Delta-RAC Sea Level Rise Adaptation Visioning Study

Policy Report

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UBC CALP

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Throughout CALP's first Delta project (funded by GEOIDE 2004 - 2007), and continuing with this project, we have had the pleasure of working with a very committed group of local citizens. The Working Group on this project included Firth Bateman, Tom Bearss, Stuart Bowyer, Robert Butler, Erica Crawford-Boetttcher, Darrell Desjardin, Angelika Hedley, Carla Marshall, Chris Reid, Todd Sinclair, Robert Tremblay, and Paul van Westendorp. Their volunteerism, dedication and insightful comments added crucial local knowledge, and acted as an important reality-check to the project.

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The CALP Delta-RAC project team:

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and
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Section One: Introduction

1.1 Project Overview

The Corporation of Delta is a low-lying municipality at the mouth of the Fraser River delta. Home to 100,000 citizens, a large portion of the community is at considerable risk from climate change induced sea-level rise and storm surges. While the Province of B.C. provides guidelines and tools for flood risk management, it is the responsibility of local governments to define their flood hazards, integrate these with land use planning policies and implement sufficient flood protection. Uncertainty in climate science and lack of effective engagement tools make it difficult for local governments to build public support for flood-related policy and action. Previous research on climate change response options, using flood scenario visualization, has proven effective in developing community awareness and support for adaptation needs (Tatebe et al. 2010).

The Delta-RAC Sea Level Rise Adaptation Visioning Study (Delta-RAC) builds on prior work between CALP and Delta (Tatebe et al. 2010), using adaptation scenarios and 3D landscape visualizations in a visioning process to explore a range of alternative response options to sea level rise. The goal is to support decision-making and further policy development for flood management in the Corporation of Delta.

Project Context

This work has been carried out as part of the BC Regional Adaptation Collaborative (RAC) project. The BC RAC is funded by Natural Resources Canada and includes close to 20 projects addressing water and climate change adaptation across BC. The Collaborative for Advanced Landscape Planning (CALP) at the University of British Columbia partnered with the Corporation of Delta and the BC Ministry of Environment to identify, model, visualize and evaluate flood adaptation options in Delta. The project took place between 2009 - 2012.

Delta has a progressive history as a leader in climate change work. The RAC project follows the Local Climate Change Visioning project, an earlier collaboration between UBC CALP and the Corporation of Delta, funded by the GEIODE National Centres of Excellence (Shaw et al. 2009, Burch et al. 2010, Tatebe et al. 2010). Delta is also participating in the high-level adaptation planning program developed by the International Council for Local Environmental Initiatives (ICLEI) - see page 18 for more information on this program.

This project draws on prior flood risk and management studies prepared for the Corporation of Delta, particularly the 2010 Delta Flood Risk and Consequence Study prepared by Delcan DHV and the 2007 Flood Management Study prepared by Kerr Wood Leidal.

Through the RAC project, CALP and Delta commissioned an additional study on flood-risk assessment, which resulted in the 2011 Delcan DHV Technical Memo on Sea Level Rise Dike Breach Analysis.

Project Scope

The Delta-RAC project built on existing research and knowledge of local climate change vulnerability to identify, visualize and evaluate hard and soft adaptation options to coastal flood risk due to sea level rise. Following the broad principles of the Local Climate Change Visioning (LCCV) process (Pond et al. 2010), the project explored how mapping and visualizations, based on local climate science of sea level rise, storm surge, and increased storm water in Delta, BC, can advance land use planning decision-making and implementation for adaptation to anticipated flood issues. As a local climate change case study, the project aims to inform the development of best practice guidelines and other adaptation tools, including science-based visualization techniques, in order to provide a precedent for municipal decision-making and land use planning related to climate change in other BC communities.

The Delta-RAC project is one case study in a larger set of projects funded by GEOIDE that is testing the effectiveness of geo-visualization tools and participatory processes to support decision-making around climate change (Pond et al. 2012).

As part of the BC RAC project, the Delta project incorporated findings from other teams, such as the Ministry of Environment's updated Sea Dike Guidelines, Guidelines for Management of Coastal Flood Hazard Land Use, and draft Policy Discussion Paper (Ausenco Sandwell 2011(a)(b)(c)).

This project did not examine the effects of other potential threats such as earthquakes, tsunami, Fraser river floods, intense rain storms, liquefaction, peak oil, environmental refugees, accelerated climate change, salt wedge intrusion, human impacts of a flooding event (loss of life, etc.), and sea level rise impacts on gravity-based storm water and wastewater systems.

Project Participants

Delta Staff

Corporation of Delta staff provided critical input and advice throughout all phases of the project. Staff included:

- Angela Danyluk, Senior Environmental Officer
- Hugh Fraser, Deputy Director, Engineering
- Mike Brotherston, Manager, Climate Action and Environment
- Marcy Sangret, Deputy Director, Planning
- Lisa King, Planner
- Thomas Leatham, Director, Planning

Working Group

A local working group was convened to provide feedback at all stages of the process. Working group representatives included landowners, local stakeholder groups (Delta Farmers' Institute and Delta Naturalists Society), and representative community members. This group met approximately five times throughout the project to receive information about the project and to provide feedback to the project team. The working group included 8-12 members who were recruited via suggestions from Corporation of Delta staff, and from previous research project working groups.

Expert review

During the project, key experts were consulted to provide feedback on technical issues such as indicator measurement and dike infrastructure. These included:

- Dr. Stewart Cohen, Environment Canada
- Dr. Jeff Carmichael, Flatirons Consulting
- Neil Peters, Inspector of Dikes, Ministry of Forests, Lands and Natural Resource Operations
- Jesal Shah, Engineer, Ministry of Environment
- Tina Neale, Climate Change Adaptation Advisor, Ministry of Environment
- John Readshaw, Coastal Engineer & Consultant, SNC Lavalin
- Delcan DHV

Policy Review

Throughout the project, the team also collected and reviewed relevant policy from Delta, the Province, and beyond. This includes all applicable and available technical and planning documents, reports and regulatory materials relevant to current local, regional, and provincial flood policy. Following this review, the policy implications of the project's hypothetical adaptation options have been evaluated to identify where current policies support or hinder these kinds of adaptation approaches, and what changes might be necessary to implement these options.

Literature Review

The team also collected and reviewed relevant literature, other case studies, and technical data and information, to provide background information for the selection of local climate change scenarios and adaptation options.

Technical Report and Project Posters

An accompanying technical report describing project methodology and results, as well as a set of project posters, were also developed. The posters can be found in Appendix 2 of this report. Scholarly papers and a book chapter (Pond et al. 2012) are also in process which include descriptions of this project.

A project website has been created: delta-adaptation-bc.ca

1.2 Document Scope and Structure

This document is intended to describe a variety of sea level rise adaptation options for the community of Delta, and its individual neighbourhoods and areas. It should be used as a way to advance dialogue, planning, community engagement and capacity-building, and ultimately policy development on this critical issue. It provides a cross-comparison of the implications and trade-offs associated with each scenario so that the community understand the pros and cons of a range of options, and can then further develop or adapt viable scenarios. Each scenario may not be suitable, or even possible, within every neighbourhood and area in Delta. This report is structured to provide a choice of approaches for the community and its individual neighbourhoods as the community moves forward with adaptation planning.

The document is divided into 5 key sections:

1. Introduction. Section One introduces the project, including the background, context, scope, process and framework.

2. Delta Now. Section Two describes the current conditions of Delta, BC, and briefly describes current policy.

3. Why Adapt? Section Three provides a baseline overview of the potential climate change impacts for Delta.

4. What Can Delta Do? Section Four is structured around the adaptation scenarios. The scenarios are presented individually, each as a complete set of options for the community to choose as its future course. Each scenario is discussed in detail, including a scenario description, the assumptions used for the scenario, the broad implications of the scenario, the current policy that supports or conflicts with the scenario, and relevant case studies or precedents. This is followed by a set of policy implications for each scenario.

5. How Should Delta Move Forward? Section Five summarizes the key project assumptions and implications for the Corporation of Delta. Through the process, over-arching policy issues emerged as important findings across all scenarios. These are listed in this section and suggested as priority issues for the community to consider as it moves forward with sea level rise adaptation planning. Also listed in this section are some key policy implications for each scenario. These implications are not addressed in existing policy, and would have to be considered if the scenario were to be adopted.

1.3 Project Process

The goal of the project was to generate a range of adaptation options or scenarios to inform future climate change planning in Delta. To achieve this goal, the project used an iterative process developed by UBC CALP, called the Local Climate Change Visioning (LCCV) Process. (This process is adaptable for any local government working on climate change visioning. For more information, see CALP's LCCV Guidance Manual (Pond et al. 2010)).

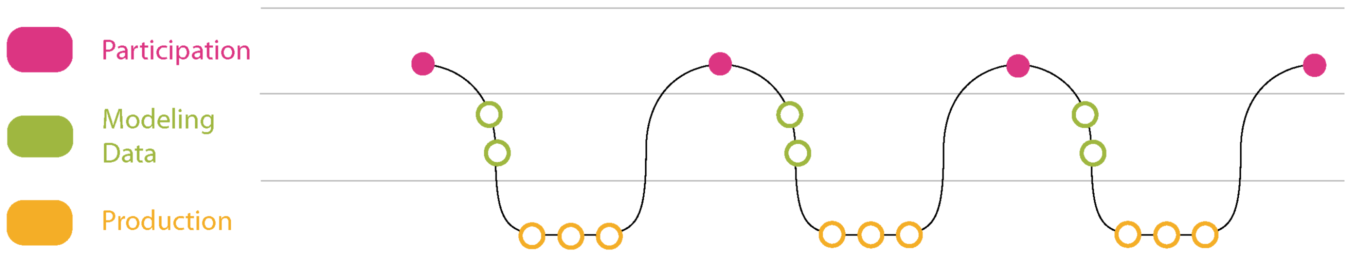


Figure 1-1: CALP's Local Climate Change Visioning Process (LCCV). LCCV is an iterative, participatory process that includes three phases for communities to create a local vision for climate change planning.
image credit: Jon Salter

The Delta-RAC Local Climate Change Visioning process took place in three phases:

1: Participatory Scenario Building & Indicator Definition

2: Data Integration, Modeling, and Visioning Package Development

3: Policy Implications, Capacity Building & Dissemination

Phase one, Participatory Scenario Building & Indicator Definition, took place in the first year of the project. Key activities included creating a work plan for the entire project, establishing a time scale and geographic scope for the analysis, determining critical baseline (current) data and future climatic data projections, creating a list of relevant potential economic, environmental and social indicators, and creating draft scenarios for analysis. Geographic scope varied across indicators: for example, the local impact of dike upgrades was shown visually for two particular neighbourhoods, but impacts on agricultural land were considered across the entire corporation. Plans were established for participatory collaboration with both corporation technical staff and with engaged local community members. The latter were included through the creation of a community Working Group. Plans were laid for when and what kind of interaction would take place with both of these groups over the course of the project. A review of existing relevant policy also took place.

Outcomes included a project work plan, selection of two specific neighbourhoods for which results would be visualized, a draft set of scenarios and indicators, a policy context statement (Tatebe et al. 2010), and the creation of a community Working Group and its working mandate.

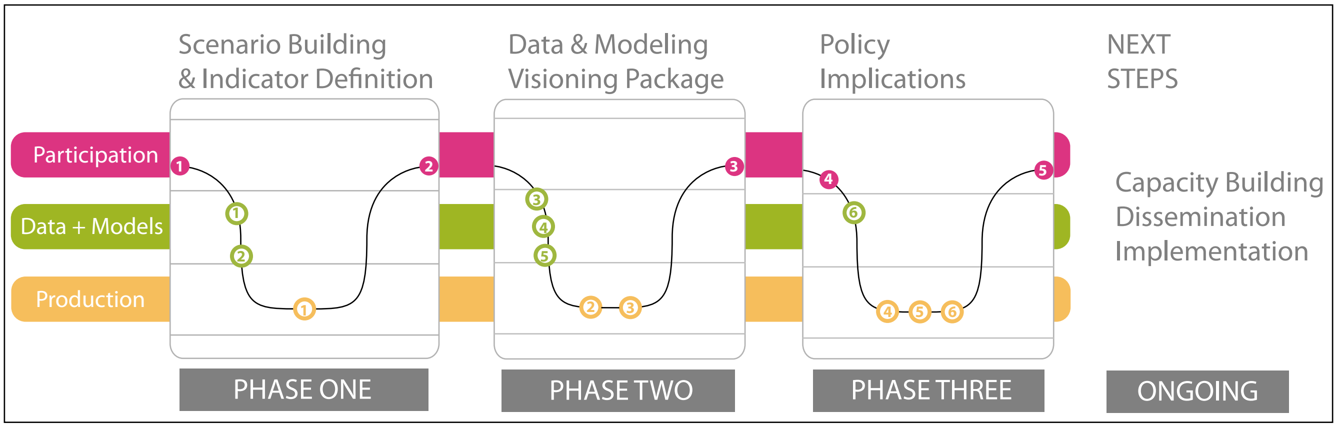


Figure 1-2: Delta-RAC project process

Participation
① **Working Group Meeting 1**
② **Working Group Meeting 2**
③ **Working Group Meeting 3**
④ **Delta Planners Meeting**
⑤ **Council Presentation**

Data & Models
① **Local Climate Change Scenario Definition**
② **Adaptation Options & Key Indicators**
③ **Scenario Impacts & Adaptation Options Analysis**
④ **Delcan Technical Report**
⑤ **Policy Review**
⑥ **Policy Gap Analysis**

Production
① **Preliminary Visualization Development**
② **Second Draft Visualizations**
③ **Policy Review Report**
④ **Final Visualization Packages**
⑤ **Policy Implications Report**
⑥ **Technical Report**

image credit: Ellen Pond, Sara Barron

The second phase, Data Integration, Modeling, and Visioning Package Development, took place in the second and third years of the project. In this phase, the team used the draft scenario frameworks generated in phase one, and gathered additional data to create preliminary visualizations. These visualizations were then tested through multiple review workshops with Delta staff, the working group, and invited experts. The visuals were revised and refined based on the feedback received. At the same time, the indicators were refined and measured. The main outcome was a final set of visualizations for the scenario frameworks, and indicators with which to compare them. These final packages were presented to Delta staff, the working group, and invited experts for final feedback and refinement.

The final phase, Policy Implications, Capacity Building & Dissemination, used the Visioning Packages and on-going policy review to draft a set of policy implications for each scenario. These were brought to Delta Staff and then finalized in this report. A technical report was also prepared to share key project lessons related to data gathering and modelling. Project outcomes will be presented to Delta Council, and will be disseminated through a dedicated website.

Evaluation Framework

The Local Climate Change Visioning process for Delta-RAC used a conceptual Evaluation Framework throughout the project, primarily in phase two, to help identify, model, visualize, and evaluate adaptation options for the Corporation of Delta. The framework uses 4 steps:

1) Model climate scenario impacts (focused on sea level rise)
Climate scenario impacts are defined by combining local climate science data, linked to global climate science and emissions data, with local knowledge to project the best available scenario(s) of future climate impacts for a particular community.

After reviewing future climate scenario projections, the team chose to move forward with the projection of 1.2 m of sea level rise for Delta by 2100. This projection corresponds to the Ministry of Environment's recommended global sea level rise curve for planning and design in British Columbia (Tatebe et al. 2010). See section 3.1 for further detail.

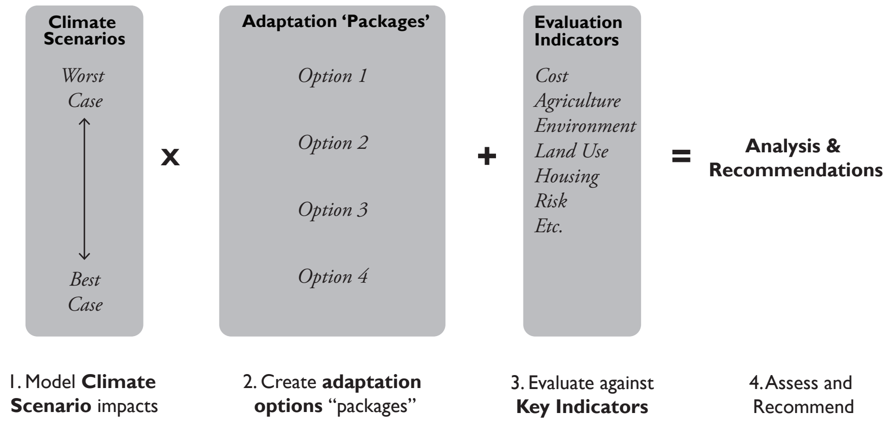


Figure 1-3: Delta-RAC Evaluation Framework. This diagram illustrates the evaluation framework used in this Delta-RAC project to evaluate the adaptation options generated through the project process.
image credit: Jeff Carmichael, Kristi Tatebe

2) Create and visualize adaptation options "packages"
Adaptation option "packages", or scenarios, represent potential long-term policy alternatives that a region could choose to adapt to future flooding risks. Although no particular scenario would likely be implemented in isolation from other options, the scenarios are presented and analyzed separately to aid understanding of the benefits and weaknesses of each particular approach. Based on this, it is expected that communities would create more nuanced, blended approaches for public consideration and potential implementation.

The scenarios were created by the research team based on literature review and team experience, and were revised through repeated interaction with Corporation of Delta staff and the community Working Group. Each scenario was associated with multiple local trends, drivers, and other underlying assumptions and data on topics such as population growth, energy use, and other socio-economic factors. A more detailed discussion of Scenarios can be found in section 4.1.

3) Evaluate against key indicators and implications
Indicators help to measure the differences and potential performance across scenarios. An initial, broad set was first established to represent a wide range of economic, environmental and social issues within the community, then later narrowed to a key set of indicators supportable by data and resources. The indicators include both quantitative and qualitative issues.

The final set of indicators and implications for the Delta RAC project evaluate key variables for a range of issue areas, including: cost, agriculture, habitat, infrastructure, transportation, housing, land use, quality of life, risk/vulnerability, and regional issues.

4) Assess and Recommend
The final step of the framework, assessment, considers the three previous steps in combination. Issues emerged from the adaptation scenarios that led to revisions to the list of key indicators necessary for understanding scenario implications. For example, the visualizations led to more qualitative understandings of the scenario impacts, such as how the character of the streets might change. The indicators helped the team understand more quantitative implications, such as how much land area would be affected by sea level rise. When combined, the framework components provide a structured approach for understanding and evaluating the adaptation options and developing further recommendations.

Section Two: DELTA NOW

2.1 Delta - Current Context

This section gives an overview of the current situation in Delta, including a current policy review.

The municipality of Delta is located in the southwest portion of Metro Vancouver, and is made up of three urban communities: Ladner, located in the lowlands, and Tsawwassen and North Delta, located on higher ground. The suburban residential neighbourhoods of Boundary Bay Village and Beach Grove can be found in the lowlands along Boundary Bay. The Tsawwassen and Musqueam First Nations have treatied lands in Delta. Almost half of Delta is farmland, while one-fifth is Burns Bog.

Delta's population of just over 100,000 is projected to reach approximately 112,00 residents by 2021, with most of the increase in North Delta. Over 20,000 people live in Ladner, which has over 6000 residential lots.

Delta occupies part of the alluvial deposit created by the Fraser River as it flows into Georgia Strait. About half of Delta's land area is less than 1.5 metres above mean sea level and a dike system defends these areas against high tides and storms. Almost every winter, farms are flooded from major rainfall events. In some years, there is flooding and property damage in residential areas resulting from severe weather events.
(Corporation of Delta, 2011; Delcan 2010).

Indicators

The final set of indicators for the Delta RAC project evaluate key variables for a range of environmental, economic and social issue areas that were identified with project participants, including the working group. The indicator narratives below give a picture of key issues in present day Delta that can be used to compare to the future scenarios in Section 4, on pages 35-75.

Agricultural Land

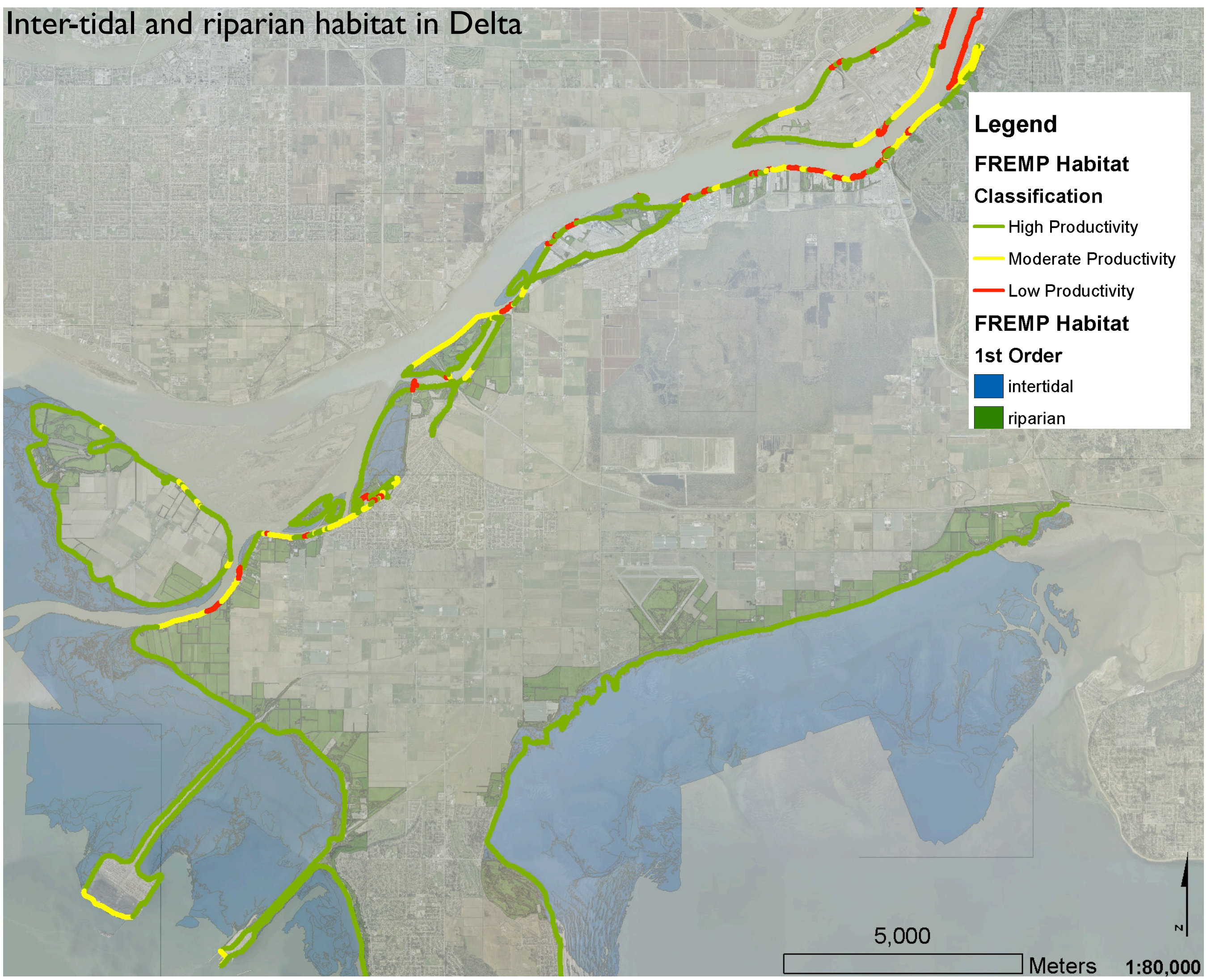
Delta currently supplies of **26%** Metro Vancouver's gross farm receipts

- **Community Character**
  Farming contributed to the early settlement of the municipality, and today, adds to the economy, identity, and to residents' quality of life.
- **Agricultural Economy and Food Security**
  The Fraser Delta is one of the most productive agricultural areas in Canada. Approximately 200 farms in Delta generate about $161,000,000 of gross revenue. Soil-based agriculture - dairy, vegetables, and fruits - continue to play a significant economic role, while greenhouses are a growing sector. There are 10,085 hectares (24,929 acres) in the Agricultural Land Reserve (ALR) in Delta. Delta currently supplies 26.1% of gross farm receipts in Metro Vancouver. Farms provide jobs and tax revenue for the community, though the exact value of these has not been calculated for this study (Zbeetnoff et al. 2011, Corporation of Delta 2011, CitySpaces 2007).

Impacts to Wildlife Habitat

- **Pacific Flyway and Fraser River Estuary**
  The Fraser River Estuary is an important stopover on the Pacific Flyway, and is used by up to 5 million migratory birds annually. This critical habitat around Boundary Bay and its uplands supports the largest wintering populations of waterfowl, shorebirds and birds of prey in Canada. The Fraser River Estuary's marshes support migrating salmon at a critical stage in their development before they migrate out to sea. Important habitat and recreational areas include: the Reiffel Bird Sanctuary, Boundary Bay, Ladner Marsh, and the Alaksen National Wildlife Area (Corporation of Delta 2011).

Figure 2-1. Intertidal and Riparian Habitat in Delta. The green lines indicate that much of Delta's shoreline habitat has been classified as highly productive. *image source: Fraser River Estuary Management Program (FREMP)*



Land Base

The top five land uses in Delta by area are:

- Agriculture 46%
- Burns Bog 17%
- Single Family Residential 11%
- Parks 10%
- Industrial 7%

Transportation

- **Local Transportation**
  Delta provides transportation routes for agricultural, commercial, commuter, recreational and other regional, and local traffic.

- **Key regional transportation linkages**
  Delta has important transportation links for people and goods movement across the region: Highways 99, 91, 17, and 10 and the South Fraser Perimeter road (under-construction) cross Delta, connecting Canada to the United States, and the Lower Mainland to Vancouver Island and the Gulf Islands via the BC Ferries Terminal. Deltaport is the largest shipping terminal and coal exporter in the Lower Mainland.

Critical Infrastructure

- **Civic**
  Civic infrastructure includes the Municipal Hall, Delta Hospital, Leisure Centres, Community Centres, Recreation Centres and 25 elementary/secondary schools and learning centres.

- **Dikes**
  Delta currently has 61 km of dikes protecting low lying areas of the community from both river and ocean flooding. The confinement of the Fraser river to its present channels began during the early part of the 20th century. Before then, distributary channel switching occurred regularly. Dikes and other channel training structures have stabilized the main channel of the delta, leaving Roberts Bank relatively sediment starved and susceptible to erosion. Currently, the Corporation of Delta is responsible for the maintenance of dikes and pumping systems to protect up to historically 1/200 year flooding event levels. The reality is that some dikes and sea-walls are below these levels.

Homes and Buildings

- **Single family neighbourhoods**
  Delta's communities are primarily composed of single family residential neighbourhoods. Single family and duplex housing make up 81.5% of the housing stock. Low rise apartments (less than 5 storeys) account for 14% of the housing stock, and the rest is in higher-rise apartment and mixed use buildings.

Culture and Heritage

Historically, farming and fishing were the foundations of Delta's economy. Delta continues to be a community characterized by agriculture, the natural environment, riverfront communities, and, now, single family neighbourhoods.

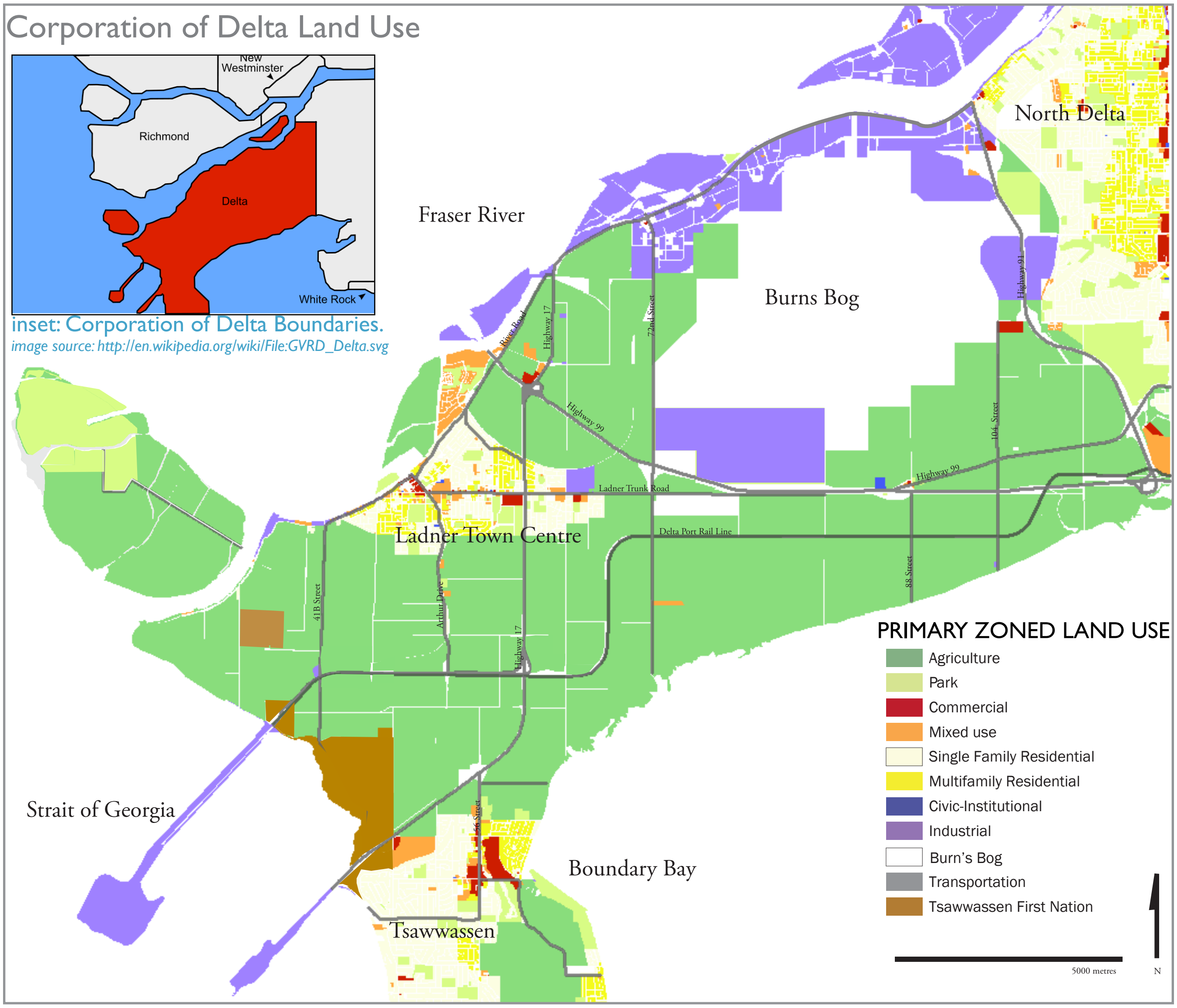
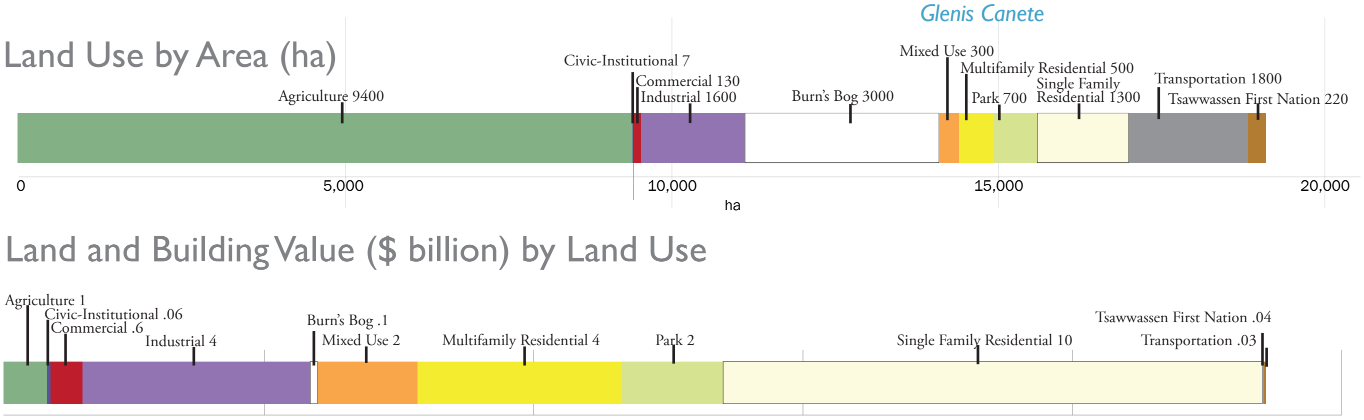


Figure 2-2: Land Uses in the Corporation of Delta (2008)
image credit: Glenis Canete

Figure 2-3: Delta Land Use and Building Value (2008). Total area (*image credit: Glenis Canete*



2.2 Policy Review

In 2003, Bill 56 (the Flood Hazard Statutes Amendment Act (the Act)) was passed by the BC Government. This amended the Local Government Act to enable local governments to designate flood hazard areas, flood construction levels and setbacks. In effect, this Act devolved responsibility for flood protection from the province to local governments. However, the Province, as represented by the Ministry of Environment, still retains regulatory authority over flood protection structures (e.g. dikes, under the Dike Maintenance Act and the Inspector of Dikes (IOD)). Therefore, the Ministry of Environment regulates local diking authorities via regional Deputy Inspectors of Dikes around the province. All new flood protection projects, as well as updates or repairs to existing structures must be approved by the IOD prior to construction. Although dikes and other structures are inspected by the Provincial Inspector of Dikes, local governments are responsible for the required maintenance, upkeep, and upgrading of these structures.

Other Provincial legislation referring to flood management include the Drainage, Ditch and Dike Act, which deals with the administrative aspects of diking including construction, taxes, enforcement, expropriation, compensation, asset transfer etc. Flood response in BC is governed by the BC Emergency Program Act. The act gives local authorities the ability to declare local states of emergency to respond to flood disasters.

The above Provincial Acts set the regulatory framework for flood protection in BC, while guidelines help local governments to fulfill their responsibilities under these Acts.

In May, 2011, the BC Ministry of Environment completed Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use to account for more recent estimates of local climate change. These guidelines include new Sea Dike Guidelines, Guidelines for Management of Coastal Flood Hazard Land Use, and a draft Policy Discussion Paper. The guidelines recommend levels of sea level rise to plan for the 50, 100 and 200 year time horizons (the sea level rise planning curve, shown on page 20).

Documents reviewed include:

Province
- 2003 Flood Hazard Statutes Amendment Act
- Local Government Act
- Dike Maintenance Act
- Drainage, Ditch and Dike Act
- BC Emergency Program Act
- BC Building Code
- 2011 Sea Dike Guidelines
- 2011 draft Policy Discussion Paper
- 2011 Guidelines for Management of Coastal Flood Hazard Land Use
- Dike and Rip Rap Design and Construction Guides
- Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment

Delta
- Climate Change Initiative
- Flood Management Plan
- Flood Management Strategy Workplan
  - Area Flood Protection Plans
  - Floodplain Bylaw
  - Flood Risk & Consequences Study
- 5-stage Flood Management Plan
- 2010 Financial Plan
- Official Community Plan (OCP)
- Local Area Plans
- Development permit area (DPA)
- Zoning Bylaw
- Building and Plumbing Bylaws
- Soil Removal and Deposit Bylaw
- Subdivision and Development Standards Bylaw

Figure 2-4 Policies Impacting Flood Management in Delta

Province of British Columbia

Legislation - Legal Acts

- Flood Hazard Statutes Ammendment Act - 2003
- BC Emergency Program Act
- BC Building Code
- Local Goverment Act
- Dike Maintenance Act
- Drainage, Ditch and Dike Act

Gives local governments authority via OCP's

Guidelines

- Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use
  - Sea Dike Guidelines *
  - Guidelines for Management of Coastal Flood Hazard Land Use *
  - Draft Policy Discussion Paper *

* updated in BC RAC

- Riprap Design and Construction Guide
- Environmental Guidelines for Vegetation Management on Flood Protection Works

Corporation of Delta

Guiding Documents

- Delta's Climate Change Initiative (2007)
- Flood Management Plan

Plans/Studies

- Flood Management Strategy Workplan (2008 Council Report)
- 5-Stage Flood Management Plan (2007 emergency response plan)
- Corporation of Delta 2010 Financial Plan

Bylaws

- Official Community Plan (2009)
  - Local Area Plans
  - Development Permit Areas
- Zoning Bylaw
- Building and Plumbing Bylaw
- Soil Removal and Deposit Bylaw
- Subdivision & Development Standards Bylaw

Related Policies & Agencies

- Fraser River Estuary Management Program (FREMP) (1985)
- ICLEI Guide and Workbook for Municipal Climate Action (2010)
- Metro Vancouver
- Tsawassen First Nation
- Department of Fisheries and Oceans
- Ministry of Transportation
- Agricultural Land Reserve

Figure 2-4 is a visual summary of the relationships between the many policies and acts impacting flood management in Delta. Provincial Acts set the regulatory framework for flood protection in BC, and guidelines help local governments to fulfill their responsibilities under these Acts. The Corporation of Delta has a high-level climate change initiative that guides action and subsequent policies and bylaws concerned with flood adaptation. These include the Official Community Plan, Local Area Plan, Development Permit Areas, and other bylaws with an influence on flood proofing. These all point to existing Provincial standards for flood protection. See page 90 for sources. *image credit: Kristi Tatebe, Sara Barron*

The Corporation of Delta has a high level climate change initiative that guides action and subsequent policies and bylaws concerned with flood adaptation. Other policies with an influence on flood proofing include the Official Community Plan, Local Area Plans, and Development Permit Areas.. These all refer to existing Provincial standards for flood protection. In addition, a flood management strategy is under development that includes the completed Flood Risk and Consequences Study, future improvements to Delta's flood protection system, and a future floodplain bylaw.

In 2010, the Delta OCP was amended to include a section on Climate Change. This section provides an overview of the impacts expected under climate change, and a summary of the Climate Change Initiative. In the Climate Change section, a Community Energy and Emissions Plan (CEEP) is mentioned under a description of future works. The CEEP is currently underway and its primary objective is to mitigate the production of community greenhouse gases. Subsequent policies that deal primarily with mitigation are the green fleet plan, building plan, infrastructure, plan, and staff education and communication plan. Other parts of the climate change section of the official community plan include participating in senior government programs and initiatives to address climate change and help plan for local-scale impacts of climate change (Tatebe et al. 2010).

Please see the individual scenarios sections on pages 40-75 for more details on current policy and implications for further policy change.

Other relevant programs:

Local Governments for Sustainability (ICLEI Canada)

The "Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation" uses a milestone approach to adaptation planning. The guide and workbook were developed by the Canadian branch of Local Governments for Sustainability (ICLEI Canada 2011). A five milestone methodology is employed to guide municipal staff through the adaptation process. The ICLEI adaptation project aims to assist local government staff with understanding regional climate change impacts, vulnerabilities, risks, and appropriate responses.

The Corporation of Delta is a participating in ICLEI's pilot program. They are currently at Milestone 2, refining impacts and considering service areas for each impact. They expect to work through the rest of Milestone 2 and reach Milestone 3 by summer 2012.

Public Infrastructure Engineering Vulnerability Committee

Engineers Canada have addressed the need for infrastructure to adapt to climate change through their efforts with the Public Infrastructure Engineering Vulnerability Committee (PIEVC). The PIEVC approach focuses on the assessment of the engineering vulnerabilities of Canadian public infrastructure to climate change impacts. Delta's engineering staff works closely with PIEVC integrating knowledge and best practices with Delta's existing flood and infrastructure practices.

Section Three: WHY ADAPT?

The United Nations' Intergovernmental Panel on Climate Change released a portion of their 4th Assessment Report in February 2007. The report concludes that "unequivocal warming of the climate system" has and will continue to occur because of human activities – primarily from the burning of fossil fuels and the resulting release of harmful greenhouse gases (GHGs). *Corporation of Delta. 2009*

3.1 History of flooding in Delta

Because of its coastal delta setting, Delta is vulnerable to flooding from both the spring freshet on the Fraser River, and from storm surge and high tide events from the Strait of Georgia (more likely in the winter months). Currently, much of Delta is protected by dikes and a drainage/pumping system. In written history, the greatest flood on record occurred in 1894 and affected large areas in southern BC. However, not much structural damage was sustained due to minimal development in the area. This was not the case in the 1948 flood when dikes failed. Ten people died, 2000 homes were lost and 16,000 people were evacuated. It is estimated that the same event today could cause an estimated $1.8 billion dollars in damage (Corporation of Delta 2009).

