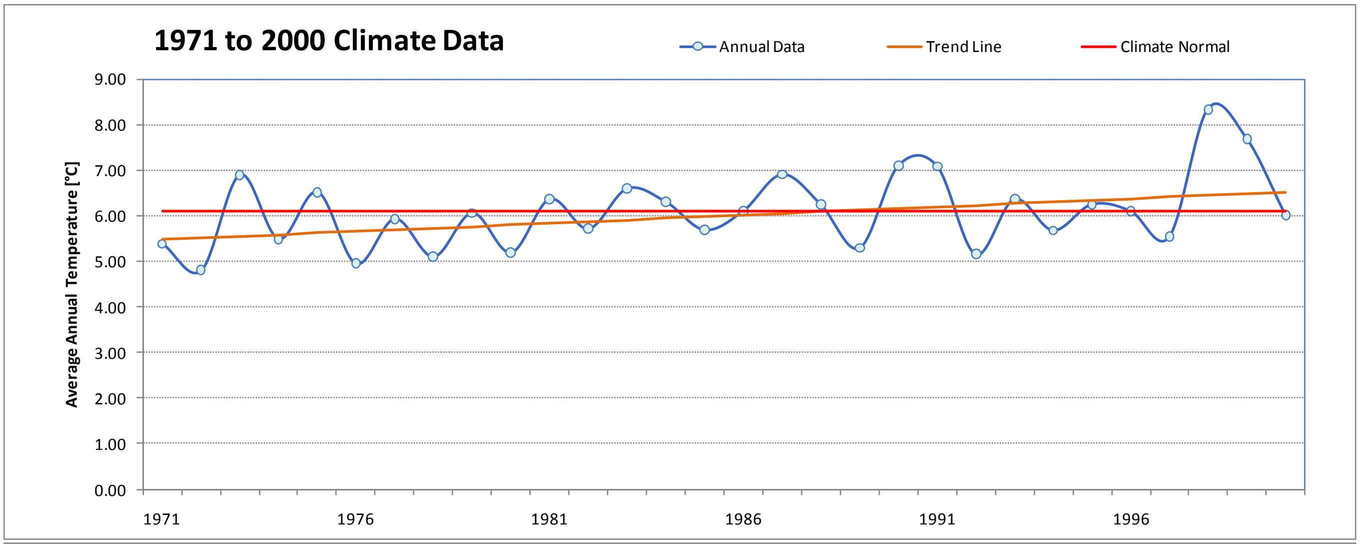


Figure 1: Total Precipitation [mm (equiv.)] for Ottawa, Ontario.

Average Annual Temperature [°C] for Ottawa



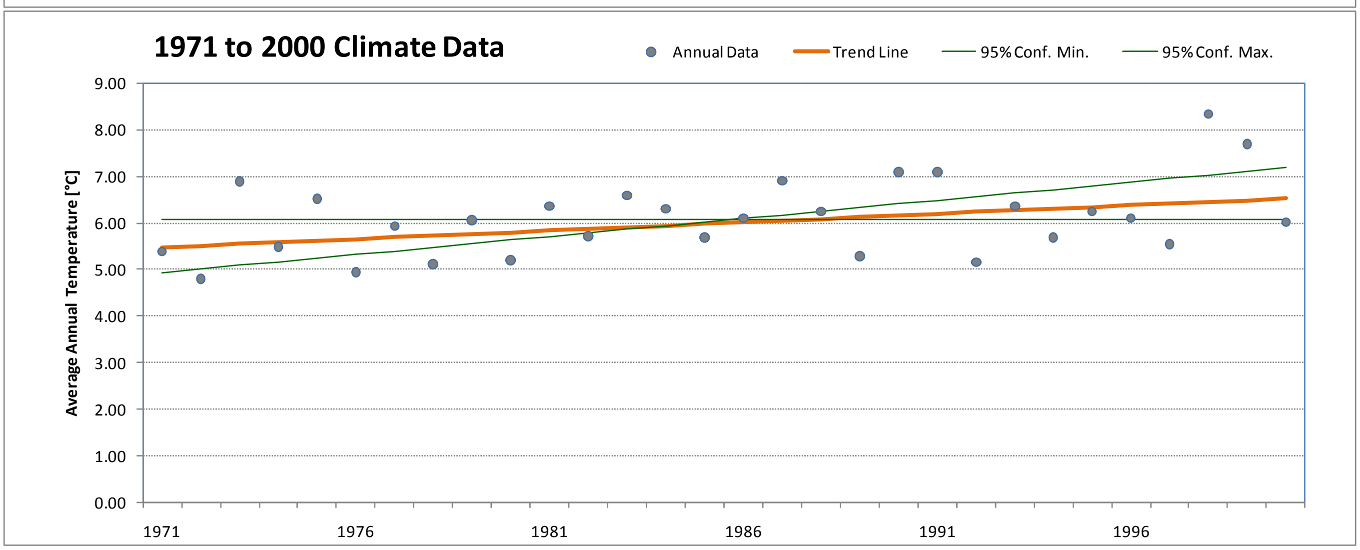
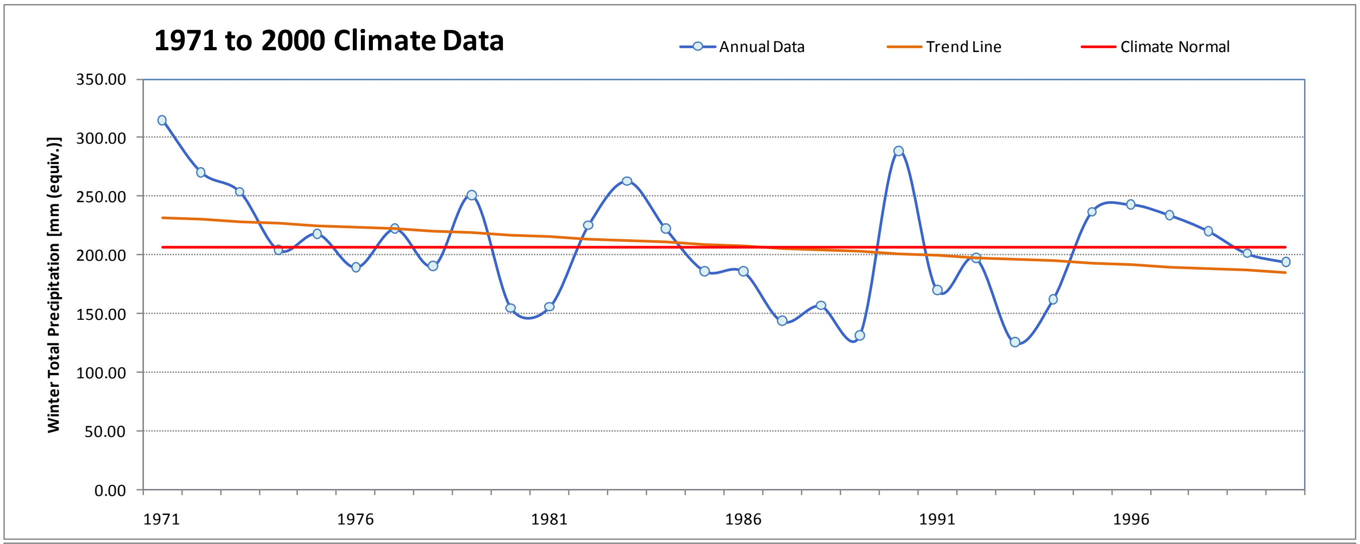


Figure 2: Average Annual Temperature [°C] for Ottawa, Ontario.

Average Winter Precipitation [mm (equiv.)] for Ottawa



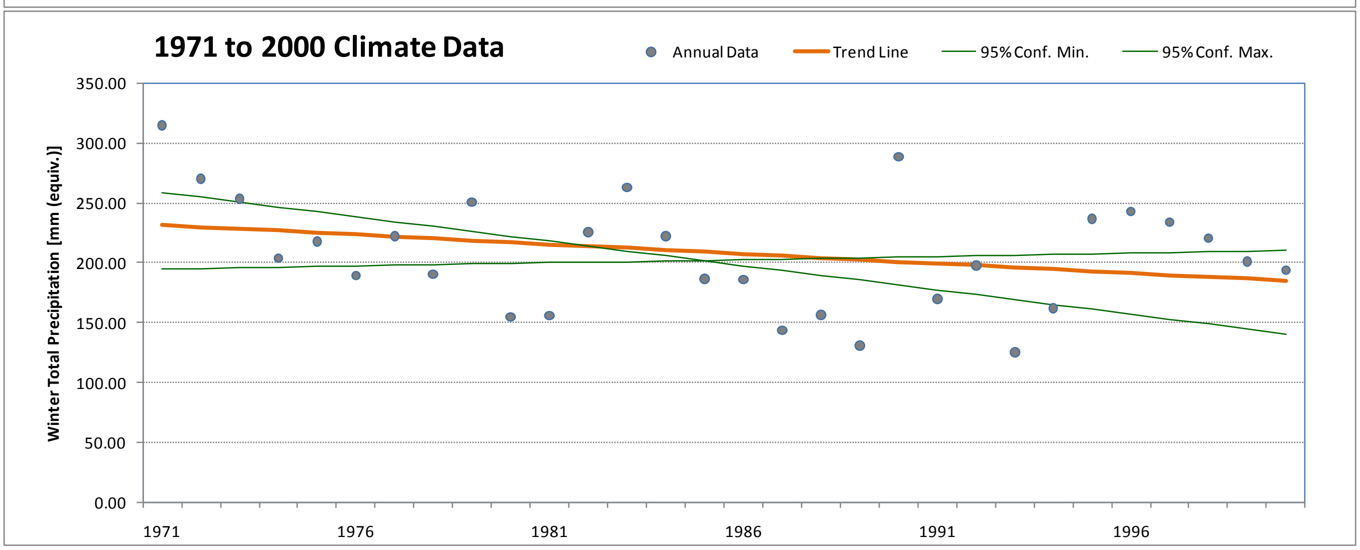


Figure 3: Winter Total Precipitation [mm (equiv.)] for Ottawa, Ontario.

Average Number of Days with Freeze-Thaw Cycles [#] for Ottawa

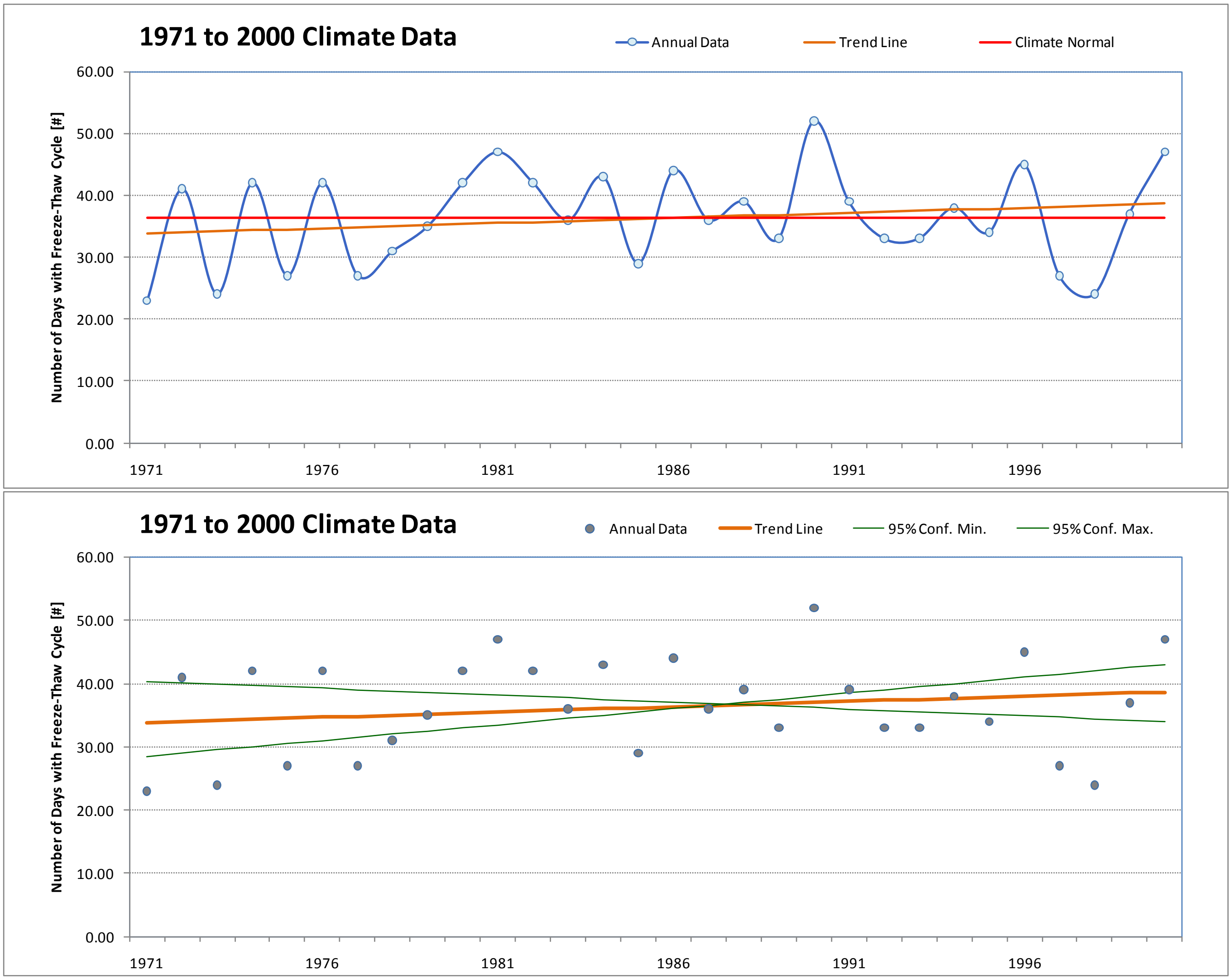
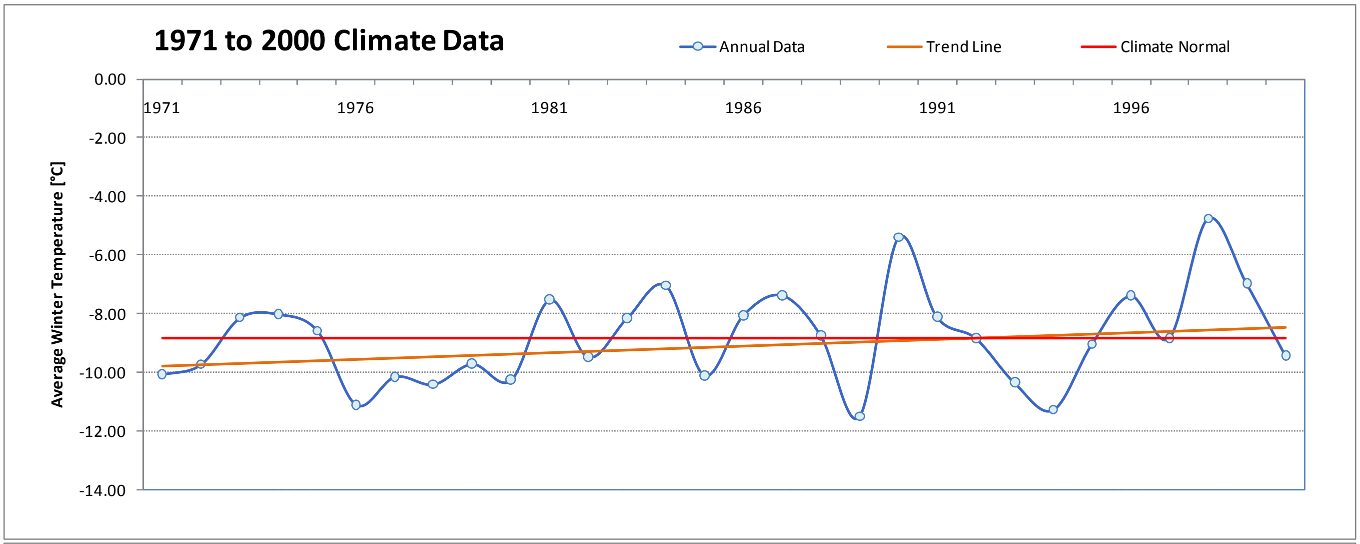


Figure 4: Number of Days with Freeze-Thaw Cycle [#] for Ottawa, Ontario.

Average Winter Temperature [°C] for Ottawa



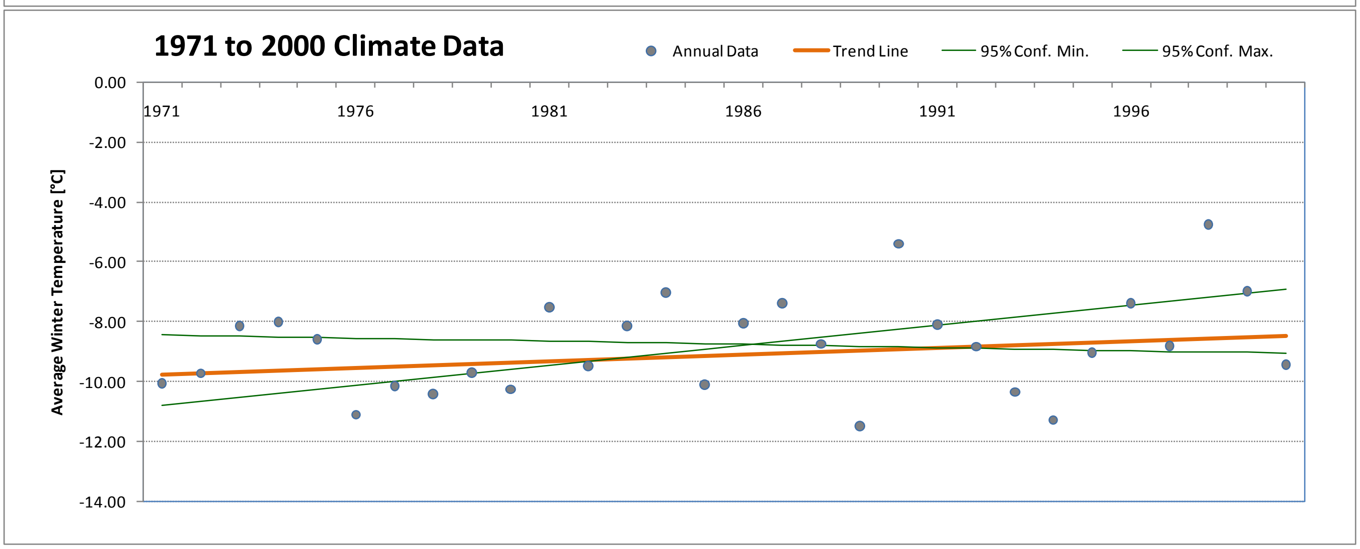


Figure5: Average Winter Temperature [°C] for Ottawa, Ontario.

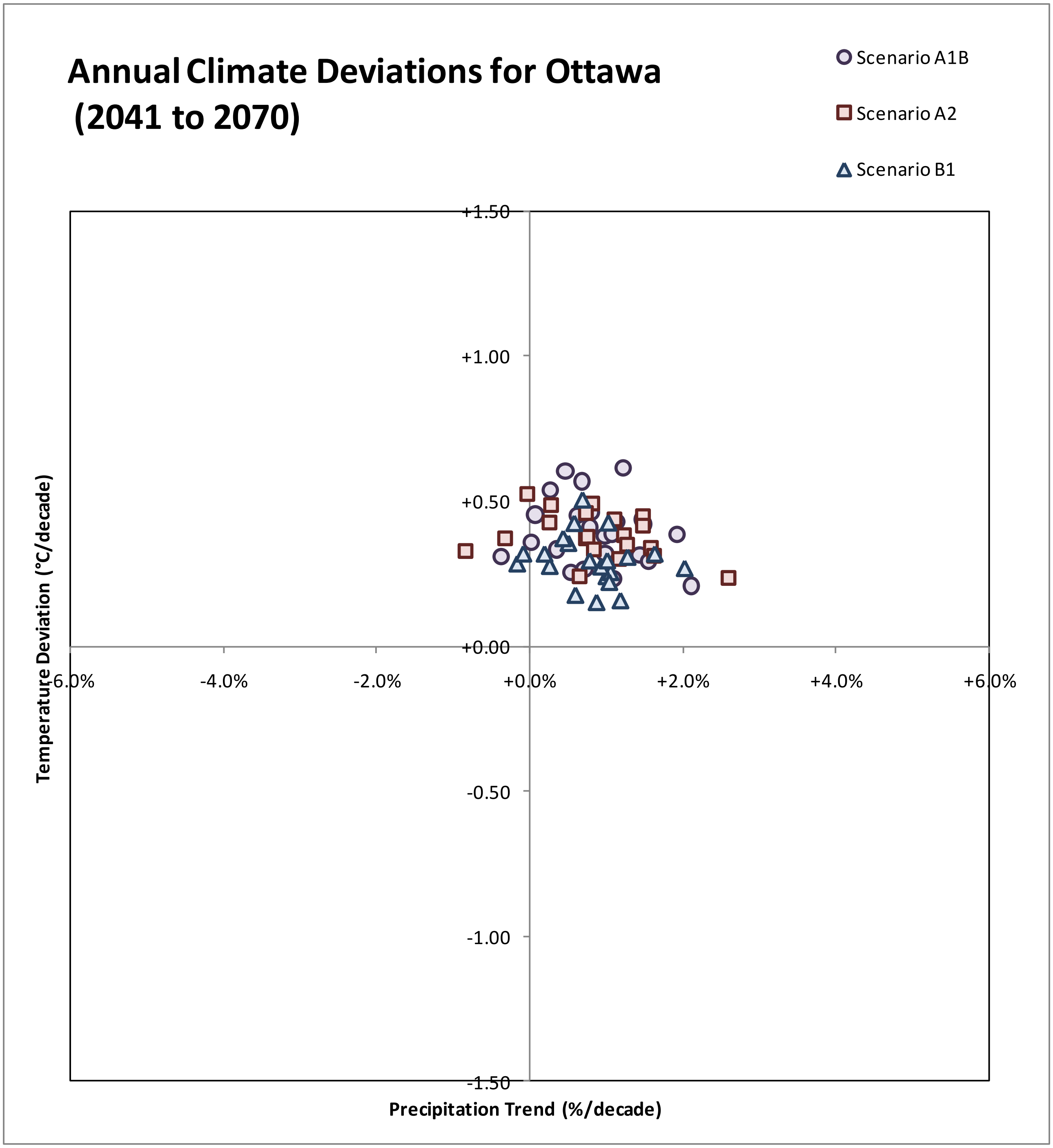


Figure 6: Annual Climate Deviations for Ottawa

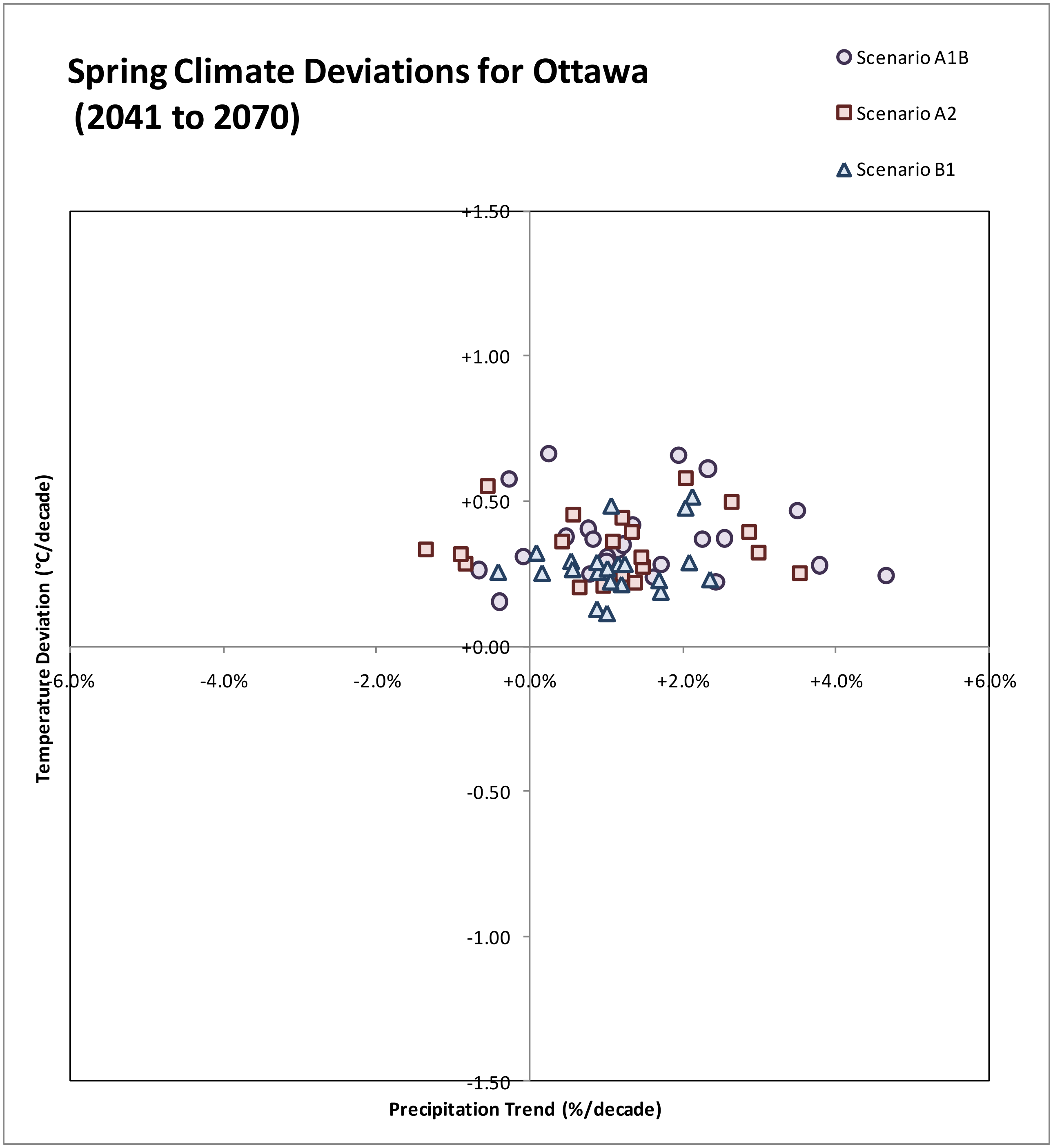


Figure 7: Spring Climate Deviations for Ottawa

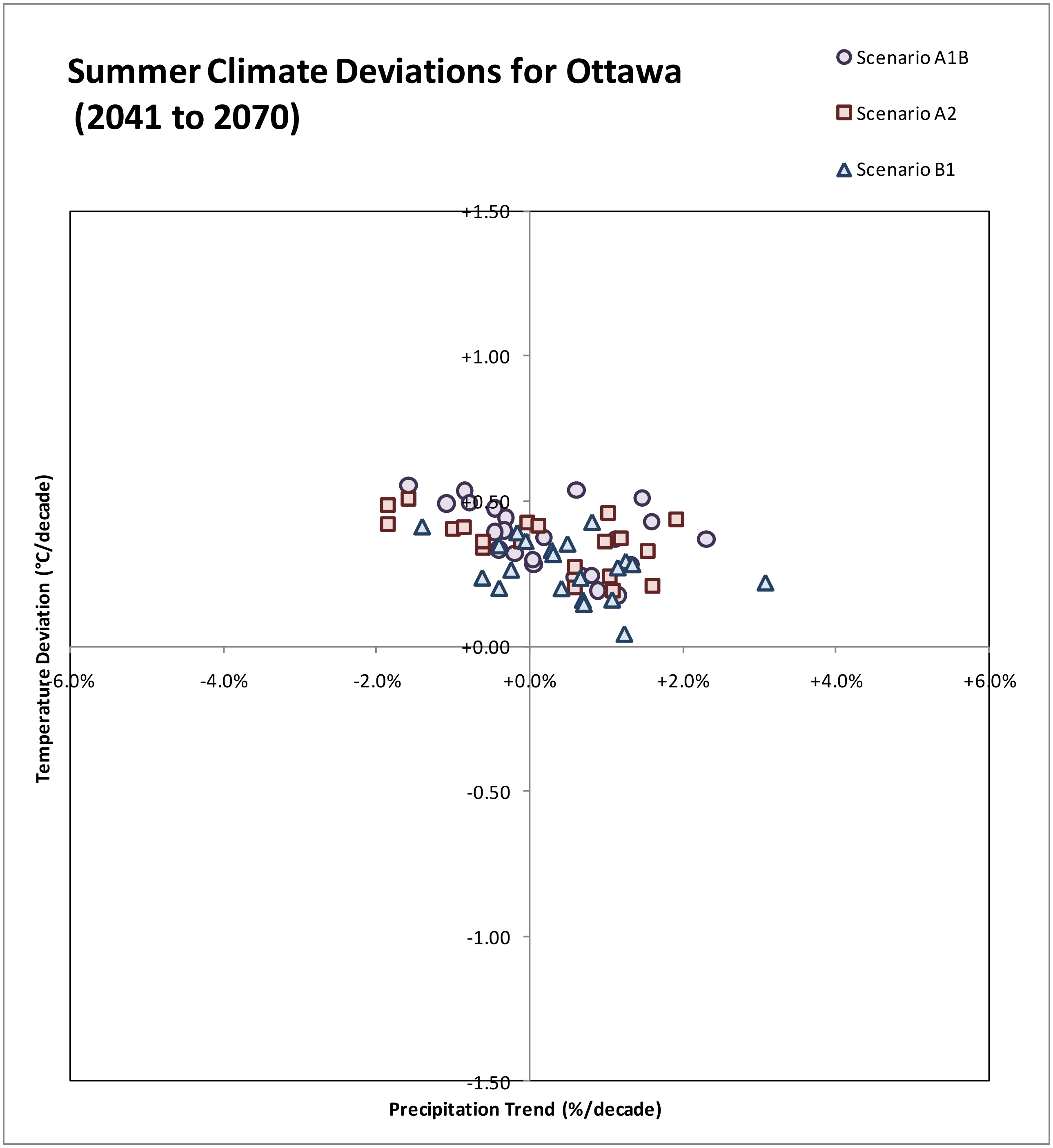


Figure 8: Summer Climate Deviations for Ottawa

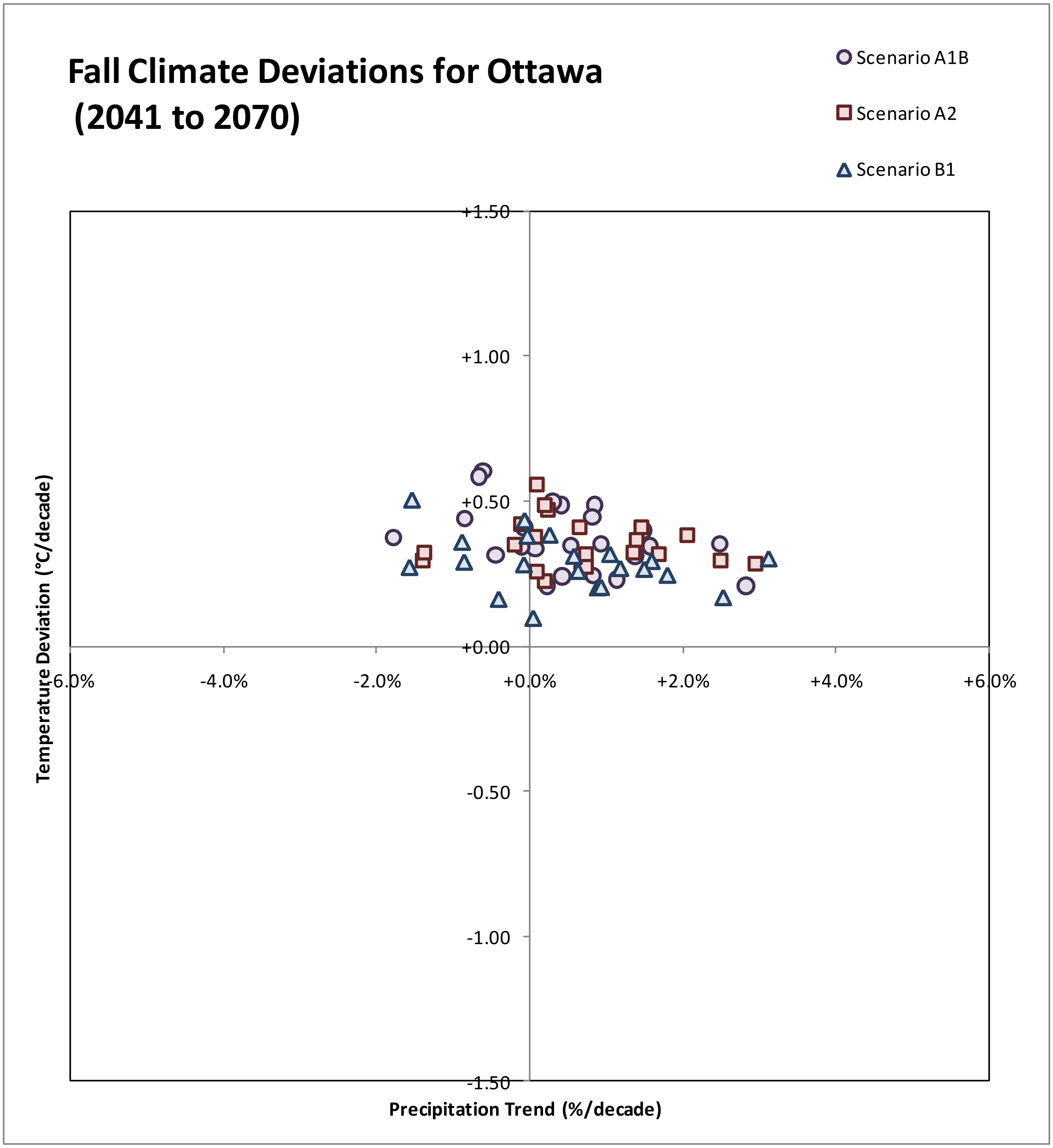


Figure 9: Fall Climate Deviations for Ottawa

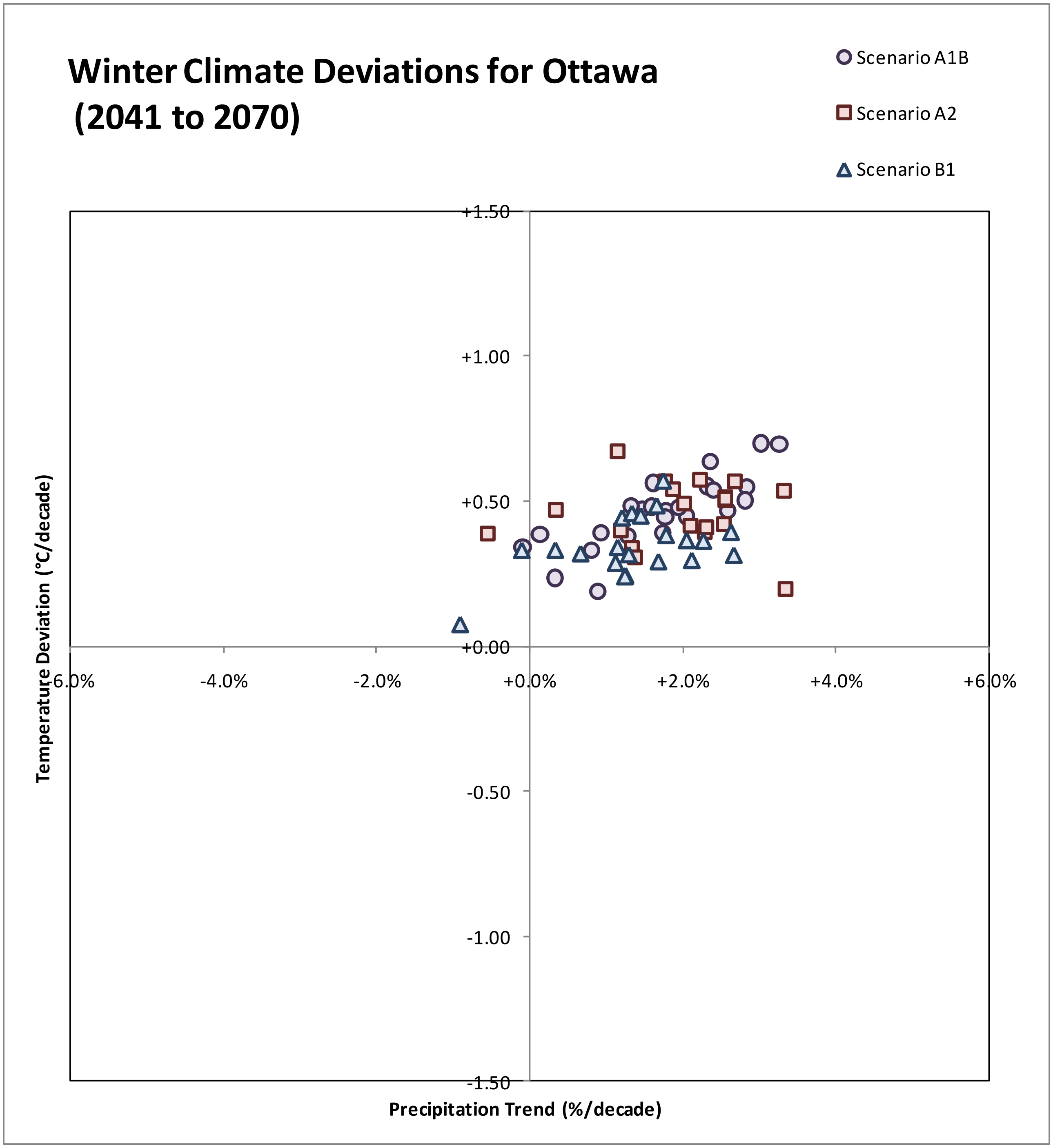


Figure 10: Winter Climate Deviations for Ottawa

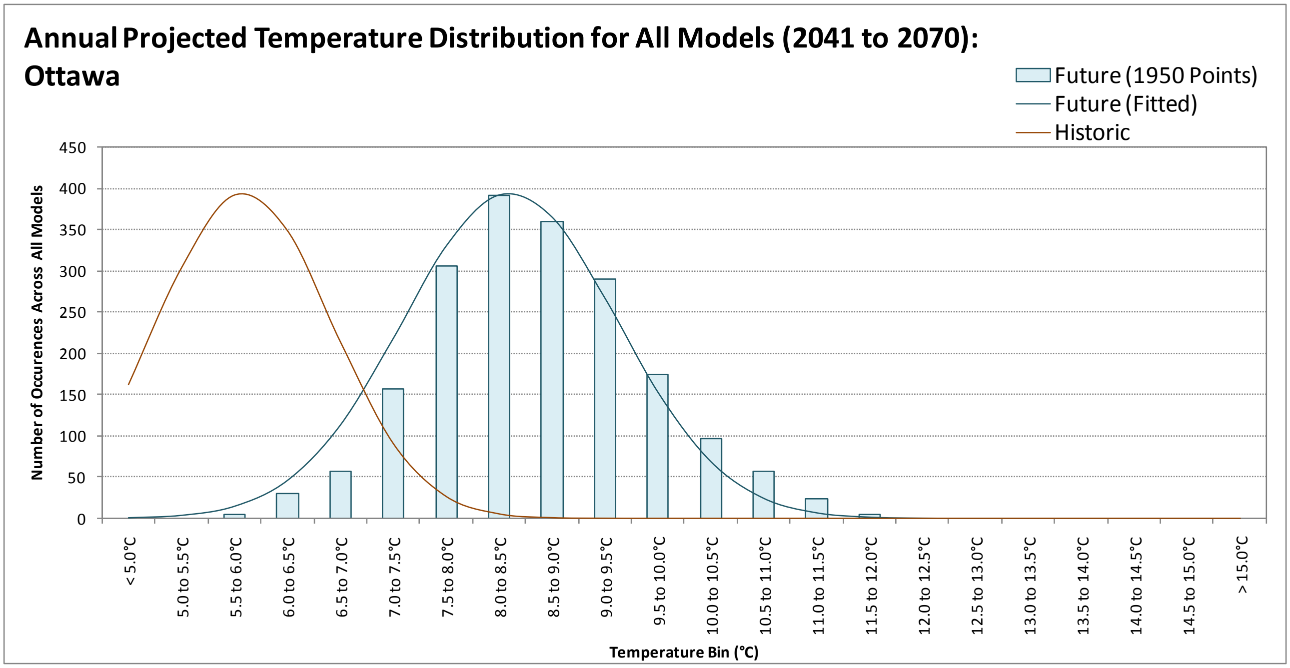


Figure 11: Projected Temperature Distribution

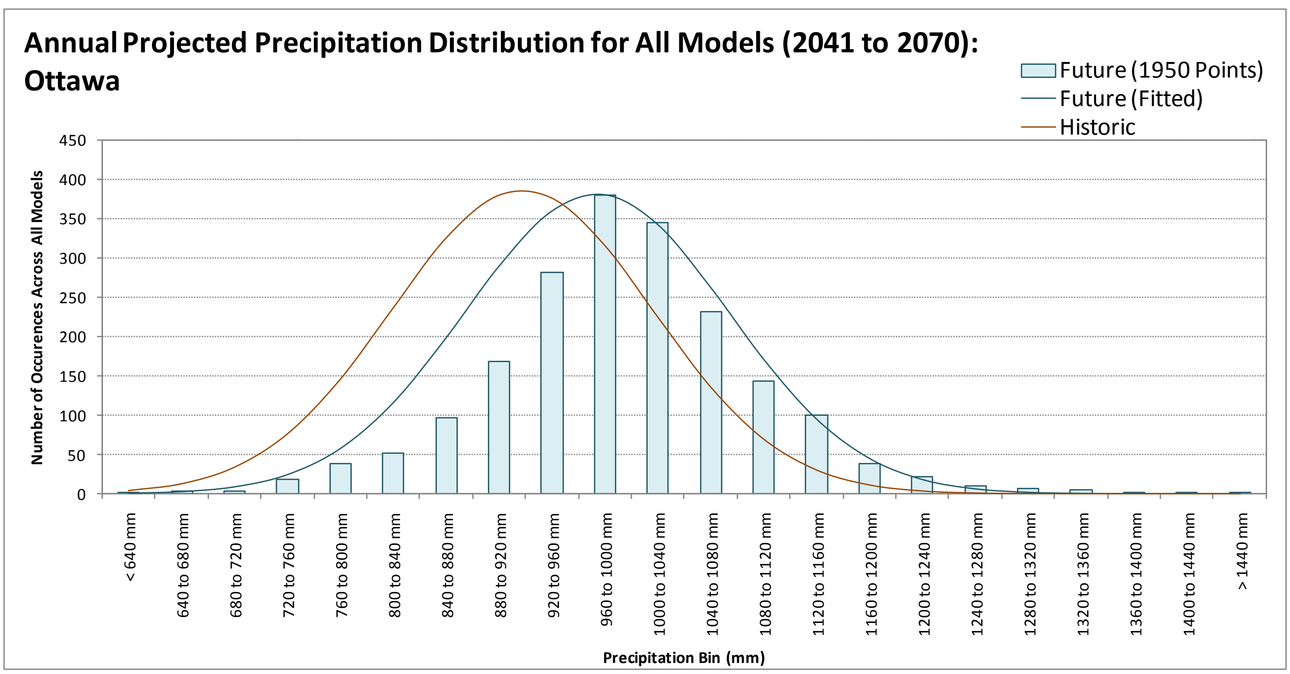


Figure 12: Projected Precipitation Distribution

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MODULE 2: URBAN IMPACTS FOR ONTARIO MUNICIPALITIES

Learning Objectives and Outcomes

By the end of the module, participants will have:

- Reviewed many of the impacts of climate change that are expected in Ontario, and how these could affect municipal responsibilities
- Identified which of these impacts are likely to be of significance to their own communities

Introduction

As discussed in Module 1, climate change is introducing gradual shifts in weather patterns and also ushering in the conditions for more extreme weather. A number of first order impacts of climate change are listed in Table 1.

Table 1: First Order Impacts of Climate Change

First Order Impact	How it is Produced
Warmer average temperatures	▪ Greenhouse gases reflect some infrared radiation back to earth, warming the planet
Increased variability in weather patterns	▪ Increasing amounts of freshwater introduced into the ocean due to melting glaciers and ice shelves disrupts normal ocean currents and alters the heat exchange between the ocean and atmosphere, affecting weather over the entire planet ▪ Formation of cloud cover is amplified as rising temperatures increase evaporation rates, thus contributing to higher precipitation levels ▪ Rising temperatures may affect wind speed
Frequency and intensity of storms	▪ Warmer air in the atmosphere holds more water which can result in more intense precipitation ▪ Hurricanes are formed in warm waters (26°C or more) so rising oceanic temperature could result in more frequent and intense hurricanes
Sea level rise	▪ Thermal expansion – water expands as it gets warmer ▪ Melting glaciers, polar ice and ice mass over Antarctica and Greenland
Permafrost thaw	▪ Rising temperatures responsible for permafrost thaw
Melting glaciers	▪ Rising temperatures melt glacial ice
Increased evaporation and effects on lakes and rivers	▪ Warmer water evaporates more quickly ▪ Warmer air is able to absorb more water
Seasonal shifts	▪ Rising temperatures are resulting in smaller seasonal amplitude (difference in temperature between seasons) ▪ Changes in terrestrial phase (relative timing of temperature trends)

Most of these changes will have flow-on impacts for Ontario municipalities, though some changes – such as sea level rise, permafrost thaw and melting glaciers – will be more significant for communities in other parts of Canada.

This backgrounder outlines how some of these first order impacts of climate change are likely to affect urban municipalities in Ontario, with a focus on the following:

- Heat, smog and air quality and related health impacts
- Water levels and municipal water supply
- Intense precipitation and flooding impacts
- High winds and storms.

It also reviews the costs of extreme weather for municipalities and a case study on the impacts of climate change for urban forests.

Many of the impacts of climate change will be similar to those we have already experienced as a result of past weather extremes. Consequently, this backgrounder takes a look at how higher temperatures, drought and low water levels, floods and storms have affected Ontario communities previously, to get a feel for the impacts that we need to protect against in the future.

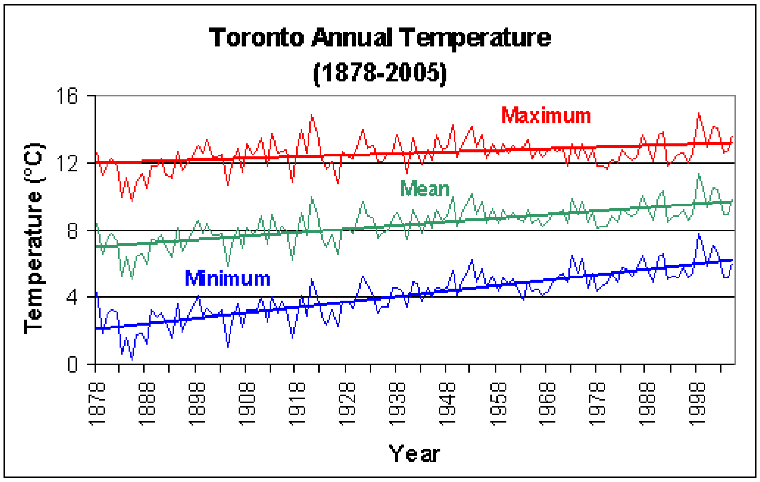
Climate Change Impacts: Heat, Smog and Air Quality

Since 1948, average temperatures in Ontario have increased by up to 1.4°C. These changes have been most dramatic in the spring, with the largest increase in warm days found in Northern Ontario. In built up areas, the replacement of vegetated surfaces with asphalt and concrete, coupled with waste heat emissions have created urban heat islands, compounding temperature increases due to climate change.

Climate change is expected to bring about more prolonged and intense heat waves and periods of drought. By 2050, the number of days per year with maximum temperatures greater than 30˚C is expected to double. Increases in both the average temperature and the intensity and duration of extreme heat events in many parts of the world have been identified as key climate change risks for human health. However, increases in winter minimum temperatures are expected to be greater than increases in summer maximums, a trend that has already been witnessed in Toronto, as shown in Figure 1.

Smog and air pollution levels are a function of atmospheric conditions. Higher air temperatures speed up the chemical reaction between nitrogen oxides (NOX) and volatile organic compounds (VOCs) to form ground-level ozone (O_3), the primary ingredient in smog. Smog is especially problematic during periods of extended warm weather. As temperatures have increased in Ontario over the past century, annual mean ozone levels have increased as well.

Figure 1: Annual Temperature Change in Toronto, 1878–2005



Source: Environment Canada, 2006

Impacts of Extreme Heat on Health

Extreme heat presents numerous public health risks, especially to vulnerable populations located in neighbourhood "hot spots". Vulnerable populations include the elderly, infants, individuals with pre-existing health conditions (cardiovascular, diabetes, respiratory), low income individuals, individuals living alone or in crowded conditions, and those without air conditioning. The elderly are at greatest risk, which is of concern given Canada's aging population.

A heat wave that hit Chicago in 1995 killed an estimated 550 to 800 people, and in Europe more than 70,000 people died from a succession of heat waves that struck in 2003. In both cases, the vast majority of those killed were seniors. In Toronto during the summer of 2005, six deaths occurred in rooming houses and shelters, where a lack of air conditioning combined with fire codes that required doors to remain shut raised internal air temperatures to critical levels.

Because heat is generally a contributing factor rather than the sole cause of death, under-reporting of heat-related mortality presents difficulties in tracking vulnerable populations. The time lag between a heat event and the availability of mortality data 3-5 years later also makes the identification of vulnerable populations difficult.

Healthy individuals, while less likely to die from extreme heat, can suffer from fainting, dehydration, heatstroke, heat cramps, heat exhaustion.

Impacts of Heat on Infrastructure and Transportation Systems

Intense summer heat creates several issues for pavement performance. As this heat increases with climate change, these problems will be exacerbated. Pavement rutting occurs wheels under heavy loads leave permanent impressions on the road surface resulting in surface irregularities and decreased performance. Surface rutting affects the asphalt top layer only, while more severe rutting also affects base and sub-base layers. Certain types of pavement cracking are also brought about by intense heat (alligator and longitudinal). While rutting and cracking will rarely result in road closures, they do result in slower traffic flow and stoppages due to road and bridge repairs.

Extreme heat can pose an additional threat to rail transportation where tracks can buckle in extreme heat. This is thought to be a contributing factor in an Amtrak derailment near Washington that injured 101 people in July 2002.

Impacts of Warmer Winter Temperatures on Infrastructure

The most significant future temperature increases are expected over the winter period. This will affect the frequency of freeze-thaw cycles. In months like January and February where mean temperatures are at their lowest, this will be less significant as temperature increases are less likely to raise mean temperatures above 0°C into the thaw zone. It is more probable that climate change will alter the frequency of freeze-thaw events in the tails of the winter season, in late fall and in early spring. Not all areas will be affected equally by these changes. Research specific to the City of Toronto predicts decreases in freeze/thaw cycles for example, while research that examines the Province as a whole predicts increased frequencies. It is unclear how areas will be affected, given the larger resolution of climate modelling and the variances in localized winter conditions across the province.

Freeze-thaw cycles put a great deal of strain on infrastructure, wearing it out faster and leading to costly repairs and replacements. Natural Resources Canada notes that environmental factors account for the greatest portion of pavement deterioration and that freeze/thaw cycles are vastly more destructive than damage due to extreme summer heat. Up to 50% of deterioration on high-volume roads and as much as 80% on low-volume roads can be attributed to weather effects. Much like pavements, buildings are also susceptible to winter freeze-thaw cycles, where building surfaces are degraded as a result of repeated ice expansion and melting.

Impacts of Climate-related Changes to Air Quality on Health

Air pollution has been linked to numerous medical conditions such as asthma, bronchitis, heart attacks and strokes. Smog and poor air quality are major concerns for Ontarians. Numerous studies link short-term ozone (smog) exposure to an increased risk of death. The Ontario Medical Association estimates that in Ontario, 17,000 hospital admissions and 60,000 emergency room visits were attributable to air pollution in 2005. By 2026, these numbers are expected to increase to 25,000 and 88,000 respectively. These increases are attributed to higher ozone concentrations and a growing urban population.

Socially isolated seniors, children, newborns and people with pre-existing health conditions are particularly vulnerable to air pollution. High temperatures and prolonged heat waves worsen air quality. This is compounded by the fact that during a heat event, people turn to air conditioning for relief, increasing energy consumption and peak energy demand. Because power generation in Ontario is often operating at capacity during heat events, this peak demand is currently satisfied by coal fired plants in the Ohio Valley, leading to increased air pollution in Ontario.

Other Expected Health Impacts – Vector-Borne and Food-Borne Illnesses

With warmer winters, many insects have higher survival rates. Lyme disease, Human Granulocytic Ehrlichiosis and Rocky Mountain spotted fever – all spread by black-legged ticks – are present in southern Ontario and are expected to become more prevalent.

Figure 2: Expected Range of the Black-legged Tick under Climate Change

Source: Charron and Sockett, 2005

West Nile virus is another disease already endemic to Ontario. Summer heat waves, warm winters, and spring droughts are all expected to increase with climate change and all increase the bird-mosquito-human infection cycle of West Nile virus.

Food-borne illnesses tend to peak in the summer when warm temperatures promote pathogen growth in food. Research by Health Canada has demonstrated the relationship between temperature and food-borne disease; as air temperatures increase, so do the number of food-borne disease outbreaks. With the onset of hotter summers, like those of 2005 and 2010, we can expect to see a rise in the incidence of food poisoning.

