Municipal Case Studies:

CLIMATE CHANGE AND THE PLANNING PROCESS

Delta

Natural Resources Canada
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Canada

Even though almost everyone grumbles about our local weather, we have become accustomed to it. We have *adapted*. Depending on where we live and the season, we sport umbrellas, snow boots or ball caps. Our homes are insulated, crops are irrigated, and we shop in weather-conditioned, indoor malls. So, when scientists tell us our climate is changing and about to change more quickly, it is difficult to grasp the significance in our daily lives.

Our regional climate, wherever we live in Canada, has always been changing — gradually and naturally. But, in the past 20 years, international scientific research has determined that the pace of climate change is accelerating, with some areas becoming more and more vulnerable. With the early 2007 release of the latest report from the Intergovernmental Panel on Climate Change (IPCC), the reality of climate change and the growing challenges of adaptation are increasingly recognized and accepted. So too is the need for national governments to respond with efforts to mitigate these effects.

Closer to home, in urban and rural settings across the country, discussions will be focussed on what local climate changes are likely, how they will impact our physical and built environments, and how we should respond. It is easier to discuss what is happening locally and what we can do about it, instead of grappling with the monumental global challenge of greenhouse gas emissions. Community planners and municipal engineers will find themselves at the crux of local discussions, especially in relation to assessing potential impacts and developing policy responses. The vocabulary of these discussions will embrace terms such as "vulnerabilities", "maladaptations", "mitigations", "risk management" and "adaptive capacity".

Forward-looking local governments are starting to factor anticipated climate changes into their planning and budgeting. However, few, if any, local governments have climate change researchers within their administrations. Most rely on research undertaken by other levels of governments and universities.

Five Municipal Case Studies

In 2004, the Earth Sciences Sector of Natural Resources Canada (NRCan) and the Canadian Institute of Planners agreed to co-sponsor ways to help build capacity at a local government level related to planning for climate change. This partnership led to a number of activities, including this series of case study brochures. The brochures have been produced to help community planners learn more about scientific practices and terminology, along with ways they might approach assessing local risks and developing locally appropriate responses.

There are five case study communities. In different ways and for different reasons, these communities are already experiencing the effects of accelerated climate change.

- In Calgary, warmer weather and changing precipitation patterns are affecting the city's sole water supply.
- In Salluit, a Northern Quebec coastal community, rapidly melting permafrost is threatening to undermine existing infrastructure.
- In Delta and Graham Island, BC and along the New Brunswick coast in the Gulf of St. Lawrence, rising sea levels and increased storm frequency and severity are impacting habitats, property and infrastructure.

Each case study was led by scientists and involved the participation of local planners, municipal managers/engineers and, in some cases, elected officials. Wherever possible, the study included broader community consultation through workshops and focus groups.

Summary

Delta occupies part of the alluvial deposit created by the Fraser River as it flows into Georgia Strait, on its way to the open Pacific. About half of the land area is less than 1.5 metres above sea level and a dyke system defends against high tides and storms. More than 103,000 people live in Delta and on the adjacent Tsawwassen First Nation reserve. Almost every winter, farms are flooded and, in some years, there is flooding and property damage resulting from severe weather events in areas with inadequate protection.

Globally, sea levels are rising and are predicted to increase at a faster rate in the future. On a local basis, it is difficult to predict the magnitude of sea-level rise but, for low-lying communities like Delta, it is extremely important to understand what may happen in order to anticipate consequences and plan how to respond.

This study focuses on one tidal flat — Roberts Bank — located along Georgia Strait. The bank is host to important ecosystems and economic infrastructure, including an internationally significant fish and migratory bird habitat, a large container port and a busy ferry terminal. Within the next 100 years, sea-level rise and intensified storminess are likely to significantly affect Roberts Bank and the adjacent upland areas.

The study's main aim was to undertake locally-relevant, scientific research on sea-level rise to help increase certainty for local decision-makers and stakeholders about likely outcomes. The specific objective of the scientific team was to investigate the potential impacts of rising sea level and extreme water levels on Roberts Bank.

Using data gathered from extensive monitoring and the use of aerial laser scanning of the inter-tidal sea bed, the researchers modelled future conditions.

