Managing Municipal Infrastructure in a Changing Climate

CBCL LIMITED
Consulting Engineers

Municipalities
Newfoundland and Labrador

PMA
Professional
Municipal
Administrators

Newfoundland
Labrador

Photo Credit: Katherine Perrott

Brigus, NL

Acknowledgments and Credits

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Prepared by:

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GLOSSARY

Adaptation: Adjustment in natural or human systems to a new or changing environment. Adaptation can be anticipatory or reactive.

Asset Management: A business process and decision-support framework that:

(1) covers the extended service life of an asset,

(2) draws from engineering and economics, and

(3) considers a diverse range of assets.

Climate Change: Refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from:

- human activities that change the atmosphere's composition (through burning fossil fuels) and the land surface (deforestation, reforestation, urbanization, desertification, etc.);
- natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun;
- natural processes within the climate system (changes in ocean circulation)

Extreme Weather Event: An event that is rare and occurs only 10% or less of the time. Definitions of "rare" vary, and what is called "extreme weather" may vary from place to place.

Greenhouse Gas (GHGs): Gases in the Earth's atmosphere that trap heat, including carbon dioxide, methane, nitrous oxide and others. Greenhouse gases are a natural part of the atmosphere, but human activities, such as the burning of coal and oil, have increased the concentration of these gases significantly. Burning fossil fuels to create energy is the primary source of greenhouse gases and a significant cause of climate change.

Mitigation: The steps we must take to reduce the pace and extent of climate change caused by greenhouse gas emissions. Mitigation policies and technology could either reduce emissions (by using energy alternatives to oil and gas, for example) or find new ways to store emissions so that they do not pollute our atmosphere (by planting new trees to act as emission "sinks," for example).

Municipal Infrastructure: Any public infrastructure asset owned and managed by a municipal or regional government. These typically include assets such as roads, bridges, sidewalks, water and wastewater systems, waste disposal sites, public transit systems, parks and recreational facilities, civic buildings such as town halls, fire stations, and municipal depots. Some jurisdictions also own and manage commercial and recreational ports and harbours, and social housing.

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Resilience: The ability of an ecosystem or species to function as it copes with stress. Species that adapt to climate change by shifting their ranges are resilient. Resiliency can also be used to describe nations and local communities that successfully use new technologies and policies to lessen the disruptive impacts of climate change.

Salt Water Intrusion: Displacement of fresh surface water or groundwater by the advance of salt water. The combination of sea-level rise and excessive pumping of coastal aquifers, can pull sea-water inland.

Sea-Level Rise: An increase in the mean level of the ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land-level subsidence.

Tools (for adaptation): Methodologies, guidelines and processes that enable organizations to assess the implications of climate change impacts and relevant adaptation options in the context of their environment. Types of tools include, climate change models, scenario-building methods and decision support tools, as well as more specific tools, such as crop or vegetation models.

Traditional Knowledge: A cumulative body of knowledge handed down through generations, about the relationship of living beings with their environment.

Vulnerability: The susceptibility to be harmed. Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.

Text sources

Adapting to Climate Change: An Introduction for Canadian Municipalities. Natural Resources Canada (2010).

Climate Change Glossary. The Conservation Fund (2012).

Glossary of Climate Change Terms. United States Environmental Protection Agency (2011).

Municipal Infrastructure Investment Planning (MIIP). National Research Council Canada (2004).

INTRODUCTION

What is this Workbook?

Communities across the country are becoming increasingly concerned about how global climate change affects them at the local level. Nationally, the federal and provincial governments have established a series of Regional Adaptation Collaboratives (RAC) focused on climate change adaptation. In Atlantic Canada, the four provinces and the federal government have partnered with municipal associations, engineering groups, and other stakeholders to form the Atlantic Climate Adaptation Solutions Association (ACASA), which is focused on a variety of projects that consider the scientific, technical, and social components of climate change adaptation.

In Newfoundland and Labrador, as part of ACASA, the Department of Environment and Conservation has led the development of *7 Steps to Assess Climate Change Vulnerability in Your Community*, a comprehensive tool targeted at helping municipalities assess their vulnerabilities to climate change. The tool has been developed in partnership with Municipalities Newfoundland and Labrador, the Professional Municipal Administrators Association, and Memorial University of Newfoundland.

The workbook, *Managing Municipal Infrastructure in a Changing Climate,* focuses specifically on climate change and municipal infrastructure, and complements the *7 Steps to Assess Climate Change Vulnerability in Your Community* tool. The workbook is designed to be completed by municipal officials and staff in a group setting over a period of 3 hours. It guides participants through a series of exercises, beginning with a discussion of municipal infrastructure, how it is planned, constructed and maintained. In the second section, participants are asked to consider how their communities are being affected by changes in local weather patterns. In the final section of the workbook, participants will discuss what can be done to manage and protect municipal infrastructure to minimize the vulnerability of their community to the impacts of a changing climate.

These topics are explored using a combination of case study information and a series of breakout session exercises. The workbook includes a bibliography and links to references and other sources of information for those who wish to pursue the topics presented in greater detail.

Photo Credit: Kimberly Bittermann

Gambo, NL

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INFRASTRUCTURE

What is Infrastructure?

Most people think of roads and power lines when they think of the term "infrastructure". However, infrastructure includes much more than that. The Merriam-Webster dictionary defines infrastructure as:

> **in·fra·struc·ture** – noun \ in-fra-struk-cher
>
> **1:** the underlying foundation or basic framework (as of a system or organization)
>
> **2:** the permanent installations required for military purposes
>
> **3:** the system of public works of a country, state or region; also the resources (as personnel, buildings, or equipment) required for an activity.
>
> **Source:** Merriam-Webster Dictionary

Essentially, infrastructure consists of the physical and organizational assets that are needed to support the basic functions of society and the economy. Using this definition, infrastructure can include both hard and soft components. Hard infrastructure refers to the physical assets necessary for the functioning of society, such as roads, bridges, water and sewer systems, electrical and telecommunications networks, and so on. Soft infrastructure refers to social capital, such as human resources relied on to provide social services. In this workbook, we will focus on hard infrastructure that is owned and managed by local government.

In Canada, infrastructure responsibilities are shared between all three levels of government.

At the federal level, infrastructure responsibilities include large assets such as airports, seaports, inter-provincial ferries, search and rescue, military facilities and national parks. The federal government also funds other types of infrastructure through funding agreements with provincial and municipal governments.

At the provincial level, infrastructure responsibilities include provincial highways and other transportation facilities (including ferries and airports), energy related infrastructure, health and educational facilities, provincial parks, and public buildings used to deliver government services.

At the local level, municipal governments are responsible for infrastructure that serves the community, such as streets and sidewalks, water and sewer services including treatment plants, stormwater management systems, parks and community buildings, and facilities. Increasingly, local governments are forming partnerships to plan and manage infrastructure on a regional basis.