Climate Change Impacts: Water Supply and Quality

Ontario borders four of the five Great Lakes and contains more than a quarter of a million lakes, rivers and streams as well as rich groundwater resources. The province relies on these waters for household, agricultural, and industrial uses. Ontarians currently use about 260 litres of water per capita per day, nearly twice as much as other countries with similar standards of living.

The hydrologic cycle is very sensitive to changes in temperature, precipitation and evaporation, therefore, as climate changes, so too will the hydrologic cycle. Table 2 presents the expected changes in hydrological parameters for the Great Lakes Basin.

Table 2: Hydrological Changes Expected in the 21st Century, Great Lakes Basin

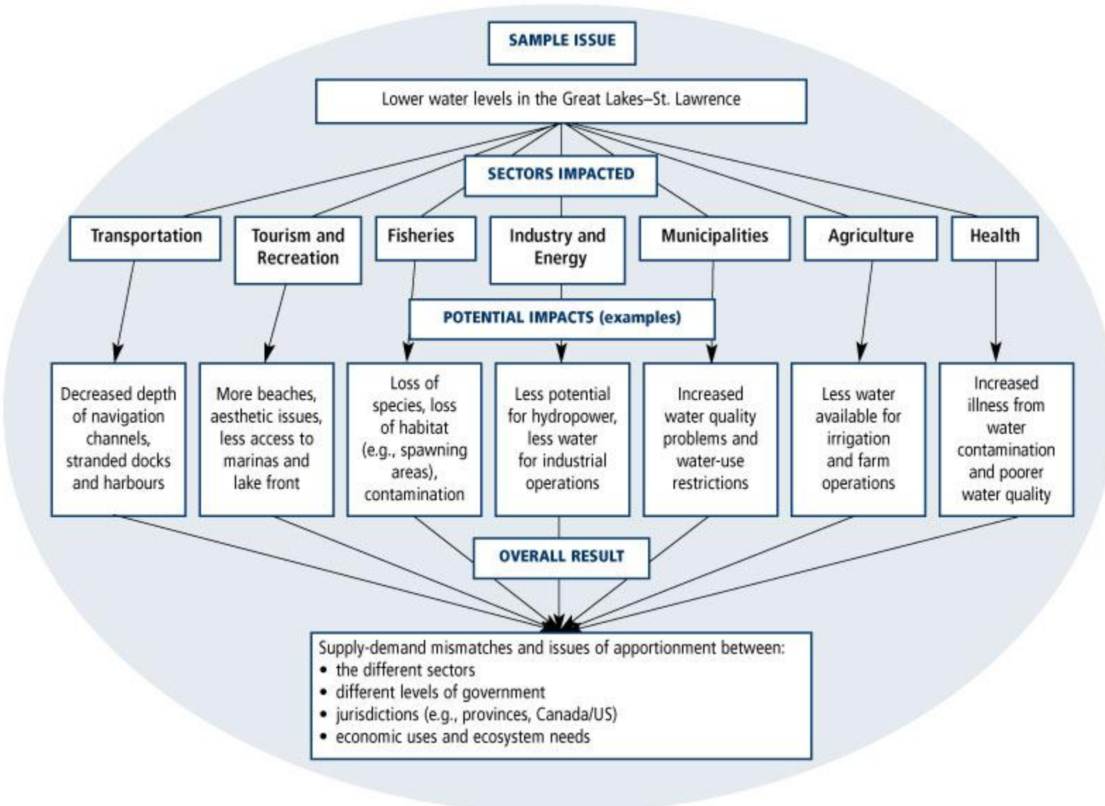
Hydrological Parameter	Expected Changes in the 21st century, Great Lakes Basin
Runoff	▪ Decreased annual runoff, but increased winter runoff ▪ Earlier and lower spring freshet (the flow resulting from melting snow and ice) ▪ Lower summer and fall low flows ▪ Longer duration low flow periods ▪ Increased frequency of high flows due to extreme precipitation events
Lake levels	▪ Lower net basin supplies and declining levels due to increased evaporation and timing of precipitation ▪ Increased frequency of low water levels
Groundwater recharge	▪ Decreased groundwater recharge, with shallow aquifers being especially sensitive
Groundwater discharge	▪ Changes in amount and timing of baseflow to streams, lakes and wetlands
Ice cover	▪ Ice cover season reduced, or eliminated completely
Snow cover	▪ Reduced snow cover (depth, areas and duration)
Water temperature	▪ Increased water temperatures in surface water bodies
Soil moisture	▪ Soil moisture may increase by as much as 80 percent during winter in the basin, but decrease by as much as 30 percent in the summer and fall

Source: De Loë and Berg, 2006

Water is a critical cross-sectoral resource; changes to hydrological cycle brought about by climate change will therefore have far reaching consequences.

As climate change proceeds, the incidence of low surface and ground water levels is expected to increase throughout the Great Lakes Basin. Climate models project that Lake Ontario water levels, for example, could drop 8 to 47 cm (approximately 3 to 21 inches) by 2050. As shown in Figure 3, changes to Great Lakes water levels alone can significantly impact a number of sectors simultaneously.

Figure 3: Impacts of Lower Water Levels in the Great Lakes-St. Lawrence



Source: Lemmen and Warren, 2004

While the impact of climate change on our water resources is already being felt across the province to varying degrees, these changes will continue to become more pronounced in the future. There are three key areas of impact on Ontario's water resources with implications for municipalities: water shortages and droughts, surface water levels, and water quality.

Impacts of Lower Water Levels, Water Shortages and Drought

Although a water-rich province, Ontario is not immune to serious water shortages or drought, particularly in the southern regions of the province. Between the years 1998 and 2002, and again in the summer of 2007 Ontario experienced some of the worst droughts in its history. Table 3 provides an overview of recent droughts and their impacts in Ontario.

Table 3: Drought Events in Ontario, 1997–2007[1]

Year	Drought event
1997	Hot, dry conditions during the summer of 1997 forced Ottawa Valley farmers to use feed reserves for cattle or sell off part of their herds. Harvests came earlier than usual, with most farms experiencing half the normal grain yields.
1998	1998 was the driest year on record for Ontario boreal forests and the third driest 12-month period in 51 years for the Great Lakes/St. Lawrence region. The summer-fall drought forced many residents near London to truck in water because their wells had dried up, and prompted the first voluntary fishing ban on the Grand River.
1999	Unseasonably warm surface temperatures combined with lower precipitation and less runoff from rivers and streams meant that by the end of 1999 the levels of all the Great Lakes fell below the 80-year average. Some groundwater levels in the Grand River basin fell to the lowest mark in 130 years.
2001	In 2001, Canada experienced one of its most severe and extensive droughts. Nearly all of Ontario's crops were desiccated by dry weather and heat. The Great Lakes region experienced its driest summer in 54 years of records. Farms between Windsor and Kitchener suffered the driest 8 weeks on record.
2002	In 2002, lack of rain created drought in central Canada for the second summer in a row. Sarnia, London, Kitchener and Waterloo had the driest August on record. Toronto recorded its driest August since 1937. In urban areas, the lack of rainfall ravaged thousands of trees, with many dying or affected by pest attacks or disease.
2007	In 2007, a prolonged drought prevailed across a broad swath of Ontario from Chatham north to Peterborough; by late summer, watersheds of seven Conservation Authorities experienced a Level II low water condition. May through August rainfall was down 37% from 30-year averages resulting in significant yield reductions for soybean and other crops.

Water shortages are projected to become more frequent as summer temperatures and evaporation rates increase. It is expected that sections of Durham County, Waterloo and Wellington Counties, and the shoreline of southern Georgian Bay – areas where populations are expected to increase significantly – will likely become more vulnerable to shortages within the next 20 years.

Impacts on Agriculture

Agricultural production is of key importance to a number of municipalities, as an economic driver and a source of food. In Ontario, the sector is valued at $10 billion. Agricultural production is very sensitive to climatic variations and extremes. Hotter and drier summers and increased drought events can lead to destruction of crops, earlier harvests, and drying up of farm wells. The consequences are hard to ignore; the drought event in 2001, for example, led to crop losses totalling close to $300 million across the province.

[1] Adapted from: "Getting to KNOW – Annual Report 2007/2008" (Environmental Commissioner of Ontario, 2008) and "Canada's Top Ten Weather Stories Archive" (Environment Canada, 2010).

Figure 4: Soils in Drought Conditions

Source: Environment Canada, 2004

Impacts on Infrastructure

In many communities, water supply and distribution systems are nearing the end of their service life and are already stressed by rapidly increasing urban populations.

Increasing incidence of drought will require greater effort to maintain or replace aging water distribution systems, and intensification of water monitoring and conservation programs. In a study examining the sensitivity to drought of urban municipal water systems in Ontario's Toronto-Niagara region, Kreutzwiser et al. (2003) identified several features of communities at risk, including: dependence on groundwater or river water, aging or poorly maintained distribution networks, or systems with limited storage capacity relative to demand.

Lower water levels are expected to reduce hydro-power in the province and to reduce the efficiency of nuclear and coal-fired plants by affecting the availability and temperature of cooling water.

Impacts on Water Quality and Treatment Costs

Monitoring by the Ministry of the Environment suggests that climate change is already affecting the quality of Ontario's water resources (2009). For example, blue-green algae populations are increasing in northern Ontario lakes in response to warmer air temperatures and longer ice-free seasons. Algal blooms lead to taste and odour problems in municipal water supply, an ongoing problem for municipalities drawing water from Lake Ontario and Lake Erie, particularly in late summer and early fall.

In regions where population growth, urbanization and industrial development currently affect water quality, climate change is expected to be an additional stressor. Low water levels, for example, reduce the natural assimilative and purification capacities of water bodies such as wetlands. Lower water tables reduce the ability of wetlands to filter contaminants such as metals, nutrients and sulphates so that even if pollutant loadings remain constant, their concentrations in water increase.

Figure 5: Microcystis Bloom in Hamilton Harbour, 2006

Source: NOAA, 2006

Not surprisingly, reduced water quality leads to increased water treatment costs, in many cases placing an additional burden on financially stressed municipalities. Decreased water quality is also expected to increase treatment costs and further compromise water treatment systems in several First Nations communities, many of which have been struggling with water quality issues over the past decade.

Impacts on Shipping

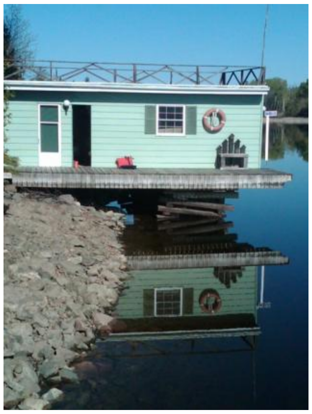
Lower water levels restrict commercial navigation in shipping channels, locks, and ports. In order to keep stay afloat, Great Lakes ships may have to reduce cargo, resulting in extra trips and higher shipping costs. When the Great Lakes-St. Lawrence River system experienced record low water levels in 2001, for example, shipping slowed significantly, at an estimated cost of $11.25 million. Because most Great Lakes ships carry wheat, cement, iron ore, coal and steel, this could have knock-on effects for the construction, food and steel industries.

Impacts on Recreation and Tourism

Low water levels are also expected to have an impact on the quality of recreational experiences available in waterfront municipalities and to adversely affect those dependent on income from tourism. Recreational boating and fishing, for example, would be impacted by low lake levels. Infrastructure investment would be required to extend docks or to dredge channels, and some marinas, launching ramps, boat storage facilities and fishing areas could become unusable for extended periods of time.

Lower ground water levels, too, could have an impact on recreation. The slow release of water from underground reservoirs provides a reliable, minimum flow of high quality water to countless streams, lakes, and wetlands. Changes in ground water levels would no doubt affect the habitats of fish, waterfowl and mammals, potentially limiting activities such as angling, hunting and bird watching.

Figure 6: Low Water Level in Lake Ontario

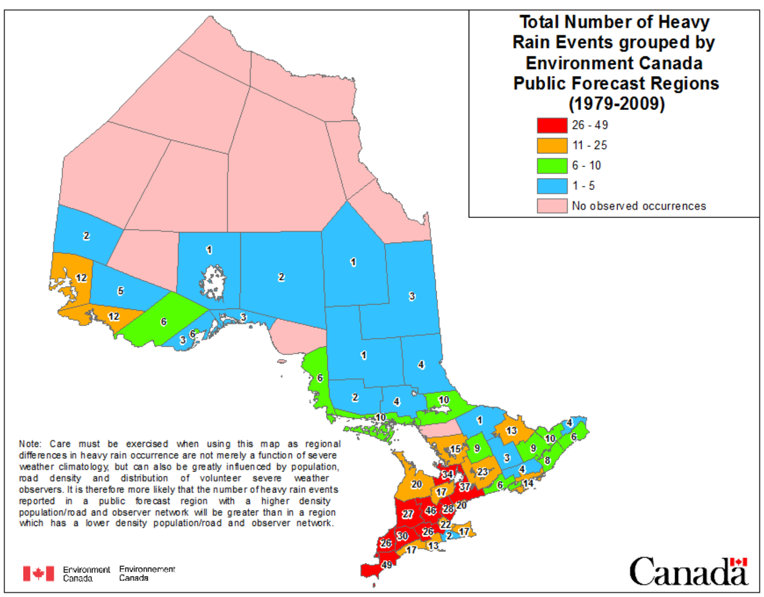


Source: Gord Miller, Toronto Star, 2010

Climate Change Impact: Intense Precipitation and Floods

Many communities in Ontario are already vulnerable to flooding from intense and/or prolonged precipitation. This is especially true in urban areas with limited permeable surfaces or impeded drainage or where soils have been saturated by persistent rainfall or melting snow. While southern Ontario suffers more floods, the northern and eastern regions of the province have experienced serious floods as well, as shown in Figure 7.

Figure 7: Heavy Rain Events in Ontario, 1979–2009



Source: Phil Chadwick, Environment Canada, 2010

The impacts of such floods vary by the geographic features of the region, built environment, intensity of the event and the area's preparedness. Table 4 outlines some of the impacts of recent Ontario floods.

Table 4: Major Floods from Intense Precipitation in Ontario, 2000–2010

Year	Type of Event	Region	Impacts	Estimated Cost
2009	Thunderstorm – 109 mm of rain in two hours	Hamilton	Thousands lost power; forced closure of roads and highways; 7000 basements flooded	\$200–\$300 M
2008	Thunderstorm – 70–80 mm of rain in 24 hrs	Thunder Bay	Portions of highways and roads washed away; State of Emergency called	\$2 M in repair for roads and other infrastructure
2005	Thunderstorms – 100 mm of rain in less than 1 hr	From Kitchener to Oshawa	Basement flooding; structural wind damage; washed out 30m of Finch Avenue (Toronto); swept people into the Don River (Toronto); power outages	\$540 M 15,000 claims submitted
2004	Tropical storms Cobourg: 82 mm Kingston:137mm Ottawa: 135 mm Trenton:111.2 mm	From Cobourg to Trenton	Basement floods; overturned trees; power outages; parts of Highway 401 closed due to flooding	Not available
2004	Thunderstorm – 240 mm (at Trent University) in about 5 hrs	Peterborough	State of Emergency declared due to the fact that much of the city was under 1 m or more of water; overwhelmed sewage system; collapsed roofs, basement flooding; power and communication outages; roadways and sidewalks destroyed	\$88 M in insured losses \$25 M for emergency repair and restoration of infrastructure.
2002	Thunderstorm – 220–401 mm in the affected regions of Ontario	Northwestern Ontario, Manitoba and Minnesota	Roads and railways disrupted; damage to residences, commercial properties and agricultural land	\$31 M

Source: Atmospheric Hazards – Ontario Region "Historical Flood-Related Events", 2010

Climate trends and projections suggest that Ontario will experience increases in the frequency and severity of heavy precipitation events and of related flooding. As Table 5 shows, intense precipitation events and floods are showing steady growth. In its 2006-2007 annual report *Reconciling Our Priorities*, the Environmental Commissioner of Ontario makes note that Environment Canada estimates that 100-year storms will become 50-year storms by 2090. If adaptive action is not taken, current infrastructure and emergency management capabilities may be overwhelmed.

Table 5: Estimates of Observed and Projected Climate Changes for Ontario, 2006

	Trend to 2006	By 2050
Mean Temperature	+0.6 °C	2–3 °C
Total Rainfall	+1% per decade	+1% per decade
Extreme Rain Events	+5–7% per decade especially in spring	+5% per decade
Total Runoff and Groundwater	Little change	Decline of 10–20% (more evaporation)
Great Lakes Levels (measured by flow at Niagara)	-7% (30 years)	Decline of 0.3 to 1 m in lake levels
Severe Winter Storms	Increased intensity	15–20% increase in intensity

Source: Adapted from Bruce et al., 2006

Impacts on Infrastructure

The significant underinvestment in municipal infrastructure over the last several decades has made it more susceptible to the effects of flooding and other impacts of climate change. In recent years, intense precipitation in many Ontario communities has washed out roads, downed communication lines, damaged power and water systems, overwhelmed sewer and treatment facilities, and interrupted important functions such as electricity distribution, communications, transportation and emergency services.

On August 19, 2005, dozens of thunderstorms tracked across Southern Ontario between Kitchener and Oshawa. The storms dropped up to 150 mm of rain in 2 to 3 hours in some locations, and spawned two tornadoes. In Toronto, a rapidly rising Black Creek washed out a section of Finch Avenue, destroying water and gas mains, electricity lines, telephone cables and other infrastructure, as shown in Figure 9. The storm caused an estimated $540 million in damage and is the most expensive natural disaster that Ontario has experienced to date.

Figure 8: Finch Avenue, Toronto, August 19, 2010

Source: TRCA, 2006

Impact on Homes and Businesses (Basement Flooding)

Basement flooding and sewage backup are common occurrences in some regions of Ontario. A survey by Allouche and Freure (2002) of 26 Canadian municipalities found that 42% experienced basement flooding several times per year and 92% at least once every few years.

Many municipalities have combined sewage and storm water systems. This type of structure is vulnerable since large precipitation events can cause stormwater to spill into the sewage line, often resulting in sewer backup into homes and local businesses through drains, sinks and toilets. The Peterborough storm of 2004 provides an important example of this type of damage. In a 24-hour period between 6,000 and 8,000 commercial and residential properties reported flooding damage.

Impacts on Health

Intense rainfall affects water quality, by creating a rush of water that carries contaminants into stormwater systems, creeks, rivers, and lakes. In towns or cities with combined sewer and stormwater systems, heavy stormwater flows can surge into sewer lines, overwhelm treatment plants and be released into local lakes and rivers. Health impacts related to extreme precipitation are summarized in Table 6.

Table 6: Associated Health Impacts of Extreme Rain or Snowfall in Canada

Extreme Weather Event	Examples of Health Impact Pathway(s)	Examples of Potential Health Effects	Populations at Higher Risk
Extreme rain or snow fall	▪ Flooding and its after-effects (e.g. poor indoor air quality from growth of moulds) ▪ Increase in populations of mosquitoes and other disease carriers ▪ Contamination of drinking water by chemicals or waste in surface runoff ▪ Failure of essential infrastructure (e.g. sewers, water treatment facilities) ▪ Algal blooms and other changes in aquatic ecology	▪ Physical injury, shock and trauma ▪ Death by drowning ▪ Respiratory illness ▪ Outbreaks of vector-borne infectious disease ▪ Outbreaks of cryptosporidiosis, giardiasis, amoebiasis, typhoid and other water borne infections	▪ Children ▪ Seniors ▪ People living along coasts or waterways ▪ People with chronic illnesses ▪ People with compromised health status ▪ People with impaired immune systems ▪ People with inadequate or no housing

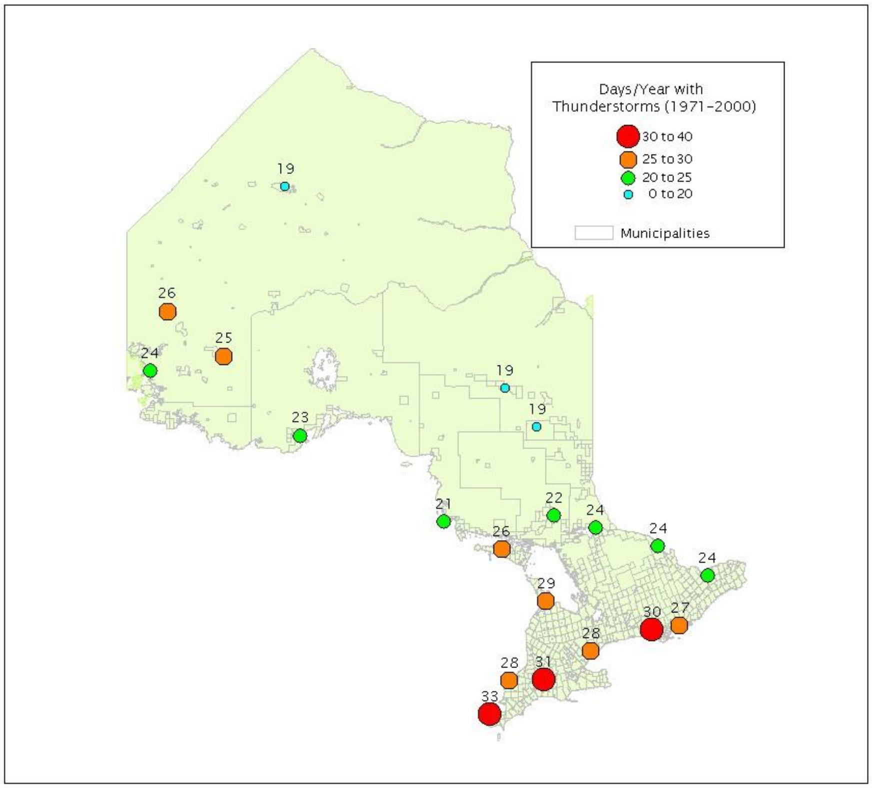
Source: Berry, McBean and Seguin, 2008

Climate Change Impact: High Winds and Storms

Ontario is vulnerable to several types of storms and high wind events.

Thunderstorms, which occur most frequently in mid-latitude regions where warm moist air masses meet up with cooler air, are frequent events in the province. Communities along the north shore of Lake Erie and Lake Ontario experienced an average of 30 or more thunderstorms per year during the period 1971-2000. Central and northern Ontario communities experience fewer thunderstorms, as shown in Figure 10.

Figure 9: Average Days per Year with Thunderstorms, 1971-2000



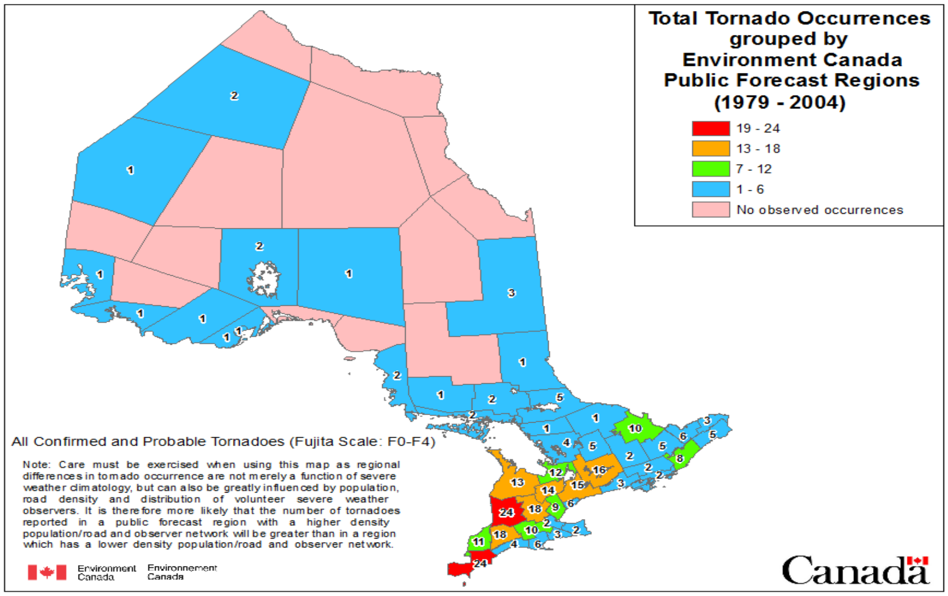
Source: Environment Canada, 2003

Thunderstorms usually involve lightning strikes, strong winds, heavy rain, sleet or snow and sometimes hail. In severe thunderstorms winds may gust to 140 km/h or more. Thunderstorms may occur individually, or as part of a cluster of storms. Severe thunderstorms can spawn tornadoes and waterspouts, large hailstones, and flash floods.

About 80 tornadoes hit Canada each year, about one quarter of these in Ontario. As can be seen in Figure 11, the southwest experiences the largest number of tornadoes in the province. Windsor is the most tornado prone city in the province. In Ontario, 11 tornadoes occur on average per season, usually between April and October. However, in 2006, 23 tornadoes occurred, double the long-term average for Ontario; in 2009, Ontario experienced 29 tornadoes.

Most tornadoes in the province are F0 or F1 on the Fujita scale (with F0 being the weakest and F5 the strongest). Nevertheless, an F1 tornado carries winds up to 180 km/h, which can uproot trees and overturn cars.

Figure 10: Tornado Occurrence in Ontario, 1979–2004



Source: Environment Canada, 2009

Ontario also experiences tropical storms, usually the tail end of Atlantic hurricanes that have moved inland and lost energy. Though not quite as destructive as full force hurricanes, tropical storms can still bring severe thunderstorms, heavy rain, high winds (63 – 117 km/hr) and localized flooding. According to Environment Canada (2003), tropical storms are expected in Ontario roughly once every 11 years. However, since 2003 there have been three tropical storms and one derecho (a long-lived, straight-line windstorm) in the province. Table 7 provides a summary of some of the major storms that have hit Ontario in the last 50 years.

Increases in severe thunderstorms are expected as a result of climate change because of warmer temperatures and a rise in atmospheric water vapour. A recent study by atmospheric scientists at Purdue University and the National Severe Storms Laboratory (2007) in the US suggests that increases of temperature and moisture will more than compensate for an expected decrease in vertical wind shear and produce stronger thunderstorms in future.

Although greater numbers of tornadoes have been observed in Ontario during the last decade, it is not clear that this is due to global warming. However, researchers at the National Aeronautics and Space Administration have recently run climate models that suggest that as climate warms, the most violent severe storms and tornadoes may become more common. While most of these changes are expected in areas that are currently vulnerable to tornadoes, there is a chance that rising temperatures could prompt tornadoes in areas where they have not previously been observed.

Table 7: High Wind and Storm Events in Ontario, 1954–2009

Year	Type of Event	Region	Impacts	Cost
		Hurricane/Tropical Storm		
2008	Tropical Storm Ike (106 km/hr winds)	Port Colborne and surrounding regions	Downed trees, power outages, road closures, washed out roadways	N/A
2006	Derecho (200 km/hr winds)	Northeastern Ontario, Algonquin, Killarney	1 death; felled trees; roads closed; damage to radio towers, residential and commercial properties	N/A
2004	Hurricane Frances	Southeastern Ontario	Widespread flooding	N/A
2003	Tropical Storm Isabel	Lake Erie and Lake Ontario	4 m waves in Lake Ontario; power outages; fallen trees; localized flooding	N/A
1954	Hurricane Hazel (110 km/hr winds (avg) max: 155 km/hr; 28 mm of rain in 48 hrs)	Southern Ontario	81 deaths; 4,000 left homeless,; bridges and roads washed out; homes washed into Lake Ontario	$100 M in 1954 CAD. Equivalent to $1 B in 2010 CAD
		Tornadoes		
2009 (April, June, and August)	Tornadoes (18 touched down, 2 were F2 winds at 115km/h)	Southwestern Ontario, Northwestern Ontario	5 deaths; damage to residential and commercial properties; uprooted trees; power lines damaged causing hundreds of thousands to be without power	$100 M for the August 20th tornado
2005	Tornado (F2 storms 180–250 km/hr)	Southwestern Ontario	Damage to roads, farms, uplifted roofs, trees downed	Contributed to $500 M in damages
2004	Twin Tornadoes	Stratford and Mitchell	Power cut from Alymer to Walkerton; trees uprooted; cattle injured or killed; damage to farms	N/A
1985 (May)	Tornadoes	Barrie and Central Ontario	14 tornadoes; 12 deaths (8 in Barrie); 281 injured; 6,000+ houses damaged	$110 M

Source: Adapted from Environment Canada, 2010

Warmer sea surface temperatures are also expected to increase the intensity of Atlantic hurricanes, and potentially result in a greater number of high-intensity tropical storms reaching Ontario. Atlantic hurricanes have doubled in intensity in the last 30 years according to an analysis by MIT researchers (2008).

Ontario is also susceptible to a range of winter storms including snow storms and freezing rain events. Although relatively rare, freezing rain has the highest cost per event of all hydro-meteorological hazards in Canada. Freezing rain has direct and severe effects on transportation and energy distribution networks, with indirect ramifications for commerce. Freezing rain results in slippery road conditions that result in large numbers of accidents. Rail and shipping operations are not immune to these effects, and walking conditions also become hazardous, resulting in many injuries due to slips and falls and high numbers of emergency room visits. The economy suffers as a result of shocks to the transportation industry and also due to the large numbers of insurance claims that arise as a result of freezing rain.

How the frequency of freezing rain events will change with climate change is difficult to predict, although for Ontario, average increases in the order of 10-20% are expected. The highest increases are predicted for northern Ontario, while southern Ontario could see decreases in such events. Overall, increases over winter months are anticipated as opposed to late fall or early spring (Cheng et al., 2007).

The impacts that result from storms depend on the specific features of the storms themselves – such as lightning strikes, strength of the winds, intensity and duration of precipitation, presence and size of hail – and of the environment where the storm touches down. Events that hit urban areas often have greater impacts due to the density of population, buildings and infrastructure.

Impacts on Health

High wind and storm events often threaten human health and safety. Flying debris and damage to buildings and power lines are among the chief causes of injury and death during a high wind event.

Table 8: Health Impacts Associated with Severe Storms in Canada

Extreme Weather Events	Examples of Health Impact Pathway(s)	Examples of Potential Health Effects	Populations at Higher Risk
Severe storms	▪ High winds ▪ High waves and storms surges ▪ Flooding ▪ Property damage ▪ Damage to essential infrastructure (e.g. power lines, hospitals, water treatment plants) ▪ Damage to personal property ▪ Increased risk of automobile accidents	▪ Physical injuries or death from falls, collapsing buildings, windblown debris, house fires, motor vehicle accidents etc. ▪ Hypothermia ▪ Electrocution ▪ Food-borne disease ▪ Respiratory illness and asthma due to pollen and spores ▪ Drowning ▪ Stress disorders from loss of family members, property or livelihoods.	▪ People living in storm prone areas ▪ People living in low-lying coastal areas or in regions prone to flooding ▪ People living in areas where environmental degradation has created hazardous condition.

Source: Adapted from Belanger et al., 2008

Impact on Infrastructure

High winds and storms can destroy street lighting, topple trees onto power lines or house roofs, lift roofs from buildings and block roads. In 2008, for example, Tropical Storm Ike downed trees, creating widespread power outages in Windsor, London and Port Colborne as well as more limited outages in Eastern Ontario communities such as Peterborough, Belleville, Bowmanville and Huntsville. Falling trees shut down several roads in southwestern Ontario, and severe flooding in some regions washed out sections of highway.

Overhead power lines are quite vulnerable to storms. Table 9 outlines the extent of storm damage to the electricity transmission and distribution system for Southern Ontario for just one year. (Longer term statistics for the entire province are not available.)

Table 9: Impacts of Storm Damage to the Grid in Southern Ontario, September 2005 to 2006

Severe storm dates	Customers affected (loss of service)
September 29, 2005	93 000
November 6, 2005	120 000
November 16, 2005	50 000
February 4, 2006	100 000
July 17, 2006	170 000
August 2, 2006	150 000
September 24 and 27, 2006	93 000

Source: McMillan and Monroe (2006), cited in Chiotti and Lavender (2007)

Tornadoes are an even greater threat to infrastructure. Tornadoes are characterized by a vortex of wind whirling at high speed that can uproot trees, overturn cars, lift roofs off buildings, and hurl debris everywhere.

The most destructive tornadoes that Ontario has experienced featured multiple vortexes. The Barrie tornado event of 1985, for example, was marked by 14 individual tornadoes in the same region and resulted in 8 deaths, 155 injuries and damage to over 600 homes and 16 factories.

On June 6, 2010, an F1 tornado hit Leamington, Ontario. Winds destroyed 13 homes, damaged a marina, flattened commercial orchards and greenhouses, and destroyed power lines. The town declared a State of Emergency that lasted two weeks.

Impact on Agriculture

"Tornado Alley" runs through the rich farmland of southwestern Ontario, the province's vegetable belt. One tornado has the potential to decimate many acres of productive agricultural land and destroy thousands of dollars worth of crops. Nutrient-rich topsoil is often blown away during high wind events and while replaceable to a certain extent, such an endeavour costs money and deprives the soil of important minerals, negatively affecting future crop yields.

Conclusions

As this Module has shown, climate change is expected to bring a number of changes to weather in the Province and have subsequent impacts on Ontario communities. The expected changes to weather in the province include:

- Higher temperatures in all seasons, but especially in winter
- More variable precipitation, with increases in both the incidence of drought and intense precipitation
- More storms and higher windspeeds.

These changes in weather patterns will likely result in a number of impacts that municipalities increasingly will have to take into account.

- Increased number and length of heat waves
- More smog and poor air quality
- More flooding
- Increase in some vector-borne, foodborne, and waterborne diseases
- Infrastructure damage as a result of excess heat, intense rain or heavy snow, high winds, and freeze-thaw cycles
- Economic impacts resulting from lost business
- Higher costs from weather-related events.

Often, the impacts will pose significant social and economic hardships for entire communities, as the examples of the 2004 floods in Peterborough or the 2009 tornado in the City of Vaughan have shown. However, these climate change impacts will not be consistent across Ontario and it may be difficult to predict when and where specific weather events will occur and to what level they will impact municipalities. For this reason, municipalities in Ontario will need to identify their individual vulnerabilities, assess their preparedness, and take steps to address these climate change impacts through plans, projects and programs that are climate change adaptive.

Case Study: The Costs of Climate Change for Municipalities

Municipalities and communities will bear many direct and indirect costs of climate change. These are likely to be reduced – but not eliminated – by adaptation. This case study outlines the types of costs likely to be incurred by municipalities, communities and residents, using examples of the costs of recent weather events that illustrate the financial implications for municipalities of future climate change.

Weather-Related Damage to Infrastructure and Buildings

The economic impacts of several recent storms demonstrate the potential costs of climate change. The August 19th storm of 2005, described on page 13 resulted in more than $47 million in direct costs to the City of Toronto for culvert and road restoration, repair of damage to the sewer system, remediation of parks and eroded streams, and other costs. The insurance industry paid out more than $500 million in total insured losses after the storm for auto, commercial and sewer backup payouts. Uninsured losses are not known. On July 15, 2004 in Peterborough, 200mm of rain fell and flooded the downtown, causing almost $110 million in direct damage to the City`s public and private property according to Conservation Ontario.

On August 20, 2009, an F2 tornado struck the City of Vaughan, just north of Toronto, costing the City more than $400,000, York Region more than $725,000, and damages to private property of more than $17 million.

A July, 2010 hailstorm in Calgary, Alberta caused more than $400 million in damage to vehicles, windows and rooftops. Another $39 million was claimed in early 2009 due to heavy snowstorms in the Lower Mainland of British Columbia, focused around the City of Vancouver, mostly for burst pipes, roof collapses as a result of snow, sewer back-up problems and wind damage.

Premature Replacement of Infrastructure

With a changing climate, municipal infrastructure will need to be able to withstand more extreme weather events but also to be able to cope with extended periods of hot weather, more (or less) rainfall, greater fluctuation in temperatures and more freeze-thaw cycles. These events put a great deal of strain on infrastructure, wearing it out faster and leading to costly repairs and replacements.

Municipal infrastructure is already strained. The Institute for Catastrophic Loss (ICLR) notes that Canada currently faces a total $400 billion infrastructure spending shortfall (2010). Almost 60% of Canada's infrastructure is more than 40 years old, and roughly a third of the infrastructure deficit is for municipal infrastructure (Mirza 2007). Aging infrastructure will be hard put to withstand some of the challenges of climate change. The failure of any specific parts of this infrastructure – roads, bridges, culverts, water supply and distribution, sewage and stormwater systems, the grid – is costly and may lead to cascading failures. Climate change will further degrade infrastructure, and lead to greater expenses incurred by municipalities in the future.

In their analysis of climate change impacts and adaptation in Ontario, Chiotti and Lavender (2008) suggested that the 2004 Peterborough flood may have cost much less than the $110 million in sustained damage had the $200 million in needed infrastructure upgrades already been in place.

Emergency Services during and after Extreme Weather

While capital costs for cleaning up and replacing infrastructure are significant, the costs in salaries and overtime hours for emergency responders and front-line staff are also high. For example, the August, 2005 storm in Toronto required city staff to put in 1,600 overtime hours. On a much grander scale, an estimated 11% of employees in Ontario put in a total of 7.5 million overtime hours during the 2003 blackout, including municipal emergency personnel directing traffic, patrolling streets without lights, or restoring power over the subsequent days.

Compensation for Residents and Businesses affected by Weather-Related Events

On July 28, 2002, two hours of intense rainfall overwhelmed much of the City of Stratford's stormwater and sewage infrastructure as the Thames River overflowed its banks. Shortly after the flood, the City gave $1.3 million in emergency compensation to affected homeowners.

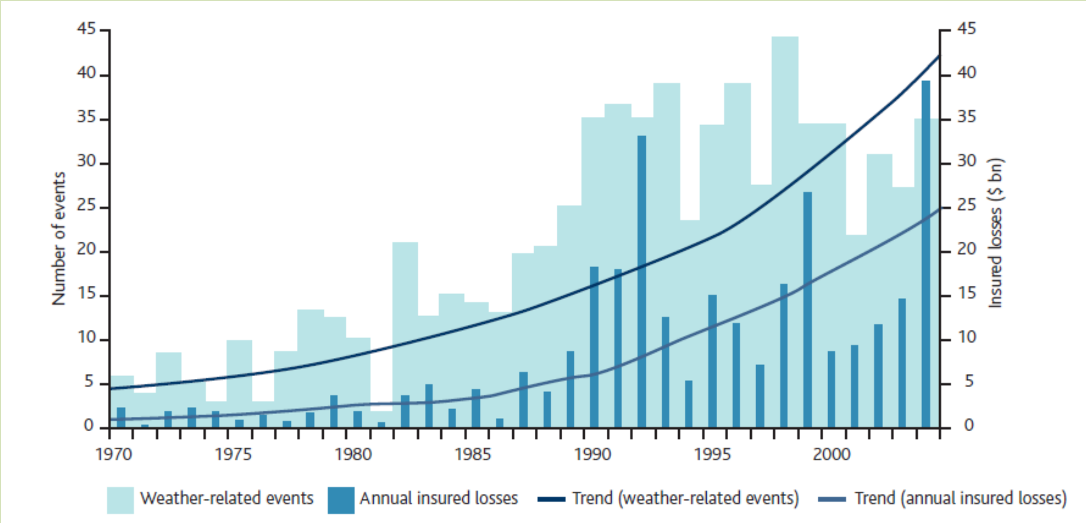
The Ontario Disaster Relief Assistance Program (ODRAP) exists to provide financial assistance for municipalities (as well as homeowners, farmers, and small businesses) when critical infrastructure is damaged during extreme weather and other disasters. However, ODRAP does not cover all costs. The impacts of climate change are likely to result in increasing demands on municipalities to pay compensation to residents and businesses damages not covered by insurance or ODRAP payments.

Insurance Costs

As more insurance claims are made as a result of extreme weather (see Figure 12), insurance premiums and deductibles for municipalities – and homeowners – will rise as on the significant physical assets that need to be covered from damage or loss as a result of weather events.

Water damage accounts for $1.32 billion a year in insurance payouts to Canadian property-owners, much of it for flooded basements. As insurers become more attuned to the increased risks posed by climate change, and because their payouts for extreme weather events have risen sharply in the past decade, premiums will increase considerably as more property owners are put at risk for damage (Sawyer and Cuddihy 2007).

Figure 11: Number of Weather-related Catastrophes and Insured Losses (2004 prices)



Source: Association of British Insurers, 2005

Another growing issue is insurance coverage. For example, store stock ruined during power outages may not be fully insured, and limits on personal effects may be in place by insurance companies. Most notably, overland flooding is not covered by insurance policies. However, as the risks for flooding increase, more and more property owners may be put at risk and have their insurance coverage restricted or withdrawn (CIP 2007). According to the *Canadian Underwriter* (2010), the Canadian property and casualty industry have begun research into whether overland flooding in some areas may be an appropriate item for insurers to begin covering.

Lawsuits

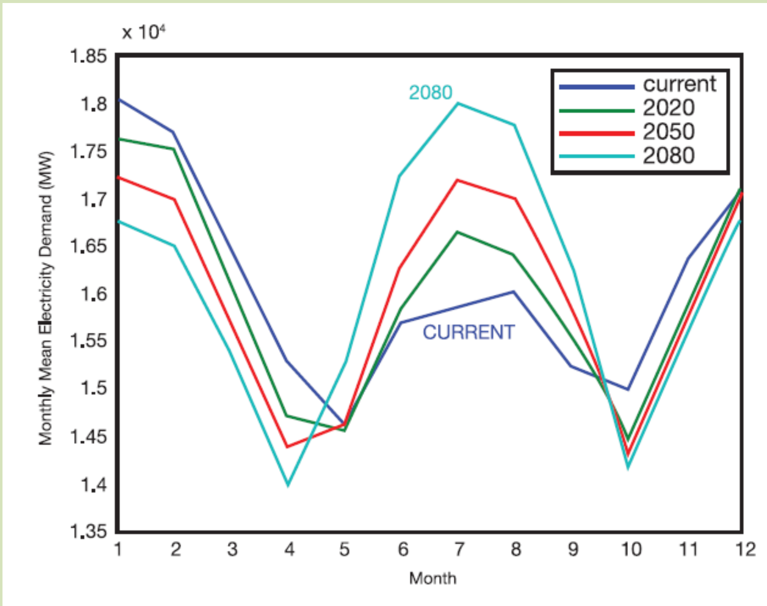
As the public begins to better understand the impacts of climate change, the risks of legal action increase if municipalities fail to take appropriate action to adapt to these changes. While they are generally protected by statutory authority and statutory immunity from most legal nuisance claims, municipalities may still be liable for negligence.

In Stratford, the previously mentioned $1.3 million in compensation given to residents by the city was not enough to cover all the damage. A class action lawsuit involving almost 800 homeowners was undertaken against the city, for failure to take preventive action despite prior flooding, warnings by the residents, and known weaknesses in infrastructure. In March, 2010, a $7.7 million mediated settlement was reached. (The flooding also necessitated a $50 million upgrade to the City's sewage system.)

Greater Energy Expenditures

A more variable climate will also bring about spikes in energy use to manage the temperatures of buildings and facilities owned by municipalities, businesses and residents, especially during extended heat waves (Figure 13). Many older buildings (or newer ones with a high proportion of glass in the building envelope) will draw much more power for air conditioning, which will increase municipal costs.

Figure 12: Projected Monthly Electrical Demand as a Result of Climate Change in Ontario



Source: Cheng et al (2001)

Impacts on Annual Departmental Budgets for Unexpected Weather Events

While many of the costs of climate change are most pronounced during acute extreme weather events, there may also be significant expenditures required as a result of extended periods of more variable weather. Snow removal, a service provided by Ontario municipalities, will be affected by more frequent and heavier snowfalls in some winters from increases in lake effect snow. The City of Toronto overspent its annual snowfall removal budget by $10 million after the heavy snow falls of 2007/08 (Toronto 2008). Other municipalities may have to spend more on invasive species or pest control, or on stabilizing riverbanks to protect from increased flow during peak periods.

Weather-related Disruptions of Business and Productivity

Ontario's economy depends in large part on a "just-in-time" delivery of services, which is put at jeopardy by extreme weather events. The large scale effects were seen in the 2003 blackout. Estimates placed the economic cost of the blackout at between $1 and $2 billion (Public Safety and Emergency Preparedness Canada 2006). Ontario lost more than 26 million of work time, most retailers and services (from health to financial) saw declines in business and sales of up to 40% in the days after the blackout, and up to 82% of small businesses in the province experienced negative effects.

Other climate change effects will have significant impacts on the economic viability of many communities. Northern communities reliant on ice roads in the winter may have difficulty transporting goods into their towns, and areas dependent on fishing or forestry may see significant shifts in the health of those resources. Agricultural communities may be the most affected. The drought experienced on the prairies in the summer of 2001 may be the costliest natural disaster in Canadian history, removing $3.6 billion from regional and local economies (Warren, Kulkarni, and Lemmen 2010).

Conclusion

While it is relatively straightforward to calculate the costs of extreme weather events already incurred by municipalities and private insurers, predicting what those costs are likely to be in the future is an inexact task. There is, unfortunately, a dearth of information that directly projects these types of costs onto municipalities in the light of climate change. This is a significant barrier for municipal climate change adaptation. Climate change adaptation will require increased expenditures in many areas, and these are harder to justify in the absence of credible information about the costs of doing nothing.

Case Study on Climate Change Impacts on the Urban Forest

Urban forests are vital for the health and liveability of our cities and towns. They sequester carbon dioxide and other pollutants, improve our water and air quality, lower air temperatures and noise levels, provide wildlife habitat, increase property value and beautify the urban environment.

Urban ecosystems compete with urban infrastructure for light, water and space in which to grow. In urban areas, vegetation is subject to increased heat due to the urban heat island effect, inferior soils due to compaction and development, high levels of salinity from the use of road salt and physical damage from human interference. This state of stress leaves urban forests more vulnerable to additional stressors such as climate change. Hotter weather, increased incidence of storms and other climate change effects mean that urban forest growth and survival to maturity are more difficult than ever to attain.

At the same time, their survival and success has never been more important, because urban trees can offset some of the impacts of climate change by reducing air temperatures and air conditioning needs, and absorbing stormwater.

Effects of Drought

Although the annual amount of precipitation may not change drastically in the future, more numerous heavy rainfall events and longer dry periods between rains are expected to negatively affect the urban forest.

There are many impacts on the urban forest from climate change. Some of these impacts affect all stages of growth from seed to maturity, while others are specific to certain growth points. In an urban area, new trees are generally planted as opposed to naturally generated, although in urban ravine and park systems, there is some degree of natural regeneration. With climate change, the greater incidence of drought means natural regeneration is more difficult to attain. Seeds need a growth medium and water to germinate and grow. Drought produces dry, compacted soils which reduces the viability of seeds.

For planted trees drought is also a major problem. Drought is very costly for tree planting programs in the municipal context given the costs that are incurred in growing them in nurseries and the costs of planting. Planted trees that have been grown in nurseries for several years have a greater initial requirement for water. With longer periods of drought under climate change, there will be a greater need for watering, which presents additional costs.

Effects of Intense Precipitation

Changes in the patterns of winter precipitation also create problems for trees in both urban and rural areas. Heavy snowfalls can cause limbs to snap or sag due to the weight of snow. Additionally, freezing rain and ice storms are a major problem for tree survival. The sheer weight of ice on tree limbs can be more than 30 times the weight of the branch itself. 6-12mm accumulations of ice cause small limbs and damaged branches to break, while accumulations of

12-25mm cause large branches to break. Figure 15 shows the effects of ice on trees after the 1998 ice storm in eastern Ontario. Falling or sagging branches, while obviously hazardous to the tree, are also a physical danger to people, electricity and telephone lines, property and transportation networks. Because urban trees are often solitary and not grown in close proximity to each other, they are particularly vulnerable to ice storms.

Figure 13: Cleanup of Downed Trees after the 1998 Ice Storm in Eastern Ontario

Source: National Defence and the Canadian Forces, 2010

Effects of Heat

While higher temperatures can be associated with increased growth, this can only happen in tandem with increases in available water and nutrition, otherwise, higher temperatures are detrimental to tree health. There is a direct relationship between heat and ozone, where ozone concentrations increase in concert with temperature for every degree above 22°C. High concentrations of ozone damage leaves and slow down growth.

Higher temperatures also mean that there is increased evapotranspiration from leaf surfaces. Evapotranspiration cools plants in the same way that humans use sweating to keep cool. However, if there is inadequate water in the soil, trees may develop wilted leaves or other health problems. Trees can close their stomata (the small pores on the leaves) in order to reduce excessive water loss; however, this reduces their ability to sequester pollutants.

Effects of Milder Winters/Longer Growing Seasons

Higher than normal temperatures are detrimental to tree health. High concentrations of ozone, which occur with high temperatures, damage leaves and slow down growth. Higher temperatures also mean that there is also increased evapotranspiration from leaf surfaces, leading to wilting of tree leaves and other tree health problems. Higher winter temperatures mean that buds can sprout earlier; this is particularly dangerous as buds that sprout during warm spells in winter are then vulnerable to temperature decreases below freezing. This results in retarded growth and decreased life expectancy.

Additionally, milder winters result in an increased proliferation of pests. Low temperatures are necessary to regulate pest populations. Higher temperatures can allow for additional breeding cycles, and reduced annual mortality for insects such as the elm bark beetle, a carrier of Dutch elm disease, therefore creating additional risk to the host tree. Trees in a state of stress are more vulnerable to pest attacks, therefore as milder winters place trees in a state of decreased health, their risk of damage from pest attacks increases.

Mature trees also have a requirement for water, but with more developed root systems, they are better capable of surviving dry spells. Still, root development in an urban system is difficult to achieve. Urban soils are generally heavily compacted which is a hindrance to root development. Water runoff from hard surfaces into drainage systems also limits the amount of water available to root systems to begin with. A consistent level of available water is desirable for all trees, as opposed to infrequent large amounts. Trees that are dehydrated do not grow significantly in height or diameter, and rarely attain a mature canopy.

A longer growing season means a greater period of time in which trees can be damaged and stressed. This means a greater potential for decreased tree health due to drought and other climate change stressors. In the late fall, growth slows, foliage is lost and trees enter a dormant state for the winter. This dormant state is designed to protect trees until budburst in the spring. Milder winters mean that trees have a longer growing season and a shorter dormant season. Higher temperatures during the winter may also lead buds to sprout earlier; this is particularly dangerous as buds that sprout during warm spells in winter are then vulnerable to temperature decreases below freezing.

Milder winters may also result in a northward migration of trees into areas not previously colonized. There are uncertainties associated with this migration. How will these trees fare in new environments? Can a tree from mid-latitudes of the United States survive in southern Canada? These questions remain to be answered.

Effects of High Winds

Trees are capable of handling moderately high winds and even grow to account for wind direction. High winds and storms present more infrequent, but considerably more hazardous conditions for trees. During a windstorm, a variety of factors determine whether or not a tree will fall or be damaged. Well developed root systems are essential in preventing trees from blowing over, as they anchor the tree and provide a counterweight to the crown. Urban environments with subsurface infrastructure and high water tables or permafrost zones tend to impede root development. High winds cause trees to sway back and forth, loosening root plates. When the degree of sway hits a critical point, gravity takes over and the tree falls.

A more common occurrence is for tree branches to become damaged or break. Dead or unhealthy branches tend to be the first casualties in a windstorm. Those that do not fall remain on the tree but need to be removed, often at a high cost. Preventative pruning limits the necessity for this, but again, this is a costly exercise. Branch damage can lead to cracking of the tree bark and open wounds on trees. These become sites of potential fungal infection, and can ultimately lead to deteriorations in tree health or death. An inventory of urban forest health is therefore desirable after a major wind event; however, this too, is a costly and often impractical exercise for municipalities.

Thousands of trees can be damaged during an extreme weather event. This has major implications for urban forestry since it takes decades and sometimes centuries to replace lost trees. A serious storm or wind event, such as Hurricane Juan, which hit Halifax in 2003, can decimate almost 90% of the tree cover in a single area.

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MODULE 3: GETTING AN OVERVIEW OF IMPACTS AND VULNERABILITIES

Learning Objectives and Outcomes

By the end of the module, participants will:

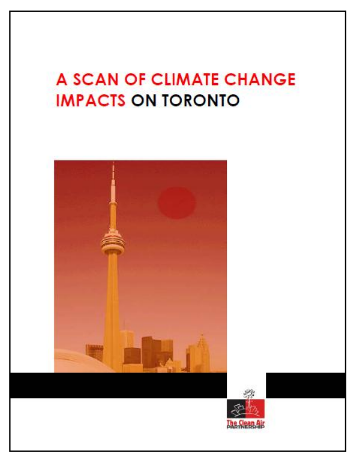
- Understand several ways to get a qualitative overview of the potential impacts and vulnerabilities of their communities to climate change
- Have discussed which of these methods might be preferable for their communities
- Have practiced using several tools for organizing and communicating information about climate change impacts and vulnerabilities.

Introduction

Getting an initial overview of the potential impacts of climate change on a community, and the vulnerable sectors and populations in that community is an important step in developing an adaptation strategy. An initial scan can be used to put climate change adaptation on the agenda of decision-makers and the public, and can garner support for the allocation of resources for more detailed assessments and adaptation planning especially if it is developed collaboratively and followed up by workshops and other forms of engagement. The review may be initiated by municipal staff, by non-governmental organizations working with municipalities or other interested parties. Some reviews are internal reports; others become public documents that help drive the adaptation process.