The results showed that Roberts Bank is likely to experience a significant "coastal squeeze":

- All parts of the tidal flats will spend more time under water.
- Higher waves will reach the marshes and dykes.
- Increased erosion will attack marshes, dykes and causeways.
- There is an increased risk of dyke breach and flooding.

Key stakeholders were involved throughout the research program. The findings form the basis for additional work being undertaken jointly by NRCan and the Corporation of Delta.

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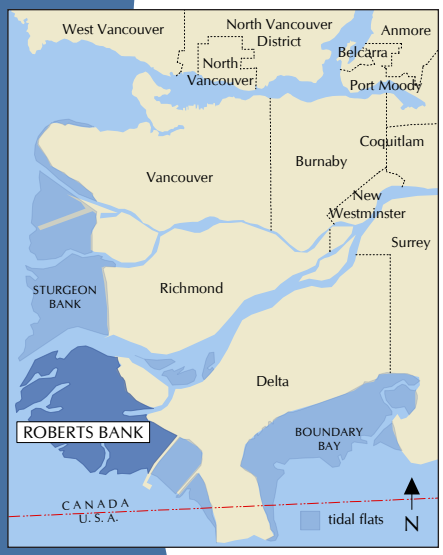

Introduction

Sea-level rise is difficult to measure and to predict. It is also challenging to convey scientific material about sea-level rise in a meaningful way to stakeholders, who have varied backgrounds, values and perspectives.

The scientific consensus is that the global average sea level rose between 10 and 20 cms during the 20th century. Globally, the Intergovernmental Panel on Climate Change (IPCC) estimates that mean sea-level will rise between 9 and 88 cms during the 21st century. To put this in perspective, during the past 100 years, the Vancouver area's sea level rose by four centimetres. This suggests that even the lowest estimate — nine centimetres — would mean a doubling of sea-level rise in coming years.

Although rising sea levels are usually thought of as something that takes place over the long-term, in low-lying areas, even small sea-level rises can have a dramatic effect in reducing the standard of protection offered by coastal engineering. During storm surges, coastal communities are at increased risk of flooding and erosion.

The IPCC also predicts increased frequency and severity of storm activity globally. This will likely mean larger, more powerful waves, more strong winds, and larger storm surges for many areas. In February 2006 an unusually high tide, combined with higher than 80 km per hour winds, created a storm surge in Delta, elevating the predicted water level of Boundary Bay by approximately 0.914 to 5.55 metres, a level just four centimetres below historic highs experienced 20 years earlier. The sand berm was breached and more than 200 homes were damaged.

The Local Partnership

In 2003, NRCan scientists formed a team of investigators to work with the communities of Delta, the Tsawwassen First Nation and other local stakeholders to study the impact of rising sea level and increasing storm intensity on Roberts Bank. The study team included natural scientists from the Canadian Wildlife Service, the Department of Fisheries and Oceans, and the University of British Columbia. Dr. Philip Hill of the Marine Studies Section of NRCanada was the lead investigator.

The Setting for this Research

Roberts Bank is located on the western edge of Greater Vancouver, a metropolitan area that is approaching three million residents. The bank's morphology is affected by a host of biophysical factors and engineered structures.

The Biophysical Context

The Fraser River stretches 1,400 kms from the Rockies to the Pacific, draining an area roughly the size of California. As the river leaves the narrow canyon at Hope, it spreads out, loses energy, and drops the coarsest of its sediments. Further downstream the gradient decreases, and the flow carries sand, silt and clay.

- The annual river load is 65% silt and clay, and 35% sand, transported primarily during the spring and summer freshet.
- A long, frost-free growing season and rich alluvial soils make the Fraser delta one of the most productive agricultural areas in Canada.