More recently, in 2006, Delta experienced storm-surge flooding, resulting from a high tide coinciding with a storm surge, in a seaside community protected by a seawall. Extreme weather events and sea level rise will make events such as this increasingly common in the years and decades to come. Global sea levels are currently rising at about 3mm/year (Bornhold et al. 2008) and the rate of sea level rise is increasing. Delta has initiated a sea-level monitoring program locally to obtain accurate multi-year trends.

3.2 Local Climate Change Impacts

Though climate change will have many impacts on the community of Delta (eg. effects on farm crops, growing conditions, soil salinity, availability of fresh irrigation water, etc.), the focus of this project was to understand the implications of one of these impacts - sea level rise. Sea level rise is one of the direct impacts of anthropogenic (human-induced) climate change affecting coastal communities. How much the sea will rise is the focus of much current research, and scientists continue to expand on their understanding of this complex issue (see Box 1). The rate of sea level rise depends in part on the response of communities all over the world in reducing their carbon emissions, but some significant rise in sea level is certain to continue for centuries based on previous greenhouse gas emissions alone. In addition, land in Delta is slowly subsiding due to the weight of the Fraser River soil deposits, increasing sea level rise for the community.

Sea level rise is one of two climate change impacts with regards to ocean flooding. In addition to sea level rise, there is a likely increase in the intensity and frequency of extreme events, including storms. While uncertainty exists regarding the exact rate of sea level rise, as well as the degree of change in extreme events, both will contribute to an increased risk of flooding, from the both Fraser River and especially from the ocean during winter storm surge and high tide events (Bornhold et. al 2008).

In order to evaluate some of the implications of sea level rise, the project team had to choose one or more reasonable projections to model. After reviewing future climate scenario projections, the team chose to move forward with the projection of 1.2 m of sea level rise for Delta by 2100. This was pragmatic, because this projection corresponds to the Ministry of Environment's recommended global sea level rise curve for planning and design in British Columbia, figure 3-1 (Ausenco Sandwell 2011(c)). Due to resource constraints, only one sea level rise projection was modeled. It is important to note that 1.2 metres is not the final level of sea level rise, but that 1.2 metres will be met sometime before or around 2100, and then be exceeded in the following centuries.

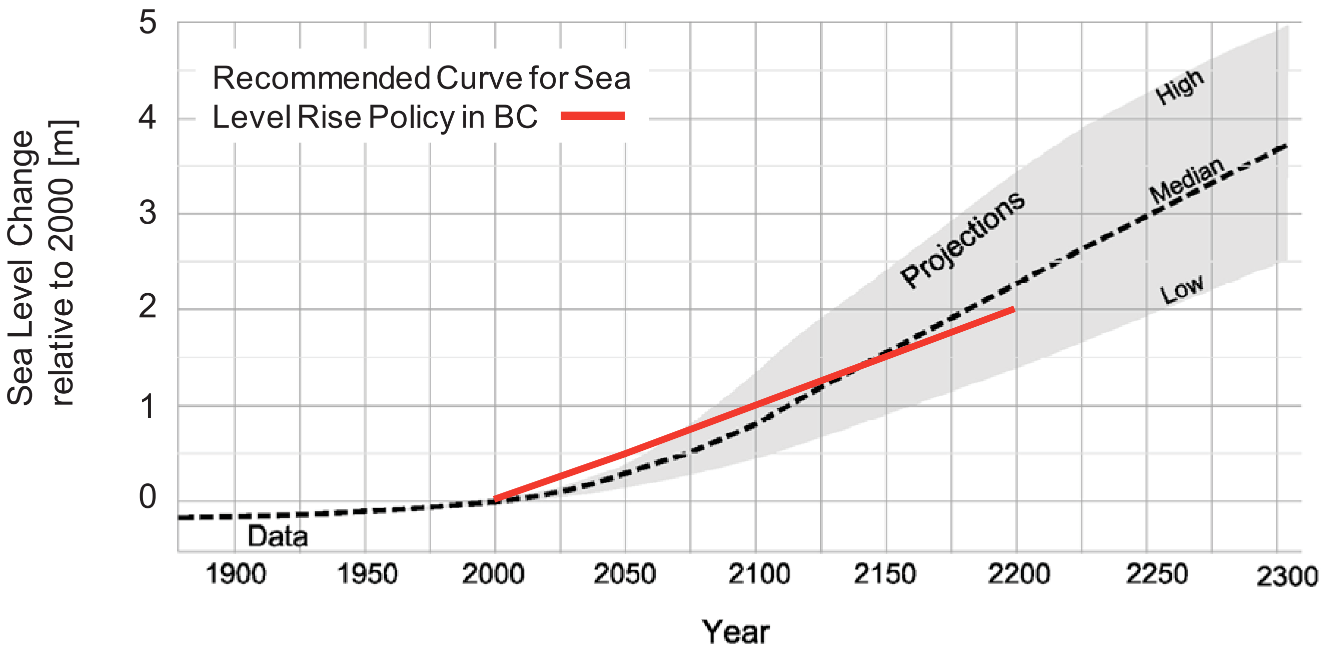


Figure 3-1: Recommended Curve for Sea Level Rise Policy in BC. This graph shows the recommended Global Sea Level Rise Curve for Planning and Design in BC, as outlined in Ausenco Sandwell. 2011(c).
image source: Ausenco Sandwell.

Box 1: Sea Level Rise Projections

Sea level rise projections continue to be modified as scientists increase their understanding of the complex mechanisms that contribute to the level of the sea relative to the land, and as measured historical and current trends are confirmed. According to the 2008 report "Projected Sea Level Changes for British Columbia in the 21st Century" (Bornhold et al. 2008) the primary mechanisms are:

1. Changes in global ocean volume due to melting of ice caps, continental ice sheets & mountain glaciers;
2. Global and regional changes in ocean volume due to thermal expansion & salinity effects on water density;
3. Regional volume changes due to dynamic atmospheric and ocean processes, such as shifting major wind systems and ocean currents; and,
4. Local changes due to vertical land motions, associated with recovery from the weight of glaciers during the last Ice Age (rebounding), subsidence (sinking) in river deltas, and tectonic processes in the earth's crustal plates.

In 2001, the IPCC Third Assessment Report (TAR) projected a global sea level rise of 20 to 70 cm by 2100. In 2007, the IPCC Fourth Assessment Report (4AR) similarly projected global sea level rise of 18 to 59 cm by 2100. These are now considered conservative (see side bar below).

According to the 2008 report "Projected Sea Level Changes for British Columbia in the 21st Century," relative sea level rise in the Fraser River Delta could be from 0.35 – 1.20 metres in 2100 (Bornhold et. al, 2008).

A similar 2008 report from the state of Washington, "Sea Level Rise in the Coastal Waters of Washington State," projects 0.16 – 1.28 metres of sea level rise for the Puget Sound in 2100 (Mote et al. 2008).

A report for New York city used a "rapid ice melt scenario" (Horton et al. 2010) based on acceleration of recent rates of ice melt in the Greenland and West Antarctic ice sheets. This scenario projected up to 1.4 metres of sea level rise for New York by the 2080s.

Comparing today's climate warming to data from the earth's paleoclimate history, Hansen argues that seas could rise up to 5 metres by the end of this century (Hansen and Sato 2011).

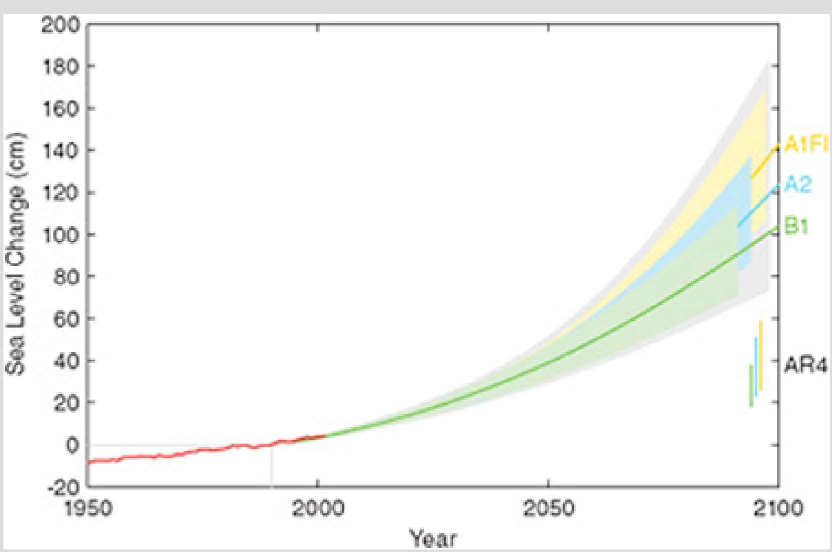


Figure 3-2: Projection of sea level rise from 1990 to 2100, based on IPCC temperature projections for three different GHG emissions scenarios (pastel areas, labeled on right). The gray area represents additional uncertainty in the projections due to uncertainty in the fit between temperature rise and sea level rise. All of these projections are considerably higher than the sea level rise estimates for 2100 provided in IPCC AR4 (pastel vertical bars), which did not account for potential changes in ice sheet dynamics and are considered conservative. The red lines shows the observations of annual global sea level rise over the past half century, relative to 1990.
image source: Vermeer and Rahmstorf 2009.

3.3 Understanding Sea Level Rise Risk in Delta

As sea levels increase, what are the possible impacts on Delta? This project used a common definition of risk for adaptation planning, as well as a simplified risk matrix, to assess the risk of sea level rise to Delta, and to illustrate a framework for possible response options.

Risk is defined as a function of the probability of an impact occurring, and the vulnerability of a community to that impact.

Risk = probability x vulnerability

The probability of sea level rise to 1.2 m is assumed to be 100% over the next 100 years or so: the uncertainty is not in the 1.2 m increase itself, which will be met and then exceeded, but in the exact timing (as shown in Box 1). The specific probability of increased intensity and frequency of storm events is still uncertain. Risk was therefore assessed based partly on the probability of dike and seawall infrastructure failure, given 1.2 meters of sea level rise, addressing the question: what is the generalized probability of infrastructure failure with 1.2 m of sea level rise?

The assessment was not a detailed Quantitative Risk Assessment (QRA, see below), but instead was based on the assumption that increased water levels would overtop the current dike and seawall infrastructure, and that overtopping eventually leads to a breach, and thus to an inundation event. The Delta-RAC project therefore assumed that multiple and cumulative flood/inundation events could occur as a result of sea level rise, if no infrastructure-based (i.e. sea dike and sea wall) adaptive action is taken. This probability of infrastructure failure under 1.2m of sea level rise is illustrated diagrammatically and visually in Figures 3-3 and 3-4 on the following page.

For Delta,
Inundation RISK =
Probability of Infrastructure Failure x Community Vulnerability

Given that sea level rise probability is 100%, and that current infrastructure is insufficient to meet the projected higher water levels, sea level rise risk to Delta can thus be defined as a function of the probability of infrastructure failure, and the community's vulnerability.

Community vulnerability includes sensitivity and adaptive capacity. Sensitivity refers to how damaging an impact might be. For example, agricultural land is likely more sensitive to saltwater inundation than habitat or park areas might be. Adaptive capacity refers to a community's ability to adapt to potential impacts, as well as cope with specific events, based on its social, economic, and institutional resources. A community's responsive action - whether to raise buildings to new flood construction levels, raise roads, improve emergency preparedness, or other measures - will reduce the vulnerability of the community.

An alternate way to assess risk is to do a Quantitative Risk Assessment (QRA), which evaluates probability and consequences of a single flood event. A QRA assesses all the factors related to probability of infrastructure failure, and then also assesses the community vulnerability or consequences of a single flood event. The Delta-RAC project does not include a QRA as such assessments would need to be undertaken for each separate dike reach, which was beyond the scope of this project. Instead, the project used a generalized risk matrix, shown on pages 24 and 25.

Figure 3-3. Ladner Dike, current high water levels. View of the Ladner dike along River Road and dike cross-section with current high water levels. The current dike infrastructure is built to handle current high water levels without failure. The probability of dike failure is very low. (All water levels are relative to mean sea level)

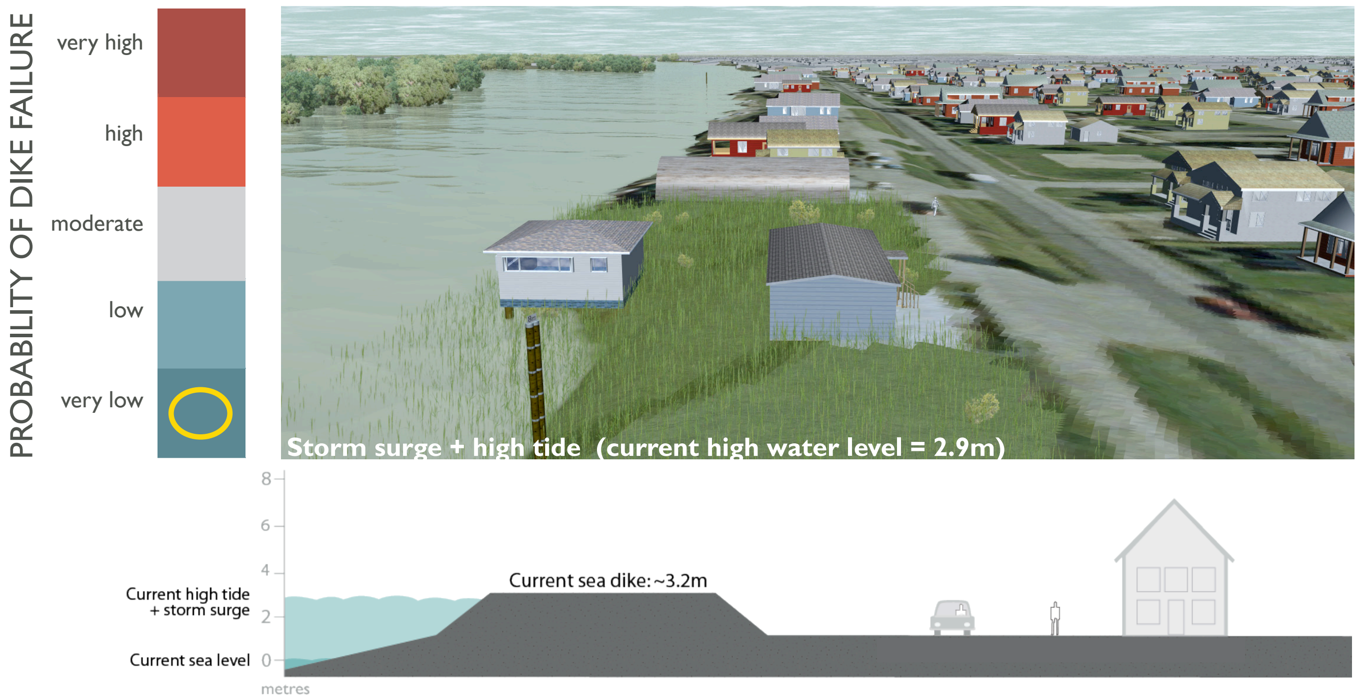
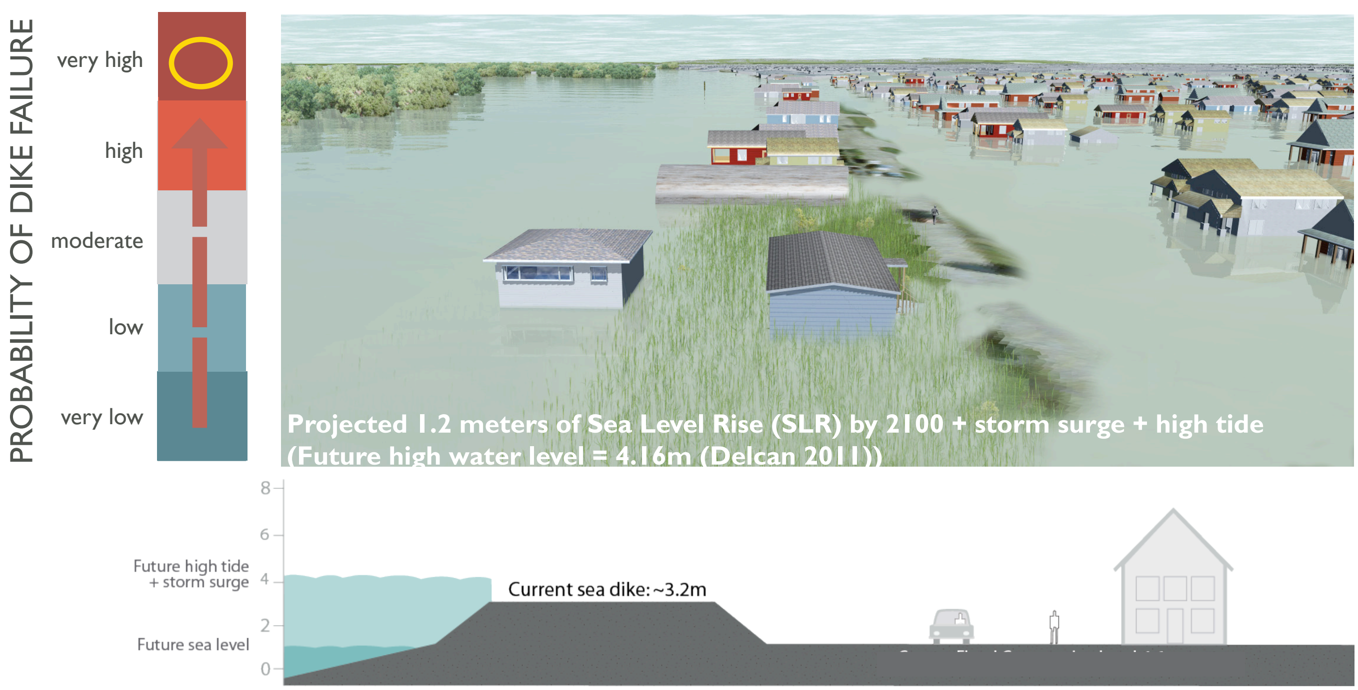


Figure 3-4. Ladner Dike, 1.2 metres sea level rise. View of the Ladner dike along River Road and dike cross-section with future high water levels, including 1.2m sea level rise. High water levels exceed the current dike heights, and therefore, if no adaptive action is taken, sea level rise increases the probability of dike and seawall failure, greatly increasing the risk of an inundation event.



Note, this is not an image of inundation modeling, rather, it shows the high water levels compared to the dike and Ladner with sea level rise, a high tide, and a storm surge. For dike breach and inundation modeling, see Figures 3-22 and 3-23 on page 34.

Risk Matrix

Figure 3-5: Risk Matrix. Current inundation risk in Delta depends on the particular height and construction of dike and seawall sections, as well as vulnerability (eg. flood construction levels) behind the dike and is therefore somewhere within the dashed line.

Each sub-area within Delta (such as Westham Island, Annacis Island, Ladner) will therefore have a specific and unique inundation risk.

Figure 3-6: Sea level rise increases the probability of infrastructure failure. Note that the overall risk to the community depends also on community vulnerability.

As shown in the Figures on the previous page, with no adaptive action, sea level rise increases the probability of infrastructure failure. However, to understand the possible risk to the community, community vulnerability must also be considered. The interaction of probability and vulnerability can illustrated using a Risk Matrix.

The Delta-RAC project used an overall risk matrix for the entire low-lying areas of Delta to illustrate the concepts of infrastructure failure and community vulnerability with sea level rise. In the future, each neighbourhood or sub-area of the community would require its own, more specific, risk evaluation and matrix, and its own unique response options.

While the probability of infrastructure failure is due to many factors, including dike construction, dike height, the intensity of storm events, overtopping, and sea level rise, the risk matrix coarsely assesses that sea level rise increases the probability of dike failure, given no adaptive action.

Similarly, the vulnerability of a community is related to the consequences of an inundation event if one is to occur (regardless of the probability of inundation occurring). Community vulnerability can therefore be assessed based on Flood Construction Levels, emergency preparedness, and other measures.

Communities that improve their adaptive capacity, or their ability to withstand or cope with an inundation event (or series of events) would reduce their overall risk to inundation. A community may have a low probability of inundation (due to being behind a dike now), yet high vulnerability to inundation (due to enormous potential damages if an inundation event does occur). Conversely, a different community may have a high probability of inundation (with minimal or sub-standard dike protection, or with sea level rise), yet low vulnerability (due to, for example, being built at an elevated Flood Construction Level). Both of these communities would have similar overall risk (high) to coastal inundation, but for different reasons.

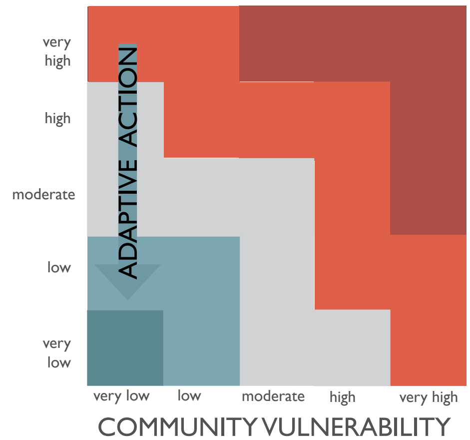
As sea level rise increases the probability of infrastructure failure, the resulting risk to the community depends on its vulnerability - a community with existing low vulnerability will experience a lower overall sea level rise risk than a community with high current vulnerability.

Adaptation responses

The risk matrix points to two different approaches to adaptation that the Corporation of Delta could choose to use in its pro-active planning:

1. Improve protective infrastructure such as dikes and seawalls. This response option reduces the probability of infrastructure failure within the next approximately 100 years, given assumed sea level rise to 1.2 meters by 2100.

Figure 3-7: Sea Level Rise ADAPTIVE ACTION #1: improve protective **infrastructure** to reduce the probability of failure, protecting the community and reducing overall inundation risk.



2. Reduce community consequences by reducing sensitivity (eg. planting saline tolerant crops) and increasing adaptive capacity (eg. adopting a flood response program, and/or raising flood construction levels and road elevations). This response option reduces the impacts on the community, if the infrastructure were to fail and a dike breach were to occur.

Figure 3-8: Sea Level Rise ADAPTIVE ACTION #2: Increase the community's **adaptive capacity** to reduce the consequences of a flood event, reducing overall inundation risk.

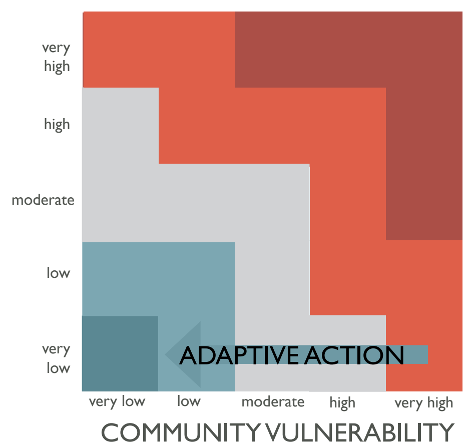


Figure 3-9: Existing dike/seawall conditions with overtopping
image credit: Glenis Canete, adapted from KWL 2007

Possible Inundation Extent

"Applying a higher water level due to climate change without increasing the crest [height] of the dikes would result in overtopping the dikes all around Delta" (Delcan 2011: 5).

The set of images on these pages come from the 2007 Kerr Woods Leidal Flood Management Strategy report (KWL 2007). The modeling assumed peak water heights of 3.5 meters above mean sea level, which represents a winter storm surge event (with an unspecified return period), as well as wind and waves, and only 10cm of sea level rise (KWL 2007).

Under these conditions, dike overtopping could occur in some areas already, as shown by figure 3-9. It is assumed that considerable and sustained dike overtopping would lead to a breach (Delcan 2011). The probability of dike and seawall failure will increase if sea level rises occur as projected and no adaptive action is taken.

Composite Vulnerability Map (figure 3-10)

Figure 3-10 is a composite map of areas vulnerable to inundation in Delta. The mapped 'Adaptation Required' areas (grey) correspond reasonably well to the new Ministry of Environment proposed Sea Level Rise Planning Areas, which for Delta is delineated as all lands below 5.6m (red and brown dashed line). (For a full discussion of Sea Level Rise Planning Areas, see Ausenco Sandwell 2011 (b), page 9 and Flanders et al 2012).

Figure 3-11 is a series of more detailed maps showing the extent of inundation based on specific dike breach simulations for six "dike reaches" (sections of dike) across Delta, with only 10 cm of sea level rise. If there were to be a dike breach, these areas could be inundated, although it is extremely unlikely the entire area would flood at the same time. Actual inundation damages will depend on the extent and depth of individual flood events, and how well prepared the community is, including adequate Flood Construction Levels, emergency preparedness, neighbourhood capacity, etc.

Assumptions used in Figure 3-11: (Delcan 2010: 37; KWL 2007: 4-10) include:

- a breach occurs about 25 hours before the peak water level is reached (high tide + storm surge
- over one day, a 300m breach develops
- the inflow volume of water is applied at a constant rate over 24 hours

With sea level rise, and without adaptive action, there could be cumulative inundation events: over time, by 2100, parts of this area could flood multiple times.

Figure 3-10: The Composite Vulnerability Map combines modeling for separate dike breach events. The areas in grey are vulnerable to inundation if a dike breach were to occur. The large white area is Burns Bog, which is slightly higher than surrounding areas and would likely not require adaptation action. *image credit: Glenis Canete, KWL 2007*

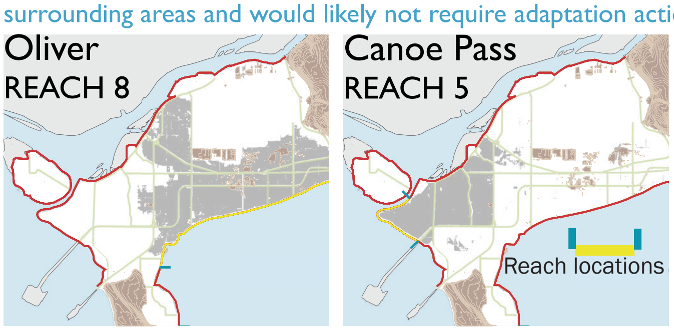
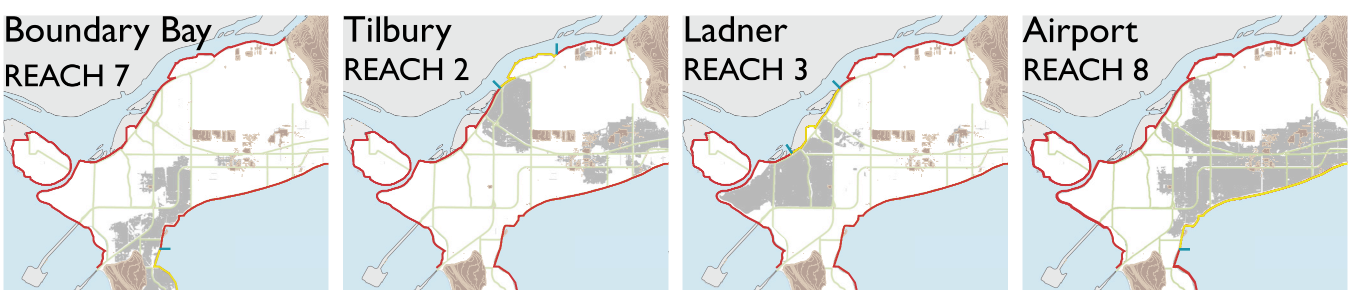


Figure 3-11: Series of Modeled Dike Breach Events. Each small map shows the results for potential inundation in a separate, modeled dike breach event (KWL 2007). Grey areas were inundated in the modeled dike breach. Red lines indicate dikes and Yellow lines indicate dike reaches. The 2007 modeling shown here has since been partially updated to include 0.3m, 0.6m, and 1.2m sea level rise (Delcan 2010, 2011). Thus, the modeling shown here may underestimate events. *image credit: Glenis Canete adapted from KWL 2007*



The next two sections assesses vulnerability and potential impacts of sea level rise for the Corporation of Delta. The assessment is divided into two sections.:

Section 3.4: Vulnerability Delta-wide by issue area using broad indicators

Section 3.5: Vulnerability in 2 specific case study areas using values & damages.

3.4 Vulnerability by issue area

Indicators for baseline/current conditions are listed below, grouped into environmental, social, and economic clusters. Impacts are estimated for all of the Corporation of Delta in each case. Indicators represent sectors that are vulnerable to climate change impacts if no adaptation action is taken. This list is not comprehensive, but covers key implications raised through the visioning process. See the Technical Report (Flanders et al. 2012) for details on how indicators were developed and assessed.

53% of Delta's total land area could be vulnerable to inundation

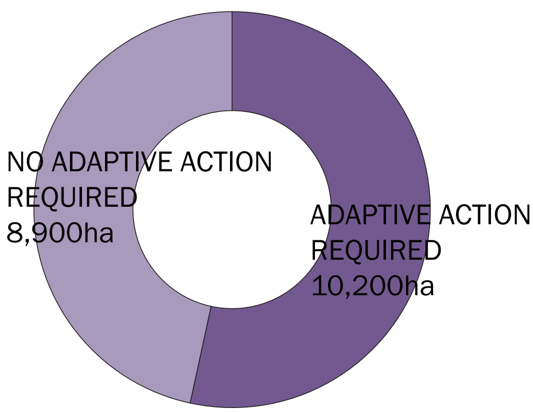


Figure 3-12: Vulnerable Land Area in Delta. Just over half of Delta's land base is directly vulnerable to climate change induced sea level rise. (This percentage would be larger if Burns Bog were included as vulnerable).
image credit: Glenis Canete

25% of Delta's total land value is within the Sea Level Rise Planning Area

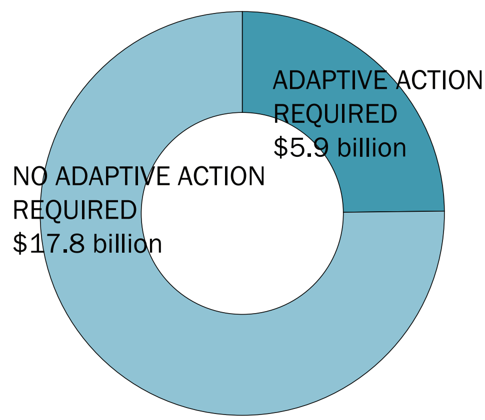


Figure 3-14: Land Value of Vulnerable Area in Delta. A quarter of Delta's total land value is directly vulnerable to climate change induced sea level rise. (Farmland has lower land value than built-up areas). *image credit: Glenis Canete*

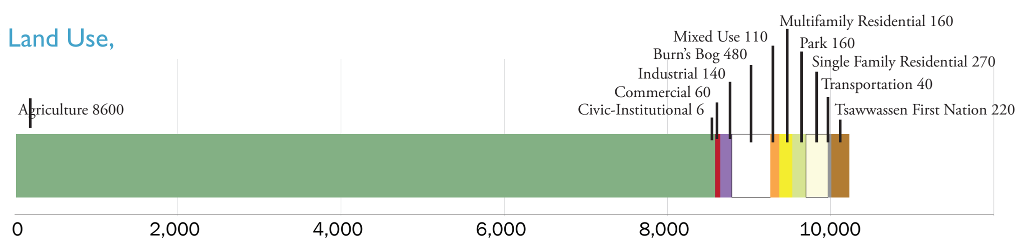


Figure 3-13: Vulnerable Area by Land Use, hectares.
image credit: Glenis Canete

Environmental Indicators	
Indicator	Potential Impacts due to inundation
Agricultural Land	90% of Delta's farm land lies within the Sea Level Rise planning area. This totals 8600 ha.*
Impacts to Wildlife Habitat	115 km of highly productive intertidal foreshore habitat 2,200 ha of riparian habitat 9,500 ha of intertidal habitat All of Burns Bog
Land Base	53% vulnerable

Social Indicators	
Indicator	Potential Impacts due to inundation
Transportation - Roads	380 km of roads are within the Sea Level Rise planning area.
Infrastructure - Dikes & seawalls	55 km of dikes and seawalls
Infrastructure - Facilities	20 critical facilities** vulnerable, including 9 schools
Impact to Buildings	8663 vulnerable
Culture/Heritage Impacts	12 culturally and historically significant features***

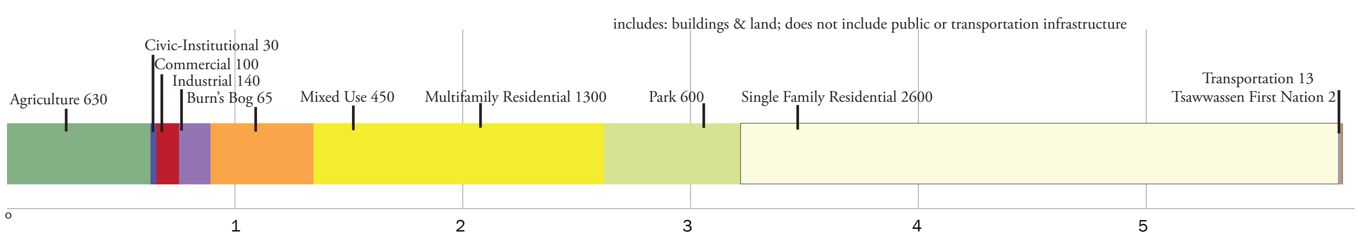
Economic Indicators	
Indicator	Potential Impacts due to inundation
Land & Building Value	$5.85 billion dollars at risk (2008 land value)

* "Continued or constant flooding could render the soil saline to the extent that most crop plants could not thrive and possibly survive. Our crop plants are not adapted, for the most part, to soils high in salts. One event would probably not render the soil uncultivatable, if drained away quickly and then the salts leached out with rain or irrigation. It may be that the soils are already high in salts (poor drainage and prone to salt accumulation anyway) and one more event would push them over the edge."
(Mullinix 2011)

** The Municipal Hall, Delta's only Hospital, Ladner Leisure Centre, Ladner Community Centre, Schools, Firehalls, and Recreation Centres lie within the Sea Level Rise Planning area.

*** This includes: St. Stephen's Church, Butler's Corner, East Delta Oyster Plant, Early First Nation Settlement, Tsawwassen First Nation Reserve, Port Guichon, Homer Stephens Park, Westham Island Bridge, Ladner Chinatown, Delta Hotel - Ladner Landing, W.H. Ladner House Site, Kirkland House.

Figure 3-15: Vulnerable Area by Land Value. ($ billion) *image credit: Glenis Canete*



3.5 Vulnerability by case study area

In order to better understand the potential impacts of sea level rise in Delta, the project team chose two case study areas to examine in greater detail. Delcan-DHV was commissioned to prepare inundation maps to quantify the effects of two sea level rise water levels in two dike breach locations.

Delcan-DHV measured flood extent and inundation depth for:

1) Base Case: the provincial standard 1/200 year storm event
2) 1.2 m Sea Level Rise: the provincial standard 1/200 year storm event plus a 1.2 m allowance for sea level rise.

As shown in table 3, peak water levels in the 2100 sea level rise scenario were 4.16 metres. The peak water level used to produce the visualizations in this report is 4.16 metres (.
* Note that a 200 year return period is the same as a 1/200 year storm.

		Peak Water Level (m)	
Location of Dike Breach	return period	Base case	SLR (+1.2m)
Ladner	200	2.96	4.16
Boundary Bay Village	200	2.96	4.16

Table 1: Sea Level Rise Scenarios used by Delcan DHV. *source: Delcan DHV 2011*

Two assumed dike breach locations were chosen: one within Ladner, and the other near Boundary Bay, corresponding to earlier breach modeling studies. The communities of Ladner and Boundary Bay/Beach Grove were chosen for the visualizations.

The case studies illustrate that each neighbourhood within Delta will have different vulnerabilities, based on varying risk factors and other conditions, for example current protective infrastructure, local opportunities, and constraints. Other factors to consider include: citizen/resident perspectives, and quality of life issues such as views. These are discussed in more broadly in the Section 3.4.

Ladner Case Study

The community of Ladner was selected as a case study for a number of reasons. It contains much of Delta's civic infrastructure, such as Delta's only hospital, the municipal hall, a leisure centre, recreation centres, firehalls, and schools. The particular breach location within Ladner was chosen because this area also contains houses outside of the dikes and River road running along the edge of dike reach.

The flood events shown in the visualizations would only occur occasionally - most of the time the landscape would not be inundated. Inundation would become more frequent towards the end of the century as sea levels rise.

Figure 3-16: Current conditions, Ladner.
Current sea level with high tide and storm surge. *image credit: David Flanders*

Figure 3-17: Current conditions, Ladner, modeled breach event
Current sea level with high tide and storm surge. *image credit: David Flanders*

NOTE: Current conditions = current dike/seawall heights and sea levels

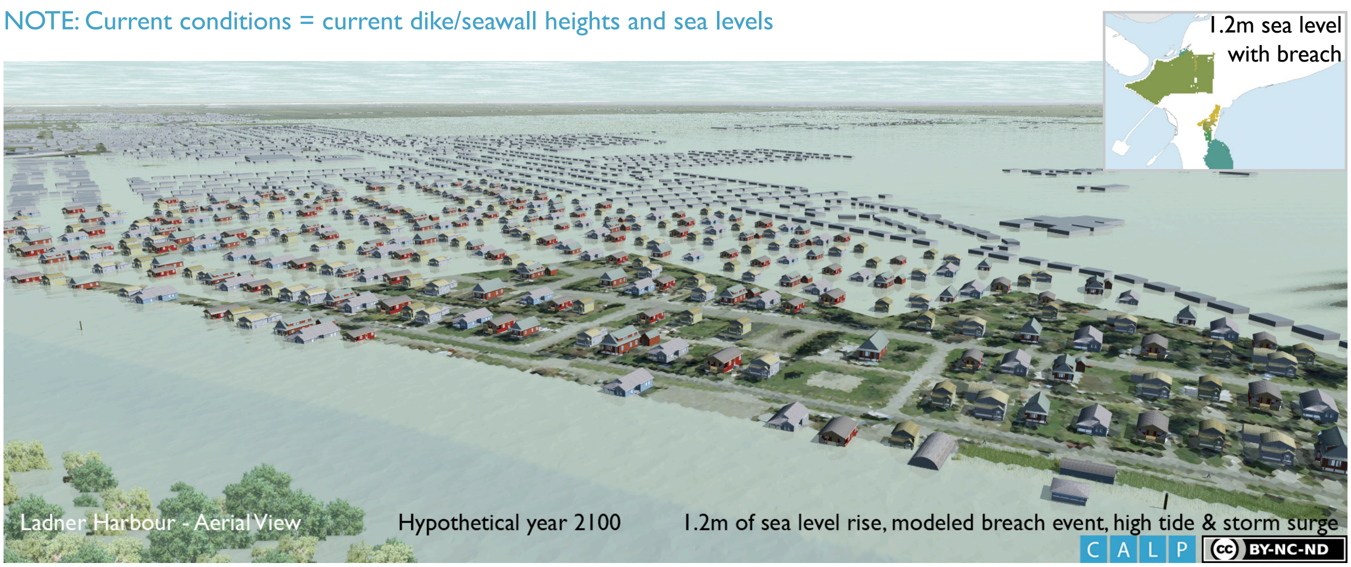


Figure 3-18: Future Conditions, Ladner, modeled dike breach event with 1.2m sea level rise, high tide, and storm surge. Dikes have been raised slightly in the modeling, see page 34-35 for more details. *image credit: David Flanders*

Boundary Bay / Beach Grove Case Study

The community of Beach Grove was chosen because it is protected by a seawall rather than a dike, it faces directly out to the Strait of Georgia, and because it is a more rural/suburban form of housing than Ladner Centre. It has nearby agricultural and park land that could be affected and can be included in visualization. The community is proud of the ocean views, which will likely be impacted by raised protection structures. Finally, the area experienced a flooding event in 2006, putting the issues of flooding from sea waters in the forefront of citizen's minds. The modeled breach location is located in Boundary Bay regional park, adjacent to Beach Grove, to match prior breach models.