Examples of Existing Impacts Overviews

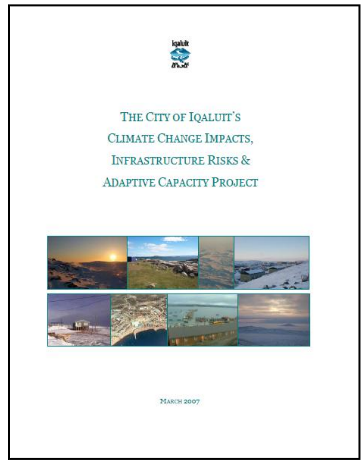
- *A Scan of Climate Change Impacts on Toronto* (2006) prepared by staff at the Clean Air Partnership, a Toronto-based environmental organization, with financial support from Natural Resources Canada. The report was based on a literature review, discussions with researchers and scientists, and workshops with staff at the City of Toronto. It identified potential impacts for water and wastewater systems, health, energy, transportation, buildings, urban ecosystems and the economy. The scan was instrumental in getting the City to include adaptation in their 2007 Climate Change, Clean Air and Sustainable Energy Plan.



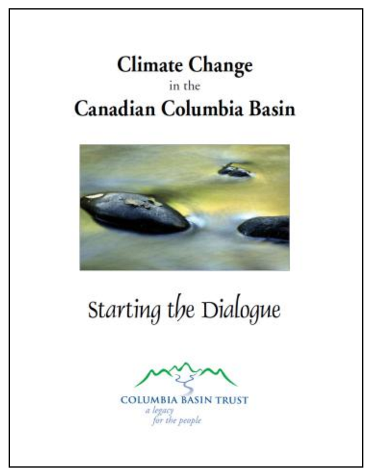
- *Capital Region District Climate Change Adaptation Study: Phase 1 Project Scoping* (2007) prepared by The Sheltair Group (environmental consultants) for the district around Victoria BC. This report was a very high-level overview of possible impacts, based primarily on a literature review, though the authors also talked to staff at Environment Canada, the Pacific Climate Impacts Consortium and Natural

Resources Canada. The report identified impacts in the following sectors: agri-food; buildings; energy; forestry; habitat and eco-system; health and well-being; mobility; recreational land; and water.[1]

- Iqaluit's *Climate Change Impacts, Infrastructure Risks and Adaptive Capacity Project* (2007) was led by a consultant (previously on staff at the City of Iqaluit and familiar with community issues) and was funded by Indian and Northern Affairs. The author conducted an extensive literature review and consulted with meteorological, risk management and climate change experts, municipal staff, and individuals who design, build and service infrastructure in Iqaluit. The report reviewed current climate trends and observations as well as climate projections for the Arctic. It reviewed issues related to thawing permafrost, increases in extreme weather, and changes in the coastal environment due to climate change. Impacts were identified for: buildings; roads, water and wastewater infrastructure; and waste disposal.



- *Climate Change in the Canadian Columbia Basin: Starting the Dialogue* (2008) was a regional impacts report initiated by the Columbia Basin Trust, and prepared collaboratively with researchers and scientists from the Pacific Climate Impacts Consortium, UBC and other organizations. (The Columbia Basin Trust initiates and funds a variety of environmental initiatives in the Canadian part of the Basin, in south-east BC.) The report was intended as background for adaptation planning in communities within the basin. It outlined recent climate-related changes in the region, future climate projections, potential impacts, and some possible responses to those impacts. The report identified likely climate change impacts for water supply, ground transportation, community infrastructure and safety, public health, hydro-electric power, forestry, tourism and recreation, and agriculture. This overview of impacts was used by Kimberley and several other communities in the region to start dialogues with municipal staff and community stakeholders on climate change impacts and adaptation.



[1] The report used a number of "influence diagrams" to illustrate how impacts might occur in these systems, a useful tool that we will describe later.

- *Quebec City's Environmental Services Adaptation Plan* (2009) took a different approach. An Environmental Services staff member obtained regional climate modelling data for the 2020's, 2050's and 2080's from Ouranos, conducted a literature review, and then consulted 10 key staff members with the Environmental Services department about impacts of concern to the department. Staff were asked to fill in the table below, identifying impacts and possible adaptation strategies that might result from projected climate changes.

Table 1: Quebec City Environmental Services Internal Adaptation Consultation for Drinking Water

Climate Change Projections	*Information Provided to Staff on:* ▪ Increasing temperatures and evapotranspiration rates ▪ Absence of precipitation over long periods
Impacts *(Identified by consulted staff)*	▪ Fresh water supplies may be compromised during the summer because of reduced flow levels ▪ Possible water shortages could lead to water restriction measures
Proposed / Existing Adaptation Strategies *(Identified by consulted staff)*	▪ Set aside funding for the purchase of municipal water conservation equipment ▪ Install rainwater collection cisterns on selected municipal buildings ▪ Develop a communication program to educate the public on how to increase efficiency of water usage

Source: Natural Resources Canada

A number of other communities in Canada – and many more internationally – have initiated or participated in studies that provide an initial overview of the local impacts of climate change. These include:

- Hamilton ON (2003)
- Greater Vancouver Regional District BC (2003)
- Calgary AB (2005)
- Fredericton NB (2007)
- Sudbury ON (2007)
- Dawson City YK (2009)

Table 2 on the next page summarizes some common features of the impact overviews that have so far been done for a number of Canadian municipalities.

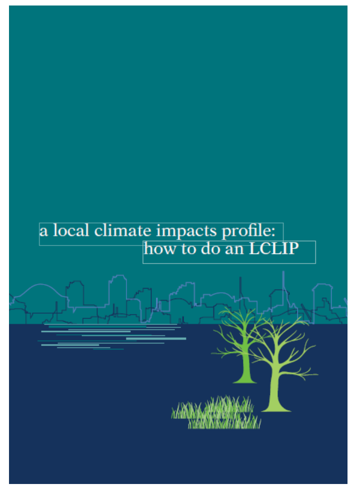
Table 2: Common Features of Impact Overviews Done in Canada to Date

Authors	▪ A small number of climate change impact scans have been carried out by municipal staff, but most publically available scans have been done by paid consultants, researchers from environmental non-profits, or academics who work closely with municipal governments and who have previous expertise about climate change
Funding	▪ Much of the work for these overviews was at least partly funded by federal government departments such as Natural Resources Canada ▪ In some cases, municipal governments paid consultants from their own budget ▪ A small number of the studies were supported by other funders
Involvement of municipal staff	▪ While municipal staff were not authors of most of the existing impact and vulnerability studies, the authors of these scans did interview municipal staff and in some cases held workshops with staff to seek their input or to get their comments on draft reports ▪ In some cases, municipal staff participated actively in the development of the report, or were on an advisory committee for the project
Involvement of climate change scientists	▪ Environment Canada contributed staff time of climate changes scientists from the Adaptation and Impacts Research Division to several projects ▪ Two provincially supported climate change consortia (Ouranos and PCIC) developed regional climate projections that were included in some studies ▪ In a few cases, university-based climate scientists and researchers contributed information on climate trends and projections
Collection and review of the risk literature	▪ All of the publically available overviews drew on the existing literature on climate change, its impacts and adaptation ▪ Some reports involved a very extensive review of the literature
Inclusion of climate change projection data	▪ All the reports discussed and presented at least some climate projection data for Canada as a whole and explained how expected changes in temperature, precipitation, etc. were likely to lead to community impacts ▪ Some of the reports had funding for and scientific help with downscaled climate projections that provided more specific regional data for assessing possible impacts
Areas of impact investigated	▪ These scoping studies varied substantially on the impacts investigated ▪ Typically, the reports identified potential impacts related to water and stormwater; energy and transportation infrastructure; buildings; and public health. ▪ Communities dependent on agriculture, forestry or tourism included a review of impacts on these sectors
Adaptation options discussed	▪ Most of the studies provided high-level suggestions for adaptation to key impacts they identified, but not an in-depth assessment of adaptation options and strategies

Some impact and vulnerability overviews done in Canadian communities have been effective in arousing initial interest within the municipality about climate change impacts and adaptation, though not all have been successful. Some of the reasons for this will be discussed in Module 10, on drivers and barriers for adapting to climate change.

Alternative Approaches to Assessing Vulnerability

1. The Local Climate Impacts Profile



The United Kingdom Climate Impacts Programme (UKCIP) has developed an alternative to the kinds of impacts overviews that have been conducted so far in Canadian communities, and that may be piloted here in the near future. This alternative is called the Local Climate Impacts Profile or LCLIP. More than 100 local authorities in the UK have developed an LCLIP.[2]

Ideally, municipalities would have a system in place for gathering and storing information related to local weather events and their consequences for municipal services and the community. However, few local governments have actually collected this information in any systematic way. The LCLIP provides an alternative. It involves gathering local news stories as a way of identifying and analyzing weather events that are already of concern to communities and which may intensify under climate change. An analysis of such events may be incorporated into a written report, presentations to Council and/or municipal staff, or other forms of communications, and can help kickstart adaptation discussions and planning.

UKCIP has developed a fairly simple approach to gathering and analyzing information from the media that could be managed by a municipal staff person, researcher on a short-term contract or a graduate student intern. Typically, the researcher will gather news stories for last five years or thereabouts. Each story will be analyzed using a spreadsheet produced by UKCIP and available on their website. The spreadsheet has a number of drop-down columns to make systematic recording and analysis easier. Table 4 on the next page is an adapted version of this spreadsheet. The news story which is analyzed is included in Appendix A.

[2] See UKCIP's LCLIP webpage for more information.

Table 3: LCLIP Spreadsheet

Heading	Description	Why Collect This?	Example
1. Source	Field to record source of the information	For future reference	The Windsor Star
2. Headline	Headline given story by the media source	Provides immediate guide to content	F1 Tornado hit Leamington
3. Date of Story	Systematic record which is searchable	For reference and to help pinpoint date of event	June 11, 2010
4. Summary of news story	One sentence describing what happened & the consequence(s)	Useful for quick reference	An F1 tornado event hit Leamington, causing damage to property and loss of utilities
5. Date of event	If actual date is given	For reference and in case further analysis later is needed (searchable)	June 6, 2010
6. Weather type	List type of weather (from drop-down list)	Allows for later sorting by weather type	Tornado
7. Weather detail, if provided	Details such as mm of rain, windspeed, tornado type	May help in understanding thresholds	F1 tornado travelled 300-400m
8. Impact(s)	Immediate impacts (from drop-down list)	Critical for the analysis; Allows sorting by impact	Toppled trees; ruptured gas mains; downed power lines; drowned crops; damage to property; flooded beach; damaged marina
9. Consequence details	Consequences of the impact (e.g. school closed	Allows analysis of social, economic, environmental impacts	Blocked roads during cleanup; loss of power in sections of town; state of emergency called
10. Location	Location can be specified from previously defined list	May help identify vulnerable areas	Leamington, Ontario
11. Responsible organization or department	Identify the department or organization with primary responsibility for dealing with the consequence identified	Highlights the department responsible for dealing with the consequence identified and that may need to develop new responses	Public works department is responsible for clearing debris and roads as well as repairing infrastructure
12. Next responsible organization or department	Identify organization or unit required to make a strategic response	Identifies organizations required to make longer term strategic plans that go beyond immediate responses	Ontario Hydro and Essex Power Corporation are responsible for restoring power to the area
13. Other responsible agencies	Identify any other organizations or units involved	Identifies organizations or units that may also need to be involved in future responses or planning	Environment Canada - responsible for analysis of tornadoes and for early warning. Essex Region Conservation Authority - responsible for flood control systems
14. Significance indicator	An initial judgment on how significant the consequence(s)	This will help you to start to identify priority areas for attention	Medium – considerable damage; no deaths or injuries.

Analysis of impact (with additional information from municipal staff)			
1. Cost	The cost of an incident or its consequences to responsible organizations	To help assess the significance of incidents	N/A
2. Reputation	The reputational impact to responsible organizations	To help assess the significance of incidents	For Essex Power and Public Works, little responsibility can be assigned as this type of event is so hard to prepare for. Environment Canada suffers a blow to their reputation for ineffective early warning. The Conservation Authority suffers a blow to their reputation for out-of-date flood control systems
3. Staff time / resources expended	Staff time or resources expended on an incident or its consequences	To add detail to the final report and help assess the significance of incidents	N/A
4. Disruption to service or operations	Any disruption to the operation or service provision of responsible organization or units caused by an incident or its consequences	To add detail to the final report and help assess the significance of incidents	Disruption to power supply; gas service to houses; water
5. Notes	Other relevant information or notes	To help assess the significance of incidents	

The spreadsheet will help sort data by:

- Weather type
- Type of impacts that result from certain weather patterns and events,
- Consequences and significance of these events
- Departments responsible for affected sectors or services.

The analysis can also help identify:

- Locations that are repeatedly affected by weather related issues
- Vulnerable groups within the local population
- Particularly vulnerable service areas
- Issues that affect several departments and may need a coordinated response
- Threats at the corporate level (e.g. costs, reputation, potential liability).

Once the stories are gathered and analyzed, the researcher will interview managers or other staff of departments that have responsibilities for the areas affected by the weather events and to seek further information and insights about the effects. Interviews might shed further light on:

- Costs incurred by the municipality for the reported weather events
- Staff resources required to deal with the problem
- Effects on services in the short- and long-term
- Effects on the community not captured in the news stories, etc.

Once an understanding of current weather / climate vulnerabilities of the community are known, the researchers can take the process one step further by examining whether climate change is likely to heighten these vulnerabilities. If the community is already shown to be vulnerable to flooding, for example, then the more intense precipitation events that are expected with climate change may well exacerbate this problem and require a more detailed analysis and adaptation planning. The results of all this information can be summarized in a report, and also presented to decision-makers, staff and the public. UKCIP has made available several examples of completed LCLIPs on its website.

2. Stepwise Analysis of Sensitivity, Adaptive Capacity and Vulnerability

Deloitte Canada developed a four-step approach to identify and analyze vulnerabilities to climate change, in their *Climate Change Adaptation Framework Manual*, prepared for Alberta Sustainable Resource Development. The four steps are outlined below:

1. ***Create a master list of programs, services and facilities for which the organization has responsibility and which might be affected by climate change.***

Master List of Water Department Responsibilities / Facilities that could be affected by Climate Change

- ✓ Groundwater or surface water supply (quantity)
- ✓ Quality of water supply
- ✓ Demand management
- ✓ Water collection, storage, and transfer systems
- ✓ Water treatment
- ✓ Water pumping
- ✓ Water distribution networks

2. ***Analyze the degree to which the listed responsibilities have a high, medium or low sensitivity to climate change. A sensitivity analysis examines the extent to which a facility or system is:***

    - Subject to existing stress due to current weather conditions or other factors
    - Subject to potential new stresses from climate change.

    Table 4 is a simplified summary of a sensitivity analysis for parts of a water supply system in Southwestern Ontario. The final column to the right provides a combined qualitative assessment of the sensitivity.

Systems that are already under stress are more likely to have adverse impacts from climate change. The team that undertakes the analysis will be drawing on professional judgement based on historical experience, the experience of similar communities, the scientific literature, etc.

Table 4: Sample Sensitivity Analysis for Water Supply in a Southwest Ontario Community

Facility or service for which the municipality is responsible	Existing Stress	Sensitivity to existing stress (H/M/L)	Potential Climate Change Stress	Sensitivity to Potential Stress (H/M/L)	Overall Degree of Sensitivity
Groundwater supply	This community depends on groundwater as their main source of water. Shortages already occur in dry summers.	High	Increased temperatures and reduced summer precipitation may decrease groundwater recharge, with shallow aquifers being especially sensitive	High	High
Quality of groundwater	Several contaminant sources are of concern, including leaking fuel tanks and runoff from agricultural operations	Medium	Reduced flows will concentrate contaminants	Low	Medium
Demand management	Housing development and land use intensification are increasing demand on groundwater, creating concern that some aquifers are being depleted	Medium	Greater demand for water due to higher temperatures expected to increase water extraction, lower the water table, and drive up costs More conflicts over water allocation likely	High	High
Water storage system	Storage systems have inadequate capacity to buffer increased demand and reduced supplies	Medium	Regions with limited water storage capacity will be more vulnerable to future drought events	Medium	Medium
Water treatment	Algal blooms are leading to taste and odour problems in municipal water supply	Medium	Low water levels and increased temperatures will contribute to increasing frequency of algal blooms	High	High
Water distribution	Distribution systems are old or nearing the end of their service life-span	High	Pumps need to work harder when lake and well levels are lower, increasing the likelihood of failure	High	High

3. Assess the adaptive capacity of the community or municipality to address current and expected future impacts.

The ability of a community to prepare for and respond to climate change so as to reduce impacts is referred to as its adaptive capacity. This capacity depends on a number of factors, including:

- **Information:** availability of useable information on climate trends, projections and impacts; the status of human and natural systems of concern; analysis of current and potential impacts; and information about current and potential response strategies
- **Institutional ability to mobilize and respond:** including recognition of the need to adapt; public support for adaptation; political will to address climate-related problems proactively; decision-making authority in areas of concern; existing adaptation activities; planning practices and processes; and coordination among relevant organizations
- **Analytical tools and skills:** the availability of analytical tools to help systematically assess risks and solutions; and the ability of stakeholders to use them
- **Technological options:** availability of technologies (which may not be complex) for adaptation
- **Infrastructure:** the status and resilience of existing infrastructure
- **Natural systems:** the status and resilience of relevant natural systems in the community or region
- **Economic resources:** access to financial resources to assess adaptation needs and implement adaptation strategies.[3]

The analysis of adaptive capacity will involve consideration of all these factors and potentially others. See Table 5 for a sample template and a fictional analysis of adaptive capacity.

[3] Adapted from Smit and Pilifosova, 2001, who also include equity as a determinant of adaptive capacity.

Table 5: Sample Analysis of Adaptive Capacity

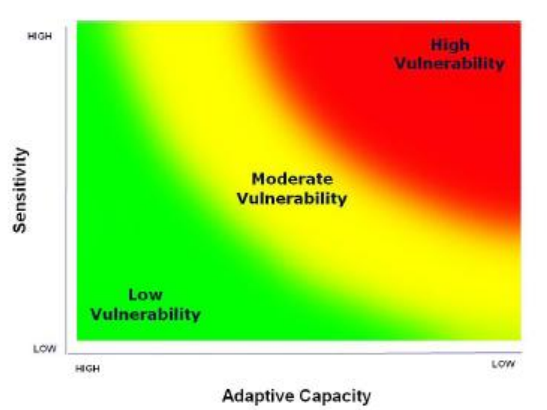
Determinant of Adaptive Capacity	Analysis of Capacity in Community X to Adapt to Climate Change Effects on Water Supply	Adaptive Capacity (H/M/L)
Information		
▪ On current local weather trends ▪ On climate projections for the community ▪ On impacts on water supply ▪ On current status of water supply infrastructure and water source ▪ About strategies to protect water supply from rising temperatures, intense precipitation, drought and other stresses	▪ Some local information is available on historical trends for average temperatures, precipitation. ▪ No local climate projections are currently available. ▪ Reports have been submitted to council on water supply capacity and demand but no overall assessment of local impacts. ▪ Recent municipal groundwater studies provide some new information on the status of local aquifers.	Medium
Institutional Ability to Mobilize and Respond		
▪ Recognition of the need to adapt ▪ Public support for adaptation ▪ Political will / leadership ▪ Decision-making authority ▪ Existing adaptation programs ▪ Planning practices and processes (that can incorporate adaptation) ▪ Coordination among relevant organizations	▪ Concerns raised by the Conservation Authority have increased the political will to take action. ▪ Currently limited communication among relevant organizations and departments; however the Conservation Authority has offered to take the lead in bringing together the relevant stakeholders to develop an adaptation strategy. ▪ The municipality has been approached to participate in local multi-stakeholder source protection committee discussions, in an effort to inform policies and zoning by-laws to protect well-head areas. ▪ Still widespread perception of water abundance and little public concern over the potential effects of climate change on water resources.	High
Analytical Tools and Skills		
▪ Availability of analytical tools to systematically assess risks and solutions ▪ Stakeholder ability to utilize these tools	▪ Groundwater flow models are available and can help inform the City's risk assessment process. ▪ Previous municipal groundwater studies noted knowledge gaps regarding available water resources and the potential impacts of climate change on infiltration rates. ▪ Provincial information gateway on source water protection should make tools more accessible.	High
Technological Options		
▪ Available technologies for adaptation related to urban water supply e.g. water metering systems;, domestic products such as high efficiency toilets, low flow faucets, systems for detecting water leaks, rainwater harvesting systems, grey water filtration and reuse, etc.	▪ Adaptation to date has been focused on encouraging long-term water conservation (e.g. planting of drought-resistant grasses in public areas, outdoor water-use restriction bylaws). ▪ There has been strong uptake of residential water conservation programs, particularly those that offer rebates and incentives toward products such as high-efficiency toilets and washing machines, low-flow faucets and rainwater barrels.	High

Determinant of Adaptive Capacity	Analysis of Capacity in Community X to Adapt to Climate Change Effects on Water Supply	Adaptive Capacity (H/M/L)
Infrastructure		
▪ Status of current infrastructure for maintaining quality and quantity of the water supply	▪ Water storage, treatment and distribution systems are nearing the end of their service life and need replacement but sufficient funding is difficult to get.	Low
Natural Systems		
▪ Status and resilience of relevant natural systems in the area	▪ Clearing of land for agriculture has resulted in drainage of low lying lands and wetland areas, and deforestation, reducing infiltration, groundwater recharge and baseflow contribution to streams. ▪ Some wellhead protection zones exist; however ongoing monitoring of water quantity and quality are needed.	Medium
Economic Resources		
▪ Access to financial resources to assess adaptation needs ▪ Access to financial resources to implement adaptation strategies	▪ Federal and provincial funding is available for site-specific projects such as water quality testing. However, funds are inadequate to support long-term monitoring and investment in human resources.	Medium

4. ***Combine the sensitivity and adaptive capacity analyses to Identify vulnerabilities.***

The assessments of sensitivity and adaptive capacity can be combined to determine overall vulnerability of specific resources, operations or facilities to climate change. The vulnerability matrix below shows how sensitivity and adaptive capacity might be mapped visually for a qualitative estimate of vulnerability.

Vulnerability Matrix



Source: Deloitte Canada (2010), p. 19

A municipal facility, operation or service that is sensitive to climate change, and has low adaptive capacity will be quite vulnerable to climate change. This can be analyzed using the following template:

Table 6: Sample Vulnerability Assessment for an Urban Water Supply

Existing and Potential Impacts	Sensitivity (H/M/L)	Adaptive Capacity (H/M/L)	Vulnerability (H/M/L)
Decreased groundwater recharge	High	Medium	High
Increased groundwater contamination	High	Low	High
Increased conflicts over groundwater resource allocation	High	High	Low
Inadequate storage system capacity	Medium	Low	High

Tools that Can Aid in an Initial Analysis of Climate Change Impacts

Several useful tools have been developed or used by authors of community climate change impact scans that municipalities might want to consider using in the development or presentation of their own reports. We describe four of these tools below.

1. Infrastructure Checklist / Matrix

The Public Infrastructure Engineering Vulnerability Committee (PIEVC) of Engineers Canada has recently published a *Vulnerability Assessment of Public Infrastructure* to climate change. To aid in this work, which is ongoing, PIEVC developed a series of matrices or checklists to help municipalities and other levels of government think about climate change issues which might affect several different types of infrastructure. PIEVC has focused mainly on assessing land-based transportation infrastructure, buildings, water supply, and stormwater and wastewater systems. However, the matrices might usefully be applied to other systems as well. Table 7, on the next page, provides an example of the PIEVC matrix for transportation infrastructure.

The column on the left provides a comprehensive list of the ways in which climate change is likely to be manifested. The upper rows list some of the types of transportation infrastructure which might be affected. The matrix guides individuals or groups undertaking the impact assessment to consider whether and how each aspect of climate change might affect the specific element listed.

Table 7: Transportation Infrastructure – Climate Change Issues

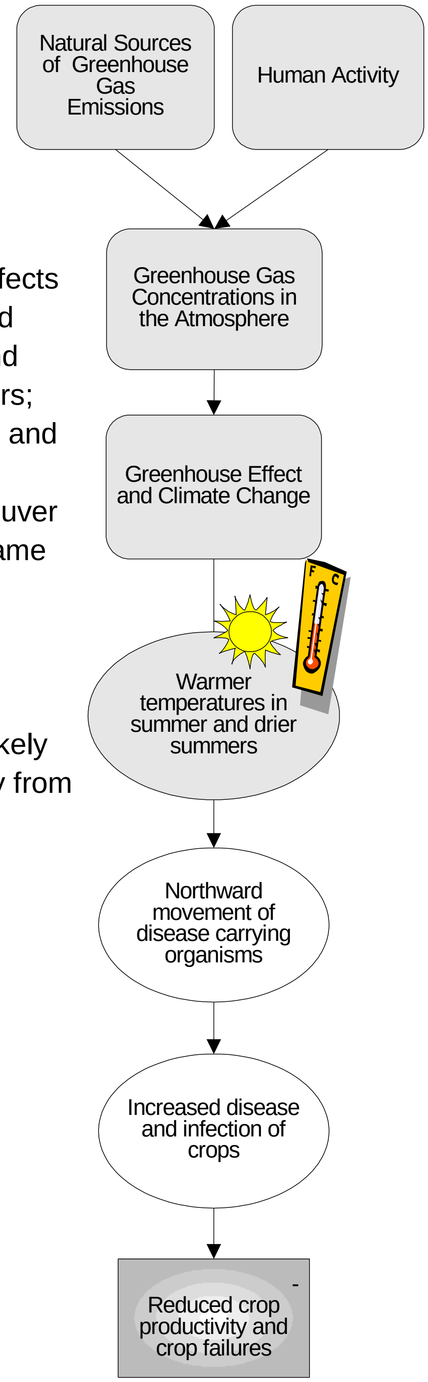
Climate Change of Concern	**Land**			**Bridges**			
	Road	Tunnel	Railway	Road		Railway	
				Over land	Over water	Over land	Over water
Increased severe weather	X		X	X	X	X	X
Storm surge	X	X	X	X	X	X	X
Warmer winters	X		X	X	X	X	X
Degradation of permafrost	X		X	X	X	X	X
Sea level rise	X		X	X	X	X	X
Sea ice melting							
Longer open water seasons / changes in ice breakup				X	X	X	X
Freeze-thaw cycles	X	X	X	X	X	X	X
Extreme heat	X		X	X	X	X	X
Freezing rain	X	X	X	X	X	X	X
Increased precipitation / Higher land moisture	X		X	X	X	X	X
Increased river flooding	X		X	X	X	X	X
Landslides	X	X	X	X	X	X	X
Increased wind speeds	X		X	X	X	X	X
Average increase in temperature	X		X	X	X	X	X
Other potential issues …							

Adapted from Table 3-8, Transportation Infrastructure – Climate Change Issues, in *Adapting to Climate Change: Canada's First National Engineering Vulnerability Assessment of Public Infrastructure*, p.3-7.

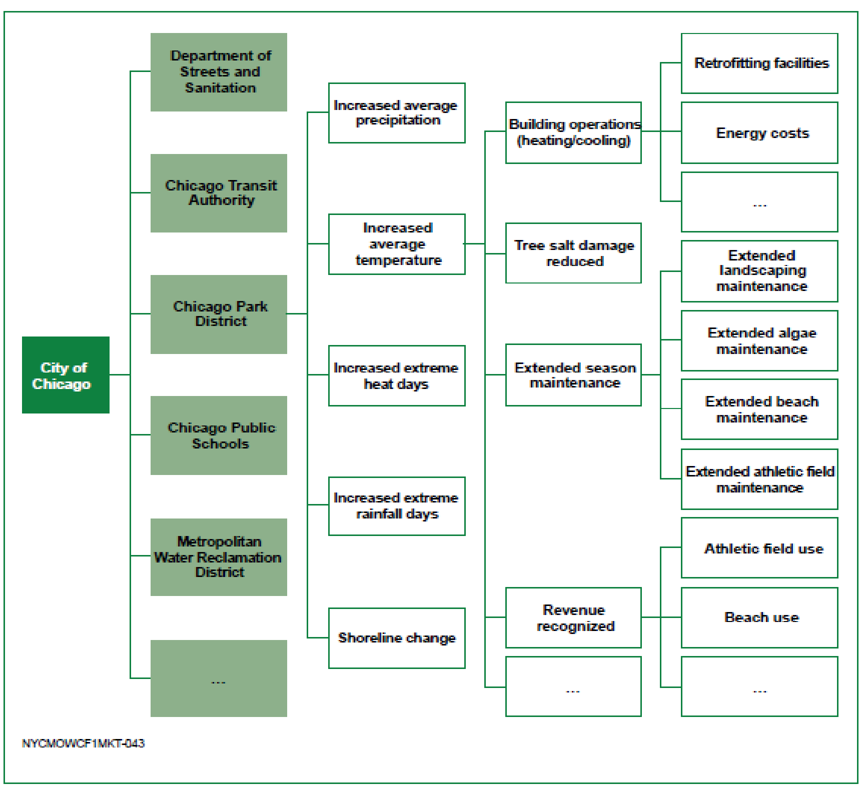
2. *Influence Diagrams / Impact Pathways*

The consulting company Sheltair developed a series of climate change influence diagrams for their 2003 report *Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver* (no longer available).

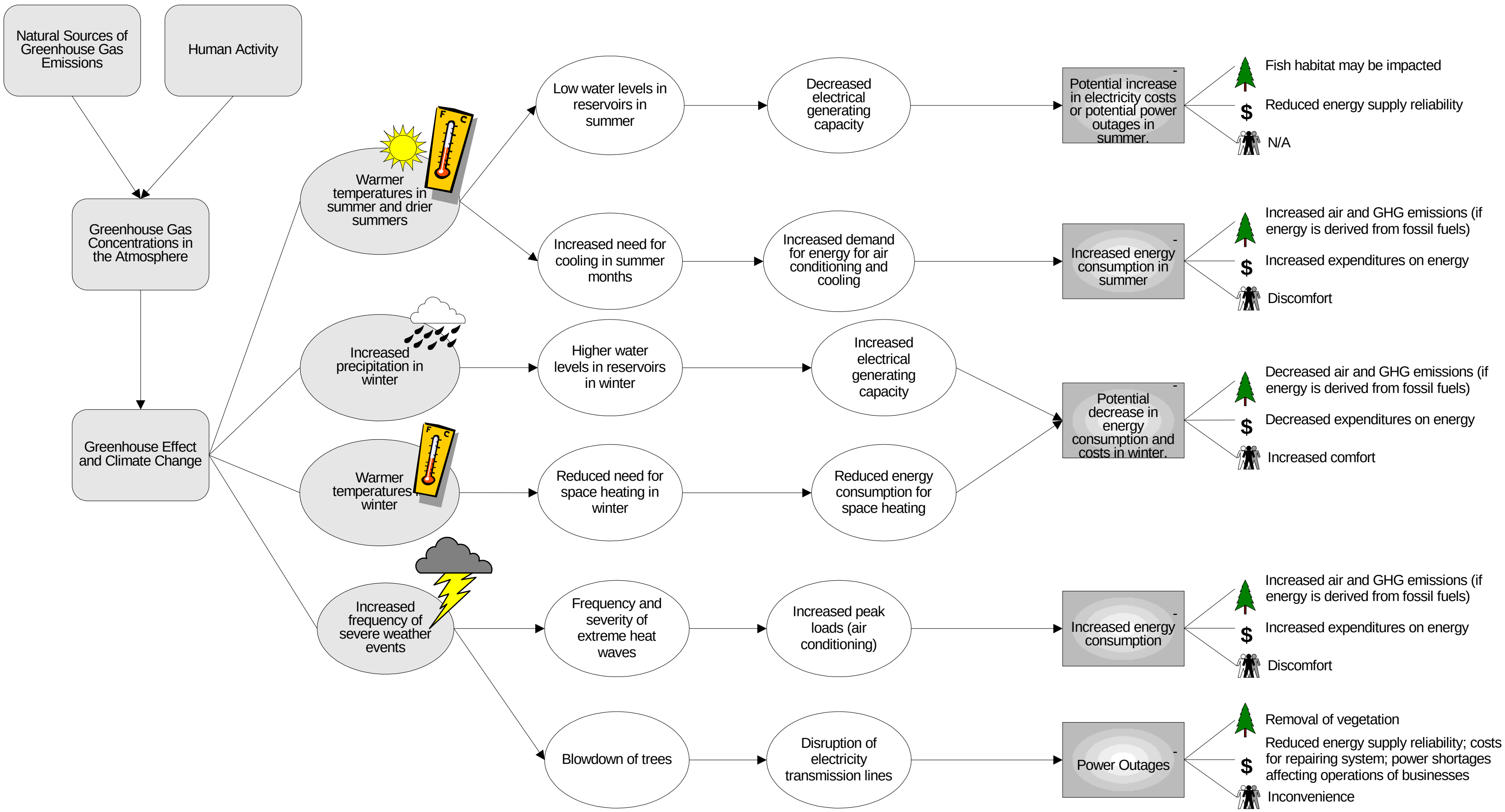
These diagrams trace the impacts of climate change from first order effects (e.g. warmer temperatures; changes in precipitation patterns; increased storminess), to intermediate effects (e.g. increased need for cooling and demand for air conditioning; increased evaporation from lakes and rivers; increased stormwater runoff and flooding), to the environmental, social and economic impacts of concern (e.g. increased expenditures on energy; property damage; health effects). One such sequence from the Vancouver report is shown on the right. A complete influence diagram from the same report is shown on the next page.



Consulting firm Oliver Wyman used a similar approach they call the "Climate Impact Pathway" in their [Corporate Risk Study](#) for the City of Chicago, to analyze and illustrate the effects that climate change are likely to create for City departments and agencies. A sample impact pathway from their summary report is shown below.



Climate Change Impacts and Adaptation for Greater Vancouver: Potential Impacts on the Energy System



Source: The Sheltair Group (August, 2003) *Climate Change Impacts and Adaptation Strategies for Greater Vancouver, Volume 2: Influence Diagrams of Potential Climate Change Impacts and Illustrative Adaptation Strategies by Urban System,* p.10

Conclusions

An initial overview of how climate change is likely to affect a local community is an important early step in getting a handle on climate change impacts and what is needed for adaptation planning. It can also serve as a good device to engage decision-makers and the public on the issues of adapting to climate change and in establishing the need for further resources to be devoted to the tasks of detailed risk assessment and adaptation planning.

Appendix A: "F1 tornado hit Leamington: Environment Canada"

By Carys Mills and Jeff Bolichowski, The Windsor Star June 11, 2010

Jay Shanks surveys the damage of his property and car caused by a tornado in Leamington, Ont., June 6, 2010. Photograph DAN JANISSE, The Windsor Star

LEAMINGTON, Ont. -- An F1 tornado touched down in Leamington early Sunday amidst a torrential flood that's drowned crops the Harrow area, damaged trees and left ditches overflowing across the southern reaches of the county.

"(Harrow) just looks like a massive lake when you drive down there," said Essex Deputy Mayor Richard Meloche, reached Sunday at the Red Bull Air Race.

He said Harrow, Colchester and Oxley were inundated by the storm.

"There's going to be a lot of corn crops that are going to have to be replanted."

Late Sunday afternoon Environment Canada confirmed that a tornado in the F1 range touched down in Leamington and travelled a distance of 300 to 400 metres. There was damage over an area of two kilometres, with the rest of the damage caused by downbursts, said Peter Kimbell of Environment Canada.

Near Kingsville, said county warden Nelson Santos, properties near the Albuna Townline were doused by a "one-two punch" of rain and suspected tornado activity. Cedar Beach was also flooded.

Though none were killed or injured, he said, trees in the area are "toppled, twisted and snapped off." Gas lines have broken in some places.

Kimbell said two tornado warnings were issued overnight. One was sent out at 11:15 a.m., but no tornado materialized. A second was issued at 2:37 a.m.

That second warning sparked off a major wind event he declined to identify as a tornado without further inspection.

A rain warning was also issued around 12:20 a.m.

That rain, said Essex Region Conservation Authority flood control co-ordinator Tim Byrne, came in a very short amount of time. He said many flood control systems around the county were old and not up to the task of handling snap rains.

"The rainfall we did receive did not warrant us issuing a flood advisory," he said.

Leamington has been under a state of emergency as of 6:25 a.m. Sunday. Decades-old trees were toppled, power lines were torn down and homes were destroyed.

No death or injuries have been reported, but strong winds caused severe structural and tree damage. Broken tree limbs are scattered throughout the affected areas, including Erie Street South from Seacliff Drive to the marina and smaller streets branching off.

Leamington's public works department called out most of its employees to deal with the wreckage. "We're just trying to clean the streets," said Allin Gelinau, who usually does garbage pickup for the town. "You come out here and it's like a war zone," he said. "This is the first time I've seen anything like it," he said.

There is also damage to the marina area, including Seacliff Park and docks that have shifted away from the pier. Falling trees and debris shattered the windows of vehicles and properties.

"I've lived here all my life and I haven't seen anything like this," said Leamington Deputy Mayor Robert Schmidt. "It's quite shocking."

Schmidt declared the state of emergency shortly after meeting with the town's emergency response team. Leamington Mayor John Adams is out of town and could not be reached for comment.

Declaring a state of emergency allows the town to receive funding from the province to help pay for its relief efforts. Schmidt said the town has also solicited aid from the County of Essex.

Essex Mayor Ron McDermott, reached on his way to the Red Bull Air Race, said things weren't as bad in Colchester and Harrow as in Leamington.

Both McDermott and Meloche said they hadn't seen the damage.

"I checked with the people and there's nothing I can do there," McDermott said. "(The people of Harrow) would probably tell me to get out of there.

"I wanted to get down there this morning but I had previous commitments." Those included attending a choir service for D-Day.

Meloche said, "I'm not going to be able to do anything."

Properties along Seacliff Drive, bordered by Fraser Road and Bevel Line, were hardest hit. Police have closed off Erie Street South at Seacliff Drive and Seacliff Drive at Sherk Street.

The F. T. Sherk Aquatic & Fitness Centre has been converted into a shelter for displaced families by the Red Cross.

"It's pretty extensive," said Miskovski. "There's a lot of property damage."

Linda Skowby was awoken at 3 a.m. when a Maple tree was hit by the storm and collapse onto her roof. She lives at 1 Park Street on the corner of Park and Erie streets.

"It just came through like a train," she said, motioning across the path where she thinks storm went.

She said she didn't know where she would stay Sunday night because she's been told to stay out of her house. Besides the crack running through her living room ceiling, there was an almost immediate smell of gas after the hit, she said. Skowby said she thinks her gas line was hit.

"I loved this area," she said.

Miskovski said roads have been blocked off to prevent the public from being injured by debris or machinery being used for cleanup.

"Because there are power outages and downed power lines, people are cautioned to be very, very careful," Miskovski said.

There were many onlookers Sunday morning, wandering in their pajamas, on bikes and talking on their cellphones about the destruction.

Essex Hydro's service update message says hydro is out on multiple roads and the estimate for service to be back is 5 p.m. Sunday. But some residents worry their power will be out for weeks rather than hours.

Police checked on a group of children who were camping at Point Pelee who hadn't been heard from since the storm and confirmed they're not injured, said Miskovski.

Town officials suspect a tornado touched down around 3 a.m., Miskovski said.

Kimbell said two teams, one from Environment Canada and one from the University of Western Ontario, will be checking out the damage in Leamington to determine if the event was a tornado.

They're looking at the direction of the debris, whether it's converging or diverging and for a long, narrow trail of damage, all characteristics of a tornado.

"We were completely unaware of it coming," Miskovski said.

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MODULE 4: CLIMATE CHANGE RISK ASSESSMENT

Learning Objectives and Outcomes

By the end of the module, participants will:

- Understand the main steps in conducting a climate change risk assessment
- Have participated in a simple risk assessment, and discussed with colleagues the strengths and challenges of climate change risk assessment.

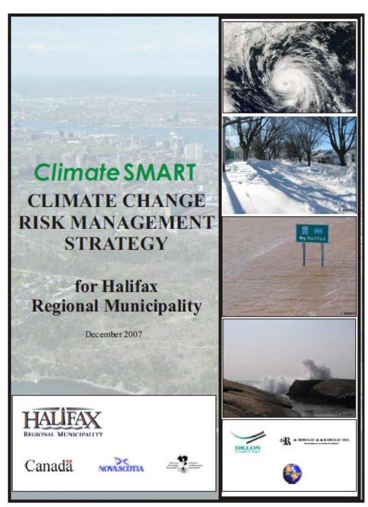
Introduction

Municipalities in many parts of Canada are beginning to undertake detailed climate change risk assessments. A number of guides for conducting this kind of assessment have been produced in the last decade and may be useful for municipalities looking to do risk assessment.

Risk assessment is a structured method for analyzing, quantifying and prioritizing risks for planning purposes. It aids the user in assessing the probability and/or frequency that a negative climate change impact or impacts will occur, and in evaluating the potential impact or consequence. Several climate change risk assessment tools are currently available to Ontario municipalities, which draw on growing Canadian experience in this field. Several of these support risk assessment at a municipality-wide level; one new protocol is designed to help individual municipal departments to assess the risks of climate change for their facilities and operations; and an engineering risk assessment protocol is also available to evaluate risks for individual pieces of infrastructure.

Municipality-Wide Risk Assessments

- Natural Resources Canada commissioned several regional risk management guides, starting with *Adapting to Climate Change: A Risk-Based Guide for Ontario Municipalities* released in 2006. Since then, the same authors have produced revised guides for Alberta, BC and the Arctic. In early 2011, the Ontario Ministry of Municipal Affairs and Housing contracted with the authors to produce a similar guide for small and medium-sized municipalities in Ontario. The guide will be available in the summer of 2011. These guides are oriented towards completing a fairly high-level whole community/municipality risk assessment.



- Working with consultants in the region, Halifax Regional Municipality developed a climate change risk assessment process for the whole municipality that they describe in their 2007 *Climate Change Risk Management Strategy Report*.

- Deloitte Canada released a *Climate Change Adaptation Framework Manual* in 2010 to guide Alberta's Sustainable Resource Development through a risk assessment and adaptation planning process. While the process was piloted at the level of a provincial ministry or department, it has several useful exercises that can be used by municipalities, including some that have been included in Module 3 of this training program.

Risk Assessments for Municipal Departments

- The City of Toronto has also been working with the consulting firm Deloitte Canada to develop and test a risk assessment protocol for use by city departments. This approach is narrower than the whole municipality approach of Bruce and Egener, Halifax Regional Municipality, or Deloitte. It guides risk assessment for all the responsibilities and services of a municipal department. This protocol has been piloted by two City of Toronto divisions, Transportation Services and Shelter, Housing and Support, and will be made available to other Ontario municipalities by the Toronto Environment Office in the near future.

Infrastructure Risk Assessments

- The Public Infrastructure Vulnerability Committee of Engineers Canada has developed a more quantitative risk assessment protocol for use in assessing climate change risks for public infrastructure, with a focus on buildings; roads and associated structures; stormwater and wastewater systems; and water resources. Unlike the previously mentioned risk assessments, this approach has so far been used mainly to provide detailed, engineering risk assessments of individual facilities or infrastructure. This protocol is not publically available yet but summaries of several completed risk assessments that have used the protocol are available. See the *First National Engineering Assessment Report*.

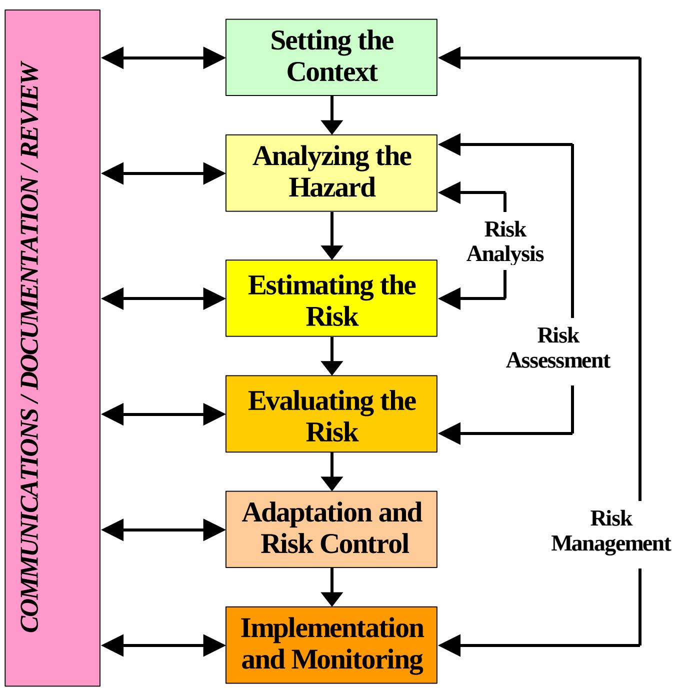
A number of existing risk assessment tools have been criticized for relying too heavily on qualitative evaluation, where users are asked to characterize the likelihood and severity of climate change related risks using categories such as ‘low’, ‘medium’ and ‘high’ for example. CSA Standards recently completed a report for Natural Resources Canada on *Mainstreaming Risk-Based Management of Climate Change Impacts in Canada*, suggesting that qualitative risk assessment instruments are successful in supporting the identification and preliminary assessment of climate change risks, but provide too little technical guidance, especially in areas of evaluation, ranking and prioritization of risks, characterization of uncertainties and comparison of adaptation options. The report recommended the development of a consensus-based, authoritative Climate Change Risk Management product specifically for municipalities, with links to more detailed technical guidance to support quantitative analysis of specific risks. In the meantime, the following outlines a more qualitative process for assessment of climate change risks for municipalities as suggested by publically available risk assessment guides.

The Risk Assessment Process

These protocols recommend broadly similar processes for conducting a risk assessment, though they vary in the level of detail required to conduct the assessment, and in the breadth of the assessment. The Canadian protocols tend to follow the Canadian Standards Association process shown in Figure 1, which outlines the risk management process as a whole. In this approach, the risk assessment component of the process comprises three stages: ***analyzing the hazard***, ***estimating the risk*** and ***evaluating the risk***.

The risk assessment may evaluate community-wide risks – as Halifax did – but is more often done for a specific municipal department, facility or operation.

Figure 1: The Risk Management Process



Source: Bruce, Egener and Noble, 2006

The process outlined below is based mainly on the first of the resources mentioned above, the risk-based guides for municipalities published by Natural Resources Canada.

Analyzing the Hazards

The first stage of the risk assessment process is to ***analyze the hazard***. Those municipalities that have conducted an impacts and vulnerability scan as suggested in

Module 3 (Initial Assessment of Vulnerabilities) will have started this process already and will have an appreciation of the range of hazards that climate change will present.

The risk-based guides for municipalities developed by Bruce and Egener recommend that a climate change adaptation project team develop ***risk scenarios*** as part of their analysis of hazards. Information for developing these scenarios will come from a variety of sources:

- ***Climate change projections*** that characterize how weather is expected to change
- ***Historical experience*** of the types of weather events that are likely to occur more frequently or become more intense as a result of climate change
- ***Experience of other communities*** with similar characteristics
- ***Professional judgement*** of experienced staff and others who understand the current vulnerabilities of the system or structure under consideration
- ***Studies of current and future risks*** for specific sectors, facilities and operations, including studies by government or academic researchers, consultants or non-governmental organizations.

The key is to:

- Analyze and understand current stresses on the systems of concern, and how current weather events and expected climate changes might add to those stresses
- Assess current methods to control the risk, how effective they are, and where the gaps might be, and
- Identify vulnerabilities.

The risk scenario might be summarized in a narrative description, an influence diagram, or a table. On the next page is a sample risk scenario that Bruce, Egener and Noble developed for their *Risk-Based Guide for Ontario Municipalities*. The scenario outlines potential risks to a municipality of an extreme storm following a long heat wave. Similar risk scenarios can be developed for the other events that are likely to occur more frequently under climate change.

Simpler risk scenarios can also be developed for individual departments or sectors within a municipality. For example, the Transportation Services Division of the City of Toronto developed a large number of simple risk scenarios and then evaluated the potential impacts of each one. The scenarios included:

- Extreme rain > Flooding > Roads blocked > Loss of mobility
- Extreme rain > Flooding > Culvert collapse > Road washout
- Extreme rain > Flooding > Bank erosion > Increase in inspections > Increase in operating budget.

The risk assessment that follows scenario development will subject each of these hazards to a more detailed analysis and will help decision-makers prioritize risks and identify adaptation responses.

Risk Scenario for an Extreme Storm Following a Long Heat Wave

Actual and Potential Hazards

- Short duration, high intensity rains more frequent and severe, expected to increase ~5% per decade, especially in springtime, leading to more erosion and flash floods
- High possibility of violent thunderstorms with strong winds
- Hot days and nights, with daytime highs in the high 30's
- Smog episodes with high ozone and particulate concentrations

Risk Issues

- Extreme rainfall can overwhelm stormwater, sewer and sewage treatment systems, resulting in local flooding, sewer back-ups, washouts of culverts and roads and flooding of underpasses
- Potential to overwhelm stormwater systems, the sewage treatment plant and to degrade the local water source
- Potential for electric power outage
- Transportation systems disrupted from flooding, non-functioning traffic signals, etc.
- Health effects from heat stress and smog, endangering lives and putting pressure on the health system
- Potential for wind damage

Current Stresses

- Stormwater system, especially in low-lying areas of the city, already taxed by intense or long-duration rains, with frequent basement flooding episodes
- In intense rainfall, combined sewer and stormwater systems in the older parts of the city release raw sewage to receiving water bodies to avoid overwhelming sewage treatment plants
- Emergency management and hospital emergency departments at capacity
- Electricity grid aging and near capacity, making it vulnerable to brownouts and blackouts during heat waves
- Aging street trees vulnerable to during thunderstorms and strong winds, bringing down power lines and damaging buildings and vehicles

Potential Stakeholders

- Emergency services
- Water department
- Electrical utility
- Telecommunications companies
- Hospitals and public health services
- Transportation services
- Land use planning
- Social services

Estimating the Risk

Risk estimation involves identifying the potential ***probability*** or ***frequency*** that particular impacts will occur and the ***severity of the impact*** or ***consequences*** of such occurrences.

Assessing the Probability / Frequency of Potential Impacts

The task here is to assess the probability and/or frequency with which identified risks are likely to occur. How far ahead to look will depend on the system(s) of concern. If long-lived and expensive infrastructure may be disrupted by a climate change impact in its expected lifetime, then this should determine the timeframe of the assessment.

The assessment could use a simple low-medium-high rating system, or something more detailed. Halifax Regional Municipality, for example, used a relatively simple system to evaluate probability, using the following ratings:

- Low probability – the frequency of the impact occurring is improbable to unlikely
- Medium probability – current knowledge indicates that the impact is likely to occur
- High probability – the impact is highly likely or virtually certain to occur.

The Risk-Based Guides for Municipalities suggests a more nuanced rating system, shown in Figure 2:

Figure 2: Frequency / Probability Rating Matrix

Frequency Event	Very Unlikely to Happen	Occasional Occurrence	Moderately Frequent	Occurs Often	Virtually Certain to Occur
Events identified in risk analysis (list each)	Not likely to occur during the planning period	May occur sometime but not often during the planning period	Likely to occur at least once during the planning period	Likely to occur several times during the planning period	Happens often and will happen again during the planning period

Source: Bruce, Egener and Noble, 2006 p. 14

Assessing the Severity of Impact / Consequences

Again, a variety of rating systems exist for assessing the consequences of potential events associated with climate change. Halifax Regional Municipality used a relatively simple system with the following ratings:

- Low consequence – Minor impacts that are likely to be short term and reversible
- Medium consequence – Noticeable social and environmental impact that will require additional resources for adequate response. Limited opportunities for reversing impacts
- High consequence – Significant social, economic and environmental impact leading to reduced quality of life. Impacts are not reversible.

Halifax assessed socio-economic consequences and environmental consequences separately, so each impact they investigated received two ratings:

- For socio-economic considerations: $\mathbf{L_S}$, $\mathbf{M_S}$, or $\mathbf{H_S}$
- For environmental considerations: $\mathbf{L_E}$, $\mathbf{M_E}$, or $\mathbf{H_E}$

These were later combined to provide a single low, medium or high consequence rating.

Bruce and Egener's Risk-Based Guides use a more detailed rating system for severity of impact, shown below in Figure 3.

Figure 3: Impact Rating Matrix

Impact / Degree	Social				Economic			Environmental			
	Health & Safety	Displacement	Loss of Livelihood	Cultural impacts	Property Damage	Financial impact on Households or Businesses	Impacts on Municipal Finances	Air	Water	Land	Ecosystems
Very low											
Low											
Moderate											
Major											
Very severe											

Evaluating the Risk

This step combines the probability and impacts estimates outlined in Figures 2 and 3, in order to construct a risk evaluation matrix, which allows you to prioritize potential impacts. A version of a risk evaluation matrix is shown below.

Figure 4: Sample Risk Evaluation Table – Intense Precipitation Events

SUMMARY OF IMPACT SEVERITY						
	Extreme	Major flooding of homes and businesses			Landslides	
	Major				Water pollution incidents	
	Moderate	Large scale evacuations	Flooding beyond previously designated floodplains			
	Low			Major power & communication outages		Culverts and storm sewer systems capacity exceeded
	Very Low					
		Very Unlikely to Happen	**Occurs Occasionally**	**Moderately Frequent**	**Occurs Often**	**Virtually Certain to Occur**
	FREQUENCY / PROBABILITY					

Extreme Risk: Immediate controls required

High Risk: High priority controls required

Moderate Risk: Some controls required to reduce risks to lower levels

Low Risk: Some actions such as public education desirable

Negligible Risk: Scenarios do not require action at this time

Adapted from Bruce, Egener and Noble, 2006, p. 21

In this example, the authors have determined that intense precipitation events are virtually certain to exceed the capacity of culverts and storm sewer systems, but estimate that the impact of these events is likely to be low. Nevertheless, the combination of these assessments result in an overall risk evaluation of “high risk” with control measures a high priority.

