Climate-Related Stresses on Human Health in a Remote and Rural Region of Ontario, Canada

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Abstract:

This thesis examines the susceptibility of human health to climate-related stresses in the rural municipality of Addington Highlands, Ontario. Human health is sensitive to climatic variations and change, and public health systems play a role in managing climate-related risks. Canada is generally deemed to have considerable capacity to adapt to vulnerabilities associated with climate change, yet there is variability among communities in their exposure and ability to manage health risks. This thesis examines the health-related vulnerability of the community of Addington Highlands. Drawing upon data gained from key informant interviews and newspaper articles, as well as other secondary data sources, the thesis documents climate-related health risks, outlines the programs and services available to deal with those risks, and assesses the capacity of the community to adapt to future climate conditions and risks. Conditions such as storms, heat stress and forest fires currently present health risks in the area, and they are expected to become more prevalent with climate change. The health risks of Lyme disease, West Nile virus and algal blooms are likely to increase in the future as the climate continues to change. Adaptation to these risks is evident in several of Addington Highlands public health and emergency management programs. The community's adaptive capacity is strengthened by its social networks and institutional flexibility, but it is constrained by its aging population, limits to the availability and access to health care services, and challenges relating to the retention of service providers. An important strategy to assist adaptation to climate change risks to health is the promotion of public awareness, a strategy to which this research contributes. This thesis research serves to identify and better understand vulnerabilities, and help stimulate actions toward preparing Addington Highlands for possible future climate-related risks.

Résumé

Cette thèse examine la sensibilité du système de soins de santé aux stress reliés au changement climatique dans la communauté rurale d'Addington Highlands, Ontario. La santé est affectée par la variabilité et les changements climatiques, et les systèmes de santé publique jouent un rôle dans la gestion des risques liés au climat. Le Canada est généralement considéré comme ayant une capacité d'adaptation considérable aux vulnérabilités reliées au changement climatique, pourtant il existe des écarts entre les communautés quant à leur exposition et à leur habilité à gérer les risques pour la santé. Cette thèse examine la vulnérabilité du point de vue de la santé des citoyens du comté d'Addington Highlands en Ontario. À l'aide de sources de données secondaires et des entrevues avec des intervenants clés, cette thèse documente les risques pour la santé associée au changement climatique, présente les programmes et services disponibles pour affronter ces risques, et évalue la capacité de la communauté de s'adapter aux changements climatiques futurs. Les événements météorologiques extrêmes, le stress thermique et les feux de forêt représentent actuellement des risques pour la santé dans la région, et on peut s'attendre à ce que ces risques deviennent plus fréquents et intenses dans le futur. Les risques pour la santé liés à la maladie de Lyme, au virus du Nil occidental, et aux proliférations d'algues vont vraisemblablement augmenter à l'avenir. L'adaptation à ces risques est incluse dans plusieurs programmes de santé publique et de la gestion des urgences pour la municipalité d'Addington Highlands. La capacité d'adaptation de la communauté est renforcée par la force des réseaux sociaux et la souplesse des institutions qui s'y trouvent, mais cette capacité est restreinte par le vieillissement de la population, des limites quant à la disponibilité et à l'accès aux services de soins de santé, et des défis quant à la rétention des fournisseurs de services.

Une stratégie importante servant à faciliter l'adaptation aux risques pour la santé liés au changement climatique est la promotion de la sensibilisation du public, stratégie à laquelle cette recherche contribue. Cette thèse de recherche sert à identifier et mieux comprendre les vulnérabilités, et incite à prendre des mesures afin que la municipalité d'Addington Highlands soit mieux préparée à affronter les risques futurs liés au changement du climat. Un effet bénéfique à long terme de cette recherche est d'inciter la municipalité d'Addington Highlands à une plus grande prise de conscience quant à sa sensibilité aux risques liés au changement climatique.

Preface

This thesis follows the article format and consists of three chapters. Chapter 1 provides an introduction to the topic, a review of the literature in the field, a characterisation of the study area, and an outline of the main elements of the thesis research, including objectives and methods. Chapter 2 consists of a manuscript prepared for submission to *Global Environmental Change*. Chapter 3 summarizes the main findings of the study, outlines its limitations, notes the main scholarly and practical contributions of the thesis, and suggests opportunities for future research. Included in appendices are examples of the newspaper data analysis and the interview data analysis, as well as the interview guide and letter of consent.

The candidate is the first author of the manuscript, and assumes primary responsibility for the conceptualization of the research, the design and execution of the empirical research, and the preparation of the manuscript drafts. Co-author and Supervisor Dr. Robert McLeman provided guidance and direction for the research, was responsible for providing and directing project funding, established initial contacts in the study community, and provided feedback and editorial input to the crafting of the manuscript. Co-author Dr. Eric Crighton helped facilitate the research program and provided suggestions and editorial inputs on the manuscript drafts.

Acknowledgements

I am grateful to Dr. Robert McLeman and Dr. Eric Crighton for their guidance, encouragement and advice throughout my time at the University of Ottawa. Dr. André Viau's helpful comments on my proposal assisted in better situating this research within the broader climate change literature. Further comments provided by Dr. Peter Berry are gratefully acknowledged. I also note with appreciation the support of Sylvie Thériault and her continued assistance in navigating the administrative tasks associated with being a graduate student. This research was supported by a special grant for environmental research from the Social Sciences and Humanities Research Council of Canada. Special thanks are also due to the people of Addington Highlands, whose experience and knowledge inform the basis of this research. Their dedication to improving the welfare of their community is inspiring and will stay with me as I continue to better understand how climate change may influence the health and well-being of people in Canada and around the globe.

Chapter 1

1.1 Introduction and Research Objectives

It has been acknowledged that global climate change impacts are being observed on both human and natural systems, including water resources, forestry, food production, coastal areas, ecosystems, industry, settlements and human health around the globe (Intergovernmental Panel on Climate Change (IPCC), 2007). Recent studies report on how the effects of climate change have manifested themselves at the global, national and regional levels, as well as on how these effects are expected to advance as greenhouse gases continue to accumulate in the atmosphere (Anderson and Bell, 2009; Balbus and Malina, 2009; Health Canada, 2008a; Health Canada, 2008b; Intergovernmental Panel on Climate Change (IPCC), 2007; Lemmen and Warren, 2004; Rose et al., 2001; Warren and Egginton, 2008).

Climate change has been identified as potentially the biggest health threat of the 21st century (Costello et al., 2009). Increasingly, research is linking climate change to illness, injury and death, and as a stressor influencing the determinants of health (Blashki et al., 2007; Costello et al., 2009; Seguin, 2008; McMichael et al., 2008). For example, potential health impacts of climate change may include injuries and mortality related to extreme weather events, such as storms or heat waves; infectious diseases related to changes in vector distribution and water quality; and respiratory and cardiovascular disease related to worsening air pollution. Although there may be some global benefits, such as less cold related deaths, the overall balance of effects of climate change on health is likely to be negative (Confalonieri et al., 2007; Haines et al., 2006). The relationship between health and climate change is complex and the impacts will vary across groups in different places and times (Comrie, 2007). As such, public health efforts to protect populations have often centred on assessing

vulnerability at both the individual and community levels (Costello et al., 2009; Forastiere, 2010; Furgal and Prowse, 2009; Künzli, 2010; Luber and Prudent, 2009). For this reason, climate change and health vulnerability assessments are often seen as the first step to adapting (Hess et al., 2011), and are undertaken so as to determine existing levels of exposure, identify and better understand sensitivity and identify factors that may increase or decrease a community's capacity to respond to changes (Ebi et al., 2009).

This research assessed climate-related stress on human health in the rural Township of Addington Highlands, Ontario, to provide a clearer picture of the vulnerability of the people of the region to climate change. It was informed by the conceptualization of vulnerability employed in the climate change field. Vulnerability in this study refers to the degree to which the study area (hereafter referred to simply as 'Addington Highlands') is susceptible to conditions that either directly or indirectly affect the health of its population. Vulnerability is a function of exposure-sensitivity and capacity reflected in adaptations (Smit and Wandel, 2006; Smit et al., 2008). Exposure-sensitivity (similar to what is referred to as risk) for this study refers to the degree to which the Addington Highlands region is sensitive to and exposed to the climate conditions which affect health; and adaptive capacity (also referred to as risk management) refers to the ability of Addington Highlands to cope or adjust to climate-related health effects (Berry, 2008; Fussel, 2005; Luers, 2005; Smit and Wandel, 2006).

These concepts form the foundation for the following research objectives: 1) identify and document current and potential climate-related stresses on health in Addington Highlands (exposure-sensitivity); 2) understand how climate-related health risks and health are

presently managed (adapting); and 3) identify potential barriers to, and opportunities for, enhancing capacity in order to adapt to climate-related health risks (adaptive capacity).

This study provides an example of a rural-focused, community-based climate-related health vulnerability assessment. It documents the role climate-related stresses have on health in the township of Addington Highlands. This study does this by documenting risks identified by community professionals in the region, recording the various community programs and services available to manage those risks, and describing how such risks may impact health in the future.

To provide a foundation for the empirical investigation of the climate-related stresses on Addington Highlands' health, the essential features of the inter-related human-environment systems that underlie health vulnerability to a changing climate are described. For this, data from secondary sources were compiled to provide a characterization of the study region's climate, population and public health services. To identify Addington Highlands' health vulnerabilities, a community-based approach was employed to collect data from key informant interviews and newspaper articles in order to describe specific aspects of the community's environment, society and services that constituted vulnerabilities to current climate and possible changes in climate.

Chapter 1 provides background information and scholarly evidence relating to the relationship between climate change and health, sensitivity of rural populations to climate-related health risks, and previous assessments and frameworks for assessing impacts (Section 1.2). The study area is described, including information on climate,

population and health characteristics, and community health services (Section 1.3). This chapter also outlines the methods and analysis (Section 1.4) employed in this study to fulfill the research objectives.

1.2 Climate Change and Health Vulnerability

The goal of this literature review is to introduce common types of climate-mediated health risks in order to position the study within the larger field of research on the health impacts of, and adaptations to, climate change. This review addresses what is known about the relationship between climate change and health, both the current and projected health risks, as well as the pathways by which climate change impacts health. The review also identifies ways to assess climate related stresses on human health and take adaptive actions to manage vulnerability.

1.2.1 Relationship between Climate Change and Human Health

National and regional studies of vulnerability to climate change carried out by governments and academic researchers indicate that the current and anticipated warming of the Earth's climate will impact Canadians' health and economic well-being (Health Canada, 2008b; Lemmen et al., 2008). Climate change may alter Canadians' exposure to climate-related health risks directly or indirectly (Séguin and Clarke, 2008a). For example, injury, illness and death can be caused directly by extreme weather events, such as heat waves, storms and floods. Whereas the indirect effects of climate factors are often mediated through ecological systems that affect food and water supply, and take the form of food and water related illnesses (e.g., *E. coli*, *Samonella, Cryptosporidium*, algal blooms), vector- and rodent-borne diseases (e.g., Lyme disease, West Nile virus,

hantavirus), and pollen allergies and air pollution (Costello et al., 2009; Ebi, 2009; Kunzli, 2006; McMichael et al., 2006; Patz and Olson, 2006).

Table 1 provides a summary generated by Health Canada of key health impact categories (e.g., temperature extremes, extreme weather events and natural hazards, contamination of water and food, air quality), their climate related causes (e.g., increasing temperatures, sea level rise, violent storms, air pollution) and projected or possible health effects (e.g., heat stroke, injury, stress related illnesses, respiratory and cardiovascular disease, outbreaks of microorganisms). Each health impact category listed may be influenced by a variety of current or projected climatic conditions, and have direct or indirect health effects.

The case of waterborne contamination is elaborated on below in order to illustrate the types of relationships that Table 1 summarises. The most direct effects of climate conditions on waterborne diseases occur through contamination of drinking water and recreational water. Storm water runoff can contaminate streams, rivers and lakes, whereas drought conditions can concentrate pathogens and chemical and radiological contaminants in water due to lower water levels (Charron et al., 2008). In Canada, heavy precipitation, snowmelt and flooding events are thought to have contributed to past water contamination and disease outbreaks (Bowie et al., 1997; Charron et al., 2004; Schuster et al., 2005; Thomas et al., 2006). For example, a severe storm in British Columbia in the autumn of 2006 resulted in a boil water advisory affecting two million people (Clarke, 2009). Also, Fleury et al. (2006) found that the occurrence of *Salmonella, Campylobacter* and *E. coli* infection increases as ambient temperature rise. Climate change is expected to increase the risks of water-borne disease due to projected changes in heavy rainfall events

and increased temperatures (Charron et al., 2008). Furthermore, climate warming may promote the growth of some species of harmful cyanobacteria (both freshwater and marine) by providing more optimal conditions for their growth independently or in combination with nutrient availability (Dale et al., 2006; Paerl and Huisman, 2008 and 2009).

Table 1: Climate risks and related health effects in Canada

Health Impact Categories	Climate-related Causes	Projected / Possible Health Effects
Temperature extremes	• More frequent and severe heat waves • Overall warmer weather, with possible colder conditions in some locations	• Heat-related illnesses and deaths • Respiratory and cardiovascular disorders • Possible changed patterns of illness and death due to cold
Extreme weather events and natural hazards	• More frequent and violent thunderstorms, more severe hurricanes and other types of severe weather • Heavy rains causing mudslides and floods • Rising sea levels and coastal instability • Increased drought in some areas, affecting water supplies and agricultural production, and contributing to wildfires • Social and economic changes	• Death, injury and illness from violent storms, floods, etc. • Social and emotional injury and long-term mental harm from loss of loved ones, property and livelihoods • Health impacts due to food or water shortages • Illnesses related to drinking water contamination • Effects of displacement of populations and crowding in emergency shelters • Indirect health impacts from ecological changes, infrastructure damages and interruptions in health services • Psychological health effects, including mental health and stress-related illnesses
Air quality	• Increased air pollution: higher levels of ground-level ozone and airborne dust, including smoke and particulates from wildfires • Increased production of pollens and spores by plants	• Eye, nose and throat irritation, and shortness of breath • Exacerbation of asthma symptoms • Chronic obstructive pulmonary disease and other respiratory conditions • Exacerbation of allergies • Heart attack, stroke and other cardiovascular diseases • Increased risk of certain types of cancer • Premature death
Contamination of food and water	• Contamination of drinking and recreational water by run-off from heavy rainfall • Changes in marine environments that result in algal blooms and higher levels of toxins in fish and shellfish • Behavioural changes due to warmer temperatures resulting in an increased risk of food- and water-borne infections (e.g. through longer BBQ and swimming seasons)	• Outbreaks of strains of micro-organisms such as *E. coli, Cryptosporidium, Giardia, S. typhi* (typhoid), amoebas and other water-borne pathogens • Food-borne illnesses • Other diarrhoeal and intestinal diseases
Infectious diseases transmitted by insects, ticks and rodents	• Changes in the biology and ecology of various disease-carrying insects, ticks and rodents (including geographical distribution) • Faster maturation for pathogens within insect and tick vectors • Longer disease transmission season	• Increased incidence of vector-borne infectious diseases native to Canada (e.g. eastern & western equine encephalitis, Rocky Mountain spotted fever) • Introduction of infectious diseases new to Canada • Possible emergence of new diseases, and of those previously eradicated in Canada
Stratospheric ozone depletion	• Depletion of stratospheric ozone by some of the same gases responsible for climate change (e.g. chloro- and fluorocarbons) • Temperature-related changes to stratospheric ozone chemistry • Increased human exposure to UV radiation owing to behavioural changes resulting from a warmer climate	• More cases of sunburns, skin cancers, cataracts and eye damage • Various immune disorders

Source: (Seguin and Clarke, 2008)

Changes in climate that affect health happen through complex interactions among social and economic processes, the physical environment, health services, culture, education, genetics and individual behaviours (Comrie, 2007; McMichael, 2003; World Health Organization, 2011). These factors are often referred to as the determinants of health (World Health Organization, 2011). For example, particular attributes of climate, such as temperature and precipitation, affect the reproduction and survival rates of viruses (e.g., malaria, Lyme disease), bacteria (e.g., cholera) and protozoa (e.g., *Guardia*), as well as vectors that transmit diseases (e.g., mosquitoes, ticks). However, while climate is a key factor influencing the presence of such disease agents, it is not the sole determining factor in the distribution of disease outbreaks. In the case of vector-borne diseases, social economic conditions and health education influences a population's usage of vector repellent and protective clothing impacting transmission rates (Charron et al., 2008; Menne and Ebi, 2006). Community vector control programs and land use patterns influence the distribution of vectors, and genetic or vaccination immunity may afford some individuals a protective advantage against contracting the disease (Campbell-Lendrum and Woodruff, 2007; Frumpkin et al., 2008).

Another key factor to consider is that programs, standards and services in place that ensure good health are reflective of current and recent climate norms for that location, and as such, they may not be as effective under new and more extreme climate parameters (Frumkin and McMichael, 2008; McMichael et al., 2006; Patz et al., 2008). This factor can include the following elements being compromised: safe water and food (e.g., flooding of a water treatment plant); housing (e.g., mould related problems after a

flood); proper civil infrastructure such as sanitation systems (e.g., mudslides triggering boil water advisories, and road damage preventing ambulance transportation); reliable power supplies (e.g., power shortages during heat waves or power loss after major storms); and health infrastructure (e.g., buildings that do not withstand extreme weather conditions) (Berry et al., 2008; Campbell-Lendrum and Corvalan, 2007; Clarke, 2009; Lemmen et al., 2008; Luber and Prudent, 2009).

The wide range of health impacts that a climate-related event can cause through a variety of pathways is exemplified by Hurricane Juan, a category 2 hurricane (Public Safety Canada, 2011). In September 2003, it made landfall in Nova Scotia as one of the most powerful and damaging hurricanes to affect Canada. Juan was responsible for eight deaths (Public Safety Canada, 2011). More than 300,000 people were without power for up to 10 days, telephone service was disrupted and the water infrastructure was compromised. The Victoria General Hospital in Halifax sustained flooding and water damage after its roof was destroyed. More than 200 patients had to be relocated to other facilities and beds at functioning facilities became scarce. Patients with even minor injuries could not be sent home since it was not safe to do so because of power, water and telephone shortages. The Victoria General did not open its operating theatres until four weeks after the event. Surgeries scheduled during that period were rebooked, which increased surgical wait lists (Fulmore and Russell, 2005).

Summarizing the above discussion on the relationship between climate change and health impacts, Figure 1 depicts the pathways by which climate can bring about adverse health outcomes through direct and indirect exposure as well as through social and economic

disruptions, all of which can be modified by environmental and social conditions and health systems in place.

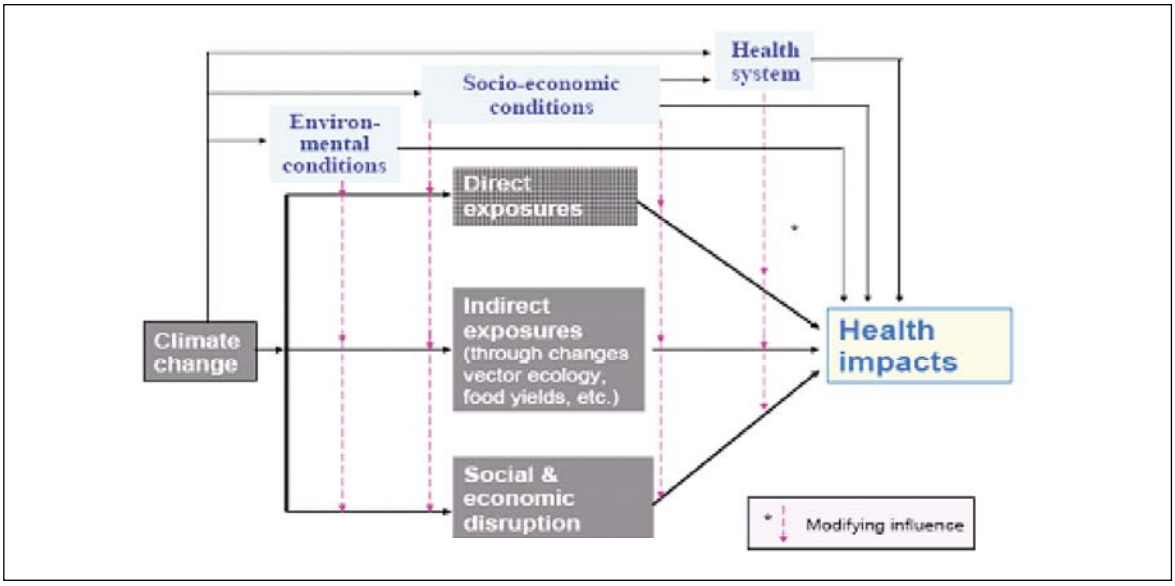

Figure 1: Pathways by which climate change impacts health, and the concurrent influences on environment, social and health system factors
Source: (Confalonieri et al., 2007)

Who you are and where you live influences climate-related health risks. Research shows that certain populations face a greater than average risk due to increased exposures, existing sensitivities or low adaptive capacity (Balbus and Malina, 2009; Medina-Ramon and Schwartz, 2008; UK National Health Service, 2009). For example, geographic location may increase exposure to extreme weather events and conditions (Patz et al., 2005). People living in southern Ontario, for example, are more at risk of the health hazards produced by extreme heat and air pollution, and those living in the Prairies are more likely to be exposed to the health effects of drought (e.g., wild fires and water quantity and quality issues) (Lemmen et al., 2008). Some individuals may be more sensitive due to pre-existing health (e.g., people with cardiovascular conditions are more

susceptible to succumb to heat illness) or socio-economic conditions (e.g., access to air conditioning during extreme heat). Moreover, an individual's recreational activities or occupation can affect their exposure to climatic conditions (e.g., running a marathon or farming during a heat wave).

Vescovi et al., (2005) provides an example of a study that assessed health risks for a particular geographic region by looking at climate and socio-economic parameters. They analysed current climate data (mean annual number of hot days with temperatures over 30°C from 1971-2000) and projected hot days (expected number of hot days with temperatures over 30°C for 2039- 2063), as well as social vulnerability indicators such as age (people over 65), poverty (low-income earners), social isolation (frequency of single person households), and education (frequency of people over 20 with less than 13 years of education) in order to estimate current and projected heat-health risks for southern Quebec (Vescovi et al., 2005). These climate variables and socio-economic parameters were integrated via a geographic information system (GIS) tool to produce comparative maps estimating present and future public health risks (Figure 2). The maps show that the number of locations across southern Quebec where people will be at risk to extreme heat will increase dramatically over the coming decades and provides information that can be used by public health officials and decision-makers (Vescovi et al., 2005).

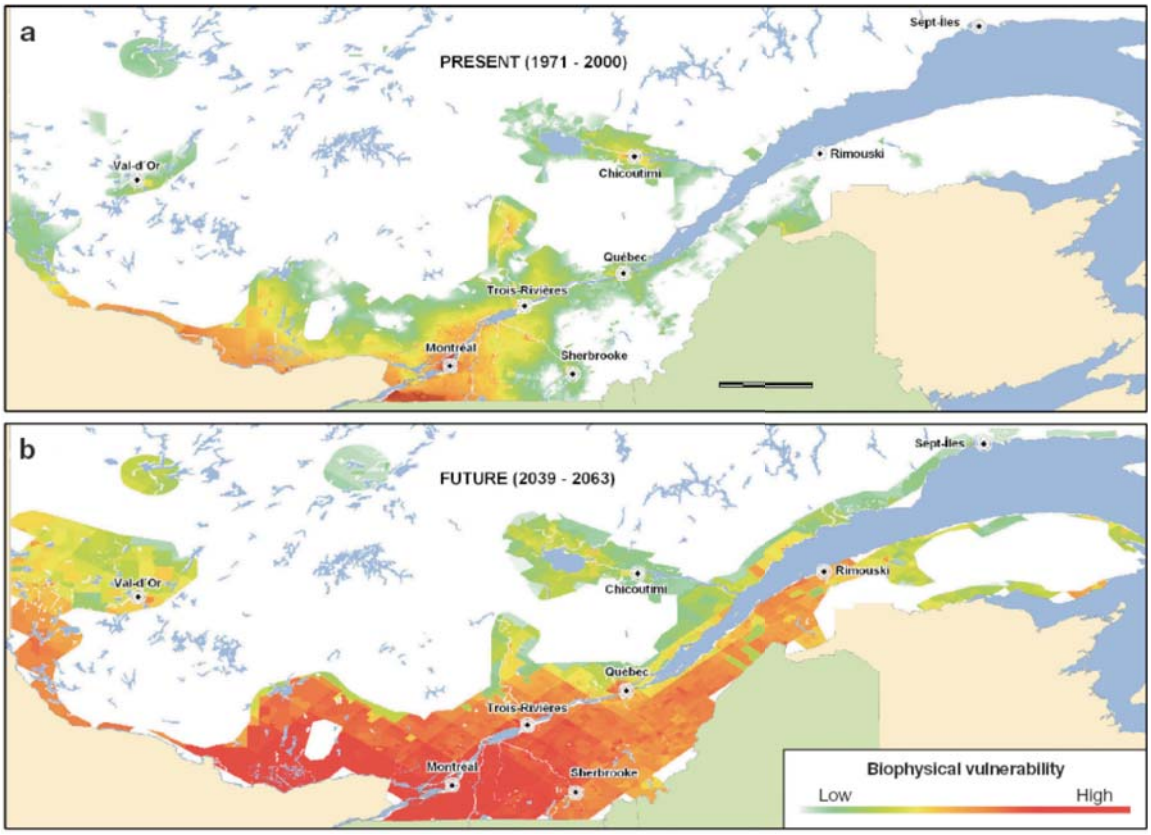

Figure 2: Map of current and future vulnerability to extreme heat events in Quebec

To characterize future climate hazards related to potential impacts of extreme heat, climate projections for 2039–2063 were calculated using the CRCM V3.6.1, driven by the coupled ocean–atmosphere model CGCMII, and following the IS92a (IPCC) emissions scenario for greenhouse gas emissions.

