Assessment of Vulnerability to the Health Impacts of Climate Change in Middlesex-London

Report Prepared for the Middlesex-London Health Unit

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Table of Contents

Table of Contents

List of Figures

List of Tables

1.0 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC, 2013), average annual global temperatures are rising and warming is largely due to the release of 'greenhouse gases' such as carbon dioxide from the burning of fossil fuels. Climate change is already affecting the health of Canadians (Health Canada, 2008) and of people around the world (Costello et al., 2009; Myers and Patz, 2009; McMichael, Woodruff and Hales, 2006). Evidence suggests that risks to health from climate change are growing for many communities in Ontario (Paterson et al., 2012; Health Canada, 2008; Buse, in press). The health effects of climate change in Canada include increased morbidity and mortality related to a greater frequency and severity of extreme weather events (e.g., extreme heat, floods, hurricanes, ice storms, droughts); increased ambient and indoor air pollution; reduced recreational and drinking water quality; as well as increased food contamination and spread of vectors that cause disease and greater exposure to UV radiation (WHO, 2012a; Health Canada, 2008). Climate change can also affect economic livelihoods (Stern, 2007) and mental health (Doherty and Clayton, 2011; Chand and Murthy, 2008). Food shortages and resulting food insecurity related to climate change are also a concern (FAO, 2008), although this connection is less clear in southern Canadian communities. Populations most vulnerable to the health impacts of climate change include seniors, children and infants, the socially and economically disadvantaged, those with chronic diseases and compromised immune systems, Aboriginal people, and residents of northern and remote communities (Health Canada, 2008).

An increase in medical conditions, physical injuries, and premature deaths from future climate change could put significantly greater pressures on health and social systems in Canada (Health Canada, 2008). Direct health costs from climate change could include emergency room and hospital admissions, costs of medication, ambulance transportation, visits with various types of health care professionals, diagnostic testing and treatment options. Indirect health costs could arise from lost income due to premature death, disability and mental health effects, worker absenteeism, and reduced productivity (Simpson and Berry, 2014). The projected increase in the number of vulnerable populations in Canadian communities (e.g., seniors, people with chronic illness) will exacerbate the economic costs of the health impacts of climate change.

Exposure of people living in Middlesex-London to climate and weather hazards such as floods, extreme heat events, air pollution and vector-borne infectious diseases is significant and growing. Due to the threats to human health and well-being and potential impacts on the sustainability of health and social services, decision makers should plan for climate change before greater health consequences are felt at local, regional, and national levels (WHO/PAHO, 2012). The role of the Middlesex-London Health Unit (MLHU) is to promote the health of the community through a wide array of programmatic and policy initiatives that prevent disease and death. Under the Ontario Public Health Standards—a list of standards and associated protocols that establish the minimum requirements for public health related program delivery among Ontario's 36 health units—MLHU is required to increase public awareness of the health risk factors associated with climate change (MOHLTC, 2008).

1.0 Introduction

The purpose of this assessment is to examine possible health vulnerabilities resulting from climate change in Middlesex-London and to identify recommendations about how to enhance adaptive capacity to address these vulnerabilities. This report focuses on key threats to health related to natural hazards, air pollution, water-borne and food-borne illnesses, vector-borne diseases, UV radiation, and food security. Baseline measures of climate-related health vulnerability in the Middlesex-London region are established through analysis of:

- Historical weather variability and the occurrence of climate hazards and impacts (e.g., air pollution, extreme heat events, floods, West Nile virus etc.);
- Future climate change projections;
- Priority health risks from climate change;
- Populations most vulnerable to current and future health impacts as determined by levels of exposure, sensitivity and adaptive capacity;
- Current risk management practices which contribute to protecting health.

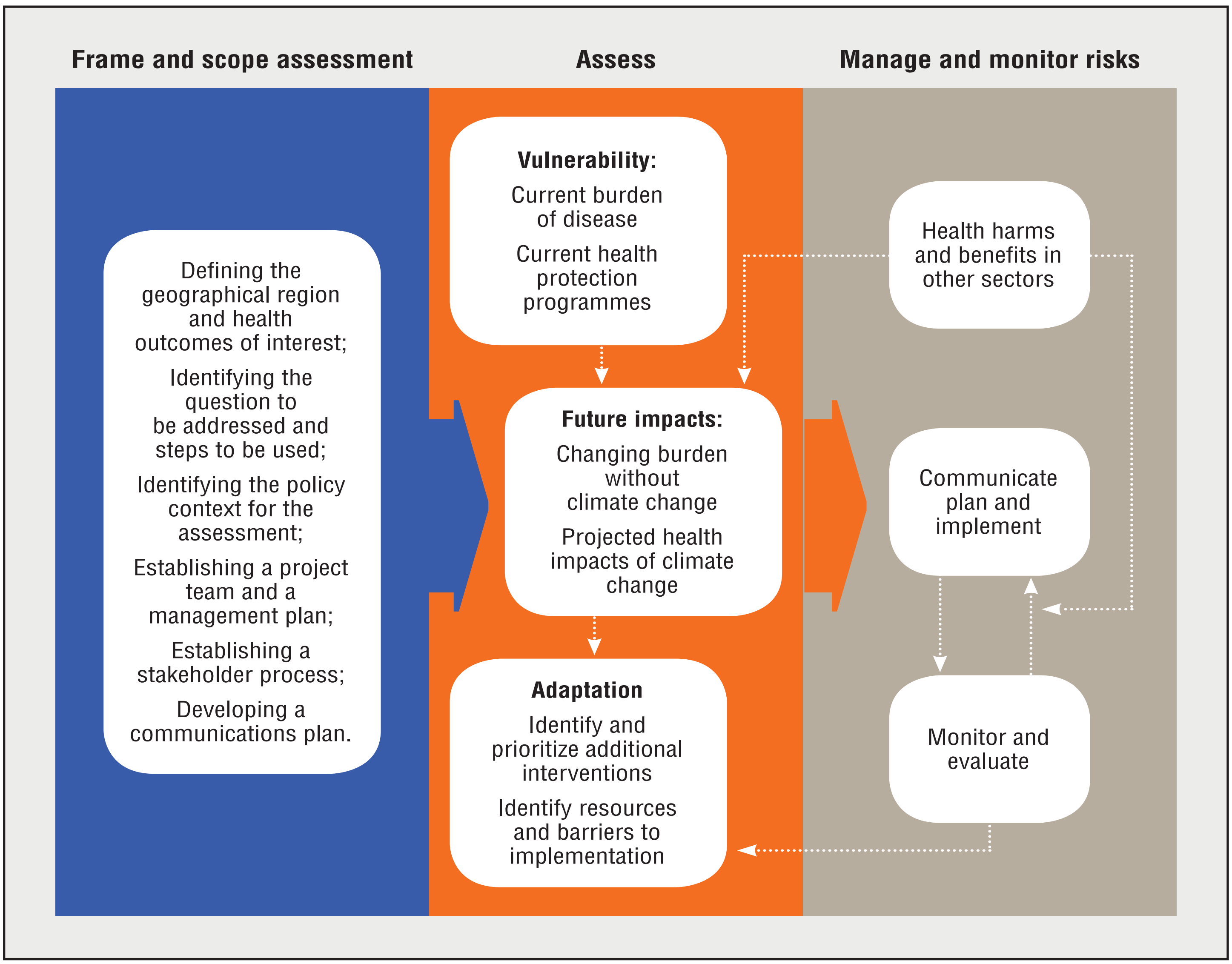
This report concludes with recommendations about how to enhance adaptive capacity to address the health vulnerabilities identified in this report including key research, and knowledge gaps that impede progress in efforts to prepare the region for climate change impacts.

2.0 Methodology

2.1 Assessment Process

An expert advisory group was created to scope the assessment, provide input on methodology, identify sources of data, review report drafts and advise on communication of the findings. Where available, data related to current and future exposure and sensitivity to climate change hazards was analyzed along with indicators of adaptive capacity at individual and community levels (Text Box). Assessment steps recommended by the World Health Organization/Pan American Health Organization (2012) (Figure 1) helped guide development of this report. Guidance regarding stakeholder engagement, identifying baseline health burdens and projecting future health impacts was particularly useful in undertaking the project. The assessment steps were tailored to the project needs identified by the advisory group and based upon resources available to the investigators.

Figure 1 - Vulnerability and Adaptation Assessment Process



Source: WHO/PAHO, 2012

2.0 Methodology

Key vulnerability concepts

Vulnerability to climate change refers to "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC 2007, p.21). Vulnerability is influenced by a range of conditions that are largely dependent on the local or regional geographic and cultural contexts in which human populations are situated. In the climate change literature, vulnerability is a function of exposure to climate hazards, sensitivity to those hazards, and the adaptive capacity which may allow humans to manage climate change and associated risks (Smit and Wandel, 2006).

Exposure is the probability of a health hazard related to climate change occurring and its relative impact on the population or community in a specific geographic area at a particular point in time (Adger, 2003). Environmental health practitioners typically conceive of exposure as the degree to which a person or population group comes in contact with a harmful agent and the extent to which a particular level of exposure can impact our health. In this report, exposure is most often measured as the particular locations where exposure may be greatest, or the number of affected persons according to particular demographic characteristics (McMichael and Kovats, 2000).

Sensitivity refers to the degree to which the health of a person or population group is affected by climate-related stimuli. It captures the proportion of the population that is more vulnerable due to particular physiological characteristics. Physiology or biology, access to health resources and services, gender, and age can make some populations more sensitive than others to the health impacts of climate change (Berry, 2008). In the context of this report, sensitivity refers to physiological sensitivity to climate change and health risks.

Adaptive capacity refers to the ability to adapt to climate change (IPCC, 2007) to limit or mitigate climate-related exposures and sensitivities. Adaptive capacity can exist at the individual level (e.g., education level that predisposes people to wear lighter clothing during a heat alert), or at the community level (e.g., policies, programs and the provision of health services that reduce risks). Adaptive capacity refers to both currently utilized and future capacities. Other important dimensions of adaptive capacity include the strength of community networks, the ability of community infrastructure to support the ability to cope with climate impacts, financial and human resources (including the knowledge required to adapt to climate change), and the effectiveness of institutions (i.e., social services, emergency response teams) (Dixit et al., 2011).

2.2 Literature Review

The literature on climate change and its relation to health impacts, adaptation, adaptive capacity, vulnerability assessments, and risk assessment methodology was reviewed. Peer-reviewed scientific publications and case studies were included in the review, although much information used was derived from various technical government reports. Information was obtained from both domestic and international sources. International literature was included if it had a Canadian component or when it provided a theoretical or methodological basis to support the analysis. Keyword content and title searches for literature to 2011 were retrieved and reviewed for applicability. Information used for the Middlesex-London assessment included literature relating to the following topics:

- Impacts of climate change on health;
- Health assessments from public health units;
- Methods for investigating health vulnerabilities from climate change;
- Best practice health adaptation measures;
- Indicators of climate change and health vulnerability;
- Current sensitivity and exposure of individuals in Middlesex-London to climate hazards;
- Current programs and adaptive capacity in Middlesex-London to protect health.

Historical climate variability was described using data from Environment Canada (2013a; 2013b). Future climate projections were provided based on data from federal government agencies (Natural Resources Canada, 2007) and an independent study conducted by researchers at the Centre for Catastrophic Loss Reduction at Western University in London, Ontario (Bruce 2011). In addition, for each health impact area of concern, vulnerability indicators were identified using results from a recent systematic review of vulnerability indicators relevant to southwestern Ontario (specifically the Region of Peel) (Buse, in press). Indicators used in the report were reviewed by officials from MLHU and Health Canada.

2.3 Stakeholder Engagement

Findings and recommendations from the assessment report were shared at a stakeholder workshop supported by Health Canada on March 27, 2014. It brought together a total of 105 officials from a broad cross-section of the community including representatives from the health professions, government agencies, and community groups. Stakeholders were identified by the expert advisory committee based upon guidance provided by WHO/PAHO (2012). They were also selected to participate in the workshop based on their knowledge of the community and their role in supporting the health and well-being of Middlesex-London residents. The purpose of the workshop was to validate preliminary assessment results with local and regional partners and collect additional information to enhance the report findings. During the workshop, participants received presentations on the assessment results, discussed concerns about currently observed impacts and began to identify collaborative efforts needed to adapt. They were asked to provide information on the following items related to the assessment:

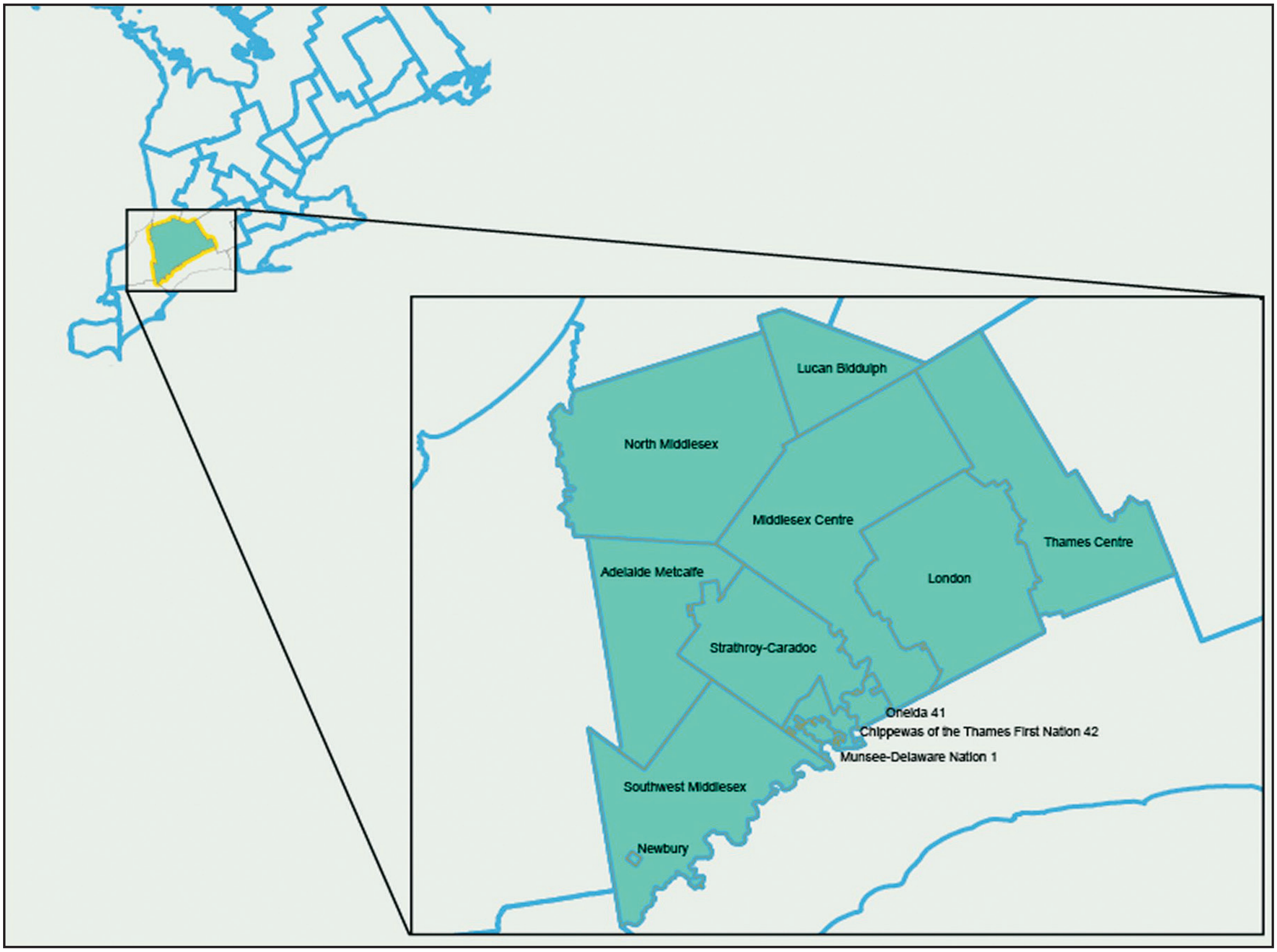
- Options for reducing current and future risks to health through adaptation;
- Challenges that exist for current and future adaptation efforts to protect health;
- Willingness of organizations to participate in climate change and health adaptation strategies;
- Effective avenues for communicating the results of the assessment.

In preparation for the workshop, a questionnaire on adaptive capacity was sent in February 2014 to individuals from 29 organizations that have a direct or indirect role in increasing resilience to climate change (MLHU, 2014c). A total of 69 individual responses were received. Questions assessed information on characteristics that make the community vulnerable or resilient to climate hazards, barriers to implementing health adaptation programs and activities, and plans or programs that can better prepare the region for future climate change hazards. Respondents were asked to consider the breadth of climate change risks to health relevant to their community (e.g., extreme weather events, air pollution, food- and water-borne illnesses, vector-borne diseases).

3.0 The Middlesex-London Region

The City of London and Middlesex County (comprised of eight municipalities) are located in a landlocked region of southwestern Ontario covering 3317 square kilometres. MLHU is responsible for the public health of the region and its respective municipalities (Figure 2).

Figure 2 – Geographic region map of the Middlesex-London Health Unit



Source: Statistics Canada, 2006c

3.1 Population

The region's most populous area is the City of London with a population of 366,151 and a population density of 132.4 people per square kilometre, as of 2011. Middlesex County is predominantly rural with approximately 73,000 people and a population density of 25.2 people per square kilometre. The population of the entire health unit which MLHU oversees was 439,151 people in 2011, which represents a four percent increase in size relative to 2006 census information (Statistics Canada, 2011a,b). Approximately one in ten people living in Middlesex County reside in rural areas. The population of Middlesex-London is expected to increase by almost one third between 2011 and 2036 (MLHU, 2014a).

3.2 Historical Temperature Variability

Environment Canada (2013a,b) defines climate 'normals' as average monthly temperature and precipitation values over the 30 year period between 1971 and 2000. Table 1 presents a comparison of historical climate data for the region and temperatures experienced between 2001 and 2012. In both time periods, daily temperature averages during December, January and February were consistently below 0°C. January was traditionally the coldest month of the year and consistently had the most extreme cold days; approximately one third of the month experienced days below -20°C with the wind chill (Table 2).

Table 1 - Historical temperature comparison for Middlesex-London, 1971-2000 vs. 2001-2012

Month	Mean Daily Tmax (°C)		Mean Daily Temperature (°C)		Mean Daily Tmin (°C)	
	1971-2000	2001-2012	1971-2000	2001-2012	1971-2000	2001-2012
January	-2.4	-1.6	-6.3	-5.2	-10.1	-8.8
February	-1.4	-0.8	-5.5	-4.8	-9.7	-8.7
March	4.2	5.2	-0.3	0.6	-4.7	-4.1
April	11.6	13.2	6.3	7.6	1	1.9
May	19	19	13	13.3	7	7.6
June	23.8	24.5	18	18.9	12.1	16.9
July	26.3	27.1	20.5	20.4	14.6	16.4
August	25.2	26.2	19.5	19.9	13.7	15.2
September	20.9	22.3	15.3	16.1	9.6	11.2
October	14	14.6	9	9.8	4	5
November	6.9	8.5	3.1	4.2	-0.7	0.8
December	0.6	1.3	-3	-2.2	-6.5	-4.9

Source: Environment Canada, 2013a,b

Table 2 - Historical extreme heat and cold for Middlesex-London, 1971-2000 vs. 2001-2012

Month	Days with Humidex		Record Daily Tmax in °C (Year/Day)		Days with Wind Chill =< -20°C		Record Daily Tmin in °C (Year/Day)	
	1971-2000	2001-2012	1971-2000	2001-2012	1971-2000	2001-2012		
January	0	0.0	16.7 (1950/25)	14.8 (Twice) 2005/13; 2008/7	10.2	7.8	-31.7 (1970/24)	-27.1 (2005/25)
February	0	0.0	17.8 (2000/26)	13.2 (2002/25)	7.7	5.6	-29.5 (1978/04)	-25.6 (2009/5)
March	0	0.1	24.8 (1998/30)	27.2 (2012/22)	2.1	1.4	-24.8 (1978/02)	-25.6 (2003/3)
April	0.3	0.3	29.4 (1990/25)	28.2 (2002/16)	0.1	0.0	-12.2 (1965/03)	-12.4 (2003/06)
May	3.1	3.3	32.4 (1987/30)	33.1 (2006/29	0	0.0	-5 (1947/10)	-2.8 (2002/19)
June	9.7	12.3	38.2 (1988/25)	33.4 (2005/27)	0	0.0	-0.6 (1972/11)	3.8 (2003/1)
July	16.9	20.5	36.7 (1941/27)	36.7 (2011/21)	0	0.0	5 (1963/09)	5.9 (2001/2)
August	15	15.5	37 (2001/08)	37 (2001/8)	0	0.0	1.5 (1982/29)	6.1 (2004/22)
September	5.6	6.3	34.4 (1953/01)	34.2 (2002/9)	0	0.0	-3.3 (1965/27)	2 (2001/26)
October	0.3	0.8	30 (1946/06)	30.3 (2007/8)	0	0.0	-11.1 (1969/23)	-5.2 (2002/31)
November	0	0.0	24.4 (1950/01)	19.6 (2008/6)	0.1	0.8	-18.3 (1951/06)	-13.5 (2008/23)
December	0	0.0	18.5 (1982/03)	16.4 (2001/5)	4.2	1.8	-26.9 (1977/11)	-22.7 (2004/20

Source: Environment Canada, 2013a,b

3.0 The Middlesex-London Region

Temperatures were traditionally highest in June through September between 1971 and 2000 where daily temperature maximums peaked at an average of 26.3°C in July and 25.2°C in August (Table 1). Approximately half of the days in July and August experienced extreme heat with humidex values above 30 (Table 2). Notably, the 2001-2012 humidex values for June and July that were above 30 increased by 27% and 21% respectively from the 1971 – 2000 period (Table 2).