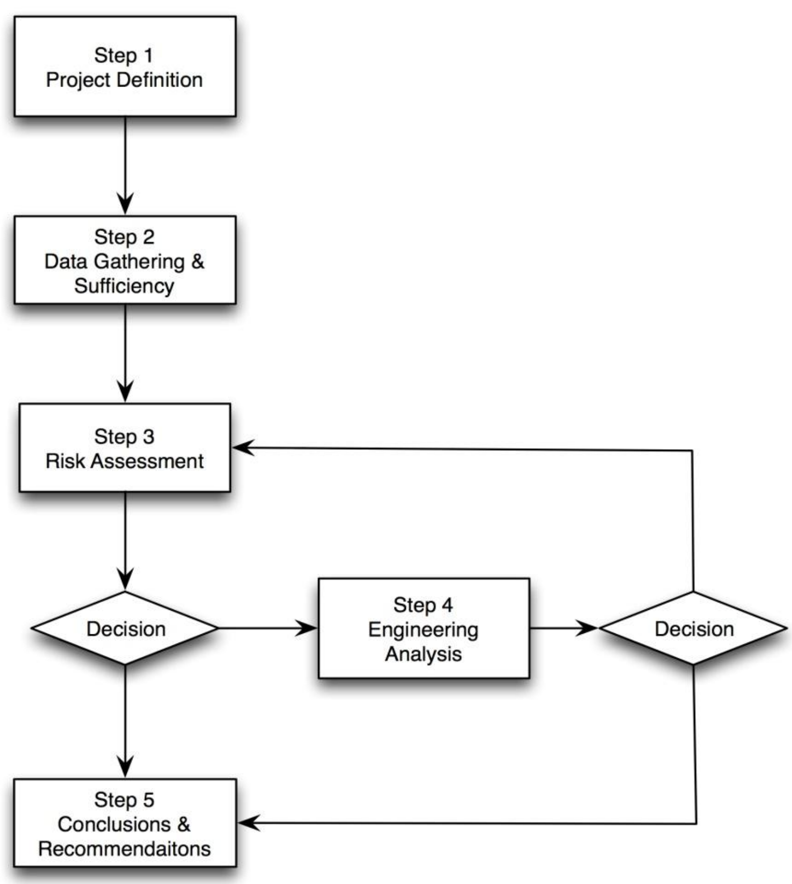
The sample risk evaluation here suggests that priority in adaptation planning be given to developing and implementing controls for landslides, water pollution incidents and culvert / storm sewer failures.

Note that these evaluations will vary from community to community, and will depend on specific features and vulnerabilities of the community, historical experience, etc. For example, the City of Toronto might not assess the impact severity of storms on culverts and storm sewers as low, given the cost of the August 19, 2005 storm.

Risk Evaluation for Infrastructure

The Public Infrastructure Engineering Vulnerability Committee (PIEVC) of Engineers Canada has led the assessment of the risks of climate change for four categories of public infrastructure: buildings; roads and associated structures; stormwater and wastewater systems; and water resources. By the end of 2011, Engineers Canada expects to have completed 25-30 case studies. Most of these studies are conducted by an engineering consultant in conjunction with the infrastructure manager. During this process PIEVC developed a protocol for the risk assessment of public infrastructure which is described below. Figure 5 provides a schematic outline for this process.

Figure 5: Overview of the PIEVC Protocol



Step 1 - Project Definition

In Step 1 the practitioner (the manager of the facility being assessed) will be asked to:

- Develop a general description of:
  - The infrastructure;
  - The location;
  - Historic climate;
  - Load;
  - Age;
  - Other relevant factors; and
- Identify major documents and information sources.

In this step the practitioner defines the boundary conditions for the vulnerability assessment.

Step 2 - Data Gathering and Sufficiency

In Step 2 the practitioner will be asked to provide more definition about:

1. Which parts of the infrastructure will be assessed; and
2. The particular climate factors that will be considered.

Step 2 is comprised of two key activities:

1. Identification of the features of the infrastructure that will be considered in the assessment:
   - Physical elements of the infrastructure;
     - Number of physical elements;
     - Location(s);
   - Other relevant engineering/technical considerations:
     - Material of construction;
     - Age;
     - Importance within the region;
     - Physical condition;
   - Operations and maintenance practices;
   - Operation and management of the infrastructure;
     - Insurance considerations;
     - Policies;
     - Guidelines;
     - Regulations; and
     - Legal considerations.
2. Identification of applicable climate information. Sources of climate information include, but are not limited to:
   - The National Building Code of Canada, Appendix C, Climate Information;
   - Intensity - Duration – Frequency (IDF) curves;
   - Flood plain mapping;

- Regionally specific climatic modeling;
- Heat units (i.e. degree-days) (i.e. for agriculture, HVAC, energy use, etc.); and
- Others, as appropriate.

The practitioner will be required to exercise professional judgement based on experience and training. Step 2 is an interdisciplinary process requiring engineering, climatological, operations, maintenance, and management expertise. The practitioner must ensure that the right combination of expertise is represented either on the assessment team or through consultations with other professionals during the execution of the assessment.

Step 3 - Risk Assessment

In Step 3 the practitioner will identify the interactions between the infrastructure, the climate and other factors that could lead to vulnerability. These include:

- Specific infrastructure components;
- Specific climate change parameter values; and
- Specific performance goals.

The protocol requires the practitioner to identify which elements of the infrastructure are likely to be sensitive to changes in particular climate parameters. They will be required to evaluate this sensitivity in the context of the performance expectations and other demands that are placed on the infrastructure. Infrastructure performance may be influenced by a variety of factors and the protocol directs the practitioner to consider the overall environment that encompasses the infrastructure.

At this point in the protocol the practitioner, in consultation with management, engineering and operation personnel, will perform a risk assessment of the infrastructure's vulnerability to climate change. The interactions identified will be evaluated based on the professional judgement of the assessment team. The risk assessment will identify areas of key concern.

The practitioner will identify those interactions that need further evaluation. The assessment process does not require that all interactions be subjected to further assessment. In fact, in most assessments most of the interactions considered will ultimately be eliminated from further consideration. Some interactions may clearly present no, or negligible, risk. Some interactions may clearly indicate a high risk and a need for immediate action. Those interactions that do not yield a clear answer regarding vulnerability may be subjected to the further Engineering Analysis.

At this stage, the practitioner must also assess data availability and quality. If professional judgment identifies a potential vulnerability that requires data that is not available to the assessment team, the protocol requires that the practitioner revisit Step 1 and/or Step 2 to acquire and refine the data to a level sufficient for risk assessment and/or engineering analysis.

The practitioner may determine that this process requires additional work outside of the scope of the assessment. Such a finding must be identified in the recommendations outlined in Step 5.

This is a key decision point in the Protocol. The practitioner is required to determine:

- Which interactions require additional assessment;
- Where data refinement is required; and
- Initial recommendations about:
  - New research;
  - Immediate remedial action; or
  - Non-vulnerable infrastructure.

Step 4 - Engineering Analysis

In Step 4 the practitioner will conduct focused engineering analysis on the interactions requiring further assessment, as identified in Step 3.

The protocol sets out equations that direct the practitioner to numerically assess:

- The total load on the infrastructure, comprising:
  - The current load on the infrastructure;
  - Projected change in load arising from climate change effects on the infrastructure;
  - Projected change in load arising from other change effects on the infrastructure;

- The total capacity of the infrastructure, comprising:
  - The existing capacity;
  - Projected change in capacity arising from aging/use of the infrastructure; and
  - Other factors that may affect the capacity of the infrastructure.

Based on the numerical analysis:

- A vulnerability exists when ***Total Projected Load*** exceeds ***Total Projected Capacity***; and
- Adaptive capacity exists when ***Total Projected Load*** is less than ***Total Projected Capacity.***

At this stage the practitioner must make one final assessment about data availability and quality. If, in the professional judgement of the practitioner, the data quality or statistical error does not support clear conclusions from the Engineering Analysis, the protocol directs the practitioner to revisit Step 1 and/or Step 2 to acquire and refine the data to a level sufficient for robust engineering analysis. The practitioner may determine that this process requires additional work outside of the scope of the assessment. Such a finding must be identified in the recommendations outlined in Step 5.

Once the practitioner has established sufficient confidence in the results of the engineering analysis, the protocol reaches another key decision point. The practitioner must decide to either:

- Make recommendations based on their analysis (Step 5); or
- Revisit the risk assessment process based on the new/refined data developed in the engineering analysis (Step 3).

Step 5 - Recommendations

In Step 5 the practitioner is directed to provide recommendations based on the work completed in Steps 1 through 4. Generally, the recommendations will fall into five major categories:

- Remedial action is required to upgrade the infrastructure;
- Management action is required to account for changes in the infrastructure capacity;
- Continue to monitor performance of infrastructure and re-evaluate at a later time;
- No further action is required; and/or
- There are gaps in data availability or data quality that require further work.

The practitioner may identify additional conclusions or recommendations regarding the veracity of the assessment, the need for further work or areas that were excluded from the current assessment.

Case Study of a Municipality-Wide Risk Assessment

Halifax Regional Municipality (HRM) undertook a climate change risk assessment for the broad community, which was released in December 2007. To begin, HRM and its partners[1] examined:

- ***Temperature and precipitation trends*** in Nova Scotia over the past century
- ***Downscaled regional climate projections*** for temperature, precipitation, extreme weather events and sea level rise over the next century.[2]

They used that information to construct ***a summary table of climate changes*** that are expected to affect the community in the 2020's, 2050's and 2080's.

Table 1: Summary of Projected Climate Changes for Halifax Regional Municipality for Tri-decadal Periods 2020, 2050, and 2080

Climate Variable	Mean Change	Variability/Frequency	Extreme Value	Knowledge Gap
Periods	**2020'2/2050's/2080's**	**2020'2/2050's/2080's**	**2020'2/2050's/2080's**	
Maximum Temperature	Increase from 1961-1990 normals +1.8/+3.2/+5.3	Hot days per year (days above 30°C) 23/34/48	Number of heat waves (days above 35°C) 2.4/6/16.9	
Minimum Temperature	Increase from 1961-1990 normals +1.1/+2.7/+4.0	Cold days per year (days below -10°C) 11/8/5	Not available	
Season Length	Frost free season (days per year) 199.3/214.9/236.9	Surprises possible. Late hard frost in spring; Early hard frost in fall	Not applicable	Specific changes related to geographical differences need to be developed.
Precipitation Amount	% Change Amount +12/ +12/+10	100 year amount becoming 50 year amount	Potential Max Precipitation increasing	Return periods vary by location and need to be validated
Precipitation Intensity	Percent change intensity <2mm -36% 2-25 mm +12% >25mm +20%	Max number of consecutive dry days 10.7/10.6/11.8	Max 120-hr (5 day) precipitation (mm)	

Excerpted from Halifax Regional Municipality (2007), page 47.

The project team also drew on published reports and discussions with scientists from Environment Canada; Natural Resources Canada; the Climate-Change Impacts and Adaptation Research Network, Atlantic Region; and the National Water Resources Institute to identify 60 likely socio-economic and environmental impacts.

[1] HRM's partners included: Environment Canada, Dillon Consulting, and de Romilly and de Romilly Ltd.
[2] Extracted from the Canadian Climate Impacts and Scenarios database

The team then investigated the expected probability/frequency of these impacts and the likely socio-economic and environmental consequences of each. The table below is excerpted from HRM's includes a sample of this tabulation.

Table 2: Risk Evaluation for Halifax Regional Municipality

Item	Probability (Frequency of event)	Consequence (Impact severity)	Segregated risk	Integ-rated risk	Risk to HRM Business Units
1. COASTAL ZONES					
a) Impacts on coastal wetlands/ecosystems					
• Sea level rise/storm surge	H	$H_S H_E$	$H_S H_E$	H	n/a
b) Impacts from erosion					
• Sea level rise/storm surge	H	$H_S H_E$	$H_S H_E$	H	H
c) Impacts from flooding					
• Sea level rise/storm surge	H	$H_S H_E$	$H_S H_E$	H	H
d) Impact on recreational use					
• Loss or relocation of beaches	H	$M_S L_E$	$M_S M_E$	M	n/a
2. COMMUNITIES/INFRASTRUCTURE/TRANSPORTATION					
e) Impacts on settlements & related coastal infrastructure					
• Sea level rise/storm surge	H	$H_S H_E$	$H_S H_E$	H	H
• Storm and combined sewer surcharging and failure	M	$M_S H_E$	$M_S H_E$	H	H
• Ice damage	L	$L_S L_E$	$L_S L_E$	L	L
• Disruption to critical utilities	M	$H_S L_E$	$H_S L_E$	H	n/a
• Increased insurance cost	H	$H_S L_E$	$H_S L_E$	H	H
• Increased economic and social costs associated with adaptation	H	$H_S L_E$	$H_S L_E$	H	H
a) Impacts on settlement patterns & land-use planning					
• Extreme events, sea level rise & storm surge					
• Increase in areas of flooding and severity	H	$H_S H_E$	$H_S H_E$	H	H
• Increased risk of forest fire in urban/rural fringe	H	$H_S M_E$	$H_S M_E$	H	H
	M	$H_S H_E$	$H_S H_E$	H	H
b) Impacts on transportation infrastructure					
• infrastructures & patterns	M	$H_S L_E$	$H_S L_E$	M	M
• frequency and cost of maintenance	M	$M_S L_E$	$M_S L_E$	M	M
• port operations	H	$M_S L_E$	$M_S L_E$	M	n/a
c) Impacts on buildings and building code criteria					
• Extreme events	H	$H_S L_E$	$H_S L_E$	H	H
3. WATER RESOURCES					
a) Impacts on the variability of quality & quantity of surface water resources					
• Potable water	L	$M_S M_E$	$L_S L_E$	L	L
• Agriculture	H	$M_S M_E$	$M_S M_E$	H	n/a
• Water chemistry	M	$M_S M_E$	$M_S M_E$	M	M
• Management of dams	M	$H_S H_E$	$H_S H_E$	H	H
b) Impacts on groundwater supplies					
• Groundwater contamination	M	$H_S H_E$	$H_S H_E$	H	H
• Quantity of groundwater	M	$M_S M_E$	$M_S M_E$	M	M
• Salt water intrusion	H	$M_S M_E$	$M_S M_E$	H	H

Item	Probability (Frequency of event)	Consequence (Impact severity)	Segregated risk	Integ-rated risk	Risk to HRM Business Units
• Agriculture	H	$M_S M_E$	$M_S M_E$	H	n/a
4. HUMAN HEALTH					
a) Impacts from extreme weather events					
• Capacity of health care system	M	$H_S L_E$	$H_S L_E$	M	M
• Thermal extremes	M	$H_S L_E$	$H_S L_E$	M	n/a
• Stress related health issues	M	$M_S L_E$	$M_S M_E$	M	n/a
• Increased incidence of toxic algae blooms	I	I	I	I	n/a
b) Impacts from vector-borne disease					
• Spread of Lyme Disease, West Nile virus	H	$H_S L_E$	$H_S L_E$	H	n/a
c) Impacts from increased air pollution with higher temperatures					
• Increase in respiratory illnesses	M	$M_S M_E$	$M_S M_E$	M	n/a
• Overloading of public health system	M	$M_S L_E$	$M_S L_E$	M	M
d) Impacts from change in UV radiation					
• Increased incidents of skin cancer, cataracts	M	$M_S L_E$	$M_S L_E$	M	n/a
e) Impacts from food-borne disease					
• Increased incidence of food poisoning associated with spoiled food	M	$M_S L_E$	$M_S L_E$	M	n/a
• Seafood affected by increased levels of pollution from increased run-off	I	I	I	I	n/a
f) Overall impact to public safety	M	$H_S L_E$	$H_S L_E$	H	H
5. MARINE/FISHERIES					
a) Impacts on physical & chemical regime of oceans					
• Temperature	I	I	I	I	n/a
• Salinity	I	I	I	I	n/a
• Increase in biotoxins	I	I	I	I	n/a
b) Socio-economic impacts					
• Fisheries	I	I	I	I	n/a
• Tourism	I	I	I	I	I
6. FORESTRY					
a) Impacts on natural disturbances, pests and rate of infestation					
• Midwinter thaws	M	$M_S L_E$	$M_S L_E$	M	M
• Forest fires	M	$M_S L_E$	$M_S L_E$	M	M
• Pest invasion	M	$M_S L_E$	$M_S L_E$	M	M
• Blowdown from Extreme Events	H	$M_S M_E$	$M_S M_E$	M	M
b) Impacts on harvesting processes					
• Variation in timing and quantity	M	$M_S L_E$	$M_S L_E$	M	n/a
c) Impacts on forest dependant communities					
• Change in harvests or species composition	M	$M_S L_E$	$M_S L_E$	L	n/a
• Insurance costs	I	I	I	I	
d) Impacts on forest structure, composition, productivity & regeneration					
• Ecosystem changes	L	$M_S L_E$	$M_S L_E$	L	L

Item	Probability (Frequency of event)	Consequence (Impact severity)	Segregated risk	Integ-rated risk	Risk to HRM Business Units
7. AGRICULTURE					
a) Impacts on crops due to drought & changing precipitation patterns					
• Storm/hail/drought damage	**H**	**$H_S L_E$**	**$H_S L_E$**	**H**	**n/a**
b) Impacts due to longer growing season					
• Higher yields	**M**	**$H_S L_E$**	**$H_S L_E$**	**M**	**n/a**
• Increased diversity	**M**	**$M_S M_E$**	**$M_S M_E$**	**M**	**n/a**
• Less loss due to frost damage	**M**	**$M_S M_E$**	**$M_S M_E$**	**M**	**n/a**
c) Impacts from changing pest & disease regimes					
• Increase in pests due to warmer winters	**M**	**$H_S L_E$**	**$H_S L_E$**	**M**	**M**
8. ENVIRONMENT					
a) Impacts on terrestrial & aquatic biodiversity.					
• Range and distribution of species	**M**	**$L_S M_E$**	**$L_S M_E$**	**M**	**n/a**
• From temp & flow changes	**H**	**$L_S H_E$**	**$M_S H_E$**	**H**	**n/a**
b) Impacts on isolated populations & ecosystems	**M**	**$L_S H_E$**	**$M_S H_E$**	**M**	**n/a**
c) Impacts on migration of species					
• Break up & low summer flows	**I**	**I**	**I**	**I**	**n/a**
d) Impacts on native species due to invasion/ migration of alien species without natural controls	**M**	**$M_S M_E$**	**$M_S M_E$**	**M**	**M**

The Halifax risk evaluation identified 21 impacts in the high risk category, of which 14 were in areas of municipal responsibility, for which adaptation responses were needed.

These included:

- Coastal erosion and impacts on transportation infrastructure
- Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events
- Increased damage and disruption of vulnerable critical utilities and infrastructure
- Projected increase in insurance costs for HRM assets
- Stress and over-loading of the adaptive capacity of public health infrastructure, from the cumulative effects of extreme events, injuries, break-down in essential services such as electrical power and communications, and introduction of diseases
- Potential for increased variability in incidents and locations of pests, and on the natural disturbance regime, pest cycles and rate of infestation.

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MODULE 5: ADAPTATION OPTIONS

Learning Objectives and Outcomes

By the end of the module, participants will have:

- Reviewed climate change adaptation actions that their own and other Ontario municipalities are already undertaking
- Reviewed additional adaptation options to reduce the likely impacts of climate change in specific municipal systems and sectors
- Discussed potential principles and criteria for selecting adaptation options
- Discussed tools for assessing adaptation options.

Introduction

Adaptation means taking action to protect our natural, built and social environments from the impacts of climate change. Adaptation can occur at many different levels:

- Individual, household or neighbourhood
- Individual businesses, business organizations or economic sectors (e.g. financial, insurance, forestry, power)
- Watershed
- Municipal, provincial or federal.

Adaptation may be:

- Spontaneous or planned
- Reactive or proactive (anticipatory)
- Short-term or longer-term
- Localized or widespread (Smit et al. 2000).

Adaptation is already underway in many municipalities across Ontario. Much of the adaptation that has already occurred has been reactive, shorter-term and localized. It is often triggered by recent climate variability and extreme weather events rather than expected changes to climate.

It is useful to identify these adaptations, many of which will serve as the foundation for more comprehensive and planned adaptation. In *Ahead of the Storm*, the framework document which outlined a high-level adaptation strategy for the City of Toronto, for example, the City described a number of adaptation activities in which it was already involved (See box on the next page.) Most of these actions were initiated for reasons other than climate change but are nonetheless expected to help reduce climate impacts, and will likely serve as the basis for a more far-reaching program.

Most municipalities in Ontario could identify a similar list of actions that they have already taken to respond to current weather conditions or for other purposes, and that will reduce the impacts of climate change for their communities.

Existing Toronto Programs That Reduce Vulnerability to Climate Change

Toronto's Heat Alert System and Hot Weather Response Plan. Toronto Public Health issues heat warnings and works with community agencies to prevent illness and death during periods of extreme hot weather. Toronto Public Health has studied climate change and its effects on heat and air pollution in the City to help long-term planning.

The Wet Weather Flow Master Plan – This 25-year plan was adopted in 2003 to reduce flooding from intense rainfall and impacts on receiving water bodies.

Basement Flooding Protection Subsidy Program – The City subsidized the costs of installing back-water valves and sump pumps on household sewer connections in order to provide additional protection against flooding from sanitary sewers.

Flood Warning Forecasting – The Toronto Regional Conservation Authority is improving the existing system to better prepare for flood emergencies and reduce damage to life and property.

The Green Roof Pilot Incentive Program – This program provided an incentive for green roofs to be installed on new or renovated Toronto buildings. Green roofs capture and retain stormwater and also cool the buildings on which they are located.

A Commitment to Double the Tree Canopy – Parks, Forestry and Recreation is undertaking a major study of canopy potential and associated implementation strategy with Planning and Transportation Services. Expanding the tree canopy in Toronto will provide shade, lessen the urban heat island effect, and reduce runoff and other effects of climate change.

The Peaksaver Program – Toronto Hydro initiated this and several other innovative programs that reduce peak electricity demand on hot summer days and reduce the risk of brownouts and blackouts during heat waves.

The Green Development Standard – The Standard provides a set of performance targets for the design and construction of new developments in Toronto. The Standard is intended to increase energy efficiency of buildings, reduce greenhouse gas emissions, reduce the urban heat island, conserve water, reduce stormwater runoff and enhance neighbourhood green space. Many of these features will contribute to reducing the impacts of climate change.

Greening Parking Lots – Draft design guidelines for greening surface parking lots have been prepared by City Planning and pilot projects are in progress. Greener parking lots are expected to reduce heat and stormwater runoff.

The Better Buildings Partnership – This program works with building owners and developers to increase energy efficiency in existing buildings and in new construction, which decreases energy use and peak energy demand, reducing the vulnerability of the grid to brownouts and blackouts during heat waves.

Emergency Plan – Toronto's Emergency Plan prepares the city to protect the health, safety and welfare of the community in the face of a variety of hazards, including several that may occur more frequently as a result of climate change.

Source: Ahead of the Storm: Preparing Toronto for Climate Change (2008)

Some adaptation is a by-product of actions taken to reduce greenhouse gas emissions. For example, municipal energy efficiency and conservation programs usually have reducing emissions as a primary goal, in addition to lowering costs and reducing pollution. However, energy conservation can also reduce loads on energy distribution systems, decreasing the chance of brownouts or blackouts in hot weather, and resulting impacts on the health of residents and the economy.

Similarly, programs to expand the urban forest canopy may originally be intended to reduce greenhouse gas emissions, but can also address climate change adaptation simultaneously, reducing heat gain in buildings through shading, cooling ambient air temperatures through evapotranspiration, and absorbing stormwater. These could be considered "win-win" options.

Types of Adaptation Options

There are two broad categories of adaptation actions:

- Building adaptive capacity, and
- Delivering or implementing adaptation by actions that reduce impacts and improve resilience.

Each of these categories can be broken down further, as shown in Table 1.

Table 1: Types and Examples of Adaptation Actions

Category	Type of Adaptation	Examples
Building adaptive capacity	Improved climate change information	▪ Expanded network for monitoring local weather data, assessing trends and providing local projections
	Research and monitoring to better pinpoint likely impacts and prioritize adaptation efforts	▪ Development of new regional IDF Curves and flood zone mapping to better assess the potential for flooding from precipitation ▪ Inventories and analysis of vulnerable infrastructure such as culverts, bridges, low-lying roads, etc. ▪ Thermal imaging to identify urban "hotspots" and vulnerable populations
	Outreach and education for the public and stakeholders about potential risks and ways to respond	▪ "Citizen Forums" such as those organized by OCCIAR in Sudbury ▪ Sustainable Neighbourhoods activities by the Toronto and Region Conservation Authority and GTA municipalities
	Creating partnerships and organizational structures to support adaptation	▪ Peel Region's adaptation collaborative involving 4 local governments and 2 conservation authorities
	Guidance and/or regulations that promote or require adaptive action	▪ Guidance for developers on incorporating adaptation into new buildings and landscaping

Category	Type of Adaptation	Examples
Delivering adaptation options	Interventions to reduce existing pressures on systems that are vulnerable to climate change	▪ Programs to conserve water, especially in areas where droughts may occur more frequently
	Interventions to increase resilience of systems in the face of extreme weather and climate change	▪ Expanding and diversifying local sources of electricity that can operate independently of the grid ▪ Diversifying planted tree species to ensure greater levels of survival…
	Creation of buffer zones or relocation programs that protect vulnerable urban systems	▪ Creation and protection of floodable green space in flood zones ▪ Relocation of vulnerable transportation lines
	Actions to fortify vulnerable structures and systems	▪ Installation of berms to protect against flooding ▪ Addition of tie-down hardware to secure building roofs against strong winds
	Forecasting and early warning systems	▪ Expanded heat and storm assessment / alert systems ▪ Communications to promote actions to protect against disease outbreaks associated with hotter weather
	Emergency response systems that incorporate planning for climate change related events	▪ Planned alternative routes and systems for transportation in the event of a flood or severe storm
	Instruments for recovery from extreme weather events	▪ Extreme weather reserve funds ▪ Incentives or requirements for adaptive reconstruction following damage from extreme weather events

A planned approach to adaptation will usually involve the application of several of these types of actions for municipal systems or sectors at risk. Some types of interventions are more preventive, and some more reactive. Not all of the adaptation options listed are within the control of individual municipalities. Some require action by provincial or federal governments and some involve conservation authorities, non-governmental organizations and other groups.

Adaptation Options for Key Municipal Sectors and Systems

There are many specific adaptation options that can be incorporated into adaptation planning in a municipality. Some adaptation options will provide protection from several different climate impacts; some will provide other kinds of benefits. Appendix A includes several tables outlining a range of generic adaptation options for different municipal sectors and systems as well as examples of adaptation actions already taken by some municipalities and related organizations. Some of the adaptation options listed need action by other levels of government or by other organizations in order to be implemented. The tables do not outline all possible options.

Where to Find out More about Adaptation Options

Unfortunately, there is not a central or regional repository in Canada or Ontario where concerned stakeholders can go to find reviews of adaptation options for municipalities or for municipal sectors and systems. In the absence of such a resource, municipal staff can search the internet for reports that recommend adaptation options for municipalities and/or municipal sectors, and can consult some of the following:

- *Ontario Centre for Climate Impacts and Adaptation Resources* – has a searchable data base of more than 2100 scholarly articles and other publications, some of which suggest adaptation options for sectors of municipal responsibility
- *Climate Changes Adaptation Reference Collection* – a collaboration of the City of Toronto and the Institute of Catastrophic Loss Reduction to provide a collection of resources relevant to municipalities (not updated since 2007)
- *Climate Change Impacts and Adaptation Division of Natural Resources Canada* – has research reports that can help identify options for municipal responsibilities such as water supply and stormwater management, though many resources are not recent.

A growing number of federal and provincial ministries, professional organizations and research institutes are also publishing reports, workshop proceedings and other materials that could provide valuable information for municipal staff looking to identify specific sectoral adaptation options and strategies.

Principles for Developing Adaptation Options and Strategies

In developing adaptation options and strategies, municipalities should consider the following principles:

- **Develop clear objectives that you want to achieve** – otherwise it will be difficult to assess the potential effectiveness of and choose among available options

- **Focus on actions to manage priority climate risks** – including major infrastructure failure and/or deaths

- **Address risks associated with today's climate variability and extremes** – as a starting point towards taking actions to reduce risks associated with longer-term climate change

- **Prioritize adaptation actions that are preventive over actions that are mainly reactive (building resilience vs. "mopping up")** – such as strategies to reduce the urban heat island effect and ambient temperatures in neighbourhood "hot spots" for example rather than limiting action to heat alert systems

- **Take advantage of current areas of opportunity** – such as periodic revisions of Official Plans or the Building Code, the Green Municipal Fund or funds for infrastructure renewal and incorporate adaptation

- **Use adaptive management** – which recognizes the value of an iterative approach, coping with uncertainty by gradually phasing in adaptation options and monitoring and evaluating the results
- **Recognize the value of no/low regret and win-win adaptation options** – adaptation options that also reduce greenhouse gas emissions, for example, or reduce costs, or improve the liveability of communities
- **Avoid maladaptive actions or actions that foreclose future adaptation options** – such as energy-intensive adaptation options that increase greenhouse gas emissions (e.g. expanded use of air conditioning) or high cost measures that reduce funds available for less costly alternatives.

Criteria for Selecting Adaptation Options

The United Kingdom Climate Impacts Programme (UKCIP) and others suggest a range of criteria to help in assessing and choosing adaptation options. These include:

- **Effectiveness –** Is the action by itself, or in concert with other actions, likely to protect against the impacts of concern?
- **Costs and Efficiency –** What are the costs of the option? Do the benefits outweigh the costs?
- **Equity –** Does the adaptation option introduce or reinforce inequities or increase vulnerability of other regions?
- **Flexibility** – Can the adaptation option be implemented incrementally, and does it allow for adjustments?
- **Sustainability** – Does it contribute to sustainability objectives?
- **Practical** – Can the action be implemented on relevant timescales? Is it technically complex?
- **Complexity –** Is the adaptation technically complex
- **Legitimacy** – Is it politically and socially acceptable? Is there current or potential public support for the option(s)?
- **Urgency –** How soon could it be implemented?
- **Robustness –** Is the option robust under a range of future climate projections and socio-economic scenarios?
- **Benefits in addition to adaptation –** What other benefits can the adaptation action achieve, helping to create low regrets and win-win strategies?
- **Synergies / coherence with other strategic objectives –** Does it help to achieve other objectives?
- **Other factors –** Which your municipality regards as important.

Tools for Identifying and Assessing Adaptation Options

A number of tools are suggested for identifying and/or assessing adaptation options. A report on climate change risk management by the United Kingdom Climate Impacts Programme – *Climate Adaptation: Risk, Uncertainty and Decision-Making* – briefly describes a variety of tools that can be used to identify and appraise options. The *Canadian Communities Guidebook for Adaptation to Climate Change* provides similar descriptions. Examples of these are listed in Table 2.

Table 2: Selected Tools for Identifying and Assessing Adaptation Options

Tool	Identifying Adaptation Options	Appraising Adaptation Options
Brainstorming – first -stage identification of options by a mix of people with different knowledge and roles within an organization	✓	
Checklists – lists of possible actions drawn up by researchers / experts for specific sectors (and which should be revised over time as knowledge about adaptation increases)	✓	
Consultation exercises – usually based on detailed document sent to stakeholders, who are asked to recommend or to comment on alternative options	✓	✓
Cost-benefit analysis[1] **–** quantifies in monetary terms as many costs and benefits as possible for each option (including non-monetary items); usually includes **discounting** techniques that may value current costs and benefits more than future ones		✓
Cost-effectiveness analysis – compares the costs of alternative options with the objective of finding the least cost alternative(s); benefits are treated as a given		✓
Decision conferencing – two- or three-day workshops led by a facilitator and analyst using interactive computer software to assist a decision-making group reach a common understanding of a problem and solutions		✓
Empirical review of options implemented by others[2] – allows for identification and assessment of actions currently in use	✓	✓
Expert judgement – consulting with internal and external experts knowledgeable about the sector and about relevant climate risks	✓	✓
Multi-criteria analysis – structured methods to score and rank options by identifying and provide weightings for social, environmental and economic criteria		✓
Robust decision-making[3] – tests a list of options against plausible scenarios (socio-economic and climatic), assessing each option for how well it would perform under different scenarios, and identifying robust options that perform well across a range of scenarios		✓

[1] UKCIP has a specific tool for costing adaptation options available on their website.
[2] The London Climate Change Partnership commissioned such a review, which identified actions in 18 cities internationally for reducing heat, flooding and water shortages, and assessed their applicability to London.
[3] The World Bank and several UN agencies are promoting the use of this technique.

Appendix A: Adaptation Options by Municipal Sector or System

Adaptation Options for Water Systems
(to adapt to low water levels, water shortages and drought, and threats to water quality)

GENERIC EXAMPLES

Adaptive Capacity

Baseline monitoring and inventories for:
- Quantity and quality of water resources
- Condition and capacity of water distribution and treatment systems
- Number, size and location of enterprises with high water demand

Improved drought forecasting, warning and monitoring systems

Delivery of Adaptation

Enhanced conservation and demand management programs to counteract increased water demand and potential decrease in supply such as:
- Expand and enhance leak identification and repair programs for municipal water systems
- Expand water metering and appropriate pricing of water including higher pricing for excessive use
- Ongoing education for the public on water conservation
- Programs such as rebates to support purchase and use of water efficient appliances and fixtures
- Support for capture and (re)use of rainwater and grey water for irrigation and other uses

Water sensitive urban design for increased resilience:
- Install xeriscaping on municipal properties
- Green design standards to support xeriscaping on new and existing developments
- Reduce hard surfaces so water can be absorbed and groundwater recharged

Increased water storage:
- Optimize reservoir operation, including mechanisms to reduce evaporation
- Develop additional reservoir capacity to safeguard supply for dry periods

Preparation for dry periods:
- Prepare drought management plans including plans to balance the needs of competing users when water availability is reduced
- Apply water use restrictions on automatic watering systems, hosing down paved areas or other water uses in periods of drought with penalties for non-compliance
- Relocate intake structures to accommodate water level changes in lakes and river channels

Protection of water quality:
- Protect existing wetlands and establishing new wetlands to retain and filter water
- Establish and maintain vegetated buffer zones around significant water bodies, streams and rivers
- Protect groundwater recharge areas to maintain quantity as well as quality
- Improve risk communication with respect to drinking water quality (e.g information on emerging pathogens)

SPECIFIC EXAMPLE

The Ontario Regional Adaptation Collaborative includes several source water protection activities that should provide help for municipalities plan for adaptation of the water system, including:
- Establishing a network of climate change and source protection experts to exchange ideas and develop resources
- Improved data collection for water resources monitoring
- Creation of risk management measures that are robust for a changing climate
- A training program on integrating climate change and adaptation into Drinking Water Source Protection Plans

Adaptation Options for Stormwater Management
GENERIC EXAMPLES
Adaptive Capacity
Distribution of educational materials to homeowners describing: ▪ Steps they can take to protect themselves from basement and overland floods ▪ Emergency management strategies
Research and monitoring to manage stormwater and flood events: ▪ Updating of Intensity-Duration-Frequency curves for design of stormwater management systems in the face of climate change ▪ Prepare or update flood maps to reflect changing risks
Delivery of Adaptation
Improvement of existing stormwater and sewer systems: ▪ Expand the capacity of storm sewers to manage extreme weather events ▪ Separation of stormwater and sewer systems and retrofitting these systems to enhance capacity
Flood-proofing of buildings in vulnerable locations, for example: ▪ Raise floor levels, electrical fittings and equipment ▪ Install overhangs to prevent infiltration of heavy rain around doors and windows ▪ Seal gaps around pipes and cable sand joints between walls and frames of doors and low level windows ▪ Construct buildings from flood resilient materials that can withstand direct contact with floodwaters without sustaining significant damage
Implementation of sustainable urban drainage systems: ▪ Reduced hard surfaces ▪ Permeable pavements ▪ Green roofs to increase on-site retention of stormwater ▪ Increased use of stormwater retention ponds, constructed wetlands and swales
Creation of natural eco-system buffers for vulnerable water bodies, low-lying areas
Improvement of land-use planning: ▪ Institute zoning to avoid buildings and infrastructure in flood or landslide prone areas ▪ Relocate infrastructure that is vulnerable to flood damage
SPECIFIC EXAMPLE
The Hamilton region has encountered recent problems with surface and basement flooding. Given the potential for climate change to exacerbate the situation with more frequent and intense precipitation events projected for the future, the City has developed a Stormwater Management Master Plan designed to address these issues to accommodate future development and population growth. The plan is currently being implemented through a number of complementary programs including: ▪ New infrastructure construction and retrofits ▪ Operations and maintenance procedures ▪ Public education to improve flood awareness ▪ Backwater valve distribution to households in areas with basement flooding problems.
The Town of Richmond Hill is a rapidly growing municipality that identified adaptation to climate change in its 10-year capital project planning process in 2007. Recognizing that climate change may likely bring about more frequent and intense rain storms, the Town rehabilitated a 20-year old stormwater flood control facility in Pioneer Park to protect infrastructure, improve water quality and enhance erosion control in the 700 hectare area. This project won a Federation of Canadian Municipalities Watershed Award in 2010, given for its leadership in proactively reducing the Town's vulnerability to climate change-related flooding and water damage.

Adaptation Options for Protection of Buildings and Infrastructure
GENERIC EXAMPLES
Adaptive Capacity
Distribution of educational materials for homeowners describing: ▪ Steps they can take to prevent damage during a high wind or storm event ▪ Recognizing and interpreting storm warnings, signs and characteristics
Increased research on ways to improve the structural integrity of buildings through cost-effective retrofits
Building and Infrastructure standards and guidelines: ▪ Create local development guidelines that encourage incorporation of climate change into building structures and landscaping ▪ Improve safety factors in codes and standards to reflect increasing variability and range of extremes and growing risks for new infrastructure under changing climate conditions ▪ Incorporate into building by-laws requirements for good maintenance to increase the resilience of structures over time
Delivery of Adaptation
Actions to fortify existing structures: ▪ Retrofit residential buildings to protect against extreme wind and storm events ▪ Prioritize and develop adaptation solutions such as retrofit technologies for the most critical regions and infrastructure types ▪ Ensure roof systems and cladding materials can cope with higher wind speeds ▪ Demolish and replace unsafe structures ▪ Reinforce essential infrastructure (e.g. hospitals and power) to ensure they are less vulnerable to high wind and storm events
Protection of vulnerable populations: ▪ Create safe havens and shelters in vulnerable areas
Improved emergency response systems: ▪ Improve coordination of emergency services and search and rescue teams ▪ Improve resilience of emergency services to high wind and storm events
SPECIFIC EXAMPLES
The University of Western Ontario and the Alan G. Davenport Engineering Group have created the *Boundary Layer Wind Tunnel* to test the structural integrity of residences and propose cost-effective retrofits to protect against high winds and storms. This research facility is contributing to an understanding of how better to safeguard homes and small buildings from storm-related impacts of climate change.
Habitat for Humanity in London, Ontario has partnered with the Institute of Catastrophic Loss Reduction on a pilot project that built three new resilient affordable homes. The houses incorporated several low-cost techniques and tools that can help homeowners protect their houses from extreme weather events including wind storms and floods that are common in London. These techniques and tools included: ▪ Hurricane straps to secure the roof to the walls of a house, making it more difficult to separate during an extreme wind event ▪ Changing nail spacing for roofing from 12” to 6” to better protect roofs in an extreme wind event ▪ Installation of backwater valves to reduce the risk of sewer backup and basement flooding.

Adaptation Options for Energy Systems
GENERIC EXAMPLES
Adaptive Capacity
Public outreach programs to engage consumers and identify weaknesses in the electricity system
Delivery of Adaptation
Expanded conservation, energy efficiency and demand side management strategies to reduce peak loads during heat waves that make transmission systems vulnerable to blackouts
Implementation of conservation programs targeted at residential households, commercial, institutional and industrial facilities, such as: ▪ Subsidies for energy audits and subsequent retrofits that make buildings more energy efficient ▪ Rebates on high-efficiency appliances and systems ▪ Installation of direct load-control devices ▪ Voluntary and contractual load-shedding agreements with commercial, institutional and industrial facilities
Increase the resiliency of the electrical distribution system by: ▪ Use of corrosion resistant materials in power lines ▪ Use of variable resistance conductors for de-icing power lines ▪ Alter overhead line design to limit sagging due to heat or ice ▪ Construction of berms or flood barriers around transformers or transmission stations ▪ Increase distributed energy generation to reduce risk of power disruption, through systems such as cogeneration and local renewable energy systems
Innovative techniques to minimize energy consumption in building construction and maintenance: ▪ Create walls using materials that require less energy for their creation and installation and that help regulate temperatures naturally and efficiently throughout the year ▪ Use thermal storage or mass to allow heat absorption during hot periods and dissipation during cooler periods ▪ Encourage natural ventilation and daylighting to allow continued facility occupancy during power outages
Strategies to reduce impact of blackouts ▪ Use of 'islanding' techniques to ensure that blackouts are limited to affected areas ▪ Increased automation (sensors, smart switches, SmartGrid) to help prevent cascading during power outages ▪ Back-up generators for key / vulnerable municipal buildings and buildings that supply important services
SPECIFIC EXAMPLES
Many municipal-level programs focus on conservation as a means of reducing vulnerability to weather-related impacts on energy distribution systems. *Peaksaver* programs, for example, allow utilities to send a signal to thermostats controlling home air conditioners to decrease demand during peak periods. Peaksaver programs are offered in several municipalities, including Toronto, Ottawa, North Bay, Thunder Bay, Sudbury, Peterborough, Hamilton and London.

Adaptation Options for Transportation Systems
GENERIC EXAMPLES
Adaptive Capacity
Research and monitoring to investigate transportation modal shifts in response to climate-related events
Delivery of Adaptation
Interventions to reduce heat impacts on roads: ▪ Adopt alternative road surface materials on most heavily used roads ▪ Increase maintenance frequency of asphalt roads
Interventions to reduce flooding and erosion impacts on ground transportation: ▪ Assess and retrofit vulnerable transportation infrastructure systems such as culverts, tunnels, bridges, subway entrances, etc. ▪ Increase capacity of stormwater collection systems to accommodate projected changes in precipitation ▪ Modify urban landscaping requirements to reduce stormwater runoff ▪ Preserve ecological buffers (e.g. wetlands)
Interventions to improve resilience of shipping industry: ▪ Encourage lighter loads and more frequent trips when water levels are low ▪ Evaluate the vulnerability of port facilities and associated infrastructure due to changes in water level, increased wave activity, storm surges and ice pile-up
Identify alternative routes in the event of disruption and/or need for evacuation
SPECIFIC EXAMPLES
After the 2005 storm washed out a large section of road at Finch and Black Creek, the City of Toronto made several changes to ensure that such damage does not occur again. These efforts include: ▪ Redesigning and rebuilding the main culvert near that intersection ▪ Altering maintenance schedules to make sure that a build up of debris does not block the culvert ▪ Constructing overland flow ramps that guide water off the main road and down into the stormwater system. The City is also in the process of conducting a risk assessment with the help of the Public Infrastructure Engineering Vulnerability Committee to assess the specific vulnerabilities and risks to other culverts, and to identify solutions.

Adaptation Options for Health
GENERIC EXAMPLES
Adaptive Capacity
Public education on climate-related health threats (vector-borne diseases, heat, air pollution, floods and storms) and prevention
Delivery of Adaptation
Interventions to reduce heat island effects: ▪ Increased street trees and tree canopy coverage ▪ Expansion of parks and green spaces ▪ Incentives and requirements for green building construction, green roofs and living walls ▪ High albedo (reflective) building surfaces ▪ Heat response systems (cooling centres, water distribution, etc.) ▪ Urban design to channel prevailing winds ▪ Heat alert and response systems to protect vulnerable populations
Interventions to reduce air pollution impacts, especially emissions reduction measures: ▪ Traffic restrictions ▪ Restrictions on processes and materials releasing volatile organic compounds ▪ Improved public transport ▪ Pollution warning system
Interventions to prevent impacts from expansion of vector-borne diseases: ▪ Early detection and warning systems ▪ Control of other factors that support the expansion of disease-carrying insects (e.g. standing water) ▪ Spraying to control infestations
Interventions to reduce health and security impacts from extreme weather events: ▪ Early warning systems ▪ Flood protection systems (see Stormwater/Flooding section above) ▪ Emergency response systems
SPECIFIC EXAMPLES
Peel Public Health administers a regional hot weather warning system. When alerts are called, a notice goes out by fax and e-mail to all stakeholders indicating both the current weather status and the prediction for the following day. The system also includes a website to communicate heat-related messaging to the public with information and guidelines targeted to different audiences (e.g. recreational facilities, indoor/outdoor workers, child care centres, the general public, agencies serving elderly/persons with disabilities, homeless shelters/outreach programs, and schools). Guidelines include general information about what to do during heat alerts, as well as information on the signs of heat over-exposure and on treatment for heat ailments. A 24-hour information line is available, including an afterhour's message that links residents to Tele-health Ontario for heat health information. At the local level, there are several intervention strategies coordinated through Peel Region stakeholders and development partners.

Adaptation Options for Urban Forests and Ecosystems

GENERIC EXAMPLES

Adaptive Capacity

Develop education programs to increase homeowner awareness of the importance of the urban forest and ways to care for trees in urban environments

Research and monitoring:

- Conduct studies to assess the structure, environmental benefits and value of urban forests
- Actively monitor trends in forest conditions, including drought stress, insects and invasive species

Delivery of Adaptation

Protect existing ecosystems (parks, tree stands, waterways, ponds, lakes, ravines, wetlands, etc.):

- Restrict new development in existing green spaces
- Protect green spaces in low-lying areas that might aid in flood management
- Develop connected greenway system to allow natural species migration

Expand interventions to increase resilience:

- Expand tree planting programs
- Plant diverse species or varieties known to have a broad range of environmental tolerances
- Introduce new species or cultivars resistant to drought, heat, pests, pollution and/or floods
- Engage private landowners in contributing to the resilience of urban forests by watering and maintaining trees, and identifying and treating pests and diseases
- Enhance conditions for tree survival and growth (increase space for roots, control soil compaction, increase watering and maintenance, adopt new planting and maintenance techniques)

Improve emergency response measures:

- Develop extreme weather response plans for urban ecosystems
- Establish contingency funds for storms to support forest restoration projects

SPECIFIC EXAMPLES

Street trees can contribute to urban stormwater management and efforts to create cooler communities. However, their growth is limited by their location and its environmental conditions including soil compaction, road salt, and debris, which hamper their ability to reach maturity. In turn, this limits the benefits that the tree can provide.

The City of Toronto Urban Forestry Services is implementing a range of new planting techniques that allow street trees to reach maturity as part of city-wide sustainability and adaptation efforts. The three main strategies being implemented include:

- Structural soil
- Continuous trench planting
- Silva Cells.

MODULE 6: AN OVERVIEW OF ADAPTATION PLANNING

Learning Objectives and Outcomes

By the end of the module, participants will have:

- Reviewed a variety of adaptation planning processes for municipalities, as set out in several recent guides and undertaken by a growing number of municipalities
- Identified key stages of the adaptation planning process that they expect would work in their own municipalities and main steps they would expect to take

Introduction

There are a growing number of international and Canadian guides for adaptation planning by municipal governments. Most of these guides recommend stepwise processes for adaptation planning that are common to planning for other purposes. Almost all of these guides provide useful insights about planning for climate change, and tools that can help in the planning process. This module will provide links to some of these guides, as well as a description of the planning processes they suggest.

In addition to drawing on planning guides, municipalities can learn about adaptation planning from the experience of a growing number of local governments which have embarked on the task. Planning in real life seldom follows the neat process outlined in most planning guides. Case studies and anecdotal reports about real planning processes demonstrate that there is no one correct way to do adaptation planning.

Local governments have been involved in a number of different approaches to adaptation in their communities.[1] Some of these processes are initiated by municipalities, but in a number of cases non-governmental organizations, researchers or even consulting companies have been the moving force behind adaptation planning. These processes will also vary in relation to the specific vulnerabilities and character of the community and the organization of the municipal government. It is useful for adaptation leaders and potential leaders to examine the ways in which municipalities have actually approached this issue to learn from their experiences. This course provides several case studies that may provide alternative models for adaptation planning.

Planning may occur at a government- or community-wide level, at a departmental level or both. In this module, we will emphasize municipality-wide planning, but the steps and stages will be similar for planning within a municipal department or agency, or planning around a specific climate change impact.

[1] It is still early days for most adaptation efforts in Canadian communities, so it is difficult to make a definitive statement about the value of different approaches to adaptation planning.

Guides for Municipal Adaptation Planning

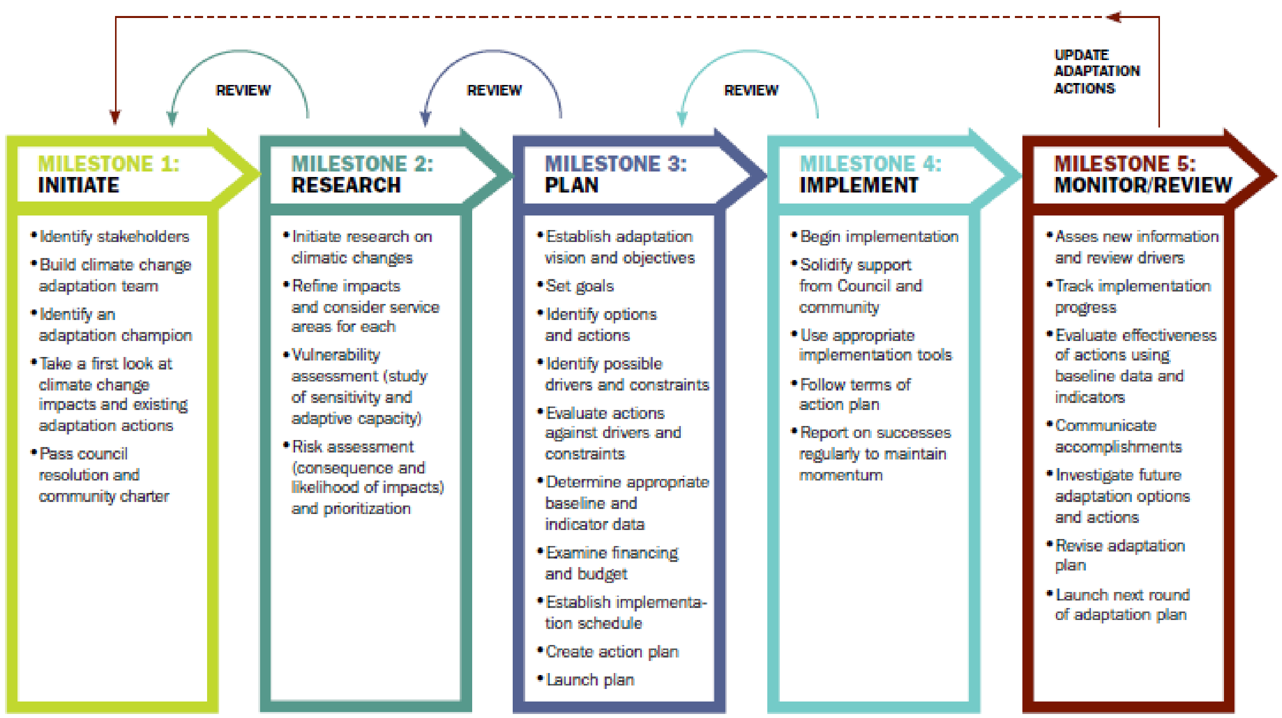
There are a growing number of guides for municipal adaptation planning. Here are some Canadian examples that could be useful for Ontario municipalities.

ICLEI-Canada

ICLEI-Canada has recently written a new guide to adaptation planning for Canadian municipalities, *Changing Climate, Changing Communities*. This approach uses a five-milestone framework similar to that used by the Partners for Climate Protection Program (PCP) for climate change mitigation planning and implementation at the municipal level.[2] More than 200 Canadian communities are participants in PCP and are familiar with this milestone framework. The use of a similar framework for adaptation planning may prove particularly useful for those communities.

Graphically, the ICLEI-Canada framework looks like this:

Figure 1: ICLEI Milestone Framework for Climate Change Adaptation



Source: ICLEI (2010)

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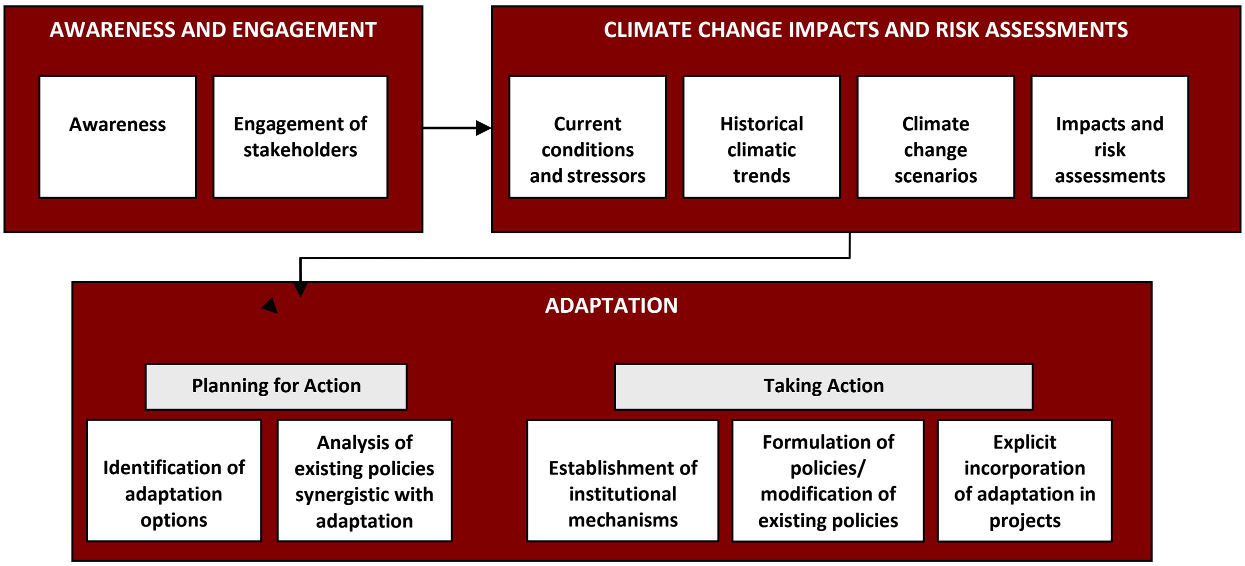
[2] The five milestones in the PCP Program are: 1) Creating a greenhouse gas emissions inventory and forecast, 2) Setting an emissions reductions target, 3) Developing a local action plan, 4) Implementing the local action plan or a set of activities, and 5) Monitoring progress and reporting results. 207 Canadian municipalities are currently members of PCP, including 52 Ontario municipalities.