Text sources

Public Infrastructure & Municipal Economic Development. Municipalities Newfoundland and Labrador (2008).

For more information on infrastructure, visit:
www.infrastructure.gc.ca

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Other types of infrastructure are provided by the private sector. In Newfoundland and Labrador, these include the infrastructure required to generate and deliver electricity and telecommunications services. It is also becoming more common for large-scale infrastructure projects, such as bridges, highways and ferry services, to be financed and operated through public-private partnerships.

Municipal Infrastructure Responsibilities

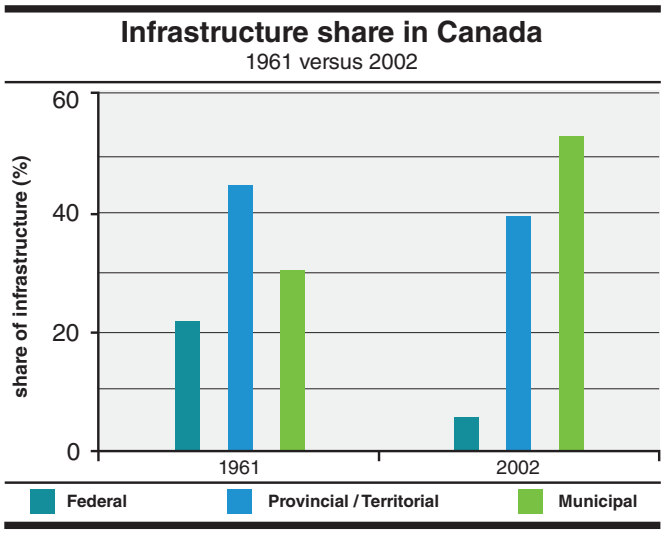
In Canada, a large portion of municipal infrastructure was built between the 1950s and 1970s, a time of strong economic growth and development. Since that time Canadian municipalities have been given an increasingly greater share of responsibility for infrastructure in the country, as depicted in the graph to the right. This is due to several factors including the growth of cities and urban regions, and greater public demands for more and better municipal services. As higher levels of government seek to divest themselves of infrastructure, municipalities are also being asked to take over and manage such things as ports and small craft harbours, small airports and highways.

Text sources

Managing Infrastructure Assets. InfraGuide (2005).

Danger Ahead: The Coming Collapse of Canada's Municipal Infrastructure. Saeed Mirza (2007).

For more information on municipal infrastructure, visit: www.infraguide.ca



The Challenges of Managing Municipal Infrastructure

Managing municipal infrastructure comes with many challenges, especially for smaller communities with fewer resources.

Aging Infrastructure

Municipal infrastructure deterioration accelerates with age. According to a recent report, only about forty-one percent of Canadian infrastructure is less than forty years old. As a result, municipalities are faced with the growing problem of keeping up with demand while maintaining deteriorating infrastructure.

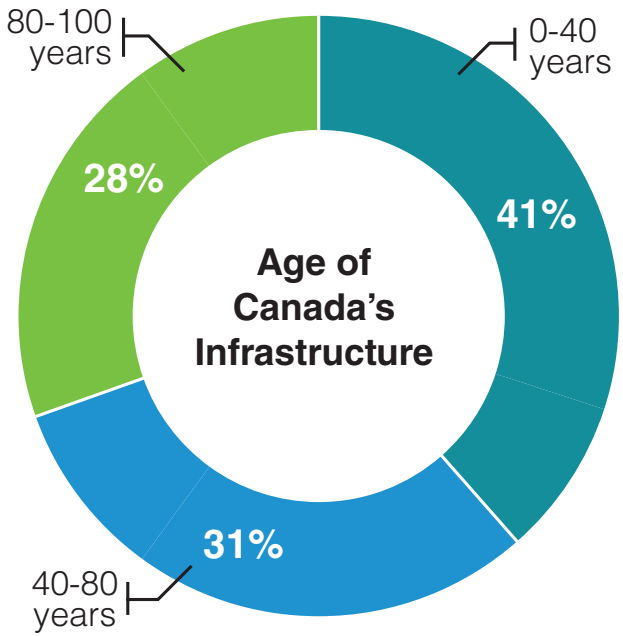
Population Growth/Decline

A proportion of municipal infrastructure is paid for by municipal property tax revenues - a funding mechanism that typically works for communities with a growing or

steady population. However, towns with a declining population and a reduced tax base still have to maintain a minimum level of essential services. This is particularly challenging in small communities when per capita expenditures for necessary infrastructure are often greater than the community can afford.

Public Demands for High Level of Service

Today, the public demands a high level of service from their municipalities. The public is also becoming less tolerant of such things as water supply interruptions and boil alerts, power outages, potholes in roads, sewer backups and lack of recreation facilities and parks. At the same time, raising taxes to pay for municipal services is often met with public opposition.



Stringent Regulations

All levels of government are implementing more stringent regulations related to public health and safety, the environment and financial management. New regulations to define more stringent criteria for drinking water quality, wastewater and stormwater discharge will require additional investments in municipal infrastructure and management.

Liability/Risk Management

Municipalities need to exercise and demonstrate an acceptable degree of due diligence regarding the infrastructure they manage. If minimum service standards aren't being met, municipalities can be held liable.

Text sources

Managing Infrastructure Assets. InfraGuide (2005).

For more information, visit:
www.fcm.ca/Documents/reports/Infraguide/Managing_Infrastructure_Assets_EN.pdf

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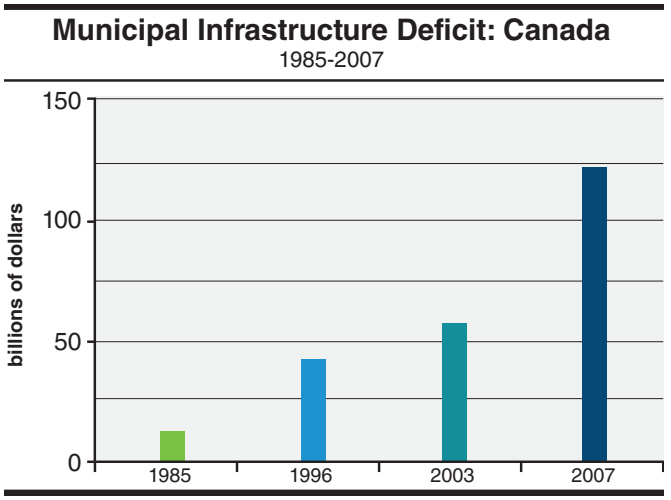
The Increasing Costs of Municipal Infrastructure

After decades of continuous use, much of Canada's public infrastructure is approaching the end of its useful life and will need to be repaired or replaced. It is estimated that Canadian municipalities spent between $12 and $15 billion dollars on infrastructure in 2005. Yet despite these investments, the amount needed to fix deteriorating municipal infrastructure throughout Canada continues to rise. The infrastructure deficit has been growing exponentially, increasing from an estimated $12 billion in 1985 to $127 billion in 2007, as shown in the graph to the right.

