

An Integrated Approach for Evaluating Adaptation Options to Reduce Climate Change Vulnerability in Coastal Region of the Georgia Basin

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Abstract

This paper presents an integrated approach that integrates climate change impact assessment/vulnerability identification, adaptation option evaluation, and multi-stakeholder participation. The integrated approach was applied in the Georgia Basin (GB) for identifying desirable adaptation options to reduce climate change vulnerabilities. Different computer-based and non-model based methods were adopted to form the integrated approach. These tools include environmental simulation modeling, geographical information system (GIS), internet multi-stakeholder consultation, and multi-criteria decision making (MCDM). The research started with the identification of vulnerabilities of ecosystems, coastal areas, and economic sectors to climate change. This was followed by an online survey and interviews that allow stakeholders to conduct a multi-criteria evaluation of adaptation options. The analytic hierarchy process (AHP), an MCDM technique, was adopted to develop an adaptation evaluation tool to identify the priorities of sustainability goals/indicators and to rank desirability of adaptation options.

The case study in the Georgia Basin of Canada provides some articulation on how the integrated approach can provide an effective means for the synthetic evaluation of the general desirability levels of a set of adaptation options through a multi-criteria and multi-stakeholder decision making process. Thus, the study contributes to the science on adaptation option evaluation. While the case study identified and evaluated a number of adaptation options to deal with potential vulnerabilities to climate change in several key sectors in the region, this paper focuses on sea level rise (SLR) impacts and adaptation options for the coastal region management. The completed research results of the case study are described in the final report submitted to Climate Change Action Fund of Canadian Government (Yin, 2001).

I. INTRODUCTION

Research on developing well designed adaptation strategies will provide the information and understanding necessary for identifying more effective adaptation options and better management plans for insuring sustainability of our life-support-system. One of the major impacts of global warming is sea level rise due to thermal expansion of the oceans and the melting of polar glaciers and ice caps. Under climate change conditions, extreme weather events are likely to become more frequent and severe. Sea level rise (SLR) and associated storm surges may cause significant damages on coastal ecosystems, commerce, industry and transportation infrastructure, human settlements, tourism, and cultural systems.

This paper presents a part of the results of a research project which applied an integrated approach to assess climate change vulnerabilities of several key sectors and to evaluate a set of adaptation options through a multi-criteria and multi-stakeholder decision making process. Geographic focus of the case study is the coastal region of Georgia Basin: the Lower Fraser Basin and eastern Vancouver Island in British Columbia, Canada. Georgia Basin's climate is an invaluable asset that makes its high quality of life possible. Lower levels of coastal area's natural and managed ecosystems are highly sensitive to sea level rise resulted from global warming. Moreover, the region's adaptive capacity has not been examined systematically. While the project identified and

evaluated a number of adaptation options to deal with potential vulnerabilities to climate change in several key sectors in the region, this paper focuses on sea level rise impacts and adaptation options for coastal region management. The completed research results of the case study are presented in the final report submitted to Climate Change Action Fund of Canadian Government (Yin, 2001).

Permanent inundation of low-lying and inter-tidal areas is a primary concern in areas such as the Greater Vancouver Regional District (GVRD). The economic, social, and environmental implications of sea level rise (SLR) in this region are substantial. Not only will SLR likely result in the permanent flooding and alteration of coastal wetlands, but it may also pose a threat to human activities. As the climate warms, it is increasingly important for developers and government policy-makers to consider the implications of SLR in their decision-making processes.

Given the great uncertainties associated with climate change, it is difficult to be certain which adaptation options will be the most desirable ones to pursue. Research on developing well-designed adaptation strategies will provide the information and understanding necessary for identifying more effective adaptation options and better management plans for ensuring the sustainability of the coastal region. In this respect, an

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integrated approach to compare and evaluate policies or options is appropriate to provide policy-makers with insight into the kinds of trade-offs stakeholders are willing to make in efforts to pursue adaptations for reducing climate change vulnerability (Yin et al., 1999; Yin et al., 2000; Yin et al., 2003).

The IA approach integrates climate change impact assessment, vulnerability identification, adaptation option evaluation, multi-criteria decision-making, and multi-stakeholder participation. A series of workshops and many different computer-based methods including simulation modeling, geographical information system (GIS), internet survey, and multi-criteria decision-making (MCDM), were used to form the integrated approach. Geographical information system (GIS) was used to provide information on the impacts of sea level rise, to identify ecosystems, coastal infrastructure, and regional communities that were vulnerable to climate change impacts from SLR. The analytic hierarchy process AHP (Saaty, 1980) was used to compare and evaluate options in an orderly and systematic manner. AHP is a multi-criteria decision making (MCDM) technique that can be adopted as an adaptation evaluation tool to identify the priorities of sustainability goals/

indicators (Yin and Cohen, 1994), and to rank the relative desirability of alternative adaptation options.

II. THE INTEGRATED APPROACH

Figure 1 illustrates the main components and procedures of the integrated assessment (IA) approach. It mainly includes four steps which are described as follows.