Clean Air Partnership

In 2007, the Clean Air Partnership published [Cities Preparing for Climate Change], a study that explored the adaptation processes of six cities in Canada, the US and the UK. While this study was not a guidebook, it did identify the steps that some leading cities are taking to adapt. The steps are shown graphically below.

Figure 2: The Adaptation Process Described in *Cities Preparing for Climate Change*



Source: Penney and Wieditz (2007), p.6

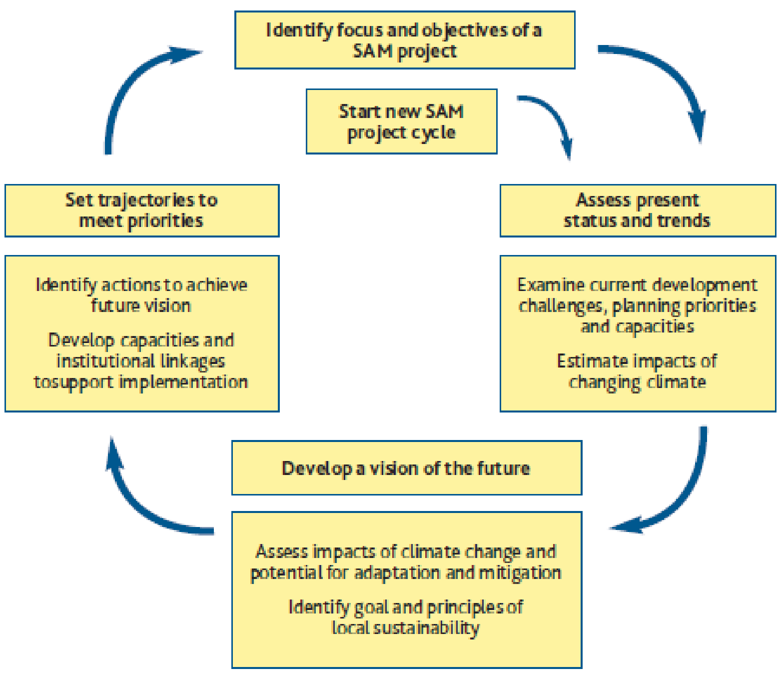
UBC Guide to Combining Adaptation, Mitigation and Sustainable Development

Researchers from the University of British Columbia recently released the guidebook, Canadian Communities Guidebook for Adaptation to Climate Change, based on pilot projects with B.C. communities. Like the ICLEI approach, this guide uses a five-step framework, as shown in Figure 3.

This guide is unique in its emphasis on the development of adaptation strategies that integrate community sustainability and mitigation objectives. The authors point out that some adaptation options may increase greenhouse gas emissions or otherwise reduce long-term sustainability, and should be considered “maladaptation”. Other guidebooks place less emphasis on this issue. The authors refer to these integrated strategies as SAM, short for Sustainable development, Adaptation and Mitigation.

A SAM project might be broadly or narrowly defined. For instance, the goal might be to develop a comprehensive community adaptation strategy that integrates sustainability and mitigation objectives, or it might be more narrowly focused on safeguarding water supplies for a community under conditions of climate change.

Figure 3: Main Steps of the SAM Framework



Source: Bizikova, Neale and Burton (2008) p. 26

The Columbia Basin Trust

The Columbia Basin Trust (CBT) in British Columbia has not developed a guidebook as such, but has drawn from a U.S. guide for adaptation planning by local governments. CBT has provided the resources for several communities in the Columbia Basin to do adaptation planning, processes that involved local governments, but also engaged community organizations and the public. CBT's factsheet Planning for Climate Change suggests the adaptation planning process shown in Figure 4, on the next page.

Figure 5: Six Steps to Successful Adaptation Planning

Six Steps to Successful Adaptation Planning

Step 1 - Get Started

- Make the commitment
- Establish a local coordinator/consultant
- Establish a local steering committee
- Develop a work plan
- Locate resources

Step 2 - Learn About Climate Change

- Seek out local knowledge and observations
- Research historical and available information
- Obtain future climate projections for your region
- Share ideas with your community

Step 3 - Identify Priorities in Your Community

- Investigate potential impacts
- Identify what is important to the community
- Talk with people about the issues
- Confirm priority issues for further investigation

Step 4 - Assess Vulnerability and Risk

- Complete sensitivity analysis
- Evaluate adaptive capacity
- Determine probability of events
- Establish priority risks and opportunities

Step 5 - Develop Adaptation Strategies and Actions

- Establish goals
- Determine actions
- Assign people to act

Step 6 - Implement and Monitor Plans

- Implement plans
- Monitor progress
- Revise plans with new information

There are several other recent adaptation guides produced for local governments in the UK, Australia and New Zealand. The UK guides, available on the website of the United Kingdom Climate Impacts Program, provide many resources, and quite detailed suggestions for developing an adaptation plan. Almost all of these guides suggest similar step-by-step processes for adaptation planning, though the order of the steps varies from guide to guide, as does the emphasis on different steps.

Selected Examples of Adaptation Planning in Canada

There are a growing number of case studies of adaptation planning in Canadian communities. Some of these provide detailed descriptions of the process which communities and/or municipalities took in developing an adaptation plan and program, and an analysis of the relative strengths and weaknesses of the process under review. We include summaries of four of these case studies in the following pages.

Unfortunately, not many of the available reports and case studies provide a clear picture of how municipalities organized themselves to begin adaptation planning. Most tend to focus on describing specific local climate change risks and high-level adaptation options. There is relatively little analysis of the drivers, barriers and challenges associated with adaptation that local governments have encountered in adaptation planning – information that could be quite valuable to other municipalities just beginning the process. Nevertheless, many of these case studies provide some insight into real-life adaptation processes and how they have been organized. The following examples provide information on a range of approaches to identifying climate change impacts and adaptation, and are all available on the internet:

- **City of Iqaluit** – *The City of Iqaluit's Climate Change Impacts, Infrastructure Risks and Adaptive Capacity Project* (2007)
- **City of Fredericton** – *Climate Change Adaptation Strategy – City of Fredericton – Stakeholder Input* (2008)
- **Dawson City** – *Dawson Climate Change Adaptation Plan* (2009)
- **Region of Peel** – *Adaptation Background Report: Peel Climate Change Strategy* (2010)

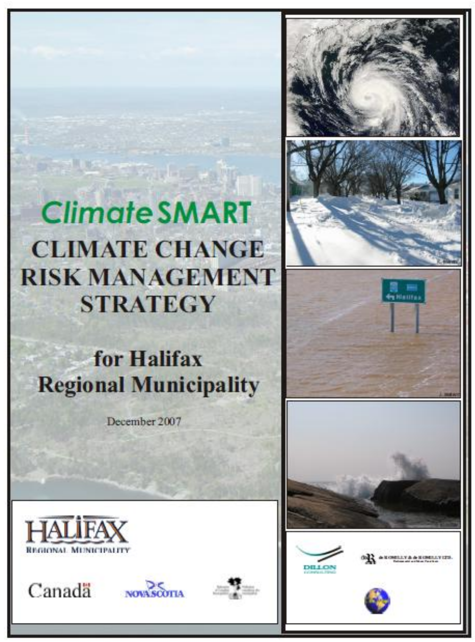
Natural Resources Canada has an *Adaptation Case Studies* webpage with links to eleven short case studies of how Canadian communities are tackling specific climate impacts. Several of the studies were published in 2006. New case studies are being prepared. Natural Resources Canada and the Canadian Institute of Planners have also published case studies of collaborative research that involved local governments in five communities. For the most part these do not describe actual adaptation planning processes in these communities.

In the case studies on the following pages, we provide an outline of the different ways in which four Canadian communities have approached adaptation planning. These are summarized in a table on pages 13 and 14.

Case Study 1 – Halifax Regional Municipality (HRM)

An important precursor to the Halifax work on adaptation was the formation in 2001 of ClimAdapt, a network of private sector environmental firms in Atlantic Canada, some of whom were consulting internationally on climate change adaptation. ClimAdapt proposed and sought funding for an intensive program of research, including an assessment of the risks of climate change for the region and development of tools for climate change adaptation decision-making. This work became a priority in 2004, as a result of the impacts of Hurricane Juan in 2003 and the blizzard "White Juan" in 2004. Environmental and planning staff at HRM joined a working group that included representatives from Dillon Consulting, deRomilly and deRomilly Limited, Environment Canada (Atlantic Region), and the Nova Scotia Environment department. This group:

- Prepared an Issues Paper for HRM on Adapting to a Changing Climate (July 2005) which provided an overview of potential climate change impacts for the region
- Held workshops with HRM staff to review and comment on the Issues Paper (October and November 2005)
- Made recommendations to include specific reference to climate change impacts and adaptation in HRM's Regional Plan, which was adopted in 2006
- Developed and posted a *Developers' Risk Management Guide* to encourage the incorporation of climate change considerations into planning for new developments
- Produced a detailed *Climate Change Risk Management Strategy* that:
  - Described administrative divisions ("business units") of the HRM government and their responsibilities that may be affected by climate change
  - Identified how climate is changing in the region and what the broad impacts are likely to be
  - Provided an overall assessment of potential risks
  - Identified adaptation responses for individual business units to respond to the risks, and describes requirements for implementation.



Municipal staff worked to engage the public on these issues by:

- Creating the Climate SMART website for Halifax citizens on climate change mitigation and adaptation

1. Developing and posting on a *Community Action Guide to Climate Change and Emergency Preparedness* on the website

- Including information about climate change impacts and adaptation in HRM's quarterly newsletter *Naturally Green*, which is distributed to all Halifax households. (Mention of climate change impacts and adaptation in these newsletters has fallen off since the Risk Management Strategy was published, however.)

HRM also commissioned a study of the *Economic Implications of Buried Electrical Utilities*, an adaptation option that could reduce the impact of storms on power services.

Currently, the municipality is focused on sea level rise and storm surge issues related to climate change. Developers proposing to construct new buildings on the waterfront are now required to consider sea level rise and long-term extreme weather into account in order to get a building permit.

Meantime, research continues to pinpoint vulnerabilities. The Geological Survey of Canada has been working with HRM, the Halifax Port Authority and others to map flood zones and conduct a vulnerability analysis of the harbour and coastal zones. They are working to define adaptation options for these areas, and incorporate them into the draft Harbour Plan.

Case Study 2 – City of Toronto

This case study, drawn from *Climate Change Adaptation in the City of Toronto: Lessons for Great Lakes Communities* (2008), provides a detailed overview of the work of the City of Toronto in 2007 and 2008 to develop an adaptation strategy and outlines 19 "lessons" of the Toronto experience for other Great Lakes communities. The City:

- Formed an Adaptation Steering Group, with representatives from all the City's major divisions, led by the Toronto Environment Office and supported by the Clean Air Partnership
- Formed an "Expert Panel" of scientists and other researchers knowledgeable about climate change and its impacts in the Toronto Region and hosted presentations by panel members at a meeting of City staff as well as at a special public meeting of the City's Parks and Environment Committee
- Convened internal meetings about climate change impacts with several City divisions and agencies likely to be strongly affected by climate change
- Prepared *Ahead of the Storm,* a "Framework Document" that outlined potential climate change impacts; described existing programs designed to reduce vulnerability to current weather extremes; identified short-term adaptation actions that could be undertaken; and laid out a longer-term adaptation process

- Prepared a highlights version of *Ahead of the Storm* for wider distribution to the public and held six consultation meetings with the public and with businesses on the contents
- Convened a special Parks and Environment meeting to receive deputations from the public on Ahead of the Storm
- Unanimously adopted the Climate Change Adaptation Staff Report, which committed the City to a long-term adaptation process.

Prior to formal adaptation planning, Toronto Public Health and Toronto Water had been incorporating concerns about climate change in their planning for heat and smog events and for stormwater management. City Planning has also considered climate change in provisions included in the City's Green Development Standard. Urban Forestry and Transportation Services have collaborated on programs to increase the viability of street trees and trees planted in parking lots, in order to combat heat and reduce runoff. The City also supported several green roof initiatives. Most of these activities have been strengthened and expanded by the City's commitment to adaptation.

Currently, Toronto Water is assessing options to safeguard 13 areas in Toronto that are vulnerable to flooding from intense rainfall. Transportation Services is conducting a risk assessment related to flooding where roads cross watercourses in Toronto.

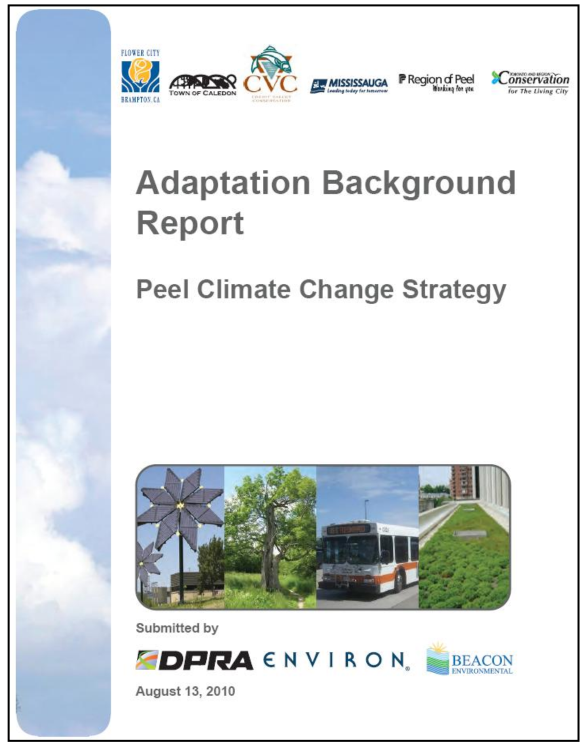
The Toronto Environment Office is also completing a detailed analysis of recent climate trends and projections of future climate change for the region, and is piloting a detailed risk assessment tool with two divisions – Transportation Services and Shelter, Housing and Support. The final version of the risk assessment tool will be used by all the City's divisions to identify and prioritize the risks associated with climate change.

Case Study 3 – Region of Peel

The Region of Peel embarked on its climate change adaptation process in 2009 when a Climate Change Steering Committee and Project Team were formed to develop a regional climate change strategy which will include both mitigation and adaptation measures.

The involvement of the partners was initiated by the Region's CAO, David Szwarc, and representatives from the Region's two conservation authorities, Toronto and Region and Credit Valley in response to the Region's Service Strategy Business Plan's environmental goals, from which the climate change strategy would emerge. Later, Peel's three local municipalities, the City of Mississauga and the City of Brampton and the Town of Caledon were brought to the table and the Steering Committee and Project Team were formed.

The Steering Committee includes high level managers and directors from climate change-impacted divisions and departments from the six partners, such as planning, environment, energy, water, transportation and parks and recreation and guides



The Project Team is a more technically-oriented group of representatives from the six partners. They include environmental planners and coordinators, specialists and analysts in public health, energy and watersheds.

Together, the Steering Committee and the Project Team met regularly and developed the Climate Change Strategy's terms of reference, and organized the Strategy development process around four major tasks:

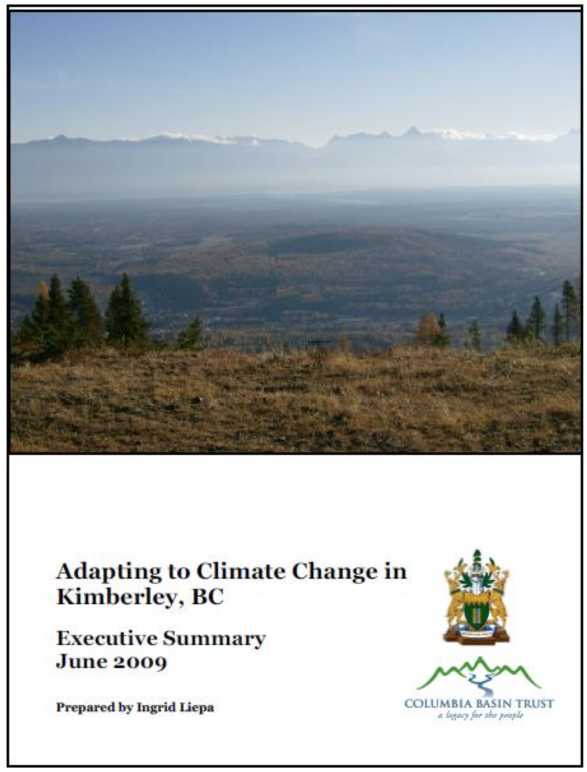
1. Background Research
2. Establishing the Strategy
3. Preparing a Draft Climate Change Strategy
4. Finalizing the Strategy

The Adaptation Background Report was written by a team of three consultants and submitted to the regional partners in August 2010. The information in the report was gathered from a document and literature review, and meetings and internal workshops arranged with the six partners and representing key sectors that will likely be affected by climate change. It summarizes climate change impacts, adaptation activities already occurring throughout the Region, draws upon practices from other jurisdictions and identifies gaps in programs and policies.

As of spring 2011, the project has moved through the Background Research and the Strategy Establishment phases, and stakeholder meetings and workshops have been undertaken in preparation of the Draft Climate Change Strategy. The two stakeholder meetings were each attended by several dozen representatives from the six partners, as well as other knowledgeable stakeholders from non-governmental organizations, academia, nearby municipalities and conservation authorities and private environmental representatives.

Case Study 4 – Kimberley, BC

Adapting to Climate Change in Kimberley (2009) provides a good description of the community-based process that the town of Kimberley (population <7000) undertook to investigate and prioritize the risks of climate change, and to develop an action plan. Kimberley's process was supported by the Columbia Basin Trust (CBT), a foundation that is encouraging communities in the Columbia Basin to undertake adaptation planning, and by researchers at the University of British Columbia's Collaborative for Advanced Landscape Planning. In 2008 and 2009, Kimberley:



- Participated in a regional workshop organized by the CBT and became a pilot community in its Communities Adapting to Climate Change Initiative, supported by an expert Advisory Committee assembled by CBT
- Hired a local project coordinator with a $30,000 grant from CBT
- Formed a Steering Committee with local stakeholders, including a City Planner and Economic Development Officer (the Mayor, City Councillors, and several senior staff also participated in public workshops)
- Worked with UBC researchers to prepare visual imagery and spatial modelling of climate impacts and possible adaptation choices to help inform community discussions
- Organized a "kick-off" workshop with 35 stakeholders who worked together to identify Kimberley's priority climate-related issues
- Conducted a direct mail survey of community residents on priority climate impacts
- Held two more community workshops including an event that engaged residents in mapping locations vulnerable to previously identified priority impacts
- Established three multi-stakeholder Working Groups to undertake vulnerability assessments for three priority areas (Natural Environment – Water and Forests; Built Environment and Municipal Infrastructure; and Tourism) and to develop a suite of recommended actions
- Prepared a final draft report which was presented at a community Open House, and completed after incorporating feedback from the event

- Presented the completed report to Council in June 2009, along with 15 high priority recommendations (action recommended within 2 years) and 60 lower priority recommendations. While most of these recommendations were in the purview of the municipality, several were directed to community and business organizations as well.

Kimberley is working to implement some of the recommendations that arose from its adaptation planning process; to integrate adaptation and greenhouse gas reduction; and to incorporate climate change into its Official Community Plan.

Table 1: Comparison of Adaptation Planning in Four Municipalities

	Halifax	Toronto	Peel	Kimberley
Make-up of Initial Adaptation Team	- Environmental & Planning staff - Consultants - Environment Canada - Nova Scotia Dept. of Environment	- Staff from 14 City Divisions - Toronto Region Conservation Authority (TRCA) - Clean Air Partnership (CAP)	- Project Team for the Climate Change Strategy included staff from the Peel, Mississauga Brampton, and Caledon, and Toronto and Region and Credit Valley Conservation Authorities - Adaptation Background Report prepared by a team of three consultants	- Municipal staff from Planning and Economic Development - City Councillor - Business representatives - Local college - Local NGO - CBT representative
Led By	Dillon Consulting & Staff from HRM 's Sustainable Environmental Management Office	Toronto Environment Office	Region of Peel Steering Committee made up of high-level directors and managers from the six partners	Local Consultant hired for the job
Involvement of Experts	Both the private sector consultants and Environment Canada brought climate change expertise to the table	- CAP, with prior knowledge about adaptation, was involved in strategy development - Expert Panel provided advice - Environment Canada and U of T scientists involved in current climate projections	The three consultants – DPRA, ENVIRON and Beacon Environmental – brought their own climate change knowledge to the Adaptation Background Report and supplemented with literature review	Scientists from the Pacific Climate Impacts Consortium and UBC researchers helped with climate projections, visualization of climate changes
Involvement of Community	Little direct involvement of the community, but outreach done through website and newsletters	Public & business consultations on the draft Framework Document; Public meeting with presentations by Expert Panel	Little direct involvement of the community, but stakeholder workshops were held with key municipal, regional, and environmental professionals	Community-based process for reviewing risks, identifying priorities and recommending potential strategies
Funding Support from Outside the Municipality	Natural Resources Canada provided substantial funds for risk assessment and tool development	Ontario Ministry of the Environment paid for CAP's participation in initial adaptation planning	Funded internally	Columbia Basin Trust funded initial work
Source of Local Climate Change	Environment Canada and	Under development currently (not used	- Literature review of existing regional	Pacific Climate Impacts

Projections	consultants on initial working group	for early part of adaptation project)	climate change projections - Some work with CCCSN website	Consortium and UBC
Vulnerability Assessment	2005 Issues Paper reviewed expected vulnerabilities	CAP's *Scan of Climate Change Impacts for Toronto* in 2006 outlined major vulnerabilities	- No formal vulnerability assessment, but recommendations are made for future ones - Gap analysis done of partners' programs and policies	Review of vulnerabilities prepared for the whole Columbia Basin by the Columbia Basin Trust
Risk Assessment	Formal high-level risk assessment and risk management strategy released in 2007	Pilot risk assessments underway in Transportation Services and Shelter, Housing and Support	- No formal risk assessment done, - Partners and consultants took a risk management approach to developing Strategy's adaptation section	Simple risk assessment s for priority areas done (identifying urgency for action as H, M or L)
Integration with Other Plans and Strategies (completed or underway)	- 2006 Regional Plan incorporated some climate change concerns - Sea level rise being incorporated in new Harbour Plan	- Incorporating into Official Plan (2010) - Heat health response planning - Stormwater management - Transportation planning - Urban forestry	- The Draft Climate Change Strategy will be supported by other regional and municipal plans - Climate Change Mitigation Strategies Report released around the same time as Adaptation Background Report	- Official Plan - 10-year Infrastructure Plan - Water supply planning - Flood planning - Wildfire risk reduction
Current Implementation Activities	- Ongoing research to identify areas and facilities at risk from sea level rise and extreme weather - Requirements for developers to take sea level rise and storm surges into account in planning - Work with Emergency Measures	- Historic climate trends and projections for the region underway - New Intensity, Duration and Frequency curves under development - Detailed risk assessments will be done by all Divisions once pilot testing is complete - Various projects in City Planning, Toronto Water, Toronto Public Health, Transportation Services …	- The Adaptation Background Report highlights existing activities of the six partners in the region - The Draft Climate Change Strategy has not gone before Regional Council as of spring 2011	- The project report and recommendations were received by the City in mid-2009 and an implementation plan is being developed as of spring 2011

Key Adaptation Planning Steps Derived from Guides and Case Studies

An analysis of the available guides and case studies of adaptation planning in Canadian and other communities demonstrates a substantial amount of overlap in the process they recommend or describe. Most include the following actions (though the order in which these steps are taken may vary from guide to guide, and community to community).

- Assemble a team that has or can develop the capacity to address the issues of climate change impacts and adaptation
- Encourage the awareness and engagement of decision-makers, staff, stakeholders and community members
- Analysis of historic climate trends and climate projections for the region
- Get an overview of the areas of likely impacts and vulnerabilities for the community, municipal operations and responsibilities (vulnerability scan or assessment)
- Prioritize areas of risk (most guides suggest using a formal risk assessment process that may include quantitative indicators)
- Assess and choose among adaptation options, keeping in mind sustainability and climate change mitigation goals
- Incorporate climate change adaptation goals in key policies
- Implement projects and programs to reduce risk and increase resilience
- Evaluate the effectiveness of efforts to reduce impacts
- Monitor ongoing changes in local climate and related impacts, and
- Modify programs which prove ineffective in reducing impacts.

The remainder of this course is designed to help municipalities undertake these steps.

MODULE 7: ADAPTATION TEAM

Learning Objectives and Outcomes

By the end of the module, participants will:

- Have an overview of different approaches municipalities have taken to develop a climate change adaptation team
- Have discussed and recommended the make-up, structure and mandate of the ideal adaptation team for their municipality

Introduction

The formation of adaptation team is a critical step in developing and implementing an effective adaptation strategy. A municipality getting ready to initiate or to participate in adaptation planning needs to consider a number of questions that will affect the makeup and purview of the team. These questions include:

- What is the scope and mandate of the adaptation team? (Is the municipality concerned about addressing an array of climate impacts, or one or two priority concerns? Is there a clearly articulated mandate?)
- What skills or knowledge might be required? If these are not readily available, how can they be acquired?
- Which municipal departments and staff need to be involved?
- How might elected officials be involved?
- Are there external agencies which should be involved (e.g. Conservation Authorities, local utilities, business organizations, NGOs)?
- Would a regional approach – working with other municipalities, for example – be workable?
- Are there climate change experts who could contribute to the work of the team, and if so, how might they be expected to participate? (As full members of the team? As advisors? Contributing research?)
- Will private sector consultants be involved in the process? If so, what role will they have? (Analyzing regional climate change trends and projections? Identifying impacts? Gaps analysis of programs? Facilitation?)
- Will community representatives be invited to participate from the beginning, and if so, how will representatives be chosen? How might community representatives change the dynamic compared to an internal municipal adaptation team?
- What are the tasks which the team is expected to carry out? (Is the task limited to an initial vulnerability assessment, after which the municipality will determine what more needs to be done?)
- Are smaller working groups needed to focus on specific tasks or issues?
- What kinds of communication and engagement tools and strategies might be used to involve municipal staff and community members who are not part of the team, and when might these be deployed?
- What is a reasonable timeframe for doing the work?

- How often does the team need to meet? Will meeting frequency change over time?
- To what extent can team members be freed up from other responsibilities to work on impacts assessment and adaptation planning?
- Who will lead or chair the team? To whom does he or she report?
- What kind of budget might be required for this work? What sources of funding from outside the municipality might be mobilized?

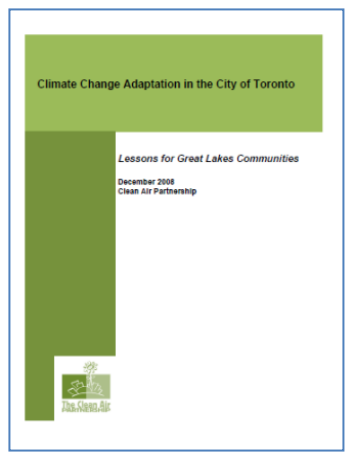
To a large extent, each municipality has to answer these questions on its own. However, several municipalities have undertaken adaptation planning and have insights that could help. These insights have been captured in a number of resources, which we have drawn on in preparing this backgrounder, including:

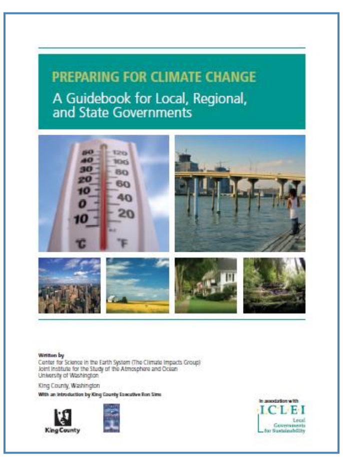
[Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation](#): ICLEI (2010)

This guide provides a detailed overview of the initial steps in the adaptation planning process, including key considerations for identifying and engaging potential stakeholders, and building a climate change adaptation team.

[Climate Change Adaptation in the City of Toronto. Lessons for Great Lakes Communities](#): Clean Air Partnership (2008)

This report includes an examination of the principal actors on Toronto's Adaptation Steering Group, involved in development of the City's adaptation strategy. The report includes a discussion of how they organized themselves and how they reached out to City staff, external experts and the public.





[Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments](#): Climate Impacts Group and King County Washington (2007)

Chapter 6 of this guidebook outlines key considerations for forming a climate change preparedness team, including: when, why, and how to form a team; characteristics to look for in team leader(s) and members; typical work efforts and products; and launching a climate change preparedness effort.

Climate Change Adaptation Resource Kit: Columbia Basin Trust (2008)

This on-line resource is the collaborative effort of several consultants who participated in Columbia Basin Trust's Initiative "Communities Adapting to Climate Change" in 2008-2009. Using examples from Kimberley and Elkford, BC, the Resource Kit outlines key considerations for starting the adaptation planning process, including topics such as identifying a local coordinator/consultant and establishing a local steering committee.

Initiating an Adaptation Process and Team

Adaptation processes and projects get started in municipalities by a variety of actors and for a variety of reasons, all of which will affect the scope, mandate, structure and work of the adaptation team. Someone – or some organization – in the municipality becomes concerned about climate impacts either because of local climate-related events or problems, or because they have been persuaded that such problems may occur. The initiator of an adaptation process might be an environmental officer responsible for work on climate change mitigation; policy or planning staff in a department affected by climate events (e.g. stormwater management, public health, emergency management, etc.); or an elected official. In other instances, this work might be spearheaded by an external organization or individual who persuades the municipal government to embark on an adaptation process, or initiates a community-based process and invites the municipality to participate.

Initiation can be a result of top-down leadership by a political or executive champion. King County, Washington, Executive Ron Sims, for example, read about climate change impacts expected for the region and mobilized staff to begin work on the problem. The leader of his Global Warming Team was his Deputy Chief of Staff and the heads of several key departments were part of the team, which was tasked to work on both mitigation and adaptation. Under his leadership, King County became one of the first local governments to incorporate adaptation into its decision making processes and to implement a number of adaptation strategies.

More often, initiation is a bottom-up process undertaken by concerned staff or by external organizations or researchers who raise awareness of climate change impacts, make available credible information in plain language, and actively lobby for the development of an adaptation strategy. The adaptation team in this case may start as more of an ad hoc group which has to gain the political or executive support it needs in order to justify municipal investment of time and resources into impacts assessment, planning and implementation of adaptation strategies. Gaining the support of decision-makers will usually require a credible analysis of the vulnerability of a community or region to extreme weather and climate change, and some demonstration of steps that can be taken to reduce this vulnerability. Ideally, these steps can be shown to build on actions the municipality or community has already taken.

Team Structure

The size and structure of an adaptation team depends on the type of planning being undertaken and the size and complexity of the municipality. For some municipalities, adaptation planning is mainly an internal process, involving personnel from one or several municipal departments. In the City of Toronto, for example, the Adaptation Steering Group was made up of representatives from 14 city divisions and agencies, as well as a consultant from a closely associated non-governmental agency (Clean Air Partnership). The team was led by the Toronto Environment Office.

In other municipalities, the planning process is more community-based. In Kimberley, British Columbia, for example, the 12-member steering committee involved City staff such as the City Councillor and City Planner, but also included a number of key stakeholders in the community, such as the Nature Park Society and Tourism Kimberley. The project was led by a coordinator paid by the Columbia Basin Trust, which was encouraging communities in the region to undertake adaptation planning.

Some municipalities may also work together on a regional-level adaptation plan. The Region of Peel, for example, is developing a climate change strategy for the geographic region as a whole. The 13-member project team and 17-member steering committee include representatives from the Region of Peel, The City of Mississauga, the City of Brampton, the Town of Caledon, the Credit Valley Conservation (CVC), and the Toronto and Region Conservation Authority (TRCA). (The Steering Committee includes Directors of a number of key departments in the partner organizations.) Consultants have coordinated workshops for the partner organizations, and prepared a lengthy background report incorporating the input of the partners.

An adaptation team can also be formed to tackle a more narrowly-defined climate-related issue. For example, in regions where heat waves are identified as a major problem, participants may include public health departments, energy suppliers and distributors, emergency management organizations, parks and urban forestry managers, planning departments and building officials, all of whom have a role in establishing or maintaining cooler urban environments or responding to heat-related emergencies.

While teams often involve cross-departmental collaboration, there are also examples of effective teams formed within individual departments. In New York City, for example, the Department of Environmental Protection developed an agency-wide Task Force, to ensure that potential impacts of and adaptations to climate change on the City's water supply and wastewater systems were factored into the Department's long-term strategic and capital planning. Task Force members included representatives from seven departments. The principal actors on the Task Force were from water supply, water and sewer operations, and wastewater treatment departments. However, the Task Force also included staff from customer services and environmental compliance. The work of this Task Force led not only to an adaptation plan for the department, but to the creation of the New York City Panel on Climate Change, which advises the Mayor's Office of

Long Term Planning and Sustainability on climate change adaptation issues and options.

Identifying Potential Participants

Early in the adaptation planning process, taking the time to go through a stakeholder identification exercise alongside a few key colleagues can help:

- Ensure that all the relevant players become involved in climate change vulnerability and risk assessments, planning and implementation
- Establish working relationships
- Secure support for the adaptation process and
- Determine how far-reaching initial adaptation activities will be.

The size and structure of the adaptation team may change throughout the process, especially as new information becomes available and the work of the team progresses. Periodically evaluating the match between team members, identified local consequences of climate change, and potential response strategies may help to identify gaps on the team and ensure the right people are included in the planning process.

Municipal Team Members

Many cities and regional governments that have taken leadership on adaptation to date have set up an interdepartmental team or teams to work together on adaptation planning. There are obvious advantages to this approach. The individual members of such teams are much better situated to understand how climate change can impact the operations and facilities of their own departments than someone in a City-wide environmental office. Bringing representatives of different departments together allows them to share information, identify common threats and develop integrated responses.

A key consideration when drawing on internal resources is the authority of its members. Some adaptation guides suggest that the majority of the adaptation team members should be departmental directors with the authority to implement changes recommended by the adaptation team. Some observers, including Cynthia Rosenzweig, who has been involved in adaptation processes in New York City for more than a decade, suggest that an adaptation team made up of mid-level policy and program staff can result in more consistent involvement and attention to the issues. Very busy department heads may not be able to attend regularly scheduled meetings and workshops, and may be able to keep up with the flow of information that is generated by and for an adaptation team. In the absence of representatives with decision-making authority, staff members who have a strong working relationship with department and division managers and who have a track record in securing funding and managerial support will be important.

Peel Region resolved the trade-off between including department heads with authority to make decisions but limited time vs. staff who are able to give the project ongoing attention but do not have decision-making authority, by establishing a Steering Committee of directors and a Project Team to do the day-to-day work.

Team Members from Outside Municipal Government

Expertise from outside local government can be mobilized to help communities with climate change impact assessments, adaptation planning and implementation. Representatives from outside organizations can bring specialized knowledge and fresh perspectives to the table, and help ensure that a given adaptation strategy is relevant, workable and supported by the broader community. Examples of potential team members from outside municipal government include:

- Representatives of arms length agencies such as Conservation Authorities or utilities
- Social service agencies working with vulnerable people
- Government or university-based climate scientists
- Business organizations concerned about local impacts
- NGOs and/or consultants working in the field.

Some municipalities have worked with outside representatives as fully participating members of their adaptation team. Others have chosen to establish an Advisory Committee or Expert Panel with expert participation to provide input throughout the vulnerability assessment or adaptation planning process. Municipalities may also choose to invite experts to comment on draft plans and strategies. Inviting local experts to conduct workshops for staff or participate in working groups is another way to mobilize local expertise, and contributes to building the capacity of staff and other stakeholders.

Table 1: Examples of Organizations that Might be Represented on a Climate Change Adaptation Team

Municipal Departments	
Building	Parks and Recreation/Urban Forestry
City Manager's Office	Planning
Economic Development	Public Health
Emergency Management	Roads/Transportation Services
Energy efficiency	Sewage and Wastewater Treatment
Engineering/Municipal works	Social Services/Social Housing
Environment	Stormwater management
Facilities	Urban forestry
Finance	Water
Fire	Waterfront
Other Potential Organizations to Include	
Business representatives	Neighbouring governments
Conservation Authorities	Non-profit or community organizations
Consulting firms with related experience	Provincial departments
Federal departments	University-based researchers
First Nations	Utilities

Mandate

Developing a formal mandate for an adaptation team can help ensure that team members develop a clear understanding of the purpose of the team and the time commitment required. If such a mandate is approved by Council or by senior executives on staff, it may help in securing resources to do the job. A team can act without a formal mandate in place, but it becomes harder to maintain momentum if and when municipal priorities change.

ICLEI and other sources suggest several questions to consider in establishing a mandate for an adaptation team:

- Will the adaptation team be established as a temporary or permanent working group?
- What work is the team required to do?
- How much time does the team have to accomplish these deliverables?
- To whom does it report?
- What authority does the team have (to get information from municipal departments, for example)?
- What resources will be made available for the team to accomplish its work?

Taking time at the start of the adaptation planning process to answer these questions may go a long way to helping keep the team focused and on track.

Functioning

Teams that have been successful at moving the adaptation agenda at the municipal level have shared a number of characteristics:

- In the beginning of their work the team – or a smaller working group – met as often as once a week
- The team was able to find and analyze climate trends data; undertake a vulnerability or impacts assessment; secure council commitment to tackling adaptation over the short- and long-term; outline some key areas where further detailed research and analysis was necessary to flesh out adaptation options and strategies; and conduct workshops to engage elected officials, staff and/or community members on the issue
- The team either had an internal research capacity (and time) or was able to get help from consultants or collaborating organizations to make the case for tackling the impacts of extreme weather and climate change, or the team was able to write/commission a report that made this case
- The team was able to secure internal or external funding to support its work
- The team had or was able to secure the support of politicians or executive officers who were very interested in seeing progress made on the file
- Many, if not all, of the members of the initial team had a strong interest in and commitment to the work (Though adaptation teams can work with members who may be sceptical about the value of interdepartmental or community-based teams, or feel

that adaptation planning is diverting them from more important tasks, it may be very hard to move forward if a vehement climate change denier is on the team!).

Leadership and Coordination

Adaptation planning requires strong leadership. A team leader – who may be referred to as chair of the adaptation committee, adaptation coordinator, or other title – is usually appointed or hired to oversee the activities of the team. Responsibilities may include:

- Collecting and keeping up with relevant climate change and adaptation information and passing it on to team members
- Writing or overseeing the writing of draft reports
- Organizing and facilitating/chairing meetings
- Liaison with external groups and experts
- Coordination of internal or community capacity building workshops
- Developing and managing a website
- Responding to requests for information
- Promoting adaptation activities and programs
- Drafting funding proposals and reports.

The location of the team leader can vary from one municipality to the next. In some municipalities, coordination may come from a senior official in the office of the CAO or City Manager, which can help keep the attention of senior decision-makers. In others, the team leader may be situated at a departmental level, such as Environmental Services.

A basic understanding of climate change and climate change impacts on the part of the team leader is desirable, but is an asset that can be improved through literature reviews, meetings with local experts, seminars and conferences, etc. It is far more critical that the leader have strong managerial skills, including an ability to effectively facilitate group interactions, with a view to keeping a diverse group of team members focused on a common goal.

Knowledge and Skills of the Adaptation Team

There are a number of desirable areas of knowledge and skills that are useful in an adaptation planning context. Knowledge areas that may be useful at the outset of adaptation planning or that would usefully be developed early in the process include:

- Current and recent historical climate parameters in the region/ community
- Basic understanding of climate change science, projections and uncertainties
- Ways in which urban areas and populations contribute to climate change
- How climate parameters (temperature, precipitation, windspeeds, seasons, etc.) can affect urban systems
- Functional knowledge of the workings of municipal infrastructure systems

- Municipal programs that are already in place to reduce the impacts of extreme weather and their effectiveness
- Municipal decision-making structures, policies and procedures and ways to access or influence them.

Skills that would be very useful to have on the adaptation team include:

- Big picture thinking
- Ability to comprehend and explain complex systems and interactions
- Facilitation skills
- Persuasiveness
- Strong written and verbal communication skills.

Again, the suite of knowledge and skills brought to the table will vary depending on the size and make-up of the adaptation team. Although a larger team can be more challenging to manage from a logistical perspective, having a larger pool of knowledge and skills to draw from can lead to a more far-ranging dialogue and more comprehensive and integrated adaptation plan.

Knowledge and Skill Development

An adaptation plan will evolve as new information and resources become available. As such, helping team members to advance their knowledge and skills will ensure that the resulting adaptation plan is relevant and up-to-date. Familiarizing staff with climate change impacts and adaptation, for example, can be accomplished through a number of channels such as[1]:

- Sending staff to external workshops, conferences, seminars and webinars related to climate change impacts and adaptation
- Organizing internal workshops and learning events
- Collecting, organizing and providing staff with existing research and best practices and
- Involving staff in research to better understand climate trends and regional climate projections.

There are a number of organizations that offer regular knowledge-building events, such as workshops, conferences, seminars and webinars. These include the Clean Air Partnership, ICLEI, the Institute for Catastrophic Loss Reduction (ICLR), the Ontario Center for Climate Impacts and Adaptation Resources (OCCIAR) and the Federation of Canadian Municipalities. Municipalities are encouraged to contact these organizations to learn more about upcoming events.

[1] *Climate Change Adaptation in the City of Toronto: Lessons for Great Lakes Communities*. Clean Air Partnership, Toronto (2008).

Municipalities can benefit greatly from taking the time to develop staff knowledge and skills. The City of Toronto, for example, undertook all of these activities during its adaptation planning process. Several members of the City's Adaptation Steering Group attended an adaptation symposium in September 2007, and participated in the Clean Air Partnership's Alliance for Resilient Cities (ARC) webinars as well as relevant webinars and seminars offered by the Federation of Canadian Municipalities, Environment Canada and ICLR.

Conclusions

The formation of an adaptation team is an important step in developing and implementing a climate change adaptation strategy. There is no one single approach to developing an effective adaptation team. Each municipality is faced with its own unique set of circumstances – everything ranging from likely climate change impacts to government priorities to intradepartmental resources – therefore the size, structure, and objectives of each municipal team will differ. Municipal staff are encouraged to talk to representatives from other jurisdictions who have undertaken, or are currently undertaking, a planning process, and to consult available guidebooks and other resources, in order to determine what type of team will best suit their planning needs.

MODULE 8: MAINSTREAMING ADAPTATION INTO MUNICIPAL PLANS AND GOALS

Learning Objectives and Outcomes

By the end of the module, participants will:

- Have considered a sample of municipal plans and discussed ways in which adaptation could be integrated into them
- Have prioritized for their own communities the plans into which adaptation should be integrated.

Introduction

There is considerable discussion in the adaptation literature about “mainstreaming” climate change adaptation into ongoing activities of organizations responsible for facilities, infrastructure, programs and services that are likely to be affected by climate change.

Mainstreaming means integrating climate change considerations into ongoing planning and decision-making. Adaptation becomes the responsibility of all affected sectors, rather than the purview of a single authority, although it still requires coordination. The King County guide to adaptation in local government refers to mainstreaming as developing more systematic ways of addressing climate change in government activities, and making decisions more robust to a range of climate change scenarios. Mainstreaming is likely to involve incremental changes in existing policy over time, as new information becomes available.

The goal of mainstreaming is to have climate change considered as one of many important factors in decision-making, in the same way that decision-makers at all levels are increasingly considering the energy (and emissions) implications of municipal policies, programs, operations and facilities. Arguments in support of mainstreaming are:

- Climate change will impact most sectors, and adaptation will require a broad suite of measures to be effective
- Because climate change will continue for the foreseeable future, adaptation requires on-going action, cooperation and collaboration
- Solutions require the knowledge of sectoral specialists, and
- Political and institutional changes are needed as well as new technical applications.

Explicit commitments to address climate change impacts in municipal plans are important because they demonstrate support for adaptation at the highest levels. Such statements may include a commitment of financial, human and technical resources and may also establish timelines for the development of related programs.

Municipal Goals and Plans that Could Incorporate Climate Change Adaptation

There are a variety of goals and plans that could or should explicitly incorporate references to climate change impacts and commitments to adaptation. In the material that follows we show how a number of municipalities and regional governments have already begun to integrate or mainstream adaptation into:

- Municipal vision statements
- Sustainability plans and goals
- Official plans and land-use planning
- Community improvement plans
- Stormwater management plans
- Source water protection plans
- Water conservation plans
- Transportation planning
- Infrastructure master plans
- Environmental assessments
- Financial plans and reserve funds
- Emergency management
- Community/district energy plans

Municipal Vision Statements

A municipal or community vision statement is often the result of an intensive process involving elected officials and community members. The process results in a vision of the future of the community which is intended to guide decision-making in the present. The process of creating a vision statement tends to support long-term thinking among the participants (though it is uncertain how much a vision statement actually affects subsequent decision-making).

Vision statements can stand alone, but more often are developed as part of a planning process for municipalities, and are often included as part of an Official Plan, Integrated Community Sustainability Plan or other plan. Many community vision statements describe a future community with strong environmental values. A smaller number incorporate a sustainability perspective. Not many yet feature a future community that is resilient to climate change.

Sustainability Plans and Goals

During the last 15 years, a growing number of Ontario communities have developed community sustainability plans and goals. This process has been stimulated by the federal Gas Tax Fund which since 2005 has provided municipalities with a portion of federal gas tax revenue for environmentally sustainable infrastructure including: public transit systems; water and sewer systems; stormwater management; solid waste management; community energy systems; and more. Participating municipalities in Ontario must show how existing plans provide a coordinated approach to community sustainability or prepare an Integrated Community

Sustainability Plan. Except for the City of Toronto, the Gas Tax Fund is administered by the Association of Municipalities of Ontario (AMO).

AMO has developed a Sustainability Planning Toolkit to help Ontario municipalities develop integrated sustainability plans. The toolkit includes a checklist of potential sustainability goals and initiatives that municipalities might embrace. A number of these initiatives can contribute to climate change adaptation and resilience in the face of climate change, although they are not identified as such in the toolkit. These include:

- Water protection plans; water distribution system upgrades; measures to capture rainwater;
- Energy conservation; co-generation of heat and electricity; renewable energy initiatives;
- Maintenance/increase of green space.

Few Ontario communities have developed sustainability plans that explicitly address climate change impacts and adaptation. The Town of Markham's draft Greenprint Sustainability Plan is an exception. Markham's Plan includes twelve "Sustainability Priorities", one of which is "Energy and Climate". See the box below.

EXCERPT FROM MARKHAM'S GREENPRINT SUSTAINABILITY PLAN

Energy and Climate: Carbon Neutral, Responsible and Resilient

Construct and retrofit communities so that they can easily evolve in response to challenges and opportunities resulting from climate change in order to create resilient community systems and provide a flexible platform for adaptation.

Adaptation and resilience recommendations identified in Markham's Greenprint Sustainability Plan include:

- *Build and retrofit public infrastructure systems, and develop programs that support net zero resource use*
- *Employ distributed, but interconnected, networks of smaller energy and water systems that will be smart, flexible and adaptable that also can adapt to climate change*
- *Implement and integrate into the planning process context-appropriate stormwater management practices that first use ecological processes like bioswales, permeable pavement, street trees and others before harvesting the resource for non-potable water supply*
- *Ensure a site's natural hydrology is maintained and enhanced*
- *Increase tree and green coverage in Markham to reduce urban heat island effects, lower ambient temperatures, and reduce summertime cooling demands, in order to decrease overall energy use*
- *Improve natural processes in urban areas by using native and resilient plant species.*

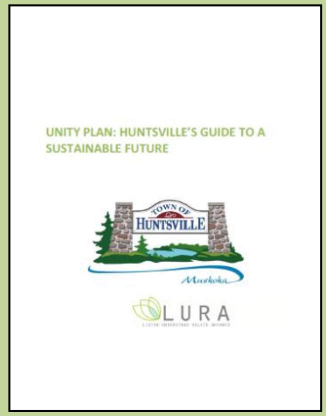
The Town of Huntsville, Ontario has also made sustainability a community priority with its recent *Unity Plan: Huntsville's Guide to a Sustainable Future*. The Unity Plan is a high level document that guides all aspects of the town's growth, development, plans, policies and initiatives, including the official plan, community improvement plans, budget, and cultural plans. Huntsville has recognized that in order to be a sustainable town moving forward, they must prepare for climate change, referring to it as one of the "universal focus areas of the Unity Plan" (p. 42).

EXCERPT FROM THE TOWN OF HUNTSVILLE'S *UNITY PLAN*

Goal #2: Municipal Operations and Infrastructure

The Town of Huntsville will strive to be a model sustainable community, by reducing its impact on the environment, and planning for climate change adaptation by following best management practices in all municipal operations and infrastructure projects and by leading by example (p. 10).

To help in this process, the Town will: "*institute a policy that senior staff stay up to date on sustainability and climate change adaptation best practices*" (p. 12) and consider climate change adaptation in the development of a municipal infrastructure sustainability plan (p. 13).



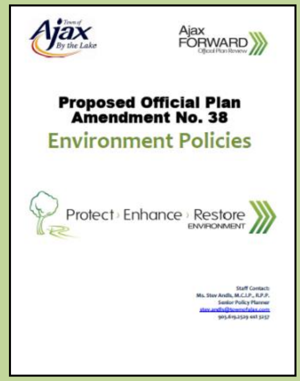
Official Plans and Land-use Planning

Land-use planning plays a significant role in shaping the overall health and resiliency of communities and municipalities. Through strong, well-articulated land use plans, municipalities can structure a process for making their communities more resilient in the face of climate uncertainty. Municipalities may incorporate climate change policies and identify specific actions to achieve climate change objectives in their Official Plans. Using the Official Plan as a guide, Council may adopt more detailed plans and specific regulatory measures. Municipal Official Plans must be reviewed not less than every five years.

As this training program is being written, several Ontario communities are working to include climate change impacts and adaptation in their Official Plans. The Town of Ajax, for example, is working to incorporate climate change adaptation into its Official Plan. Official Plan Amendment No. 38 (OPA 38), drafted following the Town's Official Plan Review in 2005, is intended to update Ajax's existing Official Plan to conform to the environmental provisions of the Provincial Policy Statement and Provincial Greenbelt Plan. More importantly, however, OPA No. 38 introduced policy direction regarding new and emerging environmental issues and concerns, including predicted local impacts of climate change and resulting adaptation and mitigation strategies. The Proposed OPA No. 38 was approved and adopted by Ajax Council in June 2010 and is currently awaiting approval from the Region of Durham.

EXCERPT FROM THE TOWN OF AJAX'S PROPOSED OFFICIAL PLAN AMENDMENT NO. 38

2.1 CLIMATE CHANGE CONTEXT AND GENERAL ENVIRONMENT POLICIES



The Town recognizes that clean water, clean air, safe and secure shelter and infrastructure, employment, community facilities and programs, public open space, a protected natural heritage system, protected agricultural land, and locally grown foods are needed to sustain a healthy community.

Climate change is occurring rapidly. In the Greater Golden Horseshoe, climate change is predicted to be characterized by: more frequent and severe wet weather events, such as flooding and tornadoes; higher air temperatures; warmer water temperatures in surface runoff, creeks and Lake Ontario; stronger winds; more surface runoff in winter and less in summer and fall; more evaporation; and less infiltration.

Consequently, the Town shall plan to address climate change mitigation and adaptation strategies. By doing so, Ajax shall enhance its adaptive capacity to moderate potential damages, take advantage of opportunities, and better cope with the consequences.

The City of Ottawa is also planning to incorporate climate change into its Official Plan. In preparation for an Official Plan Review in 2008, the City developed a series of White Papers, one of which addressed the issue of incorporating climate change into the Official Plan. *Climate Change and the Official Plan Review* provided a brief outline of climate changes expected in Ottawa, and of the primary sources of greenhouse gas emissions in the City. It also outlined the ways in which existing provisions of the Official Plan contribute to mitigation and adaptation.

