Human Vulnerability and Climate Change: An assessment of Greater Vancouver's human vulnerability to sea level rise in 2100

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Abstract

Human vulnerability to climate change is a growing concern on a global scale. This dissertation analyzes and assesses human vulnerability to sea level rise in Greater Vancouver, Canada for the year 2100. In order to understand this area of study, this dissertation works through four objectives. Firstly, a conceptual framework is created to assess human vulnerability. Secondly, modeled projections of sea level rise in 2100 from the Intergovernmental Panel on Climate Change Fourth Assessment Report and Overpeck and Otto-Bliesner (2006) are used to represent best case, worst case and catastrophic case scenarios. Thirdly, GIS mapping techniques are used to visually represent levels of vulnerability and sea level rise for the communities of Greater Vancouver. Finally, based on the above findings, recommendations for the future planning of communities through policy and mitigation are provided. Also addressed, are the limitations, potential criticisms and challenges associated with this research. Finally, the future objectives of this project are identified, with the hope that this research will be further developed. Continued work on this project is underway to review its applications in assessing human vulnerability to earthquake sensitivities. This portion of the research should be completed in early January, 2008 and will complement the research already completed to this date.

Introduction

At the dawn of the 21st century, climate change is considered one of the most serious threats facing humanity today. Plagued by unknowns and uncertainties, climate change is altering the present state of our planet through processes such as sea level rise, extremes in precipitation and an increase in global mean temperature (Brown, 2006). With a world that is increasingly at risk to disaster, practitioners in the field of emergency management are embracing new technologies that enable greater levels of preparation, mitigation, response and recovery. The increased use of GIS has enabled emergency managers to organize, analyse and display the various situations and environments that unfold during a disaster. As a result of the emerging trends associated with climate change, now more than ever, emergency managers are using the tools and resources associated with GIS to focus on integrated planning, which looks beyond the hazards to examine societal impacts such as critical infrastructure and human vulnerability.

This research was created in collaboration with the BC Ministry of Health and Oxford University's Centre for Environmental Change. The aim was to develop a conceptual framework for assessing human vulnerability to sea level rise in 2100 for the areas of Richmond, Vancouver and North Vancouver in British Columbia, Canada. Due to the inherent complexities associated with the study of vulnerability, it is imperative that this work be placed into context regarding the advancements that it has achieved, rather than the vast amount of work that remains to be done.

The Study Area: Richmond, Vancouver and North Vancouver in British Columbia, Canada

Richmond, Vancouver and North Vancouver are three cities that comprise the 21 regions of the Greater Vancouver Regional District (GVRD) and for the purposes of this research, are referred to as Greater Vancouver. With a combined population of just under one million, these three areas account for almost half of the total population within the GVRD (roughly two million) (Stats. Can., 2001). With projections pointing towards an ever-expanding population, communities within Greater Vancouver are diverging from their once homogeneous community sub-sets, to a sprawling melting pot of community diversity.

In the interest of maintaining study areas that allowed for the greatest levels of vulnerability indicators to be represented, several considerations were assessed. For instance, it was vital that all of the areas in question had: a full range of data available from Statistics Canada, had health care statistics available and had a coastline. Based on these criteria, it was assessed that the cities of Richmond, Vancouver and North Vancouver would provide an adequate study area, as all of the statistical data was available, they are all par of the Vancouver Coastal Health Authority and they all have considerable stretches of coastline.

Once this assessment was made, these three cities were further divided into community clusters based on the homogeneity of their socio-economic makeup. For the purposes of mapping these areas, topology was also an important variable, as neighbouring communities would be easier to represent on a map. As a result, Richmond was divided up into 8 areas, Vancouver into 5 areas and North Vancouver into 6 areas.

Assessing Future Projections of Sea Level Rise

Over centuries to millennia, sea level fluctuations have been in synchronous ebb and flow within the cryospheric (snow, river and lake ice, sea ice, glaciers and ice caps, ice shelves and ice sheets and frozen ground) system (Lemke and Ren, 2007). Scientists have worked to unlock the mysteries behind past sea levels, in the hopes that their findings may provide insight for the coastlines of the future.

The 20th century has witnessed a global rise in sea level between 15 and 20 cm (Bindoff and Willebrand, 2007). Although this rise may seem miniscule, it has sounded warning bells within the scientific community, as this rate is about 10 times faster than the rate over the previous 3,000 years (Garrett, 2001). Coupled with this rise, is the ever-growing concern over increasing greenhouse gas emissions. This is attributed to the expectation that associated temperature increases are expected to cause cryospheric melting, hence increasing the volume and thermal expansion of the oceans waters (Jelgersma, 1990, Kerr, 2006 and Landerer, 2006).