Climate change and socio-economic scenarios

In conducting climate change impact assessment and adaptation option evaluation studies, climate scenarios need to be specified for examining their economic, social, and environmental impacts. General circulation model (GCM) outputs and historical information can be used to design scenarios representing different climate change conditions. Sea level rise scenarios can also be specified. The climate scenarios applied in this study were selected in a manner that is consistent with the national sets of scenarios that were produced by the Canadian Climate Impacts Scenarios facility

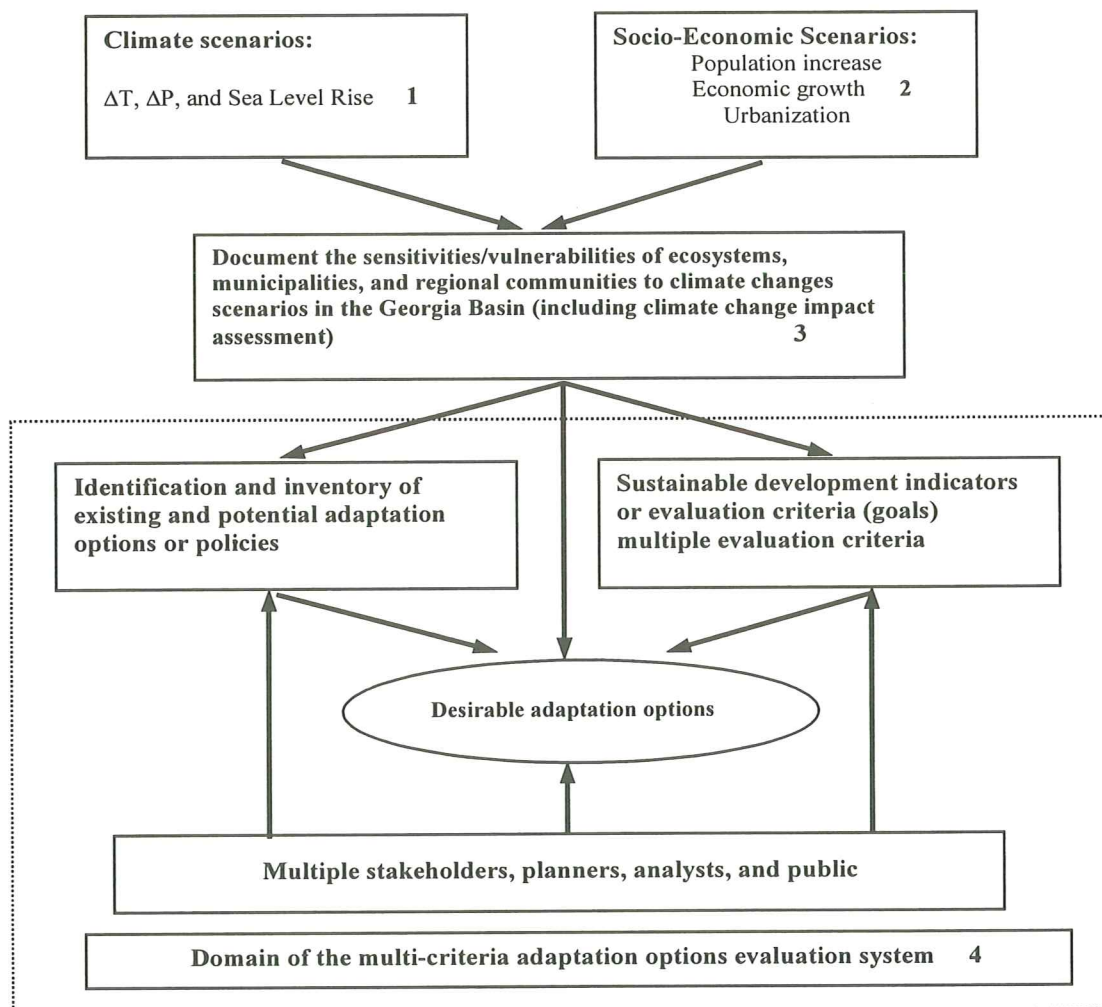


Figure 1. The Integrated Assessment approach framework

(Barrow, 2000).

Changes in socioeconomic conditions, such as population and economic growth, need to be taken into consideration in developing baseline socio-economic scenarios. Various methods can be used to set future population increase and economic growth scenarios.

GIS and climate change vulnerabilities

Geographical Information Systems (GIS) can be used as a tool to estimate the impacts of sea level rise. However, there are problems accommodating uncertainties in both the input elevation data and the magnitude of sea level rise that is applied. There are two main types of GIS uncertainty described in the literature: *database uncertainty* and *decision rule uncertainty*. In the case of modeling sea level rise, *database uncertainty* is derived primarily from measurement errors in the elevation values contained in a digital elevation model (DEM). The variability of recorded values around their true value can be described using probability theory, and the error can be quantified as a root-mean square (RMS) error. *Decision rule uncertainty* exists because of uncertainties in the magnitude of sea level rise that can be expected. The latter type of uncertainty will not be examined in this paper.

In this study, a statistic method was used to show how a continuous probability map could be generated to show the probability of inundation given a specific climate change scenario, based on the RMS error inherent in the original DEM. In the case of sea level rise, successful handling of uncertainty allows us to generate useful impact estimates despite a lack of concrete data. Knowledge of possible impacts is important for planning future developments, and for considering adaptation options to cope with global warming and sea level rise.