Visualizations

The visualizations shown on pages 31 and 33 use the Delcan-DHV dike breach models described in detail in Box 2. The Delcan hydrological models used relatively low resolution digital terrain elevations. This resolution accounts for the geometric boundaries of the flood extent (Figure 3-20 shows this clearly). These are only an approximation of an expected flood extent: in reality the flood boundaries would be much more complex and follow more subtle natural elevation changes. See the Technical Report (Flanders et al. 2012) for more details.

Figure 3-19: Current conditions, Beach Grove
current sea level with high tide and storm surge. *image credit: David Flanders*

Figure 3-20: Current conditions - Beach Grove, modeled breach event, current sea level with high tide and storm surge, The view was shifted LEFT in this visualization because the particular dike breach modeled did not show inundation in Beach Grove. *image credit: David Flanders*

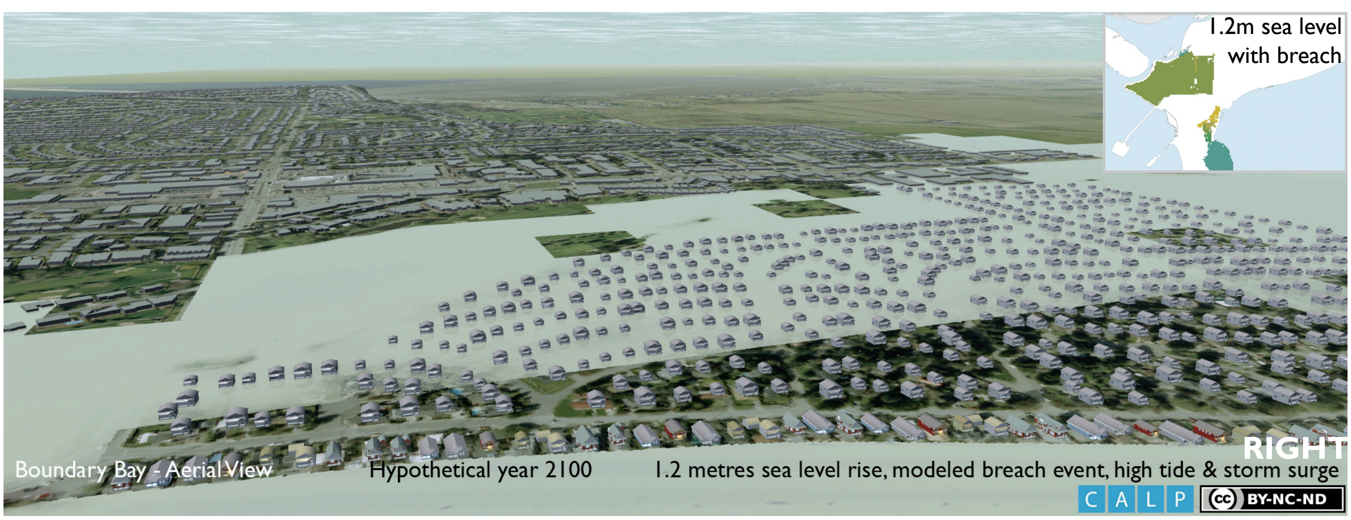


Figure 3-21: Future Conditions, Beach Grove, modeled dike breach event. with 1.2m sea level rise, high tide, and storm surge. *image credit: David Flanders*

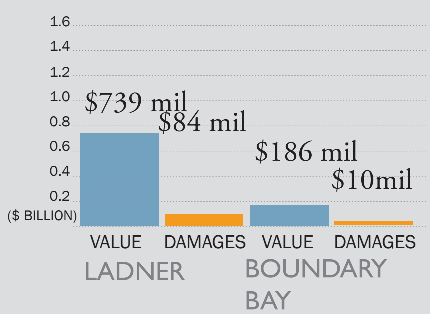
Box 2: The Case Study Damage report: Community Vulnerability

Updated Sea Level Rise Modeling

This box presents selected results of land values and potential damages in two case study locations. The modeling assumes a minimal increase in dike heights.

Figure 3-22: **Current sea level with 2 dike breach events**
image credit: Glenis Canete, Delcan DHV 2011

Value and Damages for the Inundated Areas (Land and Buildings, 2008 real dollar estimated projections- see Footnote 2 opposite)



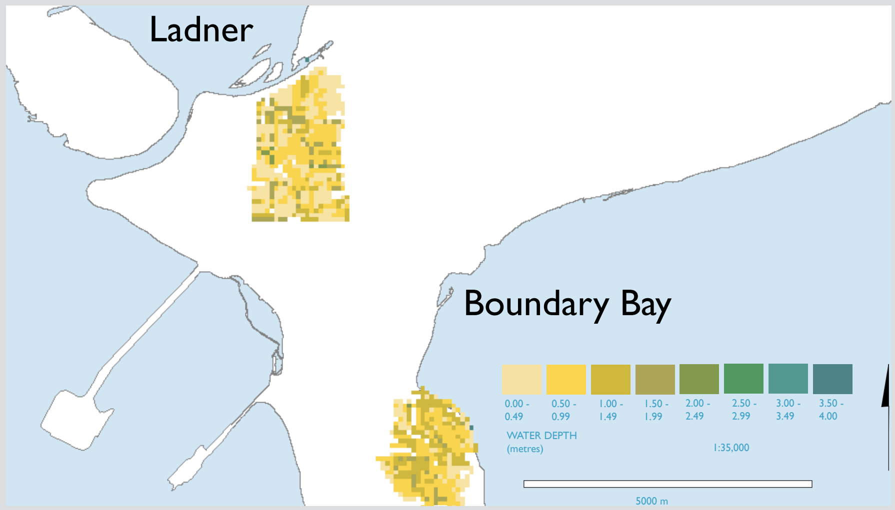
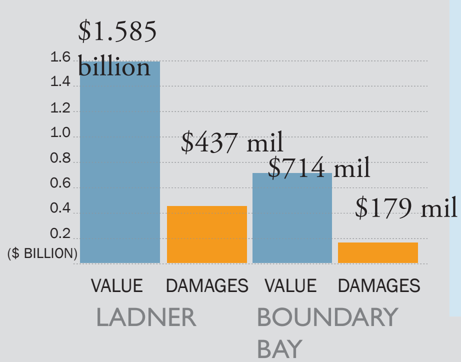
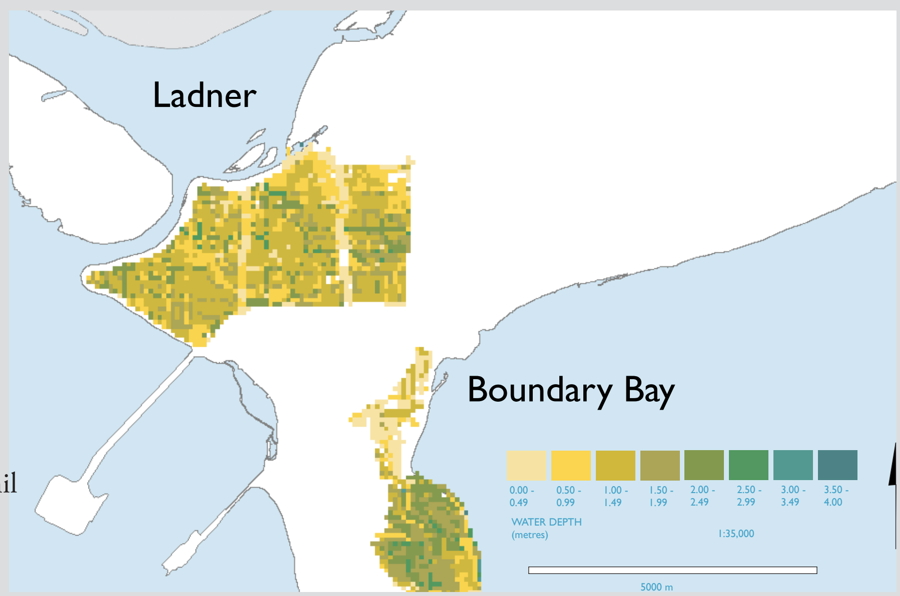


Figure 3-23: **Future 1.2M sea level rise with 2 dike breach events**
image credit: Glenis Canete, Delcan DHV 2011

Value and Damages for the Inundated Areas (Land and Buildings, 2008 real dollar estimated projections - see Footnote 2 opposite)





"Applying a higher water level due to climate change without increasing the crest [height] of the dikes would result in overtopping the dikes all around Delta" (Delcan 2011: 5). Therefore, the modeling assumed that the dikes had been raised.

These flooding maps show the modeled extent and depth of inundation due to assumed dike breach events in Ladner (Chisolm Street) and Boundary Bay (the Regional Park). Each scenario assumes a combined high tide and storm event[1].

Dike Breach Modeling Assumptions

The current sea level model (figure 3-22) assumes current sea level, a storm surge, and high tide, with a peak water level of 2.96m[1]. The assumed dike [height, or] crest elevation of 3.56m, including 0.6m of freeboard, is typical of the current infrastructure in Ladner. Some of the Boundary Bay seawalls are currently substandard, but these lower heights were not modeled, i.e. projected flood areas likely underestimate the extent of flooding due to substandard walls.

The 1.2 metre sea level rise model (figure 3-23) assumes 1.2 m sea level rise, a storm surge, and high tide, with a peak water level of 4.16m[1]. The assumed dike [height, or] crest elevation was 4.76 m, because applying a higher water level without increasing the dikes to some extent would have resulted in overtopping all around Delta.

"The assumption is that the dike fails when the water level is at its peak or when the water level exceeds the crest [height] level of the dike at the breach location" (Delcan 2011: 5).

The CALP team calculated the affected values and damage estimates for a dike breach in the case study areas in 2100, with :

"Value" for the inundated areas is the current value of all the land and buildings that would be directly flooded. Land and Buildings Values were calculated based on the flooding extent and 2008 land use values[2].

"Damages" is a percentage of the current value, representing the potential actual costs of the flooding. Damages increase with increased inundation depths.

Damages were calculated based on the flooding extent, land use, and damage functions (how much damage the inundation will cause, based on water depth and different land uses)[3]. Damage functions established for buildings were set to represent Residential and Commercial buildings (not industrial buildings)

Transportation damages, underground infrastructure (such as sewers), and indirect damages, (such as loss of production and transportation disruptions) were not assessed, which is why CALP's damage numbers are lower than those calculated by Delcan.

Source: Delcan 2011.

Footnotes

1. Modeling Method (Delcan 2011): the SOBEK computer model based on topographic and flood protection infrastructure data also includes storm surge events, the tidal cycle and sea level rise. A 1/200 year storm event was assumed, with a peak flood water level of 1.1m lasting 4 hours; the total storm event is assumed to be 35 hours.

Note that the modeling may assume better performance of the existing internal flood cell boundaries (roads, rail lines) than might actually occur - some floodwater, even under current conditions, could move into adjacent areas (see Delcan 2010 for discussion of the internal or secondary diking system).

2. The value numbers include the value of the raw land, as well as structures and improvements on the property, and were calculated based on the area of inundation by land use, multiplied by the BC Assessment 2008 values for "unimproved" [raw land] and "improved" land. The Boundary Bay numbers include data for both Boundary Bay Village and Beach Grove.

3. Assumed damage functions:

a. Land and Buildings:

i. For the current conditions, with depths generally ranging from 0.5 - 1m, a damage factor of 0.15 was used

ii. For the 1.2 m sea level rise model, with depths generally between 1-2 m in residential areas, a damage factor of 0.25 was used for buildings

iii. These depth-based damage functions were assigned based on Delcan's Damage Function for low-rise dwellings: at 1m depth, the damage factor is 0.5; at 2m, the damage factor is 0.8, and at 3m it is .92 (Delcan 2010: 14).

b. Agricultural raw land damage was assumed to be high, at 0.8, given the probable long-lasting damage caused by seawater inundation.

c. All other raw land damage was assumed to be 0.05, as the flooding lasts only from several hours to several days.

SECTION 4: WHAT CAN DELTA DO?

4.1 Scenarios

Scenarios provide a framework to address holistic, future climate change possibilities and current and future response options. The objective is to describe complex and uncertain alternative future pathways as simply as possible in "plausible storylines" or scenario narratives, tied to quantitative modeling where possible.

Scenarios provide a structured way to ask "what if" questions that explore risks, planning options, and possible outcomes while accounting for uncertainty, surprise, human choices, cultural values and complexity. In order to provide a range of possible futures, scenarios are based on modeled quantitative data (such as population projections) or quantitative assumptions, as well as qualitative data including cultural values and norms. They are thus multi-dimensional, and combine diverse elements including socio-economics and the environment.

Scenarios are schematic, aiming not for precision and detail but for essential elements and plotlines that articulate large-scale patterns. Therefore, scenarios do not express probability, but rather are used to book-end a range of possible futures. They often include extreme cases, eg. from the "do-nothing" climate change scenario with very severe impacts, to the "do everything" scenario with both adaptation and extensive mitigation associated with stabilizing the future climate. The "Do Nothing" scenario is included principally to aid understanding of the need to take action of some kind, through seeing the consequences of not taking action. "Do Nothing" is not expected to be a viable option for consideration by the Corporation of Delta. The extremes of alternative scenarios are intentionally distinct from one another so that the long-term community benefits and weaknesses of each approach can be clearly understood. *It is expected that actual policy considered for adoption by the Corporation of Delta would likely include elements from several of these scenarios.*

For example, the vulnerabilities described on p. 22 - 29 suggest the potential consequences of a "do-nothing" scenario in Delta.

Why do we use Scenarios?

Scenarios provide a mechanism to consider comprehensive future states in a coherent and easy-to-grasp manner.

By providing a framework within which communities can explore "what if" questions, scenarios can help communities:

- to explore a range of options
- to understand trade-off choices
- to understand long-term consequences
- to help make decisions at a smaller case-study scale, as well as understand the larger framing political issues.

Figure 4-1: CALP's "4 Worlds" provide one possible framework based on the IPCC emissions and other global scenarios.

World 1 (Do Nothing) has ongoing high emissions with high impacts;

World 2 (Adapt to Risk) is adaptation only;

World 3 (Efficient Development) is slow mitigation - not enough to stabilize climate - with adaptation;

World 4 (Deep Sustainability) has extensive and rapid mitigation that stabilizes climate, as well as minor adaptation.

The Delta-RAC project is exploring multiple World 2 adaptive Scenarios:

Hold the Line
Reinforce & Reclaim
Build Up
Managed Retreat

image credit: CALP

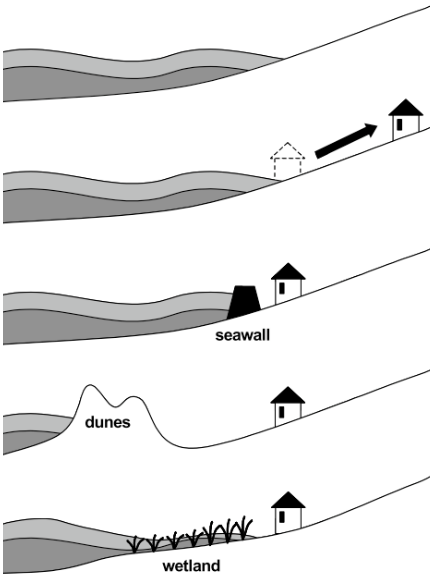


Figure 4-2: Similar Scenarios Used by Other Agencies: example scenarios used by the European Commission in their report "Proactive strategies for shoreline management"

- **No intervention**
- **Managed re-alignment**
- **Hold the line**
- **Advance the line**
- **Limited intervention**

image source: European Commission 2009

How were the Delta Scenarios developed?

The Delta-RAC scenarios were developed using the evaluation framework (see pages 10 & 11), workshops with staff, internal project discussions, and a literature review (for example, see figure 4-2). Using an iterative process, the project team created and refined scenarios for consideration and selected criteria that were relevant to Delta communities and for which analysis support was possible.

The diagram below describes the broad concepts defining the scenarios. Characteristics of the scenarios include the extent to which they maintain, lose (defense), or expand (offense) the lands under some level of protection within the sea level rise planning area. The strategies can also be characterized by the extent to which they use "armouring" engineering solutions to keep water out, or "soft" approaches that allow for some ocean encroachment and opportunities for unique community forms.

Each scenario emphasizes distinctive objectives that will be detailed in the following pages.

It is important to remember that these are initial, exploratory scenarios and not plans or proposals. They are intended as "dialogue starters" for policy-makers, practitioners, agencies, and the public. Other scenarios or blends of these scenarios may be relevant to the community, and would need to be considered and developed in greater detail as part of any official planning process. The community has decades in which to implement plans, make decisions, and implement them, but this does not mean early planning can or shall be delayed.

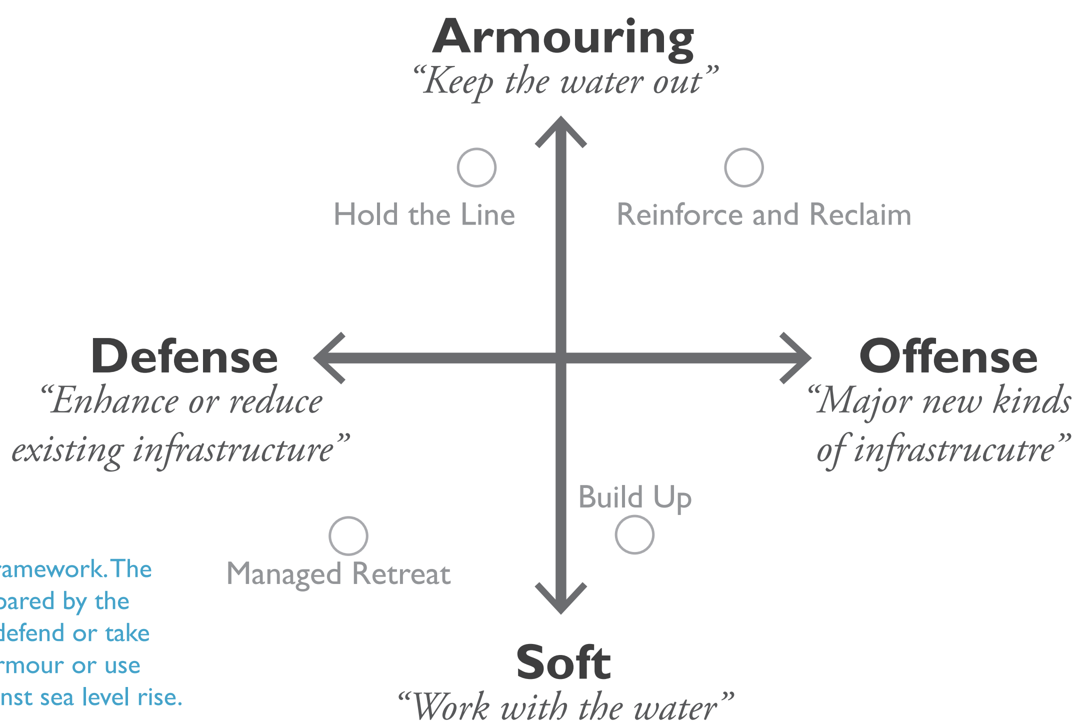


Figure 4-3: Scenario Framework. The Scenarios can be compared by the extent to which they defend or take offensive action, and armour or use softer approaches against sea level rise.
image credit: CALP

The Four Adaptation Scenarios

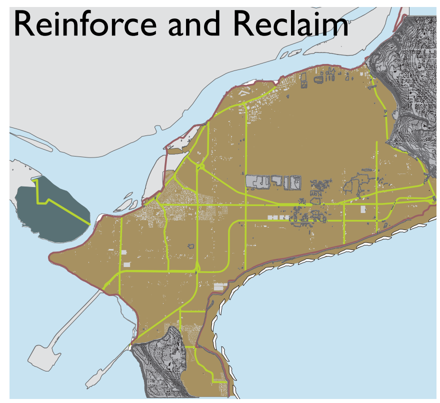
The Scenarios summarized here show hypothetical conditions assumed to be in place by 2100. The date by which such policy would need to be completed has not been included as part of this project.

1. Hold the Line *- pages 40 - 51*

This ARMOURING scenario maintains, strengthens, and raises most of the existing 55 km of Delta's dike and seawall infrastructure in order to protect against sea level rise. By 2100, the dike infrastructure would maintain the current developed area boundary and there would be no net gain or loss of land with the exception reduced intertidal habitat outside the dikes. Westham Island's sub-standard infrastructure would not be not upgraded, and the Island would eventually become an open space/habitat area that is seasonally inundated.

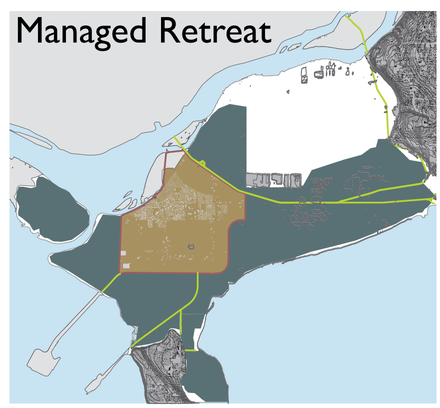
2. Reinforce and Reclaim *- pages 52 - 55*

This ARMOURING scenario is a variation on the Hold the Line scenario. It maintains, strengthens, and raises most of the existing 55 km of Delta's dike and seawall infrastructure in order to protect against sea level rise. In addition, outer dikes would close off some areas from the river/sea (eg. Ladner Harbour and Deas Island to protect the Massey Tunnel exit). Ecologically functional barrier islands would be used to reduce the probability or extent of inundation along Boundary Bay. By reducing incoming wave energy off-shore, the barrier islands would allow for slightly lower dikes or seawalls around Boundary Bay as compared to those in Hold the Line.



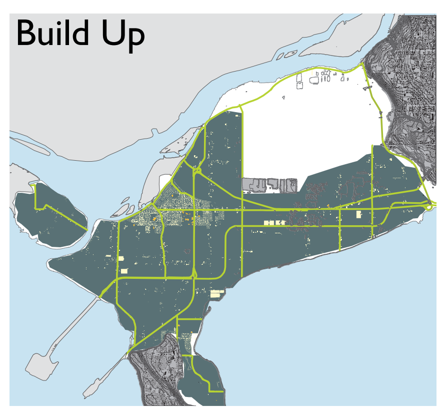
3. Managed Retreat *- pages 56 - 65*

This "SOFT" option leaves existing dike and seawall infrastructure as is for many areas, reinforcing and maintaining existing infrastructure only to protect major population concentrations and Delta-wide assets in Ladner. As a result, over time, sea levels would inundate the remaining unprotected low-lying areas. Development currently located in these unprotected areas would be gradually relocated to higher-ground or Ladner, in a phased and planned retreat over several decades.



4. Build Up *- pages 66 - 75*

This "SOFT" option leaves existing dike and seawall infrastructure as is across the Corporation of Delta. As a result, over time, with rising sea levels, water would more frequently inundate less protected low-lying areas. Current critical infrastructure such as hospitals, schools and fire halls would be raised, new residential development would be built to higher Flood Construction Levels, and older residences would be gradually raised on an individual basis. Major roads would be raised, while minor roads would be left at current elevations. During inundation events, individuals would be responsible for their own properties and access. While it is likely that numerous inundation events would occur by the end of the century, data on the projected frequency of inundation events is not yet available.

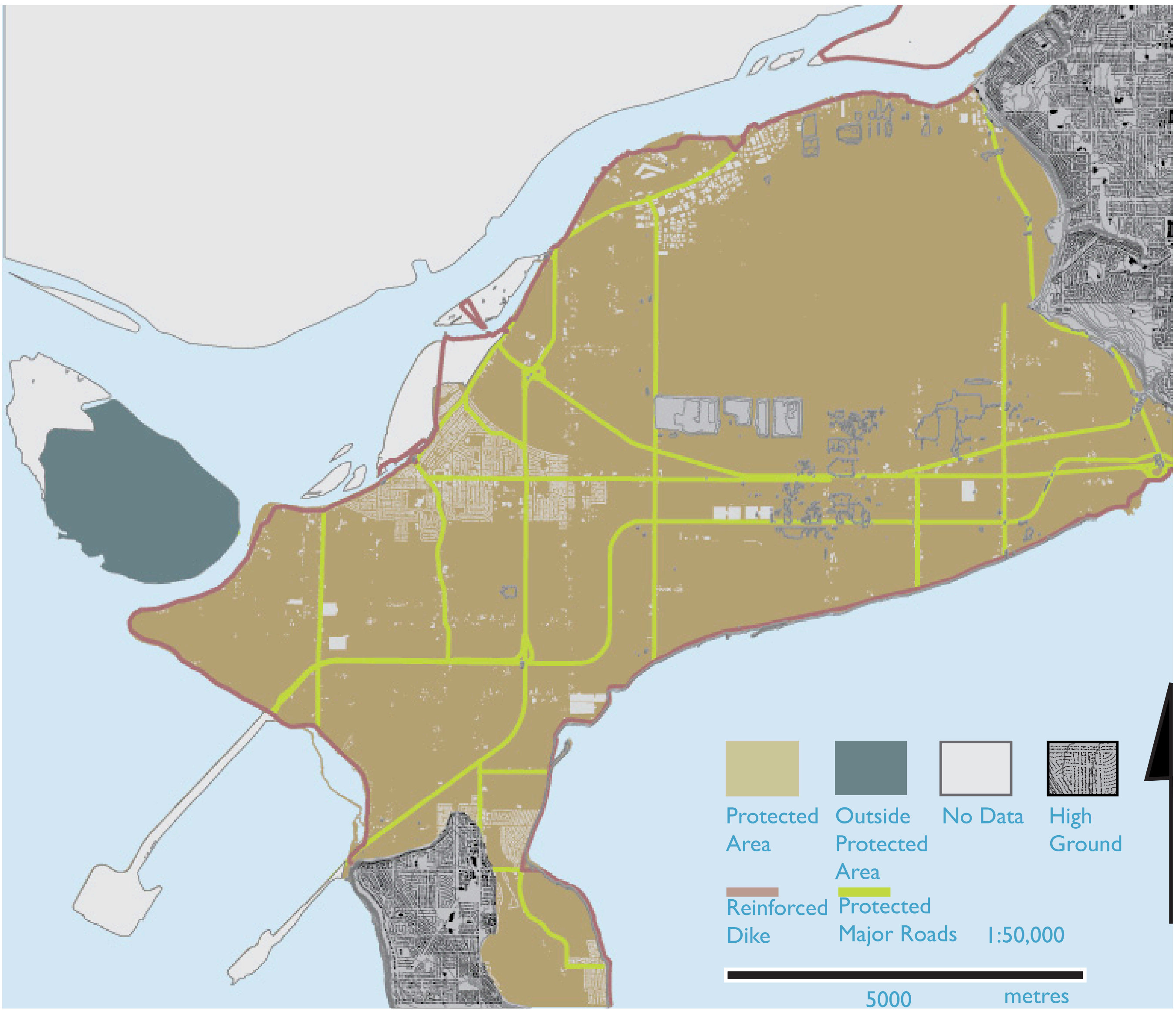


4.2 Scenario One: HOLD THE LINE

4.2.1 Scenario overview

This ARMOURING scenario maintains, strengthens, and raises most of the existing 55 km of Delta's dike and seawall infrastructure in order to protect against sea level rise. By 2100, the dike infrastructure would maintain the current developed area boundary and there would be no net gain or loss of land with the exception of reduced intertidal habitat outside the dikes. Westham Island's sub-standard infrastructure would not be not upgraded, and the Island would eventually become an open space/habitat area that is seasonally inundated. This Scenario assumes that the dike/seawall infrastructure is built to a very high standard of 6.9 meters above mean sea level- consistent with the new BC Sea Dike Guidelines - to ensure that the probability of infrastructure failure (breaches and flooding) is extremely low (near zero). This scenario assumes that flood construction levels inside the dikes are not raised. This scenario would likely be developed over many decades.

Figure 4-4: The Hold the Line Scenario proposes to upgrade Delta's dike and seawall infrastructure (red line) to protect Delta's existing low-lying areas from sea level rise. The brown areas on the map below are protected from flooding. *image credit: Glenis Canete*



SEA DIKE GUIDELINES	2010 guideline	2100 guideline
DESIGNATED FLOOD LEVEL (includes maximum high tide, sea level rise, storm surge and wind)	**3.45m above MSL**	**4.8m above MSL**
DIKE CREST ELEVATION (accounts for wave run-up, overtopping, wind and wave setup)	**4.4m above MSL**	**6.9m above MSL**

Table 2: Sea Dike Guidelines. This table shows the BC Ministry of Environment recommended dike crest elevations and flood levels that were used to produce the visualizations. The team chose to model seawalls in Boundary Bay at 6.9 metres above mean sea level, as recommended in the guidelines. The dikes in Ladner are modeled one metre lower at about 5.9 metres, as recommended by experts, because Ladner would not experience the same intensity of waves and storm surges (Readshaw communication). *Source: Ausenco Sandwell 2011 (a)*

Figure 4-5: Hold the Line Scenario, Ladner. Aerial View, illustrates raised dikes protecting Ladner (existing structure on top of dikes are assumed to remain) *image credit: David Flanders*

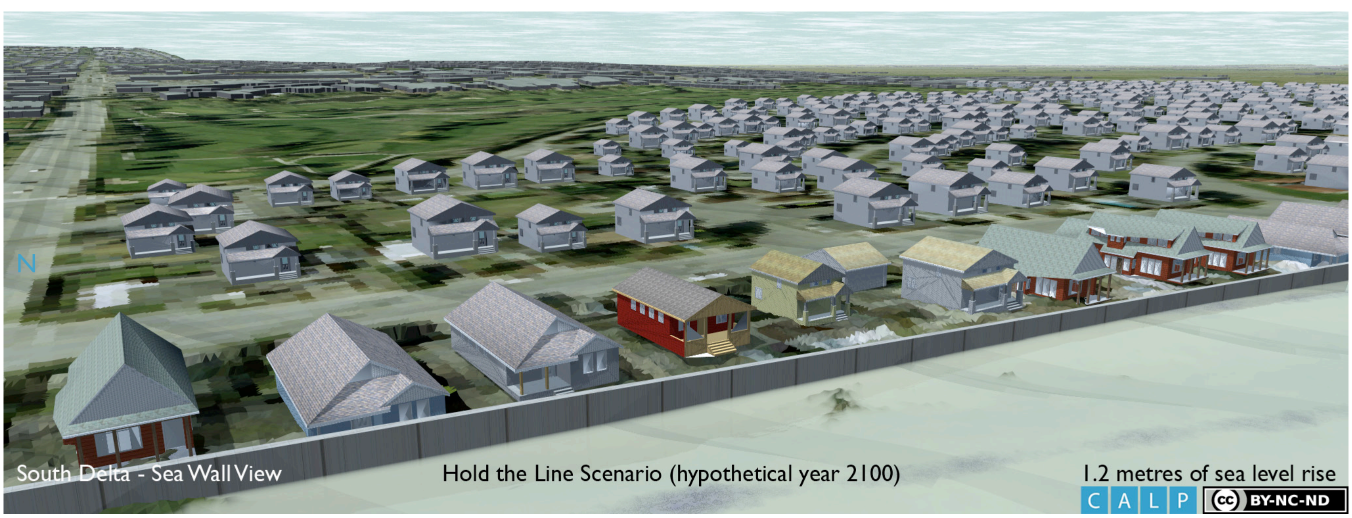


Figure 4-6: Hold the Line Scenario, Beach Grove. Aerial View illustrates a raised seawall protecting Beach Grove. *image credit: David Flanders*

For the Ladner case study, we have visualized two approaches to raising the dike. In the first approach (figures 4-7 - 4-9) the dike is raised using concrete reinforcements to allow a steeper pitch for the sides of the dikes.

Figure 4-7: Hold the Line Scenario, Ladner, Dike View, Concrete Wall. Using a reinforced wall allows the dike to be raised within a smaller footprint, causing less disturbance to River Road. *image credit: David Flanders*

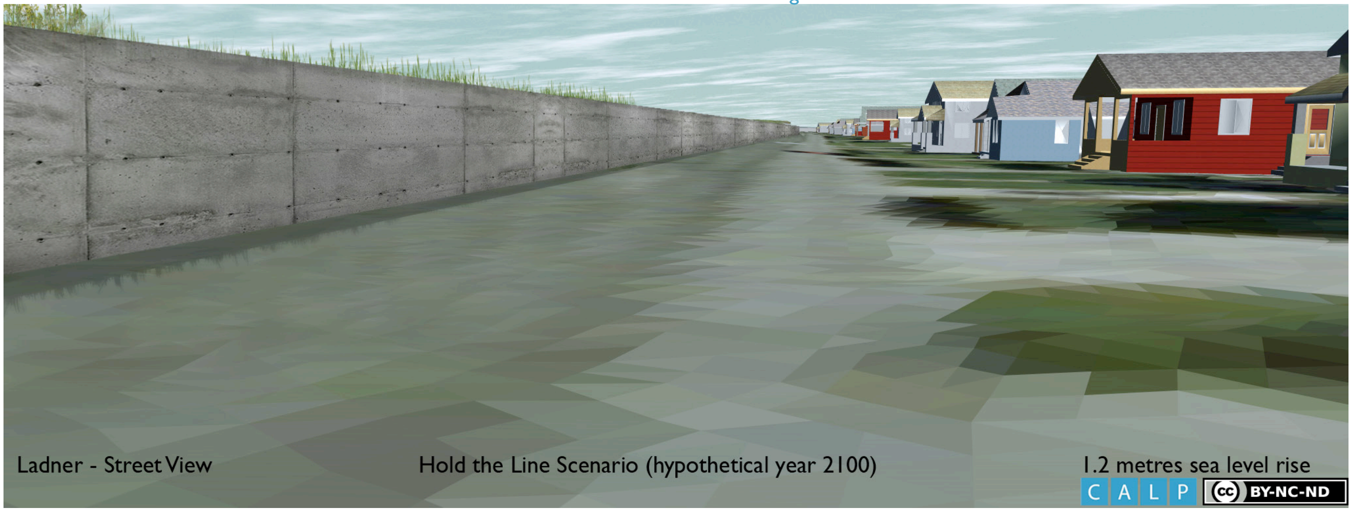
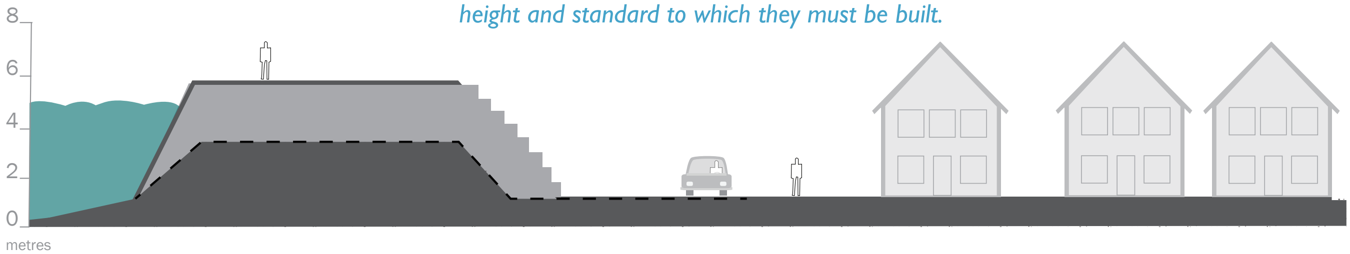


Figure 4-8: Hold the Line Scenario, Ladner, Street View, Concrete Wall. The reinforced wall allows a steeper pitch on the river road side of the dike, but could pose aesthetic concerns for neighbouring properties. *image credit: David Flanders*

Figure 4-9: Hold the Line Scenario, Ladner, Section, Concrete Wall. The section below shows an option where the dike is raised using hard reinforcements to allow a steeper pitch and smaller footprint for the dike. This approach does alter the Fraser River shoreline, which could have impacts on issues such as habitat, fisheries, and river flooding. *image credit: CALP*

Note: Building dikes to allow people on top, as shown in this diagram, increases the height and standard to which they must be built.



The approach below shows a landscaped berm with a 1:3 slope that avoids the need for hard reinforcement like the option on the previous page.

Figure 4-10: Hold the Line Scenario, Ladner, Dike View, 1:3 Slope. The dike is raised on its current centre line with a 1:3 slope. *image credit: David Flanders*

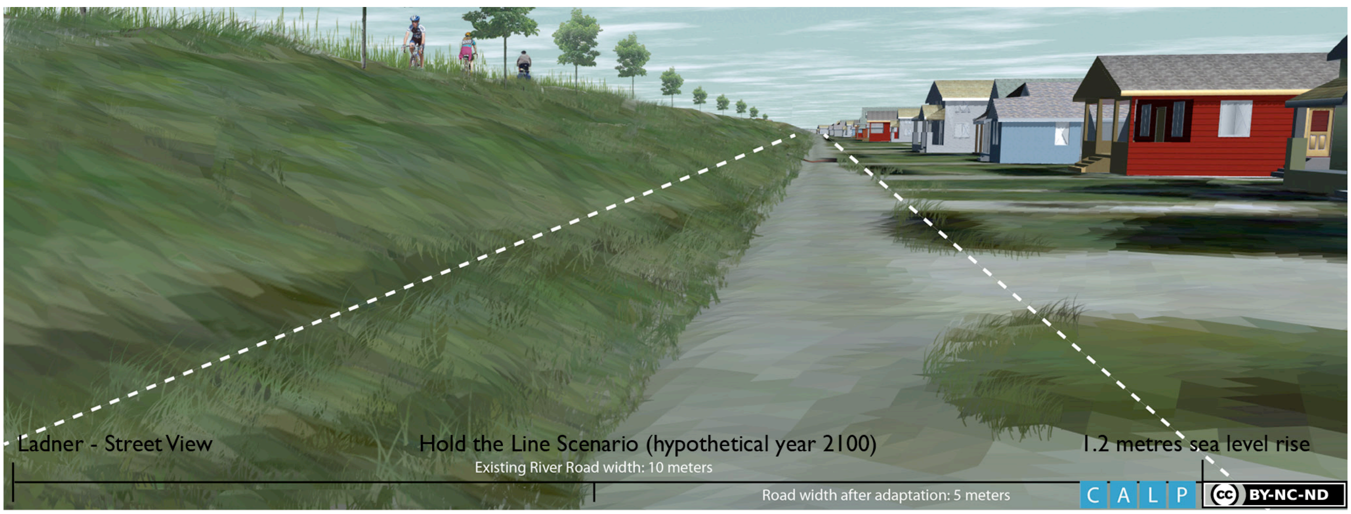
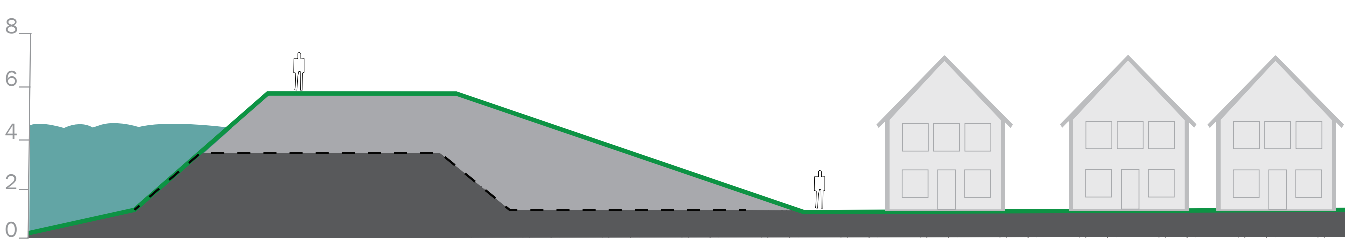


Figure 4-11: Hold the Line Scenario, Ladner, Street View, 1:3 Slope. As a result of this design, half of River Road's right-of-way is taken up by the dike, making it a single lane width. Heavier vehicle circulation would be displaced to other streets. *image credit: David Flanders*

Figure 4-12: Hold the Line Scenario, Ladner, Section Raised on Centre line. *image credit: CALP*

Figure 4-13: Hold the Line Scenario, Ladner, section.,1:3 Slope. The section below shows another option where the dike is raised inward, not on the current centreline, in order to avoid altering the Fraser River shoreline. This would avoid reducing shoreline stability and potential conflicts with the Federal Department of Fisheries and Oceans, , but would result in no space available for River Road.



For the Beach Grove case study we have visualized the community impacts of raising the seawall to the new Ministry of Environment guidelines, 6.9 metres above mean sea level.