The projections for future sea level rise vary greatly. These vast differences in estimates are due to deficiencies in scientific knowledge and in the methods used for constructing these assessments (Hoffman et al., 1983). However, the research does conclusively point to the fact that sea level rise is occurring, albeit at a rate of increase that is of great debate amongst researchers (Douglas and Peltier, 2002). For the purposes of this research, three different scenarios have been used to assess human vulnerability to sea level rise in 2100:

- Best case scenario = 9 cm (Bindoff and Willebrand, 2007)
- Worst case scenario = 88 cm (Bindoff and Willebrand, 2007)
- Catastrophic case scenario = 6 m (Otto-Bliesner et al., 2006)

The best and worst case scenarios are taken from the IPCC Fourth Assessment Report. Compared to its previous assessments, the IPCC developed enhanced statistical techniques to calculate several factors that contribute to global sea level rise. They specifically focused on the following factors:

- Ocean expansion resulting from increased water temperatures;
- Meltwater runoff from mountain glaciers around the world; and
- Meltwater runoff and calving of ice from the Greenland and Antarctic ice sheets.

Due to high levels of scientific uncertainty, the IPCC has knowingly omitted information regarding research surrounding sea level rise in relation to carbon dioxide uptake and ice sheet instability. As a result, the IPCC findings have been considered fairly conservative amongst some within the scientific community. However, for the information required for this research, the IPCC sea level rise projections have been deemed adequate. These projections not only represent the voice of the global scientific body, but they have been used throughout countless sources of academic literature as the expected sea level rise projections of the future.

On the other hand, the catastrophic case scenario for this project was taken from Otto-Bliesner et al. (2006), in which they do attempt to take into account the carbon dioxide uptake and ice sheet instability. In dramatic fashion, sea level rise is greatly increased when these factors are considered, though it must be understood that scientific understanding of these processes is poor. As a result, this scenario is intended primarily as a “what if” scenario or a reference point.

Developing a Vulnerability Framework

Although hard to define, vulnerability is even more challenging to assess. Requiring a collection of data comprised of both qualitative and quantitative terms, assessments must be made using surveys of households that include livelihood and welfare analysis, political structure and infrastructure, and access to local institutions (Cannon, 2000). For the purposes of this research, initial assessments were made through the construction of a vulnerability framework (Table 2). This framework was constructed using socio-economic indicators all available from Statistics Canada, Vancouver Coastal Health Authority and BC Housing. The indicators for this framework were chosen based on the rationale as outlined in Table 1. It is important to understand that these indicators are based on generalizations that aim to encompass a given population as best as possible and at this stage in the research are non-exhaustive. It must also be recognized that there will always be exceptions to these generalizations, but for the most part, they provide a snapshot of the socio-economic indicators within a community.

Table 1: Vulnerability Indicators

Indicator	Rationale
Population Density per square KM	Generally speaking, the higher the population density, the higher the likelihood of injuries and death during a hazard. Larger populations also pose greater challenges regarding relocation.
Household Characteristics – Ownership status	People rent because they are transients, do not have the financial resources for home ownership, or do not want the responsibility of home ownership. They often lack access to information about financial aid during recovery. In extreme cases, renters lack sufficient shelter options when lodging becomes uninhabitable or too costly to afford.
Family Characteristics	Households headed by a single parent may face significantly greater challenges in responding to an event, as greater levels of responsibility are placed on the individual parent leading the family.
Level of Education	Education equips people with the knowledge and skills to solve problems and improves their ability to access and understand information. It increases opportunities for job and income security, as well as job satisfaction.
Labour Force	Unemployment results in a decreased access to income. Unemployment is also related to increased stress levels and decreases personal happiness. When unemployment is high at the community level, this can have negative social consequences.
Primary Transportation	Individuals with access to personal transportation have a much easier time with relocation. Should a disastrous event occur, those lacking personal transportation are often left at the whim of response officials, which depending on levels of demand, can sometimes be very slow.
Household Income	Income determines many socio-economic variables. As perhaps the most important indicator of vulnerability, income plays a vital role in ones ability to overcome an adverse event.
Family Economy	Those living below the poverty line generally have less access to insurance and access to monetary resources.
Recently Immigrated	Members of this group are likely to have factors relating to ethnicity, income, and education that set them apart from the general population.
Primary Language	Communication is a key element in providing individuals information on how to respond to a specific event. If an individual cannot receive information based on an inability to understand what is being conveyed, their ability to respond can be significantly decreased.
Age	For the elderly and the very young, lack of mobility to flee, inability to withstand trauma and exacerbation of underlying disease increase vulnerability.