The GVRD DEM lists its elevation values to the nearest meter, and was created from a 1:20,000 scale TRIM map. According to the "Gridded DEM Specification Release 1.1", the data conforms to the 1:20,000 TRIM accuracy standard, whereby 90% of all points interpolated from the TRIM DEM shall be accurate to within 10 meters of their true elevation. Assuming that the data is not biased (the error is uniform), the standard deviation of the map should be equal to its root-mean square error. Thus, the RMS of the DEM is 6.10 meters (MSRM, 2003).

From a statistical point of view, individual elevation values in the DEM are normally distributed. Any quoted elevation value therefore falls somewhere under a normal curve characterized by a mean of the true value, and a standard deviation or RMS of 6.10 meters. The probability of a cell value falling at any given location can be computed as a z-score through Equation (1):

$$z = (y - m) / s \quad (1)$$

where z is the z-score; y is the observed value; m is the

mean value; and s is the standard deviation, or RMS. A z-score was computed in ArcView for the entire DEM using the following formula (Equation (2)):

$$[z - \text{score}] = (2.0 - [\text{DEM}]) / 6.10 \quad (2)$$

The z-score values were then reclassified according to a set of chosen probability ranges that are likely of interest to decision-makers.

A multi-criteria adaptation measures evaluation system

The developed methodology for multi-criteria adaptation option evaluation coupled with multi-stakeholder consultation in the Georgia Basin consists of the following three parts.

Identification and initial screening of potential adaptation options

Numerous potential adaptation options have been available for dealing with vulnerabilities to climate change. Using sources including existing literature and expert consultation, a set of possible options can be identified. To facilitate evaluation of the options in later steps of the study, it is desirable to have between 6 and 10 options. If required, an initial screening process should be performed to narrow down the list of potential options.

Sustainability goals or criteria setting

The research procedure continues with an identification of sustainability goals. In this approach, the goals are evaluating criteria or standards by which effects of climate change or/and the effectiveness of alternative adaptation options can be measured. Only three broad goals (of the environmental, economic, and social dimensions of regional sustainable development) were identified in the case study as evaluation criteria.

Multi-stakeholder consultation and multi-criteria evaluation of adaptation options

Multi-criteria options evaluation (MCOE) of adaptation measures is a major component of the study. It is used to identify desirable adaptation options that decision makers can use to alleviate the negative consequences and to take advantage of positive impacts associated with climate change in the Basin.

In this study, AHP was used to compare and evaluate options in an orderly and systematic manner. Alternative options were evaluated by relating their various impacts to the three broad sustainability goals. The process involves asking stakeholders to compare alternatives on each level in a pair-wise manner (two at a time) to determine their relative preference or relative importance of each alternative. A stakeholder could therefore specify the relative importance of the three broad sustainability

goals with respect to their individual importance in reducing climate change vulnerability, and could then compare specific adaptation options according to their relative effectiveness at achieving each goal.

The end result of the AHP is a prioritized ranking indicating the overall preference for each of the adaptation options. This technique was chosen because it could offer a multi-criteria evaluation system that was systematic and holistic, involved multiple stakeholders, and was easily able to identify trade-offs. In addition, it allows comparison based on both qualitative and quantitative information (many climate change impacts/vulnerabilities can only be described qualitatively at this point). Overall, the AHP method provides an effective means for synthetic evaluation of the general performance levels of alternative adaptation options based on a multitude of evaluation criteria (goals).

III. APPLYING THE IA APPROACH IN THE GEORGIA BASIN

The Georgia Basin study area

The research area (Georgia Basin) encompasses the Lower Fraser Basin and southeastern Vancouver Island in British Columbia (see Figure 2). The basin includes the major cities of Vancouver and Victoria, and the region is rich in natural and

human resources thus making it an attractive location for sustainability research.

Specifying climate scenarios

To facilitate coordination with other research activities involving the Georgia Basin at SDRI, a 40-year timeline was chosen for evaluation. The climate scenarios created by Canadian Climate Impacts Scenarios Project for this region over the 40-year timeline include warmer temperatures year-round, with wetter winters and drier summers (Barrow, 2000). The magnitude of the temperature increase was assumed to be between 1 and 5 degrees Celsius. Winter precipitation should be approximately 10% greater, and summer precipitation about 9% less than current averages.

The future socio-economic scenarios are consistent with the scenario development task of the Georgia Basin Future Project being conducted by the Sustainable Development Research Institute of University of British Columbia (Robinson, et al. 1996).