Source: (Vescovi et al., 2005)

1.2.2 Sensitivity of Rural Communities to Climate Change and Health Risks

Communities differ in their capacity to cope with and adapt to climate-related risks. Notably, faced with the same exposure, rural regions have been found to be more vulnerable due to differing levels of capacity and accessibility to resources (McBean, 2006; Seguin and Clarke, 2008). Haque (2002) compared rural and urban communities' ability to respond to an emergency and identified that rural communities face the added challenges relating to over-reliance on volunteers, an underestimation of the frequency of events and hazards because of a lack of knowledge and risk assessments; and inadequately trained or organized emergency personnel.

In rural regions where livelihoods are closely tied to natural resources (e.g., farming, forestry, fishing), climate change may contribute to economic decline, social disruption, population displacement and/or similar challenges (Battisti and Naylor, 2009; Friel et al., 2009; Holden, 2009; McLeman et al., 2011). For example, McLeman (2009) reports that in rural Addington Highlands, residents' livelihoods are being affected by changes in the weather, namely milder and shorter winters, which makes it more difficult for local business operators to profit from snowmobiling, ice fishing and trapping. Furthermore, less snow and ice in the winters makes ice fishing and trapping less feasible in Addington Highlands, thereby affecting secondary incomes and supplementary food sources of households that practice such activities, of which there are many. As importantly, the resulting decrease in social interactions associated with decreased participation in these activities can adversely affect the residents' sense of connection to the community (McLeman, 2009).

Rural populations are, on average, older than urban populations in Canada. Older people are identified as a vulnerable group for climate-related impacts as they are more likely to have underlying health problems that need regular medical attention, have limited mobility or impaired ability to care for themselves, have visual, cognitive and hearing impairments, have reduced literacy and experience social isolation (Kenny et al., 2009; Ledrans et al., 2004; Seguin, 2008;). In 2008, Statistics Canada released a report on rural Canada, based on data from the 2006 Census of the Population. Within predominately rural regions, 15% of the population is senior compared with 13% in predominately urban regions (Statistics Canada, 2008). Rural regions were also reported to have the highest

old age dependency ratios and also have some of the highest child dependency ratios in Canada (Statistics Canada, 2008).

These higher dependency ratios in rural regions are important as they put increasing pressure on the younger generations to care for the aged and very young (Statistics Canada, 2008). Furthermore, communities that are aging are experiencing an increase in the demand for health services for seniors (Statistics Canada, 2008). Crooks and Andrews (2008) describe some of the particular challenges that rural communities contend with when trying to meet the increased demand for health services for seniors. For example, they report that: it is difficult to attract primary care provides and specialists, such as palliative care specialists, to rural communities; rural residents are more likely to die outside of a hospital; models of health care that work in urban centres may not work in rural settings; and increasing numbers of retired people are moving to rural areas further amplifying the demand for seniors' health services (Crooks et al., 2009).

These findings are consistent with those reported by Hanlon and Halseth (2005), who also find that a lack of health services tends to result in continuing care services being 'offloaded' to family and volunteer community support networks. Given that working populations (age 15-64) in rural regions are declining (Statistics Canada, 2008), there are fewer people in the volunteer community to share the responsibilities of the care for seniors that is being offloaded, thus affecting the type of care seniors receive.

These types of factors can make a rural community more sensitive to climate-related stress on the public's health because they reduce the general adaptive capacity of a

community (Sander-Regier et al., 2010). In such settings, Hess et al. (2011) indicate that ensuring basic health service provision may be the most effective strategy for enhancing adaptive capacity for climate-related risks. On the other hand, rural communities have been reported to have more community cohesiveness, which makes responding to emergencies and delivering health messages to vulnerable populations easier (Furgal and Prowse, 2009). Notably, Hanlon and Halseth (2005) emphasize that "it is important to recognize the varieties of economic, social and political circumstances that beset different rural and remote places, and that change is as much the norm outside as inside metropolitan centres" (p. 2). The capacity of rural populations to respond to climate change is influenced by these unique circumstances (e.g., dependency on natural resources, reductions in public services and changing demographics) (Wall and Marzall, 2006). Rural place-based assessments are therefore important, in addition to regional and national assessments (discussed in the next section), as they aim to identify and document these types of interconnected factors (e.g., social, human, institutional, resources, health and economic status) in order to better gauge the vulnerabilities of a community to specific climatic conditions at a specific time. This information can then be used by decision-makers to identify actions that can be taken to reduce risks and increase adaptive capacity (Seguin, 2008).

1.2.3 How Climate-Related Health Vulnerability is Assessed

Familiarity with climate-related health effects, and the pathways by which climate can influence health, as discussed in the previous section, is a necessary prerequisite for undertaking an assessment of the impacts of climate change on health in Canada (Seguin and Clarke, 2008). Given the differences in exposure and adaptive capacity across regions, rural

communities across Canada will experience climate change differently (Warren and Egginton, 2008), which speaks to the importance of conducting individual community assessments (Ebi and Semenza, 2008). Local vulnerability assessments are important for community decision makers to understand the public health risks faced by their community and use this information to guide protective actions (Doyon et al., 2008; Health Canada, 2008c; Pengelly et al., 2007). However, there are in practice few examples of rural community-based climate change health assessments in Canada.

In Canada, assessments of vulnerability and adaptation to the health impacts of climate change have mostly been focused at the national or regional level (Chiotti and Lavender, 2008; Furgal and Prowse, 2009; Health Canada, 2008b; Lemmen and Warren, 2004; Lemmen et al., 2008). In 2008, the Government of Canada published two important national assessments. *From Impacts to Adaptation - Canada in a Changing Climate* (2007) provided a regional analysis of climate change impacts and adaptation in Canada for various sectors, including transportation, forestry, agriculture, fisheries, tourism, water resources management, infrastructure, ecosystems and human health (Lemmen et al., 2008). For example, in the chapter reporting on how climate change will influence the province of Ontario, which was reviewed for this study, a number of health risks of concern to Ontarians were identified, including illnesses and deaths related to poor air quality; food shortages; water- and food-borne contamination; extreme weather events; and changing patterns of diseases spread by animals, ticks and insects (Chiotti and Lavender, 2008). A second national assessment report issued by Health Canada, *Human Health in a Changing Climate - A Canadian Assessment of Vulnerabilities and Adaptive*

Capacity (Seguin, 2008), specifically focused on health vulnerabilities and adaption to climate change.

Both reports highlight the key health impacts from a changing climate prior to 2008, but they differ in their focus. The Lemmen et al. (2008) assessment situated human health as a sub-component of each regional chapter, whereas the Seguin (2008) assessment focused on impacts and adaptation by health issue area and within two regions, the North and Quebec. Seguin (2008) examined the scope and magnitude of current and anticipated health concerns related to air quality, infectious diseases and natural hazards, and reported on evidence collected through a wide range of methods (literature review, modeling studies, table top-exercises, interviews and population surveys) in order to provide relevant information on adaptations, sensitivities and capacity for decision-makers at all levels of government. For example, the assessment revealed differences in capacities between cities and smaller and rural communities, to plan and prepare for emergencies and disasters, indicating that small communities and rural areas are less prepared. The assessment does not, however, provide climate or health risk information at the level of individual communities. Rather, it identities common exposures, population sensitivities and adaptive capacity features that effect health, and encourages communities to undertake their own local assessment.

Some climate change and health assessments have been initiated in Canadian cities, although these are often focused on one particular risk and tend not to look at the variety of health risks posed by climatic change. Toronto, for example, has focused on heat and established early warning systems, “cooling centers” and programs to assist the elderly in the event of a heat wave (Toronto Public Health, 2009; Bassil et al., 2007). Rural

assessments are less common. Climate change and health assessments have been conducted in some Arctic and northern communities (Ford et al., 2010; Furgal et al., 2008) but despite considerable research, no examples of such assessments were found to have been undertaken in rural communities in southern Canada. The drivers of health vulnerability in southern rural communities are considerably different from those in the north (Furgal and Prowse, 2009) and so for planning purposes generalizations should likely not be made from one to the other. Rural assessments would be very valuable to Canada's southern rural communities given their particular challenges related to population change and rural service delivery (Skinner, 2008), that may constrain their capacity to respond to climate related impacts (Public Health Agency of Canada (PHAC), 2006; Statistics Canada, 2003; Statistics Canada, 2006; Statistics Canada, 2008). This lack of existing examples of rural community climate change and health impact assessments represents an important underlying rationale for this thesis research project.

1.2.4 Frameworks for Assessing Climate Change Impacts and Adaptation

A variety of conceptual and analytical frameworks for assessing climate change impacts and vulnerability were reviewed for possible use in this study (e.g., Lim et al., 2005; Polsky et al., 2003; Smit and Wandel, 2006; Smit et al., 2008). Some identify key components of vulnerability, some focus on methods for identifying and measuring future impacts, while others provide more information and direction on how to develop needed adaptation strategies. In addition to these general frameworks, climate change assessment and risk management frameworks geared specifically for health decision-makers have also been developed by researchers (e.g., Berry, 2008; Fussel and Klein. 2004; Kovats, et al. 2003; Patz, et al. 2008). These frameworks support risk management of climate related health

hazards by: providing information about new methods for conducting assessments; highlighting the importance of thresholds and of considering cumulative impacts from multiple stressors on health; and discussing the need to measure adaptive capacity to successfully prepare for health emergencies (Kovats, et al. 2003; Patz, et al. 2008). These frameworks all situate the concept of vulnerability as being influenced by the elements of exposure-sensitivity, adaptive measures and adaptive capacity (defined on page 2 above).

It is generally accepted that vulnerability to health impacts is a function of the exposure and sensitivity of populations to climate-related risks and the ability of a population to manage these risks through adaptive measures (Ford and Smit, 2004; Smit and Wandel, 2006). Generally, the adaptive capacity of a population to climate-related health risks can be influenced by the following key factors: economic resources, technology, information and skills, infrastructure, institutions and health status (Grambsch and Menne, 2003). For example, uneven access to information about climate risks (i.e., local climate modelling) and resource constraints on the ability of decision-makers to strengthen existing programs and implement new ones, has been identified as an issue for small communities to plan for or cope with the climate-related health effects (Berry et al., 2008). Adaptations, or adaptive measures or actions, are understood to be manifestations of adaptive capacity (Smit and Wandel, 2006).

This broad concept of vulnerability – reflecting both the exposure/sensitivity and the adaptive capacity – served as a basis for developing a conceptual and analytical framework to be used in this research project that would be consistent with those used in broader-scale climate-change and health research (e.g., Kovats, 2003; Berry, 2008; Fussel

and Klein, 2004; Seguin, 2008). For this research it was deemed important to develop a framework that starts with the system of interest (and hence has been called a "vulnerability as starting point" approach (Smit and Wandel, 2006)), and seeks to identify sensitivities and adaptive responses (both actual and potential future) from the people who are (or would be) doing the adapting. Such an approach is logical when the population and/or systems of interest are of local or relatively small spatial scales. This is in contrast to broader-based assessments that begin with climate change scenarios and models, or that assume human impacts and adaptive responses. This vulnerability concept and the associated analytical framework are based on those employed in various contexts and formats to conduct community-level vulnerability research (e.g. Adger and Brooks, 2003; Belliveau et al., 2006; Ford et al., 2010; Berring- Ford, 2009) and uses community members' own experiences with exposure-sensitivity, adaptive measures and adaptive capacity as a key data source in understanding their current and future vulnerability (Smit and Wandel, 2006).

Researchers using similar analytical frameworks have done so using different procedural approaches. One approach, for example, is to consider current exposure-sensitivities together with current adaptations or capacities before then considering future vulnerability (Ebi, 2009). An alternative approach is to consider current and future exposure-sensitivities, using the information on current conditions as the basis for considering possible future trends, and then looking at observed adaptations as a foundation for assessing adaptive capacity into the future (Cohen et al., 2006). It is this latter application of the framework that was employed for this community-based study of

vulnerability in Addington Highlands, for reasons related to data collection opportunities that are detailed in a subsequent section.

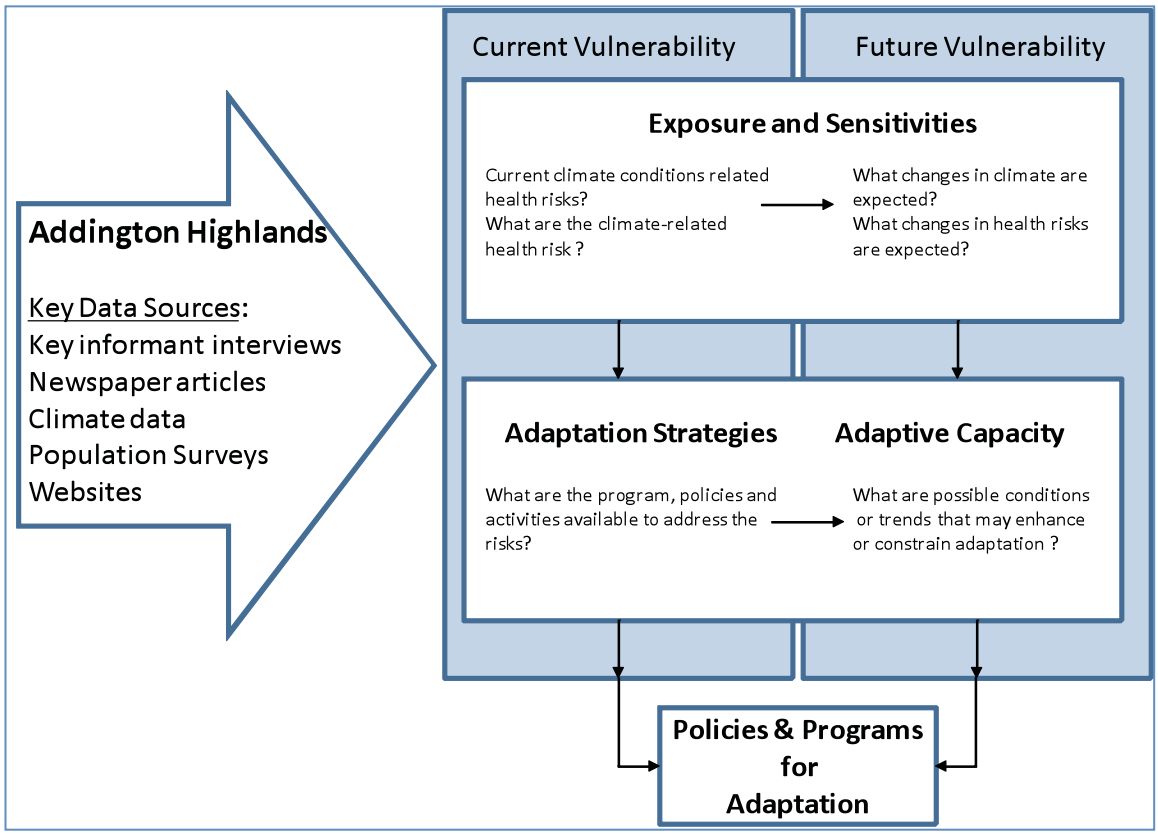

Figure 3: Framework for characterising human health vulnerability to a changing climate
(Adapted from Smit and Wandel, 2006)

Figure 3 illustrates the framework employed. It starts with the established conceptual premise that vulnerability is a function of the exposure and sensitivities of human health to climate-related conditions, and the strategies and capacity of the system to adapt to changing climate conditions. The analytical aspect of the framework is outlined in the white boxes in Figure 3, and illustrates a process for generating key questions and identifying possible data sources for answering those questions. It suggests starting by documenting the current conditions to which the population is (or has been) exposed and

sensitive (i.e., exposure and sensitivities), and identifying the measures or strategies undertaken to deal with them (i.e., adaptation strategies). These adaptations are characterized according to when and where they have been applied, by whom, and with what effectiveness. There are a variety of potential data sources for generating characterizations of current and future vulnerability, which may include, but are not limited to, key informant interviews, newspaper articles, health agency reports, existing research literature, websites, and government climate norms and trends data. The possibilities of future changes in the community-relevant conditions (i.e., future exposure and sensitivities) can be projected from current future risks by drawing on projections of future climate and other human and environmental factors (e.g., health and economic status, population projections).

Current adaptive capacity is characterized on the basis of the ability of existing adaptation strategies and resources to deal with the expected changes in conditions and risks, and an estimation of future adaptive capacity is made through the identification and assessment of the opportunities and constraints to adaptation (both existing and potential) under estimated future conditions (e.g., opportunities relating to less cold related deaths and constraints relating to increasing rates of chronic diseases). Through this process of generating a greater understanding of current and future vulnerabilities provides information of relevance to programs and policies related to health and health services for the location of interest, thereby complementing the more general information obtained from broad-scale assessments generated by Health Canada and similar government agencies. A summary of how the above framework was used to characterize human health vulnerability in Addington Highlands, in accordance with the research objectives,

is provided in the analysis section of this chapter (Section 1.4.4), and in Chapter 2. A detailed description of the specific methodology used in employing the conceptual/analytical framework follows in section 1.4 below.

1.3 Addington Highlands as a Case Study

Given the lack of previous case studies, any rural location in Canada would have conceivably been a useful location for testing the above framework. Addington Highlands made for an appropriate case study for a climate change and health vulnerability assessment, for a number of reasons. It is accessible from the University of Ottawa. Previous research has identified it as a rural area where climate-related impacts and adaptation are taking place (McLeman, 2009). Since 2007, the author's supervisor, Dr. McLeman, has been leading a team of researchers to investigate the capacity of the communities of Addington Highlands to adapt to climate change and variability. Research in Addington Highlands has indicated a sensitivity among residents to conditions such as milder winter, hotter and drier summers (McLeman, 2009). Interviews, focus groups and secondary data sources indicated that local climate change include a trend towards milder winters, hotter and drier summers, and more destructive high winds (McLeman, 2009). Issuing fire bans earlier in the season, checking weather conditions before undertaking fishing and hunting trips, and home ownership of generators in case of power outages are examples of adaptation in Addington Highlands, owing to current climate conditions (McLeman and Gilbert, 2008). This previous research provides a foundation for this study, which focuses on the health dimensions of vulnerability to changing climate conditions. In addition, Addington Highlands shares some similarities with other resource-dependent and seasonal-economy communities in Canada, rendering

findings of interest to communities facing similar changes (see earlier studies for the government of Canada based on Addington Highlands: McLeman et al 2010; McLeman and Gilbert, 2008).

Another key reason for selecting Addington Highlands for this case study is that the regional Boards of Health in Ontario, which are charged with the delivery of local public health services, adhere to several standards that require health officials to address climate-sensitive threats to health such as: infectious disease prevention and control; food safety; water safety; health hazard prevention and management and public health emergency preparedness (Ontario Ministry of Health and Long-Term Care, 2008). This indicates that climate-related health risks are recognized and, at least nominally, managed by the regional Board of Health responsible for Addington Highlands. Furthermore, standards require that the Boards of Health increase awareness of health risks associated with climate change. This research will therefore be particularly applicable to public health officials charged with such duties for Addington Highlands.

In summary, practical considerations, existing research, availability of data and information sources, and the applicability of the research to inform public health and community programs, provided a strong rationale for the study being undertaken in Addington Highlands.

1.3.1 Characteristics of Addington Highlands

Addington Highlands is located less than 200 km from Ottawa southeastern Ontario (see Figure 4). This is a sparsely populated area on the southern fringes of the Canadian

Shield that experiences a continental climate characterized by significant seasonal variations, from hot summers to cold winters. Approximately 2,500 people are permanent residents in this Township, which includes five villages—Denbigh, Cloyne, Northbrook, Flinton and Kaladar. Located at the centre of the township is Bon Echo Provincial Park (Figure 5), which draws over 175,000 visitors each year. There are 3,500 seasonal residents that also inhabit the area (McLeman and Gilbert, 2008). Furthermore, several major urban centers such as Kingston, the Greater Toronto Area and Ottawa—accounting for half of Ontario's population—are less than a 300 km drive away, making Addington Highlands a popular seasonal vacation spot in Ontario.

Figure 4: Relative location of Addington Highlands, Ontario, Canada
Source: (McLeman, 2009)

Figure 5: Villages located in Addington Highlands
Source: (McLeman and Gilbert, 2008)

The Addington Highlands area contains glaciated pre-Cambrian rock and thin soils. The area contains many lakes, rivers, streams, and wet lands, and is covered by a mix of boreal and coniferous-deciduous forests. These characteristics are reflected in the region's main economic industries, which include recreation and tourism, forestry, construction and public services, with the school being the largest employer in the township (McLeman, 2009).

From a health and climate change perspective, these biophysical characteristics are important. They not only influence the micro-climates experienced in the region, but the lakes provide recreational water for residents to cool off during periods of hot weather,

and forested areas are generally cooler than urban areas made of concrete and asphalt, especially in the evening—sometimes as much as 12°C cooler (Environmental Protection Agency, 2009). Less favourable is the fact that these conditions are hospitable to mosquitoes and ticks that can carry climate-sensitive diseases (Charron et al., 2008). Furthermore, owing to the surrounding forests, Addington Highlands residents are at risk from forest fires and their health effects.

More detail on the study area is provided on three topics of particular relevance to the assessment of climate-related health vulnerability, namely the prevailing climatic conditions, the population characteristics, and key elements of Addington Highland's health services.

1.3.1.1 Climate

Environment Canada's Climate Data Online website was searched for long-term historical weather and climate data for Addington Highlands (www.climate.weatheroffice.gc.ca/climateData/canada_e.html). Owing to a lack of climate data for the communities in Addington Highlands, a customized search for a surrounding station, 'Bancroft', was conducted. Long-term historical data (1882 to 1985) were found to exist for the Bancroft weather station, albeit with some breaks in certain years. The series was then extended for more current years by using data from the "Bancroft Auto" weather station for the years 1997 to 2006. This is consistent with the climate data analysis conducted by McLeman and Gilbert (2008).

Monthly data for all available years, from both the 'Bancroft' and 'Bancroft Auto' stations, were downloaded by choosing the XML download option offered on the Climate Data Online database and converted into an XLS spreadsheet using Microsoft Excel.

This spreadsheet was manipulated to extract mean maximum temperature data for the month of March for all available years. March was selected to see whether it could confirm Addington Highlands residents' impression that winters have become milder and shorter (ice melt happening early) over the last few decades as reported by McLeman (2009). Once the data had been arranged to form a continuous time-series, a line graph was produced using Microsoft Excel, with a linear trend line added to better indicate the long-term trend. This produced a graph showing that temperature records since 1882 (oldest records available) for the month of March indicate a warming trend towards milder winters. The graph also shows the range of inter-annual variability (Figure 6). From a health perspective, this may mean less cold-related illness or injuries.

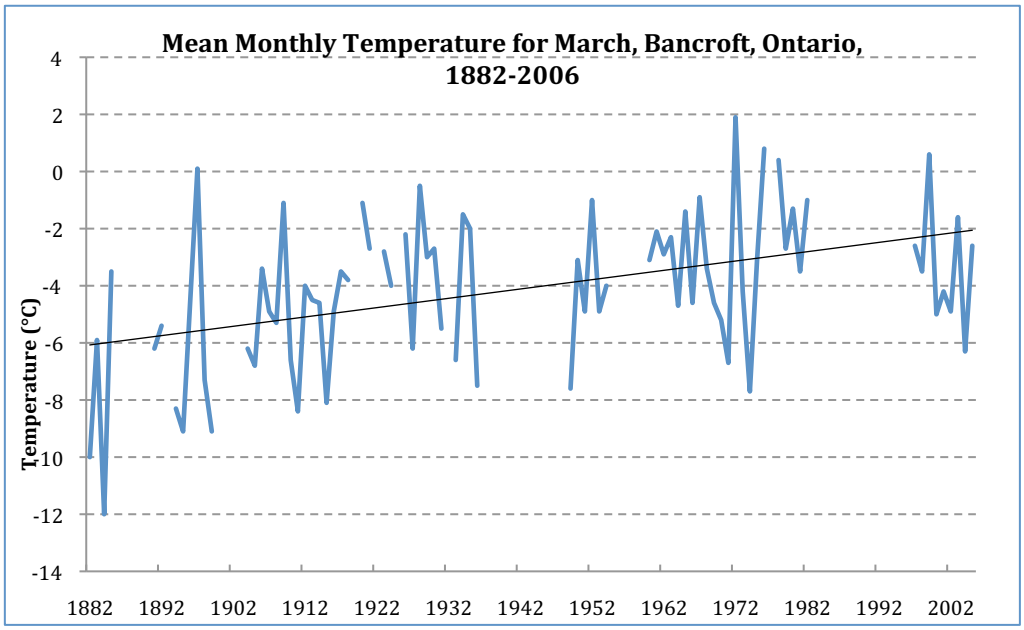

Figure 6: Mean monthly temperature for March, Bancroft, Ontario, 1882-2006
Source: Based on data from Environment Canada, Climate Data Online

To investigate whether summers in Addington Highlands were marked by extreme temperatures, an additional data series was produced using Climate Data Online, again

using the “Bancroft Auto” weather station as a proxy. For this series, since it required daily information, data had to be downloaded from the Climate Data Online database for each individual year. Data was downloaded for the last ten years available. Even though such a short period does not provide enough evidence for a climate trend, it provides evidence for the types of conditions recently experienced. Once data for 2002 to 2011 had been downloaded as XML files, a Microsoft Excel spreadsheet was created by copying and pasting the daily data for the warm weather months (May to September) in such a way as to arrange the daily maximum temperature data in one continuous time series. An additional column of data was created by using an “IF THEN” formula to identify days with maximum temperature above 25°C and an additional column for days above 30°C. A line chart of the number of “hot” days was then created using Microsoft Excel (Figure 7). The average yearly number of days above 30°C between May and September during the ten year period of 2002 to 2011 for Bancroft was found to be 7.9 days.