A general warming pattern is observed when comparing the 1971-2000 climate normals with temperatures that have been experienced in Middlesex-London over the last twelve years (i.e. 2001-2012) (Table 1). For example, when yearly averages for daily temperature are calculated, the average daily temperature maximum, the average daily temperature, and the average daily minimum temperature for the last twelve years are all significantly warmer[1] than temperatures recorded between 1971and 2000.

According to Table 1, the greatest increase in warming is seen in average minimum temperatures, indicating that the winters are becoming warmer. The number of days with wind chill and temperatures below -20°C decreased from the periods 1971-2000 to 2001-2012. The month of November was an exception with a marginal temperature increase of approximately a half a day. Summers are becoming warmer as average daily maximum temperatures have increased by up to 1°C or more over this same time period. When comparing the summer months of 1971-2000 with 2001-2012, the maximum daily temperature increased across June, July, August and September by 0.7°C, 0.8°C, 1.0°C, and 1.4°C, respectively. Between 2001-2012 the months of June and July had roughly three more days with a humidex value above 30 when compared with 1971-2000 (Table 2).

3.3 Historical Precipitation Variability

Due in part to the regional geography, London-Middlesex typically experiences extreme weather events including heavy snowfalls in the winter, seasonal rainstorms in the spring and summer and extreme winter storms and flooding from rain on snow conditions in late winter and early spring (i.e., February-April). The difference in precipitation between 1971-2000 and 2001-2012 are shown in Table 3 and Figure 3. When comparing the 1971-2000 precipitation data for the region with data from 2001-2012, snowfall has typically decreased in October, November, December and January, and rainfall has increased. This is likely attributed to the warming winters over the past 12 years. However, summers are becoming drier, with June-September seeing significant decreases in the amount of rainfall.

[1] T-tests indicate that the differences between temperature data for 1971-2000 and 2001-2012 were significantly different.

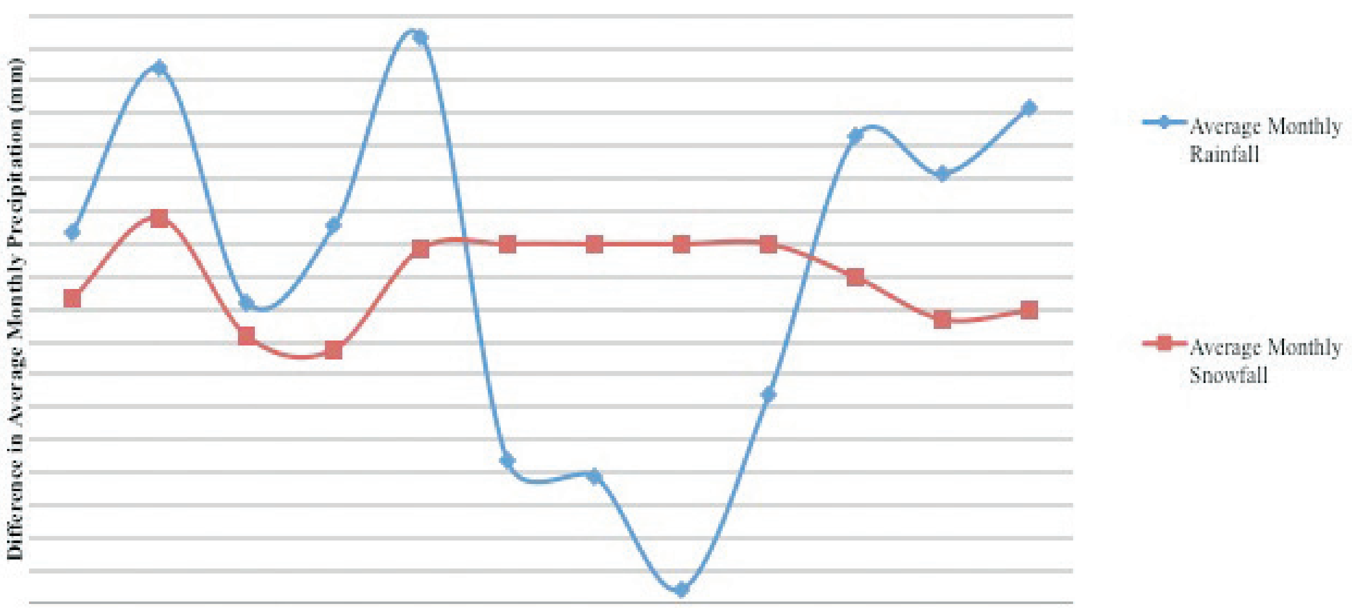
3.0 The Middlesex-London Region

Table 3 - Historical precipitation for Middlesex-London, 1971-2000 vs. 2001-2012

Month	Average Monthly Rainfall (mm)*			Average Monthly Snowfall (cm)*			Record Daily Rainfall in mm (date)	Record Daily Snowfall in cm (date)
	1971-2000	2001-2012	Difference	1971-2000	2001-2012	Difference		
January	31.1	31.8	0.7	52.6	49.3	-3.3	45 (1993/04)	32.5 (1943/03)
February	29.1	39.8	10.7	38.1	39.7	1.6	58.8 (1990/22)	30 (1965/25)
March	53.8	50.2	-3.6	28.6	23.0	-5.7	43.2 (1942/27)	27.4 (1947/25)
April	73.8	74.9	1.1	9.2	2.7	-6.5	66.4 (2000/20)	21.8 (1975/03)
May	82.6	95.3	12.7	0.3	0.0	-0.3	58.2 (1996/20)	5.8 (1961/02)
June	86.8	73.5	-13.3	0.0	0.0	0.0	82.8 (2000/11)	0.0
July	82.2	68.0	-14.2	0.0	0.0	0.0	63 (1942/05)	0.0
August	85.3	64.1	-21.2	0.0	0.0	0.0	69.9 (1940/29)	0.0
September	97.7	88.5	-9.2	0.0	0.0	0.0	89.1 (1986/29)	0.0
October	74.9	81.5	6.6	2.7	0.7	-2.1	56.9 (1954/15)	15.7 (1948/17)
November	73.7	78.0	4.3	19.7	15.1	-4.6	56.5 (1987/25)	40.6 (1970/24)
December	47.0	55.4	8.3	51.1	47.0	-4.1	45.6 (1990/29)	57 (1977/07)

Source: Environment Canada, 2013b

Figure 3 - Difference in monthly average precipitation for Middlesex-London, 1971-2000 vs. 2001-2012

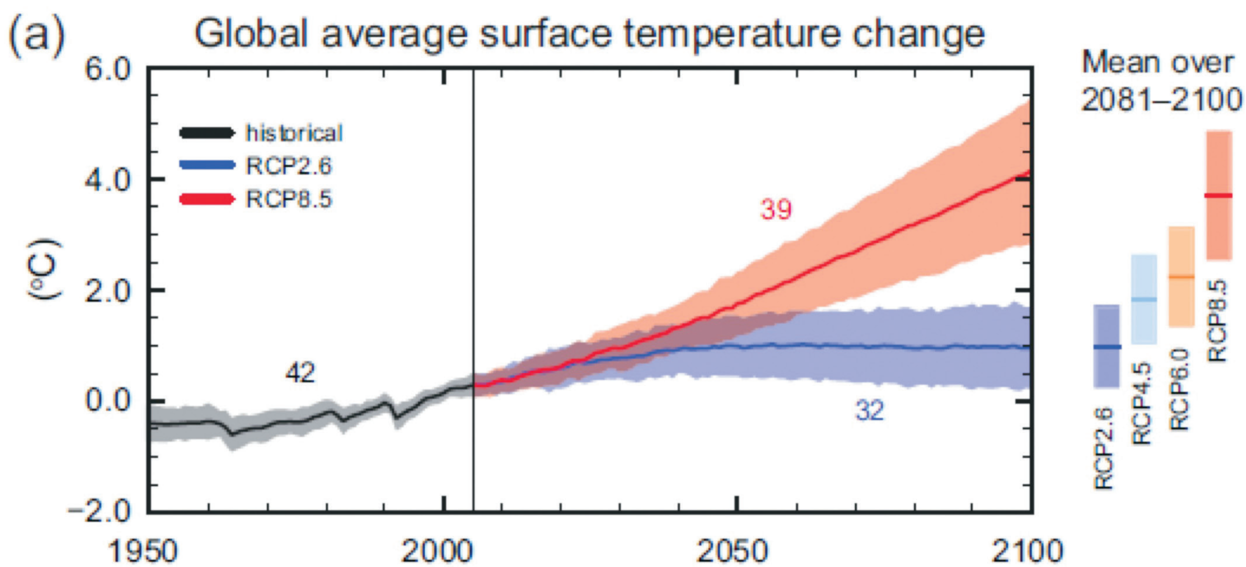


3.0 The Middlesex-London Region

3.4 Future Climate Projections

Based on the IPCC Fifth Assessment Report (2013), the global average temperature increase will likely be in the range of 0.3°C to 0.7°C for the period 2016–2035 relative to 1986–2005. For the period 1986–2005 to 2081–2100 the increase in average temperature is projected to be in the ranges derived from the 4 concentration-driven model simulations based on Representative Pathway Scenarios (RCPs). Most of the model simulations were based upon CO_2 concentrations reaching; 421 ppm (RCP2.6 - high GHG mitigation scenario); 538 ppm (RCP4.5 - GHG stabilization scenario); 670 ppm (RCP6.0 – GHG stabilization scenario); and 936 ppm (RCP 8.5 - very high GHG emissions scenario) by the year 2100. Under these simulations the projected warming between 1986-2005 and 2081-2100 is 0.3°C to 1.7°C (RCP2.6), 1.1°C to 2.6°C (RCP4.5), 1.4°C to 3.1°C (RCP6.0), 2.6°C to 4.8°C (RCP8.5) (IPCC, 2013) (Figure 4).

Figure 4 - Global average surface temperature change, 1950 - 2100



Source: IPCC, 2013

Lower emissions scenarios, with resulting lower projected temperature increases, are not reflective of the rate of current increases in GHG emissions. The global concentration of carbon dioxide in the atmosphere passed the level of 400 ppm in 2010 (Rom and Pinkerton, 2014) for the first time in over a million years (NASA, 2014).

According to Natural Resources Canada (2007), the southwestern Ontario region, where Middlesex-London is located, is expected to experience increases in temperature and precipitation, and more extreme weather (e.g. storms and resulting flooding) as the climate continues to change. Evidence suggests that in Canada, average temperatures will increase between 2°C and 4°C by 2050 (Feltmate and Thistlewaith, 2012). Figures 5 and 6 show projected seasonal changes in air temperature for Canada in spring, summer, autumn and winter by 2050s under the A2 emissions scenario relative to average values from 1961-1990. The region in which Middlesex-London is located is projected to experience warming of approximately 2.5-3.0°C in spring, summer and autumn and 3.0-3.5°C in winter by the 2050s.

3.0 The Middlesex-London Region

Figure 5 - Projected seasonal changes in surface air temperature (°C) 2050s in spring (I) and summer (J)

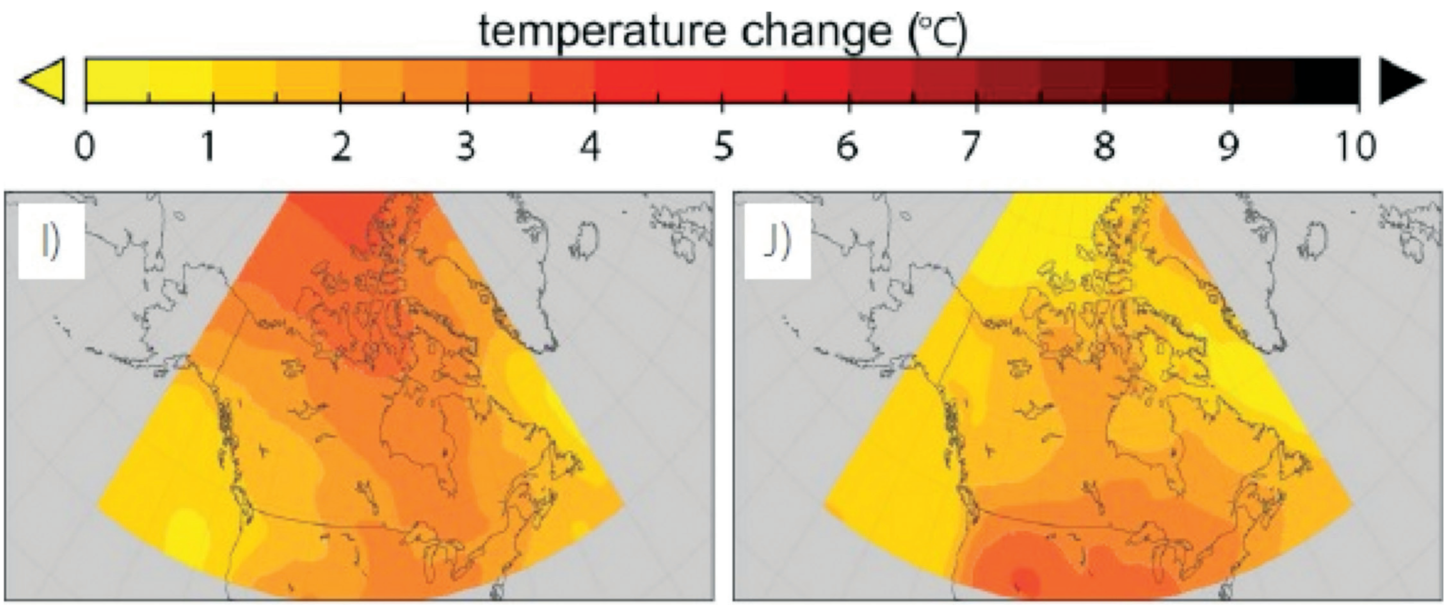
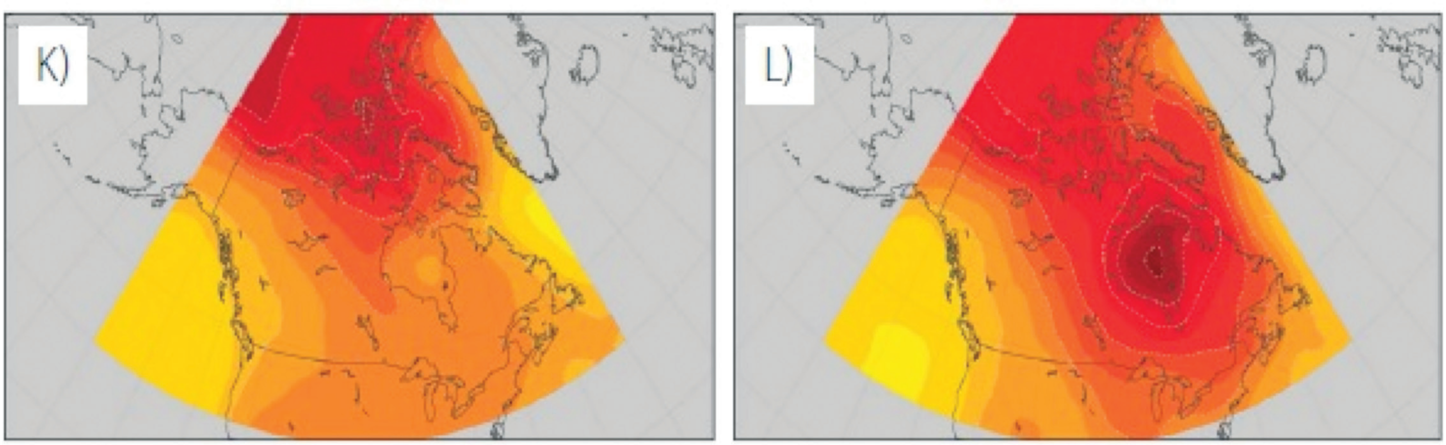


Figure 6 - Projected seasonal changes in surface air temperature (°C) 2050s in autumn (K) and winter (L)



Source: Bush et al., 2014

Even with uncertainty, temperature predictions made during the 1990s have proven remarkably reliable, and models are becoming more sophisticated (Frame and Stone, 2012).

Figures 7 and 8 show projected precipitation levels in Canada for spring, summer, autumn and winter by the 2050s under the A2 emissions scenario, as a percentage change from 1961-1990 averages. The region in which Middlesex-London is located is projected to experience a 7.5-10.0% increase in precipitation in spring, 0 – 2.5% decrease in summer, 2.5-5.0% increase in autumn and a 10.0-12.5% increase in winter.