Figure 4-14: Hold the Line Scenario, Beach Grove, Seawall View. The seawall in Beach Grove is raised to meet the new guidelines. *image credit: David Flanders*

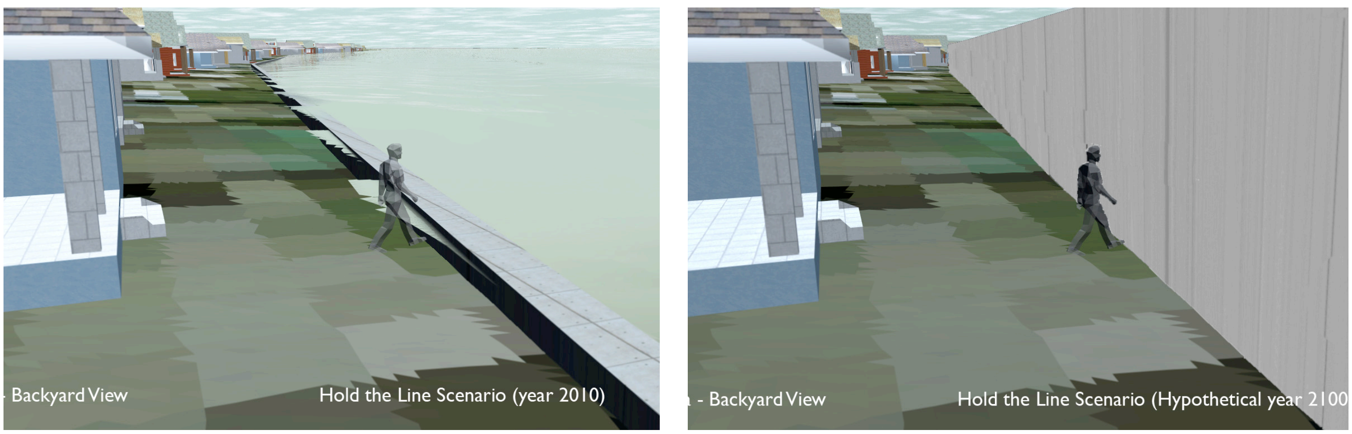
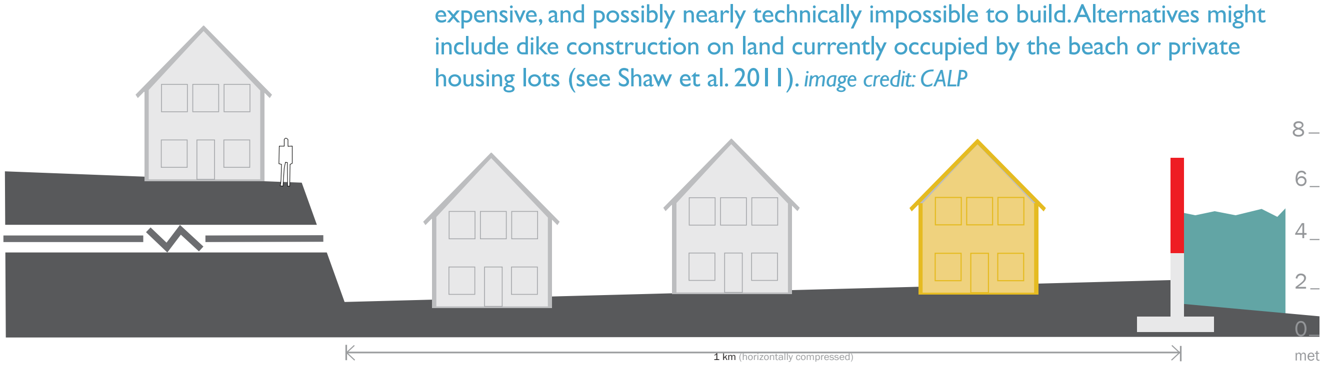


Figure 4-15: Hold the Line Scenario, Beach Grove, Backyard View. The current sea wall (left) and the raised sea wall (right). Note that the backyard in this visualization is raised. In other cases, the wall would be taller relative to the ground surface. *image credit: David Flanders*

Figure 4-16: Hold the Line Scenario, Beach Grove, section. The section below shows the sea wall raised to the new Ministry of Environment guidelines (roughly 5 metres above ground in some places where backyards have not been raised). This section is only for illustrative purpose to show how the new heights will affect views. A wall this tall to protect from rising sea levels would be prohibitively expensive, and possibly nearly technically impossible to build. Alternatives might include dike construction on land currently occupied by the beach or private housing lots (see Shaw et al. 2011). *image credit: CALP*



4.2.2 Hold the Line indicators

Implications of the Hold the Line scenario are listed below, grouped into environmental, social, and economic clusters. This list is not comprehensive, but covers key implications raised through the process.

Environmental Indicators		
Indicator	Hold the Line Impacts	Hold the Line Discussion
Agricultural Land	91% protected	Much of the agricultural land in Delta is protected from saltwater inundation behind the upgraded diking system. However, there is potential for salinization of the water table, even without inundation. For this scenario, it was assumed that the dikes would not be upgraded on Westham Island, where they are currently sub-standard, reflecting the relatively small population affected, high costs of dike rebuilding, and the need to find areas for wetland habitat to offset losses due to sea level rise outside dikes. This leaves a small portion of Delta's agricultural land unprotected against future sea-level rise. Over time, it would likely convert to habitat.
Impacts to Wildlife Habitat	"Coastal Squeeze" = Decrease in intertidal zone	Dikes are upgraded to maintain the current line of defense. The dikes effectively "fix" the coastline, preventing habitat from moving landward as the sea levels rise. The area remaining for habitat is "squeezed" out.
Land Base	91% protected	9,300 hectares of land are protected behind the upgraded diking system in this scenario.

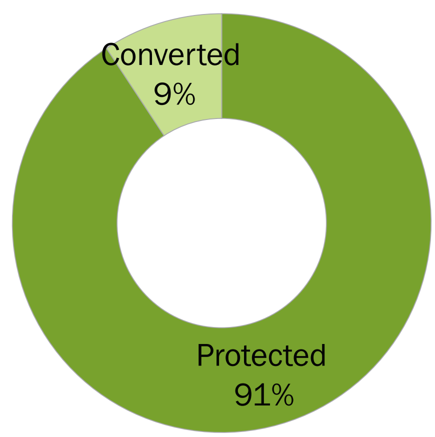


Figure 4-17: Hold the Line Scenario, Agricultural Land. Most agricultural land is protected from flooding. Over time, agricultural land on Westham Island is converted to habitat, as described above. *image credit: Glenis Canete*

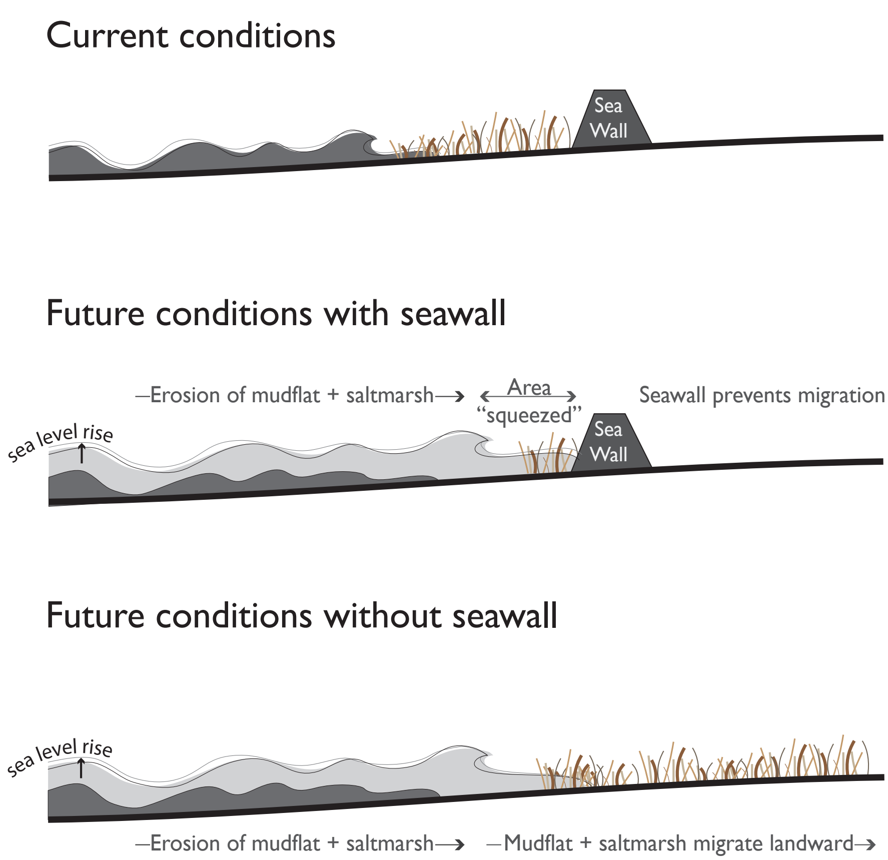


Figure 4-18: Coastal squeeze occurs when habitat has nowhere to move as sea level rises and dikes and seawalls are maintained.
image credit: Sara Barron
Diagram adapted from multiple sources.

Social Indicators		
Transportation - Roads	340 km protected 40 km unprotected 0 km raised	All major highways, arterials, and secondary roads in Delta are protected behind the dike system. The 40 km of road on Westham Island might maintained, depending on community choices, but will not be protected by upgraded dikes. As shown in figure 4-19, the increased dike height will result in much wider dikes, which may in some cases take up the entire current road right-of-way. If these transportation routes are to be maintained, some of the current roads in Delta will likely need to be re-aligned as dikes are upgraded.
Infrastructure - Dikes & seawalls	50 km dikes/seawalls raised 5 km dikes left as is	Most dikes and seawalls in Delta are raised to meet the new Ministry of Environment Sea Dike guidelines, including private sea walls.
Infrastructure - Facilities	20 critical facilities protected	In this Scenario, Delta's critical facilities, such as the hospital, municipal hall, recreation centres, schools, and arts facilities are protected behind the dike system.
Impact to Buildings	8511 protected 152 unprotected	152 buildings would not be protected relocated, or modified to adapt to sea level rise in this Scenario. We have not gone into detail to measure how many homes could be impacted by the increased dike widths, but it is likely that some would have to be purchased to accommodate the upgraded dikes.
Visual Impacts	Larger dikes and seawalls disrupt views	Heights of dikes and seawalls will increase significantly, up to 4 metres in some cases. This will obstruct first floor views from ocean front homes at a minimum.
Culture/Heritage Impacts	11 culturally and historically significant features protected	While cultural heritage features are protected within the dike system, the river community heritage of Ladner may be more difficult to maintain.
Risk	Risk reduced from protective infrastructure, but more people vulnerable	Though dikes are built to a high standard, there cannot be complete certainty that the lowlands of Delta will never be inundated. Development will continue in the vulnerable areas, putting more property and people at risk of flooding in the long term.

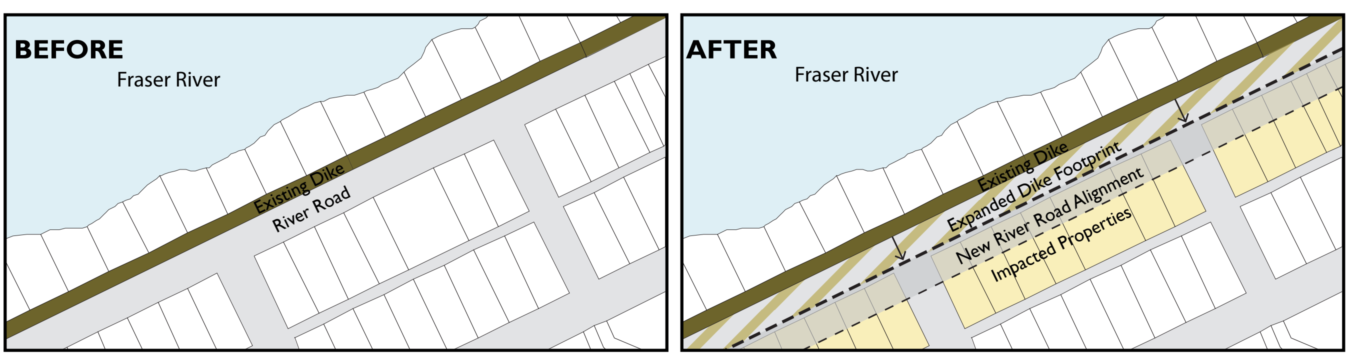


Figure 4-19: Road Re-alignments in Hold the Line Scenario. Dike-fronting properties will be impacted by the wider dike footprints required.
image credit: Sara Barron

Economic Indicators		
Costs - government	HIGH	Costs include 55 kilometres of dike, seawall, and other protective infrastructure upgrades to reduce the probability of infrastructure failure and increase protection for the entire lowland area of Delta from sea level rise. Following the new Ministry of Environment guidelines, this would require a substantial increase to the height of all sections of dike in Delta. This would also include annual maintenance costs, which could be up to 10% of the initial cost of dike upgrades annually (see Neuman et al. 2010, p.93). The costs would also include parcel buy-out along existing dikes to accommodate wider dikes (see figure 4-19).
Costs - homeowners	LOW	In this Scenario, direct costs to individual homeowners would be comparatively low. Government would be responsible for upgrading and maintaining the dike system. This may result in increased taxation, which could be increased across all of Delta (or more broadly provincially or federally depending on financing agreements for infrastructure upgrades), or could be specifically increased in the areas that benefit directly from the increased diking infrastructure.
Damages	LOW	Damages will likely be low for most of this century, possibly increasing late in the century with higher sea level rise and possibility of breaches.
Land Value	$5.8 billion protected $49 million converted	The $49 million in property values include: Westham Island farms and the Reifel Bird Sanctuary that will be affected by rising sea levels.

Indicator issues:

For many of the indicators, more detailed information (and supporting modeling) is needed for the community to make informed decisions. Issues include:

- Implications for Tsawwassen and Musqueam First Nations
- Estimate of full capital and on-going costs of dike raising
- The extent of saltwater intrusion and its impacts on agricultural viability with climate change
- Impacts on gravity storm sewers/drainage, given higher sea levels
- Location and expense of potential parcel buy-outs for road re-alignments
- Financing options (including cost-sharing with other levels of government) for the significant costs of raising dikes
- Additional costs of pumping
- Dike upgrade feasibility studies, including arrangements for private sea walls, and additional study on the risk of over-topping and appropriate "safe zones" behind dikes and seawalls
- Possible road relocation within Ladner
- Westham Island planning for future uses, relocations, habitat, etc.
- Implications for Deas Island tunnel

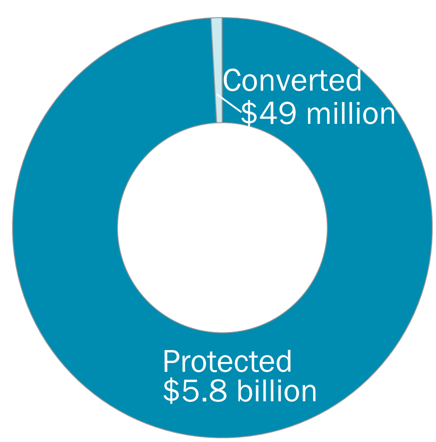


Figure 4-20: In Hold the Line Scenario, Protected Land Value. Most of the current assessed building and land value is protected. *image credit: Glenis Canete*

4.2.3 Hold the Line Policy review

Current Delta Policy that relates to a Hold the Line approach:

OCP, Schedule A 2-55
Dikes and Flood Proofing

Objective:
Protect the community from flooding.
Policies:
2.10.9 Meet acceptable engineering standards for drainage and flood risk in urban areas.
2.10.10 Plan for long term improvements to mixed uses in anticipation of sea level rise associated with global warming, and ensure that development does not preclude improvements to the mixed use system.
2.10.11 Obtain Municipal rights-of-way to carry out required maintenance where required.
2.10.12 Provide flood protection to all 1 in 200 year return period levels, from sea and river induced flooding.
2.10.13 Encourage proper and sustainable dredging of the Fraser River and secondary channels through cooperative efforts with ports and other applicable government authorities taking into consideration environmental issues.

Current Policy

Generally, current policy in Delta supports a Hold the Line approach to climate change adaptation. Within the Official Community Plan, key supporting policies include the Dikes and Flood-proofing section of the plan. This section specifies policies that support continued flood protection for the municipality.

This approach is also supported by Delta's Climate Change Initiative. The Flood Management plan includes: a seawall/dike improvement strategy to cope with sea level rise, a flood box and pump upgrade program to reduce the impacts of flood events, and a floodplain bylaw to shape future development. The plan notes that Delta will undertake Seawall/Dike improvements, and seek senior government funding to address these long term projections.

The Ministry of Environment recently (June 2011) released updated Sea Dike Guidelines that include future climate change projections. The proposed guidelines call for higher dikes based on consideration of sea level rise, storm surge, wave effects. This increases guidelines for dike crest elevations in Boundary Bay from the existing standards of 4.4-5.0 m in 2010 to 6.9-7.8m in 2100. The guidelines are "proposed" and published for consultation purposes; they are not yet government policy. Current Delta policies for flood proofing are to the current standards, not to the updated Ministry of Environment guidelines.

Some policy points to the issue of funding such large construction projects. The Utilities section of the Official Community Plan notes that "the infrastructure issues facing Delta, in the context of little future population growth, are to ensure that the existing systems are maintained, and that renewal of existing systems and creation of new infrastructure is planned in a sustainable way. Global warming and climate change have the potential to impact our infrastructure system as rising sea levels may result in future flooding." (Delta 2011. OCP, Schedule A 2-53). Ensuring a long term financing plan for continued armouring is an important consideration in adopting this approach.

Policy implications

Some policy implications of a Hold the Line approach are not addressed in existing policy. These include, but are not limited to:

- **long-term financing for increased armouring (i.e. raising dikes and seawalls), including private financing on private lots**
- **timing of improvements**
- **the spatial land-use & transportation planning implications of larger dikes, such as road realignments and property impacts and their mitigation**
- **implications for agriculture, including the probability of subsurface salt water intrusion into the water table (specifically how this affects soil quality for agriculture) and other climate change impacts such as crop types, water table level, availability of quality irrigation, etc.**
- **the habitat effects of maintaining dikes while sea level rises (coastal squeeze on tidal wetlands)**
- **the best use and appropriate management/adaptation strategies for Westham Island**
- **long term growth policy, eg. permit population growth in floodplain areas versus focus growth on upland development, etc.**
- **changes to current enabling of housing development on dikes**
- **updating emergency management and response plans to respond to increased flood depths under sea level rise scenarios**

Possible changes to existing policy required to meet "Hold the Line"

While it seems that Delta policies generally support an armouring approach to climate change adaptation, some sections of the Official Community Plan point to alternative approaches. For example, many Development Permit areas include construction elevations for buildings within land areas behind dikes (LV1, LV2, LV4, LV 5, LV6, SD1-B, SD2, SD3), which points to a Build Up approach (see section 4.4). They also require restrictive covenants that acknowledge the land may be subject to flooding (LV1, LV2, LV4, LV 5, SD1-B, SD2, SD3). A key objective in the OCP is to protect people and natural environments against threats, including flooding. This is reinforced by Policy 2.4.30 which suggests prohibiting development in flood-prone areas. This can be understood as an avoidance approach, rather than a Hold the Line approach.

If a Hold the Line approach were to be adopted, existing policy would presumably adopt the Ministry of Environment's Sea Dike Guidelines, and continue to update the crest elevations of dikes as new information emerges. A strategy on timing of improvements in relation to other land use/developments would be needed, based on climate change projections and other factors.

Coastal habitat will be lost if a Hold the Line approach is adopted, so policy goals of maintaining habitat will have to be altered to reflect this. One possible strategy that this particular Hold the Line scenario suggests is converting large areas of Westham Island to habitat over decades to mitigate the effects of coastal squeeze.

Land would need to be acquired and roads realigned to accommodate increased dike sizes. Zoning near dikes would also need to be updated to increase setbacks to allow for larger dike sizes. Further development outside or on dikes would not be allowed. This will have impacts on the cultural heritage of the Ladner river community.

New Policy consistent with "Hold the Line"

A long term financial plan would be necessary to determine the community's ability to fund dike upgrades and long-term maintenance in a changing climate.

An agricultural adaptation strategy could help current farmers adapt to climate-induced changes to farming, such as potential salt-water inundation and changing weather patterns.

Policy on existing houses on dikes should be developed in the near future, as development is continuing on river dikes.

Policy should be developed in areas that currently have private sea walls about choices, design, and land purchase arrangements in considering walls versus dikes.

Precedents

Thames River Barrier, UK

In response to the threat of flood events the Thames Barrier was erected in 1983 in the Thames River in London England to protect against both inundation from the river and tidal surges in the Thames estuary. The Thames barrier is the world's second largest movable flood barrier. During flood events, the structure's hollow steel and concrete containment fixtures collect water. The lifespan of the Thames Barrier was intended to last until 2030, however, the demand for the Barrier system has surpassed the initial projections. It has been increasingly used as sea levels rise. In response, the City of London is conducting a flood management plan that includes the introduction of floodgates that will work to protect against flooding with the current Thames Barrier system. The city has allocated £300 million for flood protection measures (Environment Agency, 2011).

Figure 4-21: The Thames River Barrier
image source: juerg-mueller.com/london/pictures/thames/thames-barrier/photos/thames-barrier-jan-2006-2-026.JPG

Superlevee, Japan

Large cities in Japan have been experimenting with building very wide, stable levees with very low grades on the backslopes. These "superlevees" provide increased protection from breach and underseepage, and are less likely to fail during earthquakes. They do require very large areas of land, and large amounts of fill to construct. They have mostly been built on vacant land or old industrial sites. Because of their design, the levees can be developed, allowing increased access to the waterfront. Typically, buildings on superlevees have been constructed on stilts and much of the land use is park and open space (Sustainable Cities Collective, 2009).

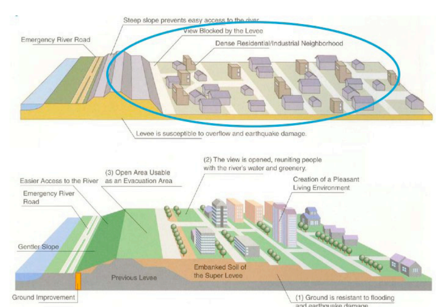


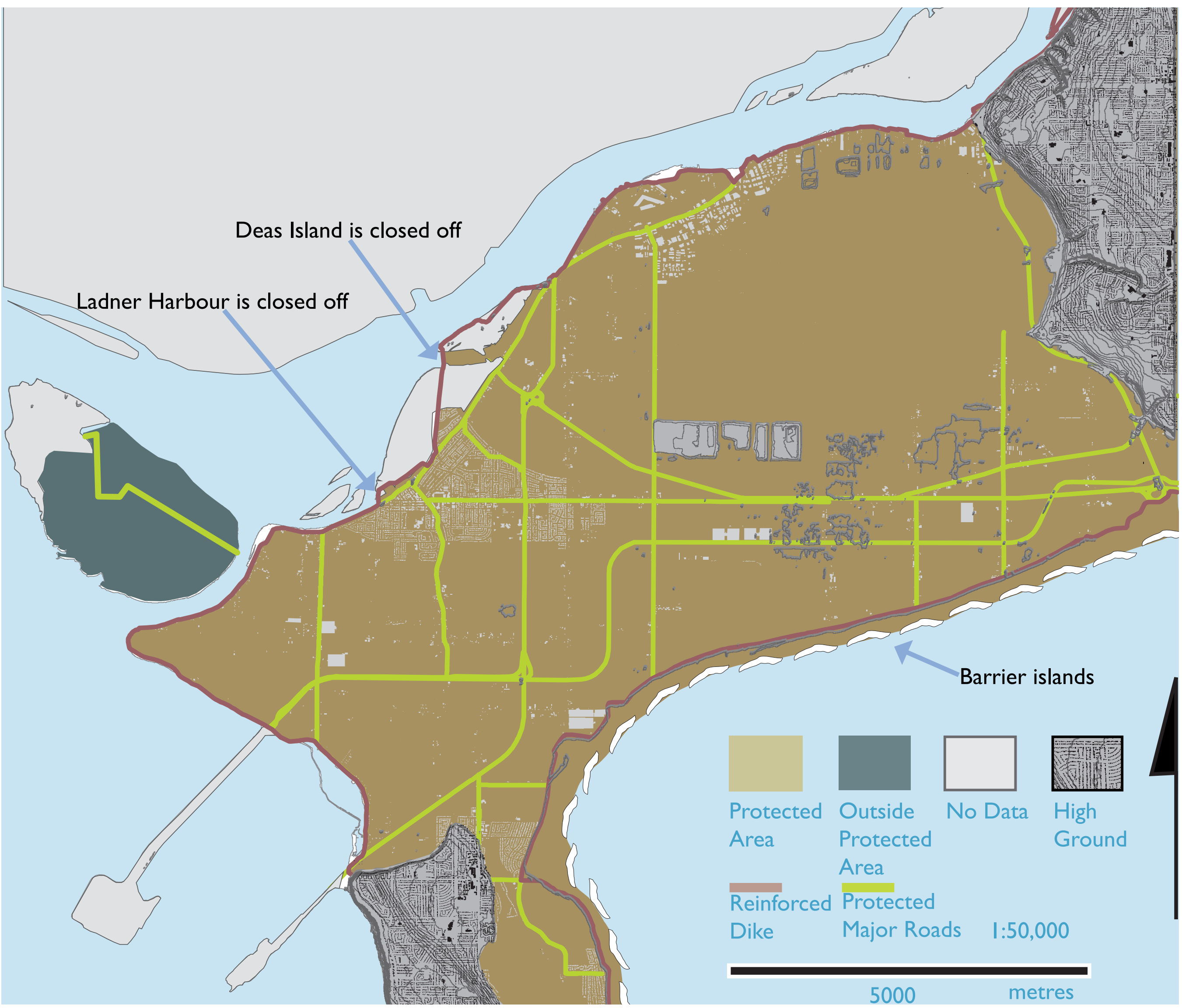
Figure 4-22, 4-23: Superlevees, Japan
http://sustainablecitiescollective.com/petersigrist/9331/levee-town-super

4.3 Scenario Two: REINFORCE & RECLAIM

4.3.1 Scenario overview

This ARMOURING scenario maintains, strengthens, and raises most of the existing 55 km of Delta's dike and seawall infrastructure in order to protect against sea level rise. In addition, outer dikes would close off some areas from the river/sea (eg. Ladner Harbour and Deas Island to protect the Massey Tunnel exit). Ecologically functional barrier islands would be used to reduce the probability or extent of inundation along Boundary Bay. By reducing incoming wave energy off-shore, the barrier islands would allow for slightly lower dikes or seawalls around Boundary Bay as compared to those in Hold the Line.

Figure 4-24: Reinforce and Reclaim Scenario Map. The Reinforce and Reclaim Scenario proposes to create barrier islands (white areas in lower right part of map) which combine with somewhat smaller dike upgrades (red line) to protect Delta's low-lying areas from sea level rise.
image credit: Glenis Canete



4.3.2 Reinforce and Reclaim Indicators

Implications of the Reinforce and Reclaim scenario are mostly the same as implications for the Hold the Line Scenario. Therefore, the Reinforce and Reclaim Scenario was treated as a sub-scenario of Hold the Line with respect to indicators and policy. Only new implications are listed below, grouped by key issue areas. This list is not comprehensive, but covers key implications raised through the process.

Environmental Indicators		
Impacts to Wildlife Habitat	Barrier islands used for recreation and/or ecological function	The barrier islands suggested in this scenario add some land area to Delta that could partially make up for land lost due to coastal squeeze. This land would be vulnerable to flood risk, but suitable for re-creating tidal habitat if appropriately designed.
Land Base	Small gains in usable land	The barrier islands provide small gains in habitat areas and in usable land
Social Indicators		
Public Acceptability - Visual Impacts	Dikes and/or seawalls would be somewhat lower than in the Hold the Line Scenario	The barrier islands work to reduce the effects of wind set-up and wave action on coastal defense structures. This will decrease the required height of these structures, though the exact amount of decrease will have to be calculated based on more detailed studies.

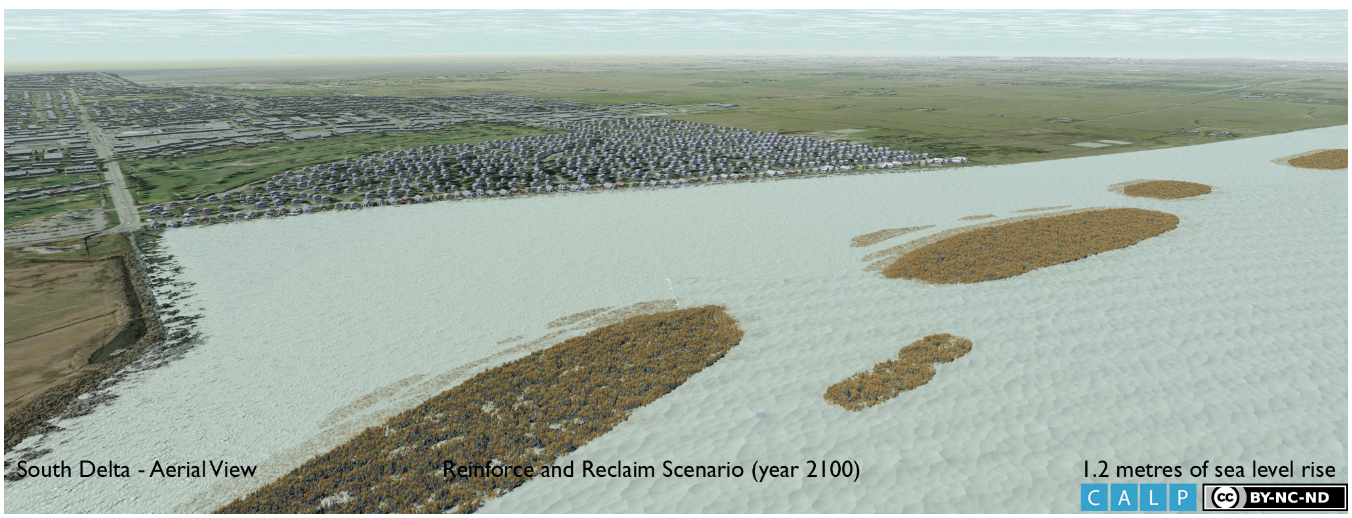


Figure 4-25: Reinforce and Reclaim Scenario, Beach Grove, Aerial View

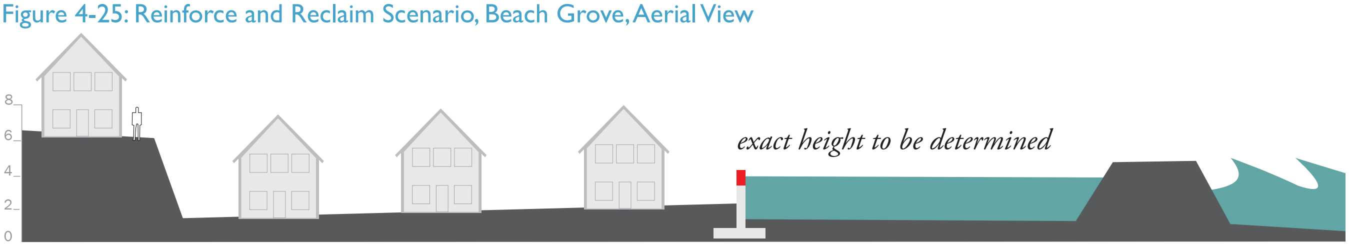


Figure 4-26: Reinforce and Reclaim Scenario, Beach Grove, Section

Figures 4-25 and 4-26: The Reinforce and Reclaim Scenario includes potential small gains in usable land, and in habitat areas. This scenario works to reduce coastal squeeze and to maintain and/or improve inter-tidal habitat.
image credit: David Flanders, CALP

Indicator issues:

For many of the indicators, more information is needed for the community to make an informed decision. Issues include:

- Implications for Tsawwassen and Musqueam First Nations
- an area by area feasibility analysis of using a barrier island approach, specifically to model the reduction in sea dike and sea wall raising
- study of how much wave action will be mitigated by the barrier islands, and how much this affects the design height of the seawall and/or dike
- a full ecological study of habitat impacts and potentials of barrier islands
- financing options (including cost-sharing with other levels of government) for the significant costs of raising dikes AND building the barrier islands
- on-going maintenance costs and requirements of the barrier islands
- feasibility and implications of Deas Island, Ladner Harbour, and other reclamation projects

4.3.3 Reinforce and Reclaim Policy review

For policy, Reinforce and Reclaim is treated as a sub-scenario of the Hold the Line and the policy review is the same as Section 4.2.3.

Policy implications

There are similar policy gaps as the Hold the Line scenario. Specific to Reinforce and Reclaim, implications that are not addressed include:

- **Choice of armouring approach for each neighbourhood. Some may support more "soft" armouring, such as barrier islands, while other might choose "hard" armouring only, such as dikes and seawalls.**
- **Land use choices for barrier islands. Suggestions include:**
    - habitat
    - agriculture (if viable)
    - energy generation, such as solar or wind farms

Changes to existing policy

If a Reinforce and Reclaim approach is adopted, existing policy should allow for neighbourhood input on choice of an armouring approach in each local area.

Policy goals of maintaining habitat would have to be altered to reflect the community's priorities. Though the barrier islands will likely provide some habitat, they cannot replace all habitat that will be lost as sea level rises. There could be regional implications and policies for offsetting habitat loss in Delta.

New Policy consistent with Reinforce and Reclaim

New policy should be created to prioritize land uses for the barrier islands. This would require some agreement with federal and provincial agencies (Fisheries Act, transportation considerations, wildlife management areas, etc.). Delta would possibly need to obtain a foreshore lease from the province to have administrative jurisdiction over the foreshore and sub-tidal areas where the barrier islands would be built.

Precedents

Louisiana Beach Nourishment

Beach nourishment has been used as the primary form of shore protection and beach restoration on the Louisiana coast, likely because it is very cost effective. It involves dredging sediments such as sand or silt from a nearby location and then placing the sediment and vegetation on the beach and nearshore to compensate for erosion of sand from the beach system. This approach is "softer" than building a hard structure, and it preserves the beach. There is currently a proposal to restore the Chandeleur Barrier Islands, which were devastated by Hurricane Katrina, using beach nourishment with sand and shell, and saline habitat.

Galveston, Texas

The coastal barrier proposal for the Galveston-Houston, Texas area was dubbed the "Ike Dike" because its proposal followed the damages incurred by the 2008 Hurricane Ike. The Ike Dike proposal includes three components: the existing seawall in Galveston, land barriers, and sea barriers.
The existing seawall is retained in this proposal since it efficacy at protecting against storm surge on the Galveston Bay side has been proven with the surges experienced with Hurricane Ike. Land barriers are extensions starting at the existing seawall. The land extensions are proposed to include sand and vegetation that mimic sand dune systems that provide a more naturalized appearance than the conventional seawall. The third component is two sets of gated sea barriers positioned at the mouth of Galveston Bay and the tip of Galveston Island. The costs of this proposal are perceived as a fraction of the costs associated with hurricane relief and individual armouring projects in the region (www.tamug.edu/IkeDike).

West Vancouver

The community of West Vancouver is currently working restoring its foreshore to its natural state. They have negotiated a foreshore lease with the province in order to have administrative jurisdiction over the area to carry out their projects. Their efforts include installing sub-tidal reefs to alter the sediment transport at various 'disturbed' inter-tidal sites across the foreshore to re-establish a more natural nearshore environment. Reported benefits include decreased wave energy at the shoreline, resulting in increased stability. They have also noted an increase in marine plants and animals in the area.

Figure 4-27: Chandleur Islands
image source: science.nationalgeographic.com/wallpaper/science/photos/coastlines-gallery/chandeleur-islands/

Figure 4-28: The Ike Dike proposal in Galveston, Texas.
image source: tamug.edu/IkeDike

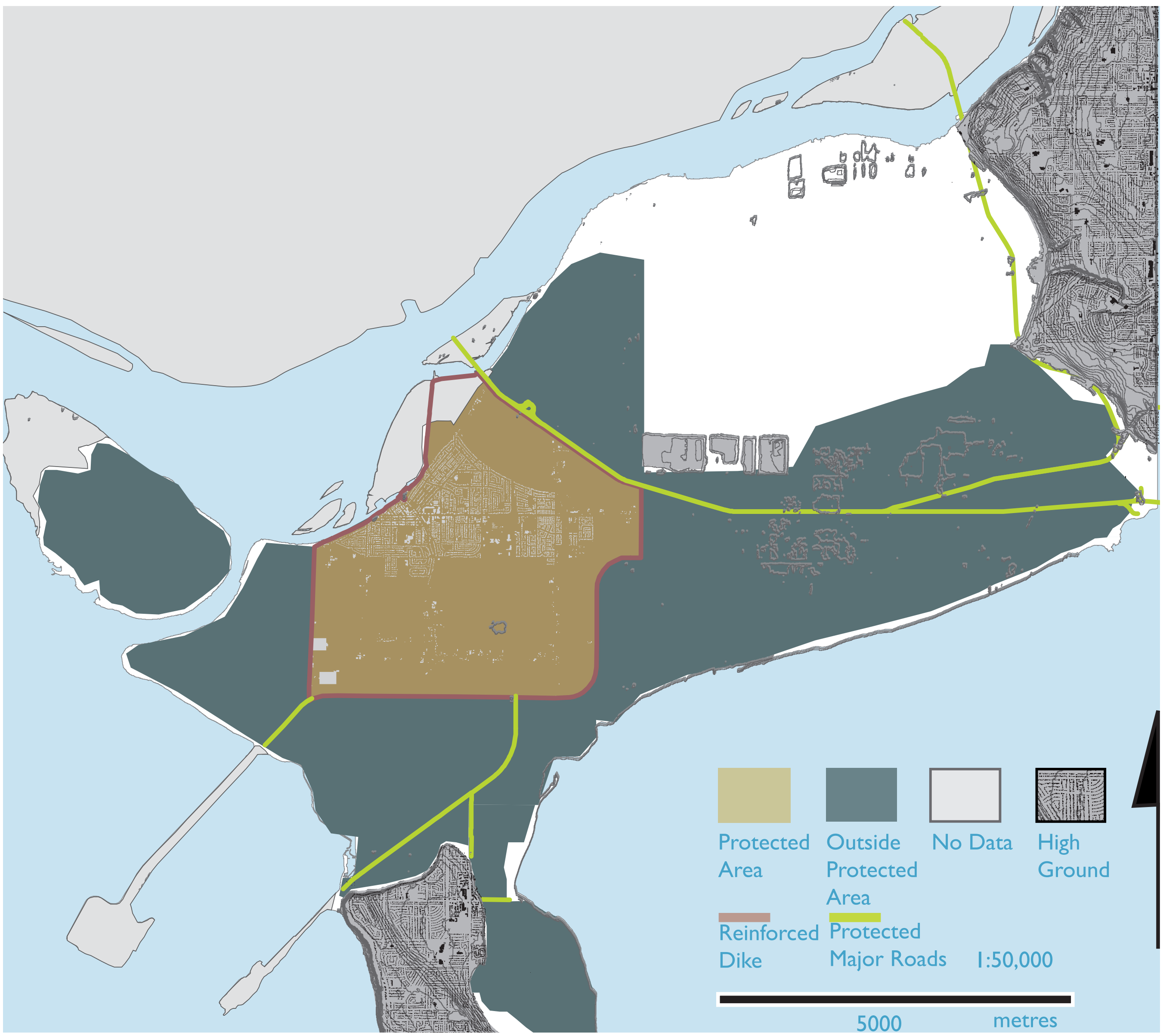
Figure 4-29: Lawson Pier, West Vancouver: shoreline enhancement.
image source: westvancouver.ca/uploadedImages/Community/Environment/Foreshore/Lawson_Pier_2.jpg

4.4 Scenario Four: MANAGED RETREAT

4.4.1 Scenario overview

This "SOFT" option leaves existing dike and seawall infrastructure as is for many areas, reinforcing and maintaining existing infrastructure only to protect major population concentrations and Delta-wide assets in Ladner. As a result, over time, sea levels would inundate the remaining unprotected low-lying areas. Development currently located in these unprotected areas would be gradually relocated to higher-ground or Ladner, in a phased and planned retreat over several decades. This Scenario combines the adaptive strategy of improved dike infrastructure with the adaptive strategy of reducing community vulnerability by planned re-location.