Temperatures above 25°C and 30°C were chosen as they are commonly associated with heat-related illness. For example, the relationship between temperature and mortality has been investigated for the City of Winnipeg. At approximately 26°C, Winnipeg’s excess mortality starts to increase as temperatures increase, and this increase becomes more exaggerated by about 30°C, with death increasing more with each degree temperature change thereafter (Health Canada, 2011). The period from May to September was chosen as that is widely considered by practitioners to be ‘the heat season in Canada’ (Health Canada, 2011). Furthermore, locals and cottagers perceive the May long weekend to be the start of summer (McLeman, 2009). May and June were also important to include in the analysis because extreme heat events early in the season generally result in higher

morbidity and mortality than events that occur later in the summer season (Health Canada, 2011). This occurrence can be partially attributed to a lack of acclimatization (Health Canada, 2011).

As illustrated in Figure 7, there is a slight downward trend in the number of hot summer days over this ten-year timeframe, and it is apparent that there is considerable inter-annual variability in the frequency of extreme hot temperatures in Addington Highlands. For example, in 2005 there were over 70 days above 25°C and almost 20 days above 30°C, whereas in 2009 there were less than 30 days above 25°C and less than 5 days above 30°C.

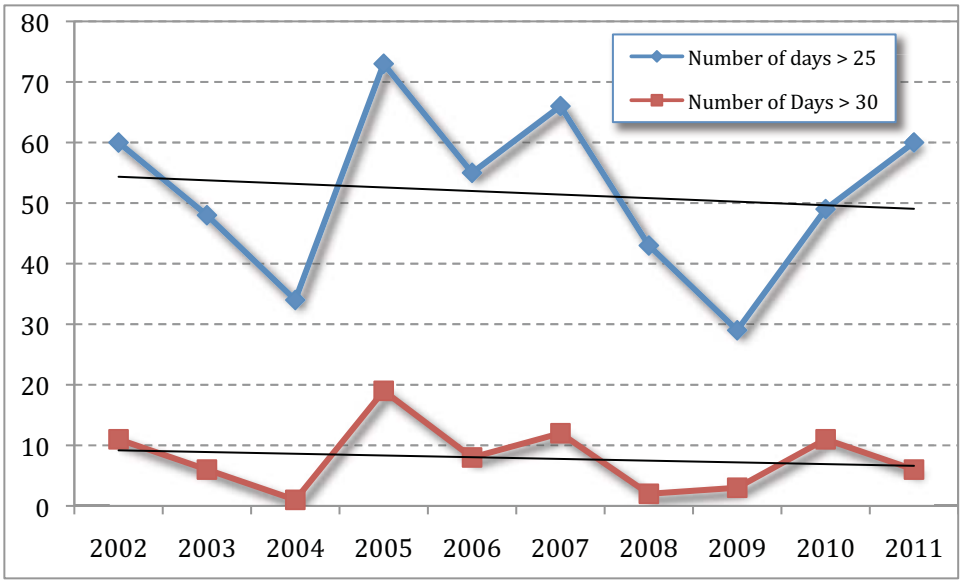

Figure 7: Number of days with maximum summer (May-September) temperatures above 25 and 30°C (2002-2011), Bancroft, Ontario
Source: Data from Environment Canada, Climate Data Online

In order to gain a further understanding of summer climate and extremes in the region (rather than only the 10 year period reported above), the average daily maximum temperatures and the average number of days with maximum temperature above 30°C for

the months of May to September during the thirty year period of 1970 to 2000 for nearby communities of Kingston, Renfrew and Belleville, were compared (Table 2). These were chosen because they are the communities closest to Addington Highlands for which data were readily available. The month of July has the highest daily maximum temperatures and the most days with maximum temperatures above 30°C. From Table 2 you can also see that Renfrew experiences on average 10.8 days a year with maximum temperature above 30°C. Kingston had fewer days above 30°C likely owning to the moderating affects of Lake Ontario. Because Addington Highlands is more inland, its climate will have more in common with Renfrew than Kingston. Of interest in this regard, the main public health offices are located in Kingston, as are the media outlets serving Addington Highlands (e.g., local T.V. and radio stations). To the extent that Kingston's experience influences the warnings and health risk messaging targeting Addington Highlands residents, this messaging may not accurately reflect conditions in Addington Highlands. Based on Table 2 results, there will likely be days where Addington Highlands will be hotter than Kingston and on such days, health risk messaging through Kingston media outlets may not be delivered to Addington Highlands.

Table 2: Average daily maximum temperatures and number of days above 30 C (1971- 2000) during the summer months for Kingston, Renfrew and Belleville, Ontario

Average daily maximum temperature (1971-2000)						
Location	May	June	July	August	September	Total Average: May- September
Kingston	17.9	22.6	25.7	24.6	19.9	22.1
Renfrew	19	23.7	26.6	25.2	19.5	22.8
Belleville	18.7	23.6	26.6	25.4	20.4	22.9
Days with Maximum Temperature > 30°C (1971-2000)						
Location	May	June	July	August	September	Total of Days: May- September
Kingston	0	0.26	1.5	0.87	0	2.6
Renfrew	0.96	2.2	4.8	2.8	0.5	10.8
Belleville	0.20	1.1	3.2	1.3	0.23	6.0

Source: Data from Environment Canada, Climate Data Online

Given that days with temperatures above 30°C occur in the area surrounding Addington Highlands (1971-2000), and given the number of hot days observed at the Bancroft weather station over the last 10 years (Figure 7), it becomes apparent that extreme heat already exists in this area. Natural Resources Canada (2008) warns that the frequency of extreme hot temperatures is expected to increase in Canada, and Health Canada (2011) warns that this represents a real health risk for the future. Thus, heat is one climate condition that may affect the health of Addington Highlands' residents in the future.

Furthermore, in order to get a sense of the overall seasonal climate in Addington Highlands, an examination of Canadian climate normals for the thirty year period of 1971

to 2000 was done to report on the average daily maximum temperatures, rainfall and snowfalls in the Addington Highlands area. Because there were no climate normals recorded specifically for Addington Highlands or neighbouring Bancroft, climate normals data for the nearby community of Renfrew was chosen as a proxy this time. Figures 8, 9 and 10 show the average daily temperatures, and monthly rainfall and snowfall experienced over the thirty period of 1971 to 2000 in Renfrew, respectively. These histograms provide an understanding of the types of climate conditions that occur, and give indication of the types of climate-related health risks faced by Addington Highlands residents, such as heat illness in the summer, and frost bite and injuries related to falls from slipping on ice in the winter, to name a few.

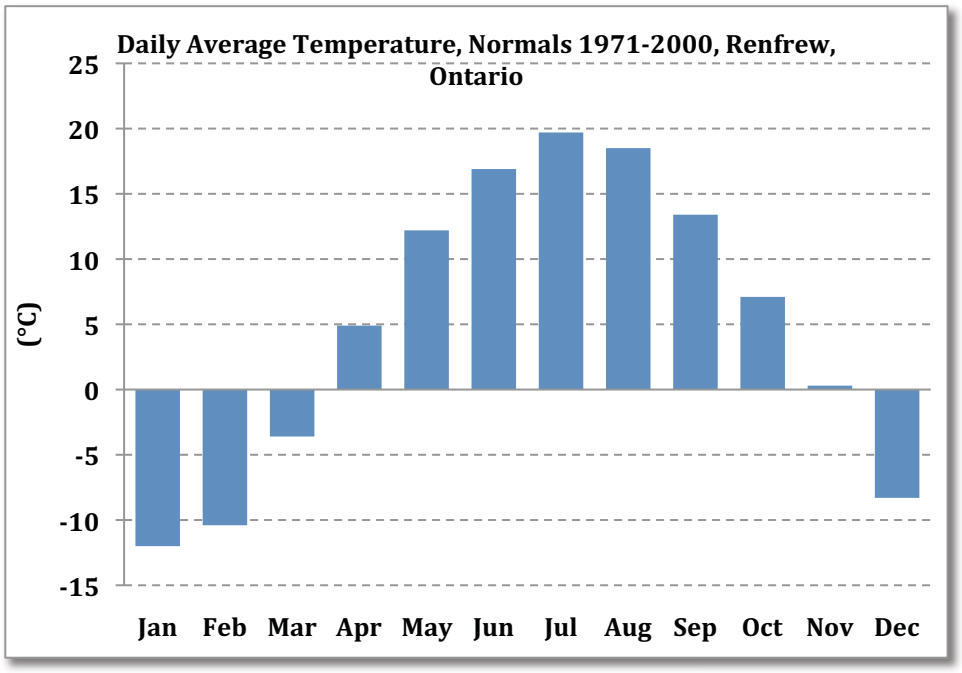

Figure 8: Daily average temperatures, normals 1971-2000, Renfrew, Ontario
Source: Data from Environment Canada's National Climate Data and Information Archive

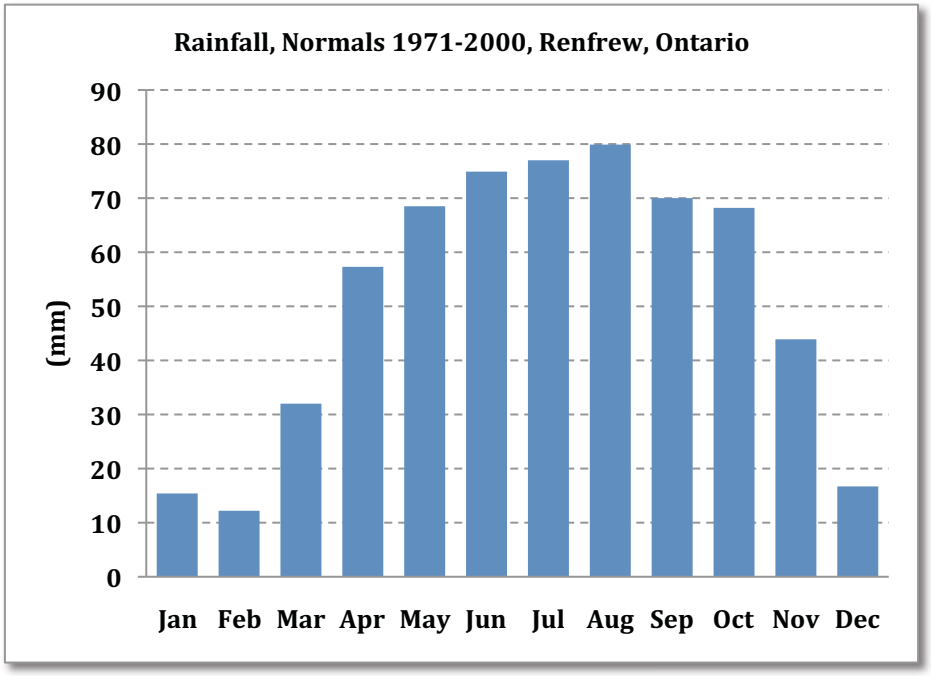

Figure 9: Rainfall, normals 1971-2000, Renfrew, Ontario
Source: Data from Environment Canada's National Climate Data and Information Archive

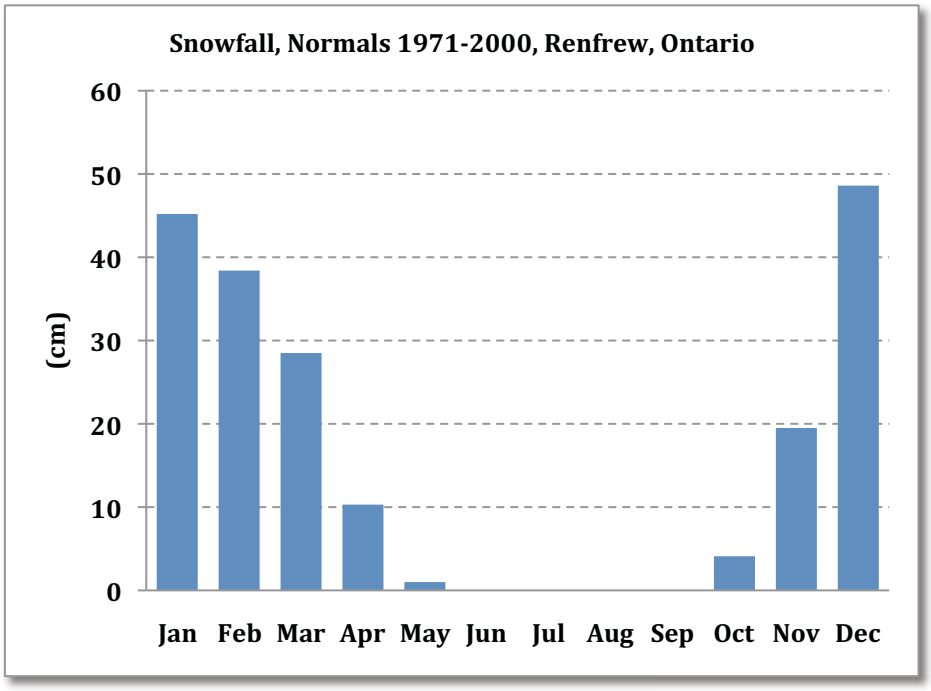

Figure 10: Snowfall, normals 1971-2000, Renfrew, Ontario
Source: Data from Environment Canada's National Climate Data and Information Archive

As mentioned in the review section (Section 1.2), the vulnerability of a community, such as Addington Highlands, to climate-related health effects is due to factors like the baseline climate and extremes (Balbus & Malina, 2009). These climate factors, for example, influence the presence of disease agents and their vectors. In this section, climate data was assembled by using data available for surrounding areas (e.g., Bancroft, Renfrew) as a proxy, given the scarcity of climate data specifically for Addington Highlands. This information provides necessary baseline information needed to undertake a climate change and health vulnerability assessment (Seguin, 2008). The above climate section has reported on such factors as: milder, shorter winter with the analysis of historic March climate data; frequency of extreme heat days (days above 25 and 30ºC for 2002-2011); average maximum summer temperatures and days above 30ºC (1971-2000); and average daily temperatures normals, and rainfall and snowfall normals (1971-2000).

1.3.1.2 Population and Health Characteristics

Population characteristics reported in this study were obtained from Statistics Canada's 2006 Community Profiles, which contained community-level information from the Canadian 2001 and 2006 census. Downloadable data presented in tabular and graphical forms were searched for information on community age characteristics, occupied private-dwelling characteristics, educational attainment, occupations, earnings and income, etc. These variables are indicators of individual and population sensitivities to climate related health risks (Health Canada, 2011; Vescovi et al., 2005; World Health Organization, 2011). Statistics Canada's information found through the Canadian Community Health Survey and National Population Health Survey did not report community information for Addington Highlands. Therefore, health information was largely accessed through the

Southeastern Ontario Health Council which disaggregated North Lennox and Addington health data from the rest of the Kingston, Frontenac and Lennox & Addington (KFL&A) Public Health unit. The Council, which is now defunct, acted as an advisory body to the Ontario Minister of Health and Long Term-Care (the Council encompassed the counties of Lanark, Leeds and Grenville, Frontenac, Lennox and Addington, Hastings and Prince Edward), and had purchased data from Statistics Canada in order to do more sophisticated analysis of health trends in their district. The information for this study reports on Addington Highlands and neighbouring North Lennox communities, and it is a better reflection of Addington Highlands than that found through Statistics Canada or the KFL&A Public Health unit, as the aggregated KFL&A health data do not show the rural and urban differences.

Addington Highlands is sparsely populated. It has an area of 1,288 km^2 with a population of 2,512 people, occupying 2,350 private dwellings. It is economically depressed—the median family income ($37,897) is almost half the provincial average ($69,158). Addington Highlands has a much lower proportion of immigrants (7.2%) than Ontario as a whole (26.8%) (Southeastern Ontario District Health Council, 2004). The educational attainment levels are lower than in the rest of the province. The percentage of Addington Highland's population with a university degree is 7%, whereas the percentage for Ontario overall is 17% (Statistics Canada, 2011). Those living in Addington Highlands with less than a high school education made up 50.1% of the population in 2001. This percentage is higher than 48 of the other surrounding census divisions (Southeastern Ontario District Health Council, 2004). From a health perspective, levels of education are significant, because promotion of health issues is more difficult when education attainment is lower.

Also, health status itself is strongly linked to educational background and those with poorer education, as a group, have markedly poorer health outcome (Southeastern Ontario District Health Council, 2004).

Like most rural communities, the average age of the population in Addington Highlands is older than urban populations (Statistics Canada, 2008). In Addington Highlands, this is due to high levels of out-migration of youth and in-migration of retirees (McLeman, 2009). Youth are leaving the region to look for work or to study in an urban setting (McLeman, 2009), which is causing the working age population (age 15-64) to also decrease (Statistics Canada, 2008). The percentage of the population aged 65 and older in Addington Highlands (24%) is considerably higher than for Ontario (14%) (Statistics Canada, 2011).

A health profile of the Southeastern Ontario District Health Council (2004) reports that people in Addington Highlands and neighbouring Lennox have more health problems than those in the rest of the Southeastern Ontario District. Addington and Lennox have higher rates of diabetes, heart disease, high blood pressure, heart attacks and obesity (Table 3). Individuals with these chronic health conditions are more sensitive to climate related health impacts, such as those associated with extreme heat events (Health Canada, 2008).

Table 3: Prevalence of selected health conditions in Lennox and Addington County, and Southeastern Ontario District Health Council population as a whole

Health Condition	Percentage of Lennox and Addington population with health condition	Percentage of Southeastern Health District population with health condition
Diabetes	6.0%	4.6%
Heart disease	7.6%	5.9%
High blood pressure	18.9%	15.2%
Heart attacks	3.8%	2.8%
Obesity	13.6%	12.7%

Source: South Eastern Ontario District Health Council, 2004

1.3.1.3 Primary, Public and Community Health Services

There are two primary health care contacts with responsibilities to diagnose illnesses and care for outpatients in Addington Highlands: the Lakelands Family Health Team located in Northbrook, which includes three medical doctors, a nurse practitioner, a chiropodist for foot care and a social worker; and a medical clinic in Denbigh that is open for one half day a week. This Family Health Team is a new addition to the organization of health services (2011). The Addington Highlands doctor recruitment committee was successful in recruiting a new doctor who will join the Family Health Team in 2012. Until recently, doctor shortages were an issue in Addington Highlands.

Persons in Addington Highlands requiring emergency services or specialized care (e.g. childbirth) are required to travel to a hospital in a neighbouring community, such as Bancroft, Nappanee, Renfrew or Pembroke. Two ambulance bases are currently located in Addington Highlands Township, one in Northbrook and the other in Denbigh. The ambulance services are a first point of contact for out-of-hospital medical care and are

important for these villages as the closest hospital is at least an hour's drive away. There has been an on-going county review of ambulance services, and consideration has been given to closing the Denbigh ambulance base. There is one pharmacy located in Northbrook, which first opened in 2011. Laboratory and x-ray services are not available in the township.

Addington Highlands is part of the Kingston, Frontenac, Lennox and Addington (KFL&A) Public Health Board. Regional Boards of Health are charged with the delivery of local public health programs and services based on the Ontario Public Health Standards (Ontario Ministry of Health and Long-Term Care, 2008). The primary focus of public health is the promotion of a healthier population, reducing the demand on the health care system, and responding to threats to health, which complement the work of the primary health care system.

Boards of Health are responsible for the assessment, planning, delivery, management, and evaluation of a variety of public health programs and services that address multiple health needs, as well as the contexts in which these needs occur (Ontario Ministry of Health and Long-Term Care, 2008). Several programs and protocols within the standards explicitly require Ontario public health units to manage climate-related stresses to health. These include infectious disease prevention and control, food and water safety measures, prevention of injury and public health emergency preparedness activities, among others. Thus, the foundational standards for public health units in Ontario, including the KFL&A Public Health unit, are directed to manage some climate-related health risks and raise awareness of them (Ontario Ministry of Health and Long-Term Care, 2008).

The South East Community Care Access Centre is located in Northbrook and provides access to health and personal support services to help people live independently in their home. There is one long-term care home with 60 beds in Northbrook. It serves Addington Highlands, and North and Central Frontenac. Land O' Lakes Community Services centre provides social services and offers 3 programs: the Adult Protective Services program; the Community Support program; and the Land O'Lakes Women's program. Land O' Lakes Community Services has over 150 volunteers who assist in delivering many of the agency's services.

The information collected about climate, population characteristics and the public health system, as discussed in the preceding sections, hint at the ways in which people may be vulnerable (e.g., health effects associated with temperature extremes, reduced capacity to adapt owing to low incomes, high population of seniors, population with health conditions that may increase their susceptibility to climate-related illnesses, reliance on volunteers for service delivery). However, to better understand the scope of potential vulnerabilities and to inform adaptation, more information on the key exposures-sensitivities and adaptive strategies and capacity is required. It is to fill this gap that a community-based analysis of vulnerability was undertaken.

1.4 Methods and Analysis

This research assessed climate-related stresses on health in the Township of Addington Highlands, Ontario, Canada to provide a clearer picture of the region's vulnerability to climate change. It was informed by the conceptualization of vulnerability and an analytical framework widely employed in the climate change field (e.g., Lim et al., 2005;

Polsky et al., 2003; Smit and Wandel, 2006; Smit et al., 2008), which are described in the previous review section (Section 1.2.4). The framework chosen for this study (Figure 3) provides the foundation for investigating the following research objectives: 1) identify and document current and potential climate-related stresses on health in the Addington Highlands region (exposure-sensitivity); 2) understand how climate-related health risks and health are presently managed (adaptive measures); and 3) identify potential barriers and opportunities for enhancing capacity in order to adapt to emergent climate change risks to public health (adaptive capacity).

The research approach considered current and future exposure-sensitivities first, using information on current conditions as the basis for considering possible future trends, and then looked at observed adaptations as a foundation for assessing adaptive capacity into the future (Cohen et al., 2006; Smit and Wandel, 2006).

The study identifies and documents the role climate-related stresses have on health in the rural Township of Addington Highlands. It does this by documenting risks identified by community professionals in the region, recording the various community programs and services available to manage those risks, and describing how such risks may impact Addington Highlands residents' health in the future. These methods, which employ expert judgement, are consistent with those most commonly used for assessing potential health risks of climate change (Fussel and Ebi, 2008). Data used in this study were collected through key informant semi-structured interviews, newspaper articles, reports and websites.

1.4.1 Participant Engagement and Semi-structured Interviews

Purposeful and snowball sampling recruitment strategies were employed in order to identify and select participants. Participants were initially selected based on the characteristic that they worked in health, emergency or community services and through snowball sampling in which possible participants were identified by speaking to people employed in professional roles in Addington Highlands (e.g., Township Office, Library), who knew people in the relevant fields. Participants were also identified based on interviewees recommending other people working in the field during an interview. Website searches were also used to identify key individuals (e.g., Addington Highlands website). Dr. McLeman, who has established himself as a researcher in the area, facilitated introductions to key contacts, which served as a starting point for snowball recruitment.

Ethical guidelines relating to human research were followed to ensure the protection of individuals and of human rights (University of Ottawa, 2011). When approaching people for an interview, they were informed of the purpose of the study, the types of participants being sought, the issues to be discussed and the time required. This information was also written on the introductory letter of consent using University of Ottawa letterhead, which was provided to participants. At the beginning of each interview, the purpose of the research was explained and participants were assured of their anonymity and that the research results would be available to them. They were also encouraged to ask questions. Hand-written notes were taken throughout the interview and were typed up shortly afterwards.

The framework employed for this study (Figure 3) informed the questions that were asked during the interviews. Given the nature of vulnerability, and the complexity of the factors involved in its analysis, interviews were chosen, as opposed to questionnaires, because they are more explanatory in nature and allow the respondents to raise issues that may not have been considered when formulating the questions (Hoggart et al, 2002; Valentine, 1997). The semi-structured interviews were open-ended and allowed for the documentation of interviewees' explanations on the processes, trends, and risk management activities influencing vulnerability with minimum bias from the interviewer. Interview questions followed the interview guide for all interviewees; and questions were asked in the same order to ensure consistency (Hoggart et al., 2002; Valentine, 1997). A semi-structured interview guide contained questions responding to the research objectives. The interview guide was used to collect data on vulnerability by focusing on the core themes of exposure-sensitivity, adaptation and adaptive capacity (Table 4).