- The estuary, produced by the joining of the river with the Strait of Georgia, contains rich habitats for fish and wildlife. The estuary's marshes support millions of migrating salmon at a critical stage in their early development before they migrate out to sea, and act as a staging area for adult upstream spawning migration.
- The estuary has Canada's highest concentration of wintering birds. It is a key feeding and resting stop on the Pacific Flyway for migratory birds, and provides essential habitat for more than 300 species of birds and more than 80 species of fish and shellfish, including all five Pacific salmon species.
- Two ecological segments of the estuary are characterized as marine delta fronts — Sturgeon/Roberts Bank and Boundary Bay. They are directly influenced by marine waters from the Strait of Georgia, and the salinity of the water influences their flora and fauna.
- The confinement of the river to its present channels began during the early part of the 20th century. Before then, distributary channel switching occurred regularly. Dykes and other channel training structures have stabilized the main channel of the delta, leaving Roberts Bank relatively sediment starved and susceptible to erosion.

Despite dredging, channelization, dyking and causeways, the Fraser River estuary remains an exceptionally rich habitat for fish and wildlife – 300 species of birds and 80 species of fish and shellfish depend on the estuary's marshes for food and protection.

Socio-Economic Context

The tidal flats are bounded by two communities: the municipality of Delta and the Tsawwassen First Nation. Both communities have infrastructure that would be affected by flooding and have aesthetic, recreational, and traditional interests associated with Roberts Bank.

Delta Municipality

The municipality of Delta is located in the extreme southwest corner of mainland BC, 30 kms south of the City of Vancouver. Bounded by water on three sides — the Fraser River, Boundary Bay, and Georgia Strait — daily life is impacted by currents, tides, seawalls and storms.

- Delta has more than 102,000 residents, most of whom live in three urban communities separated by productive farming areas and a bog-type landscape.
- A dyke system shelters the low-lying areas. It protects the urban settlements of Ladner and Tsawwassen, the farmlands and other low-lying areas from daily flooding. The elevation of the Delta lowlands is between 1 and 1.5 metres, while high tides can be 2.0 metres. To maintain dyke integrity, Delta is vigilant about maintaining and improving this system.
- Delta's drainage system is a combination of closed pipe systems, box culverts, open ditches, sloughs, floodboxes and pump stations. It is closely monitored and upgraded through annual maintenance programs, new construction and infrastructure improvements. Ditches are found throughout Delta's farming and urban communities. Delta's staff work to maintain this infrastructure so water drains freely to the outlets without causing flooding. This is achieved with large drainage pump stations, large floodboxes and ditches/drainage channels.
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- During the summer months when the risk of flooding is generally lower, water levels are increased to assist the local farmers with crop production. This is achieved by installing baffles at the floodboxes, allowing Fraser River water to enter the local ditches. Irrigation activities include liaison with farmers.

- The municipality has committed considerable resources to the issues of flood management, storm water management, and dredging. A Dykes and Drainage Advisory Committee keeps abreast of relevant issues and provides advice to staff and Council on policy relating to these issues.

Several agencies have policy and regulatory measures to protect habitat and limit development in areas subject to flooding – for TODAY'S climatic conditions.

Tsawwassen First Nation

Archaeological evidence shows that there were Aboriginal seasonal settlements along the shores of the Strait of Georgia dating back 4,000 years. Today this area is a 290-hectare reserve lying adjacent to Roberts Bank; 168 people live on the reserve. The word *Tsawwassen* means "land facing the sea".

The Causeways

Two large causeways have altered the coastal morphology of Roberts Bank during the past 45 years, first through their construction, and subsequently through frequent dredging to maintain shipping depths. These interventions have changed sediment patterns and triggered tidal creek erosion.

- The Vancouver Port Authority's (VPA) Deltaport container cargo terminal and coalport facility, constructed in 1968, is accessed by a three-kilometre causeway perpendicular to Roberts Bank. VPA plans to significantly expand the facility in response to industry projections, which indicate that container traffic on the west coast of North America will triple by 2025.
- A second perpendicular three-kilometre causeway crosses Roberts Bank, providing access to BC Ferries' main terminal. Originally constructed in 1959, using 1.9 million metres^3 of boulder, rock and gravel fill, the causeway has been expanded several times.

Land and Water Use Planning

There are several jurisdictions which have an impact on land-use planning for Roberts Bank.