3.0 The Middlesex-London Region

Figure 7 – Projected seasonal changes in precipitation (%) 2050s in spring (I) and summer (J)

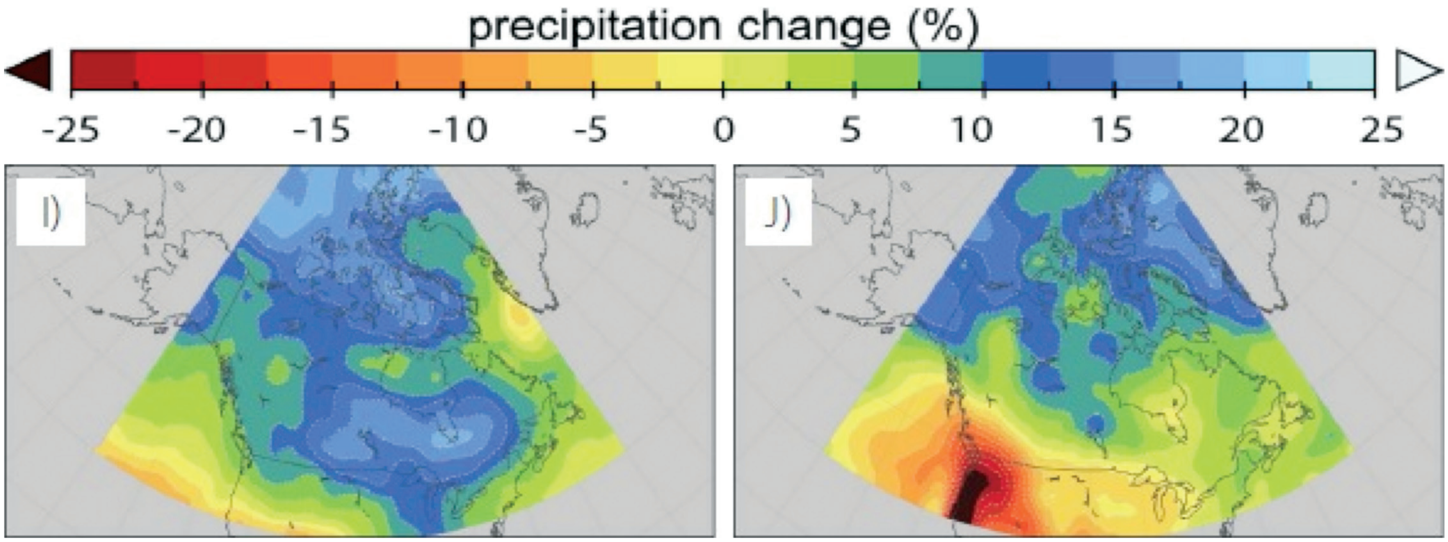
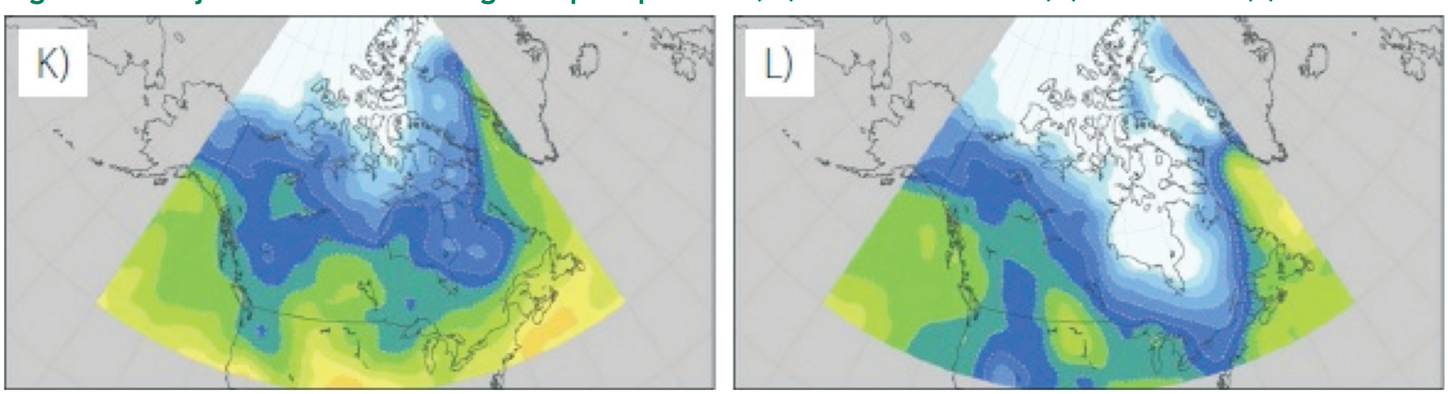


Figure 8 – Projected seasonal changes in precipitation (%) 2050s in autumn (K) and winter (L)



Source: Bush et al., 2014

Based on a report by the Institute for Catastrophic Loss Reduction (Bruce, 2011) that uses projections indicative of past emissions patterns, winter months in southwestern Ontario are expected to experience a 5-20% increase in precipitation and a 5-10% decrease in snowfall (as a percentage of total precipitation). By 2050, intense precipitation events (rainfall of 20 mm or more) are expected to increase by 10%. Further, there is an expected 40% increase in freezing precipitation events that last for six hours or longer (Bruce, 2011).

Warming temperatures will likely also impact wind patterns and river flows, creating increased hazards to human health. Intense winter storms with high winds are expected to increase by 8-15% by 2050 relative to 2010. Across Canada, storms with wind speeds exceeding 100km/h have increased by 16% since 1970-1990 (Bruce 2011), although most of this is attributable to large increases in coastal regions. However, tornados have increased in Ontario (Environment Canada, 2011). In 2006 and 2009 there were 29 such storms recorded; the yearly average number of tornados for this province is 11. Despite increases in intense precipitation creating flood risks, hotter and drier summers may decrease annual stream flow rates across southwestern Ontario by 10% (Bruce, 2011).

4.0 Extreme Weather Events And Natural Disasters

Key Messages

- Vulnerability to extreme weather events such as extreme heat, extreme cold and flooding will be affected by key demographic factors (e.g., growing population of seniors, older adults needing help with daily living activities, large numbers of people with chronic illnesses) that mediate the impacts of these events.
- The number of hot days that can affect health is expected to rise in coming decades due to climate change while the number of cold days will very likely decline. Annual heat-related mortality in London is projected to increase in the future while cold-related mortality is expected to decrease, although severe winter storms may still be of concern for the region.
- There is wide exposure of people, businesses, community services, and infrastructure to flooding and this is expected to increase with climate change but perhaps not significantly.
- Middlesex-London has a strong network of services that help reduce health risks including hospitals, mental health facilities, long-term care facilities, emergency shelters and drop-in centres.
- The City of London, Middlesex County and municipalities have emergency plans that are reviewed annually and 21 evacuation centres. MLHU has an extreme temperature alert protocol it follows in the event of extreme heat or cold but its effectiveness in protecting health is uncertain.

4.1 Exposure

Middlesex-London has experienced a range of extreme weather events such as extreme heat events, intense precipitation events leading to flooding and snow and ice storms. Climate change is expected to increase the number, intensity, spatial extent and duration of many extreme weather events including rain, hail, thunder and lightning, strong winds, and extreme heat events (IPCC, 2012; Ebi, 2009). For example, in North America, the return period for heavy precipitation events is expected to almost half by 2046-2065 depending on the emissions scenario used (IPCC, 2012). Consequently, heavy precipitation events are expected to become more frequent. Research investigating the impact of climate change on storm patterns in the eastern United States indicates that 100-year storm events may happen every three to 20 years, and 500-year floods could occur once every 25-240 years by the end of the century (Lin et al., 2012). Few projections of future extreme weather events due to climate change exist at the regional scale for Middlesex-London.

4.1.1 Extreme Heat Events

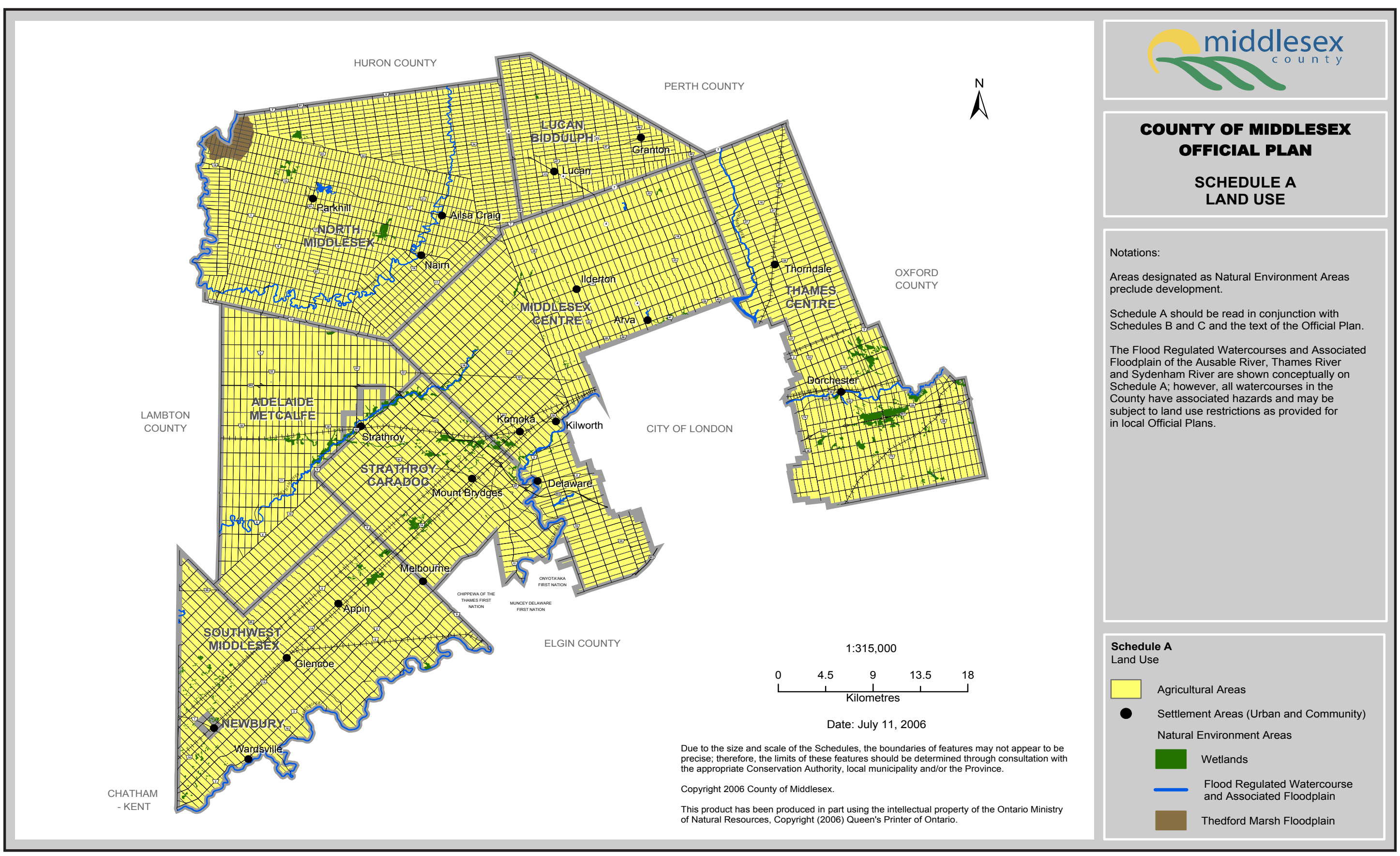
The number of hot days in Middlesex-London between May and October (humidex value greater than or equal to 30) increased between 2001-2012 compared to 1971-2000 (Table 2). Between 1971-2000, there was an average of 2.4 days per year in the City of London where humidex was greater than or equal to 40 (Klaassen, 2012). From 1981-2010 the average had increased to 2.7 days per year. In 2006, there were 2 days where humidex was greater than 45, and July 14 of 1995 had the highest humidex value on record at 50 (Klaassen, 2012). Extreme temperatures are projected to continue to increase throughout the region over the next century (Casati et al., 2013).

4.0 Extreme Weather Events And Natural Disasters

The Urban Heat Island Effect and the Built Environment

Urban areas are often associated with impervious land cover, a high concentration of concrete and minimal green-space that can result in an "urban heat island" effect (UHI) (Tomlinson et al., 2011). Average temperatures in UHIs can be 1-3°C (1.8oF – 5.4oF) warmer than surrounding areas (Health Canada, 2009) and evening air temperature differences can be as high as 12°C (EPA, 2009). UHIs are common throughout the heavily populated region of southwestern Ontario (Smoyer et al., 2000) and have been documented in the City of London (Blackwell, 2012). In comparison, Middlesex County is likely less prone to the UHI effect due to the largely agricultural and forest land cover throughout the region (Figure 9). Greater exposure of the people of London to extreme heat exacerbated by the UHI means that they are more vulnerable to associated health impacts than are residents in rural surroundings. Efforts to reduce the UHI through the design of communities (maintenance of existing infrastructures and future building) can help ameliorate the health effects of extreme heat (Stone, Hess and Frumkin, 2010).

Figure 9 - Land use in Middlesex County



Source: Middlesex County, 2006

Exposure to extreme heat is also greater for people living or working on higher floors of buildings without adequate air circulation or air-conditioning (CEHTP, 2011; Martinez, Imai and Masumo, 2011). As well, some homes that are in disrepair may be thermally inefficient and can increase heat exposure to residents (McMichael, Woodruff and Hales, 2006), as can residences on higher floors of buildings (Health Canada, 2011c). Data for thermally inefficient housing is unavailable for the region, but in 2006, 6.2% of all dwellings in the region required some form of major repair. In addition, 16.6% of all dwellings in the region were located in high-rise apartment towers greater than five stories high (Statistics Canada, 2006a).

Outdoor Activities

People who attend outdoor events or undertake outdoor activities in the summer (e.g., exercise regularly) are at increased risk of experiencing heat-related health effects due to prolonged heat exposure or high levels of physical exertion (Health Canada, 2011b; Balbus and Malina, 2009). In 2006, approximately 32,000 people (7.6% of the population) living in Middlesex-London reported walking or cycling to work as their primary mode of transportation (Statistics Canada, 2006a,b). People who are active outdoors need to take precautions on hot days (Health Canada, 2011a). Large events such as festivals, sporting events and concerts during the summer may increase the number of people exposed to extreme heat and require effective adaptations to avoid emergency situations. Information on the number of people that attend Middlesex-London's many outdoor summer festivals and events is not readily available for the region.

Occupational Groups

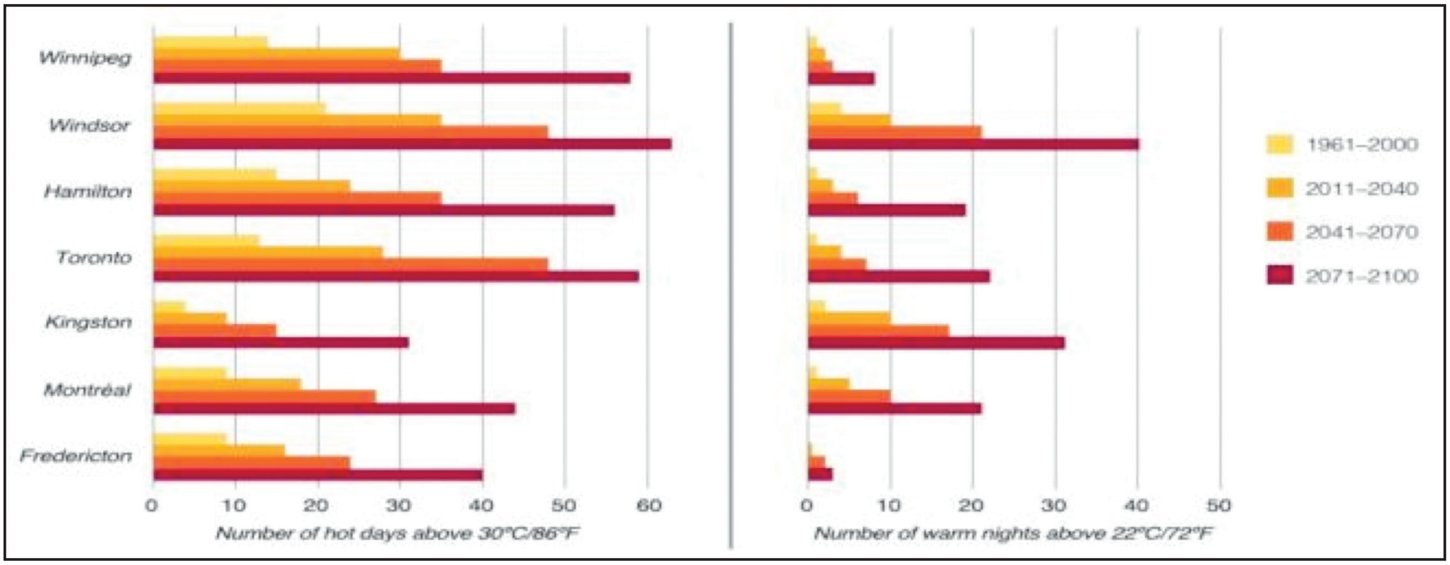
Some occupational groups may have more exposure to extreme heat including people that work in warm indoor environments (e.g., bakeries, factories) that are not air conditioned (Jendritzky and Tinz, 2009) and outdoor workers, such as people who work in construction trades or parks and recreation (Kjellstrom et al., 2009). In 2006 there were 6,230 persons employed in agriculture and other primary industries (i.e., mining, forestry), and 13,490 persons employed in construction in Middlesex-London (Statistics Canada, 2006a). There were also 2,785 chefs and cooks in the region, 845 heavy equipment operators, and 5,790 transportation labourers/trades helpers (Statistics Canada, 2006a), some of which may be exposed to dangerously high temperatures during extreme heat events. With climate change, risks experienced by these occupational groups will grow, particularly if individuals, or their employers, do not take adequate precautions.

4.1.1.1 Projected Impacts of Climate Change

Casati et al. (2013) projected temperature increases for select cities in the Windsor-Kingston corridor in southern Ontario. The number of hot days for this region could more than double by the end of the century. The number of warm nights for many of these cities could increase by more than four-fold over the same period (Figure 10). More warm nights increase health risks since the body is unable to cool down after hot days (Health Canada, 2011c).

4.0 Extreme Weather Events And Natural Disasters

Figure 10 - Projected hot days and warm nights for select Canadian cities



Source: Caseti et al., 2013

Heat-attributable mortality has been estimated for some Ontario municipalities. In Toronto, between 1954 and 2000, it is estimated that 120 deaths occurred per year (approximately 10.1 deaths per 100,000 people per year) as a result of heat exposure (Cheng et al., 2005). Peel Region Public Health has similarly reported an increase in deaths attributable to prolonged hot weather (Peel Region Public Health, 2008). The baseline rate (1981-2000) for annual heat-related mortality in London is estimated to be 4.3 deaths per 100,000 (Martin et al., 2011). Due to climate change, these rates are projected to increase to 9.3 per 100,000 in 2031-2050, 15.3 per 100,000 in 2051-2070, and 23.0 per 100,000 in 2071 and 2090 (Martin et al., 2011).

4.1.2 Extreme Cold

Middlesex-London has a history of cold winters and extreme winter weather. However, as reported in Section 3.2, winter temperatures are warming and snowfall is increasingly being replaced by rainfall as temperatures remain closer to, or above, the point of freezing. The total average number of days below -20°C due to wind chill decreased slightly when comparing 1971-2000 climate normals for the region with temperature data for the past 12 years (2001-2012). For North America, the IPCC (2012) reported that cold days and cold nights are “very likely” to become much less frequent during this century because of climate change.

4.1.2.1 Projected Impacts of Climate Change

The projected impacts of climate change on cold-related mortality are uncertain due to limited research on this issue. A recent study suggests that climate change will not have a significant effect on cold-related mortality (Ebi and Mills, 2013). However, Martin et al. (2011) projected that the observed annual cold-related mortality in London of 47.8 deaths per 100,000 people (from a 1981-2000 as baseline) will decrease to 42.5 per 100,000 in 2031-2050, 38.4 per 100,000 in 2051-2070, and 33.4 per 100,000 in 2071-2090.