Table 4. Semi-structured interview guide

Area Being Characterized	Guiding Questions for Semi-Structured, Key Informant Interviews (in approximate order of presentation)
Icebreaker	How long have you lived and worked in the community?
Exposure & Sensitivity	What are the weather conditions like in your area? What are your summer and winter conditions like? What types of extreme weather do you experience?
Adaptation	What community programs or services are you involved in?
Exposure & Sensitivity	What types of weather conditions, if any, have influenced your operations over the last 5-10 years?
Adaptive Capacity	How would you describe the general health of people in your region?
Adaptation & Adaptive Capacity	What are some of the health, social and emergency services available in your area?
Adaptation	Do you use weather information in your planning? What type of information do you find the most helpful?
Adaptive Capacity	What strengths and weaknesses have you or your organization experienced in meeting current service demands?
Exposure & Sensitivity	Do you believe that weather and climate have an impact on the health of people in your community? If so, in what way?
Exposure & Sensitivity	Who in your community is at risk to climate-related health impacts identified?
Adaptive Capacity	If the weather events that you identified were to happen more often or become more severe, how would that affect your operations?
Adaptive Capacity	What makes your community vulnerable or resilient to the climate-related health impacts identified?
Exposure & Adaptation & Adaptive Capacity	Do you know of other information sources, websites or reports that contain information to address some of the questions?

Nineteen key informant, semi-structured interviews were conducted between June and November, 2011. The interviews were primarily conducted in Addington Highlands, although a few interviews were conducted in Nappanee and Kingston as that is where the headquarters are located for public health and emergency services. Fourteen interviews were conducted in person at the person's place of work and five were conducted over the telephone. The interviews lasted between 30-90 minutes. Three groups of individuals

were interviewed: 1) individuals from public health services, 2) individuals from emergency services, and 3) community representatives, which included key community volunteers working in the above stated fields, or those who have participated in community committees regarding health and emergency services (Figure 11).

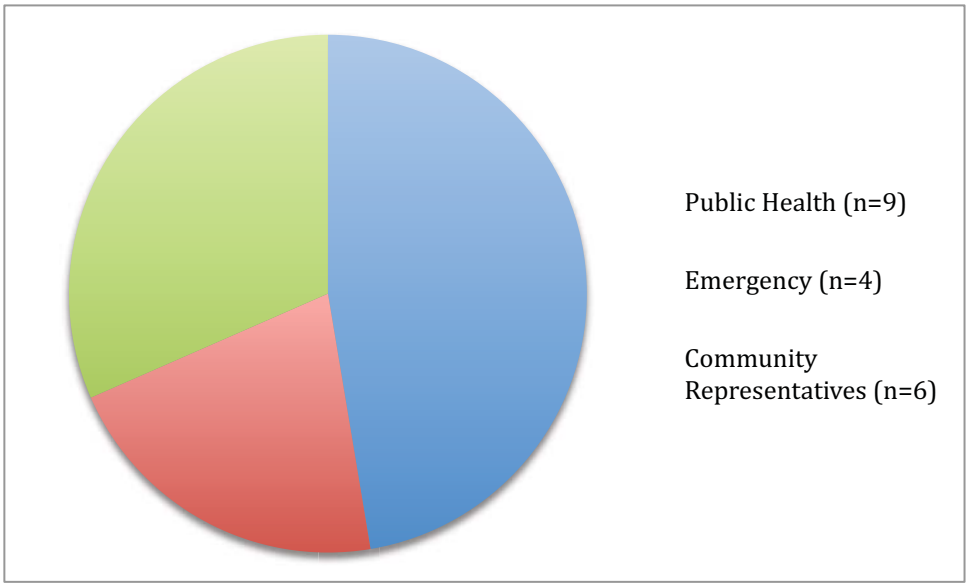

Figure 11: Interviewees by professional role, n=19

1.4.2 Reports and Websites

In order to gain more information, or corroborate existing information on exposure-sensitivity, adaptation and adaptive capacity for Addington Highlands, findings from the semi-structured interviews were complimented with information from published literature and government websites (n=26), as well as information in community service and committee reports (n=32). In many cases, without prompt, interviewees directed the researcher to various websites or reports for further information regarding the questions that they were being asked. For example, when identifying the ways that weather impacts health, an interviewee said that she did not think that there had been any reported cases of

West Nile virus in Addington Highlands, but stated that it could be confirmed by consulting the Public Health Agency of Canada's website. Likewise, when asked for the strengths and weakness in meeting current public service demands, one interviewee provided several reports that had been written regarding the ambulance service review in Denbigh. Furthermore, the last question posed during the interview was: 'Do you know of other information sources, websites or reports that contain information to address some of the previous questions?' All the websites, literature or reports that interviewees identified were reviewed for this study. For example, at the suggestion of an interviewee, the local Pioneer museum-heritage site in Cloyne was searched for records and reports on major storms, such as the 1998 Ice Storm and the microburst that occurred in the summer 2002. The key website sources and samples of reports used in for this research are summarized in Table 5.

Table 5: Key information resources utilized in the assessment of vulnerability

Examples of Websites Reviewed	Example of Reports Reviewed
KFLA Public Health	Addington Highlands Emergency Response Plans
Addington Highlands Township	County of Lennox and Addington Emergency Response Plans
Lennox and Addington County	County of Lennox and Addington Ambulance Service and Organization Review
Ontario Ministry of Health and Long-Term Care	Land O'Lakes Community Services Annual General Meeting Report
Ontario Ministry of Natural Resources	Township Council Meeting Summaries
Ontario Health and Integration Network	Ontario Forest Fire Annual Reports
Statistics Canada	Township Council Meeting Summaries
Environment Canada	KLFA Public Health Annual Reports
Public Health Agency of Canada	Lyme Disease Reports and Maps
Health Canada	Pioneer Museum Database on Storms

1.4.3 Newspaper Articles

Media analysis is a rich source of public health information, and is becoming more commonly used as a data source because it contains descriptive information that is not typically recorded in administrative databases or may not be remembered by interviewees (Barnes et al., 2008; Kennedy et al., 2006; Renzulli et al., 2006; Wilson et al., 2005). For example, Soskolne et al. (2004) utilized newspaper reports as an epidemiologic data source for research on climate change impacts and adaptation related to extreme weather events in Alberta. The authors report that newspapers contain information regarding the direct and indirect impacts that extreme weather events can have on health and socio-economic outcomes. They found no evidence to refute the accuracy of health and contextual information from newspapers during their data verification stage. They concluded that newspapers contain useful information regarding climate-related health impacts and local adaptation options (Soskolne, 2004).

For this study, an internet search was undertaken to identify news sources covering Addington Highlands. The Frontenac News, a weekly newspaper based in Sharbot Lake, was found to cover Addington Highlands. The Frontenac News has an online edition, with articles available online from November 1999 to present. The last decade of articles were chosen for review (2001 to 2011). Article titles were scanned for words and topics relating to: weather events and climate (e.g., storms, severe winds, heavy rain, heat, cold, snow and temperature), health care (e.g., ambulance services, new health clinic, doctors), public health (e.g., Pine Meadow Nursing Home), emergencies (e.g., fires, flood, accidents), community services (e.g., outdoor learning center, Lions Club, Meals for Wheels), seniors (e.g., senior's housing), and municipal affairs (e.g., township office, fire

hall, road work). There were typically 8 articles to scan for each weekly edition, representing on average 416 article titles scanned per year of the review.

Over 4,500 article titles were scanned for the purposes of this study, and of these, 308 articles met the title search criteria, for which 182 contained relevant content. When the article met the search criteria, the article was copied and pasted into a word document, so that it could be further reviewed and analyzed. Sometimes, articles that were screened in by title search and then reviewed, did not contain relevant content and were then omitted from the analysis stage. For example, an article titled 'Hot weather and Hotter Music' met the search criteria, but did not contain any weather or health related information. Rather the article described an outdoor music festival. There were also several articles that reported on the same situation, with some subsequent articles summarizing previous details or detailing a new element of the situation, each of these articles were treated like a stand-alone article (e.g., ambulance service review). Also, each month the Frontenac News reported on the most recent Addington Highlands Council meeting. These articles on Council meetings often contained relevant information, and represented a significant portion of the relevant articles reviewed for this study.

1.4.4 Data Analysis

The approach used to analyse the data was informed by grounded theory (Creswell, 1998), in which categories and ideas are developed from the data, guided by the original research objectives. Data gathered from key informant interviews, newspaper articles and secondary sources were organized with respect to each of the three research objectives (Table 6). A general description of the analysis for each objective follows. Heat is used

as an example to illustrate the analysis processes. Similar processes as those utilized to describe and assess heat were used for other categories (i.e., forest fires, storms), with slight modification in order to address the range of characteristics and data being analysed for each category.

Table 6: Data sources utilized to address the research objectives

Research Objectives	Data Sources
1. Current and potential climate-related health risks (exposure and sensitive)	-Key informant interviews -News paper articles -Websites (e.g., Health Canada, Public Health Agency of Canada, KFL&A Public Health Unit, Natural Resources Canada, Ontario Ministry of Natural Resources) -Reports -Environment Canada Online Climate Database -Canadian Disaster Database -Statistics Canada
2. Current management (adaptation practices)	-Key informant interviews -News paper articles -Websites (e.g., KFL&A Public Health Unit, Township website, Public Health Agency of Canada) -Reports (e.g., Addington Emergency Plan, Ambulance Review)
3. Barriers and opportunities to future adaptation (adaptive capacity)	-Key informant interviews -News paper articles -Websites -Reports (e.g., Community Service Annual Meeting) -Statistics Canada (e.g., income and education levels)

Research objective 1 involved two analytical components as illustrated in the research framework. The first component (i.e., current exposure and sensitivity) identified and documented the current climate-related stresses to health based on information from the key informant interviews, news paper articles, and other secondary sources on the ways in which the community has experienced climate-related stresses. The second component (i.e., future exposure) addressed potential future climate-related stresses by acquiring

estimates of change for climate conditions from literature reporting on climate model projections, and relating these to the identified current exposures.

Moreover, results for research objective 1 that were derived from the key informant interviews were analysed by recording the exposure and sensitivities indentified by each respondent via the four interview questions that addresses this issue (Table 4). Within each climate-related category (e.g., heat) information was collected on such factors as the nature, frequency, severity, timing and impacts of events. This information was cross-referenced and supplemented with the data on events in each category from newspapers and other secondary sources. The combined information was evaluated in an inductive manner (Craig, 1997; Creswell, 1998; Parfitt, 1997) for patterns relating to the research objectives.

For example, as part of the first component for research objective 1, it became apparent that extreme heat is already occurring in Addington Highlands. Interviewees identified heat as a health issue in the region, newspaper articles reported on heat and health warnings issued by the local public health unit, and climate data indicated that days with temperatures above 30°C occur in the surrounding area. Then for the second component related to research objective 1, literature from Natural Resources Canada's most recent assessment reported that the frequency of extreme hot temperatures is expected to increase in Canada, and Health Canada warns that this represents a health risk for the future. Thus, this information was used to document the potential for heat to be an increasing health risk in the future for Addington Highlands.

Research objective 2, which sought to understand how climate-related health risks are presently managed, was pursued by integrating information from key informant interviews, newspaper articles and secondary sources, as summarized in Table 6. Interview questions on services related to climate stresses (Table 4), provided information on the adaptation programs and practices, and on the community conditions. Government and health agencies' websites were particularly helpful in addressing research objective 2.

Addressing research objective 2, several formal and informal adaptation programs and practices to adapt to heat were identified by interviewees, such as heat and health warning systems, designated cooling centre in Cloyne, recreational waters and green spaces to stay cool, for example. More details on the KFL&A Public Health unit heat warning system was found on their public health website, as well as heat-health messaging being communicated to the public during the heat period. Interviewees also described community conditions that reduced the risk (e.g., temperatures cool down in the evening in Addington Highlands, providing reprieve).

Research objective 3, which sought to identify barriers and opportunities to future adaptation, was addressed directly in the informant interviews (Table 4), with responses categorized into recurring themes, and also by inferences when existing strategies and measures were considered relative to possible changes in climatic stresses.

As part of research objective 3, for example, interviewees identified several barriers to using the cooling centre in Cloyne (where the local public health unit building is located),

such as a lack of awareness by residents that it is a cooling centre, and the possibility that those who know that it is a cooling centre may not have sufficient income to purchase the required fuel to drive to the cooling centre or other air conditioned areas (e.g., area is dispersed and economically depressed, as per Statistics Canada data). Furthermore, there is no public transportation available to those without vehicles.

1.5 Conclusion

This chapter has provided an introduction and context for a case study of climate-related stresses on population health in the rural region of Addington Highlands, Ontario. It outlines the relationships between climate change and human health impacts.

A review of frameworks for assessing impacts of climate change provided the basis for a conceptualization of climate-related health vulnerability, related to exposure-sensitivity and adaptive capacity, and for a framework for analysis, starting with the documentation of current exposures and adaptive strategies as the basis for assessing future prospects.

The study area of Addington Highlands is described with particular attention given to its climate, population and health characteristics, and its public health services. The methods for collecting and analysing the data were presented, such as the procedures for conducting key informant interviews, the analysis of newspaper articles and the use of secondary data sources. The analytical methods are largely inductive, involving categorization, cross-referencing and data interpretation related to addressing the research objectives.

Chapter 2 presents the findings from this research, presented in the form of an article manuscript that will be submitted to a peer-reviewed scholarly journal upon completion of the thesis defence. As will be seen, the findings suggest that storms, extreme heat and forest fires currently present health risks for Addington Highlands and are expected to become more prevalent with climate change, and some vector-borne diseases are likely to become more common in the future.

Chapter 2

Journal Manuscript

Title: Assessing Climate-Related Stresses on Human Health in a Remote and Rural Area: A Case Study from Eastern Ontario, Canada

Chapter 2 consists of a manuscript prepared for submission to *Global Environmental Change*. The candidate is the first author of the manuscript, and assumes primary responsibility for the conceptualization of the research, the design and execution of the empirical research, and the preparation of the manuscript drafts. Co-author and supervisor Dr. Robert McLeman provided guidance and direction for the research, was responsible for providing and directing project funding, established initial contacts in the study community, and provided feedback and editorial input to the crafting of the manuscript. Co-author Dr. Eric Crighton helped facilitate the research program and provided suggestions and editorial inputs on the manuscript drafts.[1]

Abstract:

Human health is affected by climatic variations and change, and public health systems play a role in managing climate-related risks. Canada is generally believed to have considerable capacity to adapt to climate change, yet there is variability among communities in terms of their vulnerability to climate-related health risks and ability to manage those risks. Most existing assessments of climate and health tend to be broad-based, and there are few examples focused on rural or remote populations. This study

[1] In the manuscript for *Global Environment Change*, Tables 7-9 along with many of the specific details described in Sections 2.3 through 2.4 will be included as 'Supplemental Materials' when submitted. These details have been included in this thesis version in order to facilitate the review by the thesis examination committee and so that they can be shared with Addington Highland participants as per the research consent form. The submitted manuscript will have a condensed methodology and study area section and adhere to the word count guideline of the journal.

develops a model for examining the health-related vulnerability to climate change of rural populations, and applies it to the rural municipality of Addington Highlands, Ontario. Using secondary data sources and key informant interviews, climate-related health risks and existing programs and services that deal with these were identified and documented, and an assessment made of the capacity of the community to adapt to future climate conditions. Storms, extreme heat and forest fires that currently present health risks in the area are expected to become more prevalent with climate change, with emergent risks like Lyme disease, West Nile virus, and dangerous algal blooms likely to become more common in the future. Local public health and emergency management programs appear reasonably well-adapted to current risks, in large part due to the strength of local social networks and institutional flexibility. Current adaptive capacity is constrained by the aging population, limits of the availability and access to health care services, and challenges relating to the retention of service providers, constraints that will need to be addressed if future adaptive capacity is to be made sufficient to meet changing climate risks in the future. An important strategy to assist adaptation to climate change risks to health in rural communities like Addington Highlands is the promotion of public awareness of emergent risks and limits to adaptation. The model and methods presented here are not particular to the case study area, and with modification might be adapted for use in other rural communities.

Keywords: Climate Change, Human Health, Adaptation, Assessment, Vulnerability, Adaptive Capacity, Rural, Public Health

2.1 Introduction

Global climate change has been identified as a major environmental health concern that will affect the urgency of many existing health risks and introduce new health risks in currently unaffected regions (Confalonieri et al., 2007; Costello et al., 2009;). The potential health outcomes include, but are not limited to, the direct impacts of injury, illness and death caused by extreme weather events, such as heat waves, storms and floods; and the indirect effects of climate factors mediated through ecological systems, such as food and water quality and related illnesses (e.g., *E. coli*, *Samonella, Cryptosporidium*, algal blooms), vector- and rodent-borne diseases (e.g., Lyme disease, West Nile virus, hantavirus), pollen allergies and air pollution (Costello et al., 2009; Ebi, 2009; Kunzli, 2006; McMichael et al., 2006; Patz and Olson, 2006). Although, there may be some global benefits to a warmer climate, such as fewer cold related deaths, most analysts conclude that the overall balance of effects of climate change on health is likely to be negative (Confalonieri et al, 2007).

The effects of climate change examined at the global, national and regional levels have highlighted the health impacts (Berner et al., 2005; Confalonieri et al., 2007; Lemmen at al., 2008; McMichael et al., 2003; Menne and Ebi, 2006; Stern, 2006). Climate change and health vulnerability assessments are increasingly used as a tool to determine existing levels of risk, identify and better understand vulnerabilities, and stimulate actions to increase the capacity of individuals and communities to respond to new or changing conditions, and have, for example, been undertaken in Canada, U.S., Finland, Germany, U.K., Australia and Portugal (Confalonieri et al., 2007; Ebi et al., 2006; Seguin, 2008). Assessments can be undertaken, and adaptation measures implemented, at national,

regional or local levels and each provides information intended to inform decision making at their respective levels (World Health Organization, 2011). For an assessment to best inform adaptation measures, the assessment should be undertaken at the scale and scope at which policy and program decisions are being made and implemented (Ebi and Semenza, 2008). For example, national level assessments may be useful to plan for adaptations to be implemented by federal agencies (e.g., health promotion, awareness raising, humidex index, wind chill advisories), while local vulnerability assessments can inform local adaptation planning (e.g., opening cooling centres, adjusting emergency services).

Because climate-related health risks vary by geographic location, and are highly influenced by exposure to microclimates and storms (Patz et al., 2005), local assessments are able to gauge capacity at the local level to cope with and adapt to climate-related events, investigate differences in health risks within local populations, and inform development of community-specific adaptations measures (Balbus and Malina, 2009; Medina-Ramon and Schwartz, 2008). Studies elsewhere have shown community adaptive capacity with respect to climate and health may be influenced by locally-specific factors such as poor local infrastructure, limited availability of health and emergency services, economic disparities and lack of awareness of risks (Berry, 2008; Kolivras and Comrie, 2004; Luber and Hess, 2007; McMichael et al, 2006; Younger, et al., 2008;). Discrepancies in health status across communities, such as those between rural and urban populations, are also important considerations (e.g., Altmayer et al., 2003; Statistics Canada, 2008; Public Health Agency of Canada, 2006). Rural and resource-dependent populations have particular characteristics, such as dependency of agriculture, economic

decline, difficulty recruiting and retaining staff, constrained access to services, funding challenges and population displacement (Skinner et al., 2008; Berry et al., 2008), which erode their adaptive capacity generally, making them more vulnerable to climate change impacts (e.g., food insecurity) (Battisti and Naylor, 2009; Bryant et al., 2000; Holden, 2009; McLeman, 2010; Wall and Marzall, 2006).

In Canada, assessments of vulnerability and adaptation to the health impacts of climate change have mainly been focused at the national or provincial levels (Chiotti and Lavender, 2008; Furgal and Prowse, 2009; Lemmen and Warren, 2004; Lemmen et al., 2008; Seguin, 2008). There are few examples of local-level climate and health assessment or models for conducting these. Examples of local-level climate-related health vulnerability assessments in rural communities are especially scarce. To this end, this article introduces a methodology for undertaking such assessments and reports results from its application in Addington Highlands, a rural township of eastern Ontario, Canada.

This article begins by introducing the basic model, situating it within existing scholarship that takes a vulnerability-based approach to assessing the health impacts of climate change. The methodology is then outlined, followed by a description of the key features of the study area's climate, population and public health services. The findings, which draw on information collected from community members and secondary data sources are then presented. These data sources were used to: 1) identify and document current and potential climate-related stresses on health in Addington Highlands; 2) understand how climate-related health risks and health are presently managed; and 3) identify potential barriers to, and opportunities for, enhancing capacity in order to adapt to climate-related

health risks. While particular results may be specific to the study area, the model, methods and general findings of the case study may be useful for the study of local assessments of climate and health in rural communities elsewhere.

2.2 A Vulnerability-Based Approach to Understand Rural Health and Climate Change

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007, p.21). A variety of conceptual and analytical frameworks for assessing climate change impacts and vulnerability are offered in the research literature (Lim et al., 2005; Polsky et al., 2003; Smit et al., 2008; Smit and Wandel, 2006) including some that are geared specifically for health decision-makers (Fussel and Klein, 2004; Kovats et al., 2003; Patz et al., 2008). These frameworks commonly situate the concept of vulnerability as being constituted by exposure-sensitivity, adaptive measures and adaptive capacity of individuals and communities (Clarke and Berry, 2011). The ability to manage risks is frequently referred to as adaptive capacity; it includes conditions within the community that either facilitate or constrain the ability to adapt or respond to climate-related health risks in the future (Fussel and Klein, 2004; Fussel and Ebi, 2008; Smit et al., 2008; Yohe and Ebi, 2005). Generally, the adaptive capacity of a population to climate-related health risks is believed to be influenced by factors such as economic resources, technology, information and skills, infrastructure, institutions and population health status (Grambsch and Menne, 2003; Yohe and Tol, 2002). Adaptations, or adaptive measures or actions, are understood to be manifestations of adaptive capacity (Smit and Wandel, 2006).

Vulnerability – reflecting both the exposure/sensitivity and the adaptive capacity – provided a basis for the conceptual and analytical framework developed in this project, and makes it consistent with broader-scale climate-change and health research (e.g., Kovats, 2003; Berry, 2008; Fussel and Klein, 2004; Seguin, 2008). The analytical aspect of this framework starts with the system of interest (and hence, has been called a "vulnerability as starting point" approach (Smit and Wandel, 2006)), an approach that has been used to conduct community-level research on non-health impacts of climate variability and change (e.g., Adger and Brooks, 2003; Belliveau et al., 2006; Ford et al., 2010; Berring-Ford, 2009). It seeks to identify sensitivities and adaptive responses (both actual and potential) with the participation of people who are (or would be) doing the adapting. Such an approach is logical when the population and/or systems of interest are of local or relatively small spatial scales, and contrasts with broader-based approaches used in assessments that begin with climate change scenarios and models and assume human impacts and adaptive responses (Luers, 2005; Smit and Wandel, 2006; Berry, 2008; World Health Organization, 2011). In such research, community members' own experiences with exposure-sensitivity, adaptive measures and adaptive capacity become a key data source (Smit and Wandel, 2006; Ebi et al., 2006).

Figure 12 illustrates the framework, showing the underlying conceptual premise that vulnerability is a function of the exposure and sensitivities of human health to climate-related conditions, and the strategies and capacity of the system to adapt to changing climate conditions. Superimposed on this backdrop is the analytical approach (outlined in the white boxes in Figure 12), which identifies key questions and possible data sources

for answering those questions. These start by documenting the current conditions to which the population is (or has been) exposed and is sensitive, and identifying the measures or strategies undertaken to deal with them (i.e., adaptation strategies). These adaptations are characterized according to when and where they have been applied, by whom, and with what effectiveness, and lead to a characterization of the capacity of the local system to adapt to changing conditions in the future.

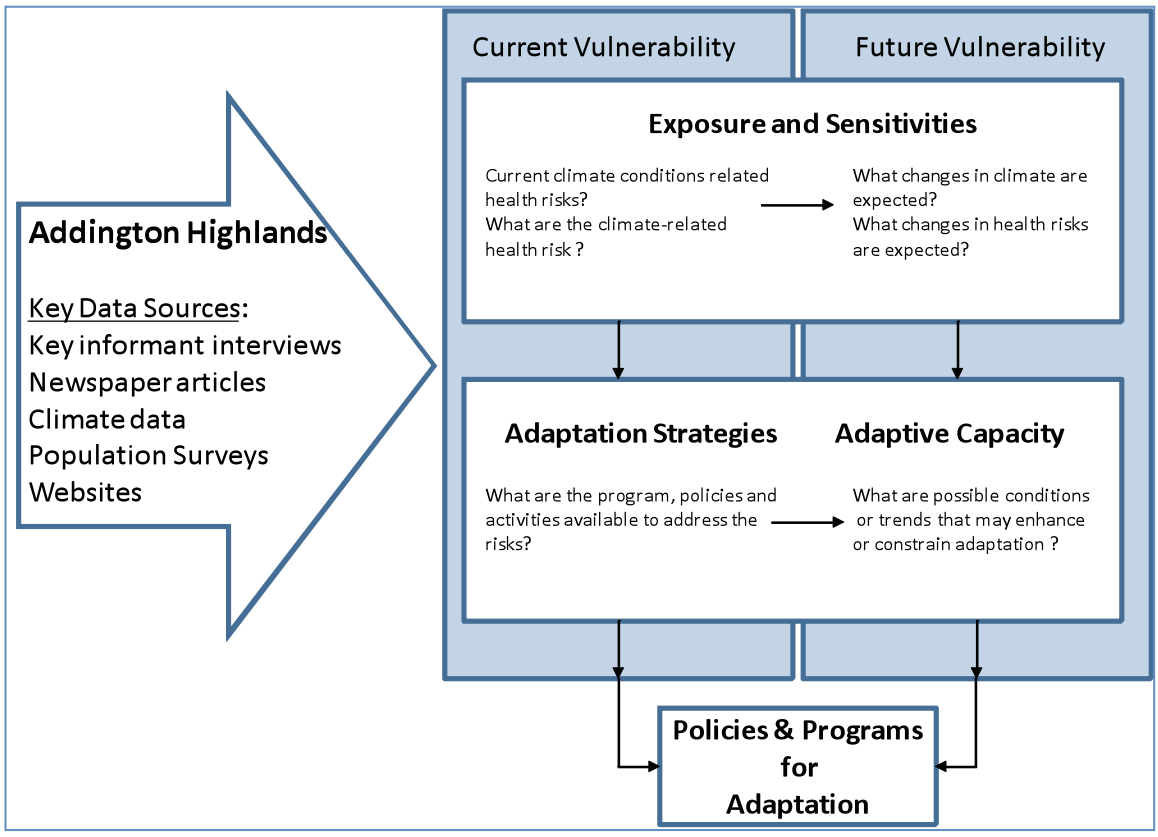

Figure 12: Framework for characterising human health vulnerability to a changing climate
(Adapted from Smit and Wandel, 2006)

There are a variety of potential data sources for generating characterizations of current and future vulnerability, which will inevitably vary from one particular community or population to the next. Examples may include, but are not limited to, key informant

interviews, health agency reports, newspaper and other media reports, existing research literature, websites, and climate norms and trends data. Possible future changes in exposure and sensitivity can be projected from current risks by drawing on projections of future climate, such as information from climate models and populations estimates. Adaptive strategies are characterized on the basis of the ability of existing adaptation strategies and resources to deal with current exposure. By identifying opportunities and constraints to current adaptation strategies (both existing and potential) and informed by the expected changes in future exposure and sensitivity, an estimation of future adaptive capacity is made is order to characterise future vulnerability. The application of this framework leads to an understanding of current and future vulnerabilities, and provides information which can be used to inform programs and policies related to health and health services for the location of interest, thereby complementing the more general information obtained from broad-scale assessments generated by government agencies such as Health Canada (Seguin, 2008).