- Delta has its own Official Community Plan, which sets out policies and guidelines related to land use, development, services, amenities and infrastructure. The plan identifies a number of "environmentally sensitive areas", development is significantly limited in these areas. The shoreline along Roberts Bank is identified as being environmentally sensitive.
- Delta is a member of the Greater Vancouver Regional District and is a signatory to a regional plan that includes a "Green Zone". This land designation protects the region's natural assets and, by so doing, creates a boundary for urban growth. The Green Zone is extensive in Delta and includes:
    - Fraser River foreshore, channels, islands and wetlands;
    - Georgia Strait dykes, foreshore, inter-tidal areas and accreted lands; and
    - Banks, marshes, sloughs and drainage ditches.
- Planning for the water side of the dyke system is also affected by the Fraser River Estuary Management Plan (EMP). The EMP was developed by a partnership of agencies and serves as a policy guide for municipalities and other agencies with jurisdiction or interest in the estuary.
- The EMP identifies Roberts Bank as a "red-coded" area. Red-coded habitats include productive and diverse habitat features that support critical fish and wildlife functions on site. Development in red-coded areas is restricted but may occur, provided that mitigation is applied through site location and/or design to avoid impacts on habitat features and functions. Habitat compensation is not an option, as a rule.
- In Delta, "Area Designations" have been developed in consultation with the EMP staff for appropriate uses on the water side of the dykes of Roberts Bank, and estuary waters.

Research Methodology

The Roberts Bank tidal flats play an international role in maintaining biodiversity of terrestrial and aquatic ecosystems in two main ways: 1) as a stopover and vital link along the Pacific Flyway for millions of migrating birds, including the Western Sandpiper; and 2) as important habitat for fish populations, supporting five species of salmon. In particular, the eelgrass beds on Roberts Bank provide habitat for juvenile salmon.

The majority of the research was aimed at achieving a better understanding of the pressures from anticipated changes in the Fraser River and the marine environment from a physical and ecological standpoint.

Intertidal flats represent important sediment sinks within the coastal environment. Roberts Bank combines many different types of sedimentary environments with tidally dominated biological zones. Sediment quality is critical in the maintenance of healthy aquatic ecosystems. Often over-looked by the casual observer, marine sediments provide important habitat for numerous organisms, from invertebrates to fish. The intertidal and nearshore subtidal sediments also represent critical forage for many birds that feed on the algae and invertebrates. Eelgrass beds provide refuge for many species of fish and invertebrates, and feeding areas for many species of waterfowl.

Both sediment type and biological activity play important roles in seabed stability. Computer models of coastal sedimentation rarely use measured values of seabed strength. The data collected in this study provided one of the first useful datasets for calibration and improvement of modelling.

The pre-existing morphology has a significant impact on how sediment is transported and how water and waves are directed. In order to predict the response of Roberts Bank to accelerated sea level rise and intensified storminess, it was necessary to develop a wave/current model. Data on wave and tidal currents was collected in 2003/04 along four transects within Roberts Bank. In the spring of 2003, the data was monitored over 31 days under a wide range of offshore wave conditions and tidal elevations. During this period, there were four storm events. Another set of measurements was collected in the winter of 2004.

The team also used LIDAR technology to provide extensive data on sedimentary patterns. LIDAR is the technology of using pulses of laser light striking the surfaces of the earth/seabed and measuring the time of pulse return. Light Detection And Ranging (LIDAR) is analogous to RADAR except that light waves are used instead of radio waves. A scanner is mounted in the bottom of an airplane, similar to an aerial camera. LIDAR scanning can occur day or night, as long as clear flying conditions are present.

This research pioneered the use of LIDAR technology to predict future patterns of seabed stability and susceptibility to erosion. This remote sensing technology allows scientists to rapidly and accurately map the inter-tidal seabed at very high resolution.

Results and Consequences

Locally, the natural response of the Roberts Bank shoreline to rising sea level will be for the sea to migrate inland, inundating agricultural land, with all parts of today's tidal flats spending more time under water and with higher waves reaching the shoreline marsh. But, because the coast is dyked, the tidal flats are likely to shrink. More of the tidal flats will be submerged and subject to wave attack. This is likely to result in increased erosion of the tidal flats and, potentially, the undermining of the dykes, as well as the port and ferry facilities.