Competing priorities, particularly in health and education, have squeezed federal and provincial budgets, while local governments have faced funding pressures arising from their reliance on revenues generated through property taxes. At the same time, infrastructure projects have become increasingly costly as a result of increases in the price of materials.

In Newfoundland and Labrador, many communities have benefitted from Federal-Provincial cost-shared programs that provided funds for repairing and replacing aging infrastructure. These programs require the financial participation of all three levels of government. However, many smaller communities find it difficult to avail of these programs as there is limited capacity to raise or borrow funds to cover the municipal contribution.



Text sources

Managing Infrastructure Assets. InfraGuide (2005).

Danger Ahead: The Coming Collapse of Canada's Municipal Infrastructure. Saeed Mirza (2007).

For more information on the infrastructure deficit, visit: www.fcm.ca/Documents/reports/Danger_Ahead_The_coming_collapse_of_Canadas_municipal_infrastructure_EN.pdf

What is Sustainable Municipal Infrastructure?

Most municipalities take a reactive approach when it comes to infrastructure management. As a result, many towns are faced with unplanned repair or replacement expenses and service interruptions as they deal with problems as they arise. In order to provide a consistent level of service, municipalities need to reconsider how they plan, design and manage their infrastructure assets.

sus·tain·ab·le de·vel·op·ment – se-sta-ne-bel di-`ve-lep-ment

"Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs."

Source: World Commission on Environment and Development, 1987

sus·tain·ab·le in·fra·struc·ture – se-sta-ne-bel in-fra-struk-cher

"The design of new infrastructure, and the re-design, rehabilitation, re-use or optimization of existing infrastructure, which is consistent with the principles of urban sustainability and global sustainable development"

Source: Department of Civil Engineering, University of Toronto, 2001

Managing infrastructure sustainability offers municipalities the chance to meet new demands within a fiscally responsible and environmentally sustainable framework, while maintaining a high quality of life for residents. Successful sustainable infrastructure will provide the following benefits:

- Lower ongoing operating costs
- Longer system life
- Reduced maintenance
- Reduced environmental impact

Essentially, sustainable infrastructure requires that municipalities get the most out of every dollar they invest in infrastructure. Effective infrastructure planning is not about simply getting services to as many households and businesses as possible; it's about ensuring a high standard of construction and maintenance and maximizing the utilization of the infrastructure that is developed.

The Town of Trinity Bay North is an example of a town that is reconsidering how it manages its infrastructure in a fiscally responsible and more sustainable way. With a declining and aging population, the Town has planned to "grow' into a smaller, stronger town by investing in improvements to existing infrastructure in core areas of the community, and implementing policies that concentrate development in areas that are already serviced.

Text sources

Managing Infrastructure Assets. InfraGuide (2005).

Public Infrastructure & Municipal Economic Development. Municipalities Newfoundland and Labrador (2008).

For more information on sustainable infrastructure, visit: www.crcresearch.org/sustainable-infrastructure/sustainable-infrastructure

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Tools for Managing Municipal Infrastructure

Funding

Municipal infrastructure in Newfoundland and Labrador is funded in part by the provincial government through the Municipal Capital Works funding program. This program fosters the development of cost-shared projects in a wide range of municipal infrastructure, including water and wastewater treatment, roads, recreational facilities and fire equipment, and is available to local governments of towns, regions, local service districts or Inuit Community Councils. Other funding programs include Multi-Year Capital Works Funding (for larger municipalities) from the Government of Newfoundland and Labrador, and the Building Canada Fund and Canada Strategic Infrastructure Fund from the Government of Canada. Many municipalities also use their portion of funds from the Gas Tax Agreement to pay for sustainable infrastructure projects.

Municipal Servicing Plans

Most municipalities have a Municipal Servicing Plan; a plan that shows how the town will be serviced with municipal water and sewer services over time. However, once established, these plans are rarely reviewed and revised to consider changing circumstances in the community. There is a need for towns to review and revise their Municipal Servicing Plans to consider and address anticipated impacts of climate change on the community.

Photo Credit: John Drover

Change Island, NL

The Public Sector Accounting Board (PSAB)

In 2009, all Canadian municipalities were required to record their tangible capital assets. This inventory, which included infrastructure, also documented such things as the age and assessed value of all municipal assets. As a result, it is a useful resource for asset management planning.

Asset Management Planning

One way to achieve sustainable infrastructure is to develop an asset management plan; a comprehensive plan to sustain infrastructure. Creating a successful plan will ensure that financial resources are available to operate, rehabilitate and replace infrastructure at the optimum time to achieve the lowest life cycle cost. Asset management planning also considers a comprehensive risk assessment, which incorporates financial, environmental, health and safety factors. This plan requires consistent monitoring, which will ensure long-term affordability and reduce the potential for unintended costs.

Seven Steps of Asset Management Planning

The framework for an Asset Management Plan can be described in terms of seven questions, as outlined by the InfraGuide program:

1. What do you have and where is it?
2. What is it worth?
3. What is its condition and expected remaining service life?
4. What services are expected and/or needed?
5. When do you need to do it?
6. How much will it cost and what is the acceptable level of risk?
7. How do you ensure long-term affordability?

Text sources

Managing Infrastructure Assets. InfraGuide (2005).

For more information on asset management, visit: www.fcm.ca/Documents/reports/Infraguide/Managing_Infrastructure_Assets_EN/pdf

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BREAKOUT SESSION 1

Municipal Infrastructure in Your Town

What do you have and where is it? → How much is it worth? → What condition is it in and how long will it last?

Time: 30 minutes

Objective: This exercise will help you to identify the infrastructure assets in your community, including the type, age, condition and where possible, location. Identifying the location of infrastructure on a map or a sketch of your town provides a visual picture that will be used to identify areas where infrastructure may be vulnerable and will assist you in future planning.

Materials: Workbook and Town map (if available). If a town map is not available, a sketch of your town may be used in its place. PSAB Financial Statements may also be helpful in completing this activity.

Exercise:

1. Break into small groups.
2. Using the types of infrastructure listed in Table 1 on pages **37-40**, mark the approximate location of each type of infrastructure you have in your town on the map provided.
3. Once you have identified the locations of infrastructure in your town, complete Table 1. The general value of each type of infrastructure may be estimated by referring to the Appendix on pages **45-48**, or your PSAB Financial Statement (if available). Indicate the condition of the infrastructure, the expected lifespan, and any other comments about the infrastructure, such as its age, how often it is maintained, or if there have been any previous problems.