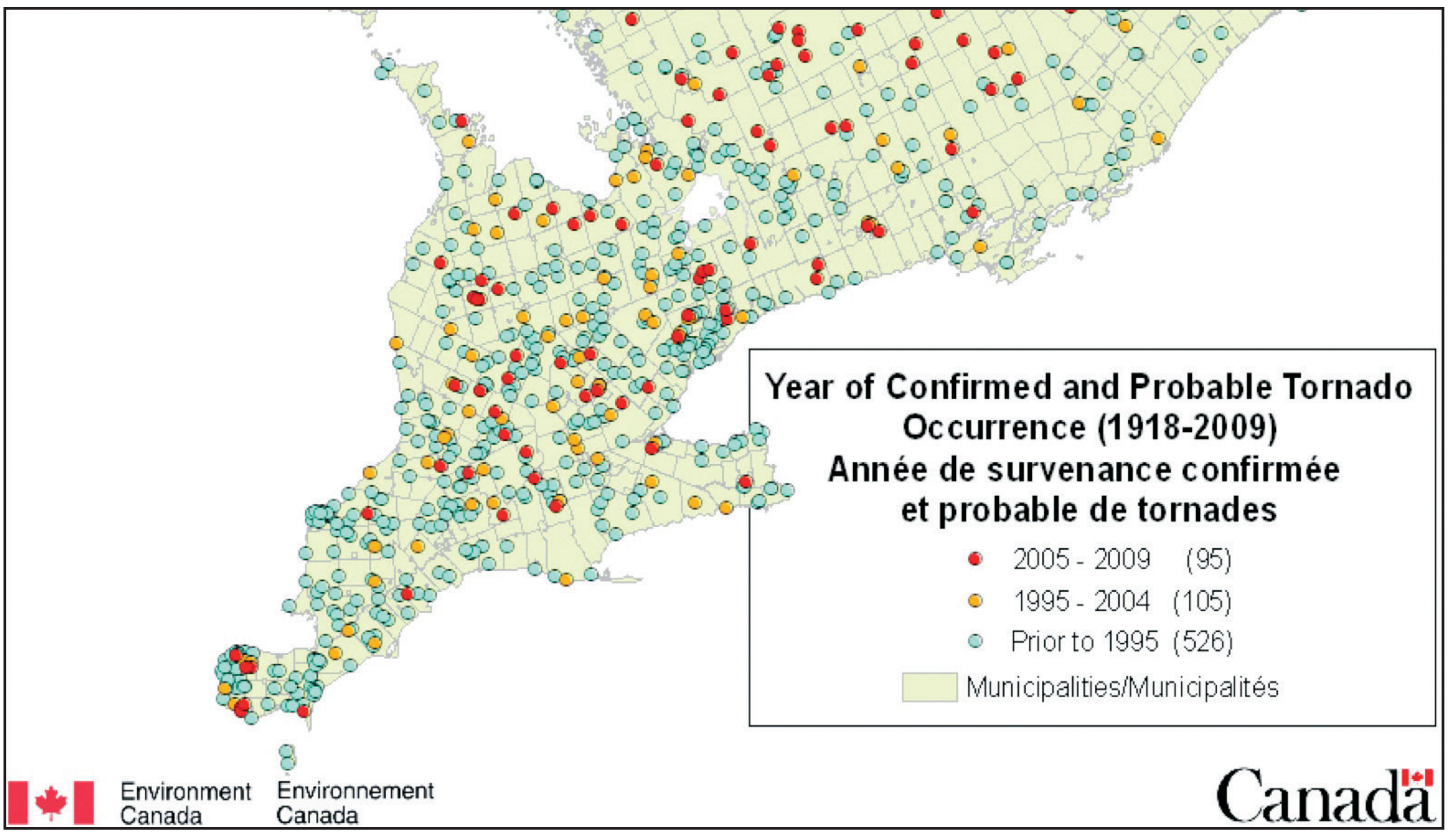
4.0 Extreme Weather Events And Natural Disasters

4.1.3 Flooding and Severe Storms

Many people, businesses, community services and significant infrastructure in Middlesex-London are at risk from flooding. A key determinant of flood risk in a region is the percentage of impervious surfaces which prevents rain absorption, causes rain water to pool and increases the probability of flooding if storm water infrastructure is overwhelmed. Data from 2008 indicate that approximately 32% of the surfaces in the City of London are impervious and may pose flood risks, particularly for areas of the city located near the Thames River (City of London, 2010a). The predominantly rural nature of Middlesex County may decrease flood risk in some municipalities where there is a higher proportion of agricultural land and natural land cover capable of absorbing rain water. However, rural areas can be flood prone, particularly if they occupy low lying areas in close proximity to flood plains.

The number of tornadoes in southwestern Ontario has increased with 95 occurring over the 4 year period from 2005-2009 compared to 105 occurring over the 9 year period from 1995-2004 (Figure 11). Tornadoes can be highly destructive and lead to significant morbidity and mortality.

Figure 11 - Historical overview of tornado occurrence in Southwestern Ontario, 1918-2009



Source: Environment Canada, 2011

4.0 Extreme Weather Events And Natural Disasters

4.1.3.1 Projected Impacts of Climate Change

Hebb and Mortsch (2007) assessed population vulnerability to flooding in the Upper Thames River Basin in the City of London under different climate scenarios. Their study used baseline climate and climate change flood-line scenarios to map 100-, 250-, and 500-year flood vulnerability using census data and information from the Upper Thames River Conservation Authority (Figure 12). Findings from the study are presented in Table 4. Under "wet" climate scenarios (increased frequency and/or intensity of rainfall), the number of buildings and people affected by flooding increases from the historic baseline for the 100-, 250-, and 500- year floods, although the impacts are not large (less than 10% increase). Under the "dry" scenario, for each flood-type, there would be significant reductions in the number of buildings and people affected compared to the historic baseline.

Table 4 - Population and dwelling counts in the City of London affected by flooding under different climate scenarios

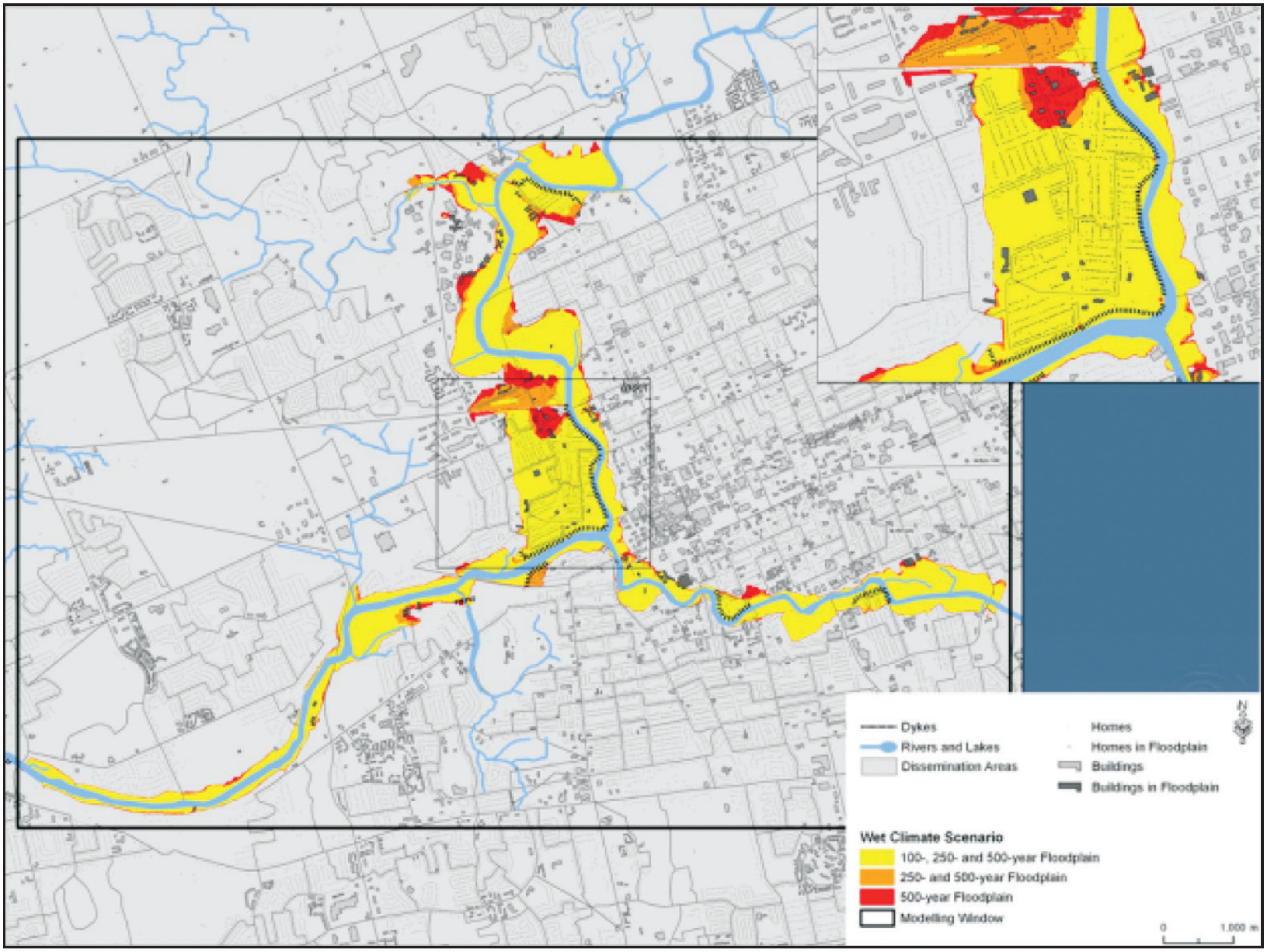
Flood Line	Climate Scenario	No. of Homes Flooded	No. of Buildings Flooded	Proportion Affected (2006 census data)	
				Population	Dwellings
100-year	Historic	1141	34	7701	3969
	Dry	68	18	4881	2521
	Wet	1249	42	7949	4109
250-year	Historic	1376	58	8474	4381
	Dry	1059	33	7351	3802
	Wet	1486	59	8745	4543
500-year	Historic	1560	71	9119	4740
	Dry	1155	36	7717	3988
	Wet	1690	83	9388	4886

Note: 'Dry' and 'wet' climate scenarios were developed using models generated by the Canadian Climate Impacts Scenarios group. 'Dry' conditions refer to models projecting warming temperatures and historically low levels of precipitation, whereas 'wet' scenarios (the likely impact of climate change for the area of Middlesex-London) refer to models projecting warmer seasonal temperatures and greater amounts of precipitation. Both the 'dry' and 'wet' scenarios are compared against historic scenarios which reflect climate conditions and flooding occurring between 964-2001.

Source: Adapted from Hebb and Mortsch, 2007

4.0 Extreme Weather Events And Natural Disasters

Figure 12 - City of London 100-, 250- and 500-year floodplains under various climate change scenarios



Source: Hebb and Mortsch, 2007

In addition, climate change may lead to more tornadoes as weather extremes increase (WMO, 2013).

4.2 Sensitivity

Data on extreme weather-related morbidity and mortality in Canada and in Middlesex-London is limited. Information on weather-related disaster-attributable morbidity and mortality is currently unavailable for the region of Middlesex-London since death certificates and hospital records typically do not attribute injury or death to extreme incidences of weather. Active surveillance of hospital admissions during extreme climate events can be a useful mechanism for assessing risks and identifying affected populations of extreme weather (McMichael and Kovats, 2000).

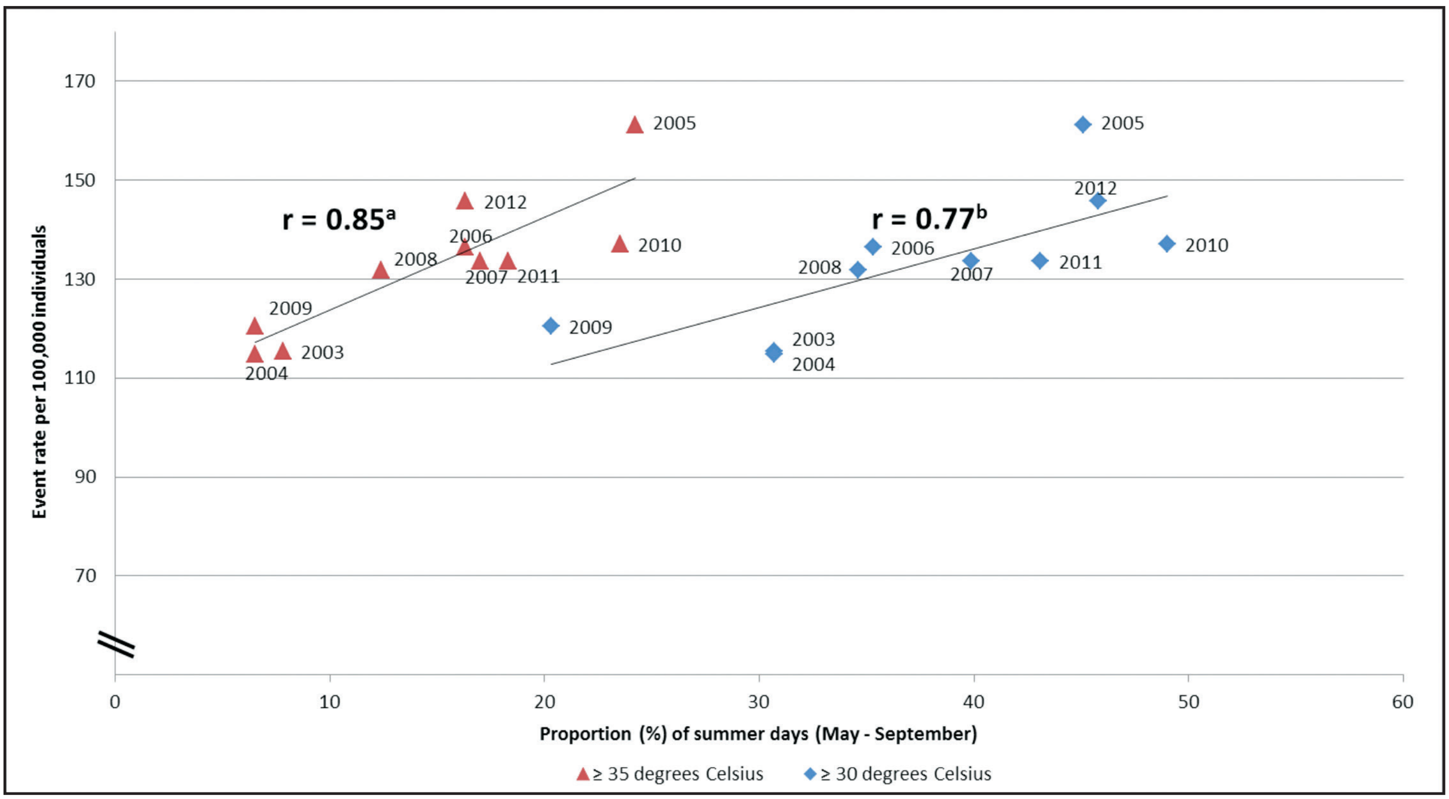
4.0 Extreme Weather Events And Natural Disasters

4.2.1 Health Impacts of Extreme Heat Events

Hot temperatures can impact health by affecting the body's ability to regulate core temperature which can lead to skin rashes, cramps, dehydration, syncope (fainting), exhaustion and heat stroke (Health Canada, 2011b). Extreme heat can also worsen pre-existing health conditions, such as cardiovascular, cerebrovascular, respiratory diseases and neurological disorders (Health Canada, 2011b; Kenny et al., 2010). Bassil et al. (2008) found that collecting data on human exposure and heat-related morbidity and mortality is challenging due to inadequate health surveillance and monitoring systems; therefore, heat-related illness may go under-reported.

Many Canadian communities experience increases in mortality when temperatures rise above 25-26°C but there is significant variability across jurisdictions (Health Canada, 2012). One study found a correlation between humidex and emergency room visits and hospitalizations in Middlesex-London (Shariff et. al., 2014). Figure 13 shows that heat-stress related morbidity (hospitalizations or emergency room visits for heat-related illness) is positively correlated with increasing summer humidex values.

Figure 13 - Association between heat-stress morbidity and summer humidex values in the Middlesex-London Region, 2003-2012



Source: Shariff et al., 2014

4.0 Extreme Weather Events And Natural Disasters

People in Middlesex-London that are particularly vulnerable to heat-related illnesses include the elderly, people living in rural areas and those with co-morbidities (e.g., diabetes, asthma, chronic obstructive pulmonary disease, congestive heart failure). In contrast, marginalized populations, recent immigrants and infants and toddlers (0-5 years of age) do not seem to experience higher rates of heat-stress related events (emergency room visits or hospitalization) than does the general population (Shariff et. al., 2014). Extreme heat events may have other more indirect health impacts. One study reported increases in assaults and domestic violence in Montreal (Quebec) during hot weather, particularly when temperatures were above 30°C (Ouimet and Blais, 2001).

4.2.2 Health Impacts of Extreme Cold

Extreme cold conditions can pose significant health risks to Canadians. People exposed to extreme cold conditions who do not take preventative measures are at risk of windburn, frostbite, hypothermia and death (Health Canada, 2013a). People more vulnerable to the health risks of extreme cold include (Health Canada, 2013a; Cheng and Su, 2010):

- Homeless and socially isolated people;
- Outdoor workers;
- People living in homes that are poorly insulated;
- People with certain medical conditions such as diabetes, peripheral neuropathy, and diseases affecting the blood vessels;
- People taking certain medications including beta-blockers;
- People who exercise outdoors and winter sport enthusiasts;
- Visitors to the region and newcomers;
- Infants (under 1 year);
- Seniors (65 years or older).

4.2.3 Health Impacts of Floods and Severe Storms

Flooding and heavy precipitation events have a variety of health impacts ranging from injury, illness and in extreme cases, death (Ebi and Semenza, 2008). Illness or injury can result from exposure to contaminants and suspended material in flood waters such as sediment, solid and liquid material, raw sewage, hazardous objects and pollutants or other toxins from a chemical spill (Du et al., 2010). Injuries typically occur during and immediately after a flood from wading through waters when contact with hazardous objects is likely. Floodwater can contaminate the local water supply through, for example, damaging the sewage system, and also the food supply thereby increasing the potential for communicable diseases (Noji, 1995). Heavy precipitation events that often lead to flooding have been strongly correlated with water- and vector-borne disease outbreaks (Hjelle and Glass, 2000; Engelthaler et al., 1999; Parmenter et al., 1999). The psychosocial effects of flooding can arise from the loss of loved ones, property and livelihoods, the effects of displacement of populations and crowding in emergency shelters (Carroll et al., 2009; Acharya et al., 2007; Adhern et al., 2005). Primary and secondary health impacts of floods are presented in Table 5.

4.0 Extreme Weather Events And Natural Disasters

Table 5 – Primary and secondary health impacts of floods

Primary Health Impacts	
Impact	**Cause**
Mortality	Drowning or acute trauma (e.g. debris or building collapse) usually attributable to motor vehicle accidents or inappropriate behavior in flooded areas (e.g. swimming, surfing)
Shock, hypothermia	Exposure to floodwater which is often below human core body temperature
High blood pressure, heart attacks and strokes	Exertion and stress related to the event
Physical injuries such as lacerations, skin irritations, bruises, wound infections	Direct contact with flood water
Infection, pulmonary swelling, lung irritation, fungal infection	Aspiration of water into lungs
Sprains, strains and orthopedic injuries	Contact with water-borne debris, attempts to escape from collapsed structures, falls from ladders, attempts to rescue people or possessions, etc.
Electrical injuries	Contact with downed power cables/lines, circuits and electrical equipment in contact with standing water
Burns (fire-related or chemical) and explosion-related injuries	Disturbed propane and natural gas lines, tanks, power lines and chemical storage tanks; toxic gas emissions; rescue boats coming in to contact with power lines

Secondary Health Impacts	
Impact	**Cause**
Exacerbation of existing illnesses, including chronic diseases	Disruption/decreased availability of emergency and ongoing health services, especially if health infrastructure is affected, including: decreased ability to provide/access care; displacement of patients and staff; impaired surveillance of illness, injury, toxic exposure; loss of medical records; loss/impairment of medication and medical devices
Carbon monoxide poisoning	Inappropriate use of unventilated cooking tanks (e.g. barbeques), pressure washers and gas powered generators
Burns/smoke inhalation	House fires started by candles
Dehydration, heat stroke, heart attack, stroke	Exposure of vulnerable populations to environmental stresses in days following event
Water- and food-borne diseases – upset stomach/gastrointestinal problems, infectious diseases with longer incubation periods including Hepatitis A, Legionella pneumophila, Norovirus, Rotavirus, Hepatitis A and C	Water and food contamination (e.g. from sewage overflows, flooding of agricultural areas and transport of sediment, fertilizers, pesticides, etc., leakage from tanks holding petroleum products, landfill materials), chemical contamination of water (e.g. from flooding of industrial sites)
Respiratory problems/symptoms	Mould and respiratory contaminants from mould, bacteria, fungal growth on damp structures Also, due to Legionaella, Chlamydia, pneumonia, Burkholderia cepacia, and Mycobacterium avium

Source: Berry et al., 2014

4.2.4 Children, Older Adults and Pregnant Women

Children (10.8% of the Middlesex-London population in 2011) and older adults (14.8%) can be more sensitive to extreme weather because they tend to be more dependent on caregivers in the event of an emergency. Children are more physiologically sensitive to hot weather because they produce more body heat per unit body mass and therefore experience faster heat gain. In addition, they sweat less than adults and begin sweating at higher temperatures. The body-surface-area-to mass ratio of children is higher than adults which means that they absorb much more heat from a hot environment (Health Canada, 2011c) putting them at greater risk of illness and death during hot temperatures.