As rising sea level squeezes the tidal flats against the dykes, this important ecosystem will be displaced, and, in some places, completely lost. For birds, because the tidal flats will be exposed

for a shorter period of time, and there will be erosion of surface layers including diatom bioflims, food availability will be decreased. For fish, there will be stress on the eelgrass habitat and an erosion of marsh habitat, also decreasing food availability.

In light of Delta's low-lying topography, rising sea levels and increasing storminess are significant concerns for the municipality, Tsawwassen First Nation, Vancouver Port Authority and BC Ferries. There are several ways that climate change will affect the area's infrastructure:

Key stakeholders collaborated to identify specific concerns, review scientific research, and brainstorm impacts and potential actions.

Consultation Process

From the beginning of this project, the scientific team was committed to engaging key stakeholders and communities. Team members felt it was absolutely vital to have a process that gives stakeholders the opportunity to share their concerns and perspectives at an early stage, as well as to interact at milestones within the research stage. In this sense, stakeholder involvement helped to shape the scope of the technical assessment.

Before convening workshops, a series of one-on-one meetings were held with stakeholders to refine objectives, priorities and concerns, as well as to confirm gaps in knowledge about climate change. Given the past relationships amongst stakeholders, this was important as a means for the study team to understand the different perspectives of the stakeholders and to avoid historic tensions from derailing the workshop process.

The first stakeholders' workshop was held in the fall of 2004. Concerns were identified and grouped, based on whether they were ecological, social or physical. Participants were encouraged to identify potential measures to monitor and address these concerns. Representatives from the following organizations participated in the workshop:

- BC Ferries;
- BC Ministry of Water, Land and Air Protection;
- Canadian Wildlife Service;
- Canadian Climate Impacts and Adaptation Research Network;
- District of Delta;
- Fraser River Estuary Management Program;
- Fraser Basin Council;
- Georgia Basin Action Plan;
- Greater Vancouver Regional District;
- Natural Resources Canada;
- Tsawwassen First Nation; and
- Vancouver Port Authority.

A second, two-day workshop was held in March 2005. This included a field trip, followed by a day-long review, discussion of the early findings of the research program and identification of potential performance measures. In March 2006, another day-long stakeholder consultation was held to finalize the project and address stakeholders' concerns regarding next steps.

- putting additional pressure on the regional dyke system and causeways, potentially undermining their structural integrity, leading to subsidence and saltwater flooding;
- compromising the efficiency of the drainage irrigation system by having sea levels higher than existing drainage ditches and storm sewers;
- increasing saltwater intrusion would degrade freshwater quality and quantity, with a detrimental effect for agricultural operations; and
- affecting the float home communities that are located along the outer reaches of the Fraser River estuary.

The research shows that a "coastal squeeze" will result in increased erosion of the tidal flats and, potentially, the undermining of the dykes, as well as the port and ferry facilities.

Relevance of this Research

At this stage, the area's stakeholders are much better informed about the likely consequences of sea level rise on Roberts Bank and its upland areas. The term "coastal squeeze" has taken on a new meaning and, for some, an increasing sense of urgency. For the municipality of Delta, the project has a broader implication — a rising sea level and increased storminess could impact all coastal and low-lying areas of the municipality.

Managing coastal squeeze requires long term land use planning. The following matters require further research and closer consideration by all agencies with an interest in the future of Roberts Bank and the areas impacted by changing sea level:

- evaluation of the salinization of municipal water intake;
- loss of habitat for benthic organisms, as well as fish and wildfowl;
- storm intensity-duration and frequency; and
- impact of the port expansion on sedimentation patterns.

Armed with compelling scientific data, stakeholders will be in a position to shift their focus to the examination of potential mitigation and adaptation strategies. Some possible strategies — or their combination — for Roberts Bank include to:

Delta's planners and engineers will be key to analyzing the strategies for mitigation and adaptation.