Sample:

Type of Infrastructure	Location	Estimated Replacement Cost	Condition of Infrastructure	Lifespan of Infrastructure	Other Comments
Water Supply System Water Tower	Along coastline, on steep slope, near river, etc	$300,000	Very old. Needs to be replaced	May last another 5 years	The Water Tower has been leaking and giving problems the past few years. The town is unable to afford the cost of maintaining the system with these problems. Road to tower in poor condition.

CLIMATE CHANGE

What is Climate Change?

The International Council for Local Environmental Initiatives (ICLEI) defines climate change as follows:

cli·mate change – noun \ kli-mat chanj

1: Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer).

2: Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic (human induced) changes in the composition of the atmosphere or in land use.

Source: ICLEI, 2008

The Intergovernmental Panel on Climate Change (IPCC) has concluded that the evidence for climate change is now unquestionable and that most of the observed temperature increases since the middle of the 20th century have been caused by increasing concentrations of greenhouse gases (GHGs) resulting from human activity, such as the burning of fossil fuels and deforestation. The greatest warming is expected to occur over land and at high northern latitudes.

Climate change is an important issue for Newfoundland and Labrador. As a coastal province with over 90 per cent of the population living near the sea, Newfoundland and Labrador is exposed to many long-term impacts of climate change. Forecasts suggest that the province will experience temperature increases by mid-century, relative to historical averages, of between 2-4ºC. While this may appear to be a small increase, it is actually quite significant considering that the global temperature has risen by only 5ºC since the last Ice Age. Increases in annual precipitation, number of frost free days, and heavy rainfall events are also likely to occur.

The graphic below provides a general glimpse of anticipated climate changes in Newfoundland and Labrador. It reveals that climate change variables are expected to increase by mid-century, when compared to the current and past climatology. While these changes will vary across the province, they provide a general indication of how climate may change.

Projected Climate Change Indicators by Mid-Century

Mean Annual Temperature Increase	4.01°C
Increase in Frost Free Days	44.51
Average Annual Precipitation Increase	0.05mm
Heavy Rainfall Events	1.34

Adapted from *7 Steps to Assess Climate Change Vulnerability in Your Community*; table produced by Dr. Joel Finnis, Memorial University of Newfoundland, Department of Geography.

Text sources

Changing Climate, Changing Communities. ICLEI (2008).

Charting Our Course: Climate Change Action Plan 2011. Newfoundland and Labrador (2011).

For more information on climate change, visit: www.ipcc.ch

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How Does Climate Change Impact Municipalities?

The impacts associated with climate change are already being observed around the world and increasingly severe impacts are expected in the future. Glaciers are shrinking, polar ice is melting faster than ever before, storms are increasing in frequency and intensity, and ecosystems are being adversely affected. Municipalities are increasingly vulnerable to the impacts of climate change.

Sea-Level Rise

Sea-level rise is a particular concern for many low-lying communities. Combined with storm surges, many areas can expect increased flooding, or flooding where none has previously occurred. Rising sea-levels may also cause greater salt water intrusion, which could compromise groundwater wells and other freshwater sources.

Ecosystem Impacts

Warmer temperatures, which may be accompanied by shorter winters and longer summers, can impact natural ecosystems causing droughts and increased risk of forest fires. Warmer temperatures can also result in a lack of ice in winter, which has significant implications in northern areas like Labrador where the presence of sea ice provides an important means of winter travel.

Coastal Erosion

Coastal erosion is a natural process, but the severity and rate of the erosion will likely be accelerated by climate change. As a coastal province with over 17,000 km of coastline, coastal erosion has already affected vulnerable municipalities like Admiral's Beach. While erosion in these locations may not be linked to climate change alone, the impacts highlight the need to better understand long-term changes in the environment.

Text sources

Climate Change: Responding to Climate Change. Newfoundland and Labrador (2010).

For more information on climate change impacts, visit: www.davidsuzuki.org/issues/climate-change/science/impacts

Photo credit: Geological Survey NL

Coastal erosion in Admiral's Beach, NL

Photo credit: NRCan

Storm surge damage in Ferryland, NL

Extreme Weather Events

Perhaps the most serious impact of climate change is the increase of extreme storm events. Canada has seen a change in the frequency of extreme temperature and precipitation events since 1950. Such changes include fewer cold days, more extreme warm days and more days with extreme precipitation. Many of the most severe and costly impacts will be associated with projected increases in the frequency and magnitude of extreme events and associated natural disasters, such as flooding due to high-intensity rainfall, storm surges, ice and wind storms, heat waves, and drought.

Flooding, in particular, is among the most prominent climate hazard Canadian communities face, and has been the cause of some of Canada's worst disasters. Increasingly intense rainfall associated with summer storms, and more rapid and extensive snowmelt associated with rising temperatures in northern communities, could heighten the flood risk in many communities.

Globally, the number of severe damage-causing storms has increased from an average of 150 per year in the early 1980s to between 250 and 300 per year in the period from 2000 to 2004. In Canada, scientific models show shorter return periods of extreme weather events (the estimated interval of time between occurrences). Examples of extreme weather events in Newfoundland and Labrador are provided to the right. Although there is some debate as to the connections between extreme events and climate change, it is important to consider the consequences of these events and their implications for communities throughout Newfoundland and Labrador.

February 2007 - Daniel's Harbour

A major storm affected the west coast of Newfoundland, with waves of 8m reported at Daniel's Harbour.

August 2008 - Middle Cove

A "rogue wave" at Middle Cove beach washed inland, covering the entire beach, reaching as far as the parking area. The wave cast four people out to sea, knocking several others off their feet. The four were taken to hospital but no serious injuries occurred.

December 2009 - Battery, St. John's

Consistent high winds over a 24-hour period resulted in exceptionally high seas along the east coast of the Avalon Peninsula. The Narrows (the entrance to St. John's Harbour) was impacted by large waves, with wharves, stages and fishing sheds damaged in the Battery.

December 2009 - Ferryland

High seas washed out part of the road leading from Ferryland to the lighthouse, damaging property and the breakwater. This same part of the road was similarly affected in 2004. About 150m of cribbing was washed away, leaving the area vulnerable to further damage.

Text sources

Changing Climate, Changing Communities. ICLEI (2008).

Climate Change: Responding to Climate Change. Newfoundland and Labrador (2010).

For more information on extreme weather events, visit:
www.nr.gov.nl.ca/nr/mines/outreach/geologicalhazard.html

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Case Study: The Impacts of Hurricane Igor

The severity of Hurricane Igor underlines the need to understand and prepare for changing environmental conditions. This destructive event, which is estimated by Environment Canada to be unmatched in the province's recent history, caused an estimated $150 million in damages. At its peak, Igor cut off 150 communities from transportation routes and affected electricity to an estimated 70,000 people. Hurricane Igor reshaped the natural environment and at the same time destroyed roads, homes and buildings, and directly impacted countless residents around the province.