2.3 Application of the Model to the Case Study: Data Collection and Analysis Methods[2]

The model introduced in Figure 12 above was applied to a case study of rural health vulnerability to climate in the Township of Addington Highlands, Ontario, the characteristics of which are outlined in section 2.5 below. First, a more detailed

[2] In the manuscript for *Global Environment Change*, Tables 7-9 along with many of the specific details described in Sections 2.3 through 2.4 will be included as 'Supplemental Materials' when submitted. These details have been included in this thesis version in order to facilitate the review by the thesis examination committee and so that they can be shared with Addington Highland participants as per the research consent form. The submitted manuscript will have a condensed methodology and study area section and adhere to the word count guideline of the journal.

description of the primary and secondary data collection and analysis methods used in the case study is warranted.

2.3.1 Semi-structured Interviews

Purposeful and snowball sampling recruitment strategies were employed in order to identify and select participants with experience or knowledge directly relevant to understanding climate-related health risks and response options in the study area. Ethical guidelines relating to human research were followed to ensure the protection of individuals and of human rights (University of Ottawa, 2011). Given the nature of vulnerability, and the complexity of the factors involved in its analysis, interviews were seen as preferable to other methods such as questionnaires or focus groups, because they are more explanatory in nature and allow the respondents to raise issues that may not be discovered by the researcher through other methods (Hoggart et al, 2002; Valentine, 1997). The interviews were semi-structured and open-ended to allow for the documentation of interviewees' explanations on the processes, trends, and risk management activities influencing vulnerability. An interview guide was used to collect data on vulnerability by focusing on the core themes of exposure-sensitivity, adaptation and adaptive capacity (Table 7).

Table 7. Semi-structured interview guide

Area Being Characterized	Guiding Questions for Semi-Structured, Key Informant Interviews (in approximate order of presentation)
Icebreaker	How long have you lived and worked in the community?
Exposure & Sensitivity	What are the weather conditions like in your area? What are your summer and winter conditions like? What types of extreme weather do you experience?
Adaptation	What community programs or services are you involved in?
Exposure & Sensitivity	What types of weather conditions, if any, have influenced your operations over the last 5-10 years?
Adaptive Capacity	How would you describe the general health of people in your region?
Adaptation & Adaptive Capacity	What are some of the health, social and emergency services available in your area?
Adaptation	Do you use weather information in your planning? What type of information do you find the most helpful?
Adaptive Capacity	What strengths and weaknesses have you or your organization experienced in meeting current service demands?
Exposure & Sensitivity	Do you believe that weather and climate have an impact on the health of people in your community? If so, in what way?
Exposure & Sensitivity	Who in your community is at risk to climate-related health impacts?
Adaptive Capacity	If the weather events that you identified were to happen more often or become more severe, how would that affect your operations?
Adaptive Capacity	What makes your community vulnerable or resilient to the climate-related health impacts identified?
Exposure & Adaptation & Adaptive Capacity	Do you know of other information sources, websites or reports that contain information to address some of the questions?

Nineteen key informant, semi-structured interviews were conducted between June and November, 2011. Interviews were conducted in the study area of Addington Highlands except where for public health and emergency services officials whose organizations are headquartered elsewhere. Fourteen interviews were conducted in person at the person's place of work and five were conducted over the telephone. The interviews lasted between

30-90 minutes. Three groups of individuals were interviewed, namely, individuals from public health services, emergency services, and community representatives, which included key community volunteers working in the above stated fields, or those who have participated in community committees regarding health and emergency services. Methods utilizing expert judgement, such as the ones employed for this study, are consistent with those used most commonly for assessing potential health risks of climate change (Fussel and Ebi, 2008).

2.3.2 Websites and Reports

In order to gain more information, or corroborate existing information on exposure-sensitivity, adaptation and adaptive capacity for Addington Highlands, findings from the semi-structured interviews were complimented with information from published literature and government websites (n=26), as well as information in community service and committee reports and community archives (n=32). Interviewees often referred to various websites or reports for further information regarding the questions that they were being asked. Furthermore, the last question posed during the interview was: 'Do you know of other information sources, websites or reports that contain information to address some of the previous questions?' All the websites, literature or reports that interviewees identified were reviewed for this study. The key website sources and samples of reports used for this research are summarized in Table 8.

Table 8: Key information resources utilized in the assessment of vulnerability

Examples of Websites Reviewed	Example of Reports Reviewed
KFLA Public Health	Addington Highlands Emergency Response Plans
Addington Highlands Township	County of Lennox and Addington Emergency Response Plans
Lennox and Addington County	County of Lennox and Addington Ambulance Service and Organization Review
Ontario Ministry of Health and Long Term Care	Land O'Lakes Community Services Annual General Meeting Report
Ontario Ministry of Natural Resources	Township Council Meeting Summaries
Ontario Health and Integration Network	Ontario Forest Fire Annual Reports
Statistics Canada	Township Council Meeting Summaries
Environment Canada	KLFA Public Health Annual Reports
Public Health Agency of Canada	Lyme Disease Reports and Maps
Health Canada	Pioneer Museum Database on Storms

2.3.3 Newspaper Articles

Media analysis is a rich source of public health information, and is becoming more commonly used as a data source because it contains descriptive information that is not typically recorded in administrative databases or may not be remembered by interviewees (Barnes et al., 2008; Kennedy et al., 2006; Renzulli et al., 2006; Wilson et al., 2005). For example, Soskolne et al. (2004) utilized newspaper reports as an epidemiologic data source for research on climate change and extreme weather events in Alberta and concluded that newspapers contain useful information regarding climate-related health impacts and local adaptation options (Soskolne, 2004).

For this study, the Frontenac News, a weekly newspaper based in Sharbot Lake, was found to cover Addington Highlands and has an online edition, with articles available

from November 1999 to present. The last decade of articles were chosen for review (2001 to 2011). Article titles were scanned for words and topics relating to the research objectives (e.g., weather events and climate, health, public health services, seniors, municipal affairs). Approximately 4,500 article titles were scanned for the purposes of this study, and of these, 308 articles met the title search criteria, for which 182 contained relevant content. When the article met the search criteria, the article was reviewed and analyzed. For example, regarding municipal affairs, the Frontenac News reported on monthly Addington Highlands Council meetings, which often contained relevant information, and represented a significant portion of the relevant articles reviewed for this study.

2.3.4 Data Analysis

The approach used to analyse the data was informed by grounded theory (Creswell, 1998), in which categories and ideas are developed from the data, guided by the original research objectives. Data gathered from informant interviews, newspaper articles and secondary sources were organized with respect to each of the three research objectives (Table 9). A general description of the analysis for each objective follows.

Table 9: Data sources utilized to address the research objectives

Research Objectives	Data Sources
1. Current and potential climate-related health risks (exposure and sensitive)	-Key informant interviews -News paper articles -Websites (e.g., Health Canada, Public Health Agency of Canada, KFL&A Public Health Unit, Natural Resources Canada, Ontario Ministry of Natural Resources) -Reports -Environment Canada Online Climate Database -Canadian Disaster Database -Statistics Canada
2. Current management (adaptation practices)	-Key informant interviews -News paper articles -Websites (e.g., KFL&A Public Health Unit, Township website, Public Health Agency of Canada) -Reports (e.g., Addington Emergency Plan, Ambulance Review)
3. Barriers and opportunities to future adaptation (adaptive capacity)	-Key informant interviews -News paper articles -Websites -Reports (e.g., Community Service Annual Meeting) -Statistics Canada (e.g., income and education levels)

Research objective 1 involved two analytical components as illustrated in the research framework. The first component (i.e., current exposure and sensitivity) identified and documented the current climate-related stresses to health based on information from the key informant interviews, newspaper articles, and other secondary sources on the ways in which the community has experienced climate-related stresses. The second component (i.e., future exposure) addressed potential future climate-related stresses by acquiring estimates of change for climate conditions from literature reporting on climate model projections, and relating these to the identified current exposures.

Moreover, results for research objective 1 that were derived from the key informant interviews were analysed by recording the exposure and sensitivities indentified by each

respondent via the four interview questions that address this issue. Within each climate-related category (e.g., heat) information was collected on such factors as the nature, frequency, severity, timing and impacts of events. This information was cross-referenced and supplemented with the data on events in each category from newspapers and other secondary sources. The combined information was evaluated in an inductive manner (Craig, 1997; Creswell, 1998; Parfitt, 1997) for patterns relating to the research objectives.

Research objective 2, which sought to understand how climate-related health risks are presently managed, was pursued by integrating information from key informant interviews, newspaper articles and secondary sources, as summarized in Table 9. Interview questions on services related to climate stresses, provided information on the adaptation programs and practices, and on the community conditions. Government and health agencies' websites were particularly helpful in addressing research objective 2.

Research objective 3, which sought to identify barriers and opportunities to future adaptation, was addressed directly in the informant interviews, with responses categorized into recurring themes, and also by inferences when existing strategies and measures were considered relative to possible changes in climatic stresses.

Data gathered from the key informant interviews, newspapers articles, reports, websites and local newspaper articles were organized with respect to the components of the analytical framework, namely current and future exposures and sensitivities, present adaptive strategies, and adaptive capacity for the future. For the interview data, similar

answers were clustered together according to theme and examined for patterns and trends (Crang, 1997). Information from the other sources clustered similarly. All data around similar themes were then combined and interpreted in an inductive manner in order to address the proposed research objectives (Craig, 1997; Creswell, 1998; Parfitt, 1997).

2.4 Overview and Key Characteristics of the Study Area

The Township of Addington Highlands is located less than 200 km from Ottawa in southeastern Ontario (Figure 13). This is a sparsely populated area on the southern fringes of the Canadian Shield that experiences a continental climate characterized by significant seasonal variations, from hot summers to cold winters. Approximately 2,500 people are permanent residents of this Township, which includes five villages—Denbigh, Cloyne, Northbrook, Flinton and Kaladar. Located at the centre of the Township is Bon Echo Provincial Park, which draws over 175,000 visitors each year. There are 3,500 seasonal residents that also inhabit the area (McLeman and Gilbert, 2008). Furthermore, several major urban centers such as Kingston, the Greater Toronto Area and Ottawa—accounting for half of Ontario's population—are less than a 300 km drive away, making Addington Highlands a popular seasonal vacation spot.

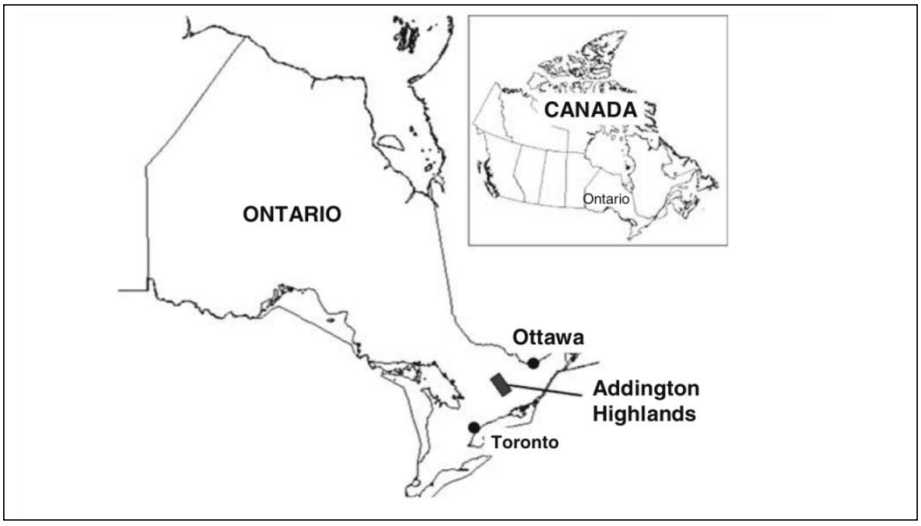

Figure 13: Relative location of Addington Highlands, Ontario, Canada
(from McLeman, 2009)

The Addington Highlands area contains glaciated pre-Cambrian rock and thin soils. The area also contains many lakes, rivers, streams, and wet lands, and is covered by a mix of boreal and coniferous-deciduous forests. These characteristics are reflected in the region's main economic industries, which include recreation and tourism, forestry, construction and public services, with the school being the largest employer in the Township (McLeman, 2009).

From a health and climate change perspective, these biophysical characteristics are important. They not only influence the micro-climates experienced in the region, but the lakes provide recreational water for residents to cool off during periods of hot weather, and forested areas are generally cooler than urban areas made of concrete and asphalt, especially in the evening—sometimes as much as 12°C cooler (Environmental Protection Agency, 2009). Less favourable is the fact that these conditions are hospitable to mosquitoes and ticks that can carry climate-sensitive diseases (Charron et al., 2008).

Furthermore, owing to the surrounding forests, Addington Highlands residents are at risk from forest fires and their health effects.

Given the lack of previous rural case studies, any rural location in Canada would have conceivably been a useful location for investigating climate change and health vulnerability. Addington Highlands made for an appropriate case study for a climate change and health vulnerability assessment, for a number of reasons. Addington Highlands has been the focus of other multi-disciplinary research investigating local climate trends and their implications for built infrastructure, the economy and natural resources (McLeman and Gilbert, 2008), identifying it as a rural area where climate-related impacts and adaptation are taking place (McLeman, 2009). Proximity, existing research, availability of data and information sources, and the applicability of the research to inform public health and community programs, provided a strong rationale for the study being undertaken in Addington Highlands.

2.4.1 Climate

To describe the types of climate conditions that occur, and give indication of the types of climate-related health risks faced by Addington Highlands residents, this study used Environment Canada's Climate Data Online, which contains historical temperature records from the late 1800s as well as climate normals for the period 1971 to 2000 (www.climate.weatheroffice.gc.ca/climateData/canada_e.html). However, owing to a lack of climate data for the communities in Addington Highlands, climate data from the weather station in Bancroft, which is located approximately 50 km west of Addington Highlands, and Renfrew, which is located approximately 100 km north-east of the study

area, were used as a proxy for this study. Figure 14, showing temperature records since 1882 (oldest records available) for the month of March, indicate a warming trend towards milder winters. The graph also shows the range of inter-annual variability. From a health perspective, this may mean less cold-related illness or injuries.

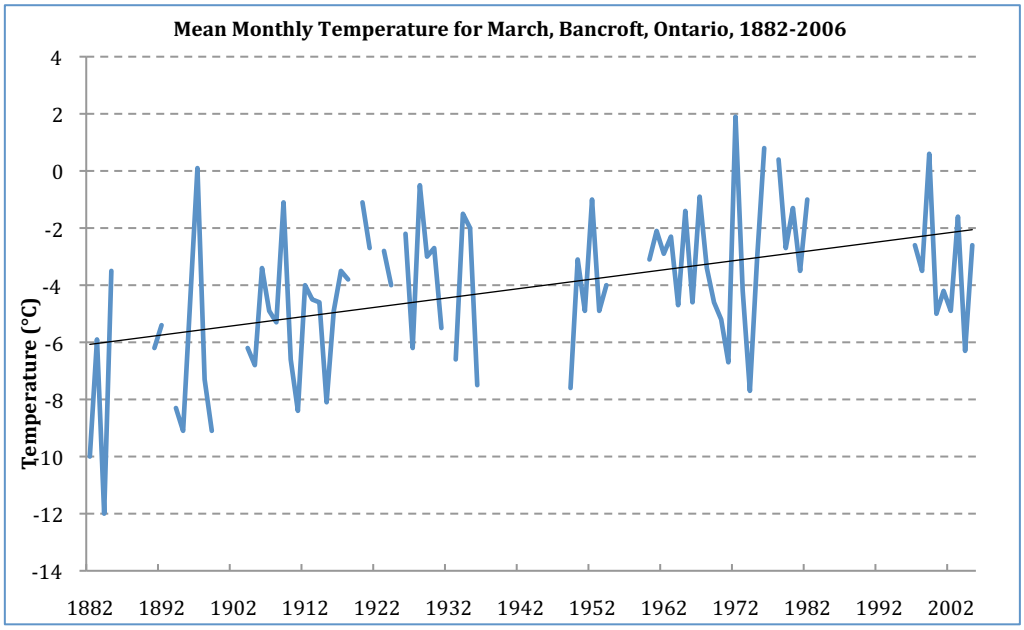

Figure 14: Mean monthly temperature for March, Bancroft, Ontario, 1882-2006
Source: Based on data from Environment Canada, Climate Data Online

As illustrated in Figure 15, there is a slight downward trend in the number of hot summer days over the last ten years, and it is apparent that there is considerable inter-annual variability in the frequency of extreme hot temperatures in Addington Highlands. For example, in 2005 there were over 70 days above 25°C and almost 20 days above 30°C, whereas in 2009 there were less than 30 days above 25°C and less than 5 days above 30°C. The average yearly number of days above 30°C between May and September during the ten year period of 2002 to 2011 was 7.9 days. Temperatures above 25°C and 30°C are commonly associated with heat-related illness (Health Canada, 2011), and the

period from May to September is widely considered by practitioners to be 'the heat season in Canada' (Health Canada, 2011). Furthermore, locals and cottagers perceive the 'May long weekend' to be the start of summer (McLeman, 2009). May and June are also important to include in the analysis because extreme heat events early in the summer season generally result in higher morbidity and mortality than events that occur later in the summer season (Health Canada, 2011). This occurrence can be partially attributed to a lack of acclimatization (Health Canada, 2011).

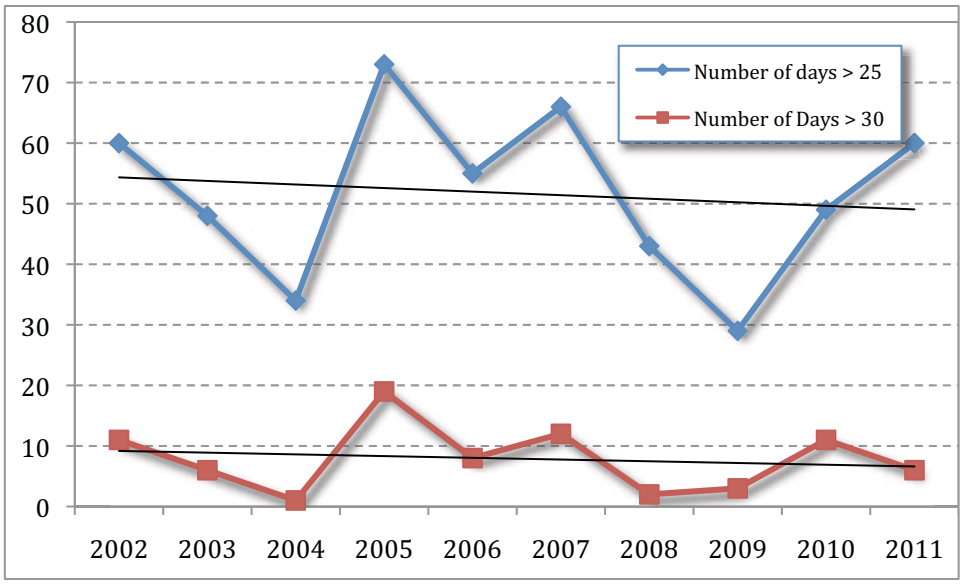

Figure 15: Number of days with maximum summer (May-September) temperatures above 25 and 30 º Celsius (2002-2011), Bancroft, Ontario
Source: Based on data from Environment Canada, Climate Data Online

Given the number of hot days observed over the last 10 years (Figure 15), it becomes apparent that extreme heat already exists in this area. Natural Resources Canada (2008) warns that the frequency of extreme hot temperatures is expected to increase in Canada, and Health Canada (2011) warns that this represents a real health risk for the future.

Thus, heat is one climate condition that may affect the health of Addington Highlands' residents in the future.

Furthermore, Figures 16, 17 and 18 show respectively, the average daily temperatures normals, rainfall and snowfall normals experienced over the thirty period of 1971 to 2000 in Renfrew, Ontario. Because there were no climate normals recorded specifically for Addington Highlands or neighbouring Bancroft, climate normals data for the nearby community of Renfrew was chosen as a proxy. These climate normals suggest heat illness in the summer, and frost bite and injuries related to falls from slipping on ice in the winter, are possible risks.

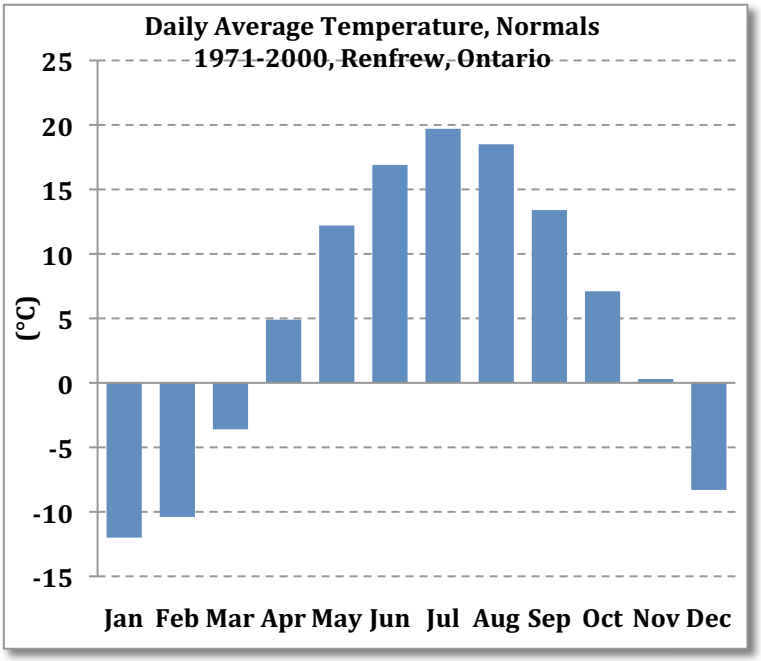

Figure 16: Daily average temperatures, normals 1971-2000, Renfrew, Ontario
Source: Data from Environment Canada's National Climate Data and Information Archive

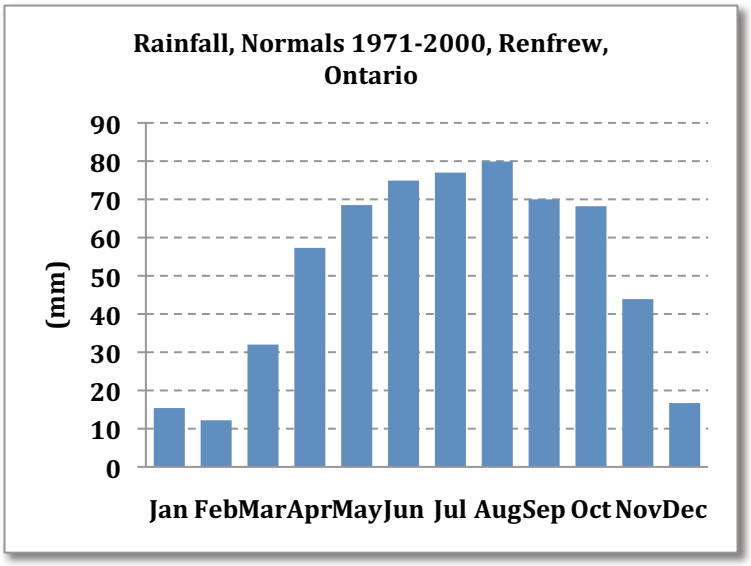

Figure 17: Rainfall, normals 1971-2000, Renfrew, Ontario
Source: Data from Environment Canada's National Climate Data and Information Archive

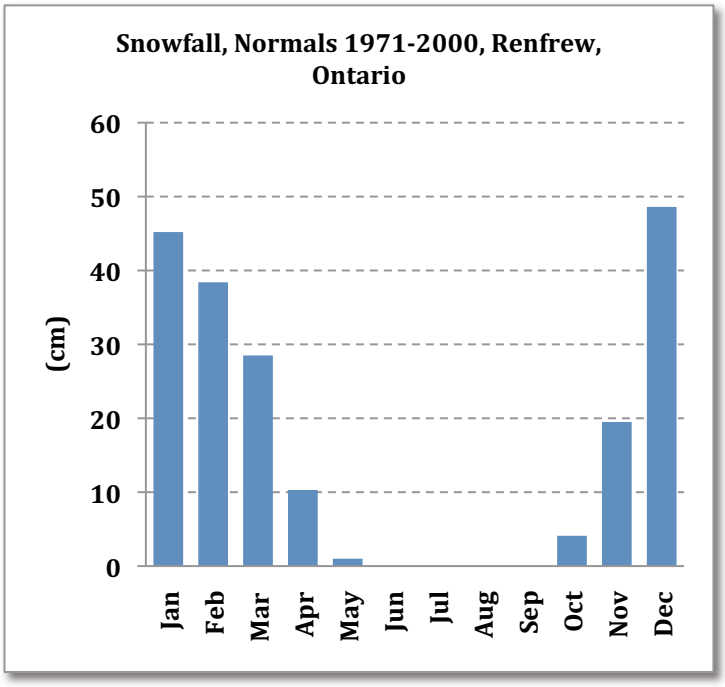

Figure 18: Snowfall, normals 1971-2000, Renfrew, Ontario
Source: Data from Environment Canada's National Climate Data and Information Archive

The vulnerability of a community, such as Addington Highlands, to climate-related health effects is due to factors like the baseline climate and extremes (Balbus and Malina, 2009). These climate factors, for example, influence the presence of disease agents and their vectors. In this section, climate data was assembled by using data available for surrounding areas, specifically Bancroft and Renfrew as a proxy, given the scarcity of climate data specifically for Addington Highlands. This information provides necessary information needed to undertake a climate change and health vulnerability assessment (Seguin, 2008). The above climate section has reported on such factors as: milder, shorter winter; frequency of extreme heat days (days above 25 and 30ºC for 2002-2011); and average daily temperatures normals, and rainfall and snowfall normals (1971-2000).