Identifying vulnerabilities to climate change and potential adaptation options

Coastal region vulnerability

The impacts of climate change on coastal regions have been

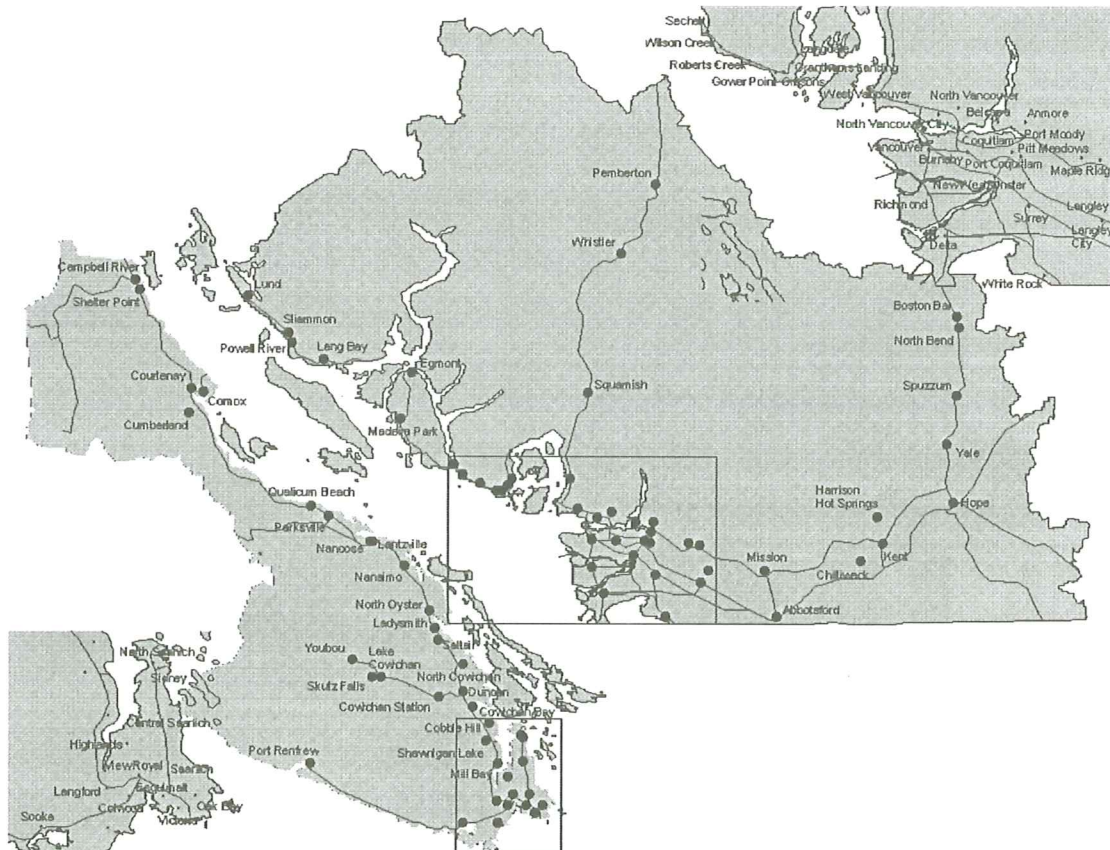


Figure 2. Map of the concerned research area — Georgia Basin

broken down into shoreline effects and ecological effects (Beckmann et. al., 1997). Shoreline effects include inundation of low-lying areas, erosion and/or accretion on sedimentary coasts and beaches, and disturbance (including submergence and erosion) in deltas, estuaries, and estuarine wetlands. One concern with saltwater intrusion is related to impacts on overlying lands and wells, as well as water extraction from coastal rivers and streams where extraction points may become at or beyond the saltwater front. There is also concern that pumping efforts to prevent saltwater intrusion may need to be increased or could fail. Ecological effects include impacts on human activities and developments, and changes in species biodiversity (with specific effects on wetland and inter-tidal plant and animal species/communities and sea and shore bird populations).

Shoreline effects depend on the vulnerability of the coast to sea level rise (SLR) and storm events. This vulnerability or sensitivity has been described as a function of numerous factors including relief, rock type, coastal landform, sea level tendency, shoreline displacement rate, mean tidal range, and mean annual maximum significant wave height (Shaw et. al. 1998a).

SLR can have a number of negative impacts on coastal ecosystems, commerce, industry and transportation infrastructure, human settlements, the property insurance industry, tourism, and cultural systems and values. Much of the Fraser River Delta lies below 4 meters in elevation, and parts of it currently have elevations between 0.5 and 1.5 meters below sea level (Clague et. al., 1991; Shaw et. al., 1998b). Extensive dyke systems are already in place to protect much of these lowlands from flooding, and the urban infrastructure and industrial activities of this area are already vulnerable during extreme events. They will almost certainly become even more vulnerable if the frequency of these events increases. The SLR analysis described below helps summarize some of the most highly vulnerable areas.

Sea level rise impacts: A GIS analysis

To further examine the effects of sea level rise in the Georgia Basin, and to quantify the impacts of sea level rise in the highly sensitive delta area, a simple GIS operation was performed. Sea level rise is a combination of eustatic, steric, isostatic readjustment, tectonic, and wind/current effects. The Intergovernmental Panel on Climate Change (IPCC) has predicted a global rise in sea level (due to eustatic and steric effects only) of 10.0 to 53.5 cm by the year 2040 (Carter and Hulme, 1999). With the readjustment in the Georgia Strait, sea level in the Georgia Basin can be expected to rise anywhere from -2.5 to +41.0 cm by the year 2040. Wind, current, and tectonic effects in the Georgia Strait are not expected to be substantial, but may contribute up to 2 mm/year (Beckmann et. al., 1997). Storm surges (from intense, low pressure weather systems) ranging from 1 to 1.5 m are also possible in the Georgia Strait, and magnify the impacts of sea level rise.