Figure 4-30: The Managed Retreat Scenario Map. The Scenario proposes to retreat out of some of Delta's lower density, low-lying areas over several decades. *image credit: Glenis Canete*



Scenario assumptions

In Managed Retreat, the Township of Ladner is protected by new and improved dike infrastructure, similar to that in Hold the Line. Internal "secondary" dikes also protect the township.

Key Assumptions:

- "safe zone" created & protected by new and upgraded dikes & pumping system
- All major roads outside of safe zone protected (as in the Build Up scenario)
- Existing development and critical infrastructure outside the safe zone would move to safe zones
- Maintain remaining existing dikes and seawalls at current heights
- Properties should be bought out, such that home owners would not lose their assests.

Note that flood events shown in the visualizations would only occur occasionally - most of the time the landscape would not be inundated. Inundation would become more frequent towards the end of the century as sea levels rise.

Figure 4-31: Managed Retreat Scenario, Ladner, Aerial View. The Managed Retreat scenario maintains, strengthens, and raises Delta's dike and seawall infrastructure around Ladner. Note ingress of water around Boundary Bay in the distance. *image credit: David Flanders*

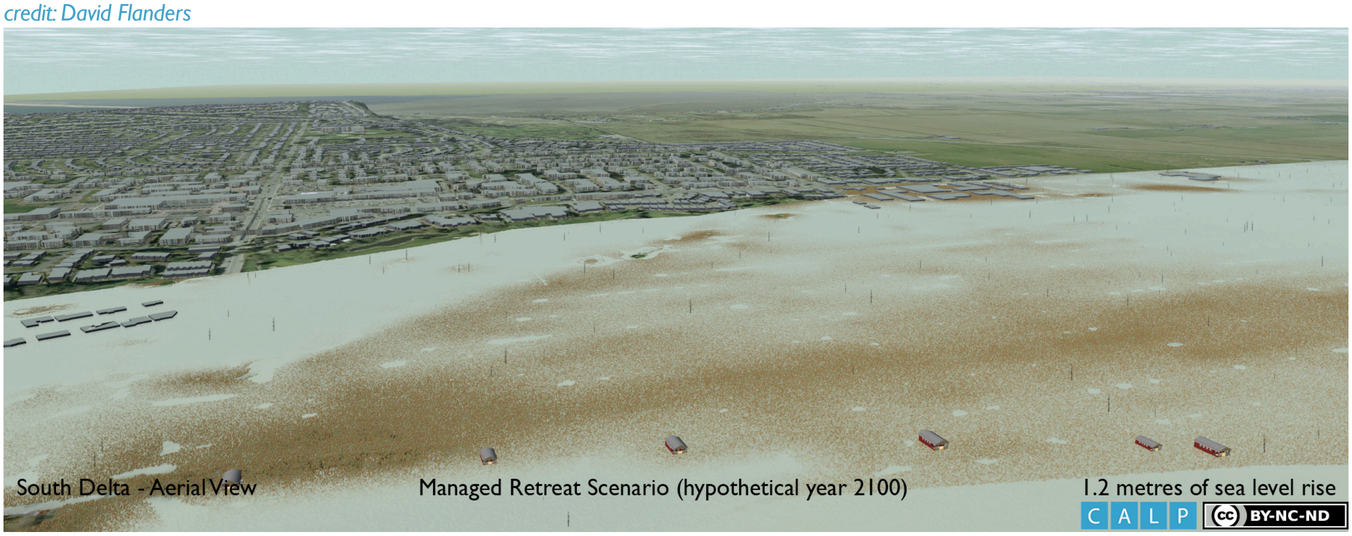


Figure 4-32: Managed Retreat Scenario, Beach Grove, Aerial View. Buildings and infrastructure outside of the Ladner area are gradually removed in phases, leaving the land to inundate during storm surges and/or high tide. *image credit: David Flanders*

In this incremental, managed retreat scenario, Beach Grove Road, 12th and 16th Avenues are raised to ensure reliable access to the community while early adopters begin moving out of the community (Figure 4-36). Gradually, due to periodic inundations, more community members migrate to higher ground in the Tsawwassen area or elsewhere(Figure 4-34, 4-37). With continuing sea level rise, inundations occur more frequently and severely, and more home-owners relocate as the coastline re-aligns. Neighbourhoods such as Beach Grove and Boundary Bay Village begin to transform from a neighbourhood of permanent residences into an area with cabins, and the raised access roads are no longer maintained (Figure 4-34, 4-38). After a transition lasting many decades, the former neighbourhoods return to an ecologically rich area as the intertidal zone migrates inward across the floodplain. Tsawwsassen may experience a population increase as residents migrate to higher lands (Figure 4-35, 4-39).

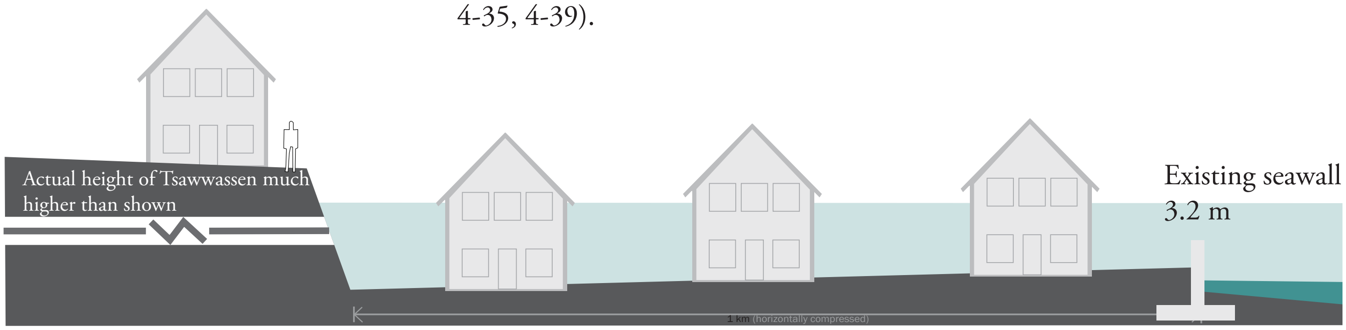


Figure 4-33: Managed Retreat Scenario, Beach Grove, Section - Stage One. Gradually, as periodic inundations increase, residents choose to move out of less protected low-lying neighbourhoods on Boundary Bay.
image credit: CALP

Figure 4-34: Managed Retreat Scenario, Beach Grove, Section - Stage 3. Existing houses retreat out of the floodplain *image credit: CALP*

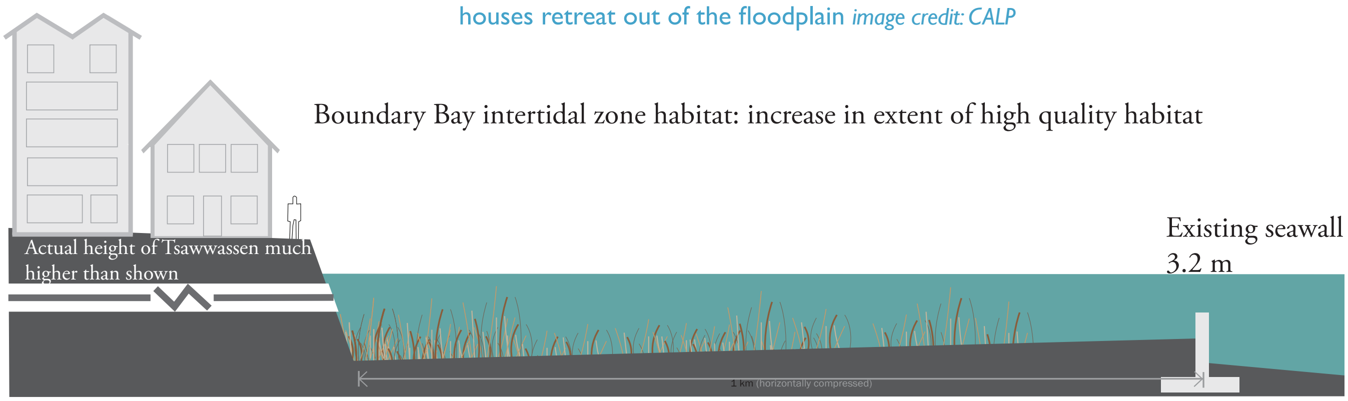


Figure 4-35: Managed Retreat Scenario, Beach Grove, Section - Stage 4. Intertidal habitat increases *image credit: CALP*

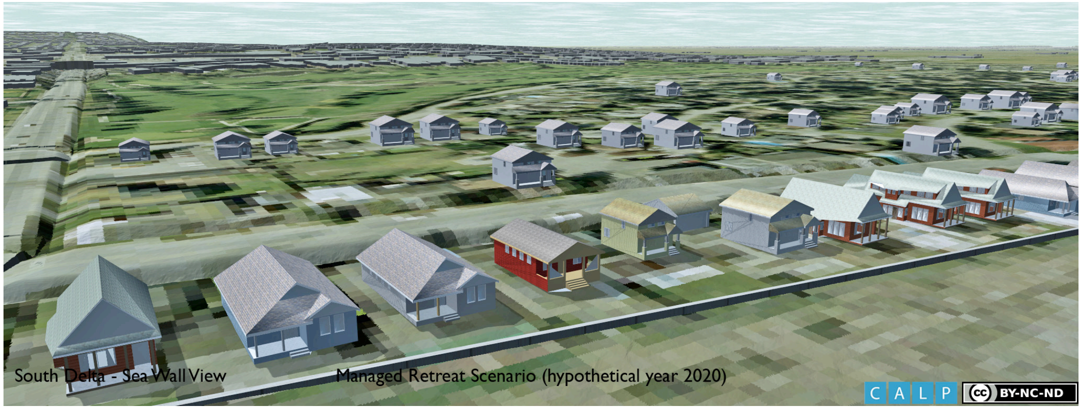


Figure 4-36: Managed Retreat Scenario - future stage one. *image credit: David Flanders*

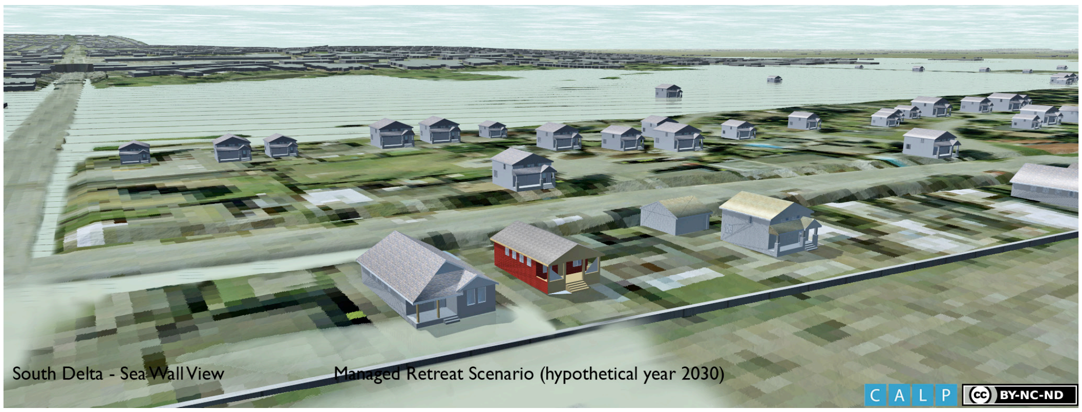


Figure 4-37: Managed Retreat Scenario - future stage two. Note - inundation is temporary. *image credit: David Flanders*

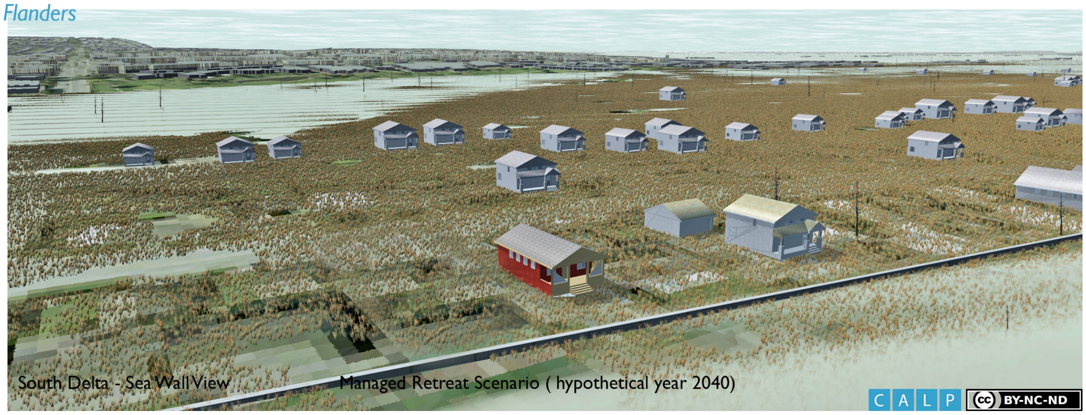


Figure 4-38: Managed Retreat Scenario - future stage 3. *image credit: David Flanders*

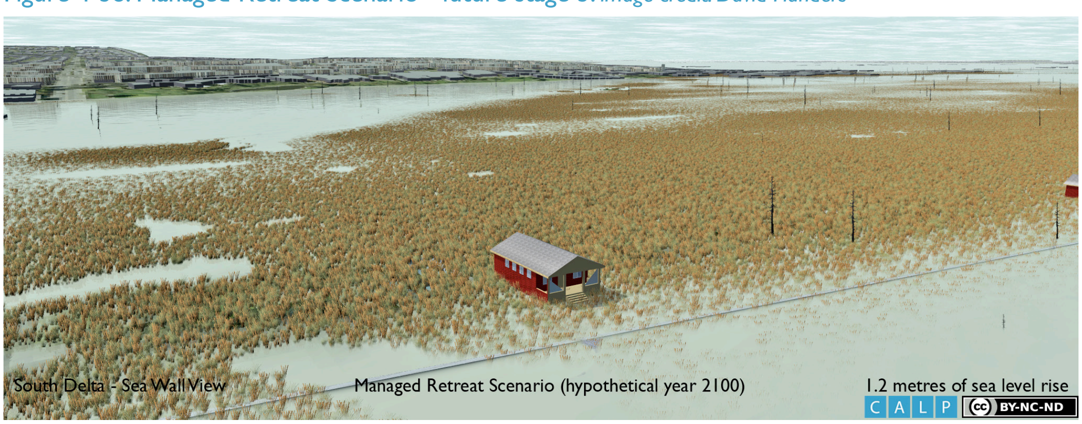


Figure 4-39: Managed Retreat Scenario - hypothetical year 2100. *image credit: David Flanders*

4.4.2 Managed Retreat indicators

Implications of the Managed Retreat scenario are listed below, grouped into environmental, social, and economic clusters. This list is not comprehensive, but covers key implications raised through the process.

Environmental Indicators		
Indicator	Managed Retreat Impacts	Managed Retreat Discussion
Agricultural Land	80 % converted	Most of the agricultural land is converted over time as repeated flooding events inundate the soil with salt water.
Impacts to Wildlife Habitat	Allows for habitat migration	Coastal squeeze is mitigated as some armouring structures are abandoned. The intertidal zone ecosystem is able to retreat inland as the sea level rises.
Land Base	21% protected	Just under a quarter of the Sea Level Rise planning area is protected behind dikes.

Social Indicators		
Transportation - Roads	110 km protected behind dikes 30 km raised 240 km decommissioned	Roads inside the smaller protected area will be maintained; 30 km of roads are raised to protect major regional transportation routes; and 240 km of roads are decommissioned over time in previously built-up areas where there are no longer needed.
Infrastructure - Dikes & seawalls	22 km dikes/seawalls raised 33 km dikes left as is	This scenario raises about 20 km of dikes around Ladner Town Centre.
Infrastructure - Facilities	20 critical facilities protected by dikes	In this Scenario, Delta's critical facilities, such as the hospital, municipal hall, recreation centres, schools, fire halls, and arts facilities are protected behind dikes.

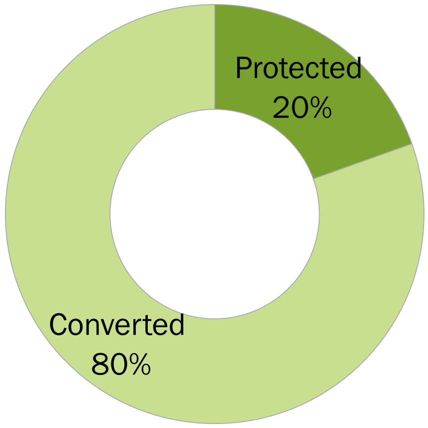


Figure 4-40: Managed Retreat - Agricultural Land. Most agricultural land is converted to habitat over time.
image credit: Glenis Canete

Social Indicators		
Impact to Buildings	5688 protected 2975 unprotected	66% of buildings in the Sea Level Rise planning area are protected behind dikes in the Ladner area. The remaining homes would gradually be relocated in a planned retreat over decades.
Public Acceptability - Visual Impacts	Some homeowners will eventually be forced to move	Sequencing of the retreat, and the choice of which areas to move away from, will be a very difficult community decision. Extensive community consultation will be necessary in this scenario.
Culture/Heritage Impacts	5 culturally and historically significant features protected	5 of the 12 culturally and historically significant features are protected behind dikes in the Ladner area.
Risk	Communities intrinsically more resilient to flood risk	By relocating development away from the most vulnerable areas, the community and its citizens are more resilient to climate change and flood risk. Though the current projection is about 1.2 metres of sea level rise over the next 100 years, this number will continue to rise. By locating away from vulnerable areas, the community is more adaptable to fluctuations in actual sea level rise, and on-going sea level rise after 2100.

Economic Indicators		
Costs - government	HIGH	Government costs in this scenario could include purchasing the land and structures in retreat areas. This is just one method of managing the retreat, but should be noted because it presents a large one-time government cost. The government is also responsible for raising and maintaining the dike infrastructure around the protected area.
Costs - homeowners	LOW	Direct costs to individual homeowners would be comparatively low. Government would be responsible for managing the retreat and fairly compensating homeowners.
Land Value	$4.0 billion protected $1.9 billion converted	

Indicator issues:

For many of the indicators, more information is needed for the community to make an informed decision. Issues include:

- Implications for Tsawwassen and Musqueam First Nations
- An adaptation strategy for agriculture, including a potential shift to structure-based agriculture
- Validity of saline-tolerant agricultural plant species
- Feasibility studies for infrastructure decommissioning
- Funding, i.e. costs of purchasing property
- Public acceptability and social impacts to the community
- Timing of required changes
- Impacts/changes require to other infrastructure, eg. substations, energy lines, pumping stations relocated or raised, etc.
- Impacts on recreation and the local economy

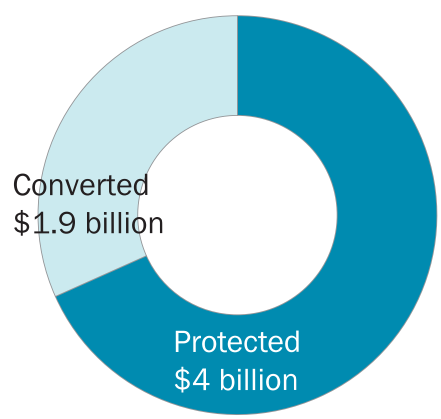


Figure 4-41: Managed Retreat - Land Value. About 60% of the vulnerable area's land value is protected.
image credit: Glenis Canete

Current Delta Policy that relates to a Managed Retreat approach:

Natural and Geotechnical Hazards Objective:
*Protect people and sensitive natural environments from negative impacts associated with slope instability, shoreline instability, **flooding,** wildland-interface fire threats or other hazards.*

Policies:
2.4.30 Carefully assess and where appropriate, prohibit development in areas prone to hazardous conditions and/or flooding.
2.4.31 Use development permit guidelines and bylaws to ensure that appropriate measures are taken when development occurs in potentially hazardous areas such as along slopes, bluffs or ravines, and in flood prone areas.
OCP Schedule A 2-20

Environmentally Sensitive Area 2 (ESA-2)
(Approximate total land area: 125 hectares; percentage of land area: 0.7%)
This designation is intended for environmentally sensitive areas or areas subject to hazardous conditions. Permitted uses include passive recreation and educational uses, limited residential development at a maximum density of 1 unit per 0.40 hectare clustered on that portion of the site having low sensitivity regarding wildlife habitat, slope slippage, and flooding due to 100 year storms.

Delta designation for future land use plan. OCP Schedule A 1-27.

4.4.3 Managed Retreat Policy review

The Managed Retreat Scenario has the least support in current policy. Though some high-level objectives point to limiting development in flood prone areas, most of the policy suggests protecting from flooding rather than re-locating away from vulnerable areas.

In the Official Community Plan, the Natural and Geotechnical Hazards section includes a policy to "carefully assess and where appropriate, prohibit development in areas prone to hazardous conditions and/or flooding." Delta also has an Environmentally Sensitive Development Permit Area (ESA-2), which includes areas subject to hazardous conditions, such as potential flooding due to 100 year storms. Development within this area is limited. This area is currently limited to 125 hectares of the Corporation.

Delta also has policies to protect habitat, which align with the aspirations of the Managed Retreat scenario. An example of this is in the Riverside Area Plan, where the first objective is "to maintain and improve the shoreline environment." An interesting policy within this objective is to encourage appropriate land ownership of habitat. Though such policies only focus on current habitat, and there is no mention of habitat shifts in relation to climate change, they could be adapted to support Managed Retreat.

According to the recent policy discussion paper (Ausenco Sandwell, 2011 (c)), there are significant barriers to a Managed Retreat approach. These include:

- public perception,
- existing land use rights,
- costs, and
- the infrequent use of decision-making tools, such as cost-benefit analysis, that incorporate non-market values.

(Ausenco Sandwell, 2011 (c)).

Policy implications

Many implications of a Managed Retreat approach are not addressed in existing policy. These include, but are not limited to:

- **Legal and cost burden implications of retreat**
- **Strategies for coordination and phasing of the retreat**
- **Mitigating social impacts and stresses**
- **Decision-making protocol for retreat/non-retreat areas**
- **Strategy for adapting agricultural lands**
- **Capacity of existing communities in upland areas to absorb more population**

Changes to existing Policy

Existing policy that supports coastal armouring and increased flood construction levels in flood-prone areas can gradually be abandoned as development moves out of these areas. The Environmentally Sensitive Development Permit Area can be expanded to include areas designated as retreat areas. This designation would have to be updated to prohibit residential buildings.

The Agricultural Land Reserve has a current mandate to protect all agricultural land. If this scenario were adopted, many acres of agricultural land would be unprotected from salt water inundation and eventually be unable to support current crops. Consultation with the Agricultural Land Commission would be necessary to alter this mandate.

New Policy consistent with Managed Retreat

A Managed Retreat scenario would require extensive community consultation. In this case, the community would have to determine which areas of the community would be converted over time to a Managed Retreat zone, and which areas would receive increased residential density. For example, in the Managed Retreat scenario as described in this process, a line of defense was drawn around the community of Ladner, loosely following major transportation routes within the community. This line of defense was chosen because Ladner contains much of the community's critical infrastructure. This type of long-term decision would require much community input.

Riverside Area Plan
A. Natural Environment
Objective A: Improve Shoreline and Upland Habitat
To maintain and improve the shoreline environment.
Policy A.1: Support River Habitat Protection
Programs
Recognize government guidelines and programs which protect the shoreline and aquatic habitats, (as indicated on the map entitled "FREMP Shoreline Designations" - see Page 13 of this report). Encourage flexibility to acknowledge the uniqueness of Riverside.

Policy A.2: Encourage Appropriate Land Ownership of Habitat
Encourage the protection and enhancement of significant shoreline habitat areas through appropriate ownership.
Policy A.3: Enhance Habitat
Encourage the enhancement of shoreline habitat areas.

Similarly, policies would have to be created for the phasing and financing of retreat. Some strategies for promoting retreat include:

- place a moratorium on new development in Managed Retreat areas
- prohibit redevelopment or reconstruction, particularly after an inundation event
- purchase properties in retreat areas

New land uses for retreat areas would have to be prioritized by the community. Additional studies (see page 87) would enable the community to make informed decisions about appropriate land uses for retreat areas. Suggestions heard throughout the Delta-RAC process included: habitat, energy production (eg. wind, solar, or biomass farms), recreation, agriculture (if viable), and unprotected residential uses. The project team assumed that a small minority of property owners might choose to remain in retreat areas, even though emergency services and flood protection would be unavailable to them. This is symbolized by the red house in the final image on page 59.

An agricultural strategy would also be required to adapt to salt water inundation. A first step would be to study soil quality and elevations for all agricultural lands within the vulnerable areas. This would provide useful information in order to make decisions about which agricultural parcels should be protected.

Precedents

Orplands and Tollesbury, UK

Managed retreat sites in the United Kingdom include Orplands and Tollesbury. The seawalls protecting the areas from inundation were allowed to breach in 1995. Both areas are now considered salt marshes and act as intertidal zones that provide habitat for birds and other wildlife (Grant 2001).

Figure 4-42: Orplands
image source: uea.ac.uk/~e130/Tollesbury.htm

Abbotts Hall Farm, Essex, UK

Abbotts Hall Farm is a 700 acre site was purchased by Essex Wildlife Trust located on the Blackwater Estuary in the United Kingdom. The seawall on site required upgrading, but Essex Wildlife Trust opted for alternative coastal defense methods. Saltwater marshes and mud flats were introduced to the site to create a sustainable coastal defense system. The farm remains productive, but also is home to wildlife native to this ecosystem (Essex Wildlife Trust 2010).

Figure 4-43: Abbotts Hall Farm
image source: essexwt.org.uk/visitor_centres__nature_reserves/abbotts_hall_farm/

King County Buyout and Elevation Program, Washington State

The Buyout portion of King County's program includes the purchase of properties in the region that are at risk for frequent flood damage. Properties are sold on a voluntary basis. The purchase of these flood-prone properties is viewed as a means to reduce the costs of emergency response and disaster assistance for flood events. Other benefits of the program include increased capacity for flood storage and conveyance, and additional open space for the community. Independent property value assessments are conducted on potential buy out properties to ascertain market value. After a purchase price is agreed upon by both the County and the property owner all existing structures are removed and the property is reassigned and re-planted as open space (King County 2012).

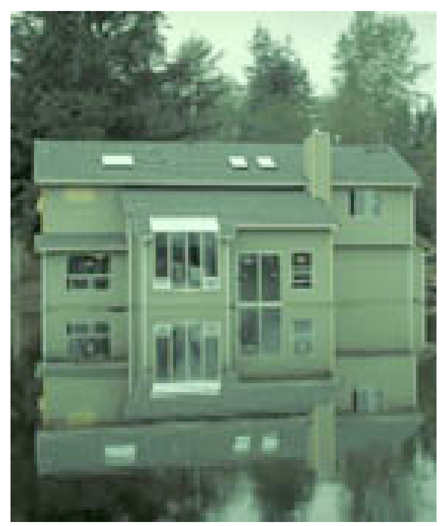


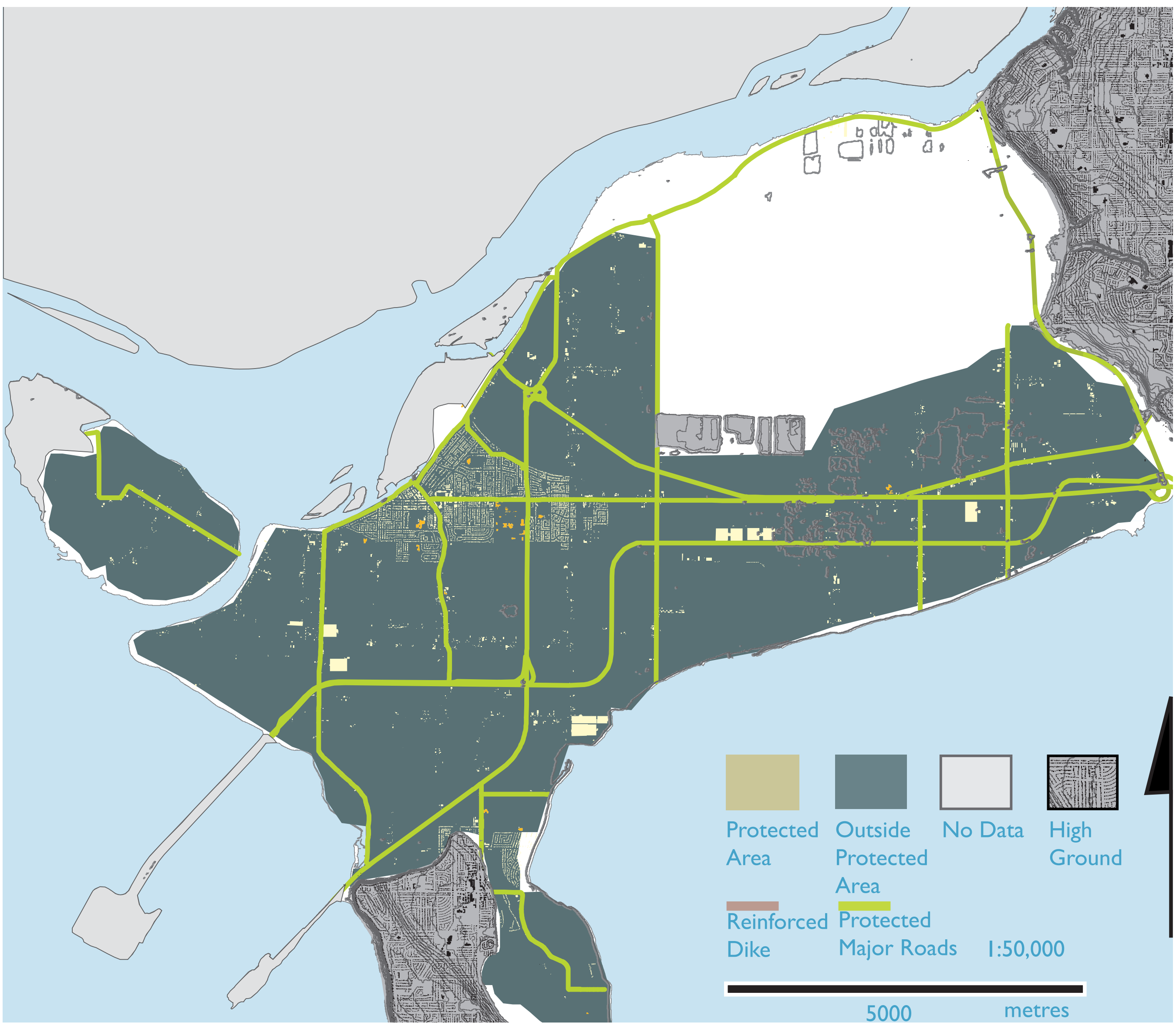
Figure 4-44: Flooded House in King County.
image source: kingcounty.gov/environment/waterandland/flooding/buyout.aspx

4.5 Scenario Three: BUILD UP

4.5.1 Scenario overview

This "SOFT" option leaves existing dike and seawall infrastructure largely as is across the Corporation of Delta. As a result, over time, with rising sea levels, water would more frequently inundate less protected low-lying areas. Current critical infrastructure such as hospitals, schools and fire halls would be raised, new residential development would be built to higher Flood Construction Levels, and older residences would be gradually raised on an individual basis. Major roads would be raised, while minor roads would be left at current elevations. During inundation events, individuals would be responsible for their own properties and access. While it is likely that numerous inundation events would occur by the end of the century, data on the projected frequency of inundation events is, however, not yet available. This scenario, like the others, would likely be developed over many decades.

Figure 4-45: The Build Up Scenario Map. The scenario proposes to focus efforts on raising buildings and critical infrastructure within Delta's low-lying areas so that they are able to accommodate occasional inundation.
image credit: Glenis Canete



GUIDELINES FOR MANAGEMENT OF COASTAL FLOOD HAZARDS LAND USE [2]	2010 guideline	2100 guideline
FLOOD CONSTRUCTION REFERENCE PLANE (FCRP) (Designated Flood Level + estimated wave effect)	**3.45m**	**5.6m**
FLOOD CONSTRUCTION LEVEL (Flood Construction Reference Plane + freeboard)	**4.05m**	**6.2m**

Table 3: Guidelines for Management of Coastal Flood Hazards Land Use. This table shows the BC Ministry of Environment recommended flood construction reference plane and flood construction levels for buildings and roads that were used to produce the buildings in the visualizations. For more details on these numbers, see the Technical Report (Flanders et al. 2012).
Source: Ausenco Sandwell 2011.

Note that flood events shown in the visualizations would only occur occasionally - most of the time the landscape would not be inundated. Inundation would likely become more frequent towards the end of the century as sea levels rise.

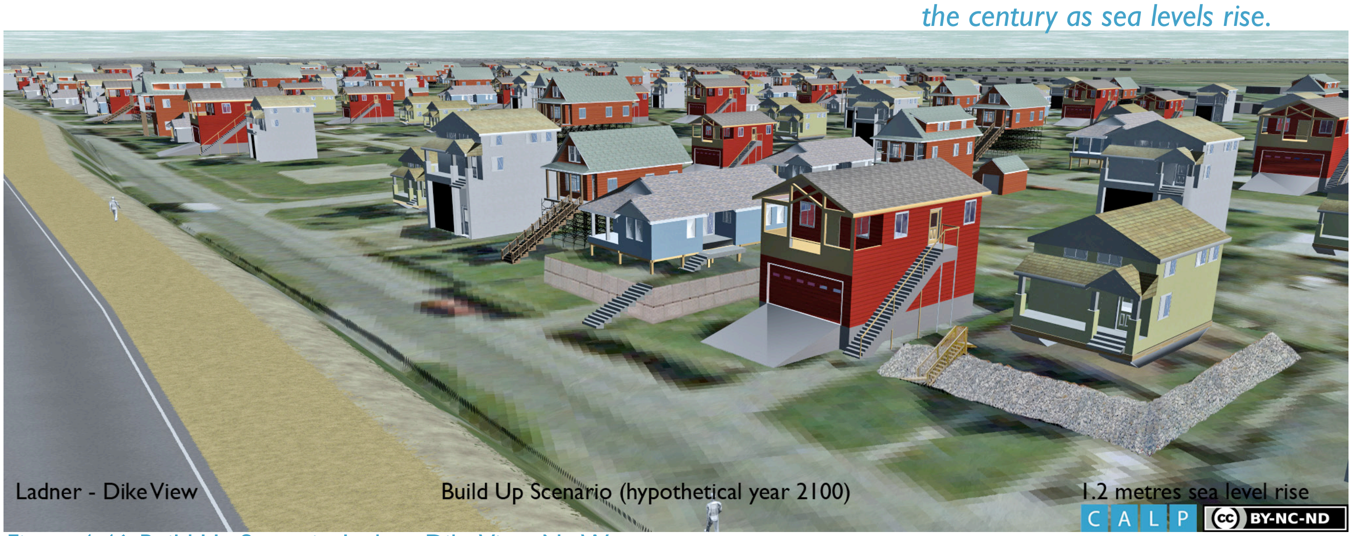


Figure 4-46: Build Up Scenario, Ladner, Dike View, No Water.

Figure 4-47: Build Up Scenario, Ladner, Dike View, with Water.

Figures 4-46 and 4-47: These dike views show the Build Up scenario in a hypothetical year 2100. Figure 4-46 illustrates the community of Ladner during most of the year, and Figure 4-47 illustrates what the community would look like during a flood event. These images show a road along the River Road dike, which is not a typical case. The team chose to illustrate the option of raising River Road as a major protected road, which happened to be within this viewpoint. *image credit: David Flanders*

Houses are built to a Flood Construction Level of around 6.2 m elevation above mean sea level, or 4.5m above the ground surface in this neighbourhood, based on the Ministry of Environment recommended guidelines on page 67 (see also Technical Report (Flanders et al. 2012)). These guidelines apply to all buildings within the sea level rise planning area. They could alternately be equipped to float. Homes that are not raised could face several meters of water during times of inundation later in the century.

As an alternate option, the houses could be raised by filling the land underneath, as is happening to some extent now in some neighbourhoods. The issue of impacts on neighbours due to changes in property line elevations, as different home-owners raise their land at different times, would need to be addressed. Land raising might thus be the preferred option for new or rebuilt development rather than for existing homes.

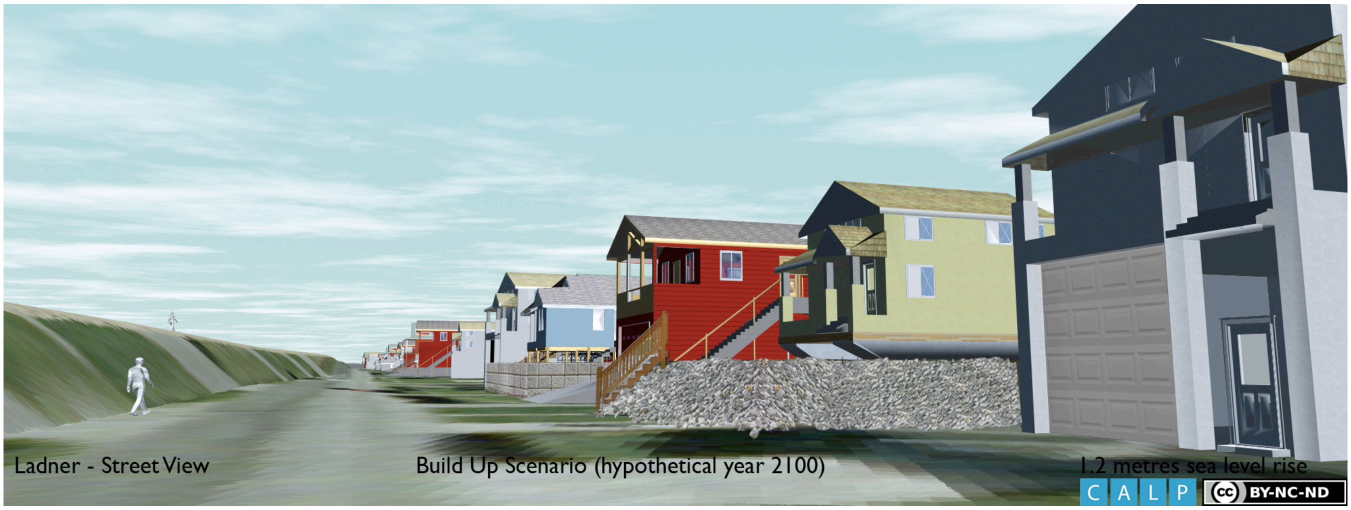


Figure 4-48: Build Up Scenario, Ladner, Street View

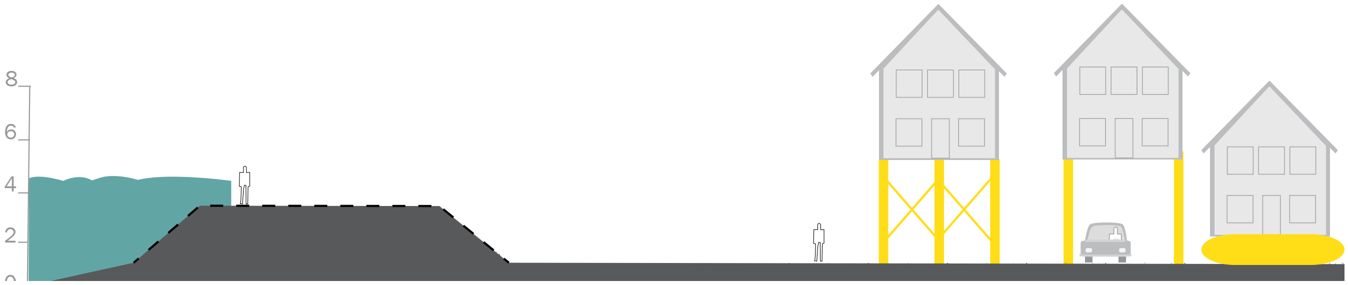


Figure 4-49: Build Up Scenario, Ladner, Section

Figures 4-48 and 4-49: There are a variety of options for raising homes above the flood construction level. Parcels could be raised with fill, or houses could be built on stilts, non-living spaces such as garages could occupy the first floor, or houses could be built on floating structures. *image credit: David Flanders, CALP*

4.5.2 Build Up indicators

Implications of the Build Up scenario are listed below, grouped into environmental, social, and economic clusters for 2100. This list is not comprehensive, but covers key implications raised through the process.