2.4.2 Population and Health Characteristics

Population characteristics reported in this study were obtained from Statistics Canada's 2006 Community Profiles, which contained community-level information from the Canadian 2001 and 2006 census. Health information was largely accessed through the Southeastern Ontario Health Council, which disaggregated North Lennox and Addington health data from the rest of the Kingston, Frontenac and Lennox & Addington (KFL&A) Public Health unit. This information is a better reflection of Addington Highlands than that found through Statistics Canada or the KFL&A Public Health unit, as the aggregated KFL&A health data do not show the rural and urban differences.

Addington Highlands is sparsely populated. It has an area of 1,288 km^2 with a population of 2,512 people, occupying 2,350 private dwellings. It is economically depressed—the median family income ($37,897) is almost half the provincial average ($69,158).

Addington Highlands has a much lower proportion of immigrants (7.2%) than Ontario as a whole (26.8%) (Southeastern Ontario District Health Council, 2004). The educational attainment levels are lower than in the rest of the province. The percentage of Addington Highland's population with a university degree is 7%, whereas the percentage for Ontario overall is 17% (Statistics Canada, 2011). Those living in Addington Highlands with less than a high school education made up 50.1% of the population in 2001. This percentage is higher than 48 of the other surrounding census divisions (Southeastern Ontario District Health Council, 2004). From a health perspective, levels of education are significant, because promotion of health issues is harder when education attainment is lower. Also, health status itself is strongly linked to educational background and those with poorer education, as a group, have markedly poorer health outcomes (Southeastern Ontario District Health Council, 2004).

Like most rural communities, the average age of the population in Addington Highlands is older than urban populations (Statistics Canada, 2008). In Addington Highlands, this is due to high levels of out-migration of youth and in-migration of retirees (McLeman, 2009). Youth are leaving the region to look for work or to study in an urban setting (McLeman, 2009), which is causing the working age population (age 15-64) to also decrease (Statistics Canada, 2008). The percentage of the population aged 65 and older in Addington Highlands (24%) is higher than for Ontario (14%) (Statistics Canada, 2011).

A health profile of the Southeastern Ontario District Health Council (2004) reports that people in Addington Highlands and neighbouring Lennox have more health problems than those in the rest of the Southeastern Ontario District (e.g., Larnark, Leeds, Grenville,

Hastings, Prince Edward). Residents of Addington and Lennox County have higher rates of diabetes, heart disease, high blood pressure, heart attacks and obesity. Individuals with these chronic health conditions are more sensitive to climate related health impacts, such as those associated with extreme heat events (Berry et al., 2008).

2.4.3 Primary, Public and Community Health Services

There are two primary health care contacts with responsibilities to diagnose illnesses and care for outpatients in Addington Highlands: the Lakelands Family Health Team located in Northbrook, which includes three medical doctors, a nurse practitioner, a chiropodist for foot care and a social worker; and a medical clinic in Denbigh that is open for one half day a week. This Family Health Team is a new addition to the organization of health services (2011). The Addington Highlands doctor recruitment committee was successful in recruiting a new doctor who will join the Family Health Team in 2012. Until recently, doctor shortages were an issue in Addington Highlands.

Persons in Addington Highlands requiring emergency services or specialized care (e.g. childbirth) are required to travel to a hospital in a neighbouring community, such as Bancroft, Nappanee, Renfrew or Pembroke. Two ambulance bases are currently located in Addington Highlands Township, one in Northbrook and the other in Denbigh. The ambulance services are a first point of contact for out-of-hospital medical care and are important for these villages as the closest hospital is at least an hour's drive away. There has been an on-going county review of ambulance services, and consideration has been given to closing the Denbigh ambulance base. There is one pharmacy located in

Northbrook, which first opened in 2011. Laboratory and x-ray services are not available in the Township.

Addington Highlands is part of the Kingston, Frontenac, Lennox and Addington (KFL&A) Public Health Board. Regional Boards of Health are charged with the delivery of local public health programs and services based on the Ontario Public Health Standards (Ontario Ministry of Health and Long-term Care, 2008). The primary focus of public health is the promotion of a healthier population, reducing the demand on the health care system, and responding to threats to health, which complement the work of the primary health care system.

Boards of Health are responsible for the assessment, planning, delivery, management, and evaluation of a variety of public health programs and services that address multiple health needs, as well as the contexts in which these needs occur (Ontario Ministry of Health and Long-term Care, 2008). Several programs and protocols within the standards explicitly require Ontario public health units to manage climate-related stresses to health. These include infectious disease prevention and control, food and water safety measures, prevention of injury and public health emergency preparedness activities, among others. Thus, the foundational standards for public health units in Ontario, including the KFL&A Public Health unit, are directed to manage some climate-related health risks and raise awareness of them (Ontario Ministry of Health and Long-term Care, 2008).

The South East Community Care Access Centre is located in Northbrook and provides access to health and personal support services to help people live independently in their

home. There is one long-term care home with 60 beds in Northbrook. It serves Addington Highlands, and North and Central Frontenac. Land O' Lakes Community Services centre provides social services and offers 3 programs: the Adult Protective Services program; the Community Support program; and the Land O'Lakes Women's program. Land O' Lakes Community Services has over 150 volunteers who assist in delivering many of the agency's services.

The information collected about climate, population characteristics and the public health system, as discussed in the preceding sections, hint at the ways in which people may be vulnerable (e.g., health effects associated with temperature extremes, reduced capacity to adapt owing to low incomes, high population of seniors, population with health conditions that may increase their susceptibility to climate-related illnesses, reliance on volunteers for service delivery). However, to better understand the scope of potential vulnerabilities and to inform adaptation, more information on the key exposures-sensitivities and adaptive strategies and capacity is required. It is to fill this gap that a community-based analysis of vulnerability was undertaken.

2.5 Findings

2.5.1 Current and Future Exposure and Sensitivity

Residents of Addington Highlands face particular climate related health risks on an ongoing basis, including those associated with storms, heat and drought, as well as the ecological effects temperature and precipitation conditions have on the risk of forest fire. In addition to these, algal blooms, Lyme disease and West Nile virus present potential future risks in this area. Each is now elaborated in turn.

2.5.1.1 Storms

Interviewees indicated that severe storms cause direct health impacts such as injuries and death, and they can also affect road conditions and travel safety. This causes additional risk as people are often required to travel in order to meet their health needs. All people interviewed reported power outages as a result of storms. Most of the interviewees (n=13) reported that severe storms are happening more frequently. From 2001 to 2011, a number of significant weather events occurred in Addington Highlands and surrounding area. As one newspaper article reported, "The latest wind storm is another one of the unusual weather events that have occurred in the last few years: the ice storm of 1998, the drought last summer, and the extremely mild winter this year (which some experts think is the warmest winter in recorded history). Global warming seems to be a reality and we are beginning to see the effects in our own region – evidenced not only by successively milder winters, but also by the unusual weather patterns we are observing" (Brison, Frontenac News, March 13, 2002).

The most significant weather event identified was the microburst (localized column of sinking air producing damaging winds) on August 2, 2002, which caused one fatality and seriously injured another person in the village of Cloyne. The psyco-social impacts of the 2002 microburst is exemplified in the following passage from a news article: "This storm was different on two fronts. Yes, homes were damaged as well as the landscape; but this storm has affected our community personally and emotionally. Personally - a family in our community has suffered a loss of life we all feel. Personally - many families have suffered damage that will take lots of work to repair. Emotionally - the fear of future

storms will remain. Emotionally - the fatigue of cleaning up and rebuilding. Emotionally - the sorrow of a lost life. This storm brought 'Winds of Change' in many of our lives. We will go on; we will learn from this; we will clean up and live. We have learned not to take nature lightly" (Alcock, Frontenac News, August 7, 2002).

A review of the Frontenac News over the last ten years identified articles on the following weather events, in addition to the 2002 microburst: three wind storms (May 2001; March 2002; August 2006); and two ice storms (December 2001; December 2009). During the interviews, some respondents (n=4) reported thunderstorms to be increasing, whereas other people (n=6) said that while thunderstorms can be a problem, they feel that there has been no change in their frequency or severity. One interviewee and one article in the Frontenac News reported an incident in 2011 where a barn in a neighbouring community was struck by lightning. Moreover, in 2006, lightning hit a street light in Cloyne, causing power outages in some areas for a couple of days. Any increase in thunderstorms in Addington Highlands could increase the risk of lightning igniting a forest fire, especially in heavy drought years (as discussed in section 2.5.1.3 below).

Most interviewees (n=15) indicated that they are currently vulnerable to ice and wind storms. Environment Canada (2011) indicates that ice storms in Ontario are most likely to happen between December and April, and can result in power lines and towers collapsing from the weight of accumulated ice, resulting in power outages. Health Canada reports that ice covered road, trails and sidewalks are hazardous for people driving or walking during an ice storm (Seguin, 2008). Furthermore, hazards documented from the Eastern

Canada 1998 ice storm include injuries from falls, hypothermia, frostbite, and deaths (Lecomte, 1998).

A news article reporting on the December 26, 2009 ice storm in Addington Highlands indicated that the storm "caused havoc on the roads and power outages in the region north and east of Northbrook, extending to Plevna, Cloyne, Ompah and Denbigh". The Addington Highlands Roads Superintendent was quoted as saying "My biggest concern right now is the trees over roads. It's just as bad, or worse than the 1998 ice storm. A few of the roads are really treed in and the trees are leaning right over the road. If they break over a car or a car runs into them it could be really bad." The article also reported that for many residents power supplies were unstable such that once power was returned it often lasted only a few hours or days and would go off again as new trees came down on the power lines. A Mayor in a neighboring community summed up how many residents are dealing with the threat of a further loss of power. "We are keeping our bathtub full of water, just in case" (Green, Frontenac News, January 7, 2010).

Most interviewees (n=15) indicated that they are currently vulnerable to ice and wind storms, and if these events were to increase, so too would their vulnerability. These people identified the potential for weather extreme (i.e., drought leading to forest fires, heavy wind storms, ice storms) to present hazards outside the coping range of the current public health system and emergency management services, especially since the geographic region is large and there is a limited number of trained professionals serving the area. For example, in relation to the 2009 ice storm affecting Addington Highlands, a news article reported that "the township crews cannot handle the amount of work that is

required on some of the roads… and the township will be contracting out some of the work for cutting down trees that are a threat to public safety" (Green, Frontenac News, January 7, 2010). If storms become more severe and frequent, as is projected under climate change scenarios (Lemmen et al., 2008), interviewees identified that emergency services and infrastructure (e.g., roads) may become compromised resulting in more adverse health impacts.

2.5.1.2 Hot Weather

All health professionals interviewed (n=9) reported vulnerabilities to hot weather manifested in dehydration, heat rash and heat stroke in the area. These heat illnesses were reported to be often accompanied by sunburns. Climate data indicates that Addington summer temperatures do reach above 30°C. In 2005, for example, there were over 70 days above 25°C and almost 20 days above 30°C (Environment Canada, 2011). There is considerable variation from summer to summer with about 8 days a year above 30°C over the last 10 years (Environment Canada, 2011). Interviewees recognized that temperatures do get uncomfortably hot, but they did not feel that heat was currently a major health risk because reprieve can be found in forested shady areas and by swimming in one of the many community lakes. A person employed in the public health field indicated that "heat can put everyone at risk from heat illnesses such as dizziness or fainting, nausea or vomiting, headache, rapid breathing and heartbeat, heat stroke and even death." The person also specified, "Health risks are greatest for older adults, infants and young children, people with chronic illnesses such as breathing and heart conditions or psychiatric illnesses and people taking certain medications. Also people who work or

exercise in the heat, homeless people, and low-income earners are at a greater risk of succumbing to heat illnesses" (July 19, 2011).

Data from the interviews revealed that the public health unit has a program to deal with heat-related risks (discussed in more detail in section 2.5.2 below), and that heat alerts had been called in the area in 2010 and 2011, which indicates that heat is considered a health threat by the KFL&A public health unit. However, interviewees indicated that they did not think that the health risk was as big of a threat in Addington Highlands, because even during consecutive days of hot weather, temperatures tended to drop at night giving people a chance to cool down and recover.

Over and above these direct heat-related health impacts, one individual interviewed indicated that an increase in family and domestic violence occurs when the weather is hot. This is consistent with literature indicating that hot temperatures are linked to increases in aggressive behaviours both in laboratory and field studies (Anderson et al., 2000; Butke and Sheridan, 2010). Heat has been correlated with increases in assaults and domestic violence in the United States, Europe and Canada (Anderson et al., 2000; Butke and Sheridan, 2010; Ouimet and Blaise, 2001). Researchers studying 1995-1998 data from the Montreal area found that the number of crimes per day (aggressive and non-aggressive) rose with daily summer temperatures (Ouimet and Blaise, 2001). One observation is not enough evidence to draw conclusions, but given this person's experience and its consistency with other literature, this is an area that warrants further investigation in rural areas, especially considering climate change projections indicate a future climate with increasingly hot weather trends and more heat waves (Confalonieri et

al., 2007; Health Canada, 2011). Addington Highlands is likely to be exposed to more heat waves in the future and this may increase health related risks (i.e., prolonged heat events resulting in warmer night time temperatures).

2.5.1.3 Forest Fires

The review of the Frontenac News since 2002 identified three significant forest fires that affected Addington Highlands and surrounding area. Most interviewees (n=16) indicated that forest fires are a threat to the health and well-being of individuals in the community. The acute health impacts of forest fires and heat may include hyperthermia and dehydration and exposure to smoke and ash, which can cause eye irritation and respiratory irritation. Major forest fires can also result in evacuations and loss of homes and property, which can induce stress-related hypertension or mental health issues for the people affected (Seguin and Clarke, 2008).

In September 2011, as reported in the Frontenac News, the Addington Highlands Fire Chief said that his department had responded to 112 fire calls, up from 97 at the same point last year. “There have been number of brush fires this summer, but fortunately they have been small ones and we are looking forward to the cooler fall weather” (Green, Frontenac News, September 8, 2011).

Interviewees pointed out that because Addington Highland’s geographic area is large, it can be challenging to respond to fires quickly, especially when they are located in remote areas. Also, several interviewees (n=6) reported that more cottages are being built away from maintained roads. For those cottages, property owners have created their own roads

in an ad hoc manner, some of which do not meet the required road width or height clearance required for emergency vehicles and equipment. Depending on the location of a fire or an emergency, access may be limited for emergency responders putting the health of people at risk.

Addington Highlands is a popular camping and outdoor recreational destination. As such, there is an increased occurrence of camp fires and potential for human-induced fires in the region. Some interviewees (n=3) reported that most visitors and residents are cautious, although some will still build open fires during fire ban periods. These interviewees (n=3) also suggested that because Addington Highlands' population more than doubles during the summer months with an influx of tourists, forest fires requiring evacuations during these months would present challenges in protecting health and property.

A respondent in the firefighter service indicated that several factors are coalescing to create a higher risk of forest fires, including drier conditions and accumulation of debris as a by-product of more frequent and severe ice and windstorms which bring down branches and trees to the forest floor, serving as fuel for fires. One interviewee reported that because the ground was so dry in the 2011 summer season, a campfire that had seemingly been put out had actually spread underground causing a small forest fire that had to be extinguished by local fire fighters.

This is consistent with literature that indicated that climate conditions such as hot, dry and windy conditions increase the risk of forest fires (Lemmen at al., 2008). For example,

drought conditions favour the accumulation of dry plant material, which provides abundant fuel for fires once they are ignited (Ontario Ministry of Natural Resources, 2005). This, in combination with windy weather, creates conditions for extreme fire behavior and fire spread (Ontario Ministry of Natural Resources, 2005). Forest fires can be caused by human negligence, but can also be ignited by thunderstorms. Natural Resources Canada reports that nearly 35% of all forest fires are started by lightning strikes associated with thunderstorms (Berry et al., 2008). A local newspaper article published in 2002 described Addington Highlands' situation: "Conditions are still extremely dry, so the restricted burn ban will remain in place. There have been numerous wildfires in many municipalities in our area. In our township we have had several incidents in the last few weeks. Some were man-made; others were caused by lightning strikes" (DeBernardi, Frontenac News, September 18, 2002).

As for the future, most interviewees (n=16) expected there to be increased risk of fire hazards. Interviewees cited two reasons for this increased risk: recent summer weather conditions, such as warmer temperatures and periods of drought, and the continued expansion of cottages and campgrounds into less settled areas with more vegetation, which can fuel fires. The Ontario Ministry of Natural Resources (2005) estimates that climate change will produce longer and more frequent periods of extreme weather, such as drought, that will fuel increased fire activity. Thus, forest fire hazards are likely to continue and even worsen as a result of the climate conditions and trends in Addington Highlands.

2.5.1.4 Algal Blooms

Research indicates that warm temperatures and lack of precipitation can contribute to reduced water level and result in concentration of matter and chemicals, which may foster the growth of algae (Charron et al., 2008). Two respondents reported that every year there are cases of rashes and eye and ear infections as a result of swimming in recreational waters. The cause of the rashes and eye and ear infections were not known to the interviewees. A Frontenac News article (Green, July 14, 2011) confirmed that blue-green algae is a concern in the area. A sample tested in the east basin of Sharbot Lake contained a coliform count of 58 parts per million, well above the safe drinking water level of 5 parts per million. "We've seen blue-green algae toxins in KFL&A area waters in previous years," said the Communications Officer for KFL&A Public Health. "Our message remains clear in urging residents to avoid using or drinking this water. Visible algae blooms can produce toxins and the highest concentrations of toxins are usually found in blooms and scum on the shoreline. These dense accumulations pose the greatest potential risks to people and pets" (KFL&A, Blue-Green Algae, August 3, 2011). Climate warming may promote the growth of some species of harmful cyanobacteria by providing more optimal conditions for their growth independently or in combination with nutrient availability (Dale et al., 2006; Paerl and Huisman, 2008 and 2009). Addington Highlands may be exposed to health risks associated with algae blooms in the future, as weather patterns and human and agricultural fertilization practices provide conditions that foster algal blooms.

2.5.1.5 Vector-borne Diseases

A few of interviewees (n=3) identified vector-borne disease such as Lyme disease and West Nile virus as a growing concern. No cases of Lyme disease cases in Addington Highlands were known to have occurred according to these interviewees. However, they were concerned about the possibility of increased risk with warmer weather and reported cases of the disease in surrounding areas.

Recent studies (Ogden et al., 2008; Seguin, 2008) indicate that the number of established populations of *I. scapularis* ticks – those that are capable of carrying Lyme disease – is increasing in Canada and that climate change is likely to accelerate their expansion northward, thereby increasing the probability of Lyme disease cases in Addington Highland. Figure 19 shows the progression of predicted range of *I. scapularis* under current climatic conditions (map a) and future climatic conditions (map b), simulated using a slow scenario for the rate at which *I. scapularis* populations establish and migrate. The maps estimate that Addington Highlands will remain a moderate risk area up to 2049 under a slow tick migration scenario. The scenarios use the temperature conditions predicted by the CGCM2 climate model under emissions scenario A2.

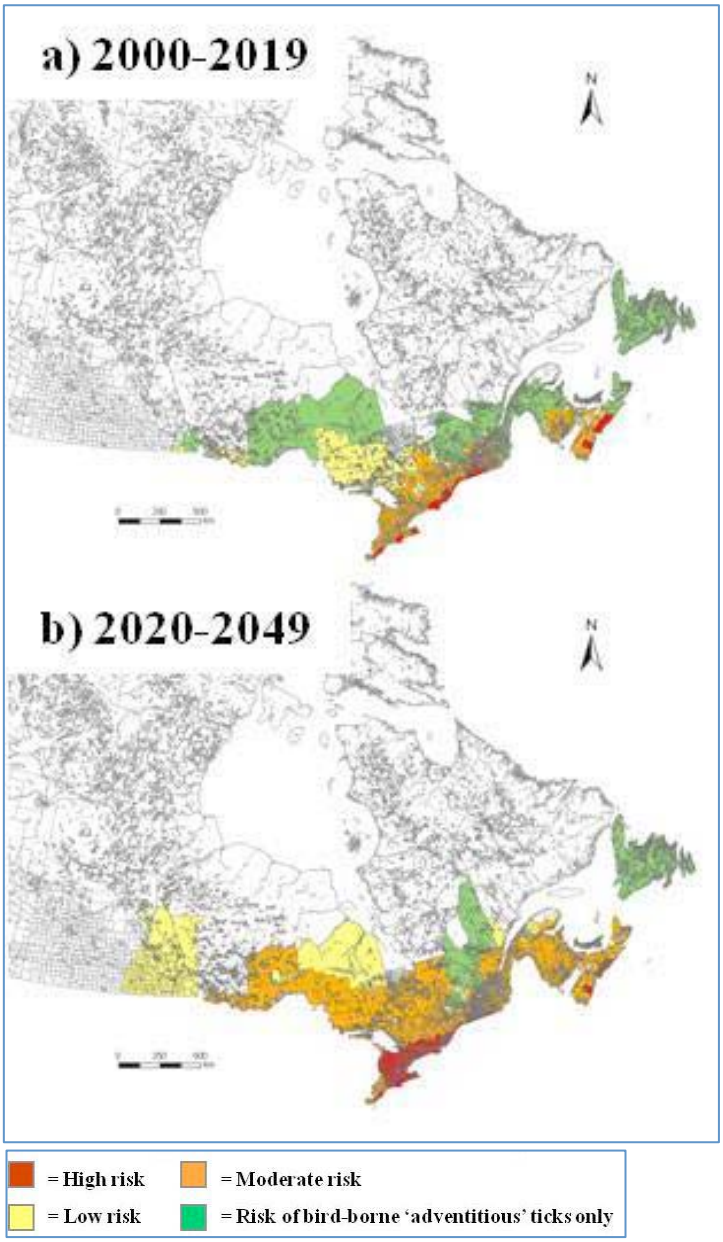

Figure 19: Risk maps for the occurrence of *Ixodes scapularis* in eastern and central Canada under current climate and future projected climate
Source: (Ogden et al., 2008)

The other climate-sensitive vector-borne disease identified by three interviewees as a possible future health threat in Addington Highlands was West Nile virus. No cases of West Nile virus in Addington Highlands were known to the interviewees or reported in the Public Health Agency of Canada (PHAC) records. However, there have been

confirmed cases in areas surrounding Addington Highlands (PHAC, 2011), and a 2002 local newspaper article reported that crows had been infected in nearby Kingston: "Last Monday here at the News we received a fax from the KFL&A Health Unit announcing the first confirmed death of crows in Kingston due to West Nile virus" (Green, Frontenac News, August 28, 2002). Higher summer temperatures and milder winters might lengthen the transmission season and expand the geographic range of mosquito vectors and hence the risk of West Nile Virus in the future (Seguin, 2008).

2.5.2 Adaptation and Adaptive Capacity

All the individuals interviewed were aware of the general health, emergency and community services that are provided within their community – even when the identified services were outside the interviewee's own area of expertise or responsibility. Interviewees were also able to identify at least one key contact for each of the service or program areas. Moreover, almost all the people interviewed (n=17) identified recent concerns relating to health and emergency services in Addington Highlands (e.g., review of ambulance service, lack of some critical health services, waitlists for doctors). All individuals interviewed were aware that the Township had an emergency plan. Almost everyone interviewed (n=17) said they used and incorporated weather information into their planning. Temperature, precipitation and weather warning information were reported as being the most helpful.