- do nothing and accept the consequences;
- reinforce the existing coastal defence system with additional engineered structures (e.g., dykes, berms, rip-rap, seawall);
- realign the coastline by moving the current dyke system inland; thereby allowing the low-lying land to flood and regenerate as a natural intertidal habitat;
- nourish tidal flats through removal of accumulated log debris, extending water channels into the area and breaking the dyke with a culvert to improve fish access and flushing of the restored area;
- additional engineered approaches within Roberts Bank, such as augmenting existing subtidal rock reefs and improved management of tidal flows between the causeways to create new fish and wildlife habitat; and
- increasing and enhancing fish and wildlife habitat at other locations within the Fraser estuary, instead of at Roberts Bank.

Applying the information learned through this three-year research program, there are a number of questions that, over time, will need to be considered by Delta and First Nations planners and engineers, emergency service providers, local businesses, insurers and coastal residents.

- Are current planning regulations and building bylaws adequate to address the climate change impacts being predicted?
- How should planners approach trade-offs between the protection of infrastructure and the protection of habitat?
- Is critical coastal habitat at risk due to coastal squeeze?
- Is there a need to adopt new guidelines for infrastructure renewal and maintenance? Where will the funding come from
- Is there a need to reposition outfall pipes (their height above current maximum high water levels) to ensure continued gravity-driven discharges?
- Is there a need to add capacity to the dyke/pump infrastructure in order to protect the agricultural economy and the low-lying residential areas?
- What order of magnitude of property damage/loss may be experienced? Will private insurers limit their liability in areas that are subject to flooding from sea level rise? Will government insurance programs become more risk-adverse?

Relevance for Other Communities

This research is relevant to all low-lying communities along Canada's coastlines, especially for rural and urban communities located at a river estuary. As sea level rises and storms intensify with climate change, private property, public infrastructure and potentially, human life will be more at risk. Productive habitats may be compromised or reduced, and farmlands may become less viable.

Importantly, this research underscores the value of developing a baseline understanding of local conditions and setting in motion a planning process that allow stakeholders an opportunity to anticipate, mitigate and adapt to changing conditions. The stakeholder process that was set up for this project had several benefits, including:

- information exchange;
- priority setting for researchers; and
- a significant engagement of communities and agencies whose decision-makers will be faced with policy, capital and operating challenges in the coming years.

Globally, insurers are beginning to review their risk appetite associated with climate change. Over time, they may consider withdrawing or restricting cover in flood-prone areas or create incentives for policy holders who take measures to proactively minimize the risk of flooding and storm damage. Some insurers already put a cap on contents insurance to encourage policy holders to take steps to protect their more valuable property in flood zones. In the future, as forecasting becomes more precise, underwriters may be able to respond to the specific predictions of the coming season.

Role of Community Planners

The ability of Canadian communities to respond effectively to climate change depends on a range of factors, including scientific information, access to financial resources and the state of existing infrastructure, education, technology and management capabilities. Some communities with lesser capacity to respond may face more risks in the future.

Historically, planners have been facilitators of change, helping to make progressive choices as societal values, needs, resources and capacities change. Recognizing change, and helping others adapt to that change, is likely to be the most enduring role of planners in relation to climate change. In coastal communities, planners will likely continue to do this through stakeholder consultation processes as part of community-wide and area-specific plans. Through these planning processes, they will help residents, businesses, investors and others learn more about the risks and trade-offs associated with them. In larger municipalities, with more resources, there may be planners whose work focuses on environmental issues, including climate change. In the largest municipalities and metropolitan agencies, there will be planning staff dedicated to the issues directly associated with climate change.

In addition to their role as communicators and facilitators of consultation processes, planners have access to policy and regulatory measures that, if supported by decision-makers, will help avoid further socio-economic risks associated with sea-level rise and storm surges.

- Policy statements and land-use designations in community plans, supported by appropriate zoning regulations, can prevent the inappropriate type and scale of land use.

  As an example, in British Columbia municipalities have the authority to designate certain areas as hazardous, environmentally sensitive, or bio diverse within their Official Community Plans. Once designated, any development proposal must follow certain guidelines and will be scrutinized by the municipality's planners. These "Development Permit Areas" are important planning tools and widely used in BC. Other provinces have similar, but differently termed, measures to help protect sensitive environments. In Delta, the municipality has already established a Development Permit Area along the entire coastline of the municipality.