Table 2: Vulnerability Framework

Level	Weighting	Indicator	Indicator Variable	Vulnerability Weighting
Level 2	Given an average weighting of 20 and ranging from a low of 10 to a high of 30	Population Density per square KM	3000 - 5000	High = 30
			1000 - 2999	Medium = 20
			0 - 999	Low = 10
				sum equation
				Equation
		Household characteristics - Ownership status	Rented	High
			Owned	Low
				Equation
		Family Characteristics	Loan-parent families	High
			Married-parent families	Low
				Equation
		Level of Education	% of population with less than a high school graduation certificate	High
			% of population with a high school graduation certificate and some post secondary without completion	Medium
			% of population with a university certificate, diploma or degree	Low
				Equation
		Labour Force	Unemployment rate 7.0-8.9	High
			Unemployment rate 5.0-6.9	Medium
			Unemployment rate 3.0-4.9	Low
				Equation
		Primary Transportation	No access to personal transportation	High
			Access to personal transportation	Low
				Equation
Level 1	Given an average weighting of 40 and ranging from a low of 30 to a high of 50	Household Income	$19,999 and under	High
			$20,000 - $44,999	Medium
			$45,000 and over	Low
				Equation
		Family Economy	Low income economic families	High

			Other, population in private households	Low
				Equation
		Recently Immigrated	Total immigrant population	High
			Non-immigrant population	Low
				Equation
		Primary Language	Primary language other than English or French	High
			English and/or French only	Low
				Equation
		Age	0-19	High
			20-64	Low
			65 and over	High
				Equation
Baseline Totals				**Area Totals**
				Vulnerability Ranking

Through extensive literature-based research and talking with experts, a context within this framework was created based on numeric weightings (table 2). These weightings range from 10 (low vulnerability) to 50 (high vulnerability) and are proportional to reflect the vulnerability of the total population. Although these weightings were arbitrarily chosen, they allow the data to be reflective of incremental levels of vulnerability based on their given assessment of high, medium and low. The rational behind choosing weightings ranging from 50 to 10 was that these coefficients represent an evenly distributed numeric spread that clearly identifies the most vulnerable compared to the least vulnerable groups within a total population.

It is important to note that even though this method yields-numerical data it cannot be directly equated to variables outside this framework. The purpose of this numerical weighting is to highlight a scale depicting high and low levels of vulnerability using given indicators. When transposed on a map, this information can offer an overview of the nature and extent of the problems that may arise.

Findings

By taking into account both sea level rise and human vulnerability, a vulnerability analysis using an indicators approach to assess the social determinants for Greater Vancouver was achieved. This assessment specifically looks at the human system in its present state of vulnerability; then, using future projections of sea level rise, analysis was done on how this additional physical stress affects an already-perturbed system.

As illustrated in figures 1 and 2, this research visually addresses the geographic variations in social vulnerability. By referring to Table 3 it is clear that there is an uneven capacity for preparedness and response and where resources might be used most effectively to reduce the pre-existing vulnerabilities. It is worth noting here than many of these vulnerability indicators (as seen in tables 1 and 2) are interconnected in complex and profound ways. While we can not know which exact systems will experience radical disruptions as a result of sea level rise, we can predict, with a huge degree of certainty, that at least some of the systems, in some of the areas, will experience very serious perturbations during this century as a result of sea level rise.

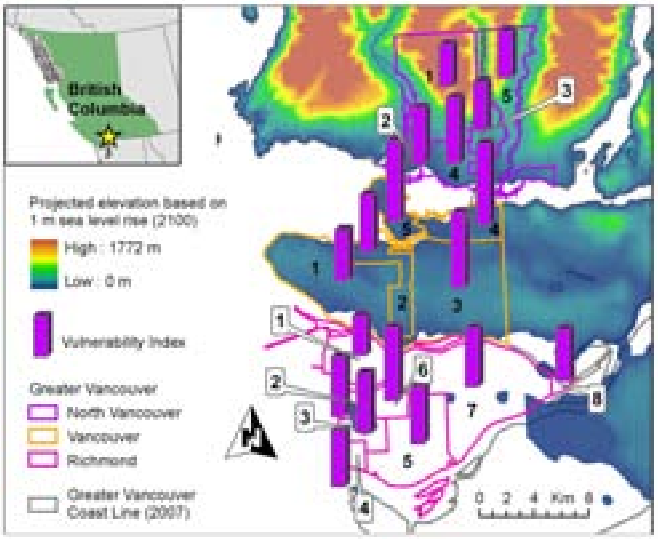

Figure 1: Map of Greater Vancouver Indicating Vulnerability and 1 metre Sea Level Rise

Figure 1 highlights the loss of land in Greater Vancouver as a result of a 1 metre rise in sea level. The areas that are shown in white would be considered underwater in this scenario. An assessment of vulnerability can be achieved by observing the purple bars represented in the figure and coupling them with the data available in table 3.