Older adults (people aged 65 and older) have a higher sensitivity to the health impacts of extreme heat and are among the most vulnerable population groups (Health Canada, 2011c). Chronic health conditions, impaired cognition, reduced mobility, the inability to sense dehydration and living alone can also significantly increase health risks for seniors (Hambling et al., 2011; Rosenweig, 2011; Balbus and Malina, 2009). Health Canada (2011c) reported that older adults may also be more reliant on caregivers to effectively adapt to extreme heat. The portion of the population in Middlesex-London aged 65 and older increased from 2006 to 2011. Between 2011 and 2031 the number of older adults is expected to grow by 118.8% (MLHU, 2014a).

Pregnant women (52.8 pregnancies per 1000 women in Middlesex-London in 2009) may experience reduced mobility during emergencies and therefore may be less able to move to safety during an extreme weather event (Balbus and Malina, 2009). Extreme heat events may pose risks to the fetus during pregnancy (Health Canada, 2011c). Significant increases in a woman's core temperature during the third week of pregnancy are associated with anencephaly, a condition where the brain of the fetus does not develop properly. As well, maternal hyperthermia during the first five months of pregnancy has been linked with congenital malformations such as the occurrence of microphthalmia (abnormally small eyes) (Health Canada, 2011c). The effects of heat stress on the woman carrying the baby are less well understood (Health Canada, 2011c).

4.2.5 Chronic Diseases, Mobility Limitations and Mental Health

People with chronic diseases, mobility limitations and/or disabilities may be unable to protect themselves or engage in adaptive behaviours during extreme weather events (Health Canada, 2011b). For example, a number of pre-existing health conditions can increase the risk of developing heat-related illness because of physiological factors leading to compromised heat tolerance. These include cardiovascular conditions, respiratory conditions (COPD, asthma), renal illness or failure, neurological disease, hypertension, diabetes, obesity and malnutrition (Health Canada, 2011c). Overweight and obese individuals may be especially prone to excessive perspiration during hot weather putting them at increased risk of dehydration and heat exhaustion (Health Canada, 2011c). Decreased mobility, confinement to bed and dependence on caregivers is also associated with increased risks from extreme heat (Health Canada, 2011c).

The region's rates of asthma (7.8%), high blood pressure (18.8%), and overweight/obesity (52.2%) are similar to provincial averages. Additionally, 11.3% of the population reported that they often experienced activity limitations attributed to medical conditions or long-term health problems, and 14.5% of the population reported experiencing pain that prevented them from doing some or all daily activities (CCHS, 2009/10). In 2009/2010, 24.3% of persons aged 65 years and older reported needing help with daily activities relative to

INTRODUCTION
METHODOLOGY
THE MIDDLESEX-LONDON REGION
EXTREME WEATHER EVENTS AND NATURAL DISASTERS
AIR QUALITY
VECTOR-BORNE DISEASES
WATER-BORNE ILLNESSESES, FOOD-BORNE ILLNESSES AND FOOD SECURITY
ADAPTIVE CAPACITY
KNOWLEDGE GAPS

6.8% of the population aged less than 65 (CCHS, 2009/10). These statistics suggest that a significant portion of the population in Middlesex-London is highly sensitive to extreme heat (CCHS, 2009/10).

People more sensitive to climate-related mental health impacts include persons with pre-existing mental health issues (or a family history of mental illness), and persons with chronic conditions or mobility limitations (Kovats, Wilkinson and Menne, 2010). People with pre-existing mental health issues may be more likely to experience stress, anxiety, depression and other mental health effects associated with a disaster. In 2009, 5.6% of people in Middlesex-London were reported to have fair or poor mental health (CCHS, 2009/10). Over 7,500 older adults were diagnosed with Alzheimer's disease or a related dementia in the region in 2013 (Alzheimer Society of Middlesex London, 2013).

4.2.6 People Who Drink Alcohol, Use Illicit Substances or Take Medication

People on particular medications or who abuse drugs or alcohol are also sensitive to heat if substances compromise their thermoregulatory systems or lead to forgetfulness or failure to comply with appropriate health behaviours during extreme heat events (Health Canada, 2011c; Luber and McGeehin, 2008; O'Neil et al., 2005). Limited information is available on the proportion of residents in the region that are currently utilizing medications that may increase heat-health risks. According to the CCHS (2009/10), 33.4% of the population aged 19 years and older exceeded the province's low risk drinking guidelines. Low-risk drinking is defined as consumption of no more than two drinks in a single day within a week, 14 or fewer drinks per week for males and 9 or fewer drinks per week for females. According to the same survey, 9.6% of the population reported using illicit drugs in the past 12 months (not including one time cannabis use) and 9.4% of the population reported they used cannabis more than once in the past year.

Vulnerability factors that increase risks to extreme cold are similar to those for other extreme weather events, particularly extreme heat (Cheng and Su, 2010; Conlon et al., 2011). People who are most sensitive to the health impacts of extreme cold include older adults, infants, individuals with pre-existing chronic conditions or mobility limitations, people taking certain medications and people who exceed recommended daily alcohol intake or use narcotics (Health Canada, 2013a; Cheng and Su 2010).

4.3 Adaptation

4.3.1 Health and Social Services

Robust health and social services are required to reduce health risks from extreme weather events and natural disasters (WHO, 2012a). Middlesex-London has a strong network of health services that includes 11 hospitals, 5 mental health facilities, 3 long-term care facilities, 4 emergency shelters and 8 drop in centres (Table 6). These facilities are expected to provide health care services to residents and visitors during extreme weather events. The Ontario TeleHealth program enables Ontarians to speak with nurse-practitioners regarding health issues including how to prevent or reduce weather-related health risks from hazards such as extreme heat.

4.0 Extreme Weather Events And Natural Disasters

Table 6 - Overview of selected health and social services in Middlesex-London

Type	Count	List
Regional Care Centres (and affiliated hospitals/emergency services)	3 (11)	**London Health Sciences Centre** South Street Hospital; University Hospital; University Hospital Emergency Department; Victoria Hospital; Victoria Hospital Emergency Department; Children's Hospital of LHSC **St. Joseph's Health Care London** Lawsome Health Research Institute; Parkwood Hospital; St. Joseph's Hospital **Middlesex Hospital Alliance** Middlesex Hospital Alliance – Strathroy Site; Four Counties Health Services, Newbury; Four Counties Emergency Department
Mental Health Services	5	Regional Mental Health Care London; Canadian Mental Health Association London-Middlesex Branch; London Crisis Centre; WOTCH Community Mental Health Services; Mission Services of London
Regional Long-term Care Facilities	3	Mount Hope Centre for Long-Term Care; Strathm ere Lodge; Dearness Home
Emergency Shelters	4	Men's Mission and Rehabilitation Centre; The Salvation Army Centre of Hope; Unity Project; Mission Services London
Drop-in Centres (warming centres in the winter)	8	London InterCommunity Health Centre; At Lohsa; Mission Services—The Gathering Place; Mission Services—Streetscape; London Coffee House; My Sisters' Place; Youth Opportunities Unlimited; Ark Aid Street Mission

Source: MLHU (2012b)

4.3.2 Emergency Management Measures

Emergency response throughout Ontario is mandated and regulated under the Health Protection and Promotion Act, which provides directives for infectious disease control and public health preparedness. Middlesex County and the City of London and Middlesex County municipalities all have emergency plans that include information regarding how to manage extreme weather emergencies. MLHU undertakes emergency management activities and offers health services to reduce health risks from weather-related disasters. It can be the lead coordinating agency for emergency management at the regional level, or can support emergency response at the local level if emergencies are to be governed by local emergency response plans (MLHU, 2012b). MLHU's emergency response plan is reviewed annually and contains relevant information for other regional government agencies and residents in the area. The plan establishes an operational framework to mobilize staff and resources in the event of an emergency to protect life, health, the environment and property. It also ensures the continuity of operations and services at local and regional levels.

Currently, MLHU is the lead organization for the following types of public health emergencies: food recalls and contamination; infectious disease outbreaks; the spread of communicable diseases; contamination of water sources; and sanitary system failures. MLHU plays a supporting role in communicating the health risks of floods, winter storms, tornadoes, and coordinates the release of heat and cold alerts. MLHU and its staff participate in, but do not coordinate or lead on emergencies related to bioterrorism, bomb threats, chemical spills or explosions, industrial spills or contaminations, nuclear power issues, power or infrastructure failure, transportation-related disasters, and others.

The MLHU emergency response plan is a publicly accessible document that includes information for residents, such as how to protect themselves in the event of weather-related emergencies. The plan also includes communication materials for social service providers, such as guidelines to follow during boil water advisories. In the event that evacuations are needed, MLHU and its partners have established 21 evacuation centres including 4 in the City of London and 17 throughout Middlesex County (MLHU, 2012b) (Table 6).

4.3.3 Actions to Reduce Risks from Extreme Heat

Heat alert and response systems (HARS) are key adaptive mechanisms to reduce risks from extreme heat events at local and regional levels (O'Neill and Ebi, 2009; Younger et al., 2008; Health Canada, 2012). HARS should not only educate the public on the health risks associated with extreme heat, but provide information and support for protective behaviours which allow people to adapt to hot weather. A proactive community response (e.g., public health visits to vulnerable populations such as older adults living alone or the disabled) and adequate access to social and health services (e.g. cooling centres, shelters) are key components of HARS in many Canadian communities (Berry et al., in press; Martinez, Imai and Masumo, 2011). Urban and rural communities in Canada face different challenges that need to be addressed in developing and implementing HARS and in associated efforts to reduce heat-health risks (Berry et al., in press).

Heat Alerts

MLHU follows an extreme temperature protocol during extreme heat or cold events. The protocol guides activities related to issuing extreme temperature alerts to the public and assisting local agencies coordinate relief efforts. MLHU is the lead agency for issuing extreme temperature alerts in Middlesex-London. The City of London is in the process of incorporating existing extreme temperature protocol measures into the city's Severe Weather Management Plan (MLHU, 2012b). MLHU has a proactive heat-health communications campaign. During an extreme heat event, the public health unit provides information to the public through a media release including the locations and hours of cooling centres. This information is also posted on the health unit's website. Heat alerts are issued when any one of the following thresholds is reached (MLHU, 2012b):

- The daily forecast shows a humidex value of 40 or higher;
- The humidex is forecast at 36 or higher in combination with a smog alert issued by Environment Canada;
- Environment Canada issues a humidex advisory to limit outdoor activity for people in the Middlesex-London area;
- Temperatures reach 38°C or higher (without humidex).

Currently, the alert thresholds are not based on associations between heat and mortality in the region which reduces the effectiveness of the alert activities. As part of its HARS, MLHU issues directives to open cooling centres during extreme heat events. For example, during a heat wave in 2005, six community centres, all public libraries in the region, shopping centres, and neighbourhood health and resource centres were made available to receive any person in need of a cool place. Recreational water sites in the City of London (12 public outdoor pools, 12 public spray or splash pads, and 13 public wading pools (City of London, 2012b)) also extended operating hours to accommodate the potential increase in demand for access to cooling spaces.

Evaluation of the HARS, including program usage, is conducted every April and September. (MLHU, 2012b). Surveillance data on weather and temperature-related hospital admissions, ambulance use, coroner reports, and service demand is currently unavailable (MLHU, 2012b). It is of interest that despite an increase in the number of hot days over the last decade, there has neither been a significant increase in the number of heat alerts called nor heat alert days in London (Table 7).

Table 7 - Overview of recent heat alerts in Middlesex-London, 2005-2011

Year	# of Heat Alerts	# of Days with Heat Alerts
2013	3	10
2012	8	12
2011	3	11
2010	3	8
2009	2	2
2008	0	0
2007	3	7
2006	3	5
2005	4	11

Source: MLHU, 2012a

4.3.4 Actions to Reduce Risks from Extreme Cold

Cold Alerts

Cold alerts are issued by the Medical Officer of Health at MLHU when any one of the following thresholds is reached:

- Daily forecasted temperatures drop below -15°C without wind chill;
- Environment Canada issues a warning for persons in the Middlesex-London area based on wind chill forecast;
- Extreme weather conditions such as a blizzard or an ice storm are forecasted.

4.0 Extreme Weather Events And Natural Disasters

Information for the public on how to reduce risks from extreme cold events is available on the MLHU website. Shelters and drop-in centers are made available for the homeless to have access to warming places during cold events (Table 6). During periods of cold weather, outreach teams including London CAReS, provide assistance as needed to people that may be suffering from the cold. The Middlesex-London Region has experienced significant yearly variability in the number of cold weather advisories issued. Some years have had a high number of alerts and total days with alerts (e.g., 2009, 2011) (Table 8).

Table 8 - Historical overview of cold advisory alerts in Middlesex-London, 2005-2011

Year	# of Cold Advisories	Total # of Days with Cold Advisory
2014	6	38
2013	1	3
2012	0	0
2011	7	17
2010	1	3
2009	8	20
2008	5	11
2007	6	12
2006	1	3
2005	5	9

Source: MLHU, 2012a

4.3.5 Actions to Reduce Risks from Floods

Numerous flood structures have been built throughout the region to contain flooding and are monitored by regional conservation authorities. Additionally, building codes are regulated by the Minister of Municipal Affairs and Housing under the Building Code Act of 1992 which outlines guidelines for building new structures, zoning, and appropriate practices for development. However, less is known about the degree to which existing building codes afford protection to people and their property during extreme weather events and whether and to what degree they are protective under expected climate change conditions.

4.0 Extreme Weather Events And Natural Disasters

4.3.6 Adaptation Options

A range of measures exist that decision makers may use to help protect the citizens of Middlesex-London from extreme weather events and natural disasters related to climate change. These include (Berry et al., 2014):

- Air conditioning with the caveat that other solutions should be explored first, as air conditioning may contribute to climate change and air pollution;
- Better quality housing stock and appropriate infrastructure with the ability to capture energy and recycle water;
- Mitigation of the UHI through infrastructure development such as green roofs, reflective road and building surfaces, urban green spaces, interior air sealing, and use of elastometric roof coating;
- Public awareness and education campaigns to promote personal protection (e.g., extreme heat, cold, floods, tornadoes etc);
- Vulnerability assessments of high risk regions/populations;
- Physician attention to vulnerable patients, pre-summer vulnerability assessments, advice on routine care, education of health risks and appropriate behaviours;
- Development and use of vulnerability maps to allow targeting of vulnerable populations;
- Promotion of social capital development.

5.0 Air Quality

Key Messages

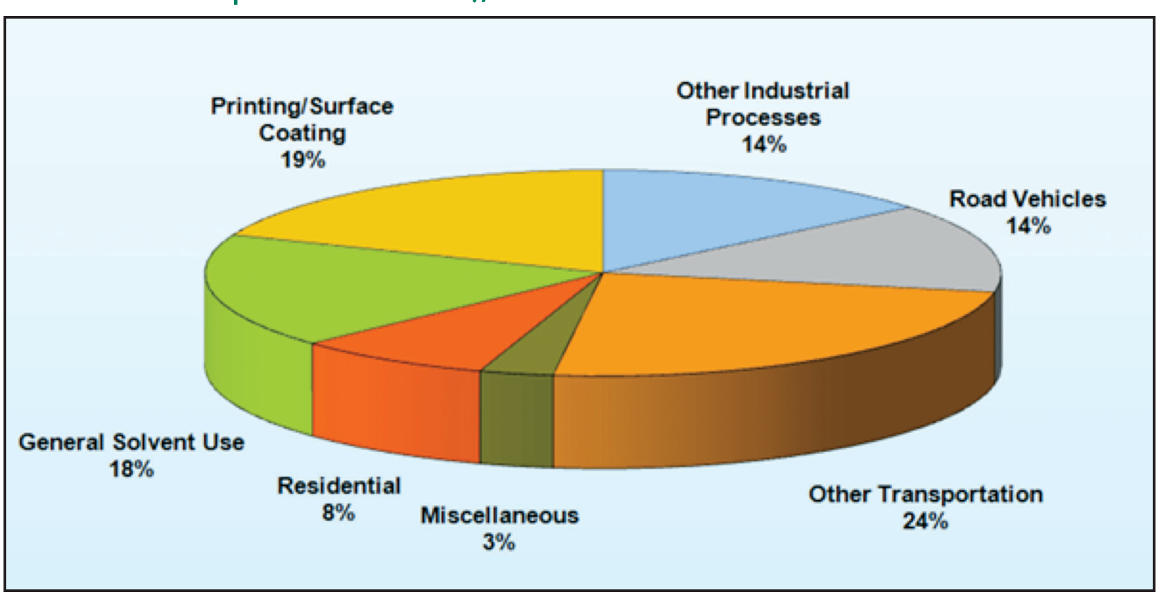
- Vulnerability to the health impacts of indoor and outdoor air pollution will be affected by key demographic factors (e.g., growing population of seniors, large numbers of people with chronic illnesses such as asthma and obesity) that mediate the effects of exposure to poor air quality.
- Air quality is generally improving; between 2004 and 2010 the number of poor air quality days and smog advisories decreased. However, average smog levels in the City of London increased between 2000-2010.
- Exposure to outdoor (smog, aeroallergens) air pollution is currently high and is expected to increase due to climate change in the absence of further adaptations.
- A wide range of actions are being taken at the national, provincial and local levels to improve air quality and to reduce risks to the health of people living in this community including air quality programs, air quality monitoring, and smog alerts.
- Information and tools are available to the public to promote actions to protect health. The AQHI is currently available in the City of London and can help reduce risks from air pollution. MLHU provides information to the public on risks from poor indoor air quality and advice to reduce harmful exposures.

5.1 Exposure

5.1.1 Sources of Pollution

Ground level ozone—a key component of smog—is a significant health issue in many Canadian communities (Government of Canada, 2012) including for residents of Middlesex-London. Sources of the two key constituents of ground level ozone in Ontario – oxides of nitrogen (NOx) and volatile organic compounds (VOCs) – are shown in 15 and 16.

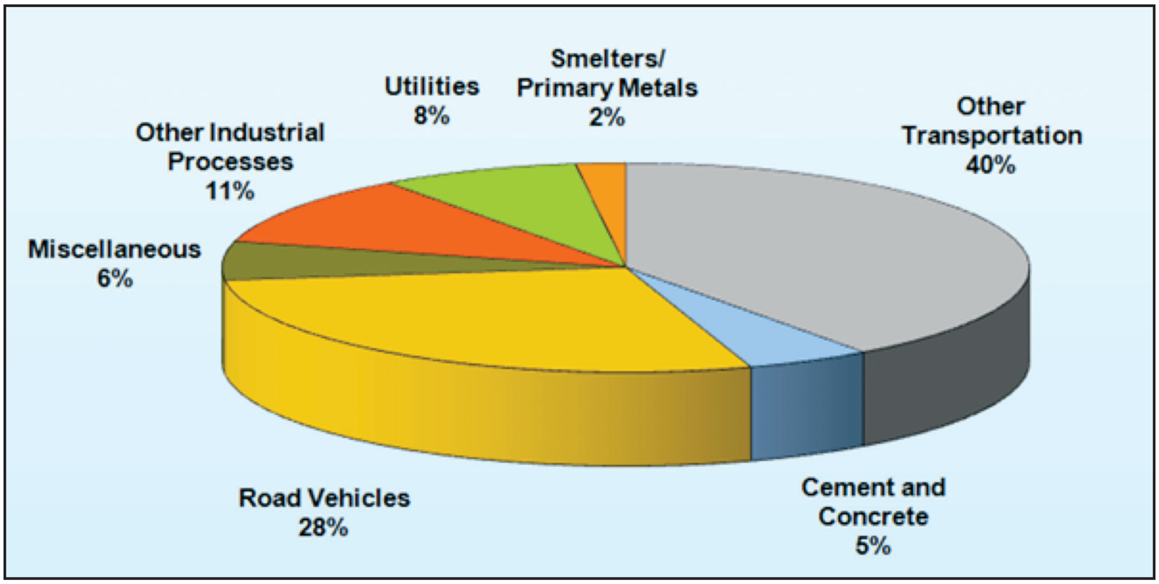
Figure 14 - Ontario volatile organic compounds emissions by sector (emissions from point/area/ transportation sources), 2006 estimates



Source: Ministry of the Environment, 2014a

5.0 Air Quality

Figure 15 - Ontario nitrogen oxides emissions by sector (emissions from point/area/transportation sources), 2006 estimates



Source: Ministry of the Environment, 2014b

Middlesex-London has seen improvements in air quality in recent years. There was a 23% reduction in maximum ozone concentrations in London between the periods of 2000-2002 and 2008-2010 (Ministry of the Environment, 2011). However, between 2000-2010 there was a 25% increase in average ozone concentrations in the City of London (Minister of the Environment, 2011). Between 2003 and 2007, the number of smog advisories in Middlesex-London was quite variable with 2005 (12 advisories) and 2007 (12 advisories) having high numbers. The number of advisories decreased significantly from 2008 to 2011 (Table 9), but this may have been due to the 2008 economic recession and the associated decline in industrial activity within Canada and the United States.