Text adopted from *Charting Our Course: Climate Change Action Plan 2011, Newfoundland and Labrador.*

Photo Credit: Fire and Emergency Services, NL

Road washout during Hurricane Igor. Random Island, NL.

Adapting to Climate Change

Adaptation to climate change can include any activity that aims to reduce the negative impacts of climate change or takes advantage of new opportunities that may be presented. Climate change adaptation includes activities that are taken before impacts are observed (anticipatory adaptation) and after impacts have been felt (reactive adaptation). In most circumstances, anticipatory adaptation will offer cost savings and be more effective than reactive adaptations.

Reactive Adaptation

Most climate change adaptation activities are carried out in response to the impacts of current climate trends and variability. For example, a farmer may notice that droughts are becoming more persistent and may switch to a more drought tolerant variety of crop. Reactive measures can involve relocating buildings and potential inhabitants from areas prone to flooding or accommodating structures through protection measures. Reactive adaptation measures may also be temporary, such as using sand bags for flood protection.

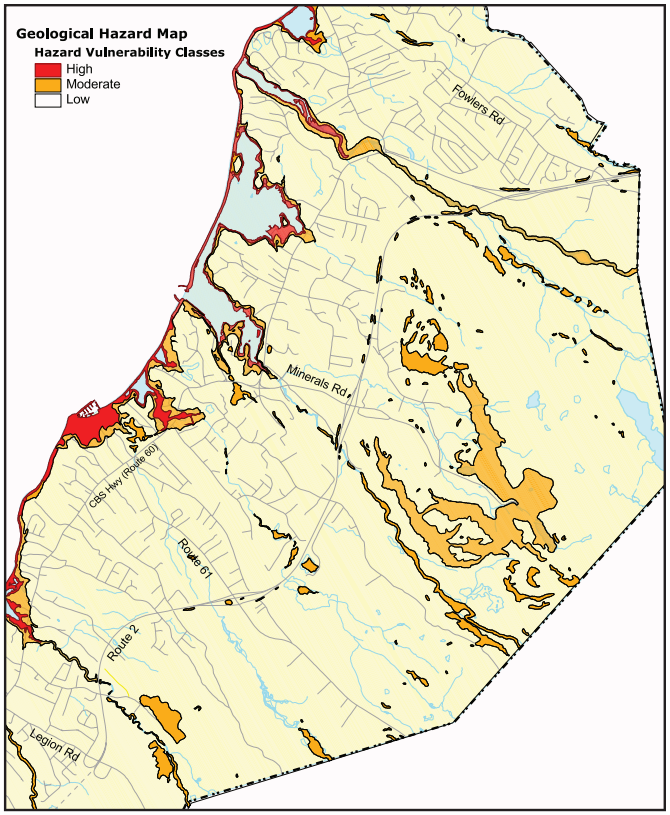
Anticipatory Adaptation

Anticipatory adaptation is more likely to reduce the long-term damage, risk and vulnerability due to climate change. It involves decision making which improves our ability to cope with future climate change. Regular assessment and risk management strategies can also help make this type of adaptation more effective. Examples of anticipatory adaptation include defending against

rising sea-levels through better flood defenses, and changing patterns of land use like avoiding more vulnerable areas for housing.

Taking practical steps now with the best information available enables communities to reduce the future risk and realize possible near-term benefits. Nevertheless, both anticipatory and reactive adaptation will not guarantee that negative impacts will not occur, but they will likely cause impacts to be less severe than would be experienced had no adaptation occurred.

The Town of Conception Bay South has taken an anticipatory adaptation approach by identifying areas that are vulnerable to geological hazards including sea-level rise. A Geological Hazard Map (see above) was incorporated into plans and policies in the Conception Bay South Municipal Plan to prevent development in areas of high hazard vulnerability.



Text sources

Changing Climate, Changing Communities. ICLEI (2008).

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Case Study: Reactive Adaptation in NL

On September 27, 2005, the Town of Stephenville declared a State of Emergency due to major flooding of Blanche Brook. The flooding caused watermains to break, leaving the entire Town of Stephenville, with the exception of the hospital, without water. Approximately 150 homes located alongside the brook were directly impacted by the flood, leaving many residents homeless. After careful consideration, the Government of Newfoundland and Labrador decided that due to public safety reasons, residents who lived in the flood control areas were to be relocated. The total estimated cost of reinstating Blanche Brook, relocating residents and providing interim accommodations was estimated to be $18 million.

Text adopted from *Stephenville Flood. Government of Newfoundland and Labrador. 2006.*

Photo credit: Department of Environment and Conservation. Government of Newfoundland and Labrador. 2006.

Case Study: Anticipatory Adaptation in PEI

Early examples where climate change scenarios have already been incorporated in infrastructure design include the Confederation Bridge in Prince Edward Island. The Confederation Bridge is a 13 km bridge between Prince Edward Island and New Brunswick. The bridge provides a navigation channel for ocean-going vessels with vertical clearance of approximately 50m. Sea-level rise was recognized as a principal concern during the design process and the bridge was built one metre higher than currently required to accommodate sea-level rise over its hundred-year lifespan.

Text adopted from *Assessment of adaptation practices, options, constraints and capacity. IPCC.*

Photo Credit: Don Jardine

Confederation Bridge, PEI

Mitigating Climate Change

Mitigation measures are designed to reduce the emission of greenhouse gases (GHGs) that contribute to climate change. Hundreds of Canadian municipalities have already undertaken climate change efforts with mitigation work to reduce emissions, such as increasing public transit, encouraging active modes of transportation like cycling and walking to reduce the use of automobile trips, or retrofitting municipal buildings to make them more energy efficient.

While mitigation measures offer long-term benefits, it is recognized that current GHG concentrations in the atmosphere are already having an impact on the Earth's climate, and, as a result, climate change adaptation is necessary to moderate harm and take advantage of opportunities. Mitigation efforts taken together with adaptation can form a comprehensive climate change response strategy that can prepare communities for climate impacts and help to lessen any future effect.

While neither adaptation nor mitigation actions alone can prevent significant climate change impacts, taken together they can significantly reduce risk. There is no optimal mix between mitigation and adaptation, and climate change policy is not about making choices between the two. Mitigation is necessary to reduce the rate and magnitude of climate change, while adaptation is essential to reduce the damages from climate change that cannot be avoided.

Text sources

Adapting to Climate Change. Natural Resources Canada (2010).