Environmental Indicators		
Indicator	Build Up Impacts	Build Up Discussion
Agricultural Land	100% converted	In this scenario, all agricultural land could eventually be unable to support current crops due to salinization of the soil after repeated inundation events. However, there is potential to shift to structure-based agriculture within Delta. Greenhouses would need to be raised significantly. Shifting agriculture to salt-tolerant plants and structure-based growing are both issues to be explored in a future agricultural plans. Implications for the Agricultural Land Reserve are to be determined.
Impacts to Wildlife Habitat	Allows for habitat migration	Coastal squeeze is mitigated as armouring structures are abandoned. The intertidal ecosystem is able to retreat inland as the sea level rises, with some modification of existing drainage infrastructure.
Land Base	0% protected from inundation	Land is not protected from inundation, but is still developable either with raised buildings or floating communities.

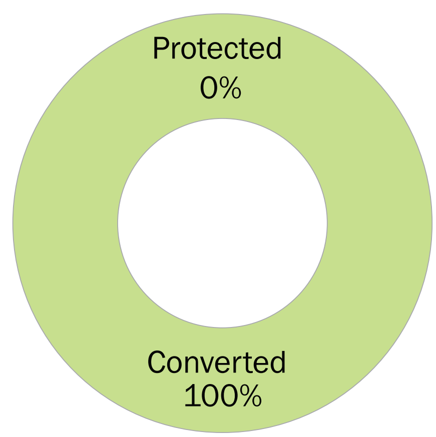


Figure 4-50: Build Up Scenario, Agricultural Land. All agricultural land is converted to structure-based systems or habitat as repeated salt water inundation limits the soil's ability to support existing crops.
image credit: Glenis Canete

Social Indicators		
Transportation - Roads	0 km protected 140 km raised 240 km not raised or protected	No roads are protected from flooding at their current elevations. About 40% of roads within Delta are raised to be higher than the flood construction level. These will provide critical access in the event of a flood. Over 60% of roads within Delta are left as-is in this scenario because they are built below the flood construction level. During a flood event, residents would be responsible for access to their homes.
Infrastructure - Dikes & seawalls	0 km dikes/seawalls raised 55 km dikes decommissioned	Dikes are not raised and will eventually breach and no longer hold back sea water, although they may continue to slow inundation as well as post-inundation drainage.
Infrastructure - Facilities	20 critical facilities raised	In this Scenario, Delta's critical facilities, such as the hospital, municipal hall, recreation centres, schools, fire halls, and arts facilities are raised to the new Flood Construction Levels.
Impact to Buildings	0 protected 8663 raised	No buildings are protected by dikes in this scenario. Instead, all homes are raised in this scenario, using a variety of techniques, or replaced with floating homes, to allow them to accommodate occasional inundations. Damage to homes is assumed to be minimal once all buildings are raised.
Public Acceptability - Visual Impacts	Built form changes	This scenario avoids tall walls and dikes, but it requires considerable modifications to existing building forms so that they are adapted to temporary periods of inundation. Entire neighbourhoods could be filled to meet raised flood construction levels, or land may be raised on a parcel by parcel basis. Both strategies would significantly change the neighbourhood character. The raised roads would also become visual barriers.
Culture/Heritage Impacts	12 culturally and historically significant features protected (if built up)	Historical and culturally significant features are raised in this scenario, which could change their character.
Risk	Prepares community for temporary inundations (adaptive capacity)	This scenario requires the community to invest in a sophisticated flood warning system and to plan for eventually frequent inundation events. This increased preparedness decreases the community's vulnerability.
Risk	Smaller risk of failure	The risk of dike or seawall failure to structures built to raised flood construction levels is smaller when compared to structures that rely solely on perimeter defenses, because the properties are protected even if the dike fails (Delcan, page 63).
Risk	Collective risk, individual responsibility	Not maintaining the dikes and seawalls is a collective risk. This scenario puts responsibility for that risk onto individual property owners. Existing properties would not be protected until they are raised to updated flood construction levels.

Economic Indicators		
Costs - government	MEDIUM	In this scenario, government spending includes the costs of elevating critical infrastructure such as the Delta Hospital and Municipal Hall, the costs of elevating a few critical roads within the Corporation, and the cost of elevating infrastructure to work with new sea levels and flood construction levels.
Costs - homeowners	HIGH	Homeowners of existing homes and developers of new homes will be responsible for raising the elevation of living areas to new flood construction levels which are significantly higher than existing levels. This may be done through raising the land on which the building sits, by raising the building through structural mean such as stilts and walls, by building houses on amphibious bases, or through a combination of the above, adding considerable costs.
Land Value	$3.8 billion sometimes inundated $1.6 billion "protected" $408.5 million converted	Sometimes inundated: this figure is the current assessed land value for vulnerable areas in Delta. It does not include "improved" value, such as buildings. Protected: it is assumed that all buildings are "protected" in this scenario because they are raised, so this number represents the current assessed building value, not including the land value. Converted: as stated above, all agricultural land vulnerable to sea level rise is assumed to be gradually converted, either to other forms of agriculture or to other uses. This number represents the current assessed value of agricultural land within the study area. Agricultural land converted to other uses may have very different value from a property perspective.

Indicator issues:

For many of the indicators, more information is needed for the community to make an informed decision. Issues include:

- Implications for Tsawwassen and Musqueam First Nations
- an adaptation strategy for agriculture, including a potential shift to structure-based agriculture at the new FCLs
- validity of saline-tolerant agricultural plant species
- feasibility studies for infrastructure raising (costs and other implications)
- transportation and emergency preparedness strategies for inundation periods
- clean-up strategies following inundation periods
- funding, i.e. costs of rasing buildings, incentives
- public acceptability
- feasibility of floating homes/communities
- timing of required changes
- impacts/changes require to other infrastructure, eg. substations, electricity lines, sewage, natural gas lines, pumping stations relocated or raised
- impacts on recreation and the local economy
- architectural standards, character allowances, and design guidelines for raised houses

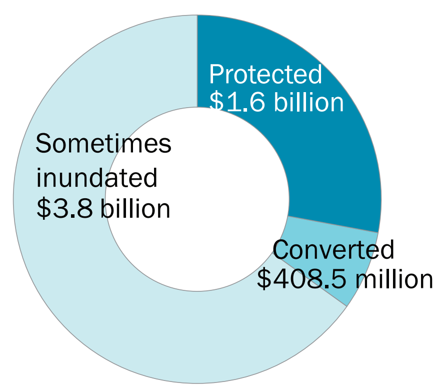


Figure 4-51: Build Up Scenario, Protected Land Value. Much of the land value is "sometimes inundated." Modified buildings are protected from inundation, and represent just over a quarter of the total value of the vulnerable area.
image credit: Glenis Canete

Current Delta Policy that relates to a Build Up approach:

OCP, Schedule A
Natural and Geotechnical Hazards

2.4.31 *Use development permit guidelines and bylaws to ensure that appropriate measures are taken when development occurs in potentially hazardous areas such as along slopes, bluffs or ravines, and in flood prone areas. OCP Schedule A 2-20*

English Bluff Development Permit Area (Tsawwassen Escarpment) Category: "B" Area: Development Permit Area SD2

No building or any part thereof shall be constructed, reconstructed, moved or extended nor shall any mobile home or unit, modular home or structure be located with the underside of a wooden floor system or top of concrete slab for areas to be used for habitation, business, or the storage of goods damageable by floodwaters lower than the Flood Construction Level, unless lesser elevations are established by the Ministry of Environment and Parks. No building shall be constructed within seven point five (7.5) metres of the natural boundary of the sea, nor within seven point five (7.5) metres of the inboard toe of any dike, nor within six (6) metres of the natural boundary of any swamp, slough, pond or ditch. (This Guideline is based on a standard established by the Ministry of Environment and Parks, Province of British Columbia.)

A Restrictive Covenant will be required under Section 82 or Section 219 of the Land Title Act acknowledging that land may be subject to flooding and saving the Municipality and the Province of British Columbia harmless from any claims arising out of damages to lands or buildings by flooding.

4.5.3 Build Up Policy review

As with the Hold the Line Scenario, some of Delta's current policy supports a Build Up approach. This includes the Official Community Plan, Area Plans, Development Permit Areas, and other Bylaws.

Though the specific numbers stated in current policy do not always align with the current Ministry of Environment suggestions, the inclusion of Flood Construction Levels within many bylaws demonstrates support for this type of approach.

Schedule A of the Official Community Plan, in the Natural and Geotechnical Hazards section, suggests using "development permit guidelines and bylaws to ensure that appropriate measures are taken when development occurs in potentially hazardous areas such as along slopes, bluffs or ravines, and in flood prone areas."

Area plans that support a Build Up approach include:

- East Ladner Area Plan's Policy A to "ensure that Ministry of Environment Flood proofing standards apply to all new development"
- Riverside Area Plan's Objective (B) to protect against flooding and erosion, specifically objective B6 to follow flood proofing standards,
- Tsawwassen Area Plan's objectives in Section F ensuring that all new development is built to provincial flood proofing standards and protecting properties from damage by ensuring adequate drainage systems.

Ladner's Area Plan and the North Delta Area Plan contain no explicit flood adaptation policies.

Development Permit Areas (DPA's) also support a Build Up approach. Many of the designated DPAs include Flood Construction Levels ranging from 1.95 to 3.5 m GSC. Many also require restrictive covenants "acknowledging that land may be subject to flooding and saving the Municipality and the Province of British Columbia harmless from any claims arising out of damages to lands or buildings by flooding" (see sidebar example for English Bluff Development Permit Area). In general, development permits are not required for:

- single family dwellings so long as current flood proofing and environmental standards have been met;
- for dike maintenance in Riverside undertaken by the Province or municipality;
- in the Streamside Protection and Enhancement DPA for emergency measures, including flood protection, or for clearing of blockages to drainage channels.

Other bylaws that support a Build Up approach include Subdivision and Development Standards Bylaw 5100 that points to raising land where required by the Ministry of Environment, and Bylaw 6060 that states a minimum building elevation of 1.6 m GSC.

Policy implications

Some implications of a Build Up approach are not addressed in existing policy. These include, but are not limited to:

- **Design considerations for raised flood construction levels;**
- **Coordination of raising existing homes/land to new FCLs;**
- **Financing for elevating critical infrastructure;**
- **Infrastructure and utility changes under a frequent inundation scenario; and,**
- **Strategy for adapting agriculture to a frequent inundation scenario and reusing former agricultural lands**
- **Strategy for access roads and emergency preparedness for flooding events**

Changes to existing Policy

Existing policy that supports a Build Up approach to climate change adaptation requires some changes. Many Development Permit Areas, Zoning Bylaws, and Building and Plumbing Bylaws state specific Flood Construction Levels. Flood Construction Levels are inconsistent throughout the Corporation of Delta, either stating specific elevations, or referring to the Ministry of Environment. Some special allowances have been made for particular buildings, and flood construction levels are currently different on the inside and outside of dikes. These should be updated to the new Ministry of Environment levels, and then updated on a regular basis as new understandings about sea level rise and associated climate impacts emerge.

The Agricultural Land Reserve has a current mandate to protect all agricultural land. If this scenario were adopted, many acres of agricultural land would be unprotected from salt water inundation and eventually be unable to support current crops. Consultation with the Agricultural Land Commission would be necessary to reconsider this mandate.

Finally, Building Code and Zoning regulations may prohibit new forms of housing. The Floating Home Residential Zone does permit construction of amphibious housing, and this type of zone could be expanded. Changes to the current Building Code and Zoning regulations would be required to allow for a wider range of housing forms that are adaptable to inundation.

Subdivision and Development Standards Bylaw 5100.
Section 5.12 Floodproofing.
The owner of land which lies within a floodplain shall raise the land as required by the Minister of Environment and the Director of Engineering; and where applicable, enter into a covenant saving harmless the Municipality and the Provincial Government in the event of flooding. The owner shall grant all rights-of-way to the Municipality which are required for the construction or maintenance of flood prevention structures or devices.

Building and Plumbing BYLAW NO. 6060 Amend. BL 6128, 2003
5.6 *The minimum building elevation of any space used for human occupancy, commercial sales, business or storage of goods, measured at the underside of a structural floor system or the top of a concrete slab, shall be no lower than 1.6 m G.S.C. Datum.*

New Policy consistent with Build Up

Community character and aesthetics emerged as a concern when discussing the Build Up scenario. The current Ministry of Environment guidelines suggest Flood Construction Levels much higher, up to 6.2 metres above mean sea level. This has major consequences for existing communities which are built around 2-3 metres above mean sea level. Approaches to meet new FCLs, such as raising land or raising individual houses, would affect neighbouring properties with issues such as drainage, solar access, and view blockage. In response to these concerns, new policy such as Design Guidelines and phasing plans would be required.

New housing forms would require a new set of guidelines associated with new and retrofit raised buildings. These could potentially integrate climate change mitigation and energy conservation requirements to address other Corporation policies and charters on greenhouse gas emissions and energy use.

Vulnerability assessments, particularly for sensitivity and adaptive capacity, would be an important requirement of raising new or retrofit buildings. For example, as buildings are raised, an assessment of the vulnerability of building occupants to flooding should be completed. Some populations are less able to physically move during a flood event. Location of facilities such as seniors housing and disabled facilities should be outside of the floodplain.

Increased density may help share the costs of raising houses. Attached houses, or even higher density clusters of raised houses within the sea level rise planning area may be a viable option for future consideration.

Precedents

King County Buyout and Elevation Program, Washington State

The King County Buyout and Elevation Program assists homeowners in raising their homes to accommodate higher flood construction levels to protect against current 100-year storm levels. Homes raised as a result of this program can significantly reduce their vulnerability to flood damage. The program retains existing housing stock and allows homeowners to remain in their homes (King County 2012).

Figure 4-52: King County Buyout and Elevation Program
image source: kingcountyfloodcontrol.org/pdfs/kcflood_river_and_floodplain_mgt.pdf

New Brunswick, Canada

Currently, adaptation strategies similar to Build Up are not used in Atlantic Canada, however there are local examples of houses built on top of elevated pylons. In these cases, individual homeowners have decided to modify their homes to protect against inundation resulting from storm-surges and sea level rise (Vasseur and Catto 2007).

Figure 4-53: Grand-Barachois (near Shediac), Northumberland Strait, southeastern New Brunswick
image source: nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/assessments/347

Floating foundations in Maasbommel, The Netherlands

The town of Maasbommel is a unique housing development along the Maas River that consists of houses built on foundations capable of floating during flooding events. The houses' foundations are constructed at the base of the riverbed, which allows the house to float during times of inundation. Flexible pipes keep the house connected to utilities when the houses are afloat (Palca 2008).

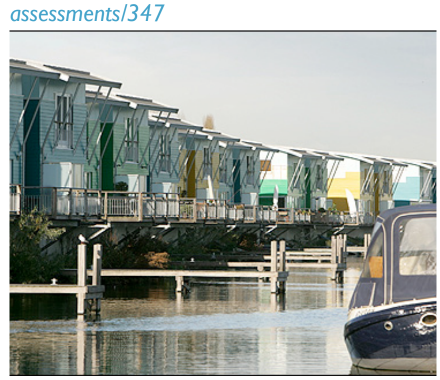


Figure 4-54: Maasbommell Floating Homes
image source: technovelgy.com/graphics/content08/holland-floating-house.jpg

Section 5: How Should Delta Move Ahead?

5.1 Recap and Overview

The Corporation of Delta is a low-lying municipality in the Fraser River delta, at considerable risk from climate change induced sea-level rise and storm surges. The Corporation has already shown leadership in addressing climate change, but there is a compelling need for further policy development and action to address these risks. The province has recently updated guidelines and tools for flood risk management; however, it is the responsibility of local governments to define their flood hazards, integrate these with land use planning policies and implement appropriate flood protection. Uncertainty in climate science and the lack of effective engagement tools has in the past made it difficult for local governments to build public support for flood-related policy and action. However, previous community-based research on climate change response options, including science-based visualization of various future adaptation scenarios, has proven effective in developing community awareness and support for adaptation needs in Delta and other Canadian communities.

The Delta RAC visioning project has been undertaken by UBC with funding from Natural Resources Canada under its Regional Adaptation Collaborative program and from the GEOIDE research network. The visioning project described in this report represents a key step toward more in-depth adaptation planning and decision-making for Delta. Building on previous studies, its goal was to provide new information, visualizations, and analysis for a range of potential community response options, as a basis for the Corporation to work with the community on developing plans for adapting to sea level rise and related implications. While the researchers at UBC's Collaborative for Advanced Landscape Planning (CALP) have benefitted from the full co-operation of Corporation staff and community stakeholder representatives as reviewers and advisors on this project, the study is not part of any official planning process. This report is provided to the municipality and the Delta community for their use as they see fit.

This section of the report summarizes the key assumptions and findings of the study, and provides recommendations on ways forward for Delta on flood-related planning generally and on alternative adaptation options.

Key Project Assumptions & Implications:

The Delta RAC visioning project is a preliminary study to advance community and government dialogue about adaptation to climate change induced sea level rise. More in-depth studies will be needed for the community to make hard decisions about how to adapt (see Section 5.3).

Sea levels are rising globally in response to increased carbon emissions, and various regional and local studies have projected more specific increases for BC's Lower Mainland. Drawing on the latest BC Ministry of Environment guidelines as the current best estimate of potential sea level rise in the Fraser River delta (assuming continued increases in global carbon emissions), the Delta RAC project assumed 1.2 metres of sea level rise by the year 2100. It should be recognized that the 1.2 metres level will be exceeded at some point, as sea level rise is projected to continue for several centuries due to time lags in the climate/ocean system. In light of accelerating rates of sea level rise, policy and planning processes should regularly re-evaluate climate science data as it becomes available, and update planning and policy accordingly.

Delta's resources and values at risk are likely to be affected by events to which rising sea levels will contribute: primarily overtopping and dike breach, leading to widespread flooding of varying depths and duration. Flood events are possible now, but will increase later if no effective adaptation action is taken. In planning for such flood risks, other factors need to be taken into account beyond sea level rise, such as occurrence of storm surges (temporary regional increases in sea level associated with weather systems), wave height, wave run-up etc. With sea level rise and without adaptive action, there could be cumulative inundation events in the Sea Level Rise Planning Area: over time, by 2100, parts of this area could flood multiple times.

Potential impacts of sea level rise include: property damage, threats to safety and livelihoods, impairment or loss of agricultural land viability through increased salinity, vegetation and habitat effects (inside and outside dikes), and various other socio-economic effects. These will put land values at risk and could significantly increase costs (see Section 3.4). With little or no effective adaptive action, the severity of impacts will depend in part on the growth in population and infrastructure in vulnerable areas of Delta over that time: broadly speaking, the greater the growth and development in low-lying areas, the higher the potential future impacts. This raises questions on the need and opportunities for focusing more growth in upland areas (eg. North Delta and Tsawwassen).

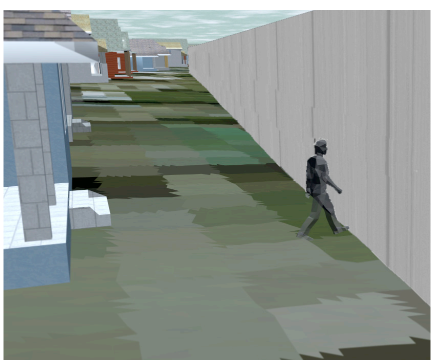
Other climate change issues and unrelated issues (eg. earthquakes, liquefaction, tsunami,) will need to be considered in future studies, potentially working in combining with sea level rise effects. This project did not examine the effects of Fraser River floods, rising energy prices, environmental refugees, accelerated climate change causing significantly faster sea level rise, salt wedge intrusion and drought, impacts due to extreme events (loss of life, etc.), and impacts on gravity-based storm water and wastewater systems.

5.2 Adaptation Scenarios & Specific Implications

It is important to remember that the adaptation scenarios described in this study are initial, exploratory "what-if" scenarios and not plans or proposals. They are intended as "dialogue starters" for policy-makers, practitioners, agencies, and the public. The intent here is not to select a preferred or recommended scenario, but to get a range of potential adaptation solutions out on the table and begin a rational process of considering their pros and cons. Other scenarios or blends of these scenarios may be relevant to the community, and would need to be considered and developed in greater detail in the next stage of planning.

Scenarios provide a framework to address holistic, future climate change possibilities and current and future response options. The objective is to describe complex and uncertain alternative future pathways as simply as possible in "plausible storylines" or scenario narratives, tied to quantitative modeling where possible.

In this study, they represent certain combinations of adaptation options, as described next for a hypothetical 2100 condition, and broadly consistent with the relevant new BC guidelines. It should be noted that the new guidelines significantly raise the recommended heights of dikes, sea walls, and flood construction levels of buildings, in comparison with existing levels, as a response to the worsening threats and improved understanding of sea level rise. Each future adaptation scenario has both pros and cons (see Table 5 for details). Some scenarios are more appropriate in specific communities within Delta than others. For this reason, we outline below key policy implications of each scenario that would need to be addressed if such a scenario were to be adopted somewhere within Delta.



Hold the Line Scenario

This ARMOURING scenario maintains, strengthens, and raises most of the existing 55 km of Delta's dike and seawall infrastructure in order to protect against sea level rise. By 2100, the dike infrastructure would maintain the current developed area boundary and there would be no net gain or loss of land with the exception of reduced intertidal habitat outside the dikes. It is assumed that Westham Island's sub-standard infrastructure would not be not upgraded, and the Island would eventually become an open space/habitat area that is seasonally inundated (assumed in all of these scenarios due to the costs of raising the substandard dikes).

Advantages: maintains high level of protection for most existing developed areas and farmland; no need to raise roads generally; least impact on current land uses.

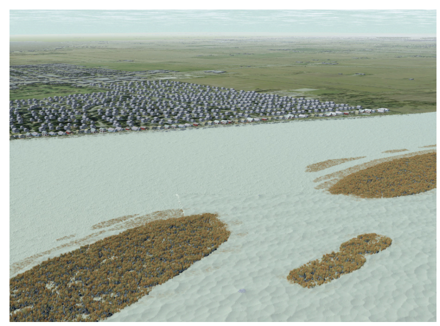
Disadvantages: high cost of raising dikes; major impacts on roads and coastal properties on or beside dikes ; view obstruction and socio-economic challenges of raised dikes and high sea walls on private property; still a risk of salinization due to saltwater intrusion to groundwater; reduced protection for Westham Island; continual need in the future for further dike raising; still some level of risk of dike breach.

Hold the Line Policy implications

Some policy implications of a Hold the Line approach are not addressed in existing policy. These include, but are not limited to:

- long-term financing for increased armouring (i.e. raising dikes and seawalls), including private financing on private lots
- timing of improvements
- the spatial land-use & transportation planning implications of larger dikes, such as road realignments and property impacts and their mitigation
- implications for agriculture, including the probability of subsurface salt water intrusion into the water table (specifically how this affects soil quality for agriculture) and other climate change impacts such as crop types, water table level, availability of quality irrigation, etc.
- the habitat effects of maintaining dikes while sea level rises (coastal squeeze on tidal wetlands)
- the best use and appropriate management/adaptation strategies for Westham Island
- long term growth policy, eg. permit population growth in floodplain areas versus focus growth on upland development, etc.
- changes to current enabling of housing development on dikes
- updating emergency management and response plans to respond to increased flood depths under sea level rise scenarios

Reinforce and Reclaim Scenario



This ARMOURING scenario is a variation on the Hold the Line scenario. It also maintains, strengthens, and raises most of the existing 55 km of Delta's dike and seawall infrastructure in order to protect against sea level rise. In addition, outer dikes would close off some areas from the river/sea (eg. Ladner Harbour and Deas Island to protect the Massey Tunnel exit). Ecologically functional barrier islands would be used to reduce the probability or extent of inundation along Boundary Bay. By reducing incoming wave energy off-shore, barrier islands would allow for slightly lower dikes or seawalls around Boundary Bay (and possibly elsewhere) as compared to those in Hold the Line.

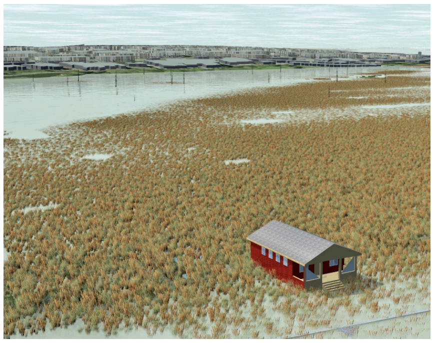
Advantages: Advantages are similar for Hold the Line, but this scenario can have lower or delayed seawalls and dikes to gain the same level of protection; possible habitat increase/more habitat management options for coasts squeeze effect. Cost issues were not evaluated.

Disadvantages: still requires significant costs of raising dikes; impacts on roads and coastal properties on or beside dikes (see Hold the Line).

Reinforce and Reclaim Policy implications

Implications of a Reinforce and Reclaim approach are not addressed in existing policy. These include, but are not limited to:

- Choice of armouring approach for each neighbourhood. Some may support more "soft" armouring, such as barrier islands, while other might choose "hard" armouring only, such as dikes and seawalls.
- Land use choices for barrier islands. Suggestions include:
  - habitat
  - agriculture (if viable)
  - energy generation, such as solar or wind farms



Managed Retreat

This "SOFT" option leaves existing dike and seawall infrastructure as is for many areas, reinforcing, maintaining and supplementing existing infrastructure to protect only the major population concentrations and Delta-wide assets in Ladner. As a result, over time, sea levels would more frequently inundate the remaining less-protected low-lying areas. Development currently located in these unprotected areas would be gradually relocated to higher-ground or Ladner, in a phased and planned retreat over several decades.

Advantages: reduces extensive dike raising costs (km of dike round Ladner?); opportunities for other uses such as expansion/restoration of wetland habitat on former farmland; eventually eliminates vulnerability in relocated neighbourhoods;

Disadvantages: cost of raising roads during transition for retreat from neighbourhoods; cost of new internal dike around Ladner possible neighbourhood concern and potential opposition to retreat; possible impacts of property values; compensation and buy-out terms uncertain at this point. Impacts on farmland and food protection due to more frequent flooding and salinization.

Managed Retreat Policy implications

Many implications of a Managed Retreat approach are not addressed in existing policy. These include, but are not limited to:

- Legal and cost burden implications of retreat
- Strategies for coordination and phasing of the retreat
- Mitigating social impacts and stresses
- Decision-making protocol for retreat/non-retreat areas
- Strategy for adapting agricultural lands
- Capacity of existing communities in upland areas to absorb more population

Build Up

This "SOFT" option leaves existing dike and seawall infrastructure as is across the Corporation of Delta. As a result, over time, with rising sea levels, water would more frequently inundate less protected low-lying areas. Current critical infrastructure such as hospitals, schools and fire halls would be raised, new residential development would be built to higher Flood Construction

Levels, and older residences would be gradually raised on an individual basis. Major roads would be raised, while minor roads would be left at current elevations. During inundation events, individuals would be responsible for their own properties and access. While it is likely that numerous inundation events would occur by the end of the century, data on the projected frequency of inundation events is not yet available.

Advantages: avoids extensive dike raising costs ad related impacts on adjoining properties; opportunities for expansion/restoration of wetland habitat or other uses on former farmland.

Disadvantages: high cost of raising roads and properties; view obstruction, solar access and socio-economic challenges of raising buildings within the neighbourhood; impact on farmland and food production due to more frequent flooding and salinization.

Build Up Policy implications

Some implications of a Build Up approach are not addressed in existing policy. These include, but are not limited to:

- Design considerations for raised flood construction levels;
- Coordination of raising existing homes/land to new FCLs;
- Financing for elevating critical infrastructure;
- Infrastructure and utility changes under a frequent inundation scenario; and,
- Strategy for adapting agriculture to a frequent inundation scenario and reusing former agricultural lands
- Strategy for access roads and emergency preparedness for flooding events

As can be seen from the above scenario descriptions, there will be no easy choices for Delta on sea level rise. A "no action" scenario would almost certainly lead at some point to increased flooding, property damage, reduced property values, high costs of restoration or compensation, loss of farmland, and potentially a public outcry. Impacts on Delta are also likely to have adverse effects on the region, especially in terms of food production. These are the likely costs of inaction.

There are though a variety of possible adaptation options and solutions to choose from, as shown by and extending beyond the four scenarios discussed here. The overall solution for Delta could well be a combination of several scenarios. However, all four of the scenarios examined bear high costs, involve some major community change through design and/or unavoidable environmental change, and raise some potentially contentious issues to be resolved. Developing community-wide and neighbourhood adaptation plans that are effective, economically feasible and acceptable to the community will take considerable time and effort. This means that, even though the community may have decades in which to develop and implement adaptation plans, early planning should not be delayed.

	Description	Baseline (current condition)	Hold The Line (future scenario)
Agricultural land	Total Agricultural land protected and unprotected	8,600 Ha	Protected: 7,800 Ha Unprotected: 800 Ha
Impacts to wildlife habitat	Qualitative effect on habitat	115 km of highly productive intertidal foreshore habitat 2,200 Ha of riparian habitat 9,500 Ha of intertidal habitat	Riparian habitat would not change significantly, intertidal habitat would decrease in extent due to “coastal squeeze” outside dikes
Land base	Total protected (by dike) and unprotected land	Sea level rise planning area: 10,200 Ha, most protected by current guidelines	Protected: 9,300 Ha Unprotected: 900 Ha
Transportation impacts (roads)	Total length of roads protected (raised) and unprotected (decommissioned)*	Roads in sea level rise planning area: 380 km	Protected (inside dike): 340 km Raised/reinforced: 0 km Decommissioned: 40 km
Infrastructure impacts (dikes / seawalls)	Total length of dikes protected (raised/reinforced) and unprotected (decommissioned)	Total dike length: 55 km (approximate)	Raised: 50 km Decommissioned: 5 km
Infrastructure impacts (facilities)	Total number of critical facilities affected (hospitals, fire, police, schools)	Protected: 20 Unprotected: 0	Protected: 20 Unprotected: 0
Impact to buildings	Number of buildings protected and unprotected	Protected: 8663 Unprotected: 0	Protected: 8511 Unprotected: 152
Culture/heritage impacts	Number of cultural/heritage sites protected by adaptive action	12	11
Land Value	Damage to private/public property from inundation event	$5.85 billion	$5.8 billion protected $49 million converted**

Table 4: Indicator measurements showing trade-offs among scenarios

Note:
* “Decommissioned” refers to infrastructure which is left as is but may not be maintained in the future.
** “Converted” refers to land that will be converted from its present use.

Reinforce & Reclaim (future scenario)	Managed Retreat (future scenario)	Build Up (future scenario)
Protected : 7,800 Ha Unprotected: 800 Ha	Protected: 1,700 Ha Unprotected: 6,900 Ha	Protected: 0 Ha Unprotected: 8,600 Ha
Riparian habitat would not change significantly, intertidal habitat would decrease less overall than in Hold The Line due to generation around barrier islands	Riparian and intertidal habitat would increase in extent	Riparian and intertidal habitat would increase in extent
Protected: 9,300 Ha Unprotected: 900 Ha + lands added in barrier islands	Protected: 2,200 Ha Unprotected: 8,000 Ha	Protected: 0 Ha Unprotected: 10,200 Ha
Protected (inside dike): 340 km Raised/reinforced: 0 km Decommissioned: 40 km	Protected (inside dike): 110 km Raised/reinforced: 30 km Decommissioned: 240 km	Raised/reinforced: 140 km Decommissioned: 240 km
Raised: 45 km Decommissioned: 10 km	Raised: 22 km Decommissioned: 33 km	Raised: 0 km Decommissioned: 55 km
Protected: 20 Unprotected: 0	Protected: 13 Unprotected: 7	Protected: 20 (if built up) Unprotected: 0
Protected: 8511 Unprotected: 152	Protected: 5688 Unprotected: 2975 (but not lost if all relocated to managed retreat area or higher ground)	Protected: 0 Unprotected: 8663 (but not lost if all built-up)
11	5	12 (if all built up)
$5.8 billion protected $49 million converted	$4.0 billion protected $1.9 billion converted	$3.8 billion in land sometimes inundated $1.6 billion in buildings “protected” if raised $408.5 million in buildings converted

5.3 Over-arching Recommendations for Advancing Adaptation

This section provides recommendations on how Delta can move forward on adaptation to sea level rise, in order to manage risks and to proactively and responsibly drive the agenda for building community preparedness. These recommendations apply regardless of which scenarios or adaptation pathways are adopted. They represent broad outcomes of the study and also reflect the experience of the research team over many years of community planning and public engagement on climate change and sustainability issues, in Delta and elsewhere. The recommendations take into account a number of important contextual factors likely to influence the success of further adaptation planning in Delta, including:

- Current public attitudes and awareness: research has shown in Delta and many Canadian communities that there are high levels of concern about climate change, but very limited awareness of effective adaptation and mitigation solutions, and often resistance to some of these solutions based on economic or quality of life concerns.
- The key role of the media: either helping to engage and inform the community about sea level rise, or contributing to polarized arguments and misperceptions on climate change related issues.
- Support of higher levels of government and other allied agencies: this support is critical to funding and partnerships for adaptation
- Access to critical scientific, engineering and costing data on the feasibility of possible adaptation measures and scenarios
- Other municipal planning and policy objectives that need to be met and which could support or conflict with adaptation goals
- Key planning horizons and local election cycles: providing suitable windows, time lines, and strategic incentives for key efforts and decisions to be taken.

These factors suggest the need for a dual strategy comprised of:

i) **a social learning and capacity-building program**, sustained over a period of several years, for the Delta community and municipal staff to become familiar with the realities of sea level rise and key concepts of climate change adaptation. This would embrace existing and new public engagement/educational opportunities, including methods such as those employed in this study and a media strategy to take advantage of media interest and responsible information dissemination. The goal is for an inclusive, structured, and informed public dialogue with shared learning on all sides, conducted well before major decisions are taken. Building public support for policy change and implementation of adaptation measures will be important in attracting funding and reducing uncertainties and costs.

ii) a planning process to develop needed information for decision-making, including input from all interested stakeholders and partners, and commissioning or sharing in new scientific and technical studies. The goals of this process would be to:

- Provide a strong basis for lobbying higher government and other potential funding sources;
- Identify and exploit win/win opportunities in meeting multiple objectives such as adopted carbon emission reduction targets and reducing dependency on fossil fuels, providing more jobs in Delta and developing the local tax base, safeguarding community assets such as wildlife and agricultural production, improved transit, etc.;
- Form strategic alliances with other communities and agencies on issues such as local food security, funding technical studies, etc.

In accordance with this dual strategy, Delta should consider the following steps as a possible road-map toward decision-making and action on sea level rise:

- **Plan for amending the OCP to systematically incorporate Sea Level Rise and related climate change issues**
  The current Official Community Plan has no reference to sea level rise. The next update should give more emphasis to these issues to ensure that future planning is resilient to future conditions. This provides an approximately 5 year window in which to establish the community capacity building program and planning studies. It also takes advantage of the period after the recent elections to initiate serious conversations on future critical issues.

- **Incorporate sea level rise planning into the ongoing activities and operations of the Corporation**
  This should apply across departments, wherever relevant, in order to avoid unforeseen legacies and costly inefficiencies through not thinking ahead. Opportunities to advance dialogue and adaptive planning through ongoing activities such as Local Area Plans, park plans, and community outreach programs should be seized in coordination with the larger strategy.

- **Adopt amended Sea Level Rise Planning Area terminology**
  The Ministry of Environment has recently proposed the creation of Sea Level Rise Planning Areas. For Delta, we recommend that this area be delineated as all lands below 5.6m. If there were to be a dike breach, lands within the Sea Level Rise Planning area could be inundated, although it is unlikely that the entire area would flood at the same time. The designation would trigger adaptive planning to sea level rise impacts within the vulnerable areas.

- **Link this project to Delta's ICLEI adaptation process**
The Corporation of Delta is currently working through the ICLEI process for municipal climate change adaptation. Sea level rise is probably the most far-reaching and iconic of the many impacts of climate change that will affect Delta. Outcomes and implications of this project should be integrated into the ICLEI process, in order to address important interactions with other climate change vulnerabilities, impacts, and adaptation/mitigation strategies.

- **Develop collaborations and alliances**
Adapting to sea level rise requires collaboration with neighbouring communities and many levels of government as stakeholders, co-funders, providers of additional staff and data resources, reviewers, etc. Below is an initial list of key partners likely to have an interest in sea level rise adaptation in Delta:

    - Tsawwassen First Nation
    - Musqueam First Nation
    - City of Surrey
    - Translink
    - Metro Vancouver
    - BC Hydro
    - BC Ministry of Transportation
    - BC Agricultural Land Commission
    - Fraser River Estuary Management Plan
    - Vancouver Fraser Port Authority
    - Federal Department of Fisheries and Oceans
    - City of Blaine, various Washington State Departments addressing similar issues

- **Develop and initiate a comprehensive Community Engagement Plan**
The residents of Delta should be engaged as soon as possible to begin the long process of discussing and planning for their community's future, in parallel with the necessary technical studies (suggested below). Though the actual implementation of planning choices may take place over decades, it is important for residents and stakeholders to feel heard and to share ownership of Delta's emerging approach to climate change adaptation.

    We have found that the local working group, representing all major stakeholders, is an effective way to gain early input and bridge to various community groups. Building on both the scenario visioning methods used in this study and the ICLEI program, a 2-3 year process should be conducted to build awareness and capacity. An early community survey would be very helpful in assessing the current state of knowledge and opinion, with a later survey to gauge progress in achieving increased preparedness and understanding of adaptation needs. Multiple community sectors and communication channels (eg. schools, websites, media outlets) will be necessary in order to reach people in their own cultural and geographic groups. Residents and stakeholders across Delta should be consulted, not just those located in the Sea Level Rise Planning Area, since there may be knock-on effects. Experts in various related topics could be brought in to inform discussions. Use of credible science-based visual media such as adaptation mapping, iconic visualizations, and images from built precedents elsewhere, should be used to gain attention, improve understanding, and help convince senior government and funding sources.

Existing and new or modified scenarios should be discussed and documented in the context of other community priorities.

This 2-3 year process to build an informed community and gather the most promising ideas on adaptation could then lead into a formal planning and consultation process for the OCP.

- **Begin detailed analysis**
  This project raised many important questions and issues that will need to be addressed through additional detailed study before the community can move forward with formal planning and decision-making. Some of these studies may be conducted through modifying ongoing budgeted processes, or could be shared with other partners. Delta should consider how to stagger these studies over the next 2-5 years. Needed studies include:

i. "No Action" Scenario developed in detail
A full study of impacts such as frequency of flooding projections and worst-case events with Fraser River flooding and rainfall intensity should be developed. This will also give a better understanding of damage costs and implications potentially avoided by the scenarios.

ii. Costing Studies
Undertake comprehensive assessments of the land, property, and ecological stock at risk and its value for the Delta community.

iii. Insurance and Disaster Relief Study
Consult with private insurance companies and all levels of government to get a better understanding of private and public flood insurance issues.

iv. Soil and Saltwater Intrusion Study
Undertake a study of agricultural soil quality and elevations in the Sea Level Rise planning area to get a better understanding of which agricultural parcels are most valuable in terms of soil quality, and which are less vulnerable to salinization of the water table. A study should be conducted to model and project potential saltwater intrusion of the groundwater table as sea levels rise.

v. Habitat Study
Undertake a detailed study of habitat within the Sea Level Rise Planning

Area and areas outside the dikes, to assess which parcels are most valuable, which are at risk to coastal squeeze, which could support habitat restoration, etc.

vi. Feasibility Study for Key Adaptation Measures
Undertake a study of feasibility of key adaptation options, and for the Build Up scenario in particular. Issues to consider are: how can infrastructure adapt over time, how can Build-up be accomplished on a parcel by parcel basis, etc.
Look at adaptation costs associated with each scenario. Future cost projections should consider implications of future cost increases in energy and other key variables.

vii. Unfunded liabilities study
Undertake a study of existing municipal infrastructure to determine how many years existing systems will last, how much is anticipated in on-going maintenance costs, and how much tax base is necessary to support these expenditures.