Table 9 - Reported poor air quality days and smog advisories for Middlesex-London, 2003 – 2011

Year	# of Poor Air Quality Days in M-L	# of Smog Advisories (# of days) in M-L	Average # of Smog Advisories (# of days) for Ontario Municipalities
2011	No Data	1 (1)	5 (9)
2010	0	2 (9)	3 (12)
2009	2	2 (4)	3 (5)
2008	5	5 (11)	8 (17)
2007	6	12 (27)	13 (39)
2006	4	4 (12)	6 (17)
2005	18	12 (45)	15 (53)
2004	13	6 (16)	8 (20)
2003	No Data	5 (14)	7 (19)

Source: Minister of the Environment, 2012a

5.0 Air Quality

The proximity of visitors and residents to various sources of transportation pollution is a key determinant of exposure to air pollution (Spickett, Brown and Rumchev, 2011) that can contribute to negative health outcomes. Middlesex-London is located in an area that contains one of the busiest regional transportation systems in Canada (MLHU, 2013c); within its jurisdictional boundaries it has two 400-series highways (401 and 402). In Toronto, Ontario, Jerrett et al. (2009) found an association between all-cause mortality and living within 50 metres of a major road or within 100 metres of a highway due to air pollution exposures. Areas adjacent to major highways in Middlesex-London have been primarily designated for commercial or industrial uses to protect residents from the effects of highway traffic pollution (City of London, 2013a). Relative to other areas in Ontario, Middlesex-London is not a highly industrial region and as such, industrial pollution is not a high concern (City of London, 2013a). Industrial transboundary pollution however, remains a significant concern in southwestern Ontario including in Middlesex-London. More than half of smog forming pollutants in this region originate from industrial sources in Ohio, Illinois and Michigan (Yap et al., 2005).

Particulate matter also poses significant risks to the health of Canadians. Typical sources of fine particulate matter ($PM_{2.5}$) include emissions from vehicles, industrial sources, forest fires and wood and waste burning, although it may also form through reactions among other air pollutants (Environment Canada, 2012). On average, $PM_{2.5}$ annual concentrations in Middlesex-London decreased by 19% between 2003 and 2010. The 6.5ug/m^3 value recorded in 2010 is one of the lowest values of all municipal jurisdictions in southern Ontario. The City of London also reduced its 3-year $PM_{2.5}$ levels by 32% between 2003 and 2010, relative to a 34% decrease across southern Ontario as a whole (MLHU, 2013c).

Little information is available about the incidence of, and proximity to, wildfires and resultant possible exposure of people living in Middlesex-London to $PM_{2.5}$. Transboundary pollution from wildfires is a concern for many Canadian communities as summer months become warmer and drier and the risk of fires increases (Berry et al., 2014). Increased temperatures and seasonal reductions in precipitation due to climate change are expected to increase the number and severity of wildfires in Canada's forests (Warren and Lemmen, 2014).

5.1.2 UV Radiation

UV radiation poses a significant health risk to the people of Middlesex-London (MLHU, 2005). Health risks associated with UV radiation exposure include DNA damage, immune suppression, skin cancer, and cataracts while some benefits also exist such as the production of vitamin D (Thomas et al., 2012; Dixon et al., 2012). The Canadian Cancer Society (2012) estimates that 81,000 new cases of non melanoma and 5,800 new cases of melanoma skin cancer will occur in Canada in 2012.The average annual incidence of melanoma in Middlesex-London from 2005-2007 was 20.9 people per 100,000 with an average of 16 deaths (MLHU, 2014f). By comparison, the incidence rate for lung cancer in that region was 60.2 people per 100,000 with an average of 209 deaths. Many people living in Middlesex-London do not regularly protect themselves from the sun; in 2008, only 40% reported wearing sunscreen or protective clothing always or often. In 2010, 33.8% of residents reported having a sunburn in the previous year (MLHU, 2014g).

5.1.3 People Who Spend Time Outdoors and Newcomers

People who work or regularly exercise outdoors are more likely to be exposed to air pollution (Government of Canada, 2012) and/or UV radiation. Visitors and newcomers may also be at higher risk to poor air quality. Kinney (2008) found that visitors may spend greater time outdoors, and that newcomers may be more likely to move to communities that are closer to transportation thoroughfares or industrial pollution sources. Information for both of these populations can be found in the section on extreme temperature (Section 4.0).

5.1.4 Socially and Economically Disadvantaged Populations

Increased exposure to air pollution can result from differences in relative income and housing conditions. In Canada and the U.S., neighbourhoods with lower incomes tend to have higher concentrations of air pollutants (Ebi, 2009; Sheffield and Galvez, 2009; Buzzelli et al., 2003; Jerrett et al., 2001). People with lower levels of education may lack an understanding of the health risks associated with poor air quality, which indicates the importance of clear and effective health communication messaging on days when health risks are higher. Little is known about the exposure to poor air quality by socially or economically marginalized groups in Middlesex-London. Poor housing conditions may also increase health risks from air pollution. McMichael, Woodruff and Hales (2006) suggest that poorly ventilated housing, such as structures requiring major repairs, may result in increased exposure. In 2006, 6.2% of all dwellings in Middlesex-London required major repairs.

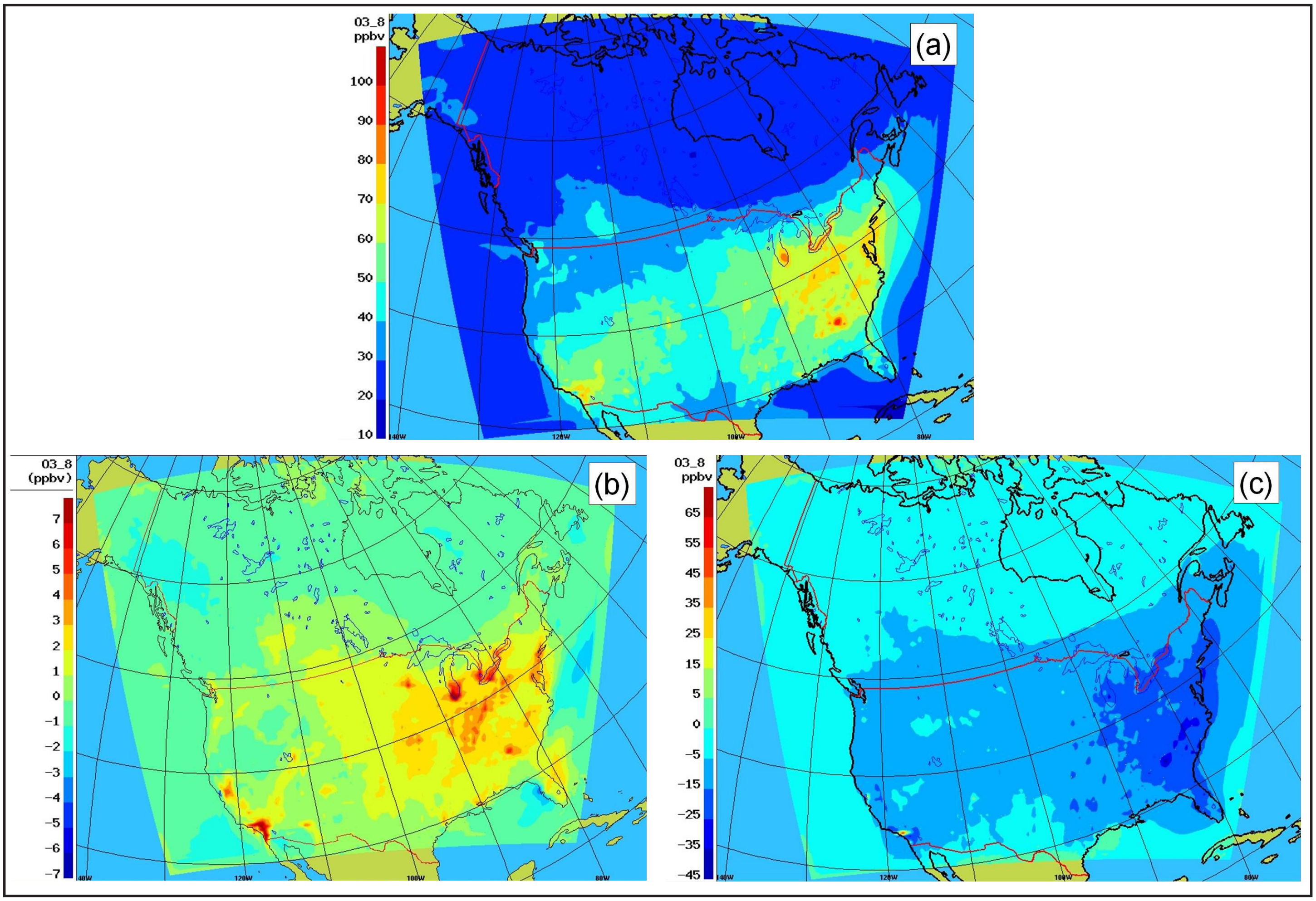
5.1.5 Projected Impacts of Climate Change

Climate change may exacerbate poor air quality in a number of highly populated areas in Canada (Kelly et al., 2012; NRTEE, 2011; Health Canada, 2008). Warming temperatures can increase aeroallergens such as pollens from trees, grasses or weeds, molds (indoor and outdoor), and dust mites that can trigger allergic responses and worsen respiratory diseases in sensitized individuals (Kennedy and Smith, 2012; Ziska et al., 2011). Due to climate change, the ragweed season has become longer in North America. It has increased by 27 days in Saskatoon and by 25 days in Winnipeg (Ziska et al., 2011). Further, high temperatures and dry conditions can favour drought and the outbreak of wildfires which can increase human exposure to particulate matter (e.g., $PM_{2.5}$) as smoke and ash spread through the air. Finally, higher temperatures associated with climate change are expected to affect chemical reactions among air pollutants leading to increased ground level ozone (Kelly et al., 2012).

With climate change, ozone concentrations are expected to increase across North America even if existing levels of air pollutants are held constant (Kelly et al., 2012; Ebi and Macgregor, 2008; Health Canada, 2008; Knowlton et al., 2004). Kelly et al. (2012) used modelling and climate scenarios to project future air quality and found that O_3 concentrations could increase by up to 9 to 10 parts per billion by volume (ppbv) with climate change by 2045, when anthropogenic air pollutant emissions are kept constant (Figure 16). Local increases in southern Ontario are expected to be in the range of 4 to 5 ppbv. However, overall decreases in air pollution levels could be achieved with further reductions of air pollutant emissions (Kelly et al., 2012).

5.0 Air Quality

Figure 16 - a) The ten year average "current" mean summer (June-July-August) daily maximum 8-hour average O_3 concentration; b) projected changes in the summer average daily maximum 8-hour O_3 between the "current" (circa 2000) case and the "future" (ca. 2045) case with climate change using constant air pollutant emissions; and the c) "current" case and "future" (ca. 2045) case with possible reductions in future air pollutant emissions



Source: Kelly et al., 2012

Note the different contour intervals used in each panel.

Climate change may increase exposure to harmful UV radiation due to higher levels of ambient UV radiation and because of changes in human behaviours (Thomas et al., 2012). A warmer climate may mean that Canadians spend greater time outdoors engaging in outdoor activities (Health Canada, 2008).

5.0 Air Quality

5.2 Sensitivity

5.2.1 Health Impacts of Air Pollution

Air pollution from climate-related exposures poses a variety of health risks to Canadians (Table 10).

Table 10 - Examples of health risks from climate change –related air contaminants

Air Contaminants	Climate Change and Related Drivers	Health Risks
Ground-level ozone	Increased temperatures	• Premature mortality • Respiratory symptoms, inflammation • Impacts on immunological defences • Cardiac effects • Adverse long-term respiratory impacts
Particulate matter - coarse ($PM_{10-2.5}$), fine ($PM_{2.5}$) and ultrafine ($PM_{0.1}$)	Wildfires Drought Renovations to weatherize buildings	• Mortality • Cardiac outcomes • Lung cancer mortality • Restricted activity days • Respiratory symptoms • Bronchitis • Asthma exacerbation
Aeroallergens (eg., from trees, grasses, weeds, molds, dustmites)	Warmer temperatures	• Allergic responses in sensitized individuals • Exacerbation of respiratory diseases (e.g., asthma and chronic obstructive pulmonary disease)
Fungi (e.g., and infectious bacteria	Moisture in buildings from infiltration of rain or flooding Poorly designed ventilation and air-conditioning systems Poor building maintenance Warmer and drier summers in western Canada	• Respiratory disease • Cryptococcal disease (cryptococcosis) which can result in pneumonia or meningitis
Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs)	Dampness in buildings	• Asthma • Allergies
Carbon monoxide (CO)	Use of portable gas-powered or electric generators, oil and gas furnaces, fireplaces, or candles during weather-related emergencies	• Fire-related injuries and death • CO poisoning

Source: Adapted from Berry et al., 2014

Poor air quality events can lead to increased emergency room visits and hospital admissions by people suffering from respiratory and cardiovascular impacts (Government of Canada, 2012).

5.2.2 Children and Older Adults

Healthy and asthmatic children, older adults - especially those with pre-existing respiratory or cardiac conditions - and people who are more active outdoors are particularly susceptible to the health effects of poor air quality associated with PM and O_3 (Government of Canada, 2012). Children typically spend greater amounts

INTRODUCTION
METHODOLOGY
THE MIDDLESEX-LONDON REGION
EXTREME WEATHER EVENTS AND NATURAL DISASTERS
AIR QUALITY
VECTOR-BORNE DISEASES
WATER-BORNE ILLNESSES, FOOD-BORNE ILLNESSES AND FOOD SECURITY
ADAPTIVE CAPACITY
KNOWLEDGE GAPS

of time outdoors in hot weather and exert higher levels of physical exertion which can lead to a high dose of air pollution to the lungs (Kinney, 2008). The elderly may have pre-existing chronic respiratory conditions that can be exacerbated by poor air quality (Government of Canada, 2012).

5.2.3 People with Chronic Conditions and Who Smoke Tobacco

People with pre-existing chronic conditions such as lung diseases, seasonal allergies, cardiovascular disease, respiratory conditions or those who are overweight/obese may be more sensitive to health effects of poor air quality (Government of Canada, 2012; Spickett, Brown and Rumchev, 2011; Sheffield and Galvez, 2009; Haines et al., 2006). In 2009, approximately 52.2% of the Middlesex-London population aged 18 years and older were overweight/obese (CCHS, 2009). In addition, 7.3% of people under the age of 65 reported having asthma, 10.7% reported having high blood pressure, and 1.8% reported having heart disease (CCHS, 2009). It is anticipated that allergies and hay fever will increase in prevalence as seasonal variation due to climate change causes an earlier release of pollen into the air and more prolonged periods of exposure. Tobacco smokers (approximately 22% of adults aged 19 and over in Middlesex-London (CCHS, 2009)) may have reduced lung capacity and therefore, are at increased risk of contracting a host of respiratory conditions (Sheffield and Galvez, 2009).

5.3 Adaptation

5.3.1 Air Quality and Human Health Advisories

The Ontario Ministry of the Environment (MOE) regularly undertakes extensive air quality monitoring and modelling. A regional air quality index (AQI) is issued daily for regions throughout the province where monitoring stations record hourly pollutant measurements of sulphur dioxide, ground level ozone, nitrogen dioxide, sulphur compounds, carbon monoxide and fine particulate matter. Calculations are based on the concentration of a particular pollutant at its highest concentration relative to its standard measure. Air quality advisories are released from MOE directly to the public through media releases. The MLHU website includes the air quality advisories and additional information about the health impacts of air pollution and protective measures to reduce risks.

Currently there is a lack of evidence supporting the relationship between the AQI and known health effects (Chen and Copes, 2013). The Air Quality Health Index (AQHI) provides information through the Internet (www.airhealth.ca) that people can use to take actions to reduce their exposure to air pollution. Information addresses the needs of the general public and is also tailored to vulnerable populations such as parents with children and infants, seniors and those with cardiovascular and respiratory diseases (Environment Canada, 2013c). The AQHI is currently available in the City of London.

Rising temperatures also promote mold growth indoors affecting indoor air quality by fostering warmer and more humid environments and through extreme weather events that cause flooding. (Potera, 2011; CMHC, 2005). Currently, MLHU provides extensive information on health risks from indoor air quality, including health effects of mold in buildings, as well as prevention and treatment information (MLHU, 2011). Additional information on exposure and sensitivity to indoor air quality are provided in the section of this report dealing with extreme weather and flooding.

5.3.2 Actions to Improve Air Quality

In Canada, action at all levels of government is being taken to improve air quality. The federal government has implemented national standards and targets to reduce the health impacts associated with poor air quality. The maximum 8-hour concentration standard for ozone is 65ppb. For $PM_{2.5}$, the maximum 24-hour concentration is $30ug/m^3$. Exceeding these concentrations can be harmful to human health, and regional health and environment authorities are responsible for reducing the likelihood of such events, and for issuing warnings in the event that they occur.

The provincial government contributes to reducing poor air quality in various ways. To reduce air pollution and promote active transportation, the province has implemented "#CycleON: Ontario's Cycling Strategy". In addition, the "Ontario Smog Strategy" was developed in 1999 to reduce emissions and improve air quality in southwestern Ontario, and a "Drive Clean Program" was enacted in 1998 to implement stricter vehicle emission controls along with anti-idling measures. Ontario's 2007 "Action Plan on Climate Change" includes GHG emissions reduction targets for the province (6% below 1990 levels by 2014; 15% below 1990 levels by 2020; and 80% below 1990 levels by 2050) and the 2009 "Green Energy and Economy Act" was designed to spur the development of alternative energies (i.e., wind, solar, biomass) to wean the province off fossil-fuel energy supply and improve air quality. The province also plays a role in establishing land use policies to reduce urban sprawl.

At the municipal level, the City of London has adopted a multi-phased strategy to improve air quality and reduce the city's impact on climate change. The "Air Quality in London: Moving Forward Locally Plan" provides information to raise awareness about how individuals, organizations and businesses can reduce their impacts on the environment and help to mitigate climate change. As of 2009, the City of London has already engaged in numerous programs and projects to improve air quality including (City of London, 2012a):

- Switching all city vehicles to ethanol-blended gasoline or low sulphur fuel;
- Adding 19 hybrid vehicles and 2 Smart Cars to its fleet;
- Building a landfill gas power plant to collect methane from biomass (with support from the provincial government);
- Implementing the tri-generation system to heat and cool city hall;
- Implementing energy performance contracts to ensure energy conservation through all city-related activities;
- Converting traffic lights to LEDs which use 85% less energy than traditional light bulbs;
- Forming the Southwestern Ontario Clean Air Council;
- Consulting the public in developing a Transportation Master Plan;
- Developing a solar photovoltaic system at Landon Library; and,
- Building the LEED gold standard North London Community Centre and Library.

Continuation of existing clean air projects by all levels of government will bolster Middlesex-London's ability to help mitigate the effects of climate change on air quality in the region.