2.5.2.1 Existing Programs that Enhance Adaptation

Addington Highlands has a number of programs and services in place to help manage potential climate-related health risks. Programs that address extreme weather events and

forest fires are summarized in Table 10. While the extreme weather and fire events can be hazardous, the existing institutional programs are generally considered to be adaptive under the current circumstances marked by the infrequency of the events. Although, as reported in the previous section, there is the potential for extreme events to present hazards outside the coping range, especially if these events become more frequent.

Table 10: Programs in Addington Highlands relating to extreme weather and forest fires

Climate Exposure	Health risks	Programs or measures	Description of Program
Extreme weather, storms	– Injuries – Illnesses – Loss of property – Mental health problems	Emergency management plans Emergency preparedness factsheet	Addington Highlands Township and Lennox and Addington County have an emergency plan. A factsheet targeting the general community is posted on the Addington Highlands Township website. It includes information about preparing for emergencies and creating an emergency kit.
Forest fires	– Injuries – Illnesses related to fire and smoke inhalation – Loss of property – Mental health problems	Provincial forest fire management strategies By-law fire ban program Provincial fire restrictions	Ontario's Fire Management Program is designed to respond to known natural and human patterns within this fire environment in a way that restricts or permits the amount of fire on the landscape. Enforced and fee based system that regulates setting of open-air fires for the lands located within the boundaries of the Township of Addington Highlands. A "Restricted Fire Zone" is an Order made by the Minister of Natural Resources, under the Forest Fires Prevention Act, that legally restricts the use of open fires in a specific area of the province. It is used when the fire hazard is extreme and/or when fire fighting resources are stretched to capacity.

KFL&A Public Health Unit's programs relating to climate-related risks are summarized in Table 11. The vulnerabilities directly related to extreme heat and those experienced indirectly via algal blooms, Lyme disease and West Nile virus are addressed by programs

that focus on detection and public information. Respondents viewed these existing programs to be suitable, particularly given the small number (or absence) of cases in Addington Highlands. Whether the programs would be adequate, if the frequency of the events increased, was not known to interviewees.

Table 11: Public health programs in Addington Highlands relating to temperature and precipitation

Climate Exposure	Health risks	Programs or measures	Description of Program
Hot summers	Sunburns	Sun safety	Sun safety is promoted through presentations, community campaigns, displays, and the provision of resources. A UV index is issued daily across Canada as part of a broader campaign to educate the public about health risks associated with UV exposure.
Hot summers	Heat illnesses	Extreme heat response plan	A series of extreme heat thresholds are in place to inform residents, health professionals, and community service providers on the measures they can take to reduce the health effects of hot, humid, and smoggy weather.
Cold winters	-Frost bite -Hypothermia -Falls	Cold weather response plan	Temperature and wind chill thresholds are used to alert residents when the temperature could be harmful to reduce the health impacts and risks associated with cold weather events. It includes monitoring Environment Canada's weather forecasts between November 1 and April 1 and notifying the community, health service providers, and the media when thresholds are reached.
Hot summers, less precipitation	Toxins emitted by blue-green algae	Public beach water sample testing	Regular samples are taken of the water at area beaches during the summer months to ensure they are safe for swimming. Beaches with water considered unsafe for swimming are posted as unsafe by use of a metal sign at the beach. Notices are sent to local media.
Increasing temperatures, warmer winters	Lyme Disease	Lyme Disease surveillance and monitoring	Lyme disease activity is monitored by collecting ticks submitted by residents and testing them for the bacteria that cause the disease. Residents will be notified within 3 to 6 weeks if the tick tests positive for Lyme disease-causing bacteria. Tick Removal Health Info Sheet is available via the public health website to help ensure the proper removal of the tick.
Increasing temperatures, warmer winters and changes in precipitation	West Nile virus	West Nile virus surveillance and monitoring	West Nile virus is monitored, and early detection and risk to the public is assessed, through the collecting and testing of dead birds. Information about properly handling and submitting dead birds is available via the public health website. Residents at risk are given important information to keep their family safe.

A variety of adaptive strategies have been adopted by individuals to deal with climate-related health risks in Addington Highlands, some of which relate to the institutional programs mentioned above. All people interviewed stated that power outages, resulting from storms in the summer and winter, are a common problem in Addington Highlands. Most people have adopted practices to manage without power. Interviewees reported that power outages during the winter months resulting from an ice storm are not a major health risk, because most homes have wood stoves, fireplaces and/or generators. Interviewees also reported that because people are used to living remotely, they have enough supplies on hand and are able to self-sustain for periods of time even beyond the 72 hours advocated by public emergency officials. Two interviewees did say that if power was out for an extended period of time, i.e., a week or longer, more issues would arise as people may not have enough fuel or fire wood or food supplies for an outage of that length.

Interviewees (n=3) indicated that sometimes people act in ways that are mal-adaptive to climate-related risk. For example, people are choosing to live and build on unmaintained or private roads that may not be accessible to emergency equipment or ambulance services. Although cottagers are aware of these limitations when building, it has not seemed to deter development in remote areas. In fact, Addington Highlands Township is under increasing demand from such cottage owners to service unmaintained roads, although such a service is one that the Township's current budget does not allow for.

While there are programs in place to manage climate-related health risks identified as a concern for Addington Highlands, it is important to examine whether these strategies will

be effective in reducing future risks. The public health and emergency management systems have evolved to deal with low frequency extreme events, and in this sense serve to represent adaptations to climatic risks. However, the effectiveness of these programs should be evaluated as the climate continues to change and these extreme events increase in frequency and severity. For example, there are public programs in place to address heat extremes, such as heat alert systems and public places with air conditioning, although interviewees indicated that there is no public transportation available for people who are unable to drive to these locations. This is significant since interviewees (n=5) indicated that because of the community's low socio-economic status, increases in the price of gas like those experienced in recent years can mean that certain vulnerable residents decide not to pursue heat mitigating activities or to seek health services that require travelling. These are the types of factors to consider when assessing adaptive capacity. Such factors are discussed more thoroughly in the next section.

2.5.2.2. Challenges and Opportunities for Enhancing Capacity

When asked to identify strengths or factors that make their community resilient to the climate-related health impacts, the most common responses from interviewees were that Addington Highlands has institutional flexibility (e.g., prompt decision making involving a small number of people) and community cohesiveness (e.g., informal social networks and willingness to help each other), both of which are considered to enhance adaptive capacity. This is exemplified in an excerpt from a local newspaper article on the 2002 microburst "We have learned to care for our community family in a deeper way: neighbours helping neighbours; people giving out food. Sharing our time and talents to get the job done has brought us closer together... has made us a community, not just in

Cloyne, but all over this area where this storm has made us one in our suffering" (Alcock, Frontenac News, August 7, 2002).

Interviewees (n=19) consistently identified informal systems functioning at the individual level – related to neighbourliness, self-sufficiency of individuals and willingness to help – as factors contributing to community capacity. At the organizational level, factors cited as contributing to capacity included extensive knowledge of community characteristics, ability to coordinate between agencies, strong volunteer base, and understanding of roles and responsibilities of the various agencies and leaders. For example, individuals in position of leadership know 'off the top of their heads' who to call during an emergency. They also have knowledge of at-risk populations and their locations. One interviewee said that he knew which specific doors he would need to knock on in an event of an emergency, in order to reach residents who are not connected to the general media and do not have telephones, and as such, would not have access to hazard information, making them at risk.

Interviewees involved in emergency and public health (n=13) noted that keeping up with current training activities was for them a priority. Interviewees involved in emergency procedures indicated that they regularly reviewed emergency telephone numbers, tested the emergency notification system, and exercised the emergency plan for practice. For example, in the aftermath of an August 2006 windstorm, Addington Highlands Council and staff initiated a de-briefing meeting with police, hydro, ambulance and Bell Canada officials to discuss how to improve communications and response times in severe storm situations along provincial highways (Green, Frontenac News, August 10, 2006).

Addington Highlands' population characteristics present some capacity challenges. The percentage of older population in Addington Highlands is particularly high and set to increase further. Most interviewees (n=17) indicated that the township has a number of formal and informal systems that provide assistance on a regular basis to persons at risk or in need. However, they also indicated that the volunteer base which serves elderly and vulnerable populations are also aging and there is not as many younger adult volunteers to take their place.

Ensuring basic health services has been an on-going effort for Addington Highlands community leaders. An interviewee claimed that the health services available in Addington Highlands 'had a long way to go' before she would agree that they were able to meet and keep up with current demands. For example, attracting and retaining health and emergency professionals were challenges that many interviewees mentioned (n=15).

Interviewees (n=12) indicated that despite many challenges, Addington Highlands has been able to maintain and even enhance some health and protective services over the last several years (e.g., new pharmacy, new doctor recruited, Denbigh Community Center, retention of Denbigh ambulance base), but that it has required considerable and concerted effort, as well as foresight, on the part of community committees and individuals in order to identify and champion solutions to problems. For example, the newspaper analysis revealed that over the last few years, Addington Highlands community members have been participating in ambulance service planning in order to validate the necessity of

retaining two local ambulance bases to be able to provide emergency services to Addington Highlands' large territory in a timely manner.

Most interviewees (n=16) indicated that local media is limited to one weekly newspaper which is inadequate for disseminating daily concerns and issues. They also indicated that available television and radio stations from other parts of the province provide inadequate coverage of local stories relating to climate-related risks. For example, one news article on the December 26, 2009 ice storm, quoted the Addington Highlands Reeve: "If this were happening in Napanee or Kingston, it would be all over the news, but since it is only out here, you don't hear anything about it" (Green, Frontenac News, January 7, 2010). Furthermore, all interviewees said that access to reliable internet service continues to be a challenge in Addington Highland, making it difficult for people to access health and emergency information on websites. A newspaper article confirmed that internet service is limited and expensive in Addington Highlands: "a satellite solution is available now for $70 a month. [...] It provides for download speeds of up to 1.5 megabits per second" (Green, Frontenac News, February 3, 2011). Owing to this, an interviewee indicated that they often will mail-out health risk information that is available on the website, although it is not ideal as it expensive and time consuming to do so. Interviewees also indicated that cell phone coverage is patchy in Addington Highlands and that you need to be near the one transmission tower to get service.

Interviewees (n=16) named storms and forest fires to be a current and future hazard, and are the focus of the remainder of this section. These two issues were chosen in order to better gauge adaptive capacity in more detail as it relates to climate-related health

emergency. Although there is no guiding framework or consensus on the criteria required for evaluating the determinants of adaptive capacity and on the indicators that should be used (Lemmen et al., 2008), key determinants of adaptive capacity are commonly noted in the literature (Berry, 2008; Smit et al., 2001; Tol et al., 2007; Yohe and Tol, 2002). These commonly cited determinants are used in this study and are listed in Tables 12 and 13, along with an assessment of Addington Highlands' adaptive capacity, based on data from interviewees and newspaper articles relating to extreme weather and fire events.

Table 12 reports on determinants related to awareness, institutional resources, human and social capital, and health and economic status, indicating how Addington Highlands performs on each category and whether this represents a positive or negative implication for the community's adaptive capacity. Many of these determinants are self-explanatory. For example, institutional economic resources are indicative of the resources available to invest towards adaptation activities. Health status is negatively influenced by high rates of diabetes, heart disease, high blood pressure, heart attacks and obesity, which make individuals more sensitive to climate related health impacts such as exposure to forest fire air pollution (Berry et al., 2008).

As summarized in Table 12, Addington Highlands' adaptive capacity is enhanced by such factors as awareness of risks and their roles and responsibilities, and effective social networks. Capacity is constrained by factors including tourists and seasonal population fluctuation, aging population, poor health, low economic status, and reliance on community volunteers. On the role of volunteers, one community service co-coordinator explained during our interview that the program that she is responsible for often faces

adversity, and that if it were not for the volunteers the program could not meet its mandate. This is exemplified in the following quote: “The credit for this program is solely to our team of volunteers. No matter what challenge I issue them they rise to the occasion always assuring me that they will make it work. I realize that I am repeating myself when I say that the volunteers are what makes this program successful, however, without them it simply would not exist”.

Table 12: Determinants of adaptive capacity relating to awareness, institutions and human capital in Addington Highlands

Determinant of Adaptive Capacity	Description	Assessment of Addington Highlands Positive (+) or Negative Effect (-) on Adaptive Capacity
Awareness	Ability to identify signals of change and their risks	(+) Permanent residents have strong knowledge of the land, community characteristics and how to cope during power outages
		(+) Community professionals have good knowledge of procedures during an emergency
		(+) Community professionals are knowledgeable about community vulnerabilities and populations most at risk
		(-) Population more than doubles in summer season. Current systems are set-up to service permanent population
		(-) Tourists are not familiar with local weather conditions or emergency procedures
		(-) General population has no experience of widespread emergencies and State of Emergency has never been called
Institutional economic resources	Structure of critical institutions and allocations of resources and decision-making authority	(+) Institutional flexibility for responsive decision making
		(+) Knowledge of roles and responsibilities of health and emergency agencies
		(-) Limited resources for unbudgeted activities
		(-) Limited number of personnel covering large geographic area – long distances and travel times can occur
		(-) Some health services are not able to meet current demand
		(-) Problems retaining staff and heavy reliance on community volunteers
Human Capital	Skills, education, experiences and general abilities of the community	(+) Community members in leadership roles are experienced, adaptable, and skilled in several professional roles
		(-) Small pool of experienced, educated and skilled professionals from which to draw from (e.g., Half the population have a high school education and 7% have a post-secondary education)
		(-) Fatigue during extended emergencies or for events with cumulative impacts (lack of relief personnel)
		(-) Seasonal residents without local knowledge
Social Capital	Informal social networks and collective life; the ability of residents to work for common community goals	(+) Strong and reliable community volunteers
		(+) Strong informal social networks
		(+) Strong community cohesiveness and initiative
		(+) Strong willingness of community members to help each other
		(-) Small and aging pool of experienced and skilled volunteers from which to draw from
		(-) Aged and aging population may require additional assistance during emergency
		(-) Young adult population dwindling
Health and Economic Status	Community and individual ability to respond	(-) Poor health status (increased rates of diabetes, obesity, heart conditions)
		(-) Economically depressed

The determinants noted in Table 13 include technology and information management and programs and services. The importance of programs and service were discussed previously and include such factors as fire bans and updated and tested emergency plans. Technology is also important for adaptive capacity as it relates to storm prediction and alerting systems to warn communities to take protective measures. Addington Highlands' adaptive capacity is supported by such factors as the risk management programs in place. The constraints on capacity include limited accessibility to communication technology, lack of public transportation, limits to the availability and access to health care services.

Table 13: Determinates of adaptive capacity relating to technology, programs and risk management in Addington Highlands

Determinant of Adaptive Capacity	Description	Assessment of Addington Highlands Positive (+) or Negative Effect (-) on Adaptive Capacity
Technology and Information Management	Availability and access to adaptation technologies and the ability of decision-makers to manage information	(-) Limited cell phone coverage
		(-) Many residents do not have access to high-speed internet
		(-) Satellite portable telephones are expensive
		(-) Local weekly newspaper is not effective in communicating information about developing emergencies
		(-) No local radio or television station through which to broadcast community specific information about weather risks
		(-) Township covers large geographic area, making speedy information acquisition or transfer challenging without modern information-communication technologies
		(+/-) Fixed wireless and satellite internet service available as of 2011, cost still a barrier for community-wide adoption
Adaptation programs and services	Formal and informal programs and services in place to manage risks relating to weather or fire emergencies	(+) Various programs and plans are in place to manage risks, including a municipal emergency plan
		(+) Community is adept at managing risks and hazards and has yet to declare a state of emergency
		(+) New local community Health Team services and pharmacy
		(-) Cumulative impacts likely to exceed capacity (i.e., traffic accident and microburst)
		(-) Inflated summer population may exceed the capacity of the services available (i.e., 2 ambulances, 1 small cooling center and 1 pharmacy service entire area and population)
		(-) Heavy reliance on volunteers and fundraising activities in order to meet current demands or upgrade facilities
		(-) Many primary health services are not locally available and require travel to neighbouring communities (i.e., hospitals, specialists, laboratories, x-rays)
		(-) No public transportation service

2.6 Discussion and Conclusions

Assessments of vulnerability have gone beyond linking climate change to health impacts (e.g., illnesses, injuries and deaths) and have begun to investigate how climate is a stressor influencing community vulnerability and public health capacity (Costello et al., 2009; Blashki et al., 2007; ; McMichael et al., 2008; Seguin, 2008). These assessments tend to be undertaken at the national and regional levels. In Canada, vulnerability assessments at the public health unit level, although less common, are important in order to inform local decision-making. Rural climate change and health vulnerability assessments, outside of Canada's North, are even less frequently undertaken, even though rural community characteristics relating to lower socio-economic and health status and aged population may make these people particularly vulnerable (Berry et al., 2008).

This study examined the health risks of climate change in a remote and rural municipality in Canada. The research identified risks to human health (exposure-sensitivity), characterised management strategies in place to address risks posed by current and future climatic conditions (adaptation) and highlighted potential barriers and opportunities for enhancing capacity to respond to emergent climate risks (adaptive capacity). This study represents the application of a climate change framework, and structures the Addington Highlands case study around the concepts of exposure-sensitivity and adaptive capacity. The contribution of this framework is that it includes both the conceptualization of vulnerability and the analytical bottom up approach, as well as facilitating the integration of multiple data to describe and understand the complex interactions underpinning human health and climate change. This approach worked well as it yielded rich data from a

variety a sources, including the community members own experiences and yet it is generic enough to be applicable to other communities and their unique circumstances.

Climate and weather-related conditions such as extreme weather events, heat stress and forest fires are currently important health risks for people living in Addington Highlands, and these risks are expected to increase with climate change. In addition, the health risks of Lyme disease, West Nile virus and infections from algal blooms are also likely to increase in the future. The findings from this study suggest that Addington Highlands is already taking action to protect public health through a variety of adaptation programs. Programs and services are in place to manage the potential climate-related health risks relating to heat and cold illnesses, sunburns, Lyme disease, West Nile virus, and emergency measures are in place for extreme weather events and forest fires. Information gathered from interviews with community officials familiar with these programs suggest that these programs are largely effective in protecting health, although as exposure increases, they may not be sufficient. Further research and evaluations of these programs would be advantageous. Furthermore, one interviewee indicated that she has observed an increase in family and domestic violence when the weather is hot. One observation alone is not evidence to draw a conclusion, but given the interviewee's particular experience, it warrants further investigation in Addington Highlands and other rural communities.

Characterization of Addington Highlands' adaptive capacity revealed important strengths and limitations. Addington Highlands has institutional flexibility for responsive decision-making and community members in leadership roles are experienced, adaptable, and skilled in several professional roles. The seasonal residents have largely adapted to the

local climate conditions and are able to manage during power outages. Addington Highlands has strong informal social networks and support systems that reduce vulnerability of many people and better position them to respond to, and cope with, emergencies. This is consistent with findings in literature noting the cohesiveness of rural communities and its importance for emergency response and the delivery of health services (Furgal and Prowse, 2009).

However, Addington Highlands, like many other rural communities, faces challenges relating to the availability of health care services in the region, recruitment and retention of health care professionals, poor health status of segments of the population, and the distance some residents must travel to obtain care or specific treatments (Hanlon and Halseth, 2005; Statistics Canada, 2008). These challenges will likely continue to intensify in the future as rural communities compete with expanding urban and megacity living for qualified health professionals and limited resources (Crooks et al., 2008).

The current burden of climate-related health outcomes is likely to increase over coming decades as a result of projected increases in life-style diseases (e.g., diabetes, obesity) (Berry, 2008). Addington Highlands has an older population structure. Furthermore, certain types of diseases associated with aging, for example diabetes and heart diseases, are already high and are expected to increase among Addington Highlands' population, which could increase their vulnerability to climate-related health risks.

Actions by public health authorities, and by individuals themselves, can directly and indirectly reduce climate-related health risks for people living in Addington Highlands. For example, general improvements in the awareness of healthier life-styles among the public would assist in the preparedness and coping ability of communities by reducing underlying health conditions. Future development and advancements in the availability of information-communication technology could also provide broader and quicker public access to health risk information, resulting in better health, preparedness, and response efforts by individuals living in Addington Highlands.

The findings of this study serve to identify and better understand vulnerabilities, and help inform actions toward preparing Addington Highlands for possible future climate related risks. The research seeks to move the Addington Highlands community towards an increased awareness regarding its sensitivities to climate-related health risks. This report also develops baseline information, which can be used to monitor changes and assess vulnerability at a future time. The framework, methodology and findings from this research may ultimately be used to develop insights regarding the types of pressures climatic changes may put on health in other rural and remote communities.

This study focused on the experiences and perceptions of individuals involved in various capacities in Addington Highlands. While this is helpful for identifying vulnerabilities that might be addressed, there are limits to such an approach. First, the study did not document the full suite of possible health vulnerabilities to climatic stimuli, some of which might conceivably occur so infrequently as to avoid notice or detection by service providers. To do so would have required a much broader

compilation of data from a wider sampling beyond those involved in public health and emergency services, such as seeking questionnaire data from permanent and seasonal residents. Furthermore, because awareness is often lacking about the direct and indirect climate-mediated health outcomes (Tamerius et al., 2007), the health impacts reported were ones where the causal pathways were known to interviewees. For example, with extreme weather events, the causal pathway is more direct and apparent (and were identified in this study). Whereas an increase in aeroallergens and corresponding worsening of seasonal allergies, or temperature and precipitation changes influencing food- or water-borne illnesses, have an indirect causal pathway and are less apparent (and were not identified by the interviewees). Thus, when a health risk is not identified, there is no way to differentiate whether it is because it is not a risk, or whether it is not identified because the climate-related causal pathway is not known to interviewees.

Also, there may be a bias in the reporting of specific events for this study, as the majority of the interviews were conducted during the summer months, and during the data collection stage, Addington Highlands experienced several heat events and windstorms. These can potentially skew the interviewees' perceptions of their occurrence and risk. Lastly, given the turnover of health professionals in the area, many respondents had not lived in the region long enough to have experienced some of the conditions that had very low occurrence frequencies.

A long-term benefit of this research is to move Addington Highlands towards an increased awareness regarding its sensitivities to climate-related risks. The information documented in this report can be used to monitor changes and assess vulnerability at a

future time. Both the methodology and findings from this research may be used to develop insights and help stimulate actions toward preparing other rural communities for possible future climate-related risks. This case study is especially valuable to the extent that rural communities rarely have the capacity, expertise or resources to undertake this type of climate change and health assessment on their own (Berry, 2008).

Chapter 3

Summary and Conclusions:
Climate-Related Stresses on Human Health in Addington Highlands

3.1 Overview

It is broadly accepted that climate change and climate variability affect Canadians' health and well-being (Seguin, 2008). However, it is difficult to predict the health impacts of future climate change because of present current uncertainty about the extent and rate of change, and socio-economic and demographic factors that influence a community's exposure-sensitivity and ability to adapt (Seguin, 2008). Health Canada emphasizes that local climate change and health vulnerability assessments, which seek to include these factors in their analysis, can reduce some of this uncertainty. This thesis research sought to contribute in this way by creating a framework for conducting local climate-health vulnerability assessments in rural areas and testing it by applying it in the rural municipality of Addington Highlands, Ontario.

The generally high level of human health in Canada provides a strong foundation for coping with climate-related health risks (Seguin and Clarke, 2008). However, there are notable health and adaptive capacity disparities within Canada, particularly in the case of rural municipalities (Akerlof et al., 2010; Berry, 2008; Public Health Agency of Canada). By documenting climate, socio-economic and demographic trends, as well as the real-life experiences of how weather and climate influence human health in a rural population such as Addington Highlands, this research contributed to the understanding of the capacity strengths and limitations that rural communities may face. A challenge for documenting this type of research is finding the right balance between including

sufficient detailed analysis to assess community exposure, adaptation and capacity so as to not oversimplify the complexity of the issue, while keeping the analysis concise and accessible so that it will be more likely understood and possibly replicated by other communities wanting to undertake assessments to understand their own vulnerability. Some of the findings in this study generated more questions than answers, and it is hoped that this research stimulates decision-makers within Addington Highlands and future researchers to continue to increase the evidence base regarding how climate-change may increase the health risks to rural communities within Canada.

This chapter presents a summary of the thesis research's main findings, a discussion of methodological strengths and limitations, an assessment of the scholarly and practical contributions, and future research avenues emerging from this thesis. Typically, each section begins with findings particular to Addington Highlands, and then teases out any potential broader implications for rural populations elsewhere.

3.2 Notable Findings

3.2.1 Rural Exposure and Sensitivity to Climate-Related Health Risks

There is evidence that the population of Addington Highlands is generally vulnerable to several climate-related health risks, which are expected to be accentuated or exacerbated by climate change. Extreme weather events and their manifestation in ice storms, wind storms, thunderstorms and heat waves were consistently identified as a current exposure and health risk, and this is in turn consistent with more general reporting from broad-based studies (e.g., Lemmen et al., 2008; Seguin, 2008). These weather events may not be particularly frequent or predictable, but they can cause considerable damage and draw

upon emergency response and public health resources when they do occur, as was the case in Addington Highlands with the 2002 microburst. Similarly, forest fires, usually associated with hot, dry and windy conditions, are low frequency events, but have the potential for major social, economic and health effects. In Addington Highlands, apart from the direct risks to health, extreme weather events have the potential to affect health by causing damage to critical infrastructure resulting in power outages and road closures, which is consistent with research elsewhere (Berry et al., 2008; Lemmen et al., 2008). Also, one interviewee indicated an observed increase in family and domestic violence during extreme weather events. One observation alone is not enough evidence to draw conclusions, but given that this is consistent with literature linking hot temperatures to increases in aggressive behaviours, (Anderson et al., 2000; Butke and Sheridan, 2010; Ouimet and Blaise, 2001), this is an area that warrants future research, in Addington Highlands and other rural communities.