The effects of data uncertainty on SLR

In this study, three sea level rise scenarios are examined to analyze the database uncertainty. Two were taken from the IPCC's projections: 0.22 meters representing a conservative estimate based on a low emissions scenario, and 1.24 meters representing a high emissions scenario. A third scenario of 2.0 meters was also chosen. Although this estimate is considerably higher than the IPCC's, it is not uncommon in the literature, and can represent a possible scenario where sea level rise is accompanied by high tide and a significant storm surge.

First, the z-score values were calculated for each scenario, then reclassified according to a set of chosen probability ranges in Table 1. Figure 3 shows the probability map for a 2.0-meter SLR. Figure 4 shows the soft probability map calculated for the 0.22-meter scenario. These maps can be used to isolate areas that are already underwater. Table 2 lists the land area with > 25% risk of inundation.

Despite the relatively long time horizon of the projections (100 years), results such as these have substantial implications for developers and planners. In many cases, even a 25% probability represents a very high risk, and perhaps a 5 or even 1% probability is more realistic when considering multi-million dollar developments and infrastructure projects.

Spatial distribution of impacts

Table 3 shows the area of each land use category in the GB that occupies land with an elevation of less than 1 m above the current sea level. Values are reported in hectares, and as a percentage of the total area in that particular land use category. Nearly all of these lands lie in the Fraser Delta. Areas in the remainder of the Basin are almost invisible on a basin-wide map, so an enlarged section of the Fraser River Delta region is shown in Figure 5.

Under a one-meter sea level rise, 850 hectares of protected areas and 18,850 hectares of unprotected natural areas are considered vulnerable to inundation unless they are protected by the dyke system. Much of this area is likely beach or estuarine wetland/marsh. If there is upland area for the wetlands to migrate, the effect of sea level rise will merely be a migration of the ecosystem. In many cases, however, developments and dykes will prevent wetland migration, and "coastal squeeze" will occur (GVRD, 2000). When they cannot migrate, coastal wetlands will be subjected to complete inundation and increased erosion. Freshwater delta estuarine wetlands will see a replacement of freshwater habitat with saltwater habitat, and the plant and animal species distributions will shift toward salt-tolerant ones. Overall, significant shrinkage of wetland area will likely be observed (Beckmann et. al., 1997).

Areas of the Nanaimo lowland near Comox, B.C. (along the east coast of Vancouver Island) will also be increasingly

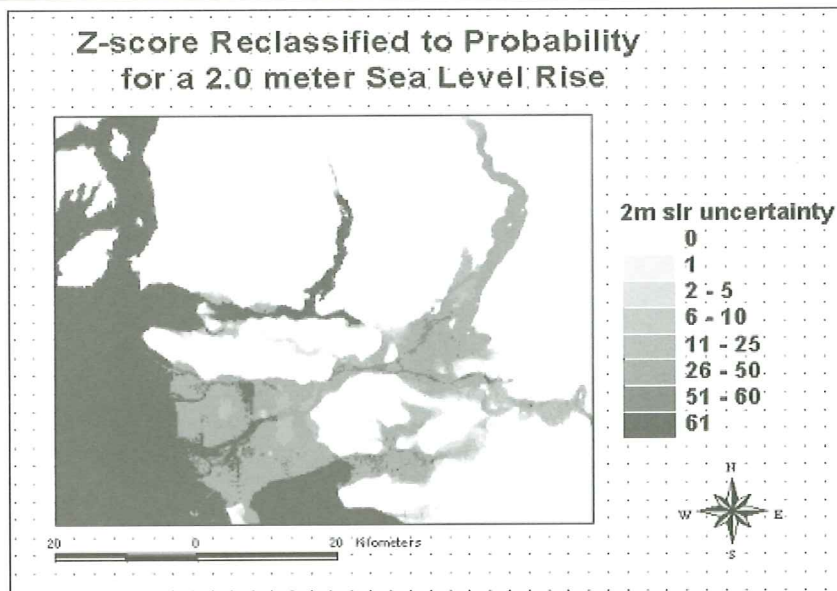


Figure 3. Probability map for a 2.0-meter Sea Level Rise scenario

subjected to flooding and/or inundation. Breaching, overwashing, and migration of spits will become increasingly common as the sea level rises (Shaw et. al., 1998a). Increases in organic material and sedimentation can be expected in the intertidal areas of the Fraser River Delta as a result of increased precipitation in winter, and these will combine with rising seas, warmer coastal waters, and changes in upwelling patterns and sea level differentials to result in significant changes in marine and estuarine ecosystems.

Socio-economic impacts

With a one-meter sea level rise, 4675 hectares of agricultural land will be below sea level and may become inundated if not protected. Salinization from periodic inundation of fields, or contamination of groundwater with salt water, can substantially reduce the productivity of these agricultural lands (Beckmann et. al., 1997). In addition, many areas of the Fraser Valley rely on groundwater supplies that may be subjected to saltwater intrusion from the rising water table (Beckmann et. al., 1997).