EXCERPT FROM THE CITY OF OTTAWA'S OFFICIAL PLAN AMENDMENT

3. The City will take measures to adapt to the effects of climate change by:


White Paper
Climate Change and the Official Plan Review

a. *Completing a climate change adaptation strategy*
b. *Considering the potential impact of climate change and adaptation strategies when completing environmental management and sub-watershed plans*
c. *Ensuring that development accounts for potential natural hazards resulting from extreme weather events such as flooding and slope failure.*
d. *d. Reducing the urban heat island effect through landscaping, tree planting, and encouragement of courtyards and innovative green spaces with permeable surfaces and trees and of green building measures such as the use of green roofs, living walls and light coloured building materials* (2009a, p. 55)

Community Improvement Plans

Community Improvement Plans (CIPs) target specific areas of the community for development or redevelopment. Initially, CIPs were developed mainly for downtown revitalization, brownfield remediation and heritage conservation projects. MMAH points out, however, that municipalities can also use CIPs to address climate change mitigation and adaptation by means of:

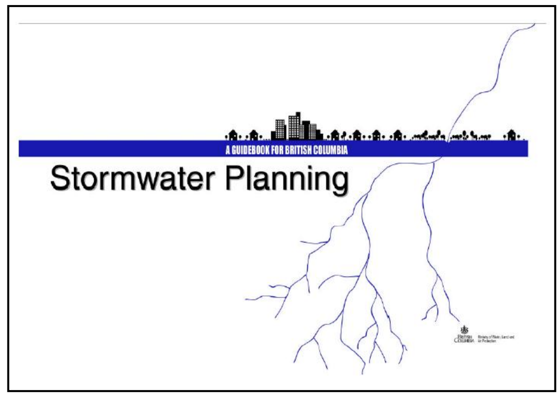
- building retrofits for energy efficiency (and protection from extreme heat or other forms of extreme weather)
- renewable and district energy systems
- low impact stormwater systems
- water conservation systems
- open space improvements including tree planting
- features that increase shade
- light coloured surfaces for pavement, roads and buildings
- permeable pavements and other features.

In 2008, MMAH developed a [Community Improvement Planning Handbook] to help municipalities with their CIPs. Although they have the potential to specifically address climate change action as a focus, few CIPs have done this to date.

Stormwater Management Plans

The increase in floods and flood damages in recent years has encouraged communities across Canada to revisit their stormwater management plans to take into account the potential impacts of climate change.

The government of Ontario has not yet provided advice with respect to incorporating climate change into municipal stormwater management planning, although the Province's new adaptation strategy, *Climate Ready: Ontario's Adaptation Strategy and Action Plan*, released in late April 2011, commits to doing so. In 2002, the government of BC released the guidebook *Stormwater Planning: A Guidebook for British Columbia,* which advised municipalities in that province to take into account expected increases in rainfall and flooding due to climate change.



In line with these recommendations, Metro Vancouver developed a Liquid Waste Management Plan that considers climate change, demographic change and aging infrastructure as factors to consider in long-term resiliency planning.

Many communities in Ontario have also begun to explicitly include climate change considerations into stormwater management plans. These include:

- The City of London, which has collaborated with researchers at the University of Western Ontario to incorporate climate change projections into stormwater and flood management planning. Researchers at the university's Department of Civil and Environmental Engineering undertook a study of the City's rainfall intensity, duration and frequency (IDF) curves to help determine what impacts climate change may have on future rainfall intensities. The report recommended that the City of London evaluate potential change of IDF curves in the range of 20% as a result of changing global climate models and that further analysis of the City's water infrastructure and management practices be undertaken. The City has been receptive to the research findings, with the results beginning to be reflected in planning for the municipal sewer and stormwater management infrastructure systems. As of January 2011, comprehensive engineering and scientific assessments were being undertaken to determine the risks that increased rainfall will have on municipal services in the future as a result of climate change.

- The City of Cambridge is preparing a new Stormwater Management Master Plan, for delivery in 2011. Cambridge is prone to flooding and the City has recognized the imperative to plan future stormwater management upgrades with climate change in mind. In their preliminary documents, the City notes that infrastructure may become stressed as a result of more intense weather events leading to flooding, and that a risk management approach to designing stormwater infrastructure will be required.

Source Water Protection Plans

Understanding the impacts and challenges climate change will have on source water systems will be critical to keeping drinking water supplies safe into the future, as the hydrological cycle is very sensitive to the changes in temperature and precipitation that climate change will bring.

As of early 2011, almost all Ontario's Source Water Protection Areas have developed, or are developing an Assessment Report for approval by the Ministry of the Environment. The Toronto and Region Source Protection Area (TRSPA) recently submitted their Assessment Report, which:

- Identifies areas where municipal drinking water sources may be at risk from both quantity and quality perspectives
- Assesses the level of risk, and
- Recommends measures to eliminate or manage the risks.

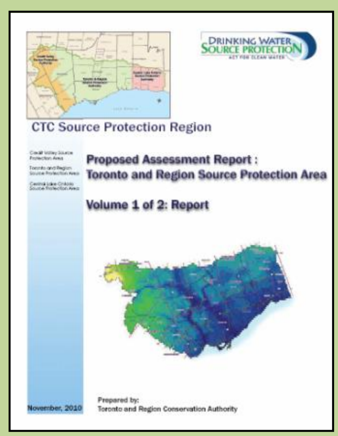
The Report briefly discusses the potential impact of climate change, recognizing that it must be considered as part of the threats assessment. Impacts such as seasonal water shortages, higher intensity storms and severe flooding events are some of the expected impacts, and underscore the need for adaptive management strategies to manage water resources.

Section 5.4 of the Report highlights areas in which the TRSPA is addressing and adapting to climate change impacts.

FROM THE TORONTO AND REGION SOURCE PROTECTION AREA DRAFT ASSESSMENT REPORT

The TRSPA identifies a variety of initiatives underway to assess and adapt to climate change. These include:

- Enhancements to the Regional Monitoring Program to measure seasonal variations and trends in local climate
- Staff participation on provincial committees developing the science behind climate change modelling
- Sustainable Communities Evaluation Program (STEP) which tests innovative water management practices that could be employed to mitigate the effects of climate change
- Collaborating with York University and the Ministry of the Environment to develop training materials on climate change science and integration with source protection.



The TRSPA submitted its Assessment Report to the Ministry of the Environment for approval on December 21, 2010, after which a Source Water Protection Plan will be developed and public consultations undertaken.

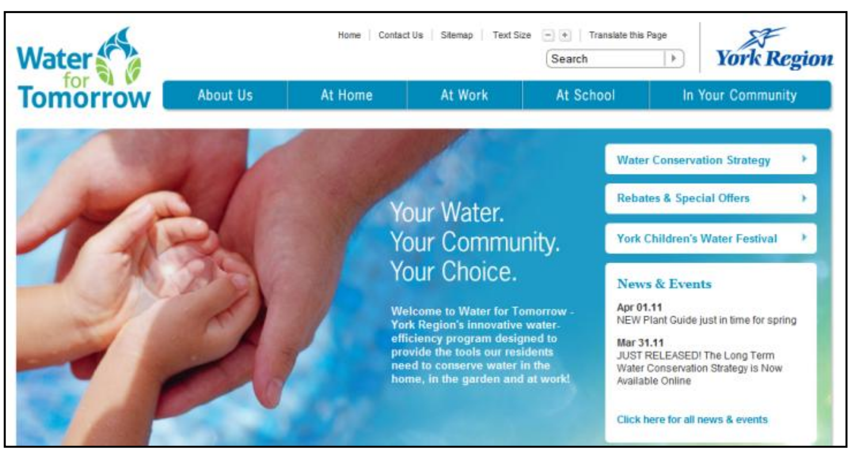
Water Conservation Plans

Although generally considered a water-rich province, Ontario is not immune to water shortages or drought events. Water shortages and droughts have been documented in southern regions of the province, and are projected to become more frequent as summer temperatures and evaporation rates increase. As such, water conservation planning is critical to ensuring that municipalities are prepared to face situations of decreased water availability.

Water conservation is also important for reducing energy consumption. Because water treatment and distribution systems are energy intensive, water conservation is considered one of the most cost effective municipal strategies for reducing energy consumption. This means that water conservation can make both water supply and electricity supply systems more resilient, especially in periods of peak demand when both water supply and electric power capacities are stretched.

On November 23, 2010, the Province passed the Water Opportunities and Water Conservation Act that, together with other efforts to encourage and promote conservation measures will require municipalities and other water service providers to begin the development of water conservation plans. Part III of the Act outlines how municipalities can identify and plan for long term infrastructure needs within water sustainability plans. The Act indicates that the regulations may require a plan to deal with “an assessment of risks that may interfere with the future delivery of the municipal service, including ... the risks posed to climate change and a plan to deal with those risks.”

York Region’s Water for Tomorrow conservation program includes a successful initiative to reduce municipal water leakage. The Region estimates that the program saves 8.1 million litres of water a day. This in turn has led to energy savings of 2,000,000 kWh a year. While not specifically addressing the impacts of climate change adaptation, the Water for Tomorrow initiative has begun to reduce the Region’s vulnerability to future climate change-related droughts, leveraging its high rates of growth to help contribute to the financial capacity to institute long-term conservation programs and expand water resources infrastructure, storage and new sources of supply.

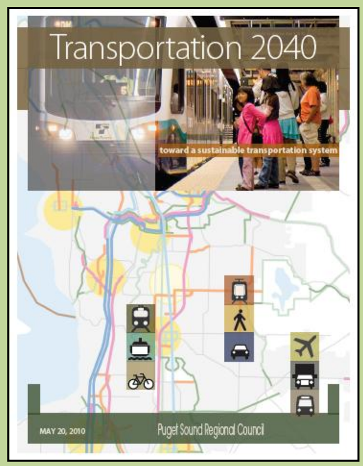


Transportation Planning

Transportation planning related to climate change tends to focus mainly on measures to reduce greenhouse gas emissions rather than adaptation measures. Where these plans do mention adaptation, emphasis is on building awareness of the issues and conducting research. However, some jurisdictions are beginning to acknowledge the need to adapt to climate change in their latest plan updates. York Region, for example, in its report *Moving on Sustainability: Transportation Master Plan Update*, has committed to "design a transportation system that is energy efficient and mitigates and adapts to the impacts of climate change" (York Region 2009), though the particulars of how this will be accomplished are not yet clear.

Transportation 2040 is an example of a regional transportation plan that takes climate change into account. The plan was developed for Puget Sound, the region surrounding Seattle, Washington. It takes into account the potential impacts of climate change on transportation infrastructure in the region, including port areas which would be most affected by rising sea levels (p. 37). The Plan also appends a white paper that addresses climate change mitigation and adaptation issues in transportation planning.

EXCERPT FROM THE PUGET SOUND TRANSPORTATION 2040 PLAN



The potential impacts to transportation infrastructure from climate change include, among other things, increased flooding and deterioration of roadways. The planning horizon currently extends 20-30 years, but adaptive response to a changing climate may call for a much longer planning horizon. Other potential strategies could include the following:

Changes to the design assumptions of roadway and other facilities.

For example, the design of facilities such as bridges may have to be re-evaluated, similar to what has been done on the three projects mentioned in Section 5, to consider the potential future impacts from increased flooding and higher water levels.

Changes to the siting of new facilities.

For example, current planning may allow the siting of facilities and infrastructure in locations that may be vulnerable under scenarios of increased flooding or sea level rise.

Creating operational response plans.

To create a more resilient transportation system, expanding the redundancy of systems could be considered, including an analysis of the connectivity and vulnerability of the system.

Incorporation of the expected increases in maintenance costs in long-range planning and capital budgets.

Inventory of critical, high-value infrastructure to evaluate the potential risks from the impacts of climate change (p. L-21).

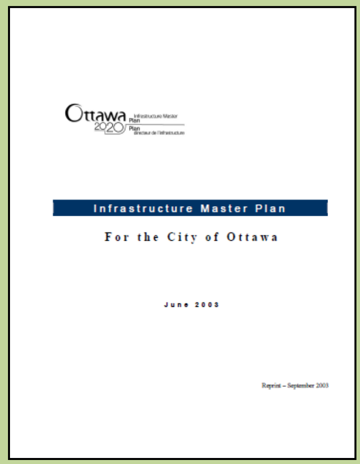
Infrastructure Master Plans

Some municipalities have developed infrastructure master plans that integrate planning for all or most of their major infrastructure systems. The integration of these plans makes it easier to coordinate municipal growth and redevelopment. In turn, this can make integrating climate change adaptation processes an easier process. The City of Ottawa's *Infrastructure Master Plan* (last updated in 2009) integrates growth planning with that of water, wastewater and stormwater infrastructure. The plan addresses the need for adapting to climate change impacts, and outlines preliminary strategies for stormwater management and groundwater resources.

EXCERPTS FROM OTTAWA'S INFRASTRUCTURE MASTER PLAN

5.2.2 Stormwater Management Policies

... [T]he anticipated impacts of climate change have been reflected in a policy calling for the implementation of "robust" drainage systems that will improve protection for events that exceed the design criteria capacity. (p. 48)



5.4.2 Land Use

Develop water balance methodologies for area groundwater resources and monitor long range stresses, such as climate change and land use change, to understand possible impacts on water balance. (p. 59)

6.1.6 Assess Impacts of Climate Change on Capacity Management [for water, wastewater and stormwater]

Although the City has an abundant supply of water, available information on climate change suggests that climate change could negatively affect current capacities of the City's sewer systems. Climate change impacts are anticipated to include an increase in extreme wet weather events although generally conditions may be drier for the latitude that includes Ottawa…

The City will:

In its investigation of the potential impacts of climate change on its sewer systems, take into account the factors related to the accommodation of future intensification in constrained systems.

Research and investigate the literature available on the anticipated impacts of climate change on sewer systems in similar climatic areas to that of Ottawa and ensure that the complexity of factors related to constrained sewer systems and growth pressures is thoroughly assessed in relation to any system changes resulting from this investigation; and

Where specific measures are pursued to mitigate the impacts of climate change on the sewer systems, give greater consideration to the construction of green infrastructure measures and to corrective and rehabilitative measures such as dual drainage designs where existing systems are most constrained and intensification is anticipated. (2009b, p. 74-75)

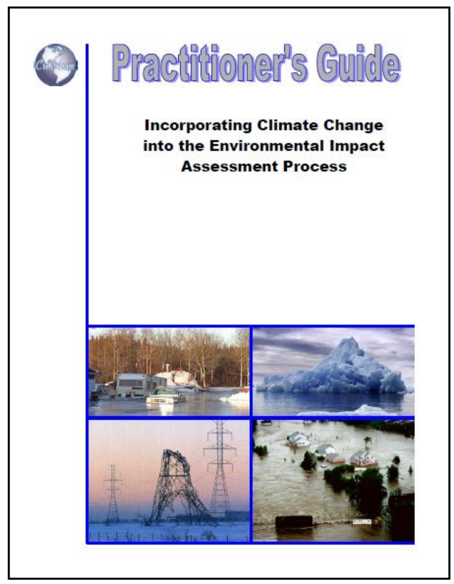
Environmental Assessments

Environmental assessments investigate the effects of proposed projects or developments on the environment. In Ontario, environmental assessments must be undertaken by all public sector proponents – federal or provincial departments or ministries, Crown corporations, and municipalities – before undertaking large infrastructure projects. The environmental assessment process in Ontario is based on broad principles that do not mention climate change. However, these principles may easily be interpreted to allow for action on climate change adaptation to be included in the process.

The Canadian Environmental Assessment Agency, in its 2003 report *Incorporating Climate Change Considerations in Environmental Assessments: General Guidance for Practitioners*, argues that the consideration of climate change impacts on a project should be a standard part of environmental assessment practice. In particular, looking more closely at climate change adaptation necessitates the consideration of:

- Changes that may occur to parameters such as temperature, wind characteristics, precipitation, ecological conditions, growing season, groundwater and surface water levels, etc. over the lifespan of the project;
- Impacts of these changes on the Valued Environmental Components within the boundaries defined for the environmental assessment, and
- Changes to the project itself because of climate change over its life, which may significantly alter key characteristics of the project.

In 2003, ClimAdapt, working with Halifax Regional Municipality in Nova Scotia, developed the guide *Practitioner's Guide to Incorporating Climate Change into the Environmental Impact Assessment Process*. They pointed out that inserting climate change concerns should not change the essential steps or sequence of the EA process, but it will influence outcomes of the various EA process steps.



Financial Planning and Reserve Funds

The costs to municipalities of extreme weather can be large and put considerable strain on municipal finances.

For example, the City of Toronto was faced with a $10 million budget shortfall after heavy winter storms in 2007/2008. In response to the growing challenge of extreme weather and concerns about future events resulting from climate change, the City created an Extreme Weather Reserve Group of affected City departments. This group recommended setting up an Extreme Weather Reserve Fund that "mitigates the financial impacts arising from extreme weather conditions on the operating and capital budgets of the City's programs and services, by providing funding at the end of the year to offset partly a budget deficit resulting from unbudgeted and uninsured weather-related costs incurred during the year."

Separate accounts were created within the fund, one for Transportation Services and another for Parks, Forestry and Recreation. As of March 2010, the Transportation Services account contained $19.142 million in available funds. However, contributions to the Reserve Fund are provided from end-of-year surpluses which, given the economic climate, may be infrequent.

The City of Burlington has also recognized the need to plan financially for extreme weather events. In 2010 Burlington established a Severe Weather Reserve Fund, expanding the mandate of an older Winter Control Reserve Fund to include all weather events. As of summer 2010, the fund has grown to $2.5 million.

London also has a Severe Weather Reserve Fund to help mitigate the costs of extreme winter weather. Surpluses from the Environmental and Engineering Services Department incurred during years with lighter snowfall would be added to the fund to be withdrawn during subsequent winters with heavier snowfall.

Emergency Management

Extreme weather-related hazards are a major reason municipalities need to prepare emergency management plans, and with a changing climate, these extreme events are likely to occur more often and may put municipalities at greater risk.

An important component of emergency management is risk reduction. The U.S. Federal Emergency Management Agency (FEMA) noted that for every $1 spent on adaptation measures in the prevention stages, $4 could be saved from the costs of response and recovery.

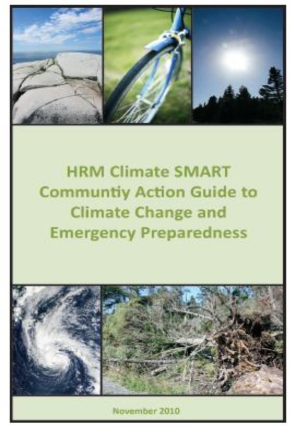
The Emergency Management Act requires Ontario municipalities to have a well-articulated risk-based management plan to prepare for unexpected emergencies that threaten human health, infrastructure or property. They are required to have a trained emergency management coordinator, control group and operations centre. They are also required to review the emergency response plan annually and to conduct public education on municipality-specific hazards.

The Ontario emergency management approach is composed of five pillars: Prevention, Mitigation, Preparedness, Response, and Recovery (EMO 2008). Within this framework of emergency management response there is plenty of room for municipalities to incorporate adaptation measures into their own overall emergency management responses. In *The Ontario Emergency Management Act and Municipal Climate Change Strategies*, a report prepared for the City of Hamilton in 2005, Adam Hyslop argued that climate change "should be a key factor in every step of the Emergency Management Program's development and implementation."

Halifax Regional Municipality (HRM) was one of the earliest Canadian communities to include adaptation as an important consideration in its emergency planning. In its Climate SMART Community Action Guide to Climate Change and Emergency Preparedness, HRM laid out a step-by-step guide for its citizens to anticipate, prepare for and respond to climate-related emergencies.

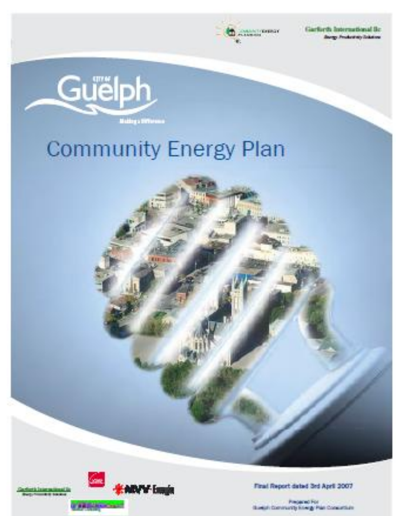
EXCERPT FROM THE HALIFAX REGIONAL MUNICIPALITY`S *CLIMATE SMART COMMUNITY ACTION GUIDE TO CLIMATE CHANGE AND EMERGENCY PREPAREDNESS*

1. *Step One: Be aware of how our community may be at risk from climate change.*
2. *Step Two: Know our vulnerabilities and resources.*
3. *Step Three: Minimize our risks through adaptation actions.*
4. *Step Four: Prepare a Climate SMART Action Plan to address climate related emergencies:*
    - *What to Do Before*
    - *What to Do During*
    - *What to Do After*
5. *Step Five: Publicize, test & evaluate the Climate SMART Community Action Plan* (p. 6).



Community/District Energy Plans

Community energy plans are long-term plans that evaluate a community's existing energy use and supply. The goal is to reduce energy consumption, improve efficiency, and increase renewable energy supply. Although most community energy plans do not address climate change adaptation explicitly, they can help strengthen the resilience of urban energy systems by reducing stress on electricity distribution systems – especially during periods of peak demand – and therefore vulnerability to climate change.



In 2004, the City of Guelph formed a Consortium involving the municipality, businesses, utilities and academics to develop a Community Energy Plan that:

- Encourages building efficiency
- Reduces transportation emissions
- Maximizes power use from locally available renewable resources, and
- Reduces peak summer demands on the electrical grid by 40% by 2031.

In the Town of Markham, 700 acres (283 hectares) of its developing town centre will be powered largely by Markham District Energy. The system consists of four plants supplying thermal and electrical services to 1.86 million square metres of office, commercial and residential space at higher-than typical densities for suburban communities.

Markham District Energy Inc., wholly-owned by the Town of Markham, will produce 3.5 MW of power at peak times that it can sell back to the grid and produce 50% fewer greenhouse gas emissions compared to a business-as-usual approach. The drivers and rationale for initiating the district energy system include;

- The 1998 ice storm and how it affected Ontario communities
- Smart growth and sustainability principles
- A major business opportunity for Markham that required security of energy supply.

Conclusions

Climate change is expected to impact many municipal sectors and services. Efforts must be made to integrate climate change considerations into ongoing planning and decision-making. By mainstreaming adaptation into plans and policies, municipalities ensure that climate change adaptation becomes the shared responsibility of all affected sectors.

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MODULE 9: COMPONENTS FOR DEVELOPMENT OF AN ADAPTATION PROGRAM

Learning Objectives and Outcomes

By the end of the module, participants will:

- Have discussed possible components of departmental, municipal or regional climate change adaptation programs
- Have reviewed examples of specific programs that have incorporated a number of these components.

Introduction

Mainstreaming goes beyond the incorporation of adaptation commitments and goals into high-level policies and plans, as discussed in the previous module. A municipality will need to implement a portfolio of activities to tackle particular climate change impacts and increase resilience.

Table 1 outlines the range of activities that may be part of a departmental, municipality-wide or regional adaptation program. Not every adaptation program will incorporate all of these activities. The mix of activities that make up a specific adaptation program will depend on the climate risk being addressed, the authority of the department or municipality, available resources and other factors.

Because planned adaptation to climate change is new for most municipalities, there are relatively few fully developed adaptation programs in Ontario or elsewhere that can serve as examples. Consequently, the material that follows draws on examples from across Canada and internationally.

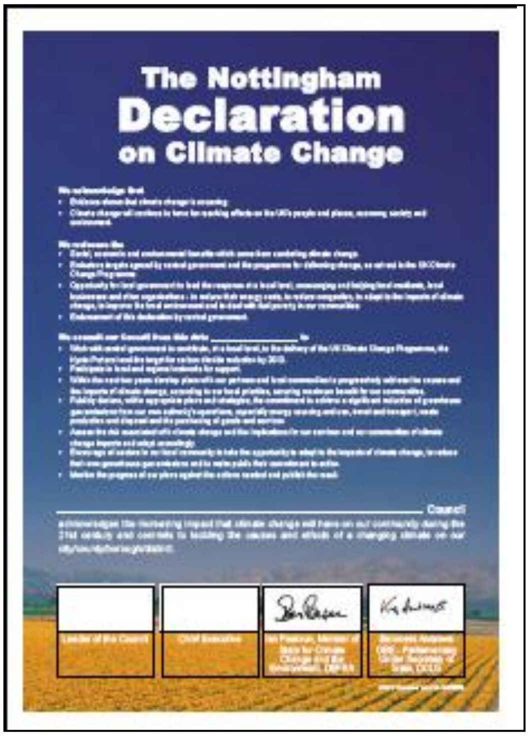
Program Component	Purpose	Description	Examples
Making a Commitment			
Adaptation Commitment	Signals support by Council for putting effort and resources into climate change adaptation	May be a stand-alone commitment, or part of an overarching vision, policy statement, or plan	Nottingham Declaration City of Iqaluit General Plan
Initial Strategy Document	Outlines the rationale for developing an adaptation strategy	Often includes initial reviews of vulnerabilities and sets out processes for developing more detailed plans and programs Vary in their depth, comprehensiveness and commitment	Halifax Regional Municipality – *Climate Change Risk Management Strategy for HRM* Toronto - *Ahead of the Storm* Whitehorse – *Whitecap*
Capacity Building			
Acquiring Information and Tools for Decision-Making	Provides information needed for adaptation planning and implementation	A range of information is needed for adaptation planning and implementation including: ▪ local climate trends and projections ▪ recent extremes and impacts ▪ risk thresholds ▪ maps of vulnerable areas and vulnerable populations ▪ adaptation options for specific hazards, etc.	Several municipalities have retained consultants to provide climate trends and projections City of London's flood plan mapping Toronto Public Health's heat vulnerability mapping PIEVC-led risk assessments of municipal infrastructure
Awareness Raising	Raises the profile of climate change impacts and adaptation in order to motivate preparation for climate change and increase support for action	May include: ▪ Publications such as brochures, articles in municipal newsletters ▪ Websites ▪ Public meetings, conferences or workshops	HRM's *ClimateSmart* website OCCIAR's Citizen Forums
Targeted Education	Increase the knowledge about impacts and adaptation options among those who make and/or influence decisions about systems that can be affected by climate change	May be aimed at: ▪ Municipal staff and senior management ▪ Elected officials ▪ Sectoral stakeholders or vulnerable neighbourhoods (e.g. utilities, developers, vulnerable neighbourhoods)	Workshops for London municipal staff on vulnerability of infrastructure Delta's Climate Change Risk Education Program
Collaborative Networks/ Partnerships	Bring together organizations and individuals whose collective experience and knowledge can help municipal departments, municipalities as a whole, or regions plan for adaptation	Collaborative networks or partnerships might be made up mainly of municipalities, or include scientists, research institutes, consultants, other levels of government, NGO's and business organizations	Toronto's Climate Change Science Advisory Group Halifax's work with the ClimAdapt consortium London Climate Change Partnership
Design Charrettes, Workshops and Competitions	Encourage creative thinking about ways to adapt to climate change in the larger community, and may result in innovative solutions to climate impacts problems	Designers and developers are invited to present alternative designs to protect communities from various impacts of climate change.	Netherlands Hotspot Zuidplaspolder project San Francisco Rising Tides Design Competition

Program Component	Purpose	Description	Examples
Delivering Adaptation			
Pilot and Demonstration Projects	Better understand the factors involved in delivering adaptation, and assess the costs, benefits and effectiveness of various adaptation options	Pilot projects allow municipalities and their partners to implement adaptation options on a small scale for demonstration and evaluation purposes	City of Vancouver – Crown Street Project Pilots demonstrating and testing green roofs / permeable pavements / street tree survival projects
Implementing Adaptation in Municipal Facilities, Infrastructure and Services	Safeguards municipal investments Sets an example for others, showing concretely how adaptation can be done	Huge variety of ways in which this can happen depending on the facility, climate impacts, and populations served	Richmond Hill's Pioneer Park Stormwater Management Project Toronto Public Health's update of its Heat Response activities York Region Emergency Drills
Economic Instruments	Encourage adoption of adaptive behaviours by businesses and residents	Include: grants, incentives, subsidies, or rebates for investing in adaption	City of Hamilton's Protective Plumbing Program City of Toronto's Eco-Roof Incentive Program King County Washington's Flood Buyout and Home Elevation Program
Negotiated Agreements	Expand the implementation of desired adaptations by businesses and developers	Negotiate the inclusion of adaptive features (e.g. trees for shade, soft surfaces, green roofs, etc.) in new developments to create more resilient landscapes	BC's Climate Action Toolkit
Voluntary Guidelines	Provides information and guidance to private sector actors with respect to preparing for climate change	Often accompanied by incentives of various kinds Most likely to engage leading edge and environmentally aware businesses, who value the reputational boost	Halifax Regional Municipality's *Developers' Risk Management Guide* ICLR's *Home Builders' Guide* Mississauga's Green Development Standard
Regulations and Standards	To ensure the implementation of adaptation strategies, applicable where municipalities and related agencies such as conservation authorities have authority to act	Standards, zoning requirements that require adaptive behaviour and by-laws that seek to prevent maladaptive actions (such as paving front yards or indiscriminately cutting trees)	Toronto's Green Development Standard MMAH InfoSheet "Planning for Climate Change"
Monitoring			
Reporting requirements and indicators	To monitor whether expected climate changes and impacts are occurring, and whether implemented strategies are successful in providing protection	May include tracking of flooding instances and costs, morbidity and mortality related to heat waves and related air quality problems, urban heat island developments, etc.	To date, most monitoring and reporting requirements have been limited to evaluations of run-off quantity and water quality associated with permeable pavements and swales

Adaptation Declaration / Commitment

A policy statement that acknowledges that climate change is occurring, and commits to assess vulnerabilities and risks and to plan and implement protective strategies signals Council and senior management support for putting effort and resources into an adaptation process.

Such commitments are made by municipalities that join FCM's Partners for Climate Projection program, and pass Council resolutions to work through the five milestones of that program, leading to the implementation of strategies to reduce greenhouse gas emissions. Almost 180 local governments in BC have signed onto that province's Climate Action Charter, which commits them to carbon neutrality by 2012.



In the UK, more than 300 local authorities have publically signed onto the Nottingham Declaration, which commits them both to reduce emissions ***and*** to assess risks associated with climate change and to adapt. Four out of five UK local governments working on a climate change strategy believe signing the Declaration to be a key driver.

Councils for several Canadian municipalities have also passed resolutions that commit them to prepare for climate change, sometimes as a result of a vulnerability assessment process that demonstrated the need to address the issue, and sometimes as part of a larger commitment to sustainability. In its recent *General Plan*, for example, the City of Iqaluit committed to:

> *"… take a precautionary approach to development by taking into account the best knowledge available on climate change impacts into its decision-making. By developing a system of monitoring, the City will increasingly build its knowledge base over time and will be able to develop more policy that builds the adaptive capacity of the community."*

High Level Adaptation Strategy Documents

A growing number of Canadian municipalities have also developed or participated in developing broad adaptation strategies. These are usually high level strategies, outlining key climate risks and processes that the municipality will use to address them, and providing direction for more detailed work to be done on specific strategies and adaptation options.

In 2008, for example, the City of Toronto adopted *Ahead of the Storm*, which recommended a number of short-term adaptation measures, and outlined the main steps of a longer-term adaptation planning strategy for the City, beginning with the development of a local climate profile and a detailed risk assessment template for application by all City departments, following which specific adaptation plans are expected to be developed.

Canadian municipalities and communities that have developed or are in the process of developing such a strategy include those listed below in Table 1:

Annapolis Royal, NS	Delta, BC	Kimberley, BC	Ottawa, ON
Arviat, NU	Elkford, BC	Le Goulet, NB	Quebec City, QC
Brampton, ON	Fredericton, NB	London, ON	Peel Region, ON
Calgary, AB	Greater Sudbury, ON	Markham, ON	Saanich, BC
Capital Region District, BC	Gwichya Gwich'in, NT	Metro Vancouver, BC	Vancouver, BC
Central Kootenay Regional District, BC	Halifax Regional Municipality, NS	Mississauga, ON	Whitehorse, YT
Clyde River, NU	Hamilton, ON	North Vancouver, BC	York Region, ON
Dawson City, YK	Iqaluit, NU	Oakville, ON	

Acquiring Information and Tools for Decision-Making

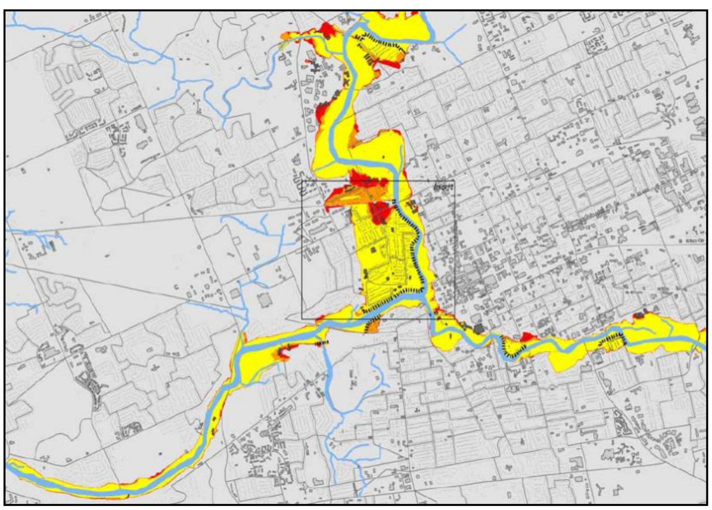
Many municipalities do not have information that they feel the need to fully assess their vulnerabilities or to target adaptation activities. For this reason, it is important to identify the information that is needed, and include in an adaptation program plans for acquiring it. This information may include:

- Climate trends and projections
- Local vulnerabilities as indicated by previous experience with extreme weather, or "creeping risks" such as reduced water supply or the expanding range of disease vectors or other insect pests
- Vulnerable locations/areas such as basement and surface flood zones; "hot spots" (urban heat islands), culverts or bridges susceptible to damage
- Identification of populations who are vulnerable because of circumstances other than location
- Risk thresholds such as precipitation intensity and duration that will overwhelm stormwater systems; temperature and duration of heat waves that result in sudden rise of mortality
- Cost and effectiveness of adaptation alternatives in reducing risks.

As they begin to consider climate change impacts and adaptation, for example, most municipalities need information on local climate trends and future projections. Municipalities such as the Region of Waterloo and the City of Toronto retained consultants for this information. Others have turned to climate change research institutes such as the Ouranos Consortium in Quebec or the Pacific Climate Impacts Consortium in BC. Municipalities that are not yet prepared to hire consultants or research institutes can gather and analyze a considerable amount of local climate trends and projections information from the Canadian Climate Change Scenarios Network website, as discussed in Module 1.

Municipalities may do an internal investigation of locations that are vulnerable to climate change by reviewing areas that have already been subject to damage from extreme weather. The City of Toronto, for example, has reviewed intense precipitation events of the last two decades and identified a number of culverts at risk. The City has selected three of these for a detailed risk assessment as part of the PIEVC program of Engineers Canada and is expecting to learn a great deal about the extent to which vulnerable culverts can stand up to intense precipitation and whether a monitoring or replacement program is necessary.

Toronto Public Health has worked researchers at Ryerson University to develop vulnerability maps for extreme heat events. The maps will incorporate information on surface temperatures, green space coverage, housing and social characteristics of at-risk populations, access to air conditioning, and the location of cool places. The maps will help Toronto Public Health target hot spots for their heat response program.



Source: Hebb and Mortsch 2007

Several municipalities, including the City of London, have begun to update flood risk maps on the basis of recent events and climate projections, to help in making future development decisions and in prioritizing protection strategies for the most vulnerable areas.

The City of Calgary needed information and tools to help with long-term water planning in the face of increased population and climate-related decline in water from the Elbow and Bow Rivers, which are fed by snowpack and meltwater from Rocky Mountain glaciers. To develop its Water Efficiency Plan the City created a water demand model to anticipate future water use patterns up to the year 2015 that considered a changing climate, growth in various consumer sectors, water rates, and housing growth. They created several different future scenarios based on various assumptions. With a goal of a reduction of 30% below 2003 levels in 2033, the City determined what scenario was most appropriate and what measures would need to be taken early on to achieve it.

Information about the effectiveness of alternative adaptation options can be more difficult to access and may require collaborative research projects. An interesting example of this is the research conducted as part of the New York City Regional Heat Island Initiative which evaluated options for reducing the heat island in different parts of New York City.

Awareness Raising Activities

In order to gain support for and involvement in adaptation planning and implementation, it is important for municipal officials and for the public to understand current and potential climate impacts and possible adaptation responses. A number of municipalities and related agencies have begun these processes. Awareness raising activities and examples will be discussed in more detail in Module 11, but a few examples are worth mentioning here.

In 2007, Halifax Regional Municipality developed its *ClimateSmart* website. The website includes an *Introduction to Climate Change*, a *Community Action Guide* that includes advice for households to prepare for climate-related emergencies, HRM's *Climate Change Risk Management Strategy*, a link to a recent *Canadian Geographic* article on HRM's work to prepare for climate change and other materials. HRM has also included several articles relating to climate change, its expected impacts and how to prepare in the quarterly newsletter *Naturally Green*, which is distributed to all residents in the city. Several other municipalities have put resources related to climate change impacts and adaptation on their websites as well.

Some communities have hosted presentations of Al Gore's *An Inconvenient Truth* and used that opportunity to discuss climate change mitigation strategies with the audience. A few have also found it useful in encouraging discussion of climate change adaptation. While the film may have limited value today, the strategy of hosting community meetings around a well-publicized film or author to kickstart a discussion of climate impacts and adaptation is one that some municipalities might want to consider.

The Ontario Centre for Climate Impacts and Adaptation Resources is preparing to launch a new program of Citizen Forums, community-based workshops to help members of the general public understand climate change impacts and adaptation in their communities. The success of the Forums will be evaluated and may prove to be an interesting option for raising awareness of adaptation.

Targeted Education

Targeted education programs go beyond awareness-raising to engage decision-makers, staff, sectoral stakeholders and even neighbourhoods at risk in considering and responding to the impacts of climate change. These educational activities may be developed internally for the staff of a specific department or municipality, or may be external programs available to many municipalities, or their professional staff. Here are a few examples:

The Institute of Catastrophic Loss Reduction and the City of London have collaborated in two workshops on the vulnerability of infrastructure to climate change, with a particular focus on flooding. Participants in the 2009 Stakeholder Workshop included staff from the City of London's transportation and stormwater divisions; risk management; wastewater; parks planning and design; and environment and solid waste. Three city Councillors also attended the workshop, as did staff from the Upper Thames River Conservation Authority and from the Ontario Ministry of the Environment. Participants in the workshop discussed a wide variety of climate change impacts and vulnerabilities of potential concern for London, and identified topics for future investigation.

The Ontario Centre for Climate Impacts and Adaptation Resources has also worked with a number of municipalities throughout the province – Barrie, Ottawa, Peterborough, St. Catharines, and municipalities in the Cataraqui region – to conduct climate change risk management workshops for staff.

The Corporation of Delta, BC has led or participated in several education programs that improve the knowledge and engagement of staff and citizens in preparing for climate change. For example, Delta collaborated with researchers from the University of British Columbia who developed climate change scenarios, maps and visual images of how sea level rise would affect the low-lying coastal community, as well as images of alternative adaptation strategies for specific neighbourhoods. These were presented in neighbourhood workshops as well as workshops with Delta Engineering and Planning staff. The Mayor and several staff members have cited the importance of the workshops (and the images) in stimulating action.

Source: Collaborative for Advanced Landscape Planning, UBC,

Delta has gone on to develop an Education and Training Plan to "educate approximately 1000 full time, part time and temporary staff about the impacts of climate change and how staff may reduce emissions or adapt." Educational activities include lunch and learn sessions, workshops, and providing the opportunity for staff to attend external climate change workshops and conferences related to their responsibilities.

The County of Gloucestershire, U.K. provides an inspiring international example of targeted education to build adaptation capacity. The County committed to incorporating climate change adaptation action across Council activities after signing the Nottingham Declaration. To build adaptation capacity the County held a series of internal workshops to stress the importance of a risk-management approach to climate change adaptation. These workshops were delivered to all elected members of the County's six district councils, senior managers, emergency planning officers and risk managers, and health officials. Following the workshops, a network of 70 "Climate Change Champions" was established, and with strong communication across Council services, climate change adaptation has been well-integrated into County Council procedures.

Collaborative Networks and Partnerships

Collaborative networks and partnerships can be very helpful in elaborating an adaptation program by pooling knowledge and strategies and sometimes resources. Such partnerships might be formed around specific, fairly short-term projects. For example, the City of Toronto invited Environment Canada, scientists from the University of Toronto, York and Ryerson, and the Toronto and Region Conservation Authority to participate in a Climate Change Science Advisory Group to help in the development of Toronto's Climate Drivers Study, which is looking at how climate is changing in the region and should provide an important input into adaptation planning for the City.

Halifax Regional Municipality worked for several years with ClimAdapt, a consortium of private sector consultants working in the field of climate change adaptation, Environment Canada, and the Nova Scotia Ministry of the Environment to carry develop a comprehensive risk management plan and several tools

Longer term partnerships can also contribute to ongoing adaptation efforts of local governments as well. The London Climate Change Partnership, convened by the Greater London Authority in the UK, brings together representatives of London's local councils, national environment agencies, utilities, transportation authorities, business associations and others. The Partnership led London's first vulnerability study, *London's Warming* (2002), and has since helped initiate a variety of studies and leveraged support and resources for adaptation projects. They are currently working on:

- London Health and Social Care Climate Action Plan
- Expanding the network of weather stations for London
- Retrofitting water efficiency measures into 1.8 million London homes to prepare for future water shortages
- Piloting a retrofit of two blocks of social housing for protection against climate impacts including overheating
- London-wide plan to manage and reduce surface water flooding
- Developing overheating thresholds for Londoners
- Monitoring adaptation in London's construction and development industries.

Design Charrettes, Workshops and Competitions

Design Charrettes, workshops and competitions are a way that municipalities can engage designers, consultants, developers and others in thinking about and proposing creative ways to develop and redevelop communities to tackle potential climate impacts.

Ten Dutch municipalities have joined the province of Zuid-Holland, the Water Board, several universities, private companies and other interested parties in the Hotspot Zuidplaspolder project, which aims to build up to 30,000 new homes, commercial properties and greenhouses in the Zuidplaspolder area, one of the lowest-lying areas of the Netherlands and subject to river flooding. The project is coordinated by Xplorelab, set up in 2007 as a laboratory for innovative work and learning. Partners in the project meet and work together on climate resilient designs for new developments. Five different pilot projects have been approved. Their designs incorporate peak rainwater storage space, storm barriers, waterproof houses, and seasonal storage of rainwater for dry periods, and green areas for natural cooling.

In 2009, the San Francisco Bay Conservation and Development Commission held Rising Tides, an international design competition with a prize of $25,000, seeking ideas to respond to sea level rise in San Francisco Bay. Entries were asked to solve the sea level rise problem with environmentally smart and simple designs that were transferable to other estuaries. The competitors were also asked to integrate green building principles. 130 competitors entered the competition. A large number of the designs offered promising solutions and in the end six entries were selected as winners, and seven received honourable mention awards.

Pilot and Demonstration Projects

Pilot projects are a relatively risk-free way in which a municipality can invest in adaptation for the purpose of showcasing and evaluating some attractive adaptation options. So far, there have been few pilots in Canadian municipalities specifically designed specifically to showcase adaptation to climate change, though a number of projects include adaptation benefits.

One of these is the City of Vancouver's Crown Street streetscape project, completed in 2006. This project replaced ½ kilometre of gutterless asphalt road with a sustainable street design incorporating a narrow roadway with vegetated swales and retention ponds. The new streetscape improves stormwater management in the community, protects the last two salmon bearing streams in Vancouver, and beautifies the street. The project introduced a porous grass paver system for parking along the road edges. This project is being actively monitored by the City in partnership with the University of British Columbia, to compare its longer-term benefits to those of a nearby standard curb-and-drainage system. This assessment should be released in the next year.

The City of Brampton and Region of Peel are collaborating with the Toronto and Region Conservation Authority's Sustainable Neighbourhood Retrofit Action Plan (SNAP) in a pilot project to improve rainwater management, protect and expand wildlife habitat, and conserve energy and water. The program is designed to encourage climate change mitigation, adaptation and overall sustainability actions in the County Court neighbourhood of Brampton.

On a smaller scale, TRCA has collaborated with Seneca College and the University of Guelph on promising projects in Toronto, Vaughan and Brampton that install permeable pavements and vegetated swales in large public parking lots and evaluate their effectiveness in reducing stormwater runoff and capturing contaminants.

Implementing Adaptation in Municipal Facilities, Infrastructure and Services

Municipalities also need to look to their own buildings and facilities, infrastructure and services when planning adaptation to climate change. When planning new facilities, for example, or undertaking a major building renovation, municipalities should take account of increases in heat, intense precipitation, potential for floods or drought, and other aspects of climate change. Some municipalities have been incorporating increased external insulation finishing systems, green roofs, strategic tree planting and overhangs for shade, and other features to reduce heat gain in facilities during the summer months and during heat waves for example. These projects can serve as showcases for adaptation practices as well as providing practical improvements that reduce the impacts of climate change.

Richmond Hill has just recently completed the award-winning Pioneer Park Stormwater Management Project that rehabilitated an existing flood control facility; provides protection to vulnerable areas, major roads and fire and police headquarters; enhances erosion control; improves water quality and stabilizes the East Don River watercourse. The Town identified that climate change would likely increase the number of intense rain storms and incorporated adaptation into the project planning from the beginning. The project includes wet and dry ponds, an oil/grit separator that captures sediment, oil and grease before it gets to the pond, use of river run stone to mimic a natural stream channel, and native vegetation to stabilize the stream bank and encourage support wildlife. The Town leveraged Federal Gas Tax funds and Ontario Infrastructure funds for the project.

Through a few of its departments, the Grand River Conservation Authority has implemented several practices that aim to make the watershed resilient to climate change. These have included implementing riparian buffers, planting trees, enhancing and restoring wetlands, restricting livestock access to watercourses, and putting more water storage back on the landscape. While relatively small measures, all of these projects have reduced the climate change impact vulnerability of the Grand River watershed, its municipalities and its infrastructure.

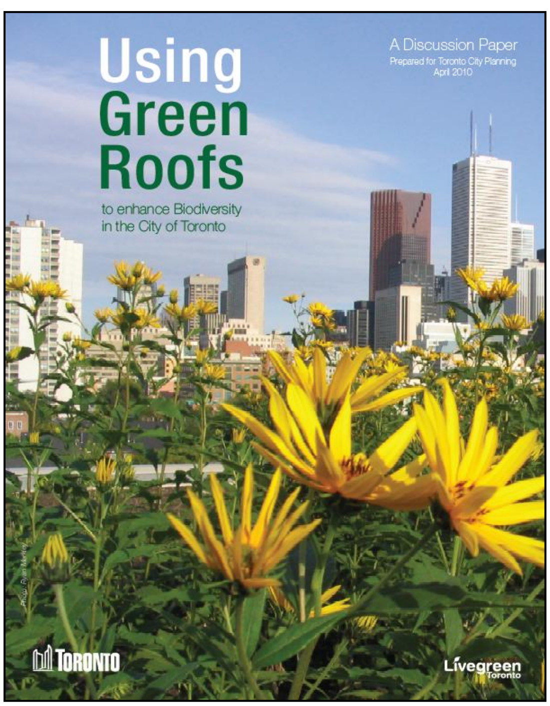
York Region has been incorporating adaptation planning into its Emergency Management services. As required by Emergency Management Act, the Region conducts annual emergency exercises to test the effectiveness of their emergency planning and engages local governments and agencies in assessing areas needing improvement in their plans and procedures. In the last six years, four of these exercises have focused on emergency response to severe weather conditions including: "Operation Strike Three" that simulated a cascade of events starting with a thunderstorm microburst that causes a power blackout; "Operation Spring Thaw" which simulated amplified flood conditions experienced earlier in low-lying areas of the region; "Operation Rising Waters", another flooding simulation; and "Whiteout", an exercise that simulated a severe winter snowstorm.

In 2009, the City of Toronto released its plan to update its Hot Weather Response Plan to respond to climate change. Several projects are underway to ensure that the Hot Weather Response Plan is effective for more intense and longer duration heat waves. These projects include a community heat registry to monitor marginally housed Torontonians during heat alerts, study of a maximum heat standard for multi-unit buildings, and identifying heat-related vulnerabilities through mapping projects.

Economic Instruments

Municipalities already utilize a variety of economic instruments to support community action on issues they deem important. These instruments include grants, subsidies, rebates, distribution of free energy or water-saving devices, and tax incentives.

In 2008, the City of Hamilton established a Protective Plumbing Program that invited the owners of 75 previously flooded residential properties to participate in a program that provided subsidies of up to $1000 for a lateral drain inspection and up to $2000 for installation of a backwater valve to prevent sewage back-up. Thirty homes participated, and twenty installed the backwater valve. Despite severe flooding the following summer, no reports of flooding occurred from residents who participated in the project. As a result of this pilot project, Hamilton Council has approved a Protective Plumbing Program that provides subsidies to homeowners who experienced sewage back-up from one of 12 eligible storms. The subsidies cover installation of a backwater valve, sump pump, inspection of sewer laterals, sewer lateral repairs and downspout disconnection.



The City of Toronto also established a Green Roof Strategy and pilot project in 2006, designed to encourage new green roof construction, with the primary aim of stormwater management. (Toronto Water administered the project.) The project provided grants of $10 per square metre in the first year or the project, and increased these to $50 per square metre in the second year to a maximum of $10,000 for a single family home and $100,000 for multi-unit residential, industrial and commercial buildings. Forty-two green roofs were installed, 27 on single-family homes, 3 on multi-unit residential and 12 on commercial or industrial buildings. Each participant provided detailed information about the green roof installations and photos which were posted on the City's website. In 2009, this program morphed into the Eco-Roof Incentive Program, aimed at encouraging a greater uptake of green roofs on commercial buildings with large flat roofs. The program is also encouraging cool roof applications to reduce the urban heat island.

King County Washington has a unique Flood Buyout and Home Elevation Program. The buyout part of the program offers fair market value for properties in flood-prone areas of the county exposed to fast-moving water. Once the home is purchased by the County, the building is removed from the site, and native vegetation planted. The program reduces the risk of flood disasters and increases open space and wildlife habitat. A limited amount of money is available each year for the program, and has been boosted by short-term federal funds after several local floods. In flood-prone areas with slower-moving waters, the County will also provide financial assistance to help homeowners elevate the finished floor of a home above the 100-year flood level.

Negotiated Agreements

In communities where increased density is desired by developers, municipalities may offer density bonuses in exchange for the inclusion of community amenities, enhanced energy and/or water efficiency targets and other improvements that go beyond regulatory requirements. In its Climate Action Toolkit, the BC government encourages this and a number of local governments in BC have embraced this practise. The Ontario Ministry of Municipal Affairs and Housing also recommends density bonussing and other negotiation strategies to encourage incorporation of climate resilient features in new developments including: green roofs; permeable paving; infiltration swales; tree planting for shade; and other features.

Voluntary Guidelines

A growing number of voluntary and best practice guidelines are being developed and published to help incorporate climate change considerations and adaptation into building developments, infrastructure and other areas. In 2007, for example, Halifax Regional Municipality published the *Climate Change: Developers' Risk Management Guide* to assist developers and HRM staff in considering climate change risks and adaptation in new or infill developments, especially those in coastal and low-lying areas, on the urban/forest fringe or in rural areas. The guide includes a Development and Building Checklist to aid the process.

More recently, the Institute for Catastrophic Loss Reduction has produced a *Home Builders' Guide* as part of their program to promote disaster-resilient homes. The guide includes guidance for reducing the risks of basement flooding, damage from high winds, hail, severe winter weather and other perils. ICLR has encouraged the Province to incorporate several of its recommended practices into the Ontario Building Code.

Some Ontario municipalities have developed their own voluntary green building standards to enhance the long-term sustainability of new developments.

In July 2010, the City of Mississauga adopted a Green Development Standard that seeks to achieve a certain level of sustainability and environmental responsibility in the City's new development. The first stage of the Standard includes climate change adaptation such as: low impact development stormwater retention, soft landscape material designed to improve air quality and reduce the urban heat island effect, and LEED silver certification for new developments.

Mandatory Regulations and Standards

Municipalities are limited in the extent to which they can pass regulations or set standards that would create requirements for adaptation. For the most part, such powers rest with provincial and federal governments. In April 2011, Ontario released a new adaptation plan that signals its intention to incorporate changes that support adaptation in a number of provincial plans and strategies and in the Building Code, but this may take some time. In the meantime, the Ontario Ministry of Municipal Affairs and Housing (MMAH) produced a short Infosheet on Planning for Climate Change that outlines ways in which municipalities can regulate adaptive actions in their communities. These include:

- Requirements for studies that address climate issues in planning applications for official plan amendments, zoning amendments, subdivisions and consents (e.g. stormwater management plans for on-site mitigation of intense precipitation events)
- Purchase or lease of land in designated areas (e.g. to create a buffer zone and/or protect vulnerable areas)
- Prohibit the use of land or erecting buildings within areas prone to flooding or other weather-related hazards
- Site plan control by-laws that include requirements for green infrastructure and low-impact development features
- Conditions of approval for new developments that include easements for greenspace and stormwater management
- Development Permit System by-laws that specify greenspace protection, water management and conservation measures, green roofs, restoration or preservation of vegetation and features to promote infiltration of stormwater.

The City of Toronto's ambitious Green Development Standard was first introduced as a voluntary standard for private sector developments in 2006 (though mandatory for City owned properties). The standard contains many elements that will increase the resilience of developments in the face of climate change including: retention of stormwater on-site; energy efficient design and renewable energy on-site; shading and reflective materials to reduce heat; permeable paving; enhanced conditions for trees; and other features.

The Standard has two tiers, each with an integrated set of sustainability targets and practices. The first tier sets out basic requirements, and the second tier is more demanding. In January 2010 the first tier became mandatory for most new developments in the City. The second tier remains voluntary, but developments that meet the tougher standard are eligible for a 20% refund of development charges.