INTRODUCTION
METHODOLOGY
THE MIDDLESEX-LONDON REGION
EXTREME WEATHER EVENTS AND NATURAL DISASTERS
AIR QUALITY
VECTOR-BORNE DISEASES
WATER-BORNE ILLNESSESES, FOOD-BORNE ILLNESSES AND FOOD SECURITY
ADAPTIVE CAPACITY
KNOWLEDGE GAPS

5.3.3 Adaptation Options

Almost 25% of the City of London's surface area is covered by urban tree canopies (City of London, 2010a). However, the Emerald Ash Borer is expected to kill most of London's Ash trees effectively reducing the cities canopy cover from 25% to 23% (City of London, 2014). Climate change is expected to pose threats to the city's suburban forest necessitating proactive adaptation planning (City of London, 2014). Improving tree coverage can help clean the region's air, and can also help to mitigate extreme heat and increase pervious surfaces to reduce flood risk (Younger et al., 2008).

The most current data for private automobile use throughout the region indicates that its modal share throughout the City of London was 84% for afternoon peak hour trips. Annual ridership of public transit on London Transit Commission services has grown since 1996, but only constitutes 7% of modal transportation share throughout the city and region. At the end of 2009, transit services included a fleet of 192 buses, 141 of which were designated as having accessibility services (City of London, 2010b). Improving access to and ridership on public transit, and encouraging alternative forms of transportation (e.g. cycling) can help to reduce the incidence of poor air quality days and exposure to harmful pollutants (Younger et al., 2008).

A range of measures exist that decision makers can use to help protect the citizens of Middlesex-London from air pollution related to climate change. They include (Berry et al., 2014):

- Public awareness and education campaigns to promote personal protection from air pollution;
- Vulnerability assessments of high risk regions/populations;
- Physician attention to vulnerable patients, pre-summer vulnerability assessments, advice on routine care, education of health risks and appropriate behaviours; and
- Development and use of vulnerability maps to allow targeting of vulnerable populations

6.0 Vector-Borne Diseases

Key Messages

- Vulnerability to the health impacts of climate-related vector-borne and zoonotic diseases will be affected by key demographic factors (e.g., growing population of seniors) that mediate the effects of exposure to related vectors.
- The burden of climate-related vector-borne diseases is currently low. In 2013 there were 2 confirmed and 1 probable human cases of West Nile Virus (WNV) in the Middlesex London area. In the same year, there were four confirmed travel-related human cases of Lyme disease and two probable cases associated with exposure to a tick in the state of Florida, United States.
- Climate change has contributed to the range expansion of the tick that harbours the Lyme disease pathogen which is spreading northward into Ontario. Climate change may increase risks from West Nile Virus and Eastern Equine Encephalitis.
- Adaptive capacity to manage climate-related vector-borne and zoonotic diseases is high in Middlesex-London. This is due to rigorous surveillance and monitoring of vectors and disease incidence, a pest control program (i.e., larvaciding, and adulticiding in catch basins), public education and outreach efforts, and regular program evaluations.
- Efforts may be needed to increase awareness of protective measures among the general public.

6.1 Exposure and Sensitivity

As the temperature warms, previously inhospitable regions in Canada are becoming more suitable for vectors that carry infectious diseases (Health Canada, 2008). In southwestern Ontario, vector-borne diseases of immediate concern, among others include West Nile virus (WNV), Eastern Equine Encephalitis (EEE) and Lyme disease. Exotic diseases such as malaria and Rift Valley Fever virus may also be of concern for some Canadian communities in the future as the climate continues to change (Iranpour et al., 2011; Berrang-Ford et al., 2009; Health Canada, 2008).

6.1.1 Mosquito-borne Illnesses

WNV and EEE are viral diseases that result from viral pathogens being passed from mosquitoes to humans. In extreme cases, WNV can result in fatalities, but in most cases, people infected will either be asymptomatic or suffer from flu-like symptoms (Public Health Agency of Canada, 2014b). EEE is a severe disease with a mortality rate of 50 to 75%. Symptoms include fever, headache, vomiting, respiratory symptoms, leucocytosis, dizziness, decreasing level of consciousness, tremors, seizures, and focal neurological signs (Public Health Agency of Canada, 2012a). In North America, the main vectors for WNV are *Culex* mosquitoes including *C. pipiens, C. restuans, C. salinarius, C. quinquefasciatus,* and *C. tarsalis* (Public Health Agency of Canada, 2011). Vectors for EEE include *Aedes sollicitans, Aedes vexans, Coquillettidia,* and *Culex* spps (Public Health Agency of Canada, 2012a). Mosquito breeding is facilitated through increased rainfall and the accumulation of stagnant water (e.g., in abandoned swimming pools, road side ditches and woodland pools) (MLHU, 2013i).

Middlesex-London regularly monitors and tests mosquito populations for the presence of WNV and EEE. Using ground-level (terrestrial) and canopy mosquito traps, MLHU identified that vector species suitable for carrying WNV comprised 86% of all mosquitoes captured in 2011, 92% in 2010 and 90% in 2009. In 2012, 70% of all mosquito larvae identified were vector species for WNV or EEE. Adult testing in 2012 revealed 17 WNV-positive mosquito traps (including 7 of 8 canopy traps and 10 terrestrial traps) and 23 WNV-positive birds (of 41 submitted for testing) (MLHU, 2013i). In 2013, there were 2 confirmed and 1 probable human cases of WNV. These cases were attributed to probable exposure of people to WNV in the Middlesex-London area. In the same year, there were 53 cases in Ontario and 115 in Canada (pers comms, Iqbal Kalsi).

In 2011, there were no EEE-positive mosquito batches identified in the Middlesex-London Region; however, 51% of all captured mosquitoes captured were suitable for carrying and transmitting the disease (up from 48% of all mosquitoes in 2010 and 26% in 2009). There were no confirmed human cases of EEE in Middlesex-London in 2012 (MLHU, 2013i).

6.1.2 Tick-borne Illnesses

Lyme disease is a serious infection caused when the bacterium is transmitted by black-legged ticks. If left untreated in the early stages, symptoms of weakness, multiple skin rashes, painful, swollen or stiff joints, abnormal heartbeat, central and peripheral nervous system disorders including paralysis, and extreme fatigue may result (Public Health Agency of Canada, 2013). Exposure to ticks typically increases with warmer temperatures and decreased rainfall through the summer and into autumn which produce favourable conditions for the spread of tick populations.

There were 12 cases of Lyme disease reported in Middlesex-London between 2000 and 2011. None of the cases of disease were contracted in the Middlesex-London area (MLHU, 2013i). In 2011, 73 ticks were submitted to MLHU for laboratory testing and two were identified as black-legged ticks—the species that may carry the disease pathogen. In 2011, there were no laboratory confirmed cases of Lyme disease in the region; however, 2 cases occurred in residents of Middlesex-London when they were travelling in other parts of Ontario. In 2012, one confirmed case of travel-related Lyme disease was reported in the region. In 2013, there were four confirmed travel-related human cases and two probable cases associated with exposure to a tick in the state of Florida, United States (pers comms, Iqbal Kalsi). At the time of writing, there was no established black-legged tick population in the region.

Older Adults, Children and People with Suppressed or Developing Immune Systems

Older adults and children have an increased risk of contracting WNV, EEE and Lyme disease because of immunosuppression due to age and development, respectively (Sutherst, 2004). The incidence of Lyme disease is highest in children between 5-9 years of age and in adults between 55-59 years of age (Public Health Agency of Canada, 2014a). People of any age can suffer serious health impacts from WNV. However, risks increase with age and people with weaker immune systems are considered to be most vulnerable (Public Health Agency of Canada, 2012b). These include people with chronic diseases, such as cancer, diabetes, alcoholism or heart disease and people that require medical treatment that may weaken the immune system (Public Health Agency of Canada, 2012b). The population in Middlesex-London that is at higher risk is therefore quite large. Reliable data on the proportion of the population with suppressed immune systems (e.g., the number of transplant recipients) is lacking. There were 4.2 people per 100,000 living with HIV/AIDS relative to 6.4 per 100,000 across Ontario in 2011 (MLHU, 2013g).

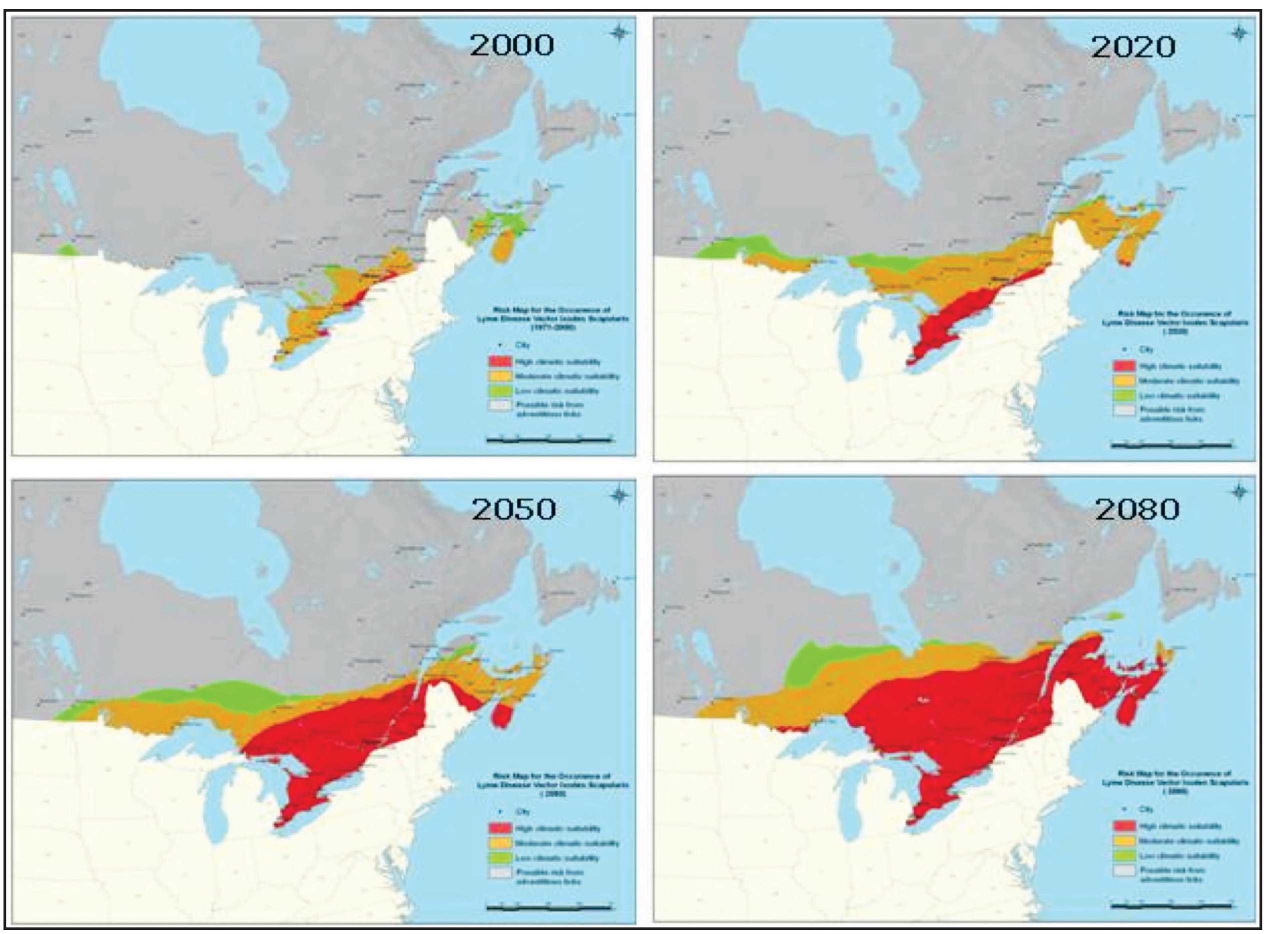
6.0 Vector-Borne Diseases

Exposure to WNV, EEE and Lyme disease is increased in people spending greater amounts of time outdoors for recreation (e.g., golfing, hunting, camping, fishing, hiking) and/or due to their occupation (e.g., parks services), placing them at greater risk of contracting these diseases (Public Health Agency of Canada, 2014a; English et al., 2009). People travelling to other parts of the world where other vector-borne diseases are endemic may also be at increased risk if they do not take necessary protective measures (Health Canada, 2008). London International Airport had 448,696 people travel through this port of entry in 2011.

6.1.3 Projected Impacts of Climate Change

In 2008, Ogden et al. projected the spread of tick populations that harbour Lyme disease northward into central and eastern Canada (Figure 17). These projections have been validated in through surveillance and monitoring (Public Health Agency of Canada, 2014a; Ogden et al., 2010). The Lyme vector is spreading into Canada at a rate of 35-55 km per year (Leighton et al., 2012). Human cases are increasing as well – from approximately 30 cases a year in 2007 to 315 in 2012. The spread of black-legged tick populations and resulting human risk of exposure to Lyme disease is projected to continue to increase over the next several decades due to climate change (Berry et al., 2014).

Figure 17 - Risk maps for the establishment and spread of the Lyme disease vector *Ixodes scapularis* under current climate (2000) and projected future climate (2020 to 2080)



Source: Ogden, 2008

6.0 Vector-Borne Diseases

6.2 Adaptation

6.2.1 Actions to Reduce Risks from Vector-borne Diseases

Monitoring vector populations and human infections are important measures for tracking outbreaks of vector-borne diseases over time (Ogden et al., 2010; Sutherst, 2004) that can improve adaptation. In Ontario, provincial guidelines exist for monitoring mosquito and black-legged tick populations. The Ontario Public Health Standards require on-going surveillance of WNV, EEE and Lyme disease by tracking the presence and abundance of mosquito and tick populations and cases of human infection. Ontario regulations 558/91 and 559/91 make WNV and Lyme disease reportable diseases under the Ontario Health Protection and Promotion Act. EEE is currently not a reportable disease under Ontario regulation 558/91, but encephalitis symptoms are reportable and classified in similar reporting categories as WNV and Lyme disease.

At the local level MLHU undertakes a range of vector management activities aimed at reducing health risks. MLHU has a comprehensive, integrated pest control program. Activities include monitoring vector population growth through terrestrial and canopy traps, dead bird testing, weekly surveillance of standing water sites, identification of mosquito larvae, control of vector mosquito larvae, and human disease case surveillance (MLHU, 2012c). MLHU also regularly tests storm water management facilities (a total of 1788 visits in 2012) and other areas of higher risk (e.g., Sifton Bog, Westminster Ponds) for increased vector activity.

Larviciding—the extermination of mosquito populations by chemically treating areas where mosquito larvae are present—is an effective mosquito management measure (Leichenko, 2011) that is employed throughout Middlesex-London. The Canadian Centre for Mosquito Management is contracted by MLHU to treat all municipal and public based catch basins, including roadsides and other stagnant or standing water locations. This is accomplished through direct or aerial application at times of the year where surveillance indicates more abundant mosquito populations (MLHU, 2012c).

Adulticiding—the application of pesticides to adult mosquitoes rather than larvae—is a key component of the MLHU vector management plan when mosquito activity poses significant health risks to the population. Adulticiding takes place once a risk assessment is carried out that includes analysis of standing water surveillance data, the presence of WNV in birds and mosquitoes and the efficacy of control methods already implemented during the season or calendar year (Minister of the Environment, 2009). If a high risk to human health is identified, the Medical Officer of Health will request that adulticiding take place.

Individuals can protect themselves by applying insect repellent, avoiding the outdoors between dusk and dawn (particularly for exposure to mosquitoes) and wearing clothing that covers skin (Public Health Agency of Canada, 2013; Public Health Agency of Canada, 2014b). MLHU has communication materials on its website targeted to the public to help reduce exposure to vector-borne diseases. MLHU reviews and evaluates their vector-management activities every year, and provides recommendations for future practices based on changes in vector and disease distribution. A public survey on Lyme disease in the region revealed generally high awareness of the disease but far fewer people taking needed protective measures. The study found that in 2012, 80% of those asked knew that people can get Lyme disease from ticks. However, fewer than 30% of people that had been in grassy fields or wooded areas over the spring and summer of 2011 took steps to protect themselves from tick bites all, or most of the time (MLHU, 2012d).

6.2.2 Adaptation Options

A range of measures exist that decision makers may use to help protect the citizens of Middlesex-London from vector-borne diseases related to climate change. They include (Berry et al., 2014):

- Development of new surveillance methods or enhancing current programs as more information on risks and adaptive measures becomes available;
- Dissemination of information for public health officials and the public;
- Tools for risk-based decision making on management (i.e., surveillance, prevention and control) of emerging/re-emerging zoonoses/VBDs (e.g., Multi-Criteria Decision Analysis).

7.0 Water-Borne Illnesses, Food-Borne Illnesses and Food Security

Key Messages

- The current burden of disease from climate sensitive water- and food-borne illnesses in Middlesex-London is relatively low. However, food-borne illnesses are difficult to monitor and are often underreported.
- The gradual increase in average temperatures and increases in the frequency and severity of extreme weather events associated with climate change are expected to increase risks from water-and food-borne illnesses. For example, climate change may increase risks from food-borne illnesses at the region's many farmers markets and other outdoor events.
- Source water protection, the regulation of drinking water services, surveillance of water-borne illnesses and public education and outreach help to protect citizens of Middlesex-London from risks to health from contamination of drinking and recreational waters.
- Existing regulations on food safety practices, the inspection of food premises; safefood training for food handlers, food safety alerts, and a DineSafe Program that provides publically accessible information on food premise inspections currently afford citizens with a high level of safety from food-borne illnesses.

The gradual increase in average temperatures and increases in the frequency and severity of extreme weather associated with climate change are expected to increase risks in Middlesex-London from water- and food-borne illnesses. The increasing temperatures associated with climate change can increase the replication rates and survival of disease vectors and pathogens that live in water and food (WHO/PAHO, 2012; Health Canada, 2008). Heavy rainfall and flooding can contaminate drinking water sources with fecal matter, chemical contaminants and other pathogens and affect regional water quality as well as increase food safety risks during emergencies (Patz et al., 2005). In addition, behavioural changes associated with increased temperatures such as expanded barbecue and swimming seasons may increase the rate of food- and water-borne infections. Increased impacts from climate change on drinking and recreational water quality and on food would have disproportionate effects on low income and subsistence food users (Health Canada, 2008).

7.1 Exposure

7.1.1 Drinking and Recreational Water Quality

A warmer climate and extreme weather can increase water temperature and change chemical and biological contamination in water sources. Middlesex-London region is particularly vulnerable to flooding during spring due to rain on snow conditions following the winter melt. Severe storms and heavy rainfall can impact water turbidity and pose problems for conventional treatment methods, although this is not considered a serious risk for Middlesex-London at present (City of London, 2013b).

Densely populated areas such as the City of London have the potential to place stress or strain on existing infrastructure and sources of drinking water; increasing population can place more people at risk of exposure to contaminated water (Strand et al., 2010). Middlesex-London's population has been increasing rapidly, about 12.9% between 1996 and 2006. The City of London is primarily serviced by an integrated water

7.0 Water-Borne Illnesses, Food-Borne Illnesses and Food Security

management system delivered from Lake Huron and Lake Erie, and the city has two back-up well fields that can be used in the case of an emergency. Many rural areas in Middlesex County are serviced by the same systems that provide water to the City of London, but others are serviced through a mixture of private and public wells which are managed by local municipalities. Rural areas are at higher risk for impacts on water quality from extreme weather events. Small water systems, including wells, may be particularly vulnerable to contamination by flooding; routine monitoring of these water sources can reduce risks to health (Brettle et. al., in press).

7.1.1.1 Outdoor Recreational Facilities

Several public beaches exist throughout the region including Fanshawe Lake, Lake Whittaker and Sharon Creek Conservation Areas. Natural recreational facilities (i.e., untreated water sources such as beaches) may be at increased risk of exposure to water-borne outbreaks resulting from weather-related factors such as heavy precipitation events. Such events have been known to lead to high *E. coli* counts at public beaches which are an indicator of unsafe levels of pathogens that can harm health. This risk results from surface water run-off being contaminated with bacteria or chemicals and being delivered to water sources used for drinking or recreational bathing (Heaney et al., 2012; Turgeon et al., 2011). A Danish study conducted in the Netherlands found that people swimming in untreated water at public bathing sites are at an increased risk of being exposed to water-borne disease outbreaks when temperatures were greater than 25°C (Schets et al., 2011). The City of London has 12 public outdoor pools, 12 public spray or splash pads, and 13 public wading pools (City of London, 2012b).Treated facilities are regulated and, when operated in accordance with regulations that protect water quality, are less likely to be impacted by warmer temperatures and extreme weather events. However, increased temperatures associated with climate change and longer summers could result in more people using water facilities to cool down with greater potential for human-source contamination that could overwhelm the treatment regime.