In some provinces, planners may also have an opportunity to have input into incentive programs that encourage responsible land use and building in flood-prone areas. Additionally, in the future, they may be called on by the insurance industry to help design guidelines for policy holders that minimize risks associated with flooding and extreme climate events.

Pass it On ...

This case study will interest government, stewardship organizations, businesses and developers who have interests in low-lying coastal areas. The insurance industry will also take note. Pass it on to others.

Sources, Contacts and Additional Resources

- *Climate Change Impacts and Adaptation Program, Earth Sciences Sector, Natural Resources Canada*. The objectives of the program are to: improve knowledge of Canada's vulnerability to climate change; better assess the risks and benefits posed by a changing climate; and build the foundation upon which appropriate decisions on adaptation can be made. The program supports research to: fill critical gaps that limit knowledge of vulnerability; undertake and support assessment of impacts and adaptation; enhance collaboration between stakeholders and researchers; and facilitate policy development.

  Canadian Climate Impacts and Adaptation Research Network (C-CIARN) – **www.c-ciarn.ca** – is a national network that facilitates the generation of new climate change knowledge by bringing researchers together with decision-makers from industry, governments, and non-government organizations to address key issues.

- *The Partners for Climate Protection (PCP)* program is a network of more than 132 Canadian municipal governments that have committed to reducing greenhouse gases and acting on climate change. PCP is the Canadian component of ICLEI's Cities for Climate Protection (CCP) network that comprises more that 600 communities world wide making the same efforts. **www.sustainablecommunities.ca**

- *The Coastal Education and Research Foundation (CERF)* is a non-profit corporation dedicated to the advancement of the coastal sciences. The foundation is devoted to the multi-disciplinary study of the complex problems of the coastal zone. **www.cerf-jcr.org**

- *The Coasts, Oceans, Ports and Rivers Institute (COPRI)* was created in 2000 by the American Society of Civil Engineers to advance and disseminate scientific and engineering knowledge in relation to sustainable development and the protection of coasts, oceans, ports, and waterways. **www.coprinstitute.org**

- *Fisheries and Oceans Canada* is the lead federal government department responsible for developing and implementing policies and programs in support of Canada's economic, ecological, and scientific interests in oceans and inland waters. The Habitat Management Division has published guidelines to protect fish populations and their habitat from the damaging effects of land development activities. **www.dfo-mpo.gc.ca/us-nous_e.htm**

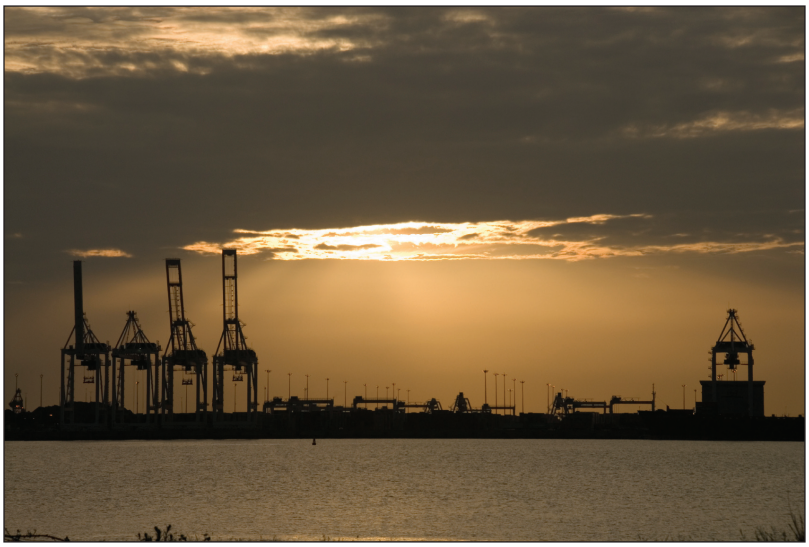
- *National Oceanic and Atmosphere Agency (NOAA)*. The agency supports The National Estuarine Research Reserve System. This is a network of protected areas established for long-term research, education, and stewardship. This partnership program between NOAA and the coastal states protects more than one million acres of estuarine land and water, which provides essential habitat for wildlife; offers educational opportunities for students, teachers and the public; and serves as living laboratories for scientists. **http://oceanservice.noaa.gov/topics/coasts/reserves**

Glossary of Climate Change Terms

The Intergovernmental Panel on Climate Change (IPCC) assesses scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. IPCC maintains a glossary of terms used in the science and study of climate change. The following terms are selected from that glossary as terms that will be increasingly used by community planners and municipal engineers.