Case Study: Corner Brook City Hall

The City of Corner Brook constructed a new City Hall in the heart of its downtown core. This $20 million state-of-the-art facility will be certified silver under the Leadership in Energy & Environmental Design (LEED) international green building rating system. The building is equipped with many environmentally-focused features such as a green roof and a Window on the World (WOW) building performance system. This green building is environmentally responsible and resource-efficient, helping Corner Brook to reduce its energy consumption and greenhouse gas emissions associated with the City Hall.

Text adopted from *www.cornerbrook.com*

Photo credit: Michael Carroll

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For more information on Climate Change and Infrastructure, refer to *7 Steps to Assess Climate Change Vulnerability in Your Community*

http://atlanticadaptation.ca

BREAKOUT SESSION 2

How has your Town been affected by climate change?

Time: 30 minutes

Objective: This exercise will help you to recognize how climate change may be affecting your community and identify the costs involved, and areas most at risk. By identifying the key areas in your town that are most affected, it will help to focus future adaptation plans

Materials: Workbook and town map (if available). If a town map is not available, a sketch of your town may be used in its place.

Exercise:

1. Break into small groups.
2. Complete Table 2 on Pages **41-42** and determine what climate change issues are directly affecting your town.
3. On the map you used in Breakout Session 1, highlight the location of areas that you have listed in Table 2. You should use a different colour marker than the colour used in Breakout Session 1.

Photo Credit: Norm Catto

Sample:

Climate Change Issue/Event	Has your Town been affected by this issue?	Details about this issue	What was affected?	How much did it cost?
Sea-Level Rise	Yes	Every year the tidal waves are coming closer to my house. This is especially noticeable during storms in the fall. This year, severe damage occurring along the bottom of my yard.	Several houses along the coast	Fence needed repair - $8,000 Sidewalks were washed out - $35,000

CLIMATE CHANGE AND INFRASTRUCTURE

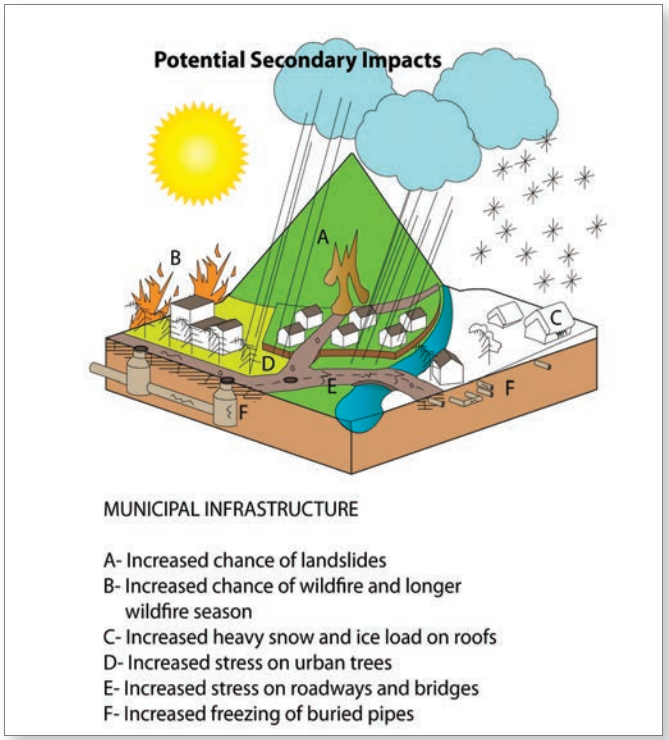
How Does Climate Change Impact Municipal Infrastructure?

Recent flooding and hurricane events, which have resulted in property and infrastructure damage, injury, and death demonstrate the vulnerability of Atlantic communities to climate change.

The climatic conditions that communities in Newfoundland and Labrador will need to contend with in years to come will be similar to those in the past. While severe weather events, which include hurricanes, ice storms and blizzards, are common to Newfoundland and Labrador, we can expect these events to be more intense due to the extra energy that will be driving weather systems. As a result, infrastructure damage such as road and culvert failures may become more frequent given that older infrastructure was not built to withstand these changing conditions. Low-lying communities will also face significant challenges as sea-levels rise. Therefore, it is important to understand how extreme weather events may damage infrastructure before it is too late.

Salt Water Intrusion

The combination of sea-level rise and excessive pumping of coastal aquifers allows sea-water intrusion inland, which can eventually contaminate wells, rendering water undrinkable. Salt water intrusion is a serious issue which may occur quite rapidly over a short period of time. For example, excessive use of the wells at L'Anse-aux-Meadows during the Viking Millennium celebration resulted in salt water intrusion within one month.



Source: Columbia Basin Trust. 2010.

Water Treatment and Distribution

Poorly maintained or aged water and sewage infrastructure are more vulnerable to damage from floods and freeze-thaw cycles. Periods of extreme precipitation may overwhelm water treatment facilities, or cause sewers to overflow, resulting in contamination of water. Flooding from intense storm events can also wash contaminants into water supplies. In either case, water treatment plants will be challenged to handle incoming water containing sediments and contaminants.

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For more information on Climate Change and Infrastructure, refer to *7 Steps to Assess Climate Change Vulnerability in Your Community*

http://atlanticadaptation.ca

Furthermore, periods of drought or climate-related shortages of water may also be compounded if there are undetected leaks in the piping system.

Stormwater Management

With increasing storm activities and a higher occurrence of flooding, it is important for towns to have stormwater management systems in place. Often, present stormwater management systems do not take projected increases in storm activity into account. Stormwater management systems need to be able to handle greater volumes of water. If they do not have the capacity to handle increased amounts of precipitation, the result could be road, culvert, and bridge washouts, as well as flooding.

Building and Property Damage

Heavy rainfall within a short period of time can cause slope failure. This occurred in Trout River in 2009, when periods of heavy rain caused two separate landslides, which displaced a house and two sheds from their foundations.

While a landslide can be very damaging to a community, building and property damage is more likely to be caused by flooding. Individuals and municipalities have a tendency to underestimate the damage created by flood events such as storm surges, rain-on-snow events and ice jams.

Road Damage

Road transportation is by far the largest component of the transportation sector in Atlantic Canada. Changes in climate that will affect road systems include periods of extreme heat and cold, and increased freeze-thaw cycles. In addition, for many coastal communities, sea-level rise will require coastal roads to be moved or rebuilt at higher elevations to avoid damage.

Extra infrastructure costs from climate change in the next 25 years will mostly be for maintaining or replacing roads, runways and water and sewer systems.

It is estimated that the impacts of climate change could add 10% to 20% to infrastructure costs by 2030, and an additional 10% to 12% by 2080. Further, the climate-related challenges that communities face are compounded by the maintenance, monitoring and replacement costs of aging infrastructure.

Text sources

From Impacts to Adaptation: Canada in a Changing Climate 2007- Chapter 4: Atlantic Canada. Vassuer and Catto, Government of Canada (2007).