Monitoring

So far, monitoring has mainly happed with some pilot projects that have included requirements for evaluating and reporting on the results of the projects. In Ontario, this has happened for some projects that have implemented permeable pavements and swales and investigated the effects on run-off. Monitoring should be built into more adaptation activities, to ensure that the adaptation options and strategies that are implemented have the desired protective effect. Inclusion of monitoring may require the identification of indicators of success. This is discussed in more detail in Module 12.

Putting Together a Mix of Program Instruments into an Adaptation Program

Because planned adaptation to climate change is relatively new for local governments in Canada and around the world, there are not many existing programs that can be looked to as models. Too few have got to the implementation stage. However, the following case study illustrates the development of an adaptation program in Halifax Regional Municipality and how the city has incorporated many of the program components into this process.

The Components of an Adaptation Program in Halifax Regional Municipality

The Halifax Regional Municipality (HRM) has been working formally on climate change adaptation since 2004, spurred on by the experience of Hurricane Juan in 2003, followed by the blizzard "White Juan" a few months later. In 2004, Halifax established Climate SMART, an integrated strategy for both mitigation and adaptation planning. On the adaptation side, HRM worked closely with ClimAdapt, a network of private sector environmental firms interested in climate change adaptation. ClimAdapt helped bring together funds and partners for an intensive program of research and development of tools for climate change adaptation decision-making.

In developing their adaptation program, HRM undertook several of the actions previously described as potential components of an adaptation program, including:

- Formation of a ***collaborative partnership*** with ClimAdapt, Environment Canada (Atlantic Region), the Nova Scotia Environment department to investigate climate risks, and prepare adaptation tools
- Prepared an ***issues paper*** for HRM on Adapting to a Changing Climate (July 2005) which provided an initial assessment of vulnerabilities and risks
- Conducted ***workshops*** to engage HRM staff in reviewing and commenting on the Issues Paper (October and November 2005)
- ***Raised public awareness*** by:
    - Creating the Climate SMART ***website***
    - Including articles about climate change impacts and adaptation in HRM's quarterly newsletter *Naturally Green* (distributed to all Halifax households)
    - Prepared and posted the *Community Action Guide to Climate Change and Emergency Preparedness*
- ***Acquired information and tools for decision-***making, including:
    - Climate projections for the region
    - LIDAR digital elevation mapping of the Halifax port area
    - Cost-benefit study of the *Economic Implications of Buried Electrical Utilities* to assess this possible strategy for reducing the impact of storms on power services
    - Water level trends in Halifax Harbour
- ***Developed plans to incorporate climate change impacts and adaptation into municipal facilities, infrastructure and services*** by means of:
    - A detailed *Climate Change Risk Management Strategy* that identified and prioritized risks for all HRM's business units
    - Incorporation of climate change into a 25-year Regional Municipal Planning Strategy, with a special focus on Halifax Harbour, which is vulnerable to sea level rise and storm surges
    - A new stormwater management strategy with emphasis on alternative landscaping practices
- Developed and posted ***voluntary guidelines for developers*** (*Developers' Risk Management Guide*) to help incorporate climate change considerations into planning for new developments
- Set out ***requirements for developers of waterfront properties*** to prove their plans take sea levels and extreme weather into account.

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Module 10: Drivers and Barriers

Learning Objectives and Outcomes

By the end of the module, participants will:

- Identify conditions likely to drive climate change adaptations in communities.
- Identify the key obstacles and barriers which may need to be removed before pro-active adaptation steps to minimize future damage can be undertaken.
- Consider the key institutional and community mechanisms available to support the development and implementation of climate adaptation programs in their own community.

Introduction

A variety of drivers and barriers will influence whether adaptation actions are undertaken in a timely and effective manner to limit the damage from climate in Ontario communities.

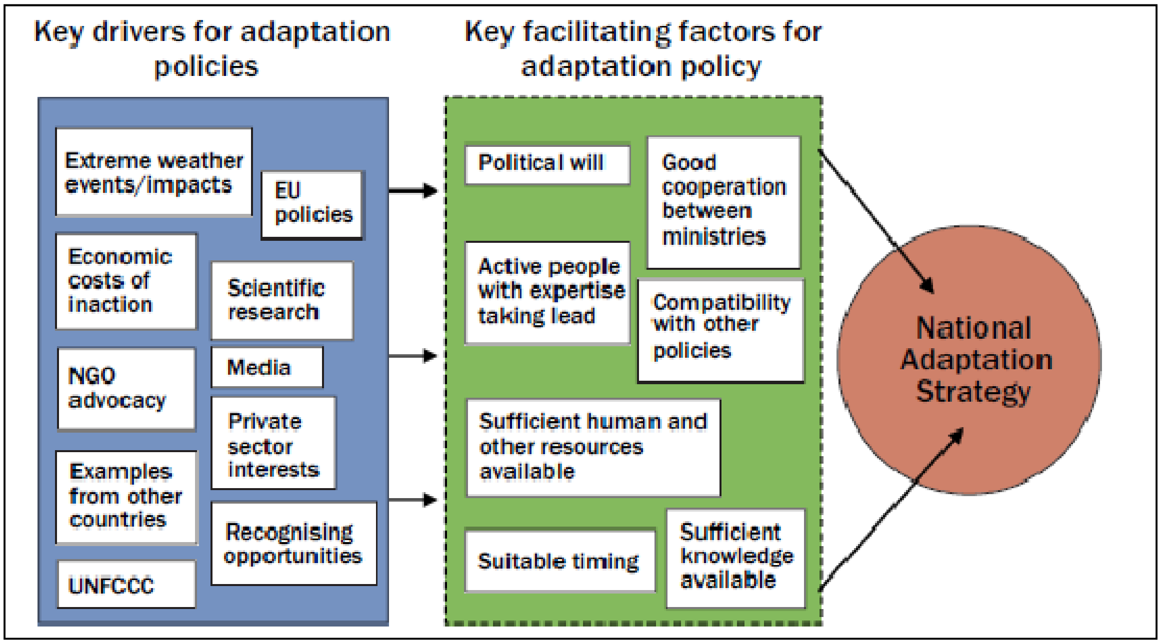
Understanding the drivers that can move municipal decision-makers to tackle climate change impacts and adaptation, as well as the barriers that frequently get in the way of making much progress can be useful knowledge for those who are concerned about taking action to improve the resilience of our communities. Adaptation advocates who can identify the drivers for climate change adaptation may be able to take advantage of them and move the adaptation process more effectively. Those who anticipate or recognize barriers when they first arise may find ways to circumvent them.

Just as the risks of climate change vary from community to community, the key drivers of and barriers to action also vary to some extent. However, observers of the progress of climate change adaptation policies and programs in different communities and countries have been able to distinguish a number of common drivers and barriers, which are discussed in this Module.

Drivers of Climate Change Adaptation

Interestingly, there is not as much discussion of drivers in the literature about climate change adaptation as there is about barriers. However, several writers have reviewed adaptation processes and interviewed adaptation leaders and have identified a number of drivers that seem to recur. European research into drivers of national adaptation programs identified a number of drivers and facilitating factors for adaptation policy at the national level, as illustrated by Figure 1 on the next page.

Figure 1: Key Drivers and Facilitating Factors for National Adaptation Strategy Development



Source: Swart et al. 2009. *Europe Adapts to Climate Change*. Partnership for European Environmental Research. Helsinki.

The following drivers of action on climate change are more specific to local governments and to the Canadian experience:

- **Extreme weather events and/or weather-related impacts:** Extreme weather that is publically associated with climate change can have a galvanizing effect on the development of adaptation planning. This might be an event that occurs in the community (the tornados that hit Vaughan in 2009 and Leamington in 2010) or a powerful event that occurs elsewhere (Hurricane Juan in Halifax, or the 2003 heat wave in Europe). Some "creeping" risks may also raise concern to the level of initiating action. The decline in available water supply, often coupled with increased demand from growing populations, has some communities in southwestern Ontario very worried about what future climate might bring. The expansion of the pine beetle in BC's forests over several years also raised the profile of the impacts of climate change in that province and stimulated several forestry-based communities to consider adaptation.

- **Recent or projected costs of extreme weather on municipal budgets:** Recent floods in several Ontario municipalities (Peterborough, Toronto, Hamilton, Cambridge, London) and the associated costs have increased awareness of intense precipitation events among municipal stormwater managers, and highlight the need for comprehensive stormwater management and adaptation planning.

- **Increasing international and national recognition of the credibility of climate science and the advance of climate change and its impacts:** A growing number of Canadians are convinced that climate change is underway, and that it is serious.[1] Concern about climate, however, tends to surge when important new scientific reports or findings are released and publicized by the media.

- **Cumulative effect of advocacy by local and national NGO's and research organizations:** Canada has a number of active NGO's that have worked with municipalities on climate change impacts and adaptation, facilitated municipal networking and interaction on climate change issues, published relevant research and advocated the uptake of climate change adaptation planning among local governments. These organizations include Conservation Authorities, Ontario Centre for Climate Impacts and Adaptation Resources, Clean Air Partnership, the Institute of Catastrophic Loss Reduction, Engineers Canada, and others. Over time, this effort has led to an increasing recognition of the need to act.

- **Participation in climate change impacts research, risk assessments and resiliency studies:** Municipal staff who are recruited to participate in climate change research (such as that led by Engineers Canada in their PIEVC projects) are increasingly becoming champions of climate change adaptation within their departments and municipalities. Participation in these projects increases their knowledge about climate change and its impacts, their insight in thinking about and proposing solutions, and their ability to justify adaptive action.

- **Peer competition and image**: Not all municipal decision-makers wish to be first movers, but few want to be seen as laggards on important issues. Consequently, when nearby municipalities with similar challenges are moving on the issue of climate change impacts and adaptation, it encourages municipal governments to look into taking action.

- **Standards and regulatory requirements:** In Europe regulatory requirements are becoming important drivers of local adaptation to climate change. This is not yet the case in Canada, although the Ontario government through MOE and MMAH is considering new adaptation-related requirements in the Building Code and is encouraging municipalities to incorporate climate impacts and adaptation in land-use, water management and stormwater planning. However, barring a major change in direction in Ontario, new requirements for considering climate impacts and adaptation planning are likely to be announced in the near future. If so, these will become drivers for local action on climate change.

[1] *Climate Compared*, a survey of 2000 Americans and Canadians in January 2011, found that 80% of Canadians believe in global warming, and 91% of those believe that it is a very serious or somewhat serious problem.

- **Legal concerns:** While it might not be a major driver yet, a number of observers are now suggesting that legal liability will become more important in propelling governments – and perhaps engineering and other firms – to take climate change into account, especially in the planning and construction of infrastructure.

Individual drivers are not usually sufficient to move municipalities to action on climate change. Action is more often the result of the cumulative or synergistic effect of several drivers operating at the same time.

Facilitating Factors

In addition to the actual drivers motivating the development of adaptation policies, several factors that facilitate the process can also be identified. These can be seen as a "filter" through which adaptation process takes place. However, the filter can also become a barrier for the development of adaptation policies, if crucial facilitating factors are missing or are too weak.

- **Leadership by an effective local "champion" of action on adaptation:** In Canada, most of the local champions who have motivated action by municipalities on adaptation are senior managers with responsibility for programs or infrastructure that is vulnerable to climate change, insight into the problem, and decision-making power or influence. (In some other countries, elected politicians have been more active champions.)

- **Knowledge and expertise:** Local governments may move more quickly if they have sufficient in-house expertise to identify and address the impacts of climate change. However, municipalities may also augment their own staff resources by drawing on the skills and knowledge of scientists and researchers in other institutions, including Environment Canada and other senior government agencies, universities, research institutes, or private sector consulting firms or networks. These experts can help communicate the science of climate change, undertake regional climate modelling, work with local government staff and stakeholders to identify likely impacts, and help identify and assess adaptation options and strategies.

- **Willingness to allocate resources:** Municipalities or municipal agencies that have specifically allocated staff to lead the development of climate change impacts and adaptation projects are generally able to move more quickly and develop more advanced adaptation processes than those who simply add these tasks to other responsibilities of environmental or other staff. This may be easier for larger municipalities, though smaller municipalities often have an ability to act more quickly. Financial resources are perhaps a thornier issue. Some adjacent municipalities are beginning to pool their resources for adaptation planning, reducing the costs of consultants, and of duplicate effort in assessing vulnerabilities and risks. Some municipalities (such as Halifax and Toronto) have partially funded adaptation planning through grants from senior levels of government, as well as committing their own resources.

- **Suitable timing:** Another facilitating factor that applies to adaptation policy development in general is the timing of the process. If adaptation policy and program development coincides with the introduction or updating of other relevant policies, or infrastructure upgrades, synergies may be obtained and the overall costs of adaptation can be reduced.

- **Interdepartmental cooperation:** Impacts of climate change such as heat waves or intense precipitation will affect the responsibilities of many municipal departments, and effective adaptation will need interdepartmental cooperation as well as collaboration with other organizations. Those municipalities that already have strong interdepartmental cooperation will have an easier time moving an adaptation agenda than those who work more in silos.

- **Compatibility with other policies:** If adaptation coincides with the development of other relevant activities such as sustainability planning, periodic revisions of the Official Plan, or infrastructure renewal, synergies may occur which can help to increase the acceptability of these policies and reduce the overall costs of adaptation. It may also be the case that existing policies that apply to day-to-day monitoring and management of weather-related events already contribute to adaptation, even if they are not labelled explicitly as adaptation policies. Building on these existing policies in such as way that they take into account future changes in climate and weather extremes can be a useful way to integrate adaptation into existing policy making.

Barriers

The willingness and ability to adapt can be affected by real and perceived barriers or constraints. This can lead decision makers to question the need for adaptation or can limit the willingness to consider a comprehensive adaptation strategy. Some barriers include the following:

- **Difficulty getting the attention/commitment of political leaders:** The short attention span of elected officials can be a major barrier to adaptation. Most political leaders are busy resolving immediate problems facing their constituents, and have little time to devote to longer-term problems like climate change, creating a mismatch between business planning horizons and the timeframe of projections of climate change. The high turnover of elected officials and staff can compound this problem, making it difficult to secure a long-term commitment to addressing climate change.

- **Limited understanding of climate risks and vulnerabilities:** Some municipalities may feel constrained by a perceived lack of understanding of climate risks and vulnerabilities, which can make it difficult to know where (and how) to prioritize adaptation actions. While there is often a general perception that climate change involves warming temperatures and heat waves, there is less understanding that climate change will involve more intense and less predictable problems such as storms, droughts, floods, tornadoes etc. Decision makers may not fully understand how these changes will impact life in their communities, or may be overly reliant on information about past conditions to make decisions.

- **Uncertainty:** Decision-makers may not feel they have enough certainty to guide decisions on adaptation. There are several sources of uncertainty, including difficulties interpreting historical climate records or forecasting future climate trends, a lack of useful precedents or evidence of adaptation in other jurisdictions, or a lack of acceptance or understanding of the risks associated with the implementation of adaptation actions. Uncertainty can be a major impediment to adaptation. For example, a municipality may feel that the uncertainty is simply too great to warrant taking any immediate action.

- **Lack of human and financial resources:** Resources for developing and implementing adaptation strategies are often inadequate. Financial resources are often in short supply, as many municipalities are faced with limited budgets that are simply insufficient to address a complex and potentially very serious set of problems. Government subsidies are often limited to short-term grants; unfortunately, once these grants are finished, it may be difficult to keep the adaptation process going. Human resources may also be limited. For example, the lack of a permanent employee dedicated to adaptation planning and implementation may place an additional burden on existing staff.

- **Existing government policies and priorities:** A lack of supportive government policies and priorities can impede adaptation progress, especially if they conflict with adaptation needs or simply encourage status quo. Government organizations are often sluggish in responding to new conditions; the status quo is almost always the default option and deviations from it are often small and incremental. Larger changes occur only very infrequently and usually only in response to major threats or pressures.

- **Lack of economic justification:** Action on climate change can be difficult in the absence of clear economic justification. Many adaptation options require major upfront expenditures. However, given that many cities have very tight budgets, and may already be having a hard time maintaining their existing infrastructure, the call to spend money to avoid future problems can be easy for decision makers to resist.

- **Difficulty getting stakeholders to the table:** Municipal staff may find it difficult to get some stakeholder organizations – local government departments, semi-autonomous agencies and key businesses – to the table. A number of organizations that should be involved in the adaptation process are often not, such as businesses that will be impacted by climate change or organizations that could have an impact on the effectiveness of adaptation options, such as developers, landowners, individual boroughs and planning councils.

Utilizing Drivers, Enhancing Facilitating Factors and Overcoming Barriers

Municipal staff who have analyzed drivers, facilitating factors and barriers within their governments and in their communities are better situated to take advantage of specific drivers to press the case for adaptation, enhance facilitating factors and tackle barriers. Communication and engagement activities, discussed in the next Module, can go a considerable distance in achieving these goals.

For example, staff who analyze and communicate the impacts and costs of extreme weather events in their own or other communities can make a stronger case for adaptation planning. Similarly, municipal departments may choose to invest in a (subsidized) risk assessment study of a major piece of infrastructure, knowing that the process will not only allow them to identify risks and increase adaptive capacity in their department and in the municipality, but that it may contribute to driving broader adaptive action.

There is no prescriptive list of steps for consciously taking advantage of drivers and facilitating factors or overcoming barriers to adaptation, as feasible strategies will always be sensitive to the local context. Some municipalities may reduce resource requirements and enhance knowledge by engaging in regional partnerships with neighbouring municipalities, leveraging a wider network of resources and expertise in the process. Others, when confronted with a limited understanding of climate risks and vulnerabilities, decide to draw on the knowledge and expertise of scientists and researchers in local institutions. Some may choose to reinforce their own in-house expertise by seeking out training and educational opportunities for staff; others yet may decide that it is in their best interest to do both.

Regardless of the options, taking the time to identify drivers and barriers is important for creating and implementing adaptation processes. Those who anticipate or recognize barriers when they first arise may find ways to circumvent them, either by re-allocating existing resources or strategically designing processes to overcome them.

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Module 11: Communicating and Engaging with Stakeholders

Learning Objectives and Outcomes

At the end of this session, participants will:

- Understand the challenges of communicating to different audiences (public, municipal staff, decision makers).
- Have reviewed and discussed a variety of ways to communicate issues related to climate change impacts and adaptation and to engage different audiences in working on these issues.
- Have discussed communication barriers and the best ways to overcome them.

Introduction

Clear communications and engagement strategies are needed to advance a climate change adaptation agenda. Political leaders, municipal staff, businesses and the general public will need to understand the current and future impacts of climate change and how we might prepare for it.

It will be helpful for adaptation leaders to set objectives for communication, define the audience and the content that needs to be conveyed, select communication channels, plan a communications strategy and evaluate the results. Communications will likely take place through a range of media in order to reach different audiences: brochures, posters, booklets, newsletters, websites, social media, in-person speeches, presentations, and in some cases, videos or ads on radio or television.

Communicating climate change impacts and adaptation information is necessary but not sufficient on its own for involving audiences in action on adaptation. Interactive engagement strategies that involve key audiences and stakeholders in adaptation discussions, planning and implementation will also be necessary.

Engagement strategies will vary according to the audience and the approach that is taken to initiate adaptation planning. Many adaptation planning processes begin internally within the municipal organization where the key audience to engage will be elected officials, senior managers and municipal staff in key departments. For community-based adaptation planning, audiences will also include business leaders, community leaders, educators and non-governmental organizations, among others, and coordinating information dissemination, dialogue, and consultation of stakeholders will require a firm consultation strategy.

This Module will highlight many of the ways in which municipalities can more effectively communicate the local effects of climate change and engage stakeholders within the community in thinking about, planning and implementing adaptation.

Guidelines for Communicating Climate Change Adaptation

Two organizations – the Center for Research on Environmental Decisions at Columbia University, and the U.S. National Research Council – have given considerable thought to communications on climate change, and have each developed a set of guidelines or principles to guide such communications, summarized in Table 1.

Table 1: Guidelines/Principles for Communicating Climate Change

Guideline/Principle	Example
Identify key audiences and tailor effective messages for each	▪ Speak to issues that matter most to the audience (e.g. health issues, environmental impacts, or costs of extreme weather) ▪ Use local examples of recent weather events that are indicative of future climate problems to make the issues more concrete ▪ Communicate the current and future benefits of acting now
Use best available science and translate scientific data into concrete experience	▪ Make analytic information memorable by using vivid images or stories ▪ Use everyday language and avoid scientific jargon
Beware overuse of emotional appeals	▪ Avoid numbing the audience with too strong a focus on disaster
Address climate change uncertainties	▪ Specify what is known with high confidence and what may be less certain ▪ Explain why uncertainty exists in climate change projections and impacts ▪ Point out that we make many important decisions without perfect knowledge
Tap into social identities and affiliations	▪ Enlist respected local "messengers" to help communicate the climate change message ▪ Emphasize shared identities and goals (e.g. concern for others)
Encourage interactive communication	▪ Bring people together and encourage them to talk to increase "buzz" and broader discussion of the issues
Communicate a positive vision of adaptation and practical examples	▪ Link adaptation to positive futures by discussing the multiple benefits that can be associated with adaptive actions ▪ Provide practical examples of adaptation actions that are already underway in the community or elsewhere
Use popular channels for communication	▪ This will include traditional materials as well as social media and the internet
Ensure communication is sustained over the longer period	▪ Climate change and adaptation are long processes and communication should be kept up to keep stakeholders abreast of information and activities

Key Audiences and Appropriate Framing

There are several important audiences for climate change impacts and adaptation communications. Because each group differs in the way they respond to information, it is important that communication is tailored to the interests, goals, concerns and level of understanding of the audience. Table 2 provides a summary of key audiences and potential framing strategies.

Table 2: Key Audiences and Framing Strategies for Communication

Audience	Role	Interests, Goals and Concerns	Strategies to Frame Information
Municipal Managers and Staff	▪ Responsible for many affected operations and services, including front-line response to climate change impacts ▪ Custodians of detailed knowledge about municipal sectors at risk and how they might be protected ▪ Involved in planning/development of adaptation programs	▪ Well-run municipality ▪ Shortage of funds for programs ▪ Workload	▪ Impacts of current weather and future climate change on responsibilities, goals, operations, programs, and costs ▪ Recognition that municipalities are already responding to extreme weather and climate impacts and that adaptation strategies can build on existing actions ▪ Preparedness for weather extremes and emergencies ▪ Potential for adaptation to reinforce other desired goals
Elected Officials	▪ Support by elected officials is critical for comprehensive adaptation action by municipalities ▪ Responsible for allocation of financial and human resources and for approving by-laws, incentives and other policy instruments ▪ In some instances they can be the key champions for adaptation programs	▪ Well-run municipality ▪ Minimizing public risks ▪ Economic security ▪ Publicity, public opinion and re-election ▪ Political legacies	▪ Financial, legal and reputational risks of climate impacts ▪ Safeguarding the public ▪ Ensuring the short- and long-term security of municipal investments and infrastructure ▪ Cost-effectiveness of prevention measures ▪ At times, stimulating the economy and creating jobs

Audience	Role	Interests, Goals and Concerns	Strategies to Frame Information
Community Leaders and the General Public	▪ Increasing awareness and knowledge about risks will help achieve public support for adaptation initiatives ▪ Decisions and behaviour at the household level can reduce risks of climate change	▪ Household safety and well-being ▪ Community impacts and security ▪ Good municipal facilities and services ▪ Effective return on investment of public funds	▪ Potential risks and risk-reduction at the level of the individual, household and community ▪ Win-win nature of adaptation initiatives that can achieve multiple benefits for the community ▪ Emergency preparedness
Businesses and Industry	▪ Support of business (or opposition) for adaptation can make a major difference in municipal decisions and allocations for adaptation ▪ Businesses that understand the risks of climate change may make changes that reduce impacts on their operations and services	▪ Security of services necessary for business operation (e.g. electricity, transportation, water,) ▪ Continuity of business	▪ Business risks related to current weather variability and extremes, and near-future climate change ▪ Risk assessment and risk management (with which many large companies are familiar) makes strong business sense ▪ Cost effectiveness of prevention measures especially for the infrastructure on which businesses depend ▪ Emergency preparedness and business continuity planning important

What Needs to be Communicated

1. How Climate is Already Changing

Information about **local or regional climate trends** can help your audience see ways in which climate is already changing, though it is not always easy to come by. (See Module 1 for sources of information.) Information on some of the following climate-related trends may be very revealing:

- Temperature trends, which could include: annual mean temperature; annual maximum temperature; annual minimum temperature; winter mean temperature; winter maximum and minimum temperatures; numbers of hot days; incidence and length of heat waves; number of cold days
- Precipitation trends, which could include: annual total precipitation; total winter precipitation; total summer precipitation; number of days with precipitation; snowfall trends; precipitation rates (millimetres per hour)

- Storm information including: frequency of high-intensity thunderstorms; tornadoes; wind speeds; freezing rain events
- Seasonal changes such as: first and last frost dates; length of growing season; leaf-out dates
- Other trends such as: water levels, time of ice break-up; length of ice-free season; flooding incidents; heating degree days and others.

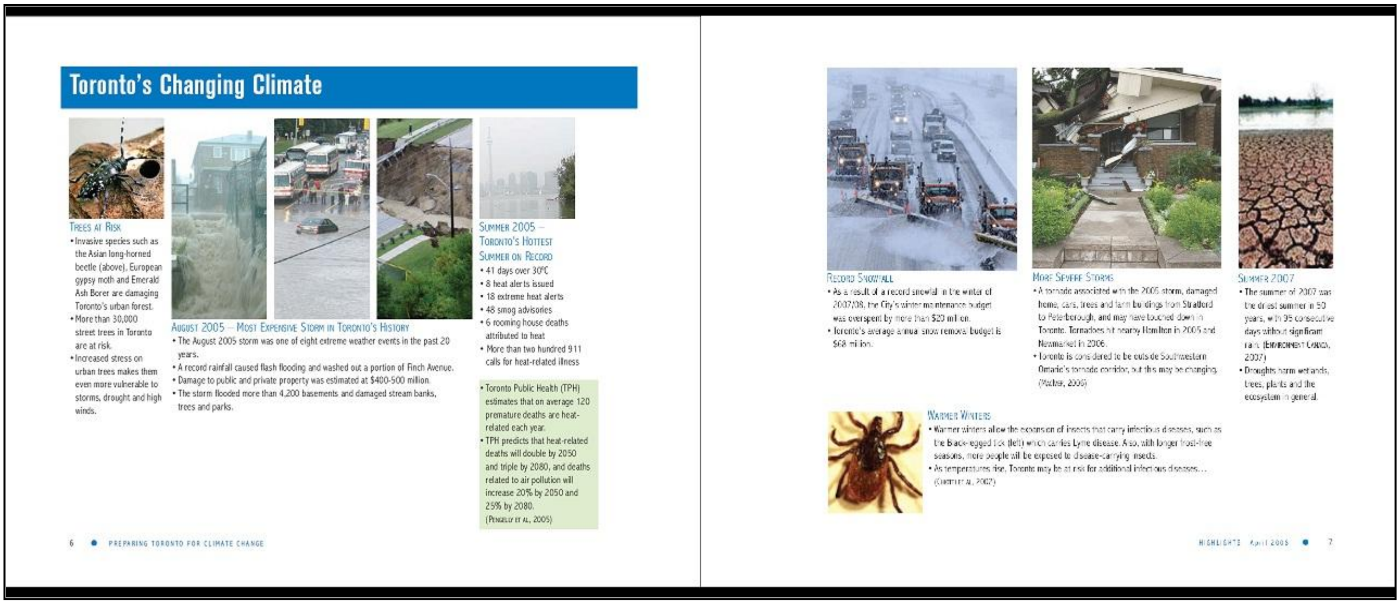
Environment Canada's *Climate Trends and Variations Bulletins* has up-to-date information on national and regional climate trends that may be useful to include in municipal communications materials.

Clear, practical **examples of climate-related impacts** are a vital aspect of climate change communication. Communicators can draw on recent weather events within the experience of the audience that illustrate ways in which climate is changing and the kinds of impacts that might be expected. Events that occurred nearby are most likely to speak to local audiences. Other weather-related disasters that have occurred further afield (the European heat wave of 2003; Hurricane Katrina's destruction of New Orleans in 2005) may also illustrate potential impacts, but should be used sparingly in order to keep the focus on local climate changes for local audience and decision-makers.

Examples of extreme weather events in Ontario that have been used to illustrate the impacts of extreme weather, which are likely to become more frequent under climate change, include:

- The ice storm of 1999 and its impacts on Eastern Ontario
- Floods and washouts in Northern Ontario in June 2002
- The blackout of 2003 (not attributed directly by extreme weather, but occurring at the end of a heat wave during a time of very high demand for electricity and air conditioning)
- The Peterborough flood of 2004
- The thunderstorm and tornado outbreak of August 19, 2005 in Southern Ontario (resulting in, among other things, the washout of Finch Avenue in Toronto and thousands of flooded basements)
- Drought across Southern Ontario from Chatham to Peterborough in 2007
- Record low water levels in Lake Superior and low water levels in the other Great Lakes in 2007
- Record snowfalls in the winter of 2007-2008
- Floods in London in 2008
- Tornadoes that struck Vaughan in 2009
- Other local or regional events that illustrate the current and potential future impacts of extreme weather.

The City of Toronto's produced the booklet *Ahead of the Storm* to explain the City's proposed adaptation process to the general public. Pages 6 and 7 of the booklet presented information on "Toronto's Changing Climate", with brief descriptions and photos of recent extreme weather events.



Toronto's Changing Climate

TREES AT RISK
- Invasive species such as the Asian long-horned beetle (above), European gypsy moth and Emerald Ash Borer are damaging Toronto's urban forest.
- More than 30,000 street trees in Toronto are at risk.
- Increased stress on urban trees makes them even more vulnerable to storms, drought and high winds.

AUGUST 2005 – MOST EXPENSIVE STORM IN TORONTO'S HISTORY
- The August 2005 storm was one of eight extreme weather events in the past 20 years.
- A record rainfall caused flash flooding and washed out a portion of Finch Avenue.
- Damage to public and private property was estimated at $400-500 million.
- The storm flooded more than 4,200 basements and damaged stream banks, trees and parks.

SUMMER 2005 – TORONTO'S HOTTEST SUMMER ON RECORD
- 41 days over 30°C
- 8 heat alerts issued
- 18 extreme heat alerts
- 48 smog advisories
- 6 rooming house deaths attributed to heat
- More than two hundred 911 calls for heat-related illness

- Toronto Public Health (TPH) estimates that on average 120 premature deaths are heat-related each year.
- TPH predicts that heat-related deaths will double by 2050 and triple by 2080, and deaths related to air pollution will increase 20% by 2050 and 25% by 2080.

(PENGELLY ET AL, 2005)

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RECORD SNOWFALL
- As a result of a record snowfall in the winter of 2007/08, the City's winter maintenance budget was overspent by more than $20 million.
- Toronto's average annual snow removal budget is $68 million.

MORE SEVERE STORMS
- A tornado associated with the 2005 storm, damaged home, cars, trees and farm buildings from Stratford to Peterborough, and may have touched down in Toronto. Tornadoes hit nearby Hamilton in 2005 and Newmarket in 2006.
- Toronto is considered to be outside Southwestern Ontario's tornado corridor, but this may be changing. (Walker, 2006)

SUMMER 2007
- The summer of 2007 was the driest summer in 50 years, with 95 consecutive days without significant rain. (ENVIRONMENT CANADA, 2007)
- Droughts harm wetlands, trees, plants and the ecosystem in general.

WARMER WINTERS
- Warmer winters allow the expansion of insects that carry infectious diseases, such as the Black-legged tick (left) which carries Lyme disease. Also, with longer frost-free seasons, more people will be exposed to disease-carrying insects.
- As temperatures rise, Toronto may be at risk for additional infectious diseases…

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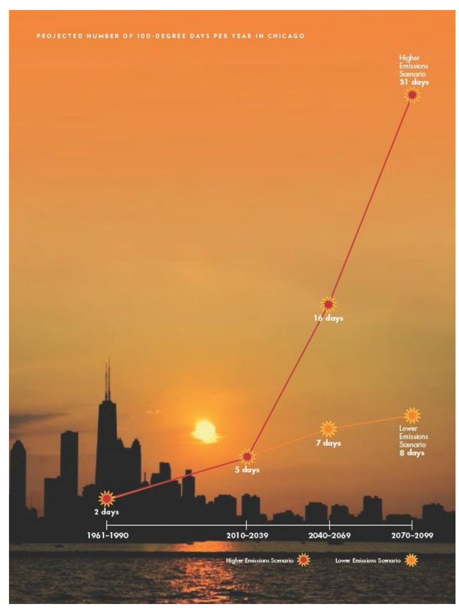
2. What is Likely in the Future – Climate Projections and Likely Impacts

If decision-makers and other stakeholder groups have a basic grasp of climate science and projections, then it is easier to gain support for action on climate change adaptation. The need here is to communicate the science in a credible way and in terms that are meaningful for specific local audiences. This is not always easy. Climate scientists are not trained to communicate their findings to the public, and most of their writing and speaking is for an audience of their peers – other scientists who speak the same language. So even though there is a growing body of climate science that is easily available on-line, municipal staff who wish to communicate about climate change may still have to interpret and simplify the language, and be selective about the graphs and charts that they use.



Depending on the intended audience, climate projection information may be presented quite simply, or with greater detail and complexity. In their *Climate Adaptation Study* for the Capital Region District of B.C., the Sheltair Group provided a simple text (with citations) that summarized expected changes in climate for the municipality as shown in the box on the next page.

It is likely to be more effective to communicate these kinds of projections using visual aids, such as the chart produced used by the City of Chicago in their Climate Action Plan to illustrate the expected increase in days over 100ºF (37.78ºC) in the next century for two different emissions scenarios.

Potential Future Primary Environmental Impacts (of Climate Change for the Capital Regional District)

The following are the main primary environmental impacts of climate change that are expected to occur in the Capital Region over the 21st Century:

- Average temperature in the South Coast of BC may increase by up to 3ºC in winter and up to 5ºC in summer
- Precipitation may increase in the months of December and January by approximately 6-7 mm over the next 100 years
- Average annual precipitation may increase by 10 to 20%
- More extreme precipitation events – increase in severity of winter storms
- Sea level is expected to continue to rise along parts of the BC coast

Potential Intermediate Environmental Impacts Due to Climate Change

The above primary impacts (meteorological and oceanographic changes) will result in a range of further changes to the land, water, and other environmental systems. According to the British Columbia Coast and Marine Environment Project (2006), these will include:

- Reduced snow pack in southern BC and at mid elevations
- Earlier spring freshet on many snow-dominated river systems
- Reduced summer stream flows, particularly on snow-dominated river systems
- Glacial retreat and disappearance in southern BC
- Warmer temperatures in some lakes and rivers
- Reduced summer soil moisture in some regions
- Increased frequency and severity of natural disturbances such as fire, diseases, pest outbreaks
- Large-scale shifts in ecosystems and loss of ecosystems, including some wetland and alpine areas
- An increase in growing days.

For straightforward information on climate science and projections, communicators may turn to the sources suggested in Module 1 of this training program as well as:

- The Report of the Expert Panel on Climate Change Adaptation, *Adapting to Climate Change in Ontario* (2009)
- NRCAN's *Climate Change Impacts and Adaptation: A Canadian Perspective*, especially the Ontario Chapter (2007)
- NASA's *Global Climate Change* website, which contains climate change information in plain language and includes images, slide shows and other useful materials.

2a. Dealing with Uncertainty

One of the most challenging aspects of climate change communication is dealing with the uncertainties of climate change. There are several sources of uncertainty in climate projections. These include:

- **Future greenhouse gas emissions** – while recent emissions trends are clear, what happens in the future will depend on economic and population growth (especially in fast growing economies such as China and India); technological change (the adoption of low carbon technologies) and other factors
- **Effects of particulates in the atmosphere –** most particulates (sulphates, dust, smoke, soot) have a cooling effect but have only recently begun to be tracked in the atmosphere
- **Clouds –** small changes in cloud cover could speed warming or slow it, but current climate models do not represent clouds well (though much research is being done on this issue)
- **Carbon absorption** – about half the carbon emitted each year is absorbed by vegetation and by the oceans, but it is unclear whether this will continue well into the future
- **Precipitation** – climate models provide very different projections for precipitation, especially at a regional level.

It is wise to be frank about uncertainties, but also to be firm about what is known. The fact that there is not a complete understanding about some aspects of the climate system does not mean that there is uncertainty about whether there will be an increase in global temperatures and related climate changes as a result of greenhouse gas emissions. Certainly some of the local consequences are uncertain. But scientists are working hard to expand our knowledge of the climate system and reduce uncertainties.

Australia’s national scientific agency, CSIRO, and Columbia University's Center for Research on Environmental Decisions (CRED) both note that people have a great need for predictability and that they tend to respond irrationally about uncertain information and negative outcomes. CRED and CSIRO suggest that the following steps be taken to addressing this:

- Uncertainty around climate change should be acknowledged and gaps in information identified. This will include exact changes in temperature or precipitation, or how they will impact municipalities specifically, and the timing of these changes and impacts.

- Present information in a way that highlights what we *do* know. For example, climate models all point to overall increasing temperatures and changing patterns of precipitation. Adaptation to climate change is a risk management issue. We prepare for many uncertain risks in the future by saving, purchasing insurance and other means. An alternative framing for some audiences might be to invoke the precautionary principle, which suggests that action be taken to reduce the risks despite the absence of 100 percent certainty about individual threats.

In order to answer really thorny questions, and to get the latest scientific information on specific climate issues, municipalities may consult the Climate Science Rapid Response Team, a group of about 100 climate scientists who have agreed to make themselves available to provide highly accurate science information in answer to questions from the media or government.

2b. Dealing with Sceptics

One of the most common barriers that municipalities will have to face with regard to climate change related communication is dealing with climate sceptics. There are a large number of arguments used by climate sceptics, including the following:

- There is no real consensus among scientists about climate change.
- There's no proof that rising CO_2 causes global warming.
- Last winter was cold and there was a lot of snow.
- The current warming is just a natural cycle.
- We can't reliably predict the weather next week, let alone 50 years from now.
- It's not feasible to reduce emissions.

It won't always be useful to argue face-to-face with a climate sceptic. However, if climate sceptic arguments are being used to create obstacles to a municipality's work on climate change, then communicators may want to respond. There are several good sources of scientific information to respond to typical arguments that sceptics use, including the following:

- The UK's National Environment Research Council – *NERC Climate Change Challenge*
- The University of Oregon's Climate Leadership Initiative – *Setting the Record Straight: Responses to Common Challenges to Climate Scientists*
- Grist Magazine – *How to Talk to a Climate Sceptic: Responses to the most common sceptical arguments on global warming*
- Australian John Cook's blog – *Sceptical Science: Getting Sceptical about Global Warming Scepticism.* Sceptical Science also has several smart phone applications that allow subscribers to access rebuttals to climate sceptic arguments at the moment they need them.

Four tactics are suggested for dealing with sceptics:

1. Address public statements made by sceptics openly and respectfully. Inaccurate statements should not go unchallenged.

2. Do not guess in responding to a sceptic. Being mistaken is more harmful than admitting you do not know. Say you'll follow up with the evidence if you need to.

3. Refer audiences to sources that have more information. Marlo Reynolds of the Pembina Institute suggests pointing out that national science academies in the United States, Europe, Japan, Canada, India, China, Russia, Brazil, Mexico and elsewhere all agree that climate change is underway. Similarly, major professional organizations such as the American Meteorological Society, the American Associations for the Advancement of Science, NASA and the U.S. National Oceanic and Atmospheric Administration (NOAA) all agree that climate change is occurring. Even the Pentagon has been evaluating climate risks and threats to global stability.

4. Invite a climate scientist from Environment Canada's Adaptation and Impacts Research Section or from a local university to tell critical audiences about climate change and its expected impacts.

3. Ways in Which We Have Already Begun to Adapt

A number of municipalities and individual departments or agencies within municipalities have provided leadership on adaptation in specific areas. Communicating these adaptation efforts is important to:

- Demonstrate that the municipality is taking leadership on climate-related problems
- Provide concrete examples of adaptation that may encourage similar efforts by community actors outside the control of the municipality
- Stimulate adaptive action by municipal officials unwilling to be seen as lagging
- Lay the groundwork for larger, more ambitious strategies.

4. What Needs to be Done to Adapt

An important aspect of communicating climate change adaptation to both residents and to key decision makers is to stress to them what will need to be done to better adapt municipalities to the potential impacts of climate change. It is one thing to explain the potential impacts of climate change, but is particularly important to build support for a broader adaptation plan or strategy by illustrating how those impacts may be dealt with.

The City of Toronto's *Ahead of the Storm Highlights* is a good example of a document that provides a quick list of adaptation actions recommended that the City undertake in the short and long term, along with their anticipated benefits made clear. See the figure below for an excerpt.

City of Toronto short-term recommendations for establishing a climate change adaptation strategy

NEW ADAPTATION ACTIONS	ANTICIPATED BENEFIT
Engage Toronto's Neighbourhoods and Communities Through 'Live Green Toronto'	To support neighbourhoods and communities in greening projects, including initiatives that will reduce climate change impacts.
Conduct the Don Trunk Sewer and Waterfront Wet Weather Flow Control Projects	To assess the effects of extreme weather on long-term performance of existing and new wet weather flow facilities and attain water quality goals.
Complete Flood Warning System Updates	To improve existing systems to prepare for flood emergencies.
Conduct Lake Ontario Shoreline Planning	Adaptive design for aquatic diversity and flood protection will take into account fluctuations of water level.
Develop Regional Extreme Precipitation Intensity, Duration and Frequency Curves	To improve ability to design storm drainage infrastructure for extreme runoff events.
Review Urban Flooding Issues	To identify future policy and program requirements for flood protection.
Conduct a Scan of Methods used in other jurisdictions to Assess Vulnerability to Heat	To create a heat-related vulnerability assessment tool that improves the effectiveness of the City's Hot Weather Response Plan.
Evaluation of the Air Quality Health Index (AQHI) Pilot	Evaluation will help identify behaviour changes that citizens are making as a result of the AQHI and identify improvements in education initiatives that can help maximize health benefits when air quality is poor.

5. *How to Prepare for Climate-Related Emergencies*

Municipalities are responsible for responding to emergencies and preparing key audiences for climate-related impacts. By effectively communicating preparation techniques, support and resources, municipalities may reduce extreme weather damages to their communities and reinforce the need for adaptation by households and businesses as well as by the municipality.

Ontario municipalities can help homeowners prepare for coming threats by giving examples of adaptation options. The Institute for Catastrophic Loss Reduction has produced Disaster Prevention Brochures that give homeowners helpful tips on how to prevent damage to their home from hazards like tornadoes, floods or winter storms.

While not focused on climate change-related weather emergencies, the City of Vancouver nonetheless shows how a municipality can communicate to its residents about how to react to emergency situations. Due to its potential earthquake risk, Vancouver recognizes that emergency situations can occur without any notice. The City has been proactive in addressing this need to be prepared through several communication methods. Its Neighbourhood Emergency Preparedness Program website offers a wealth of information, and links to two additional types of communication tools that can also be particularly useful to municipalities that face emergency weather situations. The first is a series of videos that capture the main steps for becoming prepared for emergencies before, during and after the event. Finally, the City offers frequent Emergency Preparedness Workshops all over the city, giving as many residents the change to participate as possible.

Vancouver's "10 Steps to Home Preparedness" video

Some Ontario municipalities (such as London and Ottawa) provide business continuity advice and planning guides aimed at reducing business losses and ensuring swift start-up in the aftermath of an event. An effective overview of what a business continuity plan could contain has been prepared by the Institute of Catastrophic Loss Reduction (ICLR) which has a guide, *Open for Business*, and a website that discuss how to respond immediately after an emergency, assess damages, and preparing for financial losses.

With the knowledge of *what* needs to be communicated, municipalities can then turn to determining *how* this information can be communicated to ensure effective communication of the severity of climate-related impacts and issues, as well as practical adaptation options.

There are several tools that can help municipalities communicate climate change impacts and adaptation to their key audiences. These come in several forms – visual, written, online, or a combination of all three – and should be clearly articulated and particularly relevant to the municipality and population (or segments of the population) that will experience effects of climate change.

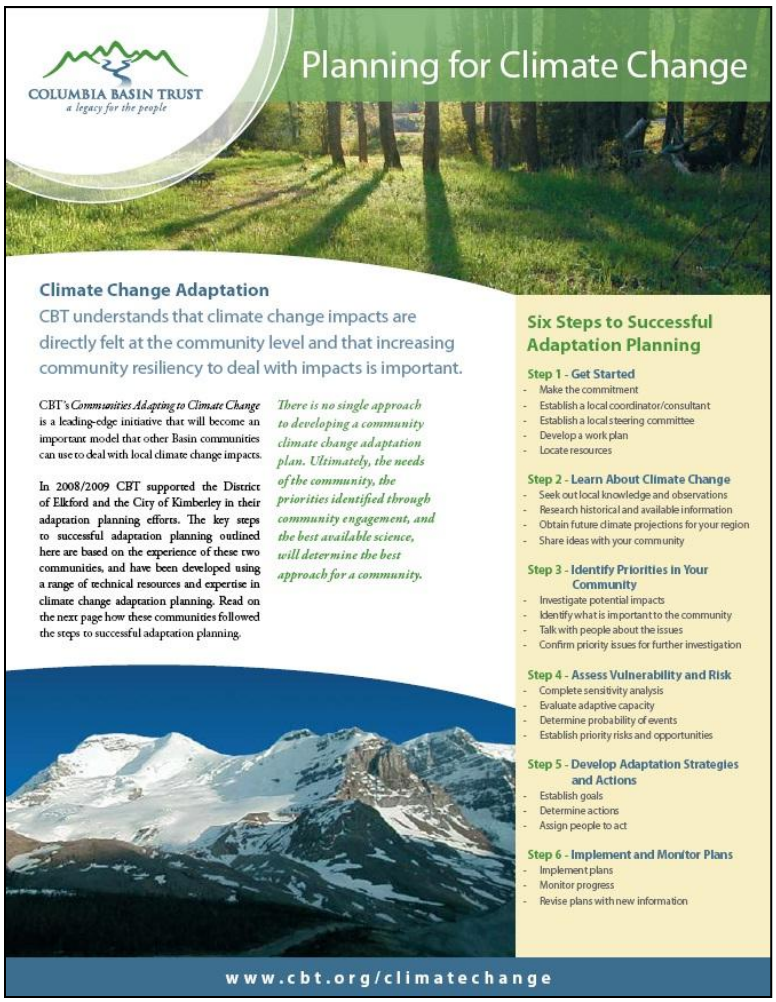
Communication Tools

There are a host of methods and tools that municipalities can use to communicate to and with elected leaders, municipal staff and the general public about climate change impacts and adaptation. The following presents information about a number of tools and provides examples of each.

Print Materials

Brochures and Factsheets

Brochures, flyers or factsheets are versatile communication tools that can be made relatively cheaply, distributed easily and reach a large number of people. They are meant to communicate short, concise messages. The best ones are short, colourful and contain easy-to-read text. The Columbia Basin Trust's two-page fact sheet, [*Planning for Climate Change*](), explains the need to adapt to climate change, sets out a broad adaptation planning framework, and gives local examples from the City of Kimberley and the District of Elkford.



COLUMBIA BASIN TRUST
a legacy for the people

Planning for Climate Change

Climate Change Adaptation

CBT understands that climate change impacts are directly felt at the community level and that increasing community resiliency to deal with impacts is important.

CBT's *Communities Adapting to Climate Change* is a leading-edge initiative that will become an important model that other Basin communities can use to deal with local climate change impacts.

In 2008/2009 CBT supported the District of Elkford and the City of Kimberley in their adaptation planning efforts. The key steps to successful adaptation planning outlined here are based on the experience of these two communities, and have been developed using a range of technical resources and expertise in climate change adaptation planning. Read on the next page how these communities followed the steps to successful adaptation planning.

There is no single approach to developing a community climate change adaptation plan. Ultimately, the needs of the community, the priorities identified through community engagement, and the best available science, will determine the best approach for a community.

Six Steps to Successful Adaptation Planning

Step 1 - Get Started
- Make the commitment
- Establish a local coordinator/consultant
- Establish a local steering committee
- Develop a work plan
- Locate resources

Step 2 - Learn About Climate Change
- Seek out local knowledge and observations
- Research historical and available information
- Obtain future climate projections for your region
- Share ideas with your community

Step 3 - Identify Priorities in Your Community
- Investigate potential impacts
- Identify what is important to the community
- Talk with people about the issues
- Confirm priority issues for further investigation

Step 4 - Assess Vulnerability and Risk
- Complete sensitivity analysis
- Evaluate adaptive capacity
- Determine probability of events
- Establish priority risks and opportunities

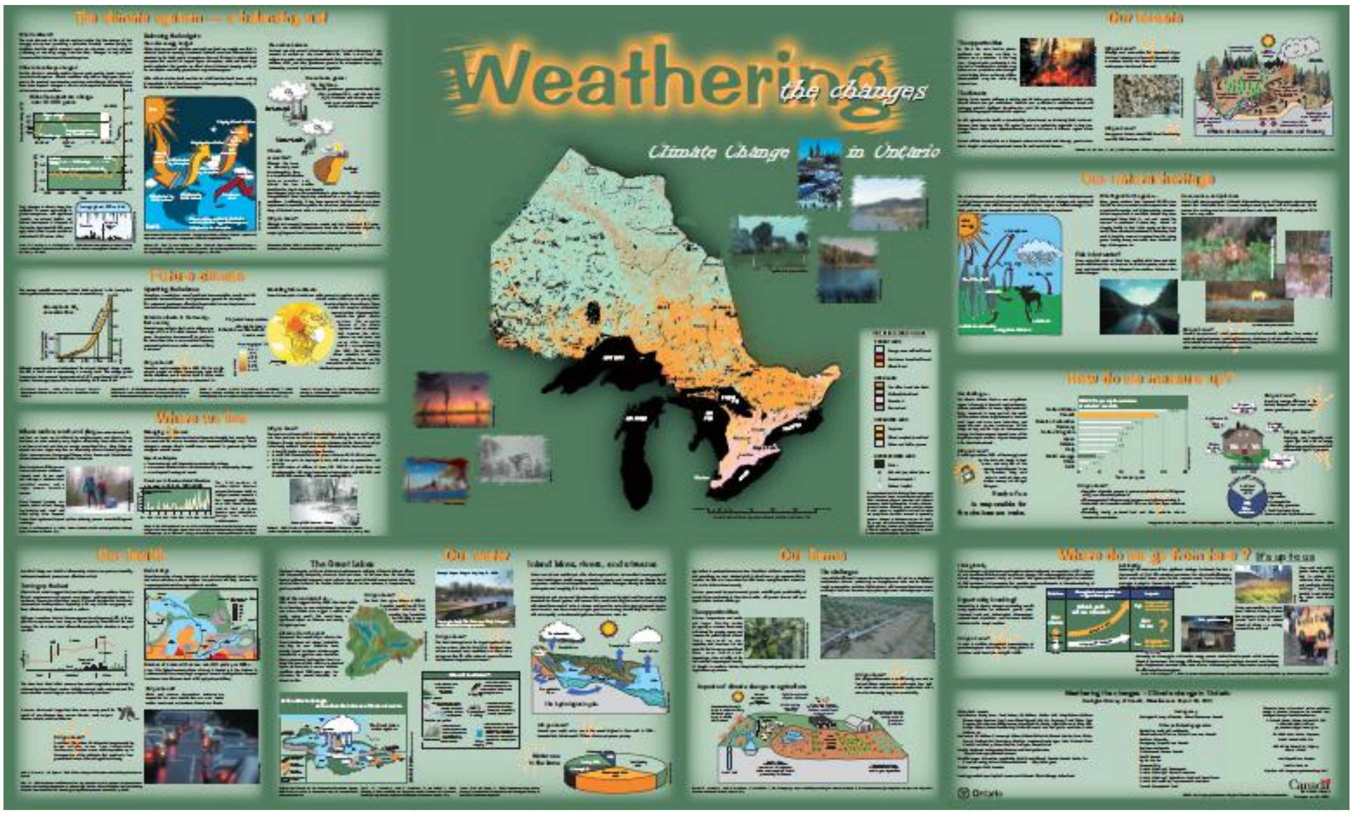
Step 5 - Develop Adaptation Strategies and Actions
- Establish goals
- Determine actions
- Assign people to act

Step 6 - Implement and Monitor Plans
- Implement plans
- Monitor progress
- Revise plans with new information

www.cbt.org/climatechange

Posters

Posters can be used in high-traffic public spaces to extend climate change impacts and adaptation messages to the general public. *Living in a Changing Climate* is a series of regional posters distributed by Natural Resources Canada. They explain the threats and opportunities created by climate change in addition to the adaptation measures currently underway, and large-format copies can be ordered from Natural Resources Canada. (Though they were produced about 10 years ago, most of the information in the posters is still relevant.)



Newsletter Articles or Special Issues

Newsletters can provide ongoing communication on a number of different topics, events and initiatives. Often they are community-based which helps municipalities personalize both the threats to the region and the solutions or actions that should be taken. A number of municipalities have regular newsletters that they distribute in their communities. These newsletters could be a good vehicle for articles that increase awareness of climate change.

Halifax Regional Municipality has included a number of articles on climate change impacts and adaptation in *Naturally Green*, its quarterly newsletter, including advice on preparing for weather emergencies. Other municipalities such as the City of Chicago offer the chance to sign up online for climate change and environmental newsletters.