- **Adaptation Adjustment**. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.
- **Adaptation Assessment**. The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility.
- **Adaptation Benefits**. The avoided damage costs, or the accrued benefits, following the adoption and implementation of adaptation measures.
- **Adaptation Costs**. Costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs.
- **Adaptive Capacity**. The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
- **Aquifer**. A stratum of permeable rock that bears water. An unconfined aquifer is recharged directly by local rainfall, rivers, and lakes, and the rate of recharge will be influenced by the permeability of the overlying rocks and soils. A confined aquifer is characterized by an overlying bed that is impermeable and the local rainfall does not influence the aquifer.
- **Capacity Building**. In the context of climate change, capacity building is a process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to participate in all aspects of adaptation to, mitigation of, and research on climate change, and the implementation of the Kyoto Mechanisms, etc.
- **Climate**. Climate, in a narrow sense, is usually defined as the "average weather" or, more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate, in a wider sense, is the state, including a statistical description, of the climate system.
- **Climate Change**. Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.
- **Demand-side Management**. Policies and programs designed for a specific purpose to influence consumer demand for goods and/or services. In the energy sector, for instance, it refers to policies and programs designed to reduce consumer demand for electricity and other energy sources. It helps to reduce greenhouse gas emissions.

- **Ecosystem**. A system of interacting living organisms together with their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth.
- **Extreme Weather Event**. An extreme weather event is an event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called extreme weather may vary from place to place. An extreme climate event is an average of a number of weather events over a certain period of time, an average which is itself extreme (e.g., rainfall over a season).
- **Habitat**. The particular environment or place where an organism or species tend to live; a more locally circumscribed portion of the total environment.
- (Climate) **Impact Assessment**. The practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.
- (Climate) **Impacts**. Consequences of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts.
- **Infrastructure**. The basic equipment, utilities, productive enterprises, installations, institutions, and services essential for the development, operation, and growth of an organization, city, or nation. For example: roads; schools; electric, gas, and water utilities; transportation; communication; and legal systems would be all considered as infrastructure.
- **Potential Impacts**. All impacts that may occur given a projected change in climate, without considering adaptation.
- **Residual Impacts**. The impacts of climate change that would occur after adaptation.
- (Climate) **Vulnerability**. The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.



Glossary of Case Study Terms

- **Benthic environment.** The marine life zone at the sea floor; distinguished from the pelagic environments, in the water itself. Shallow benthic environments are those towards the shore from the edge of the continental shelf. At the sea floor, the various benthic habitats are divided into those where the organisms live primarily on the surface of the bottom (benthic epifauna) and those where they inhabit the sediment (benthic infauna).
- **Delta.** This is an alluvial deposit, usually triangular or semi-circular, that accumulates at the mouth of a river.
- **Estuary.** The water body where a river meets the ocean so that freshwater and saltwater mix and the river level is affected by tides.
- **Salt marsh.** A community of organisms dominated by plants that are tolerant of wet, saline soils, generally found in low-lying coastal habitats which are periodically wet and unusually saline. The term salt marsh summarizes the saline conditions of the habitat as well as the vegetation that dominates it. Plants that grow in salt marshes are tolerant of two conditions: saline and wet.
- **Saltwater Intrusion/Encroachment.** This is the displacement of fresh surface water or groundwater by the advance of saltwater due to its greater density, usually in coastal and estuarine areas.
- **Sea-level Rise.** This is an increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an alteration to the volume of the world ocean. Relative sea-level rise occurs where there is a net increase in the level of the ocean relative to local land movements. Climate modellers largely concentrate on estimating eustatic sea-level change. Impact researchers focus on relative sea-level change.
- **Storm Surge.** This refers to a temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.

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