7 Steps to Assess Climate Change Issues in Your Community. Newfoundland Labrador (n.d)

For more information, visit:

www.exec.nl.ca/exec/cceeet/2011_climate_change_action_plan.html

www.nrcan.gc.ca/earth-sciences/climate-change/community-adaption/assessments/132

http://atlanticadaptation.ca

How can Municipal Infrastructure be Adapted to Climate Change?

Vulnerability to climate change in Newfoundland and Labrador can be reduced through adaptation efforts and careful planning. By identifying vulnerable infrastructure and accounting for climate change, communities can plan and build infrastructure in a manner that reduces the risk of damage and protects community health and well-being.

Coastal Communities

There are three categories of adaptation that can be used in areas affected by coastal erosion, sea-level rise and/or storm surge activity. These include:

1. Planned Retreat

Recognizing the inevitability of coastal erosion, and responding by abandoning the areas closest to the shoreline or locating only temporary or expendable structures in these areas.

2. Accommodation

Constructing buildings in ways that minimize damage (by placing buildings on elevated pylons or designing structures to withstand sea-level rise). Additionally, developing land-use and zoning plans that allow only those structures that must be built on the shoreline to be located there, while prohibiting others (such as private residences).

3. Protection

Physical reinforcement of the shoreline either by "hard" measures (seawalls, rip-rap) or by "soft" measures (vegetating steep slopes with grass).

Municipal Roads

With a greater frequency of freeze-thaw events in winter months, changes to road maintenance and salt usage will be required in order to reduce pavement damage and improve safety. Major transportation projects will have to include consideration of climate change.

Water Management

Reliance on groundwater, particularly in coastal areas, coupled with decreased summer precipitation, necessitates conservation and careful monitoring of water quality. Detailed monitoring of consumption patterns, in combination with resource assessment, represents an effective adaptation approach.

Fire Protection

Longer, drier summers increase the likelihood of forest fires around communities surrounded by forests. Emergency Preparedness Plans, forest management practices, use of fire resistant building materials, greater fire fighting capacity, and training may be needed to adapt to the increased threat of Forest File.

Text sources

Adapting to Climate Change. Natural Resources Canada (2010).

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For more information on Climate Change and Infrastructure, refer to *7 Steps to Assess Climate Change Vulnerability in Your Community*

http://atlanticadaptation.ca

Case Study: Adapting To Sea-Level Rise in Placentia

The community of Placentia has experienced the impacts of extreme weather events in the past and is working to adapt to the challenges associated with sea-level rise. In 2007, the Department of Environment and Conservation partnered with the town and a number of entities, including Engineers Canada, on a vulnerability assessment of the town's infrastructure, such as the breakwater, steel floodwall and a section of the Dunville highway damaged during Tropical Storm Chantal in 2007. This project applied the Public Infrastructure Engineering Vulnerability Committee (PIEVC) engineering protocol, and assessed vulnerabilities to the year 2050 from changing climate events. As a result, the highway infrastructure was upgraded to handle more intense precipitation events and the area experienced minimal damage during Hurricane Igor in 2010.

Text adopted from: *Charting Our Course: Climate Change Action Plan. Newfoundland and Labrador (2011).*

Photo credit: Anita O'Keefe

Placentia, NL

BREAKOUT SESSION 3

What can your Town do to protect its infrastructure?

Time: 30 minutes

Objective: This exercise will help you identify how the impacts of climate change are affecting specific infrastructure in your community. By completing the table, you will see how well the infrastructure in your town responded to major weather events. In addition, it will help you to recognize vulnerable areas that may be at risk to damage during future weather events.

Materials: Maps from Breakout Sessions 1 and 2, and workbook.

Exercise;

1. Compare the maps from Breakout Session 1 and 2.
2. Thinking of past weather or possible future events, complete Table 3 on Pages **43-44**.

Photo credit: National Post

Sample:

Vulnerable Infrastructure	Climate Change Event	How is the municipal infrastructure vulnerable?	How much would it cost to replace?	What can be done to protect this infrastructure?
Community Wharf	Storm events	Large waves and high winds could potentially destroy the wharf.	To replace the wharf would cost between $150,000 and $200,000	- A breakwater could be installed to protect the wharf - Structural improvements could help the wharf withstand large waves.
	Sea-level rise	The wharf is fixed 1 metre above the high water mark and could be submerged soon.	See above	- Flotation devices could keep the dock above water, or the frame of the wharf could be raised incrementally…

THINGS TO THINK ABOUT

Ask questions

Having completed Breakout Sessions 1, 2, and 3, think of questions to ask your town council, town planners, engineers and architects regarding how vulnerable your town's infrastructure is to the impacts associated with climate change. These discussions will be very important when preparing Municipal Plans, Municipal Servicing Plans, Emergency Preparedness Plans and when replacing or installing infrastructure.

- Break into small groups.
- Here are some questions to get the discussion started:

Yes	No	Question	Discussion Point
		Has your town assessed its vulnerability to the potential impacts of climate-related events (storms, flooding, storm surges, wildfires)?	What are the risks?
		Has your council considered the risks posed by climate-related events and included policies in your town plan to minimize or prevent impacts before they occur?	
		Has land use decision-making changed in your community in light of these policies?	If not, why not?
		Are you aware of the tools planners are using to help communities adapt to the impacts of climate change?	What policies does your town need?

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Yes	No	Question	Discussion Point
		Think about planning for municipal infrastructure. Does your town have a plan?	How long has this plan been in place? How often has it been reviewed?
		Should your town's Servicing Plan for water and sewer infrastructure be revisited in light of anticipated climate change impacts and revised accordingly?	What might need to be changed?
		Does your Capital Works Program contain priorities for replacement, repair or retrofit of vulnerable infrastructure?	Does this include identifying weaknesses in critical infrastructure?
		In light of preparing the Public Sector Accounting Board (PSAB) inventory of infrastructure and other municipal assets, does your town have a plan for maintaining and re-investing in existing infrastructure, particularly in areas that are vulnerable to the impact of climate-related events?	
		Is this part of your Municipal Servicing Plan?	What are the costs of rehabilitation, repair and replacement for critical assets?

Yes	No	Question	Discussion Point
		Does the Department of Municipal Affairs require infrastructure to be designed to anticipate and accommodate severe climate events?	
		Are there plans to permit development or install services in areas of your town that are vulnerable to flooding, erosion, storm surges and so on?	
		If so, are you rethinking site selection or construction details to reduce the risk?	
		Does your Emergency Preparedness Plan consider potential incidents that may be related to climate change such as flooding, wildfires, or storm surges?	
		Is critical infrastructure located away from hazardous or vulnerable areas such as flood risk zones?	