Considerable areas of urban land also face the risk of

Table 1. Z-score values and associated probability ranges

Classification No.	Z-Score	Probability
1	-322.295 - -3.091	0
2	-3.091 - -2.325	< 1 %
3	-2.325 - -1.644	2 - 5 %
4	-1.644 - -1.281	6 - 10 %
5	-1.281 - -0.674	11 - 25 %
6	-0.674 - 0.001	26 - 50%
7	0.001 - 0.254	51 - 60%
8	> 0.254	> 61%

inundation, and will likely require protection (See Table 3). In addition, both light and heavy density industrial land are highly vulnerable, with 800 and 750 hectares (respectively) resting on elevations below the new sea level. BC Hydro has many major hydroelectric installations that are critical nodes in the power distribution system, which are dependent on protection by the current dyke system. Moreover, the electrical power for southern Vancouver Island crosses the delta plain will also be affected (Shaw et. al., 1998b). Groundwater areas in parts of Richmond will be brought to the surface and additional funds will need to be spent on pumping (Clague, 1989). In addition, developments at Goose Spit near Comox will be susceptible to more frequent flooding/inundation, posing safety concerns.

Much of the vulnerable low lying areas in the Fraser River floodplain and delta are currently protected from inundation and flooding by an extensive system of dykes which has been

Table 2. Land with >25% risk of inundation

Land type	2.0 meter scenario	0.22 meter scenario
Resid. Single Family		
Area inundated (km ²)	42.339	30.596
Percentage of total	12%	8%
Industrial		
Area inundated (km ²)	29.702	15.883
Percentage of total	40%	22%
Trans./Comm./Utilities		
Area inundated (km ²)	27.25	19.728
Percentage of total	67%	49%
Agriculture		
Area inundated (km ²)	257.211	172.333
Percentage of total	55%	37%

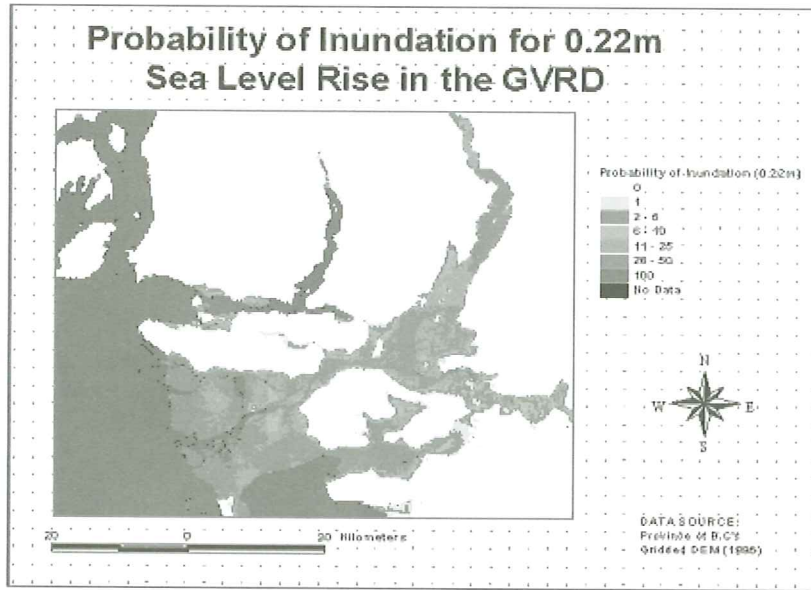


Figure 4. Soft probability map for 0.22meter sea level rise

designed to withstand a 1-in-200-year flood event (MELP, 2001). Many of the dykes in the Boundary Bay/Crescent Bay area are subject to problems with the current sea level, and building specifications do not take climate change into account. In addition, it is likely that extreme flood events and storm surges will occur more often under climate change scenarios, increasing the possibility of breaching, and additional damage to the dykes (from surges, waves, and log debris) (Wodtke, 2001; personal communication.). Many of the dykes will need

to be upgraded and/or extended to prevent damage to human activities and the built environment. Furthermore, the risk of dikes being over topped is compounded by the hazard of seismic activity that exists in the Georgia Basin.

Adaptation options

An initial screening process was conducted to reduce the number of options for further detailed evaluation. The following list of adaptation options was identified through the initial screening process to reduce the key climate change impacts and vulnerabilities presented above (see Table 4). These potential options were evaluated and compared by experts and stakeholders in the Basin.

Application of the multi-criteria adaptation measures evaluation system

The Internet adaptation option survey and the AHP method

In this study, an Internet website was created and summaries

Table 3. Vulnerable areas in the Fraser River Delta by land use

Land Use	Area (ha.)	Percentage of total area
Urban: Industrial	1550	9.21
Urban:	1125	1.56
Residential/Commercial	3200	3.66
Protected Areas	850	0.13
Unprotected, Natural	18850	0.53
Area		
Agriculture	4675	2.38
Total	30250	0.66