- **Do an area by area vulnerability analysis, then aggregate for overall planning.**
  Beyond the two case study areas modelled in this project, there are more case study areas with unique dike and other conditions that also need to be studied, such as Annacis Island and Westham Island. Risk assessments for flood control infrastructure and vulnerability, as well as adaptation opportunities, should be completed for all areas in the near future.

  Opportunities for synergies with other Corporation/Community objectives (such as reducing carbon emissions, developing more local jobs, and enhancing quality of life should be considered in these studies and in the OCP.

While climate change poses significant risks and challenges to Delta's community, there are many potential solutions to be debated and developed over time. It is hoped that studies such as this can foster further dialogue, policy development, and action in pursuing Delta's multiple objectives for the future.

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DELTA OVERVIEW

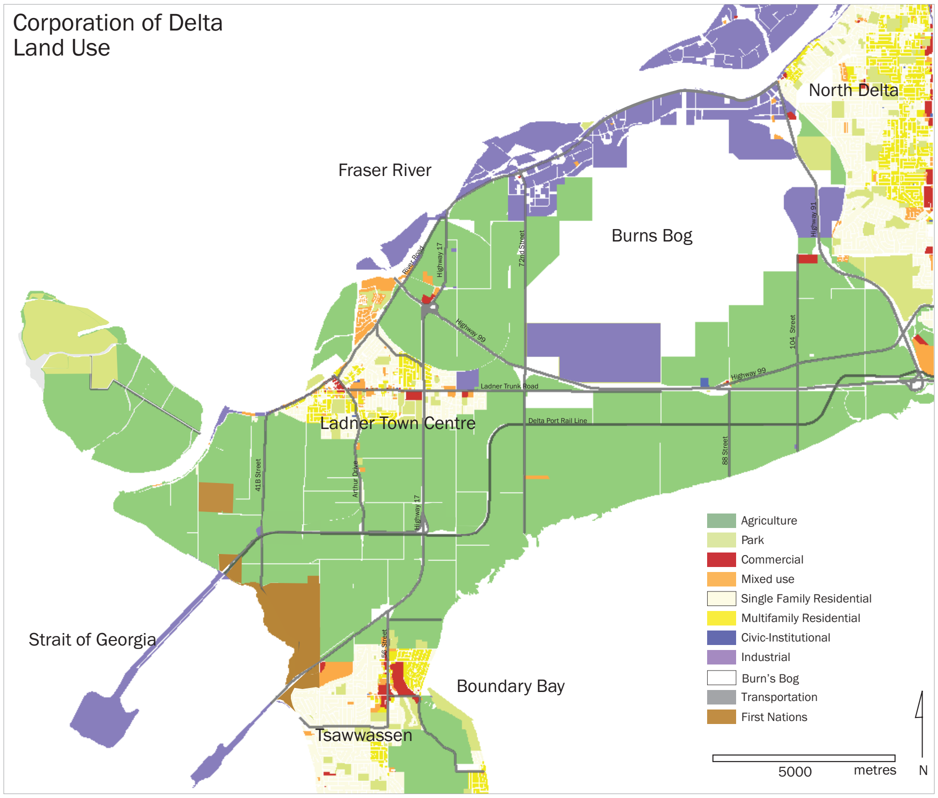
The suburban municipality of Delta, located in the southwest portion of Metro Vancouver, is made up of three urban communities: Ladner, located in the lowlands, and Tsawwassen and North Delta, located on higher ground. The suburban residential neighbourhoods of Boundary Bay Village and Beach Grove can be found in the lowlands along Boundary Bay. The Musqueam and Tsawwassen First Nation has treatied lands in Delta. Almost half of Delta is farmland, while one-fifth is Burns Bog.

Delta's population of just over 97,000 is projected to reach approximately 112,00 residents by 2021, with most of the increase in North Delta. Over 20,000 people live in Ladner, which has over 6000 residential lots.

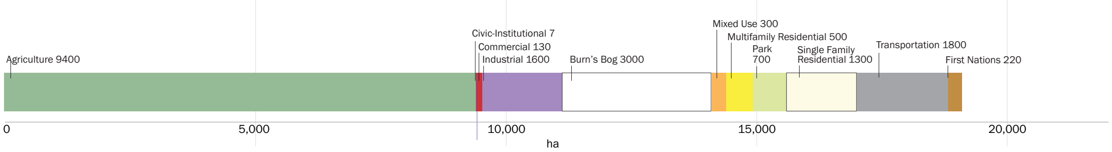
Delta has important transportation links for people and goods movement: Highways 99, 91, 17, and 10 cross Delta, connecting Canada to the United States, and the Lower Mainland to Vancouver Island and the Gulf Islands via the BC Ferries Terminal. Deltaport is the largest shipping terminal in the Lower Mainland.

Agriculture is an important industry, with approximately 200 farms generating about $161,000,000 of gross revenue. Soil-based agriculture - dairy, vegetables, and fruits - continue to play a significant economic role, while greenhouses are a growing sector.

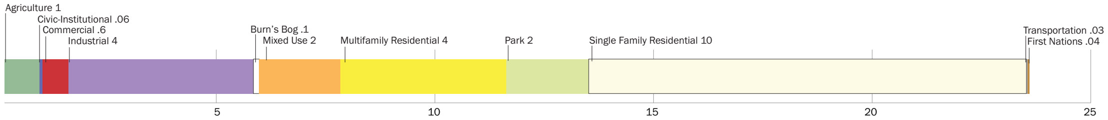
(Sources: Corporation of Delta Official Community Plan 2011; Delcan 2010)



Land Use by Area (ha)



Land and Building Value ($ billion) by Land Use

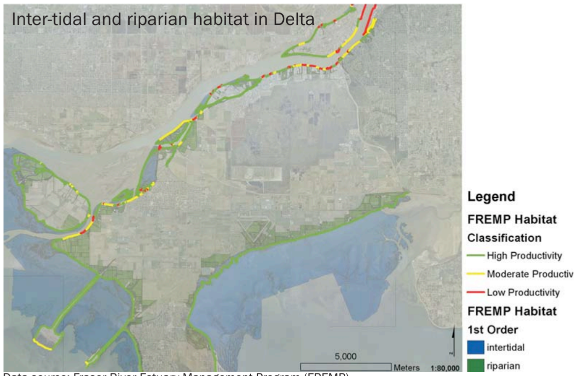


Land value was calculated by multiplying the area for each land use by the improved and unimproved value of the land (BC Land Assessment 2008 land use value data).

Habitat and Farming

Delta's wetland, estuarine, and upland habitats support the largest wintering populations of waterfowl, shorebirds and birds of prey in Canada. Up to 5 million migratory birds use the Fraser River estuary and delta as a vital stopover on the Pacific Flyway. Boundary Bay and its adjacent uplands represent the most significant migratory waterfowl and shorebird habitat on the Pacific Coast of Canada. Boundary Bay and the Ladner Marsh are provincial Wildlife Management Areas, and the Alaksen National Wildlife Area is located on Delta's Westham Island (adapted from Corporation of Delta, 2007 Revised OCP, Schedule A: 2-16).

"Farming... contributed to the early settlement of the municipality, and today, adds to the economy and to residents' quality of life. Farming also contributes to municipal and regional food sufficiency. Today, there are 10,085 hectares (24,929 acres) in the Agricultural Land Reserve (ALR)" (Corporation of Delta, 2007 Revised OCP, Schedule A: 2-24).



Data source: Fraser River Estuary Management Program (FREMP)

COMMUNITY VULNERABILITY TO INUNDATION

Delta's Sea Level Rise Planning Area

Possible Inundation Extent

The following set of images begins with a composite map of areas vulnerable to inundation in Delta, followed by more detailed maps showing the extent of inundation based on specific dike breach simulations for seven "dike reaches" (sections of dike) across Delta.

The modeling assumed peak water heights of 3.5 meters above sea level (GSC), which accounts for a winter storm surge event (with an unspecified return period), as well as wind and waves, and only 10cm of sea level rise (KWL 2007).

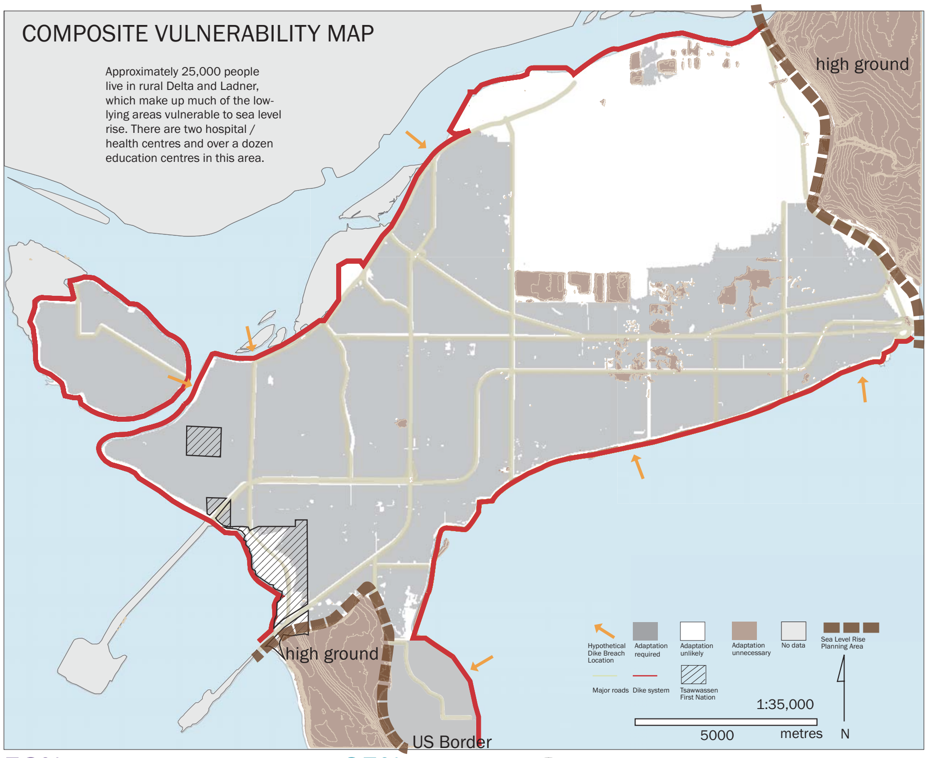
Dike overtopping could occur in some areas already, as shown by the final map in the series. It is assumed that considerable dike overtopping would lead to a breach (Delcan 2011). Inundation risk will increase with on-going sea level rise.

Sea Level Rise Planning Area

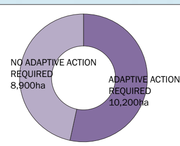
The mapped Adaptation Required areas (grey) correspond reasonably well to the new Ministry of Environment proposed Sea Level Rise Planning Areas, which for Delta is delineated as all lands below 5.6m, as shown.

If there were to be a dike breach, these areas could be inundated, although it is extremely unlikely the entire area would flood at the same time (see smaller maps below). As well, actual inundation damages will depend on the extent and depth of individual flood events, and how well prepared the community is (adequate Flood Construction Levels, emergency preparedness, etc).

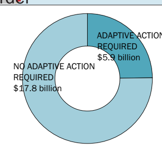
With sea level rise, and without adaptive action, there could be cumulative inundation events: over time, by 2100, parts of this area could flood multiple times.



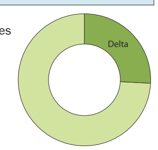
53% of Delta's total land area could be vulnerable to inundation



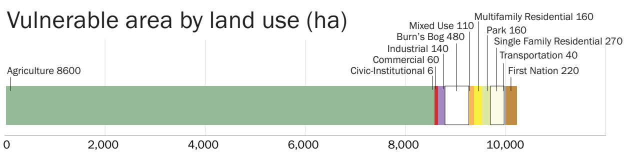
25% of Delta's total land value is within the Sea Level Rise Planning Area



Delta Supplies 26% of Metro Vancouver's gross farm receipts



Vulnerable area by land use (ha)

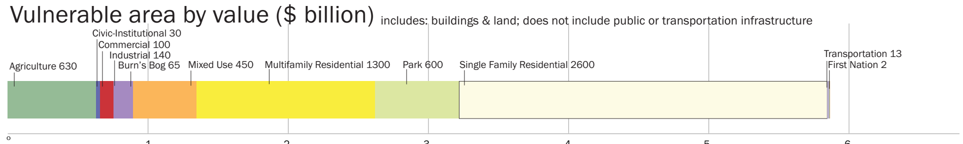


The low dollar valuation of agricultural land, compared to other uses such as single-family residential, accounts for the difference between the percentage of Delta's land area that is vulnerable, and the percentage of Delta's land and buildings value that is vulnerable.

Agricultural land values not measured by dollars include:
1. Character and community identity based on farming
2. Regional food security (farm production)

Vulnerable area by value ($ billion)

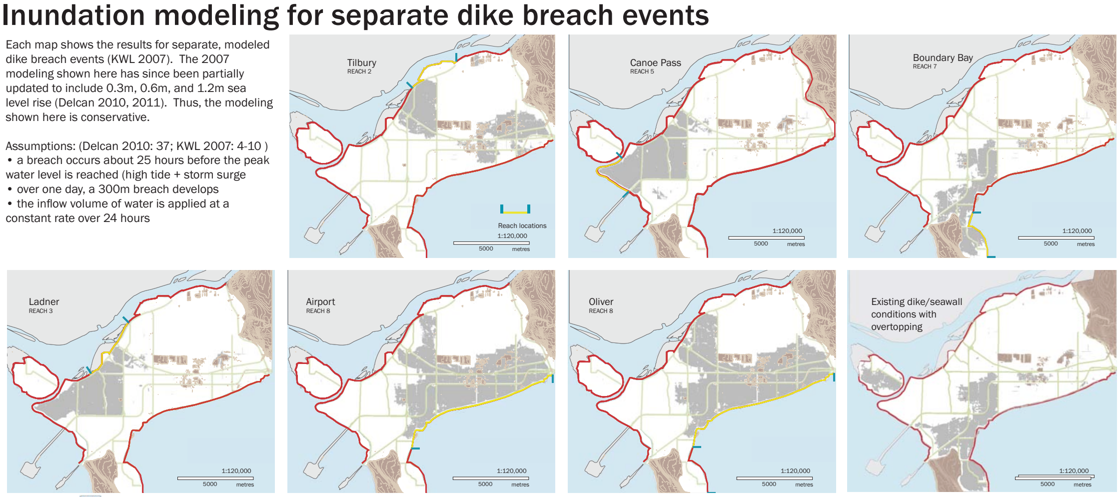
includes: buildings & land; does not include public or transportation infrastructure



Inundation modeling for separate dike breach events

Each map shows the results for separate, modeled dike breach events (KWL 2007). The 2007 modeling shown here has since been partially updated to include 0.3m, 0.6m, and 1.2m sea level rise (Delcan 2010, 2011). Thus, the modeling shown here is conservative.

Assumptions: (Delcan 2010: 37; KWL 2007: 4-10)
• a breach occurs about 25 hours before the peak water level is reached (high tide + storm surge
• over one day, a 300m breach develops
• the inflow volume of water is applied at a constant rate over 24 hours



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DELTA REGIONAL ADAPTATION COLLABORATIVE PROJECT

Project Context

The United Nations' Intergovernmental Panel on Climate Change released a portion of their 4th Assessment Report in February 2007. The report concludes that "unequivocal warming of the climate system" has, and will continue to occur because of human activities – primarily from the burning of fossil fuels and the resulting release of harmful greenhouse gases (GHGs).

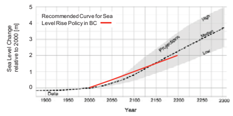
Corporation of Delta. *Climate Change Initiative: A Corporate Framework for Action.* 2009: 2.

Local Climate Change Impacts

Sea level rise is one of the direct impacts of anthropogenic (human-induced) climate change affecting coastal communities. In Delta, "**the net expected (including subsidence) regional sea level rise by 2100 for this area [Boundary Bay] is 1.2 m.**" (Ausenco-Sandwell. Sea Dike Guidelines, Appendix C. BC Ministry of Environment. 27 January, 2011: 11).

The province provides guidelines and tools for flood risk management; however, it is the responsibility of local governments to define their flood hazards, integrate these with land use planning policies and implement sufficient flood protection. The Delta-RAC project uses scenarios and 3D visualizations to explore a range of alternative response options to sea level rise, in order to support decision-making and policy development for flood management in the Corporation of Delta. This project is not a flood-risk management study, although it draws on prior studies for the Corporation of Delta, particularly the the KWL Flood Management Study (2007), the Delcan Flood Risk and Consequence Study (2010), and the Delcan Technical Memo on Sea Level Rise Dike Breach Analysis (2011).

This project has been funded by NRCAN under the Regional Adaptation Collaborative program, with additional support from the GEOIDE Networks of Centres of Excellence. Visualizations and indicators have been generated by the Collaborative for Advanced Landscape Planning at the University of BC; scenarios were developed with input from Delta staff. Many thanks to Dr. Stewart Cohen, the Fraser Basin Council, the Adaptation team at the Climate Action Secretariat, and John Readshaw. All errors and omissions are the responsibility of CALP, UBC.



Projections of Sea Level Rise in BC

Source: Ausenco-Sandwell. Sea Dike Guidelines. BC Ministry of Environment, 27 January 2011: 8.

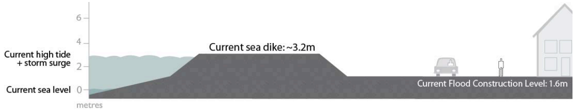
Why Adapt?

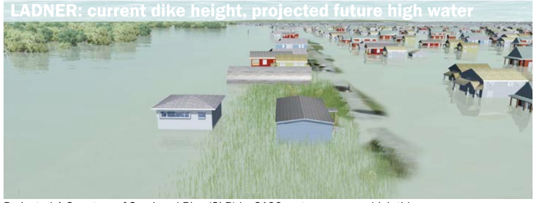
"A dike breach is assumed to be caused by overtopping [water flow or spray over the top of the dike]. The potential damages for a major dike failure range [in Delta] from $1 billion to $3 billion, not including any potential loss of human life. The highest potential damages occur when a dike breach affects the Ladner area" (Delcan 2010: 5).

"Applying a higher water level due to climate change without increasing the crest [height] of the dikes would result in overtopping the dikes all around Delta" (Delcan 2011: 5).

Storm surge + high tide (current high water level = 2.9m)

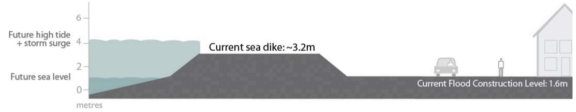
Ladner Dike Cross-Section
Current dike height, current high water





Projected 1.2 meters of Sea Level Rise (SLR) by 2100 + storm surge + high tide (Future high water level = 4.16m (Delcan 2011))

Ladner Dike Cross-Section
Current dike height, projected future high water



Sea level assumptions:
Current high water level of 2.9m: 0m mean sea level; 2m high tide; 0.9m storm surge
Future high water level of 4.16m: 1.2m sea level rise (including land subsidence); 2m hight tide; 0.9m storm surge
Wave run-up and wind set-up are minimal in Ladner and are included in storm surge
Dikes should also include 0.6m freeboard
(Delcan 2010: 59, MOE Sea Dike guidelines 2011)

Adaptation Options

The Corporation of Delta has approximately 60km of perimeter dikes and seawalls that protect its lowland areas. How should Delta adapt to Sea Level Rise over the next several decades?

Inundation RISK =

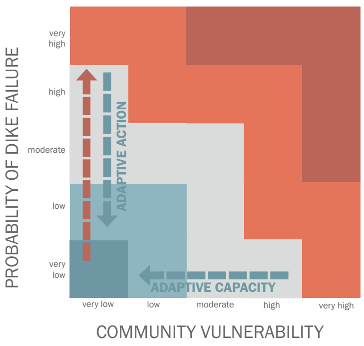
(Probability of Infrastructure Failure) X (Community Vulnerability)

The probability of infrastructure failure is due to many factors, including: dike construction, dike height, the intensity of storm events, and sea level rise.

Community vulnerability refers to the capacity of the community to cope with inundation events, and includes flood construction levels, raised roads, and emergency preparedness.

Risk Matrix

Sea level rise can increase the probability of dike and seawall failure, which increases the risk of an inundation event.



ADAPTIVE ACTION to improve protective infrastructure reduces the probability of infrastructure failure, moving inundation risk back down.

Increasing the community's ADAPTIVE CAPACITY reduces the consequences of a flood event, reducing risk from inundation.

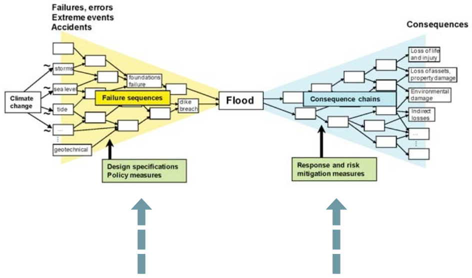
Quantitative Risk Assessment

Quantitative Risk Assessments (QRA) evaluate all the factors related to probability of infrastructure failure, which could lead to a flood event, and then also assess the community vulnerability or consequences of a single flood event (see below, adapted from MOE 2011, Draft Policy Discussion Paper: Appendix C). The Delta-RAC project does not include a QRA; however, it does assume a 100% probability of sea level rise to 1.2 meters over the next 100 years.

While a QRA can assess the probability and consequences of a single flood event, the Delta-RAC project assumes that multiple and cumulative events could occur as a result of sea level rise, if no adaptive action is taken. The project therefore explores the two different approaches to adaptation that the Corporation of Delta could choose to use in its climate change adaptation planning:

1. Improve protective infrastructure such as dikes and seawalls

2. Reduce community consequences by increasing adaptive capacity (eg.raising flood construction levels and road elevations)



Probability reduction occurs here: through improved dike and seawall infrastructure

Vulnerability reduction occurs here: increasing the community's adaptive capacity

C A L P

David Flanders, Kristi Tatebe, Ellen Pond, Glenis Canete, Jeff Carmichael, Sara Barron, Sara Muir Owen, Dr. Stephen Sheppard

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THE DAMAGE REPORT: Updated Sea Level Rise Modeling

These flooding maps show the modeled extent and depth of two inundations due to assumed dike breach events in Ladner (Chisolm Street) and Boundary Bay (the Regional Park). Each scenario assumes a combined high tide and storm event[1].

"Value" for the inundated areas is the current value of all the land and buildings that would be directly flooded. "Damages" is a percentage of the value, representing the potential actual costs of the flooding. Damages increase with increased inundation depths.

Source:
Delcan Technical Memo: Sea Level Rise Dike Breach Analysis. January 2011.

Dike Breach Modeling Assumptions

The Current Conditions scenario assumes current sea level, a storm surge, and high tide, with a peak water level of 2.96m[1]. The assumed dike [height, or] crest elevation of 3.56m, including 0.6m of freeboard, is typical of the current infrastructure in Ladner. Some of the Boundary Bay seawalls are currently substandard, but these were not modeled.

The 0.6 metre sea level rise scenario assumed a peak water level of 3.56 m, and that dike/seawall infrastructure was raised to 4.16m.

The 1.2 m sea level rise scenario assumed a peak water level of 4.16m, and assumed a raised dike/seawall crest height of 4.76m.

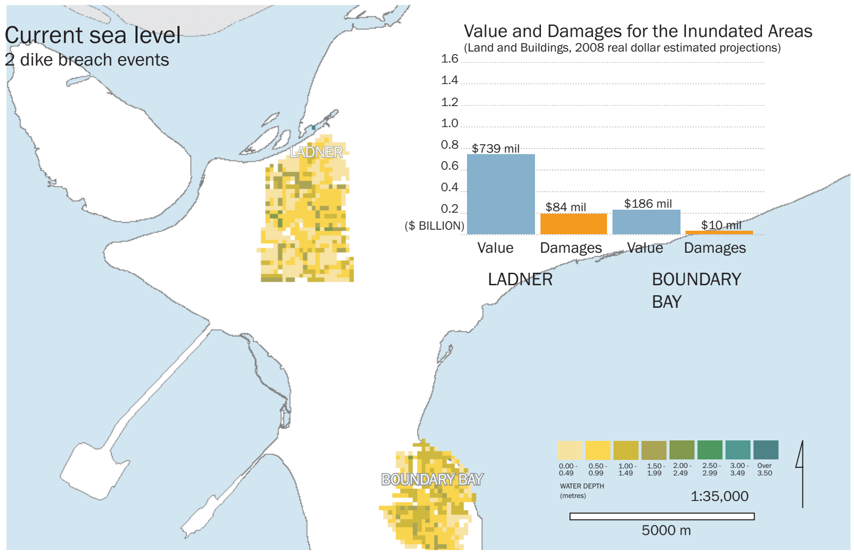
"The assumption is that the dike fails when the water level is at its peak or when the water level exceeds the crest [height] level of the dike at the breach location." (Delcan 2011: 5).

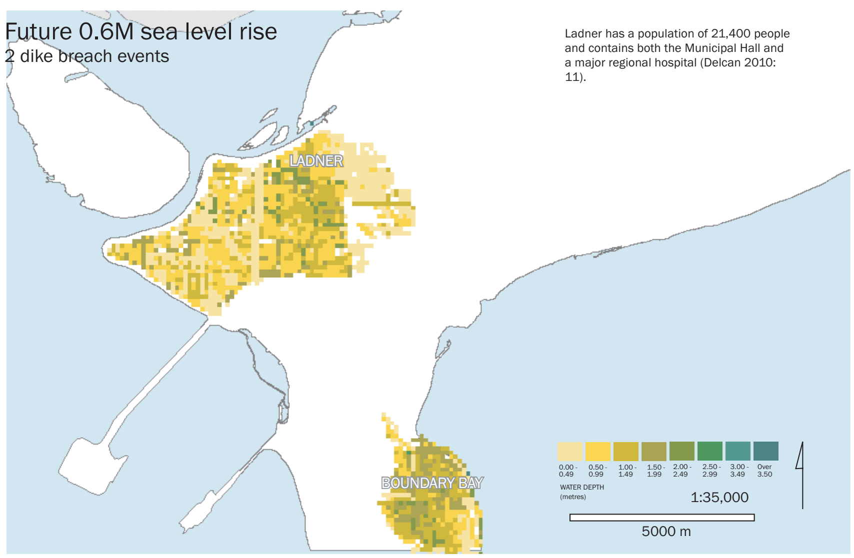
Value & Damages Modeling Assumptions

Land and Buildings Values were calculated based on the flooding extent and 2008 land use values[1].

Damages were calculated based on the flooding extent, land use, and damage functions (how much damage the inundation will cause, based on water depth and different land uses)[2].

Transportation damages, underground infrastructure (such as sewers), and indirect damages, (such as loss of production and transportation disruptions) were not assessed.





Footnotes
1. Modeling Method (Delcan 2011): the SOBEK computer model based on topographic and flood protection infrastructure data also includes storm surge events, the tidal cycle and sea level rise. A 1/200 year storm event was assumed, with a peak flood water level of 1.1m lasting 4 hours; the total storm event is assumed to be 35 hours.

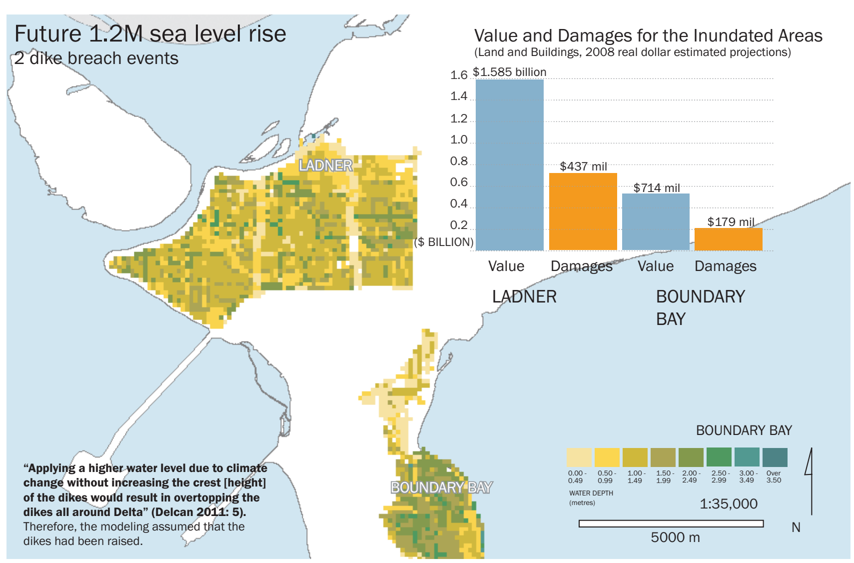
Note that the modeling may assume better performance of the internal flood cell boundaries (roads, rail lines) than might actually occur - some floodwater, even under current conditions, could move into adjacent areas (see Delcan 2010 for discussion of the internal or secondary diking system).

2. The value numbers include the value of the raw land, as well as structures and improvements on the property, and were calculated based on the area of inundation by land use, multiplied by the BC Assessment 2008 values for "unimproved" [raw land] and "improved" land. The Boundary Bay numbers include data for both Boundary Bay Village and Beach Grove.

3. Assumed damage functions:
a. Buildings:
   i. For the current scenario, with depths generally ranging from 0.5 - 1m, a damage factor of 0.15 was used
   ii. For the 1.2 m scenario, with depths generally between 1-2m, a damage factor of 0.25 was used for buildings
   iii. These depth-based damage functions were assigned based on Delcan's Damage Function for low-rise dwellings: at 1m depth, the damage factor is 0.5; at 2m, the damage factor is 0.8, and at 3m it is .92 (Delcan 2010: 14).
b. Agricultural raw land damage was assumed to be high, at 0.8, given the probable long-lasting damage caused by seawater inundation (see note below)
c. All other raw land damage was assumed to be 0.05, as the flooding lasts only from several hours to several days.

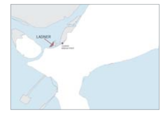
Saltwater flooding and agricultural land

"Continued or constant flooding could render the soil saline to the extent that most crop plants could not thrive and possibly survive. Our crop plants are not adapted, for the most part, to soils high in salts. One event would probably not render the soil uncultivatable, if drained away quickly and then the salts leached out with rain or irrigation. It may be that the soils are already high in salts (poor drainage and prone to salt accumulation anyway) and one more event would push them over the edge."
(Kent Mullinix, Ph.D., Institute for Sustainable Horticulture, Kwantlen Polytechnic University, email correspondence Sept 2011)



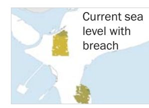
THE DAMAGE REPORT: Ladner Case Study

Visualization of the Delcan 2011 updated inundation modeling



Current conditions

current sea level with storm surge and high tide



Current conditions

current sea level with high tide and storm surge, modeled breach event

This current breach/inundation scenario probability is very low.

Future Conditions with 1.2m sea level rise

with 2 dike breach events

With no adaptive action, the Ladner dikes could overtop in the future, and the probability of infrastructure failure increases.

This future inundation scenario probability is higher than the current probability: the risk to Ladner **if no adaptive action is taken** is also higher.

CALP David Flanders, Kristi Tatebe, Ellen Pond, Glenis Canete, Jeff Carmichael, Sara Barron, Sara Muir Owen, Dr. Stephen Sheppard

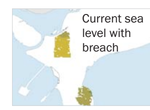
Funded by: Canada 10/12/2011

THE DAMAGE REPORT: Beach Grove Case Study

Visualization of the Delcan 2011 updated inundation modeling

Current conditions

current sea level with high tide

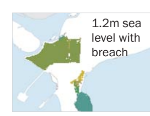


Current conditions

current sea level with high tide and storm surge, modeled breach event

Some of the current seawalls, especially along Boundary Bay Village, are below current provincial standards (Delcan 2011). This **current inundation scenario probability is low to moderate.**

With the breach point at Boundary Bay Regional Park, the risk to Beach Grove is low; however, historical overtopping events (eg. 2006) have occured resulting in flooding in Beach Grove.



Future Conditions with 1.2m sea level rise

with 2 dike breach events

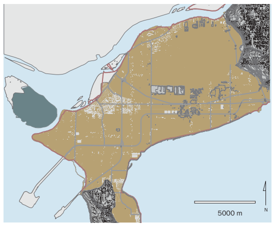
With sea level rise and no adaptive action, the seawalls will overtop during storms, and the probability of infrastructure failure increases.

The probability of this future inundation scenario is higher than the current probability, and the risk to Boundary Bay Village and Beach Grove **if no adaptive action is taken** is also higher.

RESPONSE OPTIONS: 3 SCENARIOS

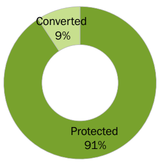
Who adapts or what adapts depends not only on the characteristics of the systems involved but also on the goals and values of the adaptors. The goal may simply be to manage the risk, to reduce exposure, or to address new opportunities. These different goals may lead to different strategies. (Cohen and Waddell, *Climate Change in the 21st Century,* 2009: 199)

HOLD THE LINE



This ARMORING scenario maintains, strengthens, and raises the existing 55 km of Delta's dike and seawall infrastructure, in order to protect against sea level rise. By 2100, the dike infrastructure holds the current Delta boundary and there is no net gain or loss of land, with the exception of Westham Island.

Agricultural land area



Most agricultural land is protected. Over time, a small amount converts to habitat.

Ecology & Habitat

– intertidal foreshore extent

+/– riparian extent

Coastal squeeze reduces the foreshore and intertidal estuaries.

Residences

8511 Protected

n/a Need to move

n/a Need to build up

.

Infrastructure

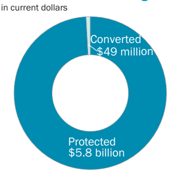
Critical infrastructure is maintained

Qualitative costs

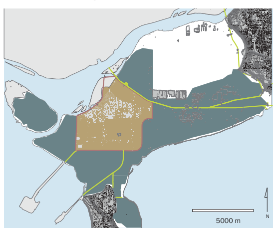
$ LOW - HOMEOWNERS

$$$ HIGH - GOVERNMENT

Value of land & buildings
in current dollars

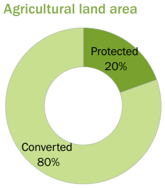


MANAGED RETREAT



This SOFT option leaves existing dike and seawall infrastructure as is for many areas, reinforcing and maintaining existing infrastructure only to protect Ladner. As a result, over time, storm surges and possibly tidal water will inundate unprotected low-lying areas. Development currently located in these unprotected areas is relocated to higher-ground or Ladner, in a phased and planned retreat.

Agricultural land area



Over time, significant agricultural land is converted to open space and habitat.

Ecology & Habitat

+ intertidal foreshore extent

+ riparian extent

Residences

5688 Protected

2973 Need to move

n/a Need to build up

Infrastructure

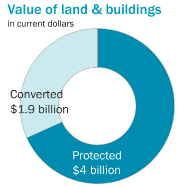
Critical infrastructure is maintained

Qualitative costs

$ LOW - HOMEOWNERS

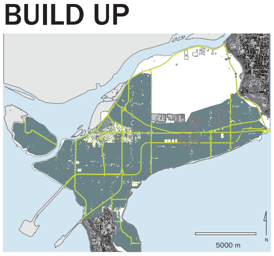
$$ MEDIUM - GOVERNMENT

Value of land & buildings
in current dollars

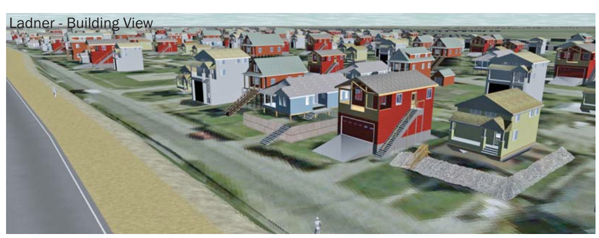


Over time, buildings are either protected or moved and land converts to habitat/open space.

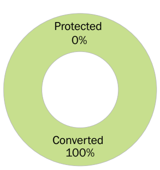
BUILD UP



This SOFT option leaves existing dike and seawall infrastructure as is across the Corporation of Delta. As a result, over time, storm surge and possibly tidal water will occasionally inundate unprotected low-lying areas. Current critical infrastructure such as hospitals, schools and fire halls are raised, new residential development is built to higher Flood Construction Levels, and older residences are gradually raised on an individual basis. Major roads are raised, while minor roads are left at current elevations. During inundation events, individuals are responsible for their own properties and access.



Agricultural land area



Over time, agricultural land transitions to open space and habitat.

Ecology & Habitat

+ intertidal foreshore extent

+ riparian extent

Residences

0 Protected

n/a Need to move

8663 Need to build up

Infrastructure

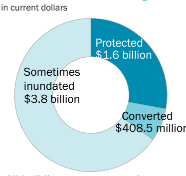
Critical infrastructure is maintained

Qualitative costs

$$$ HIGH - HOMEOWNERS

$ LOW - GOVERNMENT

Value of land & buildings
in current dollars



All buildings are assumed to be protected. Agricultural land converts to habitat over time. Residential lots and other land (non-agricultural) are sometimes inundated.

All indicators are measured for the Sea Level Rise Planning Area, excluding Burns Bog.

CALP
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Funded by: Natural Resources Ressources naturelles Canada 10/12/2011

HOLD THE LINE SCENARIO

1.2m Sea Level Rise, Year~2100

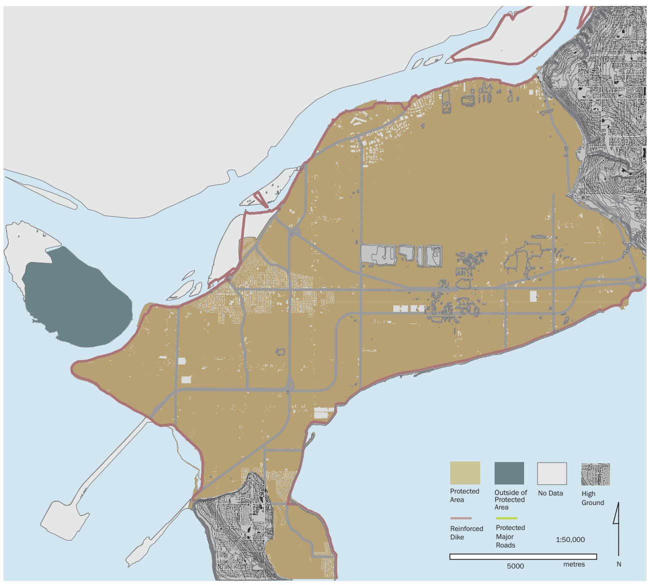
Description
This ARMORING scenario maintains, strengthens, and raises the existing 55 km of Delta's dike and seawall infrastructure, in order to protect against sea level rise. By 2100, the dike infrastructure holds the current Delta boundary and there is no net gain or loss of land with the exception of Westham Island. Westham Island infrastructure is not upgraded, and the Island eventually becomes an open space/habitat area.

Key components
dikes and seawalls

Infrastructure assumption
The dike system is built such that the probability of a breach or system failure is so low that in the context of planning, the dikes are "break proof".

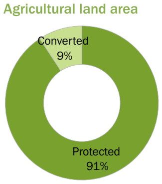
Responsibility
Corporation of Delta

Major costs
- dike and seawall infrastructure upgrades
- possible internal flood cell boundaries upgrades
- parcel buy-out where needed to accommodate larger dikes



The Hold the Line scenario proposes to upgrade Delta's dike and seawall infrastructure (red line) to protect Delta's low-lying areas from sea level rise.

Agricultural land area



Most agricultural land is protected. Over time, a small amount converts to habitat.

Ecology & Habitat

- intertidal foreshore extent

+/- riparian extent

Coastal squeeze reduces the foreshore and intertidal estuaries.

Residences

8511 Protected

n/a Need to move

n/a Need to build up

Infrastructure

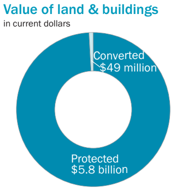
Critical infrastructure is maintained

Qualitative costs

$ LOW - HOMEOWNERS

$$$ HIGH - GOVERNMENT

Value of land & buildings
in current dollars



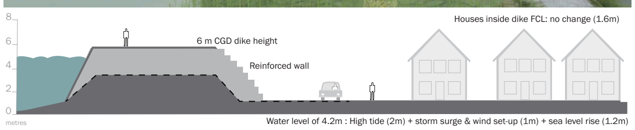
All indicators are measured for the Sea Level Rise Planning Area, excluding Burns Bog.