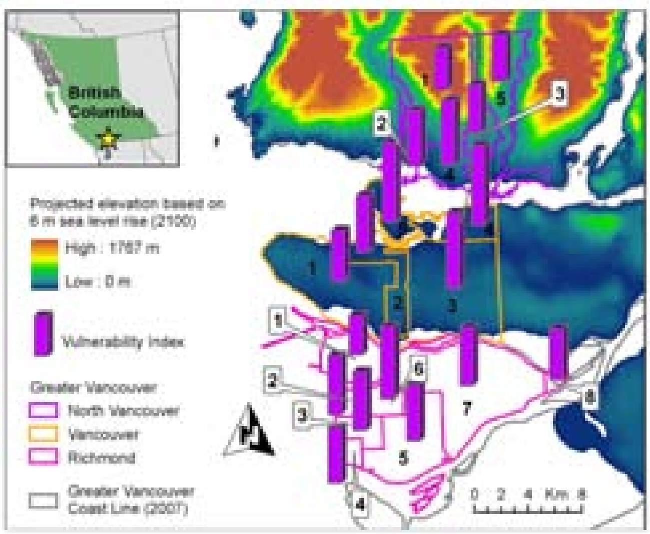

Figure 2: Map of Greater Vancouver Indicating Vulnerability and 6 metre Sea Level Rise

Figure 2 highlights the loss of land in Greater Vancouver as a result of a 6 metre rise in sea level. The areas that are shown in white would be considered underwater in this scenario. An assessment of vulnerability can be achieved by observing the purple bars represented in the figure and coupling them with the data available in table 3.)

Table 3: Assessed Vulnerability Index for Greater Vancouver

Region	Area	Vulnerability Index
North Vancouver	1	260
	2	281
	3	270
	4	294
	5	267
Vancouver	1	272
	2	282
	3	307
	4	316
	5	315
Richmond	1	256
	2	285
	3	285
	4	281
	5	281
	6	305
	7	284
	8	274

Based on an understanding that the population of greater Vancouver is ever expanding, it can be inferred that increasing human-induced pressures in coastal communities will exacerbate the effects of sea level rise. Of greatest concern to sea level rise, are the densely populated and low-lying areas where vulnerability is high. As a result of this research, it is clearly evident that relocating populations, economic activities and infrastructure would be costly and challenging, while on the flip side, mitigation efforts to hold back the sea in an effort to protect areas of Greater Vancouver would also be associated with immense costs.

Armed with the knowledge that climate change is happening, it is paramount that planning be achieved to deal with the consequences. This paper clearly identifies that planning cannot just be carried out in the form of technological fixes, the true essence of planning must manifest within the social consciousness of society.

References

Bindoff, N. and Willebrand, J. (2007) Observations: Oceanic Climate Change and Sea Level. In Solomon, S., Qin, D. and Manning, M. (eds) Climate Change 2007: The Physical Science Basis. Cambridge: Cambridge University Press. Pp. 385-432.

Brown, P. (2006) Global Warming: The Last Chance for Change. London: Dakini Books NP.

Cannon, T. (2000) Vulnerability Analysis and Disasters. In Parker D.J. (eds) Floods. London: Routledge.

Douglas, B. and Peltier, W. (2002) The Puzzle of Global Sea Level Rise. Retrieved 07 August, 2007, from American Institute of Physics web site: http://webster-alt.aip.org/pt/vol-55/iss-3/p35.html

Garrett, J.F. (2001) Climate Change and Marine Ecosystems. Retrieved 23 July, -2007, from Ministry of Environment web site: http://www.env.gov.bc.ca/air/climate/indicate/sealevel_idl.htm

Hoffman, J.S., Keyes, D. and Titus, J. (1983) Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100. Washington D.C.: U.S. Environmental Protection Agency.

Jelgerma, S. (1990) Atmospheric, Oceanic and Climate Response to Greenhouse and Feedback Effect. In Paepe, R., Fairbridge, R.W. and Jelgersma, S. (eds) Greenhouse Effect, Sea Level and Drought. Dordrecht: Kluwer Academic Press. Pp.75-84.

Kerr, R.A. (2006) A Worrying Trend of Less Ice, Higher Seas. Science, 311: 1698-1701

Landerer, F., Jungclaus, J. and Marotzke, J. (2006) Regional Dynamics and Steric Sea Level Change in Response to the IPCC-A1B Scenario. Journal of Physical Oceanography, 37: 296-312.

Lemke, P. and Ren, J. (2007) Observations: Changes in Snow, Ice and Frozen Ground. In Solomon, S., Qin, D. and Manning, M. (eds) Climate Change 2007: The Physical Science Basis. Cambridge: Cambridge University Press. Pp. 337-383.

Otto-Bliesner, B., Marshall, S., Overpeck, J., Miller, G. and Hu, A. (2006) Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciatin. Science, 311: 1751-1753.

Statistics Canada (2001) 2001 Census of Canada. Retrieved on 1 June, 2007 from Statistics Canada web site: http://www12.statcan.ca/english/census01/home/Index.cfm

Author Biographies

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