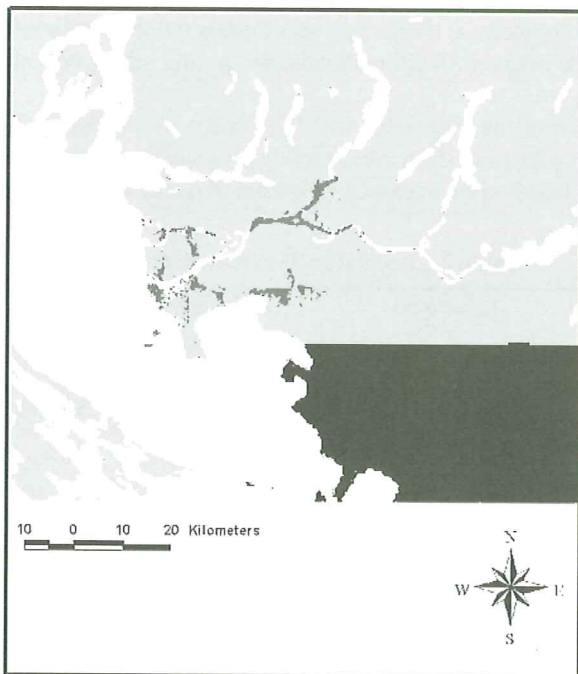


Figure 5. Areas in the GVRD that are vulnerable to sea level rise because they have an elevation of 1 m or less above sea level

Table 4. Identified adaptation options to reduce the key climate change impacts and vulnerabilities

No.	Adaptation options	Note
1	Do nothing	Do nothing in developed areas as the sea level rises; do not upgrade and/or maintain any existing dikes
2	Prevent further development	Through legislation and regulation, prohibit future development in sensitive areas; ensure new developments are set back from the shore and do not infringe on wetland's ability to retreat
3	Public repurchase	Governments or organizations repurchase vulnerable land and structures
4	Rolling easements	Incorporate rolling easements into the deeds of coastal property, converting land ownership to a temporary or conditional interest that expires when the sea inundates the property. Essentially, development has to make way for migrating ecosystems
5	Protect development	Upgrade and/or maintain the current dike system, and expand to protect other vulnerable developed areas
6	Protect ecosystems	Build protective barriers, breakwaters, etc. to protect natural ecosystems and wetlands
7	Research	Conduct further research (e.g. inventories, biological impact studies, etc.) to identify vulnerable natural areas suitable for preservation; continue to invest in sea level monitoring.

of the climate change impacts data were coded into HTML and presented on the web (<http://www.sdri.ubc.ca/aos>). A series of online surveys were created to involve experts and stakeholders in the evaluation. Having a copy of the survey available online enabled it to be quickly and easily distributed (electronically via email) to a wide range of individuals, and it presented a convenient way for stakeholders to respond to the survey questions on their own time. A paper copy of the survey was also created so it could be administered in one-on-one interviews and in small group/workshop settings.

The Expert Choice (EC) 2000 software package was used to facilitate the application of AHP in this study. Survey questions were designed according to the principles of AHP so that the responses could be input into the software program for compilation and analysis. It provides an overall score for each alternative option by distributing the importance of the goals among the adaptation options, thereby dividing each goal's priority into proportions relative to the percentage of alternative. Three goals are specified to conduct a multi-criteria AHP evaluation against which the relative effectiveness of the adaptation options can be judged. They are (1) Minimize harm to the natural environment; (2) Minimize economic costs to society; and (3) Achieve social acceptability.

With these three goals, and a set of adaptation options to compare, a decision hierarchy model was created. This decision hierarchy is quite simple because it includes a single overall goal, with two levels below it in the hierarchy: a set of criteria/goals, and a list of alternative adaptation options. Once the relative importance of individual criteria and sub-criteria is determined, decision-makers need only think about the preference of each alternative adaptation option in terms of

achieving a single criterion.

The survey was designed as a series of tables. Respondents were given a pair of goals or a pair of options, and asked to compare them using a numerical sliding scale. The comparison scale ranged from 1 to 5, with 1 representing options that are equally effective (or goals that are equally important), and 5 representing options where one is extremely more important than another (see Table 5).

Preliminary results of the AHP analysis

Responses were received for the Coastal Regions sector from respondents affiliated with academia, First Nations, and various levels of government. All except for one were stakeholders in the GVRD region of the GB, which was reasonable given the nature of the impacts in this sector.

Protect ecosystems was ranked the most desirable adaptation option for coastal regions, with *prevent further development* and *research* options scoring fairly high as well (see Table 6). Once again, the respondents' personal goal preferences and their affiliations did not appear to significantly affect their overall ranking of the adaptation options. *Public repurchase* option scored fourth overall, however, it was judged to be the most ineffective option from an economic perspective, and it was ranked considerably lower overall among those respondents favouring the economic goal. The scores for *research* option were highly variable with no observed trend, but *protect development* and *do nothing* options scored near the bottom of the list by most participants (especially from an environmental perspective) and were not considered to be very desirable adaptation options. Once again, the adaptation

Table 5. AHP comparison table: coastal region sector

Adaptation option	Relative effectiveness scale					
	5	4	3	2	1	
Coastal region sector-level adjustments						x Do Nothing
Coastal region sector-level adjustments			x			Protect ecosystems
Coastal region sector-level adjustments					x	Prevent further development
Coastal region sector-level adjustments				x		Research
Coastal region sector-level adjustments			x			Public repurchase
Coastal region sector-level adjustments					x	Rolling easements
Coastal region sector-level adjustments			x			Protect development
Coastal region sector-level adjustments			x			Protect ecosystems

Indicate the relative effectiveness of the following adaptation options to achieve the goal of minimize harm to the natural environment in the coastal region sector

Note the relative effectiveness scale: 1 – equally effective; 2 – marginally more effective; 3 – moderately more effective; 4 – strongly more effective; 5 – very strongly more effective.

options’ overall scores closely resemble their scores for the environmental goal (see Figure 6) because the environment goal was rated the most important by all but one respondent.