NOTES

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Breakout Session 1

Table 1 - Municipal Infrastructure in Your Town

Type of Infrastructure		Location	Approximate Value	Condition of Infrastructure	Lifespan of Infrastructure	Other Comments
Road System	Streets					
	Bridges					
	Sidewalk					
	Access Roads					
Water Supply System	Water Pipes					
	Fire Hydrants					
	Pressure Boosters					
	Water Tower					
	Pumping Stations					
	Water Treatment					

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Breakout Session 1

Table 1 - Municipal Infrastructure in Your Town

Type of Infrastructure		Location	Approximate Value	Condition of Infrastructure	Lifespan of Infrastructure	Other Comments
Wastewater System	Trunk Sewers					
	Lift Stations					
	Treatment Plants					
	Outfalls					
Waste Disposal Site						
Stormwater System	Culverts					
	Catch Basins					
	Retention Ponds					
Municipal Buildings	Town Hall					
	Fire Station					
	Municipal Depot					

Breakout Session 1

Table 1 - Municipal Infrastructure in Your Town

Type of Infrastructure		Location	Approximate Value	Condition of Infrastructure	Lifespan of Infrastructure	Other Comments
Recreational Infrastructure	Parks					
	Trails					
	Playgrounds					
	Sports Fields					
	Indoor Sports/ Arenas					
Coastal Infrastructure	Public Wharf/ Slipway					
	Marina					
Lighting/ Signals	Street Lights					
	Traffic Lights					
Fences						
Walls						
Retaining Walls						

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Breakout Session 1

Table 1 - Municipal Infrastructure in Your Town

Type of Infrastructure		Location	Approximate Value	Condition of Infrastructure	Lifespan of Infrastructure	Other Comments
Other Important infrastructure	Cultural Facilities					
	Provincial Highways					
	Police Stations					
	Hospitals					
	Schools					
	Other					

Breakout Session 2

Table 2 - How has your Town been impacted by climate change?

Climate Change Issue/Event	Has your Town been impacted by this issue?	Details about this issue	What was affected?	How much did it cost?
Sea-Level Rise				
Rainfall Events				
Snowfall Events				
Summer Droughts				

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Breakout Session 2

Table 2 - How has your Town been impacted by climate change?

Climate Change Issue/Event	Has your Town been impacted by this issue?	Details about this issue	What was affected?	How much did it cost?
Ice Storms				
Summer Temperatures				
Winter Temperatures				
Salt Water Intrusion				

Breakout Session 3

Table 3 - What can your Town do to protect its infrastructure?

Vulnerable Infrastructure	Climate Change Event	How is the municipal infrastructure vulnerable?	How much would it cost to replace?	What can be done to protect this infrastructure?

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Breakout Session 3

Table 3 - What can your Town do to protect its infrastructure?

Vulnerable Infrastructure	Climate Change Event	How is the municipal infrastructure vulnerable?	How much would it cost to replace?	What can be done to protect this infrastructure?

APPENDIX

PSAB: Infrastructure Unit Price Information (2007)

Water Distribution System			
Pipe Type	**Pipe Size**	**Cost per Metre (including hydrants)**	**Cost per Metre (excluding hydrants)**
PVC (type K municipex)	50mm	$105	N/A
PVC	100mm	$156	N/A
PVC	150mm	$172	$147
PVC	200mm	$195	$170
PVC	250mm	$258	$233
PVC	300mm	$267	$242
Ductile Iron (DI)	150mm	$222	$197
Ductile Iron (DI)	200mm	$252	$227
Ductile Iron (DI)	250mm	$272	$247
Ductile Iron (DI)	300mm	$275	$250
Ductile Iron (DI)	350mm	$284	$259
Reinforced Concrete (RCP)	150mm	$222	$197
Reinforced Concrete (RCP)	200mm	$252	$227
Reinforced Concrete (RCP)	250mm	$272	$247
Reinforced Concrete (RCP)	300mm	$275	$250
Reinforced Concrete (RCP)	350mm	$284	$259
Fire Hydrants	2.1M	$3,000	

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Wastewater Distribution System			
Pipe Type	**Pipe Size**	**Cost / m (including manholes)**	**Cost / m (excluding manholes)**
PVC	150mm	$280	$238
PVC	200mm	$346	$304
PVC	250mm	$366	$324
PVC	300mm	$381	$339
PVC	400mm	$440	$398
PVC	450mm	$494	$452
PVC	600mm	$625	$583
Manholes		$5,000	

Stormwater Collection System			
Pipe Type	**Pipe Size**	**Cost / m (including storm drains)**	**Cost / m (excluding storm drains)**
Corrugated Steel	300mm	$100	$58
Corrugated Steel	450mm	$125	$83
Corrugated Steel	600mm	$145	$103
Corrugated Steel	750mm	$210	$168
PVC	200mm	$186	$144
PVC	250mm	$198	$156
PVC	300mm	$206	$164
PVC	400mm	$238	$196
PVC	450mm	$267	$225
PVC	600mm	$338	$296
Storm Drains		$5,000	

Culverts		
Pipe Type	**Pipe Size**	**Cost / m**
Metal Corrugated	400mm	$125
Metal Corrugated	450mm	$137
Metal Corrugated	500mm	$145
Metal Corrugated	600mm	$156
Metal Corrugated	900mm	$184
* Prices include removal of the old culvert.		

Lift Stations		
Type	**Cost**	**Details**
Small	$80,000	Less than or equal to 7.5 hp pumps, flows less than or equal to 20 liters / second and normally single phase power.
Medium	$120,000	Pumps greater than 7.5 hp but equal to or less than 18 hp pumps, flows 21 liters /second to 75 liters / second and normally 3 phase power.
Large	$160,000	Greater than 18 hp pumps, flows 80 liters / second to 250 liters / second, 3 phase power required.

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Other Items		
Item	**Cost**	**Details**
Curb and Gutter	$70 / m	
Gutter	$30 / m	
Sidewalk	$120 / m	Based on 1,500 mm width and includes the cost of bedding materials.
Ditching	$9 / m	
Gabion (retaining wall)	$202 / m^3	
Paved Surface	$37 / m^2	Paving prices include scarifying and reshaping.
Guide Rail	$74 / m	
Road Grade	$100 / lane / m	
Gravel Road (for driving)	$9.52 / m^3	
Rip Rap	$111 / m^3	
Traffic Controller	$21,500	
Pedestrian Signals	$750	
Traffic Signal: 3 Light	$550	
Traffic Signal: 4 Light	$650	
3 Meter Pole	$3,500	
9 Meter Pole	$12,500	
11 Meter Pole	$14,000	

Municipalities Newfoundland and Labrador
460 Torbay Road
St. John's, NL A1A 5J3

Toll Free: 1-800-440-6536
Tel: 709-753-6820
Fax: 709-738-0071

Website: www.municipalitiesnl.com
Email: ccrc@municipalitiesnl.com