HOLD THE LINE SCENARIO

1.2m Sea Level Rise, Year~2100

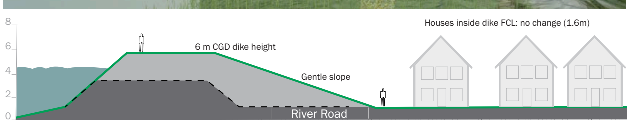
LADNER

This strategy shows a steep, concrete-reinforced wall in order to maintain the current right-of-way for River Road. The dike is only raised to 5.6m because there is less storm surge and wave run-up in Ladner than in Boundary Bay. Land use on top of the dike is no longer residential, but the dike can accomodate a greenway corridor with walking and cycling paths.



This strategy shows a landscaped berm with a more accessible 1:3 slope that avoids the need for hard reinforcement like the option above. The dike is raised on its centreline. As a result of this design, half of River Road's right-of-way is taken up by the dike, making it a one-way-only lane. Heavier vehicle circulation would be displaced to other streets.

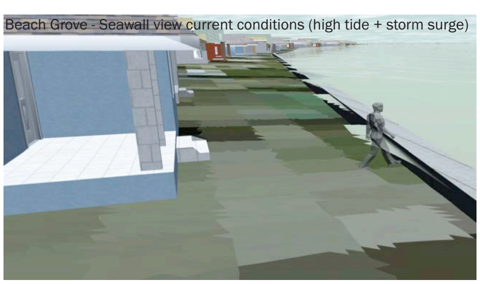
This section shows an option where the dike is raised inward, not on centreline, in order to avoid altering the Fraser River shoreline. This would avoid reducing shoreline stability, but would result in even less space available for River Road.



BEACH GROVE

The 2011 provincial Dike Guidelines suggest a top-of-dike height of 6.9m (CGD) for the Boundary Bay area.

Experts have suggested that with a vertical seawall, the wall would need to be higher than an earthen dike because of the increased wave action associated with a vertical barrier (wave run-up). Considerable coastal engineering measures, such as concrete "tetrapods" to reduce the impact of waves and storm surges, could also be required.



Horizontal scale from the seawall to Tsawwassen and vertical scale of the Tswwassen bluff have been compressed.

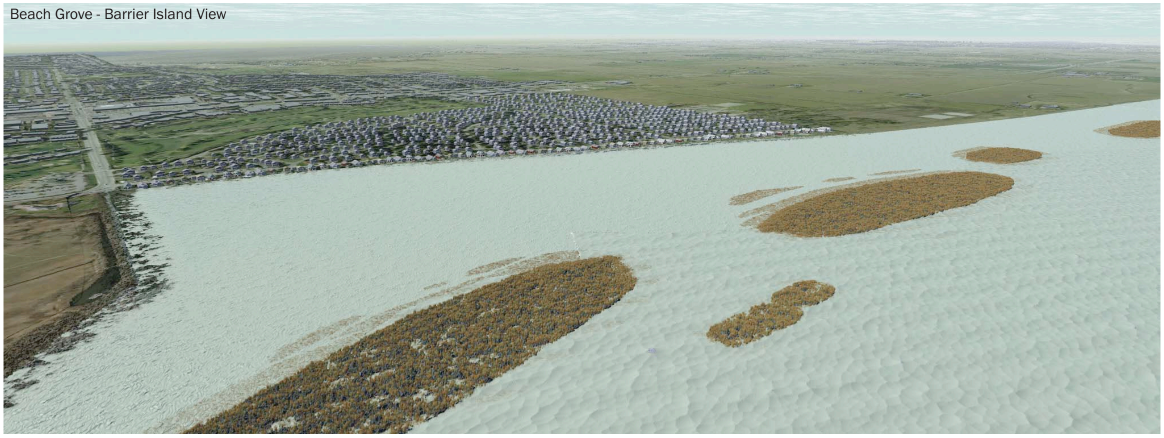
Water level of 4.9m : High tide (2m) + storm surge (1.3m) + sea level rise (1.2m) + wind set up (0.4m)

CALP UBC David Flanders, Kristi Tatebe, Ellen Pond, Glenis Canete, Jeff Carmichael, Sara Barron, Sara Muir Owen, Dr. Stephen Sheppard

Funded by: GEOIDE Natural Resources Canada Ressources naturelles Canada Canada 10/12/2011

REINFORCE & RECLAIM SCENARIO

1.2m Sea Level Rise, Year~2100



Description

This soft ARMORING sub-scenario of Hold The Line maintains, strengthens, and raises the existing 55 km of Delta's dike and seawall infrastructure, built to higher standards, in order to protect against sea level rise. In addition, outer dikes close off some areas from the river/sea (eg. Ladner Harbour, and Deas Island to protect the Massey Tunnel exit). Ecologically functional barrier islands could be used to reduce the probability of inundation around Boundary Bay. By reducing incoming wave energy off-shore, the barrier islands would allow for slightly lower dikes or seawalls around Boundary Bay, as compared to those in Hold the Line.

Key components

dikes and seawalls; barrier islands; beach nourishment

There are potential small gains in usable land, and in habitat areas. This scenario works to reduce coastal squeeze and to maintain and/or improve inter-tidal habitat.

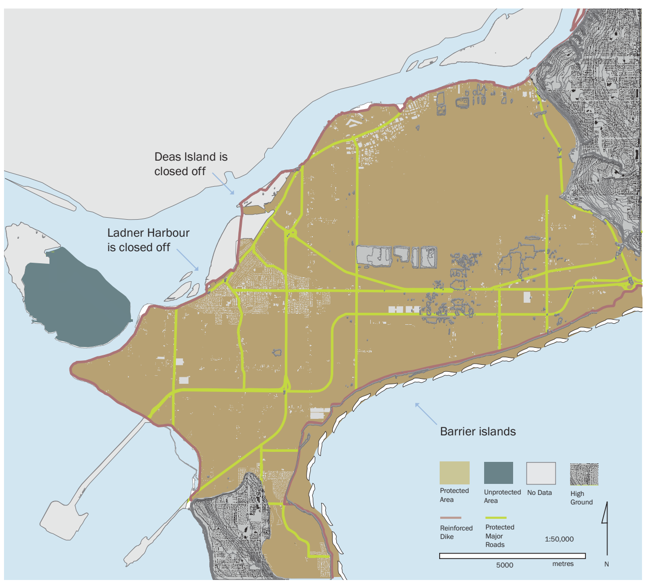
Westham Island infrastructure is not upgraded, and the Island eventually becomes an open space/habitat area.

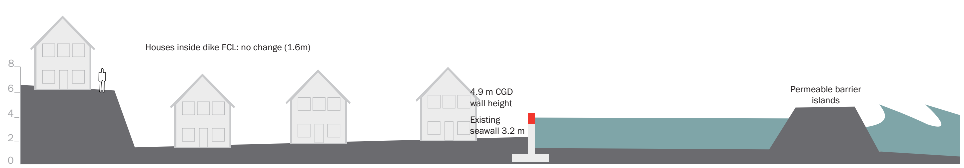
Responsibility

Corporation of Delta

Major costs

- Dike and seawall infrastructure upgrades
- Dike additions (eg. Ladner Harbour)
- Internal flood cell boundary upgrades
- Parcel buy-out where needed to accommodate larger dikes
- Barrier islands; other beach nourishment measures





Horizontal scale from the seawall to Tsawwassen and vertical scale of the Tswwassen bluff have been compressed.

Water level of 4.9m : High tide (2m) + storm surge (1.3m) + sea level rise (1.2m) + wind set up (0.4m)

CALP UBC David Flanders, Kristi Tatebe, Ellen Pond, Glenis Canete, Jeff Carmichael, Sara Barron, Sara Muir Owen, Dr. Stephen Sheppard

Funded by: Natural Resources Ressources naturelles Canada 10/12/2011

MANAGED RETREAT SCENARIO

1.2m Sea Level Rise, Year~2100

DESCRIPTION

This SOFT option leaves existing dike and seawall infrastructure as is for many areas, reinforcing existing infrastructure only to protect Ladner. As a result, over time, storm surge and possibly tidal water will occasionally inundate unprotected low-lying areas. Current development located in these areas is relocated to higher-ground, in a phased and planned retreat.

There is an overall loss of productive land, particularly agricultural, and an overall gain in habitat, given that "continued or constant flooding could render the soil saline to the extent that most crop plants could not thrive and possibly survive" (Mullinix, Institute for Sustainable Horticulture, email correspondence 2011); "flooding frequently would damage soils almost permanently" (Butler, Delta Farmers' Institute, email correspondence 2011)

Key components

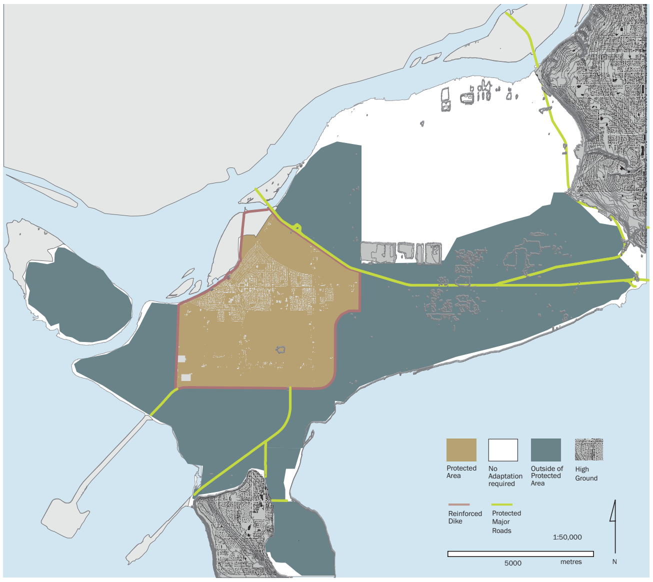
Phased removal of a few neighbourhoods

Some increased density in highland areas to accomodate lowland residents

Responsibility

Corporation of Delta

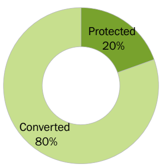
Ladner - Aerial View



The Managed Retreat scenario maintains, strengthens, and raises Delta's dike and seawall infrastructure around Ladner (red line). Buildings and infrastructure outside of this area are gradually removed in phases, leaving the land to inundate during during storm surges and/or high tide.

Beach Grove - Aerial View

Agricultural land area



Over time, significant agricultural land is converted to open space and habitat.

Ecology & Habitat

+ intertidal foreshore extent

+ riparian extent

Residences

5688 Protected

2975 Need to move

n/a Need to build up

Single family residence parcels in sea level rise planning area.

Infrastructure

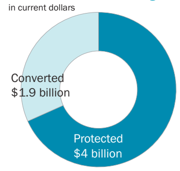
Critical infrastructure is maintained

Qualitative costs

$ LOW - HOMEOWNERS

$$ MEDIUM - GOVERNMENT

Value of land & buildings
in current dollars



Over time, buildings are either protected or moved and land converts to habitat/open space.

All indicators are measured for the Sea Level Rise Planning Area, excluding Burns Bog.

CALP David Flanders, Kristi Tatebe, Ellen Pond, Glenis Canete, Jeff Carmichael, Sara Barron, Sara Muir Owen, Dr. Stephen Sheppard
Funded by: Natural Resources Canada Ressources naturelles Canada Canada 10/12/2011

MANAGED RETREAT SCENARIO

1.2m Sea Level Rise, Year~2100

LADNER

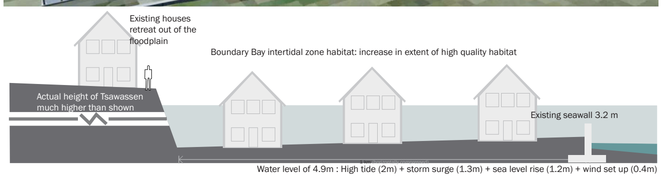
In Managed Retreat, the Township of Ladner is protected by improved dike infrastructure, similar to that in Hold the Line. Internal “secondary” dikes also protect the township.

MANAGED RETREAT PHASING

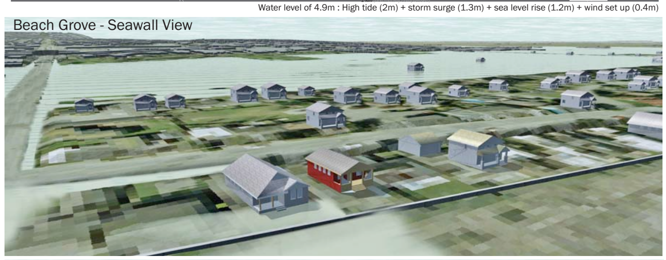
BEACH GROVE

Existing

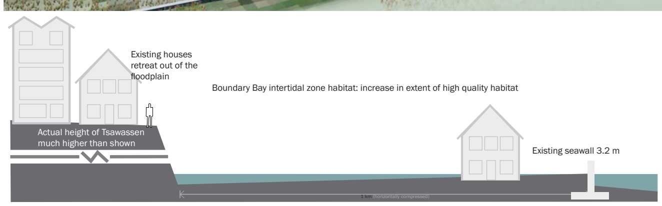
In this incremental, managed retreat scenario, Beach Grove Road, 12th and 16th Avenues are raised to ensure reliable access to the community while early adopters begin moving out of community.



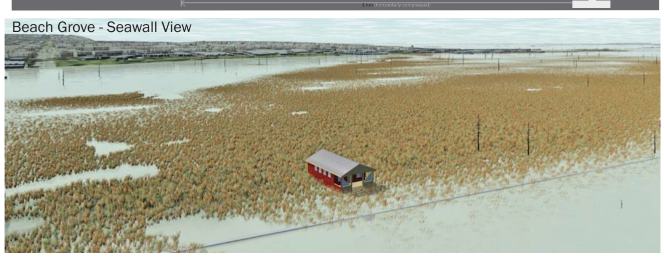
Gradually, due to periodic inundations, more community members migrate to higher grounds in the Tsawwassen area.



With continuing sea level rise, inundations occur more frequently and severely, and more home-owners are bought out as the coastline re-aligns. Beach Grove begins to transform from a neighbourhood of permanent residences into an area with cabins, and the raised access roads are no longer maintained.



After a transition lasting many decades, the neighbourhood of Beach Grove returns to an ecologically rich area as the intertidal zone migrates inward across the floodplain. Tsawsassen may experience a population increase as residents migrate to higher lands.



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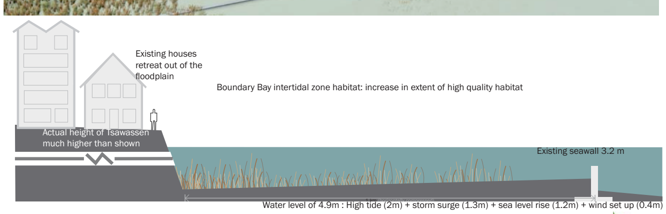


BUILD UP SCENARIO

1.2m Sea Level Rise, Year~2100

DESCRIPTION

This SOFT option leaves existing dike and seawall infrastructure as is across the Corporation of Delta. As a result, over time, storm surge and possibly tidal water will occasionally inundate unprotected low-lying areas.

Current critical infrastructure such as hospitals, schools and fire halls are raised, new residential development is built to higher Flood Construction Levels, and older residences are gradually raised on an individual basis. Major roads are raised, while minor roads are left at current elevations. During inundation events, individuals are responsible for their own properties and access.

If agricultural lands are not built up, there would be an overall loss of agriculturally productive land, and an overall gain in habitat.

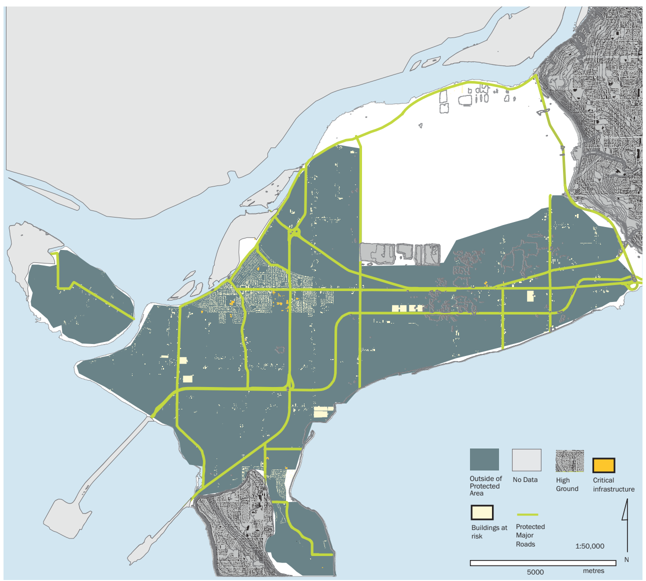
Key components

Raised buildings (Flood Construction Levels)
Raised major roads

Responsibility

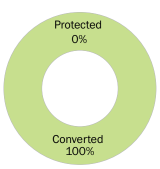
Community infrastructure (hospitals, schools, fire halls, roads): Corporation of Delta

Individual Residences: developers (new) and home-owners (existing)



The Build Up scenario does not strengthen or raise Delta's dike and seawall infrastructure. Instead, critical major roads (green lines) and infrastructure such as hospitals and schools (orange areas) are raised and protected, while individual residents are responsible for raising and protecting their own homes.

Agricultural land area



Over time, agricultural land transitions to open space and habitat.

Ecology & Habitat

+ intertidal foreshore extent

+ riparian extent

Residences

0 Protected

n/a Need to move

8663 Need to build up

Single family residence parcels in sea level rise planning area.

Infrastructure

Critical infrastructure is maintained

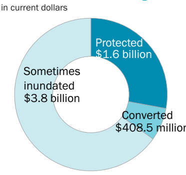
Qualitative costs

$$$ HIGH - HOMEOWNERS

$ LOW - GOVERNMENT

Value of land & buildings

in current dollars



All buildings are assumed to be protected. Agricultural land converts to habitat over time. Residential lots and other land (non-agricultural) are sometimes inundated.

All indicators are measured for the Sea Level Rise Planning Area, excluding Burns Bog.

BUILD UP SCENARIO

1.2m Sea Level Rise, Year~2100

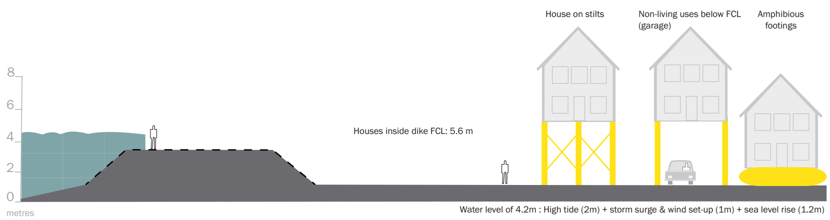
LADNER

Houses are built to a Flood Construction Level of around 6m elevation above mean sea level, or 4.5m above the ground surface in this neighbourhood. They could alternately be equipped to float. Homes that are not raised could face several meters of water during times of inundation.

As an alternate option, the houses could be raised by filling the land underneath. How to address property line elevations, as different home-owners raise their land at different times, would need to be addressed. Land raising might thus be the preferred option for new development rather than for existing homes.

Ladner - Building View

Ladner - Building View



Ladner - Street View

Delta-RAC Preliminary Policy Review

December 30, 2011

Kristi Tatebe with support from: Ellen Pond, Sara Muir Owen.

This report was produced as a first step towards the final Policy report, and remains in a preliminary, draft form.

UBC-CALP RAC Preliminary Policy Review

Table of Contents

UBC-CALP RAC Preliminary Policy Review

Introduction

The Corporation of Delta is a low-lying municipality in the Fraser River delta, at considerable risk from climate change induced sea-level rise and storm surges. Many different policy documents at both the Provincial and local government levels relate to flood management, and it is the purpose of this document to identify and clarify the relationships between these many documents and jurisdictions. This document is a precursor to a report that will make recommendations on adaptation policy in the Corporation of Delta based upon evaluations conducted as part of the BC Regional Adaptation Collaboratives project undertaken by UBC's Collaborative for Advanced Landscape Planning, in partnership with the Corporation of Delta. It is a first step that will enable the research team, and the Corporation to understand the complex web of interacting policies that influence adaptation decision-making.

Flood Policy in BC

Relationship between provincial and municipal policies

In 2003, Bill 56 (**the Flood Hazard Statutes Amendment Act**) was passed by the BC Government. This amended the **Local Government Act** to enable local governments to designate flood hazard areas, flood construction levels and setbacks. In effect, this Act devolved responsibility for flood protection to local governments. However, the Province still retains regulatory authority over flood protection structures (e.g. dikes). Under the **Dike Maintenance Act**, the Inspector of Dikes (IOD) has the authority over flood protection structures. The Ministry of Environment regulates local diking authorities via regional Deputy Inspectors of Dikes around the province. All new flood protection projects, as well as updates or repairs to existing structures must be approved by the IOD prior to construction. Although dikes and other structures are inspected by the Provincial Inspector of Dikes, local governments are responsible for the required maintenance, upkeep, and upgrading of these structures. Other Provincial legislation referring to flood management include the **Drainage, Ditch and Dike Act**, which deals with the administrative aspects of diking including construction, taxes, enforcement, expropriation, compensation, asset transfer etc. Flood response in BC is governed by the **BC Emergency Program Act**. The act gives local authorities the ability to declare local states of emergency to respond to flood disasters.

UBC-CALP RAC Preliminary Policy Review

While these Acts are legislation, the Province also has a series of guidelines that are intended to assist local governments in fulfilling the terms of these Acts.

Guidelines for flood protection in BC

- The **Guidelines for Management of Flood Protection works in British Columbia** were published by the province to assist communities in meeting the dike safety requirements set out by the Act, and outlines and consolidates current practices regarding the management of dike structures in the province.
- The **Dike Design and Construction Guide** outlines basic dike design and construction in BC, following good engineering practice. It is intended to help design professionals resolve questions or address situations they are likely to encounter regarding flood protection works. This document includes technical requirements to meet for freeboard, slope stability under seepage, erosion, piping through structures, drainage, access, practicality and cost. In BC, the standard design flood is the 200-year event for river flooding, and for sea dykes, the event with a 0.5% probability of occurrence. The document also states that it is preferred that dikes be setback rather than constructed waterside, for environmental and maintenance advantages. Total recommended dike crest heights are determined taking into account storm surge, wave run-up, and tidal fluctuations. In this document, climate change is referred to as having impacts that should be discussed with the proponent upon application, and uses a 2002 reference.
- The province also has **Flood Hazard Area Land Management Guidelines** that provides direction in terms of the regulatory tools available to local governments, floodplain mapping, minimum setbacks and flood construction levels for a range of land uses. Some of the regulatory tools outlined include Official Community Plans, Bylaws and Development Permits, subdivision approvals, and covenants. The guidelines outline application by hazard area, including the Strait of Georgia. For this area, recommended setbacks from the sea are 15 metres from the natural boundary (high water line), and Flood construction level (FCL) at least 1.5m above the natural boundary elevation. In areas protected by dikes as well, buildings must be setback from the dike by 7.5 metres, and FCL's for the stream, river or sea adjacent to the dike also followed. The guidelines also provide application information for specific land uses, and for implementation methods including landfill, and erosion protection. Appendices are provided that give local governments policy language to use in crafting bylaws, policies, and covenants.

UBC-CALP RAC Preliminary Policy Review

The Ministry of Environment is working to update these guidelines to better reflect new estimates of sea-level rise. This updating is a parallel project in the BC RAC, and includes the production of 3 new documents (currently in draft form): **Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use; Climate Change Adaptation Guidelines for Management of Coastal Flood Hazard Land Use, and Climate Change Adaptation – Draft Policy Discussion Paper.**

Other existing guidelines include:

- The **Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment**: outlines management techniques to control vegetation on dikes for the purpose of ensuring the structural and functional integrity of dike structures.
- The **Riprap Design and Construction Guide:** outlines design and construction of erosion-protection works to protect dike structures.
- The **Flood Protection Works Inspection Guide:** addresses all aspects of dike inspection – scheduling, record keeping, observations during an inspection, maintenance, and tracking.
- The **Operation and Maintenance Manual for New Works Template:** is intended to specifically address management and maintenance of new flood control structures.
- The **Dike Operation and Maintenance Manual Template:** is meant to assist local authorities with record-keeping regarding the ongoing operation and maintenance of flood protection works.

Areas of Jurisdiction that municipalities have impacting flood control/flood management

In addition to the Provincial Government's many acts and guidelines for flood protection, local governments have many tools at their disposal for dealing with flood management and protection, as mentioned in the Local Government Act and Flood Hazard Area Land Management Guidelines. Municipalities can set flood hazard area bylaws without BC Government approval, but with consideration of Ministry policy and the guidelines described above. In addition, municipalities can set guiding strategies/initiatives to direct and create a cohesive direction for other municipal bylaws and policies. Delta's 2007 "Climate Change Initiative" is one example of this kind of high-level policy, which reaches across departments and charts a direction for other specific bylaws, to provide a cohesive set of tools that help achieve a strategic goal. Tools that local governments can use to help achieve goals set out in these higher level strategies include **bylaws** – both traditional planning documents (Official Community Plans, Local Area Plans etc. that can designate Development Permit Areas for particularly flood-prone regions or take longer-term action (e.g. to restrict development in hazard areas)), and other bylaws such as subdivision bylaws, building and plumbing bylaws, etc. that may have important, though perhaps less immediately obvious impacts on flood management in a local government. As they are enacted as laws, bylaws are enforceable and one of the main ways that local governments can direct on the ground change in terms of adaptation and mitigation. Ideally, bylaws should uphold overarching policies (e.g. the Climate Change strategy in Delta).

Of course, money is needed to uphold policies in order for implementation to occur – **Financial Plans** can give insight into political priorities as well and hint at the potential success of implementation.

Flood Policy in Delta

History of flooding in Delta

Delta is a municipality in the Fraser River Delta of BC. Because of the coastal delta setting, Delta faces flooding both from the spring freshet on the Fraser River, and from storm surge and high tide events from the strait of Georgia (more likely in the winter months). Currently, much of Delta is protected by dikes and a drainage/pumping system. In written history, the greatest flood on record occurred in 1894 and affected much of southern BC. However, not much structural damage was sustained due to minimal development in the area. This was not the case in the 1948 flood when dikes failed. 10 people died, 2000 homes were lost and 16000 people were evacuated. It is estimated that the same event today could cause est. $1.8 Bil. In damage in the Fraser Valley (Corporation of Delta, 2009).)

Climate change adds uncertainty and increases the likelihood of extreme events as time passes, as well as contributing to a rising sea level. This will contribute to an increased risk of flooding, from the Fraser River but especially from the ocean during winter storm surge and high tide events. (Bornhold, et. al, 2008). More recently, in 2006 Delta experienced storm-surge flooding (resulting from a high tide coinciding with a storm surge) in a seaside community protected by a seawall. Extreme weather events and sea level rise will only make events such as this more common in the years to come. IN light of this increasing risk, Delta has a number of policies relating to climate change and flood protection in the municipality.

Overarching Policy

Delta has been recognized for its 2007 **Climate Change Initiative**. This is a cross-department initiative that is made up of 9 plans, all dealing with some aspect of climate change adaptation or mitigation, across a range of sectors. These plans include the following:

- The **Building Energy Efficiency Plan** (1 page) outlines strategies to reduce energy use in Delta civic buildings through energy efficiency retrofits.

- The **Green Fleet Management Plan** (1 page) outlines strategies to reduce Delta's vehicle fleet emissions to 20% below 2006 levels by 2015. Some strategies include hybrid-electric vehicles, best management practices training including idling reduction, better trip planning, reduction in transportation demand vi a green commuting program, use of biodiesel for 6 months of the year, and using less-polluting engines in small machinery.

- The **Infrastructure Improvement Plan** (1 page) has the dual aims of reducing GHG emissions and considering the susceptibility of infrastructure to climate change impacts. It has two main components – the Utility Service Improvement Plan (which includes drainage best management practices like swales & permeable paving, the main goal being to reduce GHGs from infrastructure), and the Transportation plan. Pump box upgrades on the dike and drainage system are also included.

- The **Education and Training Plan** (1 page) seeks to educate Delta staff about the benefits of, and opportunities for reducing GHG emissions through methods including training sessions and professional development support.

- The **Community Outreach and Education Plan** (1 page) sets out to transform the day to day behaviour of Delta residents with respect to climate change mitigation. This plan builds on pre-existing outreach activities, but also includes web outreach, new public education programs, and school programs.

- The **Urban Forestry Management Plan** (1 page) will include an inventory of current urban forest cover, and will work towards increasing this cover to 40% across the municipality through planning, outreach, and monitoring programs.

- The **Natural Areas Management Plan** (1 page) seeks to protect and preserve the biodiversity and integrity of Delta's sensitive ecosystems through watershed management, an invasive plant management strategy, and best management practices training for staff.

- The **Sustainable Development Plan** (1 page) promotes climate change adaptation and mitigation in all development projects. This is primarily accomplished through the zoning bylaw and OCP amendments, as well as the new Bill 27 targets & tools recently approved by the BC Government. This plan is based on the recommendations of a 2008 policy review for greener development (conducted by the Pembina institute for the Corporation of Delta).

- The **Flood Management Plan** (1 page) has the goal of reducing the risk associated with climate change related flooding. This plan includes a seawall/dike improvement strategy; a flood box/pump upgrade program; and a Floodplain bylaw to shape future development. The latter initiative is to be based on the results of a flood risk/consequences study. Suggested expenditures listed in the plan include $410,000 (which does not include the Floodplain Bylaw which comes from within the existing budget).

While most of these climate change initiative plans deal with mitigation, the Sustainable Development Plan and Flood Management Plan do deal more specifically with flood adaptation. These higher level strategies and plans are supported the corporation's bylaws, both of which are outlined in the next section.

Flood Protection Programs/Plans

The Corporation of Delta went before Council in June of 2008 with the **Flood Management Strategy Workplan** (Corporation of Delta, 2008b). The plan provides Council with a strategic set of guiding principles for flood management, the preliminary goals and a time line for initiation of important flood management projects.

Guiding principles set out in the strategy include:

- Strive to provide flood protection to the 1 in 200 year return-period flood design level across the municipality;
- Analyze the specific risks and consequences related to the flood design levels in each community and, if appropriate, make adjustments for a more conservative return-period based on the findings of such an analysis;
- Work toward implementation of flood protection in areas of the community that are currently vulnerable to flooding;
- Take a multi-barrier approach to flood protection, including primary barriers (perimeter dikes) in combination with secondary barriers where warranted (internal dikes), and flood protection by construction elevation (incrementally increased flood construction levels in developed communities);
- Explicitly consider the potential impacts of climate change over 20, 50, and 100 year time frames in flood protection planning;
- Secure adequate resources to deliver drainage and flood protection programs within a desired time frame;
- Consider Provincial Flood Plain Management Guidelines and related documents;
- Seek provincial and federal support for an incremental upgrading program;
- Educate the public about flood risks and adequately plan for emergencies.

Important flood management projects outlined in the strategy include the preparation of a **Flood Risk and Consequences Study**, undertaken by Delcan consultants. The latter is intended to provide an independent review of Delta's Flood Management Strategy, and to inform new optimum standards for flood construction levels and building elevations (changes that would be reflected in the Corporation's bylaws). In addition, the flood management strategy sets out a timeline for the preparation of **Area flood Protection Plans,** which would deal specifically with policy and capital improvement projects in each area of Delta. As well, a **Floodplain Bylaw** was to be presented to council, that would include key regulatory changes. All of these components were scheduled to be completed by 2010. At present, it is not known what the status of these activities is. The Flood Risk and Consequences Study was completed by Delcan but has not yet been publicly released by the Corporation. More information is needed on the progress of this strategy.

In addition to the Flood Management Strategy, a **5-phase flood management plan** (exec. Summary – 2 p) exists, which sets out actions to be taken by the municipality over the course of a flood event, in 5 separate stages. This is essentially an emergency response plan prepared by the municipality.

Delta Bylaws Impacting flood management

a) Official Community Plan

Delta's **Official Community Plan** (2005) sets broad policy directions in terms of land use and development, location and provision of services and infrastructure. It is intended to guide decisions and enactment of bylaws in the Corporation. Under the Local Government Act, an Official Community Plan must include statements and map designations for restrictions on the use of lands that are subject to hazardous conditions. A key objective in the OCP is to protect people and natural environments against threats, including flooding. This is reinforced by Policy **2.4.27** which suggests prohibiting development in flood-prone areas, and through Policy **2.4.28** which suggests the use of **Development Permit Areas** and bylaws to ensure protection if development is to be allowed in hazardous areas.

More engineering-related policies are specified in the **Utilities** section of the plan. **Policy 2.10.9** suggests meeting applicable engineering standards for drainage and flood risk in urban areas; **2.10.10** suggests that planning for long-term risks associated with Sea Level Rise to the system ensure that development does not preclude improvements to this system; **Policy 2.10.11** direct the municipality to obtain rights-of-way for required maintenance; and Policy **2.10.12** suggests that all of Delta be protected to a 1 in 200 year flood event standard.

In 2010, the OCP was amended to include a **section on Climate Change**. This section provides an overview of the impacts expected under climate change, and a summary of the Climate Change Initiative (outlined earlier in this review). The plan also mentions that future work will include a

Community Energy and Emissions Plan (CEEP). The objective in this part of the plan is "Minimize and plan for the impacts of Climate Change". The subsequent policies deal primarily with mitigation (reducing emissions, preparing a CEEP, updating the Climate Change Initiative regularly, report progress made towards targets, educate staff on emissions reductions and promote community awareness), however **Policy 2.11.6** includes participating in senior government programs and initiatives to address impacts and help communities plan for local-scale impacts of climate change, which speaks to adaptation.

In addition to these Delta-wide policies that are applicable to the municipality as a whole, the OCP contains local area plans that specify neighbourhood-specific policies. Some of these plans also contain policies that make reference to flood protection. **The East Ladner Area Plan**'s Policy A is to "Ensure that Ministry of Environment Flood proofing standards apply to all new development". The **Riverside Area Plan's** Objective B (B) is to protect against flooding and erosion, while Objective B5 is to protect dikes (require the maintenance and protection of the Riverside dyke system including flood boxes and pumping systems), and Objective B6 is to follow flood proofing standards (Require new construction and land uses inside and outside the dyke to meet flood proofing standards). The Riverside area is perhaps unique in Delta because it also has policies which allow for waterborne or adaptive housing to be constructed on the water side of the dike (such structures include float homes and pier housing). **Ladner's Area Plan** and the **North Delta Area Plan** contain no explicit flood adaptation policies. The **Tsawwassen Area Plan's** objectives in section F include ensuring that all new development is built to provincial flood proofing standards, and protecting properties from damage by ensuring adequate drainage systems.

As previously mentioned, **Development Permit Areas** (DPA's) are one tool to prohibit or specify development conditions in hazard areas. DPA's have been designated in section E of the Official Community Plan. In general, development permits are not required for: single family dwellings so long as flood proofing and environmental standards have been met; for dike maintenance in Riverside undertaken by the Province or municipality; in the Streamside Protection and Enhancement DPA for emergency measures, including flood protection, or for clearing of blockages to drainage channels.

In **Ladner Village** the DPA specifies that no buildings shall be placed outside of the diked area, and no goods damageable by floodwaters stored below **3.5m GSC Datum**, nor any building placed within 30 metres of the natural boundary of the Fraser River, unless on piles or filled (only acceptable if it

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does not protrude beyond natural boundary, and if it is protected from erosion). No buildings are to be built within 6 m of swamps, sloughs or ditches, and restrictive covenants acknowledging flood risk are required –these hold the Province & municipality harmless in case of a flood.

In the **Chillukthan Slough/Ladner Canal** DPA, flood risk is also the motivating factor. This DPA requires that alteration to natural drainage should be avoided, that in hazard areas, no buildings or storage of damageable goods should occur below **2.9mGSC Datum**, except for the elementary school, which is to be at 1.9m. As in Ladner village, a restrictive covenant applies.

In the **Ladner East/Urban** DPA, the area is in the floodplain of the Fraser River. Despite being protected by dikes, the DPA acknowledges that in the event of a dike failure the area could be at risk of flooding. As such, all buildings must adhere to flood proofing standards, and are also subject to a restrictive covenant as above.

Similarly, in the **Ladner East/Rural** DPA, the area is also in the floodplain, and although behind dikes, could be inundated in event of a dike breach. As such, siting and requirements of all buildings shall follow Provincial flood proofing standards, and a restrictive covenant applies.

In the **Riverside** DPA, development must be protected from flooding & erosion damage or located on a lot where this is not occurring. Where hazards exist, the applicant must have a professional engineer's report stating that the proposed development is not at risk, or outlining what must be done to create safety for the proposed development. This area also has a flood construction level of **3.5m GSC datum** (meaning that all habitable and/or storage spaces must be constructed above this minimum elevation.

In the **Tsawwassen Entrance** DPA area, a **2.9m GSC datum** flood construction level is specified, and a restrictive covenant also applies.

In the **Boundary Bay Foreshore and the Southlands** DPA, alteration of natural drainage to be avoided, a **2.9m GSC datum** flood construction level is specified, a 7.5m setback required from tidal areas, and a 6m setback from any pond or slough. As usual, a restrictive covenant also applies in these lands.

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b) Other Bylaws

While the OCP is perhaps the most obvious and extensive bylaw relating to adaptation, a number of other bylaws also regulate development in a way that is relevant to flood adaptation.

Delta's **Building and Plumbing Bylaw** requires that construction must be built to acceptable flood construction levels and setbacks from watercourses. The **Subdivision and Development Standards Bylaw** includes requirements for drainage and grading of new development parcels. Schedule A contains all the pertinent details regarding grading and drainage requirements. Section 5.12 of the bylaw is on flood proofing, and states that an owner must raise the land to a level acceptable to the BC Ministry of Environment and Director of Engineering, enter into a restrictive covenant holding the municipality and Province harmless in the event of a flood, and grant rights of way to the municipality for construction or maintenance of flood protection structures. The **Soil Deposit and Removal** bylaw requires municipal approval for all removal/deposit activities, and states that deposit elevations above 4.0m GSC datum require approval of the engineering department.

Other Policies impacting Flood Management in Delta:

In addition to Delta's municipal bylaws and Provincial guidelines and acts, a few other pieces of legislation affect flood adaptation in the Corporation. One is the **Fraser River Estuary Management Plan (FREMP)**. Established in 1985, the FREMP deals with development planning in the Fraser River estuary, an area that affects Boundary Bay, Roberts Bank, and the wet side of the Fraser River dikes along the north side of the Corporation's boundaries.

While not a policy per se, ICLEI has produced a guidebook for adaptation planning for local governments, and the Corporation of Delta is participating in this program.

Summary and Next Steps

In short, while Provincial Acts set the regulatory framework for flood protection in BC, and guidelines help local governments to fulfill their responsibilities under these Acts, the Corporation of Delta has a high-level climate change initiative that guides action and subsequent policies and bylaws concerned with flood adaptation. These include the Official Community Plan, Local Area Plan,

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Development Permit Areas, and other bylaws with an influence on flood proofing. These all point to existing Provincial standards for flood protection. In addition, a flood management strategy is under development that includes a flood risk and consequences study, improvements to Delta's flood protection system, and a floodplain bylaw. Though the suggested timeline for these latter activities has lapsed, their progress is unclear and more follow-up needs to be done to provide an accurate overview of current flood policies in this regard.

This document was intended as an overview of existing policies regarding flood adaptation in the Corporation of Delta, and will serve as a basis for policy recommendations regarding adaptation planning, based on insights gained during the BC RAC flood adaptation in Delta project. Once a greater understanding of the relative performance of the project's adaptation options is available, this report will be updated. The BC Ministry of Environment is currently updating the Sea Dike guidelines to account for more recent estimates of local climate change, and once these documents are released (anticipated in the near future), the implications of these new sea level rise projections and standards of flood protection (Flood Construction Levels) for the Corporation can be assessed. In addition, the policy implications of the project's hypothetical adaptation options can be evaluated to identify where current policies support or hinder these kinds of adaptation approaches, and what changes might be necessary to implement these options. The project's visualizations of these adaptation approaches will also be evaluated to ensure they reflect the policy framework. A discussion of implementation of the evaluated adaptation options would also be considered, and overall recommendations to the Corporation made in the final months of the project.

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