IV. CONCLUSIONS

The IPCC Technical Guidelines (Carter et. al., 1994) suggests that integrated assessment (IA) methods are desirable to obtain a scientific understanding of the interactions between sustainable development and climate change. It is obvious that integrated impact assessment will never be achieved based on partial analyses of the total system. Integrated study requires a multidisciplinary and holistic approach to deal with the interrelations among the economic, ecological, and social

systems. Many commonly used approaches and methods, based on selected segments of the earth system, need to be incorporated into an integrated framework (Yin, et al., 2003).

The study illustrates that under climate change conditions, extreme whether events are likely to become more frequent and severe. Sea level rise (SLR) and associated storm surges can have a number of negative impacts on coastal ecosystems, commerce, industry and transportation infrastructure, human settlements, tourism, and cultural systems in Georgia Basin.

When applying the IA approach in the GB region for the purpose of evaluating adaptation options to reduce climate change vulnerability, many of the survey respondents were not familiar with the analytic hierarchy process, and the survey

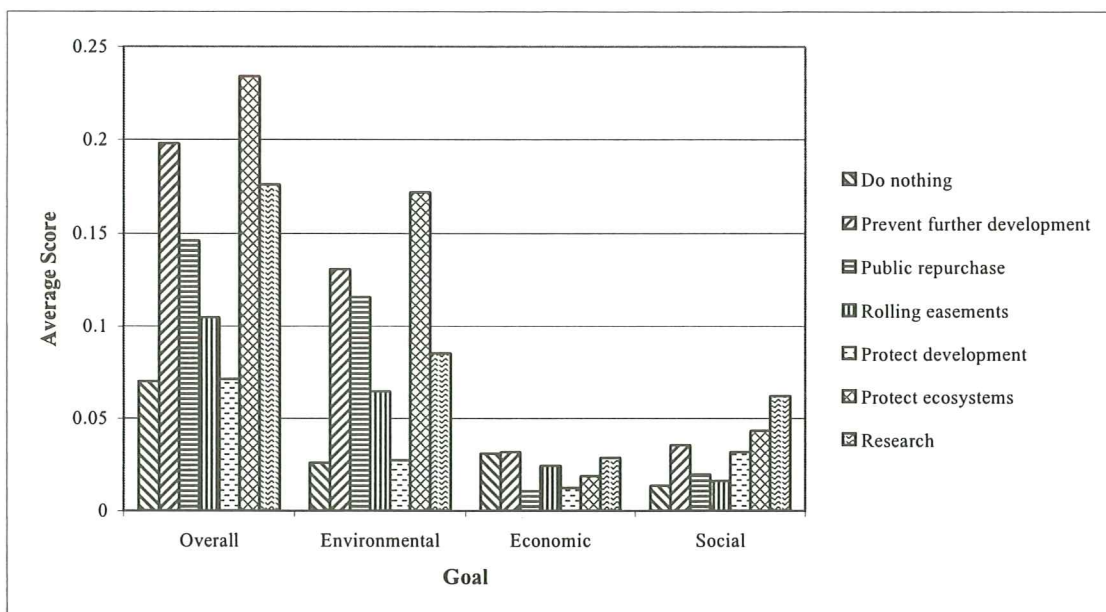


Figure 6. Average scores for adaptation options in the coastal regions sector

Table 6. Overall rank and score of adaptation options in the coastal regions sector

Rank	Overall Score	Adaptation option
1	0.234	Protect ecosystems
2	0.198	Prevent further development
3	0.176	Research
4	0.146	Public repurchase
5	0.105	Rolling easements
6	0.071	Protect development
7	0.070	Do nothing

(which takes up to half an hour to complete) experienced some difficulties. The internet website with email advertisements was created which provided an effective way to reach a large number of potential respondents. Having the survey online offers a convenient way for the stakeholders to respond the survey questions on their own time, and eliminates the substantial time lag that would be incurred if the surveys had to be mailed out. To improve the survey response rate, numerous individuals were contacted individually and asked to complete the survey in a one-on-one interview or in a small group workshop-type setting.

The research project examined alternative adaptation options for alleviating the adverse consequences of climate change in coastal region of Georgia Basin. The adaptation option evaluation was linked to regional sustainability indicators. Alternative adaptation options to deal with various vulnerabilities were evaluated against sustainability indicators. The study results provide a prioritized ranking indicating the overall preference for each of the adaptation options in coastal regions sectors of the study area.

To accomplish more on climate change research, evaluation capabilities need to be further improved, particularly in integrated assessment of climate change and its potential consequences for regional sustainability. Current level of understanding shows that climate change and its impacts will vary by sector and region, but our knowledge of specific regional and sectoral effects remains limited. Although this paper describes in general some of the vulnerabilities that may be expected in coastal region sector, it illustrates the need for further scientific research and modelling in this region to provide more detailed impact and vulnerability data. It is important to improve our knowledge on the interactions of climate variability and change, and other human-induced changes in the region including environmental pollution, land-use change, resource depletion, and other unsustainabilities.

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