Vector-borne diseases, notably West Nile virus and Lyme disease, were not identified as current risks in the study area, as there had been no reported cases, but with climate change it is expected that exposure will increase in the study area in the coming years. It is therefore prudent for local public health officials to monitor West Nile virus and Lyme disease cases in surrounding areas, particularly since it is common practice for residents of Addington Highlands to travel frequently to more southerly areas where there is a greater risk of infection. Furthermore, warmer summer temperatures and milder winters will serve to increase the transmission season and expand the geographic rage of the vectors farther north (Charron, 2006; Ogden et al., 2008).

3.2.2 Enhancing Adaptation and Building Adaptive Capacity

The public health and emergency management systems in Addington Highlands have evolved over time to deal with low frequency extreme events quite successfully, and given the close connection residents have with the natural environment, these can be seen as adaptations to climatic risks. One of the challenges in assessing adaptation and adaptive capacity associated with climate variability and extremes is that most of the hazardous conditions have a low frequency of occurrence. This intermittent exposure can invite perceptions of low risk to events and low preparedness (Berry et al., 2008). This is a particular challenge for rural communities, which have been reported to underestimate the frequency of events and hazards because of a lack of knowledge and risk assessments (Haque, 2002). Haque (2002) reports that capacity relating to emergency preparedness is further constrained in rural communities, as they tend to over-rely on volunteers, and their emergency personnel are less trained and organized than in urban centers.

Given that weather events may become more frequent and extreme, the potential that a major storm could exceed the capacity of current management systems will increase, especially if concurrent events were to occur (e.g., storm and traffic accident). Current programs may need to be 'climate proofed' – that is, to incorporate current and future climate change-related challenges and opportunities into regular planning activities so as to reduce risks to a socially acceptable level (Kabat et al., 2005). For example, in order to climate proof critical infrastructure such as power supplies and telephone lines, efforts could be made to clear trees along lines preventatively, so that during extreme winds, trees and branches would not damage the lines if they were to fall. One interviewee indicated that tree clearing along power lines was once a common practice, but was

abandoned when the Government of Ontario started privatizing and deregulating the provision of power.

Population dynamics present capacity challenges for Addington Highlands to adapt to or manage future health risks associated with changing climatic conditions. In particular, the percentage of older population in Addington Highlands is higher than in the rest of the province and is expected to continue to increase (McLeman, 2010). Although the community has a strong volunteer base which serves elderly and vulnerable populations, these volunteers too are aging and fewer younger adult volunteers are available to take their place. Such a dynamic is not unique to Addington Highlands, and has been observed elsewhere in eastern Ontario (e.g., Sander-Regier et al., 2010). Moreover, the tendency to centralize specialized health services in urban areas has left residents of rural communities, such as Addington Highlands, a long drive away from critical health services (Crooks et al., 2009).

In the face of spending cutbacks by higher levels of government, Addington Highlands is currently fighting to maintain an ambulance base in Denbigh to ensure adequate response times. The importance of this service is noted in a local newspaper article: "'The Denbigh ambulance was started in 1982 by the province because it was necessary. The need has not gone away.' [...] if the Denbigh base is removed, 'ambulance response times will be greater than 30 minutes, 80 per cent of the time'" (Green, Frontenac News, October 4, 2011). Attracting and retaining health and emergency professionals has also been an on-going challenge for Addington Highlands given its low population base, creating a slow but steady erosion of residents' access to health services. The combination of a dwindling proportion of younger adults and increasing aging population, as well as

growing exposure to climate-related health risks can be expected to place growing strains on services that are barely managing to meet current needs. Hanlon et al. (2011) report that health professionals in rural areas commonly engage in volunteerism, and undertake more than their formal duties and responsibilities without compensation because of their attachment to place and in order to manage increasing demands, which are in part due to the offloading of the provision of health services. Again, similar dynamics as described in the Addington Highlands case study may be emerging in other rural areas, which would reduce their capacity to respond to climate-related health risks, and provides further evidence for the need for more locally-based climate health assessments.

3.3 Methodological Strengths and Limitations of the Research

One of the key strengths of the research methods employed in this research is that data collection and analysis were guided by a framework that was adapted to investigate climate related health vulnerability in a rural community. Each data source has strengths and limitations and the use of several served to triangulate evidence and increase the validity of the findings. Semi-structured interviews allowed for flexibility in the way issues were addressed by the interviewee, and thereby did not presume that climate change brought about health risks. Another benefit from this method is that interviews were able to fill information gaps created by observations and data, and allow for the investigation of more complex behaviours, motivations and interplay of factors (Hoggart et al., 2002; Valentine, 1997). For example, climate data indicated the occurrence of days with temperatures of at least 30°C in Addington Highlands, which would suggest heat-related health impacts. However, the semi-structured interviews uncovered that, owing to cool evening temperatures and accessibility of cool recreational waters, the actual risk of

heat illnesses is not a major concern for those responsible for public health in the community. This consequently contradicts the information provided in broad-based climate-health assessments generated by Health Canada and others. While it may generally be true that extreme heat presents a significant health risk for eastern Ontarians living in urban centres just a short drive to the south or east, heat was not seen as a high-priority by health professionals servicing Addington Highlands. This again highlights the need for locally based assessments, and particularly rural climate health assessments, to complement broader based studies.

While expert opinion is important in identifying vulnerabilities that might be addressed, it does have its limits. A study only using expert opinion might not uncover the full suite of health vulnerabilities to climatic stimuli, which typically requires a much broader compilation of data from a wider and more representative sampling, including data from permanent and seasonal residents. Furthermore, awareness is often lacking about the direct and indirect climate-mediated health outcomes (Tamerius et al., 2007), and the health impacts reported through the interviews conducted for this research were ones for which the causal pathways were known to interviewees. For example, with extreme weather events, the causal pathways are more direct and apparent because there are easily identifiable. Whereas an increase in aeroallergens and corresponding worsening of seasonal allergies, or temperature and precipitation changes influencing food- or water-borne illnesses, have indirect causal pathways and are less apparent (and were not identified by the interviewees). Thus, when a health risk was not identified, there is no way to differentiate whether it is because it is not a risk, or whether it is not identified because the climate-related causal pathway is not known to interviewees. This could be

addressed by administering questionnaires that specifically collect data on past and current health outcomes that are known to the researcher to be climate sensitive (e.g., allergies, respiratory conditions, diarrhoeal and intestinal illnesses, heat stroke).

There may also be a bias in the reporting of specific events for this study, as the majority of the interviews were conducted during the summer months. Had the interviews taken place in winter, perhaps winter extreme events may have been at the forefront of discussions. Furthermore, during the interview data collection phase, Addington Highlands experienced several heat events and windstorms that caused power outages and infrastructure damage, which can potentially skew the interviewees' perceptions of their occurrence and risk (Creswell, 1998; Dunn, 2005). This emphasizes the need to triangulate key informant data with secondary sources such as newspaper reporting to reduce the potential for such biases.

In this regard, newspaper articles were an important data source for this research as they described specific aspects of the community's environment, society and services that constituted vulnerabilities to current and possible changes in climate. Often, the information found in the newspaper articles was not recorded or remembered by interviewees to the same level of detail. For example, when identifying conditions over the last decade that influenced operations, an interviewee indicated that dry, hot and windy conditions led to more severe fires. The interviewee could not recall how many major fires had happened in the last decade, but he did recall an instance when a water bomber was called in, although he stated he could not remember the circumstances (i.e., year, location, duration, weather conditions). Fortunately, more details were found in newspaper articles, reporting instances when water bombers had been used, such as the one that follows indicating that the fire chief "called the

Ministry of Natural Resources early on, and within an hour a helicopter arrived with an MNR crew from Haliburton. Eventually 3 CL 415 water bombers were brought in to douse the flames from above. 'Without the water bombers we wouldn't have had any way of stopping the fire, because it was moving faster than we could run,' he said, 'We had the perimeter knocked down by late Saturday, but there are still hot spots popping out from underground fires three days later, and we'll have to keep checking all week'" (Green, Frontenac News, May 10, 2007). This is consistent with other research that reports that even participants in a position of power may not have access to, or be able to recall some information required to address interview questions (Hughes, 1999). Thus, newspaper articles for this study were an important data source as they provided very specific information about what happened, when and where. Unfortunately, not all rural areas may be served by such efficient and electronically archived reporting, as is Addington Highlands by the Frontenac News.

Data collection was also challenged owing to the turnover of health professionals in the area, many respondents had not lived in the region long enough to have experienced some of the weather conditions that had very low occurrence frequencies. For example, only one half of the people interviewed experienced the 1998 ice storm. This is especially relevant for climate change-related research as climate is measured over periods of 30 years or more. In communities with even higher rates of professional staff turnover, this may be a particularly challenging methodological factor when conducting local assessments.

Although the snowball techniques recruitment method proved useful in that it focused on the experiences of those on the ground and was an efficient way to identify interviewees,

it also introduces a selection bias, which can reduce the validity and transferability of the findings (Kaplan et al, 1987; Van Meter, 1990). Furthermore, snowball recruitment techniques are biased towards individuals with inter-relationships, and therefore can over-emphasise cohesiveness and reinforce like-mindedness (Griffiths et al, 1993). This has the result that people with different or opposing views may not be referred to, and would not have had an opportunity to partake in the research (Van Meter, 1990). Although this bias is something to consider when interpreting the findings, it is not likely to be a big effect, as Addington Highlands is a small township, and those interviewed for this study represent a large portion of the total population of professionals with the knowledge or responsibilities relevant to this topic (e.g., there is only one pharmacy in Addington Highlands).

Moreover, a challenge for all studies seeking to characterize the nature of community-relevant vulnerabilities to climate change is the need to acquire information about people's experiences from the people themselves. To do this with minimal bias requires finding questions that invite insights pertinent to the research objectives, yet at the same time do not lead respondents to answer in a particular way (Valentine, 1997). This is particularly difficult when dealing with climate change and health, given the wide range of interpretations and evaluations of the topic among people in general (Berry et al., 2011). This challenge was addressed in this thesis by focusing first upon the conditions that people identified as having experienced and were familiar with, and then used this information as the basis for considering possible changes in these identified conditions in the future. However, a climate change specific bias is still a concern, as the interview letter of consent indicated that the research is about climate change and its health impacts.

A related challenge for the study was that various measures, strategies or actions were in place or undertaken in the municipality to deal with a range of events and risks for which climate was not identified as the prime driver of the responses (e.g., forest fires, disease, etc), yet all of these events and risks are influenced by weather and climate conditions. In this context, the adaptations to climate change – frequently referred to in Intergovernmental Panel on Climate Change documents and related climate change programs – are not separable from ongoing, established initiatives to deal with risks that arise from multiple stressors. Thus, it is difficult to identify adaptations, unless the researcher is knowledgeable about the risks, understands the direct and indirect climate-related causal pathways, and is familiar with the roles and responsibilities of various agencies in protecting health or responding to emergencies.

Associated with this is the observation that efforts to improve the adaptability of Addington Highlands' public health system will most likely occur via modifying or 'climate proofing' existing programs. This is consistent with the process of 'mainstreaming' identified elsewhere in the literature. This research can assist decision makers in their mainstreaming efforts, as the findings report on areas that are currently seen as limiting Addington Highlands' ability to respond to risks, such as those related to extreme weather events and forest fires (see Tables 12 and 13).

3.4 Scholarly and Practical Contributions

A key contribution was that data collection and analysis were guided by a framework and approach, which was specifically adapted to investigate climate related health

vulnerability for this research. Thus, the case study demonstrated how an existing conceptual framework and analytical approach traditionally used to guide research on the effects of climate change on other sectors (e.g., agriculture, forestry, transportation) can be combined and modified in order to characterize climate-related health vulnerability at a community level. The contribution of the application of this framework is that it includes both the conceptualization of vulnerability and the analytical bottom up approach, and facilitates the integration of multiple data to describe and understand the complex interactions underpinning human health and climate change. In order to address the research objectives, it was important to develop a framework that starts with the system of interest (and hence has been called a 'vulnerability as starting point' or 'bottom up' approach (Smit and Wandel, 2006)), and that seeks to identify sensitivities and adaptive responses (both actual and potential future) from the people who are (or would be) doing the adapting. Such an approach is logical when the population and/or systems of interest are of local or relatively small spatial scales. This is in contrast to broader-based assessments that begin with climate change scenarios and models, or that assume human impacts and adaptive responses.

Furthermore, the assessment of health vulnerability to climate change in a rural municipality produced detailed and multidisciplinary information that is not often obtainable through any other means. Similar to some other studies, vulnerabilities were most commonly associated with changes in the frequency and magnitude of extreme weather events rather than gradual trends in temperature. Also consistent with other studies was the finding that adaptations generally occur through small modifications to existing programs or strategies. Attributes of vulnerability identified for this rural case

include the issues of access to health services, telecommunications, personal transportation and the age and income distribution of the population.

The contextual information gained through this research can be used by other communities to inform their own climate change adaptations. For example, the tables included in this study that list climate risks and adaptive programs in Addington Highlands can be adapted to other communities to identify their own risks and adaptive programs. By comparing the programs in Addington Highlands with their own, other communities can assess if they have similar programs and whether they too may be addressing and mainstreaming climate change based on their current practices. Similarly, the adaptive capacity table produced in this study can prompt other rural communities to consider the types of indicators that may be relevant for the assessment of their adaptive capacity. This case study is especially valuable to the extent that rural communities rarely have the capacity, expertise or resources to undertake this type of climate change and health assessment on their own (Berry, 2008). Both the methodology and findings from this research may be used to develop insights and help stimulate actions toward preparing other rural communities for possible future climate-related risks.

3.5 Future Research Opportunities

As discussed in the previous sections, some of the findings in this study need to be investigated further before conclusions can be drawn, and it is hoped that this research stimulates future researchers to increase the evidence base regarding how climate-change may increase the risks to the health of rural communities within Canada.

As reported in this study, there are programs in place in Addington Highlands to either prevent or respond to many climate-related health risks (e.g., vector-borne disease surveillance and monitoring, sun safety promotion, heat alert and response plan, recreational beach water testing). Further analysis on vulnerability warrants an evaluation of the effectiveness of such programs. An evaluation may include documenting the occurrence of a particular health outcome, awareness of risk among the public or practitioners, utilization of programs by the public, and effectiveness of communication messages, to name a few. Such information would help to understand if current programs are adequate or if instead, they need to be augmented or new programs are necessary to manage current and projected health risks. For example, the current system of surveillance and monitoring in Addington Highlands for West Nile virus is dependant on individuals collecting dead birds and bringing them to Kingston for testing, entailing a 1.5-2.5 hour car trip one-way. Given the distance and cost, it would seem that residents would be unlikely to participate in the absence of a personal incentive to do so. The surveillance process used to monitor West Nile virus in Addington Highlands should be evaluated to determine its effectiveness. If such a situation exists in other rural and remote areas, and in many it likely does, public health authorities need to seek new low-cost, easy-to-implement innovations for West Nile virus surveillance in rural and remote areas in Canada.

In order to gauge adaptive capacity for this study, data was reported relating to determinants of adaptive capacity commonly investigated in climate change literature (e.g., technology, human capital, resources, programs and service, risk management). More research on indicators that are especially important when measuring adaptive

capacity for health outcomes specifically is required. Furthermore, research is needed regarding which indicators should be given priority when human and financial resources are not available to undertake a comprehensive rural climate change and health vulnerability assessment. Another area that could be expanded on in future research includes the association between aggressive behavior and hot weather in rural communities. Furthermore, a long-term benefit of this research is to move Addington Highlands towards an increased awareness regarding its sensitivities to climate-related risks. The information documented in this report can be used to monitor changes and assess vulnerability at a future time.

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Appendix A: Example Newspaper Data Analysis Chart

		Weather Events		Emergency Services		Health Services		Seniors		Community Services	
Title of Article	Date of publication	Exposure and Sensitiviy	Adaptation and Adaptive Capacity	Exposure and Sensitiviy	Adaptation and Adaptive Capacity	Exposure and Sensitiviy	Adaptation and Adaptive Capacity	Exposure and Sensitiviy	Adaptation and Adaptive Capacity	Exposure and Sensitiviy	Adaptation and Adaptive Capacity
Addington Highlands Council - Nov 2/11	November 10, 2011				Firehall						Community Center
Addington Highlands Council - Sep 19/11	September 22, 2011				Ambulance and Firehall		New Medical Clinic				New Community Center
Fate of Denbigh ambulance still undetermined	September 22, 2011				Ambulance						
Griffith, Matawatchan and Area Ambulance Network formed	September 15, 2011				Ambulance						
Addington Highlands Council	September 8, 2011			"112 fire calls, up from 97 at the same point last year"	Joint Fire Board and Firehall						New Community Center
One More Reason to Loath End of Summer	August 15, 2011									preparing for winter	
Addington Highlands Council -Aug 2/11	August 4, 2011				Firehall					Outdoor learning center	
L&A Defers Seeking new location for Northbrook ambulance base	August 4, 2011				Ambulance						
Volunteer firefighters and EFR teams practice emergency procedures	July 14, 2011				Fire fighters						
Residents concerned about signs of pollution in east basin of Sharbot Lake	July 14, 2011	Algal blooms									
Ambulance decision delayed	July 14, 2011				Ambulance						
Addington Highlands Council	July 7, 2011				Fire tanker; Ambulance						Affordable housing; community center
Northern Ambulance Planning a Mess	July 7, 2011				Ambulance						
Community unites to keep Denbigh ambulance service	June 30, 2011				Ambulance						
Addington Highlands Council - Jun 6/11	June 9, 2011						New Medical Clinic				New Community center
Addington Highlands Council – May 16/11	May 19, 2011				Firehall						Community center; affordable housing
Addington Highlands Council	May 5, 2011						New Medical Clinic				New Community Center
Addington Highlands Council -- March 21/11	March 24, 2011				Firehall, Fire services						
Addington Highlands Council	March 10, 2011				Ambulance				Seniors' Housing		New Community Center
Public consultations on seniors' health care in rural communities	March 10, 2011								Seniors' Health		
Family Health Team comes to Denbigh and Northbrook	February 10, 2011				Health		Health Services; New Medical Clinic				
Sattelite Service Touted	February 3, 2011				Internet Services						
Ideas for Denbigh schoolhouse put future of Denbigh Hall in doubt	January 27, 2011						Health Services; Clinic				New Community Center
Addington Highlands Council - Jan 17/11	January 20, 2011						Clinic				New Community Center
New Northbrook doctor has local connection	January 6, 2011						Health Services, Doctor				

Appendix B: Example of Interview Data Analysis Chart

Exposure & Sensitivity	Heat	Wind Storms	Ice Storms	Lightning	Dryer Summers	Milder Winters	Rainier Winters	Shorter Winters	Other				
What types of weather conditions have influenced your operations over the last 5-10 years?	INT-L, INT-F, INT-K, INT-G (and more humid), INT-M	INT-L, INT-F, INT-D, INT-M, INT-G, INT-P, INT-Q, INT-I, INT-J, INT-N, INT-U, INT-A, INT-V, INT-T	INT-D, INT-M, INT-G, INT-P, INT-Q, INT-I, INT-J, INT-N, INT-U, INT-V, INT-T	INT-L, INT-F, INT-D, INT-M, INT-Q, INT-U, INT-T	INT-K, INT-T	INT-D (and less snow), INT-G (and less snow), INT-Q, INT-R	INT-K, INT-V	INT-K, INT-V	INT-L (cold); INT-F; INT-M; INT-G (cold)				
What are the weather conditions like in your area? What are your summer and winter conditions like? What types of extreme weather do you experience?	INT-L, INT-F, INT-K, INT-G (and more humid), INT-M	INT-L, INT-F, INT-D, INT-M, INT-G, INT-P, INT-Q, INT-I, INT-J, INT-N, INT-U, INT-A, INT-V, INT-T	INT-D, INT-M, INT-G, INT-P, INT-Q, INT-I, INT-J, INT-N, INT-U, INT-V, INT-T	INT-L, INT-F, INT-D, INT-M, INT-Q, INT-U, INT-T	INT-K, INT-T	INT-D (and less snow), INT-G (and less snow), INT-Q, INT-R	INT-K, INT-V	INT-K, INT-V	INT-L (cold); INT-F; INT-M; INT-G (cold)				
	Resilient					Vulnerable							
Adaptation & Adaptive Capacity	Sense of Community	Knowledgeble Workers	Flexibility and Adaptability	New Services	Other	Limited Resources	Attracting & Retaining Professionals	Infrastructure / Telecommunications	Seasonal Residents	Low Socio-economic Status	Shrinking Volunteer Pool	Older Population	Other
What makes your community vulnerable or resilient to the climate-related health impacts identified?	INT-A, INT-L, INT-F, INT-V, INT-K, INT-T, INT-M, INT-G, INT-D, INT-U, INT-P, INT-Q, INT-I, INT-J, INT-N, INT-B, INT-O, INT-H, INT-E	INT-A, INT-V, INT-M, INT-T, INT-G, INT-P, INT-J, INT-N	INT-A, INT-L, INT-F, INT-M, INT-V, INT-T	INT-L, INT-F, INT-V, INT-G, INT-A, INT-K, INT-T, INT-D, INT-M, INT-U, INT-P, INT-Q, INT-B	INT-L, INT-U, INT-G, INT-N	INT-A, INT-L, INT-F, INT-V, INT-D, INT-M	INT-A, INT-L, INT-F, INT-D, INT-M, INT-P, INT-Q, INT-G, INT-U, INT-I, INT-J	INT-A, INT-L, INT-F, INT-I, INT-J, INT-N, INT-D, INT-M, INT-V, INT-K, INT-T, INT-G, INT-U, INT-P, INT-O	INT-L, INT-M, INT-T, INT-J, INT-H	INT-L, INT-F, INT-G, INT-T, INT-H	INT-A, INT-L, INT-I, INT-J, INT-N, INT-G, INT-U, INT-C, INT-O, INT-H	INT-A, INT-L, INT-F, INT-M, INT-G	INT-L, INT-M, INT-T

Appendix C: Interview Guide

Area Being Characterized	Guiding Questions for Semi-Structured, Key Informant Interviews (in approximate order of presentation)
Icebreaker	How long have you lived and worked in the community?
Exposure & Sensitivity	What are the weather conditions like in your area? What are your summer and winter conditions like? What types of extreme weather do you experience?
Adaptation	What community programs or services are you involved in?
Exposure & Sensitivity	What types of weather conditions, if any, have influenced your operations over the last 5-10 years?
Adaptive Capacity	How would you describe the general health of people in your region?
Adaptation & Adaptive Capacity	What are some of the health, social and emergency services available in your area?
Adaptation	Do you use weather information in your planning? What type of information do you find the most helpful?
Adaptive Capacity	What strengths and weaknesses have you or your organization experienced in meeting current service demands?
Exposure & Sensitivity	Do you believe that weather and climate have an impact on the health of people in your community? If so, in what way?
Exposure & Sensitivity	Who in your community is at risk to climate-related health impacts?
Adaptive Capacity	If the weather events that you identified were to happen more often or become more severe, how would that affect your operations?
Adaptive Capacity	What makes your community vulnerable or resilient to the climate-related health impacts identified?
Exposure & Adaptation & Adaptive Capacity	Do you know of other information sources, websites or reports that contain information to address some of the questions?

Appendix D: Letter of Consent

uOttawa

Université d'Ottawa
Faculté des arts
Département de Géographie
University of Ottawa
Faculty of Arts
Department of Geography

Research project – interview consent form

Impacts of climate change on health service delivery and emergency medical services in Addington Highlands

Thank you for allowing me to interview you with respect to the ways in which climatic events and conditions influence the health care needs and delivery of services in Addington Highlands. The interview will take place at a time and location of your preference, and I will last 30-60 minutes. The information you provide will be of great assistance in helping me understand the future challenges that will be faced by the public health system in this region under future climate change and the possible opportunities for planning accordingly.

I would like to record information from our interview via handwritten notes. Information provided by participants will be pooled to interpret trends and future needs. The names of participants will not be given in any public reporting of findings from this study. References to the types of organization (e.g. long-term care facility, county emergency preparedness committee, etc) will be the only identifiers used in public reports. Participation is completely voluntary and you may withdraw at any point without any negative consequences. In return for your participation, the results of this project will be provided to you directly in hard-copy or electronic format, as you choose.

If you have any questions after the interview is completed, please do not hesitate to contact me. If you have any questions or concerns about my conduct during this interview, please do not hesitate to contact my supervisor or UO Research Ethics Office.

My thanks again,

Kaila-Lea Clarke

(consent signatures on reverse)

T 613-562-5725
F 613-562-5145
60 University (0147)
Ottawa ON K1N 6N5 Canada

Consent: I, _____, hereby consent to being interviewed by Ms Clarke. I understand all information I share will be protected and stored securely in locked facilities in Dr. McLeman's office for a period of ten years, at which point it will be destroyed. My personal details will not be shared with anyone other than Ms Clarke or Dr. McLeman of uOttawa. There are two copies of this form, one of which is mine to keep.

_____ _____

Signature (interviewee) Date

_____ _____

Signature (K-L. Clarke) Date