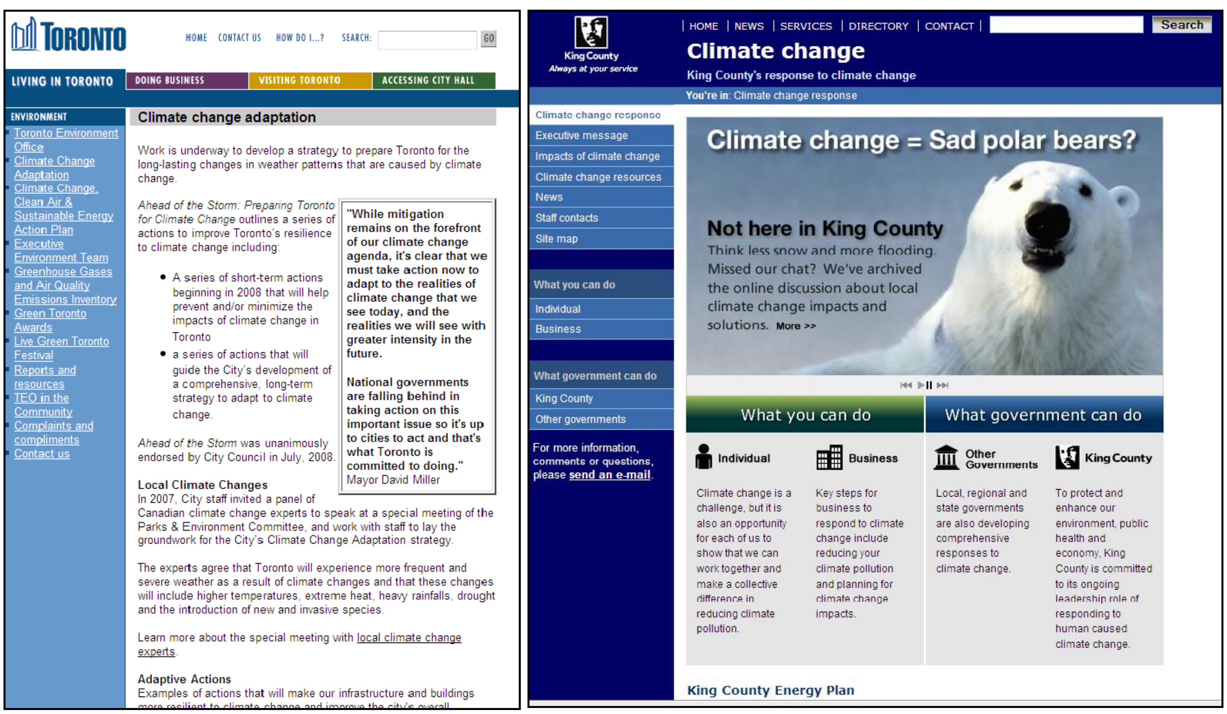
Websites

Increasingly, municipalities are developing a presence online in order to reach more people, especially younger populations. Municipal websites can be an important first step to communicate the local impacts of climate change and what municipalities are doing to adapt.

Many municipalities including Toronto, Sudbury, Halifax, Vancouver have created websites that discuss climate change as a threat to their communities and report on city-wide adaptation efforts and options. These websites make it is possible to reach a large number of citizens as well as to advertise initiatives to other regions and provinces.

Not all websites have the same appeal or target audience in mind. The City of Toronto and the King County (Washington State) websites on climate change contain similar information, for example, listing climate change initiatives, links to climate change plans and targets, how they fit into broader municipal and provincial or state policies, and so on. However, one is mainly a web space for plans, meeting reports and other documentation. The other is visually appealing, with plenty of information on potential climate change impacts, what is being done to address the impacts of climate change, and how individuals and businesses can both reduce emissions and respond to climate change impacts. The two websites appear side-by-side for comparison in the figure below.

Screenshots of the City of Toronto and King County Climate Change Adaptation Websites



Social Media

Social media and emerging mobile technologies also present an opportunity for municipalities to reach many people using devices and online platforms with which they are comfortable. Municipal use of social media to communicate to citizens has been fairly minimal, but it presents an increasingly-important way in which people are able share knowledge with each other.

The City of Boston's Mayor's Office of Emergency Management uses both Facebook and Twitter to communicate about emergency preparedness, share links to relevant news articles and offer tips on protecting personal life and property. The figure below shows a recent short message, or "tweet" posted by the Mayor's Office of Emergency Management.

Sample Tweet by the City of Boston Mayor's Office of Emergency Management

Those who "follow" the Office will have received this message and may have been prompted to visit the link to learn how to be safer in flood situations. This type of messaging is a quick (often done in real-time), cheap and easy way for municipalities to reach many residents simultaneously.

Municipalities could also offer the opportunity for users to easily "share" a municipality's climate change adaptation website or articles by using social media icons such as Facebook, Twitter, or StumbleUpon, letting interested users spread the message themselves through their networks of friends and contacts. An example of what that might look like is shown below.

Typical social media "sharing" icons on Chicago's Climate Action Plan website

HowTo.gov has produced a guide for government organizations on the use of social media. The Fels Institute of Government at the University of Pennsylvania also recently published a well-researched and easy to read guide *Getting the Most of Social Media: 7 Lessons from Successful Cities*.

While it is important for municipalities to have a strong web presence, especially as places for the public to gain information and knowledge, it must be noted that communication should continue through more traditional methods and the act of engagement should ultimately be done face-to-face with 'real' people.

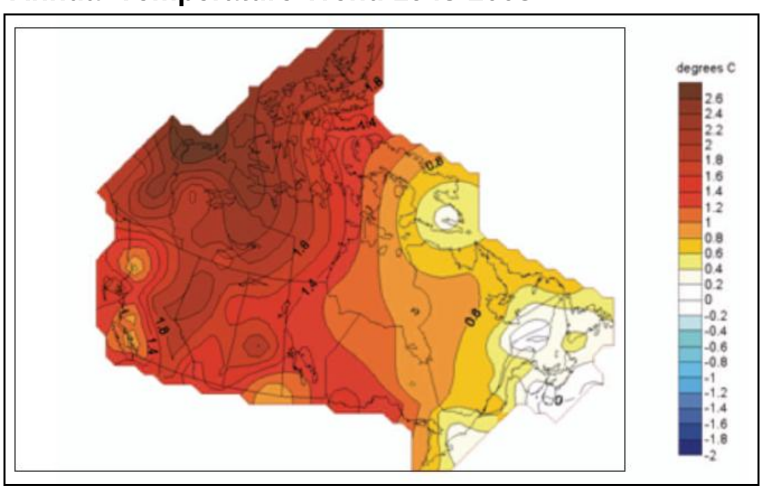
Visual Communications

Visual information is a very important tool for communicating climate trends, climate change impacts, and adaptation options, quickly and simply conveying information, and often packing more of a punch than written or verbal information alone. For municipalities communicating with municipal employees, the public or policy makers who may not have a background in climate science or adaptation planning, maps, graphs and charts, photographs, videos and computer simulations can communicate areas of risk, climate change impacts or potential adaptation strategies quite effectively. This section will explore several of the visual methods of communication and how they may be used to communicate the need to adapt.

Maps

Maps can provide an effective way to make climate information tangible. They help pinpoint the geographic effects of climate change, and because everyone is tied to a specific place can be very persuasive about bringing home climate change impacts as well as showing the wide-ranging effects over broader scales. The figure below depicts temperature trends in Canada over the past 60 years. While a lay person may not fully understand the climate science that explains this change, the change itself is easily understood.

Annual Temperature Trend 1948-2008

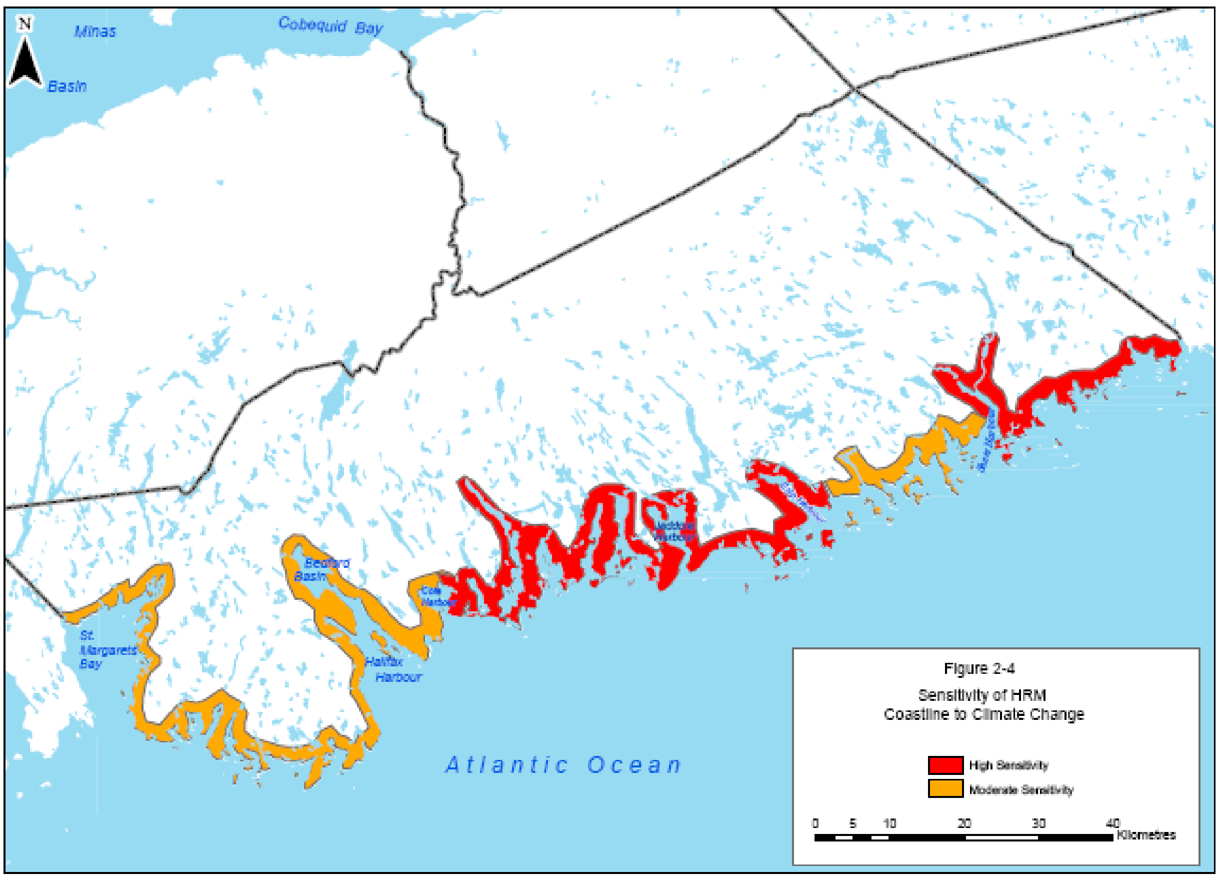


Source: Environment Canada, 2009

Similarly, hazard maps can quickly show areas of vulnerability to audiences. Moreover, hazard maps give the reader the ability to quickly identify impacts that pertain to them; flood risks in their neighbourhood or near their workplace; projected increases in tornado occurrence near a cottage; or surface temperatures in their neighbourhood.

Several municipalities have used hazard maps to communicate climate risks as part of their adaptation planning. Halifax Regional Municipality developed several hazard maps depicting the vulnerability of Halifax's coastline to climate change. This type of map allows municipal workers to identify whether critical infrastructure or buildings are vulnerable. Policy makers can use this type of visual to determine where to channel funding and the public can determine the ways in which a flood can impact them.

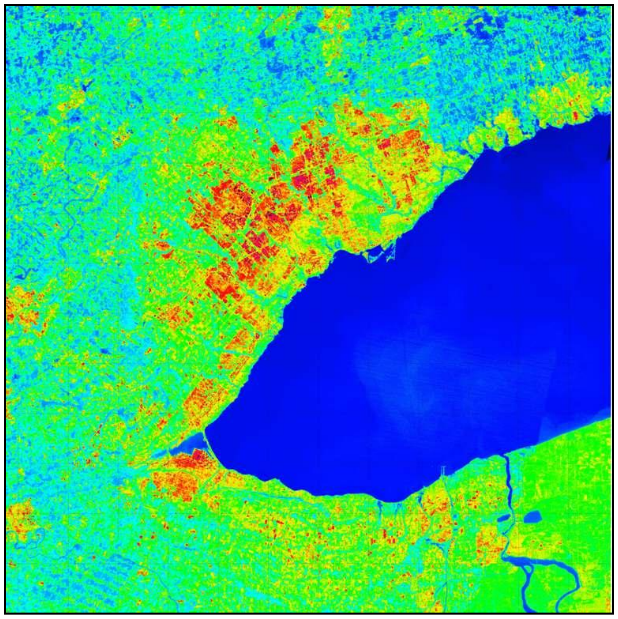
Map showing Sensitivity to Sea Level Rise in the Halifax Regional Municipality



Source: Halifax Regional Municipality, Climate Change Risk Management Strategy, 2007

Natural Resources Canada and the Clean Air Partnership collaborated on several urban heat projects to study the urban heat island effect in the Greater Toronto and Hamilton Area and to work with municipalities on strategies to deal with it. NRCAN provided the GTA with surface temperature maps derived from satellite thermal monitoring for the area. These maps have proved very powerful for municipal health and planning staff who have used them to raise awareness of urban "hot spots" and of the need for resources to tackle urban heat islands.

Heat Map showing Surface Temperatures in the GTA



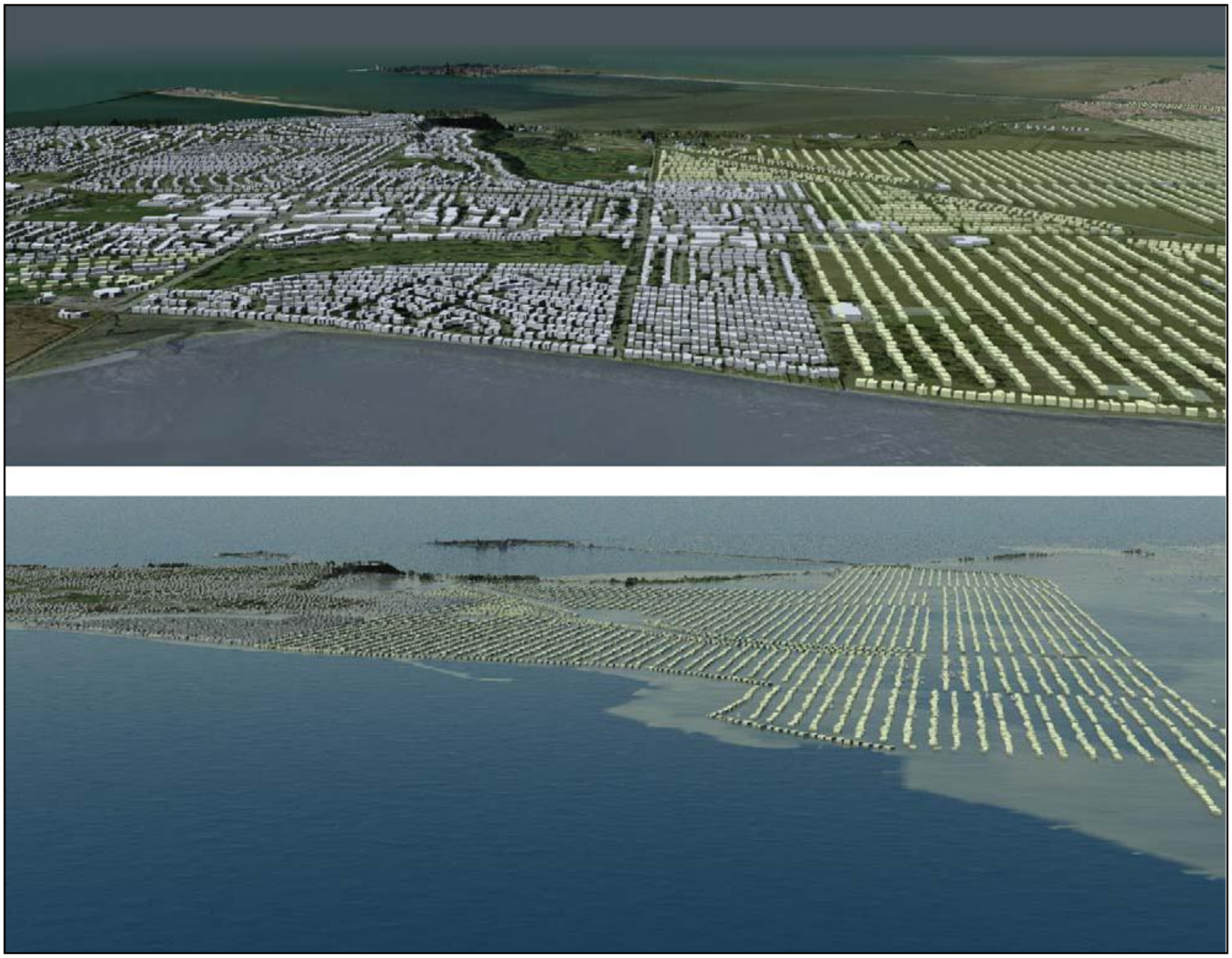
Source: Natural Resources Canada, 2009

Visualizations

Computer-developed visualizations are an increasingly important communication tool. Using GIS-based software to enable the use of modelling in conjunction with “photo-realistic software”, programs can create a visual image of a projected occurrence to clearly depict the potential impacts of a changing climate on a community.

UBC’s Collaborative for Landscape Planning (CALP) developed the Local Climate Change Visioning Project in Delta, BC to show residents and policymakers the potential impacts of climate-related storm surges and sea level rise in their community, an example of which is shown on the next page.

Visualization Depicting Tsawwassen, BC under a "Do Nothing" Scenario



Source: Shaw et al., 2009

CALP also investigated projected sea level rise in Delta, B.C. and used photo-realistic software to show the extent to which this could impact a specific neighbourhood (a) in the figure on the next page. They also developed visuals to show a variety of adaptation and community sustainability options, including installation of a large berm (b); use of a sea wall and raising houses on stilts to protect against storm surges – and with added solar panels (c); and a new, low-carbon urban design that combines a sea wall, with low-carbon energy and food production within the community.

These visualizations were used in community meetings and in workshops with municipal officials, and proved very effective in stimulating discussions in the community about climate change impacts and adaptation and action in the municipality.

Visualized Adaptation Options in Delta, British Columbia

Films and Videos

As visual resources, films or videos are highly versatile. Some municipalities have used videos to show potential climate change impacts and promote adaptation actions.

Videos from news reports and weather coverage, such as the Weather Network's Tornado tears across Leamington, Ontario, can be part of a communication strategy as they are presented in an easily understood format, use clear language, and are often very immediate. The Leamington tornado example visually demonstrates the extent of damage and interviews with homeowners can personalize the danger.

After the widespread flooding in Toronto on August 19, 2005, the City commissioned a video on the Basement Flooding Protection Plan which demonstrates the extent of the problem facing many basement owners, from inadequate infrastructure to topographic weaknesses, and promotes adaptation efforts underway.

In British Columbia, a project on adapting to climate change in the Fraser River Basin was initially illustrated through two twelve minute long videos produced by an environmental communication and engagement firm.

One of the introductory videos, [Adapting to Climate Change in the Fraser River Basin], focuses on municipal operations related to water use and supply in the Basin. The video is geared to municipal officials and those already working within the fields of infrastructure and climate change adaptation. With proper context and initial background information, however, it could be used as part of a broader communication strategy targeted at the general public. The videos have been widely distributed across British Columbia and throughout the rest of Canada and the United States to municipal governments and professional associations.

Planning and Sustaining Communication

The Scottish government has produced an on-line toolkit which provides guidance for developing and implementing a longer-term communications strategy. The toolkit includes a communication planning template that can be used to help communicators determine in a systematic way just what they would like to achieve with their communication materials. An adapted version of this template can be particularly useful for municipal staff to convey to communications departments or communications firms what they wish to communicate.

Because climate change is an ongoing problem that cannot be addressed in the short term, sustained communication is important. This enables municipalities to relay information regarding progress in ongoing adaptation efforts, emerging needs, changes in climate-related impacts and new adaptation endeavours. Additionally, it allows them to receive and incorporate feedback regarding changes in their community and emerging vulnerabilities.

Often local governments will use a variety of tools to achieve this ongoing dialogue. Varied and long-term communication can reach a large portion of the population, provide motivation and ensure continued involvement in community level adaptation programs.

Communications Planning Template
What do you hope to achieve with this piece of communication? What are your aims and objectives?
Who is the target audience?
What are the main messages? (Try to limit these to no more than three)
What do you want your audience to do or think as a result of the communication?
What tone should the communication adopt?
What communications channels have you considered to reach your target audience - newsletter, email, workshop/meeting, leaflet, poster etc?
What format have you been considering (e.g. leaflet or poster size)?
Are there any guidelines on imagery and style of imagery to use/not to use? (e.g. positive vs. negative; colour vs. black & white)
Are there any constraints or requirements? (e.g. required templates, logos…)
Is there any supporting material you can refer to for further information?
How will we know if the communication works?
What is the delivery date?
What is the budget?

Source: Adapted from the Scottish Government's Climate Change Adaptation Communications Toolkit

Engaging Stakeholders

Communication alone is not sufficient to create the conditions for adaptation. Municipalities need to engage their staff, senior managers, elected officials, citizens and other stakeholders in thinking about and supporting efforts to adapt. Engagement events and processes are designed to promote participation in adaptation and to encourage action.

Australia's *Framework for Stakeholder Engagement on Climate Adaptation* identifies several benefits from engaging stakeholders:

- A clear communication and exchange of information is facilitated with all parties developing a more thorough understanding of the issues and possible solutions and hearing alternative viewpoints.
- The decision-making process is improved because better insight into potential equitable outcomes, solutions to conflicts and effective planning are gained.
- Involved groups and individuals are strengthened through increased awareness, confidence, skills and cooperation.
- Outcomes are more likely to last because the decision-making has increased in quality and acceptance gained amongst stakeholders.

The UNDP's *Adaptation Policy Framework for Climate Change* outlines some key points for effective engagement:

- ***Clarity***
  Clarify what engagement is for. Support for an adaptation process? Involvement in the process?
- ***Process***
  Define the engagement processes and techniques to be used. What time and money is available? Who will organize it?
- ***Management of information***
  Appropriate information should be available to stakeholders to be engaged, provided through the communication tools identified earlier in this Module.
- ***Support and capacity development***
  While individuals will have unique knowledge and capacity to bring to the engagement process, some may need to be brought up to speed on certain issues to ensure that everyone is on an equal footing.
- ***Transparency***
  Stakeholders should be identified and invited in a transparent way.

- ***Give time for the process***
  As it takes time to develop an engagement process, build partnerships, strengthen networks, and build trust amongst stakeholders, engagement processes can take time to develop and mature.
- ***Feedback and flexibility***
  Processes will not always work to the same level of effectiveness or have the same impact with different stakeholders at different times. Flexibility within the engagement process is key, and feedback should be built-in so that it can be changed if need be.

Who to Engage and How

Municipal action on climate change adaptation often begins with a few key individuals at a municipality who are concerned about current climate trends and events and believe that the impacts of future climate change need to be addressed. Communicating within the organization is an important aspect to gaining wider acceptance amongst decision-makers and making progress on this issue.

Climate change adaptation stakeholders are those people who will be impacted by climate change, affected by adaptation efforts, municipal decision-makers and those who implement and monitor adaptation efforts. Those who should be engaged include: elected officials, senior staff, outside agencies, and the general public.

Elected Officials

Elected officials hold the power to make municipal-wide decisions, allocate funding, and determine if adaptation projects will be implemented. Sometimes elected officials take the lead on climate change adaptation, as was the case with two early international leaders on adaptation – the former Mayor Ken Livingstone at the Greater London Authority (UK), and King County Washington's former Executive, Ron Sims. These two leaders made work on climate change impacts and adaptation a priority within their governments, and ensured that resources and staff time were available to deal with it. More often, however, elected officials will have to be persuaded of the merits of addressing adaptation in municipal plans and programs. Those Councillors and Mayors who already support a range of environmental initiatives, especially those who are identified with climate change mitigation efforts, are more likely to be open to initial work on adaptation.

A growing number of forums are trying to engage elected officials and senior management in thinking about climate change impacts and adaptation:

- Over the last several years the **Federation of Canadian Municipalities** included sessions on climate change adaptation at its Sustainable Communities Conferences, which were attended by a large number of municipal councillors from across the country. The 2010 conference held a roundtable on municipal adaptation, with short presentations from municipalities already working on adaptation, followed by a lively discussion that involved several municipal councillors.

- The **Association of Municipalities of Ontario** has a Climate Change Task Force working on both mitigation and adaptation programs. The Task Force includes 11 Ontario councillors and mayors.
- The **Ministry of Municipal Affairs and Housing** has also begun to include workshops on climate change adaptation in some of its regional municipal conferences, attended by a number of councillors and mayors as well as CAOs. MMAH has recently become committed to working on climate change adaptation and is likely to step up these activities.
- The **Ontario Centre for Climate Impacts and Adaptation Resources** offers climate change risk management workshops for municipalities and communities. Those municipalities that host the workshops often involve elected officials in them.
- **ICLEI**, which partners with FCM in the Partners for Climate Projection program – which has 54 Ontario members – has begun a similar pilot program for climate change adaptation. It is expected that as members in these programs, municipal councils will pass a resolution committing to achieving the milestones set out by the programs.
- **Clean Air Partnership** hosted the Alliance for Resilient Cities Symposium in Toronto in the fall of 2007. Several of the municipalities whose councillors and staff attended the event have developed adaptation policies and programs in their communities.

These developments are creating more fertile ground for discussions with elected officials about climate change adaptation. Municipal staff may be able to alert elected officials to relevant events and programs and encourage them to participate.

A more direct approach to engaging elected officials is to organize events in the municipality on climate change impacts and adaptation and to invite the participation of politicians. Municipal staff may be limited in their ability to do this, especially at the start of an adaptation process. Once work on adaptation has begun, however, staff may be able to organize public meetings that involve elected officials and further interest them in the process. City of Toronto staff did this in 2008, hosting a Climate Change Adaptation Experts Meeting held in Council chambers. Six or more councillors attended the meeting, as did many municipal staff and members of the public. The event created more awareness and interest on the part of elected officials, and contributed to the unanimous support by Council for a proposed adaptation strategy later that year.

Community environmental and other organizations may also be able to engage elected officials. After the Clean Air Partnership completed its *Scan of Climate Change Impacts on Toronto*, the Executive Director made appointments with almost every Toronto councillor, giving them a copy of the colourful report, and talking to them about climate change adaptation. This spurred councillors who were members of Council's Parks and Environment Committee to add impacts and adaptation to the Climate Change Action Plan that was then under development, and to maintain an ongoing interest in and support for development of an adaptation strategy.

Senior Management and Staff

Municipal management and staff are key stakeholders to engage. They know better than anyone how weather in the short-term and climate in the longer term affects their facilities and operations. Many of them will have already put in place some adaptive programs to cope with climate events and trends (though they may not recognize their actions as adaptation to climate change). And they will be the people who design, implement, and enforce adaptation measures. Their early and ongoing engagement is essential.

One outstanding example of this occurred in King County, Washington, where the County organized a one-day conference *The Future Ain't What it Used to Be*, designed to engage municipal staff from the county and all the local governments within it in addressing four areas of expected climate change impacts. The 2005 event drew 650 people and kick-started one of the most successful local adaptation processes in the U.S.

Smaller internal conferences and workshops have been successful at initially engaging municipal staff in Canadian communities on impacts and adaptation. As part of the Adapting to Climate Change in Toronto project led by Clean Air Partnership, for example, adaptation workshops were held with City of Toronto staff in 2005 and 2006. Workshops were held again after the City committed to developing an adaptation strategy in 2007. The first of these was for members of the cross-departmental steering group that oversaw development of the strategy. A workshop was also held with interested staff on using the Climate Change Scenarios Network to access information on climate trends and projections. To engage City departments responsible for infrastructure, another workshop was organized with Engineers Canada to talk about the risk assessment pilots by their Public Infrastructure Engineering Vulnerability Committee. (The City has since committed to two PIEVC infrastructure risk assessments, one for culverts, and the other for high-rise residential buildings.) Departmental workshops were also held with Toronto Water and with Toronto Public Health. All of these events had the effect of engaging staff – even some climate sceptics – in thinking about impacts, and in gradually involving many of them in the longer term work of adaptation.

Other internal events that can engage staff include:

- **Voluntary brown-bag lunch seminars**, such as those organized in Delta BC, that may bring in climate change experts to talk about the scientific basis behind climate change and adaptation, representatives from other governments to relate their experiences, or departmental staff to talk about their work on climate change
- **Department meetings** scheduled to include presentations, provide a place for discussion and coordination, and to formally plan next steps on adaptation
- **Scientific briefings** to councils and senior staff to help build support from the key municipal decision-makers
- **Internal newsletters and intranets** can be a way to inform staff and encourage discussion.

External workshops and conferences can also contribute to the engagement of municipal staff. All the forums that were listed on the previous page as places where elected officials might get engaged in discussions on climate change adaptation also serve municipal staff. However, staff can also engage in impacts and adaptation discussions in professional associations to which they belong. The Canadian Institute of Planners, Ontario Municipal Water Association, Ontario Public Health Association, Professional Engineers Ontario and other organizations have hosted conferences and workshops designed to get their members thinking about and acting on climate impacts and adaptation.

Workshops can kickstart, and even help to sustain staff interest in the issues. However, more formal processes of engagement are needed to cement involvement. The most successful adaptation processes involve cross-departmental committees, steering groups or task forces that meet on a regular basis and work together to develop overarching strategies and share more specific departmental concerns and plans. Ideally, such committees report to a senior management team, and make periodic reports of progress to the team to gain support and resources for their work.

Community, Environmental and Business Organizations and their Leaders

Community leaders may be critical stakeholders to engage because they often drive behavioural change at the local level. In some communities, organizations outside the municipal governments have been the main drivers in getting municipalities involved in adaptation. In some, the advice offered by community leaders can provide important guidance for the implementation of adaptation. In others, their support can be quite important for the promotion and uptake of adaptive behaviour by businesses and households in the community.

Municipalities can engage community organizations and leaders in adaptation planning in a number of ways, each of which involves a different level of commitment and participation:

- Surveys (of knowledge, attitudes and concerns, or to identify preferred adaptation options)
- Focus groups
- Community-based forums or workshops
- Design Charrettes (e.g. to design adaptive neighbourhoods)
- Advisory committees
- Expert panels
- Task forces
- Participatory decision-making.

A number of smaller communities in B.C. and the Yukon have successfully involved community leaders in the prioritization of climate impacts issues and the development of high-level community strategies, substantially raising the profile of preparing for climate change in their communities. The lessons from these experiences for municipalities who set up a community engagement process are as follows:

- Involve an array of organizations likely to be affected by adaptation planning, casting a "wide net" to try to gain representation from all organizations who might be affected or who could contribute substantially, including business, education, healthcare, utilities, non-profit and community organizations

- Involve stakeholders early in the process
- Ensure their independence
- Make the process transparent
- Assure participants that outputs from the engagement process will have a genuine impact on the final outcome
- At the beginning of the process prepare and provide accessible and reliable information on climate change and its likely impacts, known vulnerabilities and potential solutions that have already been discussed and other information that might help ground the discussion in reality
- Provide appropriate and skilled facilitation to ensure a good exchange of ideas and information between municipal and community representatives
- Engage stakeholders in discussing how climate change might affect their members, prioritizing issues and developing a vision for community adaptation
- Try to come to consensus on directions for adaptation
- Support community leaders in mobilizing and educating their membership, employees or associates and bringing the adaptation discussion to the broader community.

Virtually all guides to community engagement, whether on the development of sustainability or climate change strategies, stress that the process always takes time and should not be rushed.

The General Public

The extent to which a municipality will want to engage the public on these issues will depend on the goals of the engagement process and resources available to carry out this engagement.

However, engagement of the general public will help them recognize and prepare for the impacts of climate change at the level of individual households and neighbourhoods, and may increase public support for adaptation processes and expenditures.

Several municipalities have used community meetings as a means to engage the public. Some examples are given below.

Toronto: As part of the development of the city's Climate Change Adaptation Plan, six public consultation meetings were held, targeting different groups within the city. These meetings included presentations that discussed the major challenges that Toronto would be facing and asked participants to contribute suggestions about areas where the city needed to focus adaptation efforts. A description of the process is available in *Climate Change in the City of Toronto – Lessons for Great Lake Communities*.

Kimberley: During the development of Kimberley's climate change adaptation plan *Adapting to Climate Change in Kimberley, BC*, the municipality used community meetings to engage the public in two ways. First, meetings were designed to share information gathered about climate threats specific to the area. Secondly, they provided opportunities to hear from community members regarding the concerns and ideas for adaptation. See the case study at the end of this Module for further description of Kimberley's engagement process.

Vancouver: Vancouver took a web-based approach to engaging the community on climate change adaptation. Through their Talk Green To Us website, municipal staff encourages the public to share ideas about climate change adaptation and sustainability. Though the program is connected to Vancouver's larger goal to be the "Greenest City" by 2020, this type of community participation could be adapted to municipal adaptation programs quite easily.

City of Kimberley, B.C. Climate Change Adaptation Engagement Process

The City of Kimberley, British Columbia, engaged the community as it was developing its Climate Change Adaptation Plan through a series of six workshops - three were public, one was by invitation, and two took place at Kimberley's high school with Grade 10 students; a community survey that was mailed directly to residents; and news releases in local media.

The invited workshop brought together fifty stakeholders from the community who were identified by the adaptation planning process Steering Committee as having an interest in climate change impacts and adaptation. After an overview of climate change and the need for adaptation in Kimberley, the stakeholders developed an initial prioritized list of important issues to consider in adaptation planning.

The first of the two open community workshops was a "Climate 101" workshop that featured an abridged version of An Inconvenient Truth and presentations the "bigger" picture of climate change and a more in-depth look at projected local impacts. The second workshop engaged residents on planning for the impacts of climate change in Kimberley, particularly by identifying priority issues with impact pathways in facilitated small groups.

The community survey asked residents to rank the importance of 14 climate impacts as they related to the community's priority issues of water, forests, infrastructure and tourism, as well as broader questions on the need for climate change adaptation planning.

The meetings were supplemented by published news releases in the local newspaper, and received other newspaper and radio coverage. A display unit was developed and displayed at community environmental events, and a brochure made available in the City's office and at all events.

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Module 12: Indicators to Monitor Progress and Evaluate Success

Learning Objectives and Outcomes

By the end of the module, participants will:

- Have considered the types of indicators needed to monitor and evaluate adaptation programs in their own community.

Introduction

It is useful at the start of a planned adaptation process to consider how to measure progress and evaluate success and then to incorporate periodic monitoring and evaluation into the process. Monitoring and evaluation will help:

- To determine if the factors that contribute to vulnerabilities and risks have changed (and therefore if adaptation efforts need to be stepped up)
- To assess the efficacy and efficiency of adaptation efforts
- To identify critical areas needing more attention to improve their resilience to climate change
- To demonstrate that municipalities are aware of and are preparing for the consequences of climate change
- To show accomplishments.

Adaptation Indicators

Indicators are quantitative or qualitative measures that can be used to describe existing situations and measure changes or trends over time. The principle objective of adaptation indicators is to show whether adaptation policies and measures were implemented and whether vulnerability was reduced through effective actions. Adaptation indicators can also help in identifying the reasons why policies and measures were successful (or not) and why vulnerability was reduced (or not).

Specifically, indicators can be used to:

- Target, justify and monitor adaptation funding and programs
- Evaluate adaptation policy interventions
- Inform future adaptation policy development
- Compare adaptation achievements across regions
- Communicate adaptation to practitioners and the general public
- Increase visibility, transparency and accountability of government decision-making.

Unfortunately, established sets of adaptation indicators are difficult to find. This is partly because planned adaptation is a new phenomenon, and partly because the nature of adaptation makes it challenging to monitor and evaluate. Some of the challenges include the following:

- **Timescale –** The long timescales of climate change and of some adaptation processes can make it difficult to define measureable outcomes at the outset of the planning process.
- **Moving baseline –** Climate hazards are evolving; some may become frequent and severe, resulting in climate-related losses, while others may become less pronounced over the timescale of the project (e.g. freezing rain events may increase for a time, then decrease). Assessing the effects of adaptation actions can be difficult if the conditions they have been designed to cope with are changing.
- **Attribution –** It is often difficult to separate progress as a result of adaptation actions from progress achieved by other policies and programs, especially where adaptation actions are implemented by a number of responsible organizations and delivery partners across different sectors and at different scales.
- **Defining success –** The absence of agreed definitions of acceptable performance in adaptation, or even agreement about what constitutes success, coupled with the wide range of potential adaptation activities and a need for multi-stakeholder agreement on levels of acceptable risk.

Despite these challenges, a growing number of governments and related agencies recognize the importance of tracking progress on adaptation and other policies and programs, and have been urging municipalities undertake this effort.

And despite the lack of globally consistent measures or indicators for adaptation, it is still possible for municipalities to define a set of indicators to identify emerging risks and problems, assess adaptation policy options, gauge the effectiveness of adaptation programs, and demonstrate that tangible progress is being made towards increasing resilience to climate change. Several recent resources provide some guidance, and give examples of adaptation indicators. Some of the examples included in this module are taken from these resources:

- The European Topic Centre on Air Pollution and Climate Change Mitigation's technical papers *Development of Adaptation Indicators* (2009) and *Climate Change Vulnerability and Adaptation Indicators* (2008). These papers outline key principles for developing adaptation indicators to monitor the implementation of adaptation policies, measures and actions.
- The United Nations Development Programme's *Proposed Framework for Monitoring Adaptation to Climate Change* (2008). Although not written for municipalities specifically, this document outlines a framework for monitoring adaptation and provides examples of standard indicators to track the coverage, impact, sustainability and replicability of various adaptation programs.

Considerations in the Development of Useful Indicators

Generally speaking, a good set of indicators should:

- Be precise, clear and easy to understand
- Be feasible to collect, store and manage
- Use existing data sources and reporting systems were possible
- Have a baseline measure against which to compare
- Be linked as clearly as possible to adaptation measures
- Enable tracking of change over time.

Some key considerations for developing and using indicators are provided below.

- **Integrate monitoring and evaluation into adaptation planning at the outset –** This includes ensuring that the necessary resources are available.
- **Determine what should be monitored in relation to specific targets**.
- **Determine how the information relating to the indicators will be collected, managed, stored and retrieved –** In many cases, it may be possible to make use of existing data sources and reporting systems.
- **Involve key stakeholders in the selection of indicators.**

What to Monitor and Evaluate

Most of the current discussion about monitoring and evaluating adaptation focuses on the following:

- **Monitoring climate change trends, projections and impacts** – to ensure that adaptation is responsive to changing risks and vulnerabilities
- **Measuring adaptation**
    - **Assessing adaptation *processes* of capacity building, planning and implementation** – to make sure that adaptation efforts don't stall
    - **Evaluating the *effectiveness or outcomes* of adaptation actions, by measuring changes in impacts.**

Monitoring Climate Trends, Projections and Impacts

Many of the climate trends that municipalities may find it useful to track are included in the tables in Appendix B of Module 1. It is possible to get most of this data for local weather stations on Environment Canada websites. Specific climate trends that can be tracked include:

- Average annual temperature
- Average spring, summer, fall and winter temperatures
- Maximum daily temperature
- Minimum daily temperature
- Number of days with temperature above 30°C
- Length of heat waves

- Number of days with freeze-thaw cycle
- Length of cold spells
- Total annual precipitation
- Total precipitation in spring, summer, fall and winter
- Total annual snowfall
- Total annual rainfall
- End of winter snowpack
- Length of dry spells
- Number of days with >20mm rainfall
- Frequency of thunderstorms
- Frequency of high wind events
- Frequency of tornados
- And several other trends.

Climate projections cannot predict with any accuracy how many of these trends are likely to develop in future, but projections are available for average temperature and precipitation trends, and as climate models continue to improve, will provide more detail for other climate measurements.

It will be useful for municipalities to periodically revisit this data to update the available information. Currently, a number of climate trends that may be of concern for municipal facilities and services are evident, though many are not statistically significant. This situation may well change as data from the most recent decade is added to CCCSN.

Given the problems that many communities are already having with stormwater and flooding, it will be valuable also to pay particularly close attention to the intensity, duration and frequency of precipitation. A number of municipalities are working with conservation authorities to update Intensity, Duration and Frequency curves. A commitment to periodically revisit and update IDF curves will be important for ongoing risk assessment and adaptation planning.

Tracking impacts may be more challenging. Some of this work can be done anecdotally. Municipalities or regions could invest in a periodic (and relatively inexpensive) Local Climate Impacts Profile type exercise, for example, to gather information about the impacts of weather-related events that have occurred in the region in recent years. (See Module 4 for more information on LCLIPs.)

However, municipalities may want to develop a set of indicators to identify and track key impacts of concern. Klaus Jacob, who has been involved in adaptation planning in New York, suggested that the City monitor the climate-related impacts listed in the table on the next page. Many of these are either already monitored or would be relatively easy to track by Ontario municipalities. Many of these could also be used as indicators of the success of adaptation programs.

Table 1: Recommended Climate-Related Impacts for Monitoring by New York City

Climate Trend	Potential Climate-Related Impacts to Monitor
Temperature increase	Extreme heat- and cold-related illnesses / deaths Emergency service calls Unhealthy air quality days Electricity demand Heat-related brownouts and blackouts (frequency/extent) Transit service interruptions (electrical outage, rail buckling) Roadway pavement condition Cooling centre usage Swimming pool usage
Precipitation changes	Water levels in rivers, streams and lakes Water levels in reservoirs Water quality Combined sewer overflows Sewer backup complaints Overland flood incidents and extent Winter road maintenance
Storms	Electrical outages from downed lines Damage to trees and tree canopies Damage to properties from high winds Road accidents Flight delays

Source: *New York City Panel on Climate Change 2010 Report*.

Measuring Adaptation

Tracking climate changes and impacts will give municipalities a measure of what they will have to cope with in adapting to climate change, but are not themselves measures of adaptation. There are two ways that have been proposed to actually evaluate adaptation. One of these evaluates adaptation processes – how municipalities and communities are working to plan and implement adaptation. The other looks to evaluate adaptation outcomes – how successful these adaptation processes have been in reducing harm from a changing climate. Table 2 on the next page, developed for the European Environmental Agency, shows conceptually how process- and outcome-based indicators differ.

Table 2: Conceptual Framework for Adaptation Indicators

		Process-based indicators		Outcome-based indicators
Planned adaptation to climate change impacts	→	Development of adaptation policies (e.g. flood management policies/plans)		
		↓		
		Delivery of adaptation measures (e.g. construction of flood protection schemes)	→	Effectiveness of adaptation actions (e.g. reduction in economic losses due to floods)

Source: *Development of Adaptation Indicators* (2009)

Process Indicators

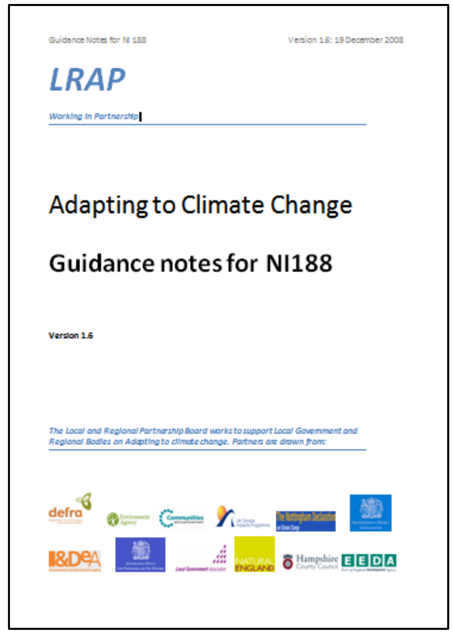
These will tend to involve qualitative assessments of adaptation processes, policies and programs that are occurring in the community. Process-based indicators are useful as short- and medium-term measures of progress, when it is too early to determine the outcomes of adaptation efforts. They can also be valuable to indicate if the appropriate resources, information, practices, preparation and planning are integrated into systems and are kept up-to-date.

A process evaluation might investigate, for example, if:

- An adaptation team has been assembled, what authority and resources it has, who is represented on it, and how it is functioning
- A strong commitment to adaptation has been made in key municipal policies, and which ones
- Climate trends and projections have been investigated for the community and reported
- Vulnerabilities and impacts have been clearly identified and investigated
- Municipality risk assessments have been done, and risks prioritized for action
- Departmental and key infrastructure risk assessments have been done
- Adaptation options have been investigated and assessed for priority risks
- An overall adaptation strategy has been developed and approved
- Adaptation projects have been initiated or fully implemented, in which sectors and for which risks
- Communication and engagement strategies have been developed and deployed, which stakeholder groups were involved

- Tracking and evaluation is being done to measure the effectiveness of the adaptation actions taken.

The United Kingdom took the lead several years ago to develop and promote indicators to evaluate the progress that local governments are making in planning for and implementing adaptation.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LRAP

Working in Partnership

Adapting to Climate Change

Guidance notes for NI188

Version 1.6

The Local and Regional Partnership Board works to support Local Government and Regional Bodies on Adapting to climate change. Partners are drawn from:

The UK Local Government Association worked with several other agencies in the UK to develop a National Indicator for local authorities to use in reporting their progress on climate change adaptation. The Indicator is a qualitative assessment, with progress measured at 5 levels (0-4).

It is expected that local governments will assess their progress periodically, and that they will gradually move up the different levels as they work on adaptation. This is similar to the Milestones process that the Federation of Canadian Municipalities and ICLEI use for assessing progress on reducing greenhouse gas emissions in their Partners for Climate Protection Program.

The Box on the next page provides an outline of the process indicator used to evaluate progress of UK local governments. The guidance notes, *Adapting to Climate Change: Source Notes for NI 188*, provide more detailed assessment criteria for each of the levels.

National Indicator – 188: Levels of Achievement in Planning and Implementing Adaptation

Level 0: Getting Started

The Local Authority has begun the process of assessing the potential threats and opportunities across its area and services (for example, flood and coastal resilience plans, emergency planning, community risk registers/strategies etc) and has identified and agreed on the next steps to build on that assessment in a systematic and coordinated way.

Level 1: Public commitment and impacts assessment; Assembling and evidence base

The Local Authority has made a public commitment to identify and manage climate related risk. It has undertaken a local assessment of significant vulnerabilities and opportunities to weather and climate, both now and in the future. It can demonstrate a sound understanding of those not yet addressed in existing strategies and actions (e.g. in land use planning documents, service delivery plans, flood and coastal resilience plans, emergency planning, community risk registers/strategies etc). It has communicated these potential vulnerabilities and opportunities to department/service heads and other local partners and has set out the next steps in addressing them.

Examples of evidence:

- The authority and partners have made a public commitment to manage climate risks (e.g. signed up to the Nottingham Declaration or equivalent)
- A Local Climate Impacts Profile or equivalent process is ongoing
- Initial assessment produced using the UKCIP climate projections
- Department heads facing significant vulnerabilities have an understanding of the issues, with evidence of actions already in place to address these
- Evidence of working in partnership and pooling of resources and expertise across sectors, areas and council tiers where applicable

Level 2: Comprehensive risk assessment (with prioritized action in some areas)

The Authority has undertaken a comprehensive risk based assessment of vulnerabilities to weather and climate, both now and in the future, and has identified priority risks for its services. It has identified the most effective adaptive responses and has started incorporating these in council strategies, plans, partnerships and operations (such as planning, flood management, economic development, social care, services for children, transport etc). It has begun implementing appropriate adaptive responses in some priority areas. In its role as a community leader the council has started working with its Local Strategic Partners (LSP's) to encourage identification of major weather and climate vulnerabilities and opportunities that affect the delivery of the LSP's objectives.

Examples of evidence:

- Comprehensive risk assessment produced
- Council Members and department heads have a detailed understanding of weather and climate risk in all vulnerable areas identified in risk assessment
- Local adaptation partnership established
- Partners aware of action taken by Council, engaged in the process …

Level 3: Comprehensive action plan (and prioritized action in priority areas)

The Authority has embedded climate impacts and risks across council decision making. It has developed a comprehensive adaptation action plan to deliver the necessary steps to achieve the existing objectives set out in council strategies, plans, investment decisions and partnership arrangements in light of projected climate change and is implementing appropriate adaptive responses in all priority areas. This includes leadership and support for LSPs in taking a risk based approach to managing major weather and climate vulnerabilities/opportunities across the wider local authority area.

Examples of evidence:

- Action plan developed and published
- Detailed understanding of risk and action taken to embed relevant adaptation response in Council strategies, plans and operations by all department heads where weather and climate risks have been identified
- Initial cost analysis undertaken and potential sources of funding identified for major vulnerabilities
- Local partners feel fully engaged and action plan includes commitment from them

Level 4: Implementation, monitoring and continuous review

The Authority and LSP are implementing the comprehensive adaptation action plan across the local authority area, and there is a robust process for regular and continual monitoring and review to ensure progress with each measure and updating of objectives. The Authority and LSP are taking appropriate adaptive responses.

Examples of evidence:

- Clear and robust continuous monitoring and review system in place
- Outputs from the review and monitoring process are ploughed back into the action plan and other relevant Council strategies

Source: *Adapting to Climate Change: Source Notes for NI 188*

These indicators are intended to assess municipality-wide processes of adaptation. Process indicators can also be developed for specific sectors or areas at risk. Table 3 provides a few examples:

Table 3: Examples of Departmental/Service Area Process Indicators

Departmental / Service Areas	Possible Process Indicators (Qualitative and Quantitative)
Water	▪ Number of homeowners participating in water conservation programs ▪ Establishment of drought forecasting, warning and monitoring systems
Stormwater Management	▪ Flood maps have been updated to reflect changing risks ▪ Construction of berms and other measures to protect structures in flood risk zones ▪ Programs to expand permeable surfaces in the community
Public Health	▪ Establishment of heat alert and response systems to protect vulnerable populations ▪ Number of health agencies and related bodies engaged in awareness-building activities
Urban Forests and Parks	▪ New sidewalk construction and tree planting techniques to aid in the survival of street trees ▪ Tree planting with species that are resilient to expected climate changes ▪ Number of homeowners engaged in tree maintenance programs
Planning / Facilities	▪ Climate change adaptation incorporated in Official Plan ▪ Green development standards that incorporate measures to protect from climate change have been adopted ▪ Green / cool roof policies and incentives have been put in place

Outcome indicators

Outcome indicators are used to measure the effectiveness of adaptation in protecting communities from climate change impacts. They address the questions:

- How effective have adaptation measures been in achieving the community's vision and goals? Have climate related losses continued, grown, or been abated? Has the community's sensitivity to climate change hazards changed?
- Have things stayed the same or grown worse because adaptation was ineffective, or because unanticipated stresses (climate or other) have aggravated the situation?

To date, few municipalities, if any, have developed a set of outcome based indicators. This is in part due to the fact that for many municipalities, adaptation planning and programs are still young and implementation has barely begun. That being said, it could be valuable for municipalities to develop both process- and outcome-based indicators at the outset of their planning process to monitor and evaluate adaptation. In instances where adaptation plans and programs are still at a relatively early stage of development, it is likely that monitoring and evaluation will focus more heavily on the use of process-based indicators. However, a gradual shift towards outcome-based indicators is desirable, especially as policy goals and program targets become more clearly defined.

Outcome indicators are likely to be sector- or risk-specific. Some potential outcome indicators for different sectors of municipality are outlined below. However, the most appropriate and feasible indicators will be developed by municipalities and municipal departments that have investigated the risks of climate change for their community and their operations, put in place programs to reduce these risks, and have defined clear goals and targets for their adaptation programs.

Table 3: Examples of Adaptation Outcome Indicators for Municipalities

Departmental / Service Areas	Possible Outcome Indicators
Electrical Utility & All Municipal Facilities & Services	▪ Heat-related brownouts and blackouts frequency / extent ▪ Electrical outages from high winds
Public Health	▪ Cooling centre usage ▪ Heat- and smog-related hospitalizations / deaths / emergency calls ▪ Incidence of vector-borne, waterborne and/or foodborne illnesses (those associated with warmer temperatures, shorter and warmer winters...)
Water	▪ Residential water consumption ▪ Water levels in rivers, streams and lakes in or adjacent to the community ▪ Reservoir levels and capacity ▪ Groundwater status ▪ Water quality measures
Stormwater	▪ Combined sewer overflows ▪ Sewer backup and basement flooding complaints ▪ Overland flood incidents and extent ▪ Infrastructure damage / costs from floods
Transportation / Roads	▪ Weather-related road accidents ▪ Pavement condition and replacement requirements (freeze-thaw, heat damage) ▪ Winter road maintenance costs ▪ Transit and commuter rail service interruptions (electrical outages, rail buckling)
Parks / Forestry Services	▪ Proportion of green space / tree canopy in the community ▪ Health of urban forest ▪ Damage to trees from storms ▪ Damage to trees from insect pests

Conclusions

Monitoring and evaluation are necessary to assess whether the adaptation goals and objectives set by a community have been achieved, and to identify and resolve problems that may have been encountered along the way. It is important for a community to establish a plan for monitoring and evaluation and use the results of this process to re-visit their adaptation plan and to update it based on new information as it becomes available.

Measuring progress on adaptation remains an area where work is needed, as there are currently few accepted and standardized indicators for local decision makers. Decision-makers need suitable performance metrics to demonstrate their readiness to deal with the impacts of climate change.

Ontario municipalities that take up the challenge of preparing and tracking indicators of climate change and of adaptation will be leaders in the field and will help ensure that all of us we learn about, evaluate and adopt better adaptation processes and improve our ability to protect our communities from climate change.