7.1.1.2 Harmful Algal Blooms

Cyanobacteria, also known as blue-green algae, is found in all natural waters. The right combination of conditions including nutrient rich waters, warm waters, and shallow, slow-moving or stagnant waters leads to the development of blooms (pers comms, Gordon Yasvinski). Since 1994, blooms of cyanobacteria and filamentous green algae have increased in Ontario (Winter et al., 2011). Warmer temperatures associated with climate change are a key contributor to the spread of these blooms (English et al., 2009).

Health risks from cyanobacterial toxins include respiratory irritation and allergic-type reactions when coming in contact with the skin (Health Canada, 2013b). Some cyanobacterial toxins attack the liver (hepatotoxins) or the nervous system (neurotoxins) and prolonged exposure may lead to long-term chronic effects. Consumption of water, fish or blue-green algal products containing elevated levels of toxins can result in headaches, fever, diarrhoea, abdominal pain, nausea and vomiting. Exposure to the toxins while swimming can lead to itchy and irritated eyes and skin, as well as other hay fever-like allergic reactions (Health Canada, 2013b). Not all cyanobacteria and blooms are toxic to humans. While harmful algal blooms are relatively less common than non-harmful algal blooms, in 2009, the Fanshawe Lake Conservation Area swimming beach in Middlesex-London was closed due to the presence of blue-green algae (Fanshawe Conservation Area, 2013).

7.0 Water-Borne Illnesses, Food-Borne Illnesses and Food Security

Water treatment plants mitigate the potential risk of exposure to toxins in drinking water through the depth of the water intake which is not near the surface where blooms occur. Municipal water treatment plants are also able to filter out the cells which contain most of the toxin. However, people with private water systems that are exposed to bloom toxins are more vulnerable to health impacts (pers comms, Gordon Yasvinski). The continued monitoring and treatment of algal outbreaks in the region's lakes and streams will be required as temperatures increase throughout the area due to climate change.

Socioeconomic Status

People with lower incomes and education may be differentially exposed to contaminated water (English et al., 2009), but more information is required to assess exposure given particular settlement patterns and access to or use of drinking water delivery systems and public beaches in Middlesex-London.

7.1.1.3 Projected Impacts of Climate Change

As temperatures continue to increase in the Middlesex-London region with a greater number of extreme heat events, people may increasingly use beaches to escape the heat, increasing their risks from contaminated water. In fact, the risk of drowning may increase as well. The National Drowning Report (Drowning Prevention Research Centre Canada, 2011) linked an increase in drowning deaths in Canada with hotter summers in 2005, 2006 and 2007 because of more people participating in aquatic activities. As well, travel to areas with limited access to safe drinking water can result in increased exposure to water-borne illness (Health Canada, 2008). Water-borne illness is projected to increase globally as the climate continues to change (Diaz, 2006).

7.1.2 Contamination of Food

7.1.2.1 Flooding, Outdoor Events and Travel

Food that has come in contact with flood waters (e.g., in a flooded home) is not safe to consume (McMichael and Kovats, 2000). Historically, flooding occurs between January and April in Middlesex-London, but can occur at any point throughout the calendar year. During periods of warmer weather, recreational events held outdoors—such as summer festivals or farmer's markets (7 throughout the region: Covent Garden Market Farmers Market; Ilderton Farmers Market; Lucan Farmers Market; Masonville Farmers Market; Ogilvie's Food and Artisan Market; Strathroy Farmers Market; Trails End Outdoor Farmers Market; Western Fair Outdoor Farmers Market; Southdale Artisan and Farmers Market)—may afford higher levels of exposure to food-borne illness, particularly where food is not handled, prepared or stored safely. Exposure to food-borne contamination is also possible during international or domestic travel to places that have limited access to clean drinking water (Health Canada, 2008).

7.1.2.2 Projected Impacts of Climate Change

The Food and Agriculture Organization of the United Nations reported that climate change will increase the exposure to harmful pathogens in food both in the home from contaminated foods purchased at public markets or grocery stores, and at restaurants (FAO, 2008), and risks are expected to increase in Canada as well (Health Canada, 2008). Rising temperatures are associated with increases in food-borne outbreaks of disease from microbiological agents (Rose et al., 2001), and increasing temperatures have been positively associated with salmonellosis cases in urban areas (D'Souza et al., 2004). However, food-borne illness is difficult to monitor and often goes underreported if symptoms are not severe (Health Canada, 2008).

Climate change will affect other areas of the world much more significantly than developed countries like Canada (WHO, 2012b). There is already international concern about projected migration patterns of human populations. As sea levels begin to rise, drought becomes more commonplace, and the geographic distribution of global disease changes. Water, food and travel-borne illnesses can be acquired in host countries and then be further transmitted to other locations through travel. Addressing the mental health impacts of immigrants who are disaster refugees may also require additional planning (World Health Organization, War Trauma Foundation and World Vision International, 2011).

7.1.3 Food Insecurity

Exposure to food insecurity in Canada and in the Middlesex-London region is dictated by a variety of complex drivers such as extreme weather events and climate variations, global food price volatility, the resilience and availability of local agriculture, and the individual's ability to afford healthy and nutritious food. In Canada, people at highest risk of food insecurity due to climate change are people living in northern communities including Aboriginal populations (Health Canada, 2008).

7.1.3.1 Projected Impacts of Climate Change

Climate change can affect food security globally through rising temperatures and the increasing incidence of droughts (Brown and Funk, 2008). Due to the interconnected nature of the global food system and our reliance on just-in-time delivery to grocery stores from international markets, droughts experienced in one part of the world can affect food prices and food security far away in other countries (Battisti and Naylor, 2009). In 2012, the top food producing regions in the United States, China and Russia all reported being in the midst of a 3-year period of drought which has affected the production of cereals (i.e., grains), corn, rice and produce (i.e., fruits and vegetables). Further, drought conditions have progressively increased over the last century, and droughts are typically followed by spikes in food prices due to a temporary reduction in global food supply and sustained global demand (Climate Change Food Security Organization, 2012). The negative effects of climate change on traditional foods of Aboriginal populations in northern Canada have been documented (Health Canada, 2014; Health Canada, 2008). However, the projected impacts of climate change on food security in southern Canadian communities is highly uncertain (Berry et al., 2014).

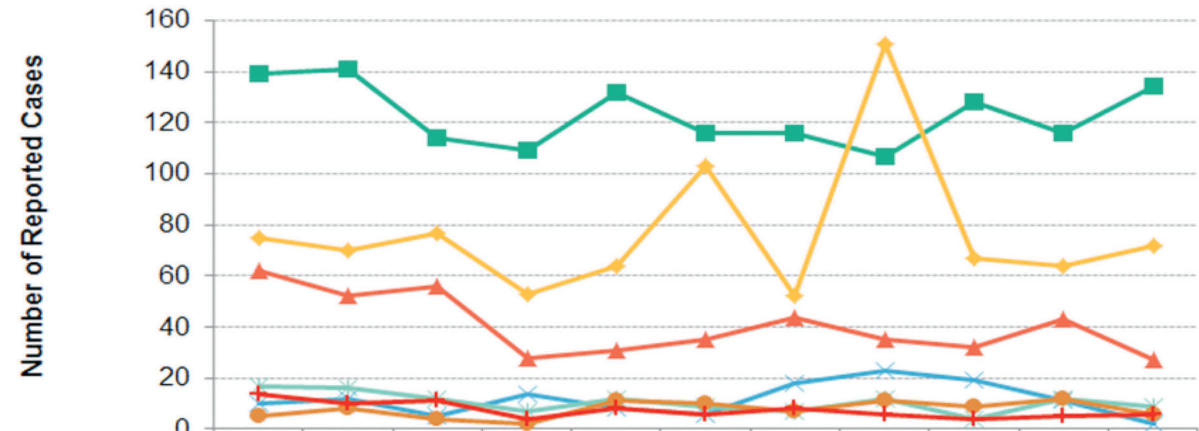
7.2 Sensitivity

7.2.1 Water-borne Illnesses

The incidence of a number of food and water-borne infections in Middlesex-London is associated with seasons and they generally increase over summer months (MLHU, 2014h). Illnesses caused by food- and water-borne diseases have been stable or have declined in the last few years in the region (Figure 18).

7.0 Water-Borne Illnesses, Food-Borne Illnesses and Food Security

Figure 18 - The number of reported campylobacter, salmonella, giardia, VTEC and cryptosporidium infections reported in Middlesex-London by month, 2000 to 2010 annual average



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Campylobacter	139	141	114	109	132	116	116	107	128	116	134
Salmonella	75	70	77	53	64	103	52	151	67	64	72
Giardia	62	52	56	28	31	35	44	35	32	43	27
Amebiasis	10	12	5	14	8	6	18	23	19	11	2
VTEC	17	16	12	7	12	9	7	12	4	12	9
Cryptosporidium	5	8	4	2	11	10	7	11	9	12	6
Shigella	14	10	11	4	8	6	8	6	4	5	6

Source: MLHU, 2014h

As reported in Figure 18 above, between 2000 and 2010 in Middlesex-London, the number of *E. Coli*, giardia, and amebiasis cases per year have declined. In 2010, there were 9 reported cases of VTEC infections (toxigenic *E. Coli*), 27 cases of giardia related illness, 2 cases of parasitic amebiasis caused by *E. histolytica* infection and 6 cases of Cryptosporidiosis (MLHU, 2013d). While some of these cases could have resulted from exposure to improperly cooked foods, they are also diseases commonly associated with the contamination of water sources, and the source of disease in most cases cannot be determined. Better monitoring of these diseases will benefit future efforts to control any increased risks to health from climate change.

Populations with elevated sensitivity to water-borne contamination and resulting illness include older adults, children and persons with suppressed or developing immune systems (e.g., transplant recipients; persons living with immune-suppressive disorders) (Casman et al., 2001; Balbus and Melina, 2009). For example, because of their lower body weight, children are at higher risk of serious liver damage from ingesting high levels of microcystins - one group of toxins released by cyanobacteria. Patients undergoing renal dialysis treatment are also at higher risk than other Canadians (Health Canada, 2013b). Data for each of these groups is captured elsewhere in this report (see Section 4.0).

7.2.3 Food-borne Illnesses

Middlesex-London has periodic outbreaks of food-borne diseases. Between 2000 and 2010, campylobacter and salmonella infections were more than two times higher than other reported food-borne diseases (MLHU, 2013d). However, rates of food-borne illness have remained stable during that time period, with only minor fluctuations year to year. In 2010, there were 72 reported cases of Salmonella, 134 reported cases of campylobacter, 9 cases of VTEC (*E. Coli*), 27 cases of giardia, 2 cases of amebiasis, and 6 cases of shigella (MLHU, 2013d). Similar to water-borne illnesses and vector-borne diseases, older adults, children and persons with suppressed or developing immune systems are particularly sensitive to food-borne illness.

7.2.4 Food Insecurity

People particularly sensitive to food insecurity under climate change include those who are already food insecure and persons with pre-existing chronic conditions, most notably high blood pressure, heart disease and diabetes. In 2009/2010, approximately 8% of households in Middlesex-London were classified as moderately or severely food insecure (CCHS 2009/10). In addition, in only one year from 2010 to 2011 the average weekly cost of a nutritious food basket to feed a family of four in Middlesex-London increased by 6.2% ($160 to $170) (MLHU, 2014i). Approximately 10.7% of people under the age of 65 in the region have high blood pressure and 1.8% self-reported having heart disease. However, people 65 and older have a substantially higher burden of high blood pressure (55.4%) and heart disease (18.8%). People living with diabetes may be less able to regulate their appetite by consuming healthy foods which can result in increased hospitalization. As of 2013, the prevalence of diabetes in the Middlesex-London population was estimated to be 5.4%, which is lower than the 6.8% provincial prevalence (Statistics Canada, 2013b).

7.3 Adaptation

7.3.1 Actions to Reduce Risks From Contamination of Drinking and Recreational Waters

An extensive slate of water quality monitoring activities in Middlesex-London helps to reduce risks to residents from drinking and recreational water contamination. Three provincial policies require a number of local risk management activities in protecting human health in relation to drinking water quality. Ontario's Safe Drinking Water Act (2002) regulates large communal and public drinking water services, but it remains up to the owners or operators of private individual systems (i.e., private wells) to ensure they meet safe water standards. The Clean Water Act (2006) regulates the protection of source water and mandates communication, outreach and awareness of source water protection by regional officers of the Ministry of the Environment. Further, the Health Protection and Promotion Act (1990) mandates the reporting and surveillance of water-borne illnesses, although the incidence of disease is likely to be underreported under existing surveillance methods. Under O.Reg 318/08 and 319/08, small communal and public drinking water systems are inspected by local boards of health on a 1-4 year inspection cycle if no problems are reported. However, given the potential challenges posed by severe extreme weather events associated with climate change, small drinking water systems can be more vulnerable than larger systems. Limitations among many small systems related to infrastructure, financial, technological and training account for this higher vulnerability (Moffatt and Struck, 2011; Brettle et al., in press).

MLHU works in cooperation with the local conservation authorities to ensure that bathing beaches are monitored in accordance with the Ontario Public Health Standards. MLHU posts links to beach closing advisories

7.0 Water-Borne Illnesses, Food-Borne Illnesses and Food Security

in other regional health units (i.e., Elgin, Huron, and Lambton counties) for people travelling outside of the region. MLHU is also required by the Ontario Public Health Standards to conduct surveillance of recreational water facilities (e.g., outdoor pools) throughout the region in accordance with the Recreational Water Protocol. In the event that people become ill from water contamination, a wide-range of health services are available throughout the region (see Section 4.3).

7.3.2 Actions to Reduce Risks From Food Contamination

The management of risks to health from food contamination are directed by a set of robust regulations and activities. The Ontario Food Safety and Quality Act (2001) provides regulations for the operation, maintenance and inspection of food processing activities and premises throughout the province. In accordance with the Ontario Public Health Standards (2008), all health units are required to conduct surveillance on suspected and confirmed cases of food-borne illness and inspect all food premises (e.g., restaurants, community kitchens, farmer's markets, outdoor events, etc.). The Public Health Standards also stipulate that health units ensure access to food safety training for handling foods properly to prevent the spread of disease. MLHU provides on its website comprehensive food safety information for facility operators, a protocol for special events, notes on food handling, storage and preparation. All inspections of food sites are conducted regularly by MLHU and the regional DineSafe program contains comprehensive records of food facility and restaurant inspections, which are publicly accessible. In the event that people become ill due to food-borne illness, the region has health and social service agencies to address these needs (see Section 4.3).

7.3.3 Actions to Reduce Risks From Food Insecurity

A number of municipally, regionally and provincially sponsored services exist throughout the region to help increase access to nutritious food for those in need. Regional boards of health are required under the Ontario Public Health Standards to monitor food affordability by publishing the results of the weekly cost of 67 food items in chain and independent grocery stores throughout the region. In 2011, the Ontario average was $169.17 per week for a nutritious food basket and Middlesex-London was slightly lower than that average at $160.85 (MLHU, 2010).

MLHU publicly posts guidelines for the distribution of donated foods on its website to ensure a safe, healthy food supply for residents throughout the region, which outlines proper storage, handling and donation procedures. Every month, MLHU also posts a list of meal programs and food banks in the format of a calendar of events and a comprehensive list which includes times and addresses of particular locations. In March 2013, there were 19 food bank programs operating throughout the region which usually provide a one to three day supply of food once every one to three months per individual or family. Additionally, there were 32 meal programs operating throughout the region supported by various community and faith organizations in March of 2013. All information is made accessible online and partnering organizations receive copies of resource sheets every month from MLHU. There are also regulations at the provincial and regional levels pertaining to sourcing local agriculture and supporting local growers and producers. Encouraging the development of appropriate policies that enhance the resilience of local agriculture can enhance the adaptive capacity of the region to global changes in food prices.

7.3.4 Adaptation Options

A range of measures exist that decision makers may use to help protect the citizens of Middlesex-London from water-borne and food-borne illnesses related to climate change. They include (Berry et al., 2014):

- Protocols for chemical and contaminant risk management;
- Monitoring of harmful algae bloom outbreaks;
- Boil water advisories;
- Expanding water reuse systems to offset reduced supply, increased demand, or both;
- Improving or expanding water treatment regimes;
- Adopting alternative energy sources at treatment plants (e.g., diversifying power sources, adding energy-efficient water pumps);
- Establishing collaborative management regimes with power suppliers;
- Abandoning or enhancing water infrastructure at risk;
- Distribution of drought public awareness materials/public service announcements, public education programs;
- Physical relocation of individuals/families to non-drought affected areas;
- School-based mental health programs in rural areas, participation of trusted adults who understand drought, early identification of mental health problems and referral;
- Training in coping mechanisms;
- Technological advances to increase food production in new climate conditions;
- Improved food delivery systems;
- Monitoring of gastroenteritis.

8.0 Adaptive Capacity

Adaptive capacity refers to the ability of individuals, communities, and institutions to prepare for and cope with the consequences of climate variability and change. Greater levels of adaptive capacity convey upon people increased ability to reduce the impacts of higher climate-related exposures which contributes to climate resiliency. Public health and emergency management officials proactively seeking to increase preparedness for climate change risks to health take measures to increase adaptive capacity.

8.1 Community Level Adaptive Capacity in Middlesex-London

A stakeholder assessment workshop was held on March 27, 2014 in the City of London. It brought together a total of 105 officials from a broad cross-section of the community including representatives from the health professions, government agencies, and community groups.

In preparation for the stakeholder workshop on climate change and health vulnerability in Middlesex-London, a questionnaire on adaptive capacity was sent in February 2014 to individuals from 29 organizations that have a direct or indirect role in increasing resilience to climate change (MLHU, 2014c). A summary of results from the workshop (Fook, 2014) and from the questionnaire is provided below.

8.1.1 Community Characteristics Increasing Vulnerability

Community stakeholders identified three key components of adaptive capacity that affect the resilience of Middlesex-London to climate change impacts on health – socioeconomic factors, levels of adaptation preparedness and community design and planning.

Socioeconomic Factors

Social determinants of health – defined by high unemployment levels in the region and people living in inadequate housing or with limited access to education - affect vulnerability to climate change impacts. Unemployment reduces income and may lead to unstable living conditions which could increase climate-related exposures (e.g., extreme heat events). Stakeholders also highlight the potential vulnerability arising from the agriculture base of rural economies, limits to fiscal resources and the significant costs of infrastructure renewal and repair.

Adaptation Preparedness

The current level of adaptation preparedness, including preparedness for extreme weather events, is a key indicator of adaptive capacity. In Middlesex-London, vulnerable populations may not be prepared for emergencies, have the necessary capacity to cope, or be resilient when an emergency happens. There is a need to ensure vulnerable populations are investing in emergency preparedness and taking precautionary steps. The resiliency of emergency management systems needs to be evaluated given that climate change may lead to more disaster situations. The capacity of these systems to respond effectively should be monitored regularly as more knowledge becomes available. Stakeholder partners also identified the importance of health care institutions having the requisite capacity to address the health risks from climate change.

8.0 Adaptive Capacity

Community Design and Planning

A preventative approach to addressing climate change impacts on health whereby harmful exposures to climate hazards are avoided to remove health threats is important for protecting populations. Stakeholders highlighted a number of important community design and planning issues related to Middlesex-London. For example, a current lack of shade combined with the urban heat island effect increase risks to health from extreme heat events. Active lifestyles can be promoted by planting more trees which also provide areas for people to find respite from the heat. In addition, aging infrastructure and vulnerability of the electrical grid to extreme weather events is a cause for concern in the community, as is residential and business development in high risk areas (e.g., on floodplains). Adaptation efforts should focus on climate resilient urban design measures, including those which achieve important co-benefits. There is an opportunity to design urban areas to encourage and facilitate active transportation to benefit health.

8.1.2 Effectiveness of Current Adaptations

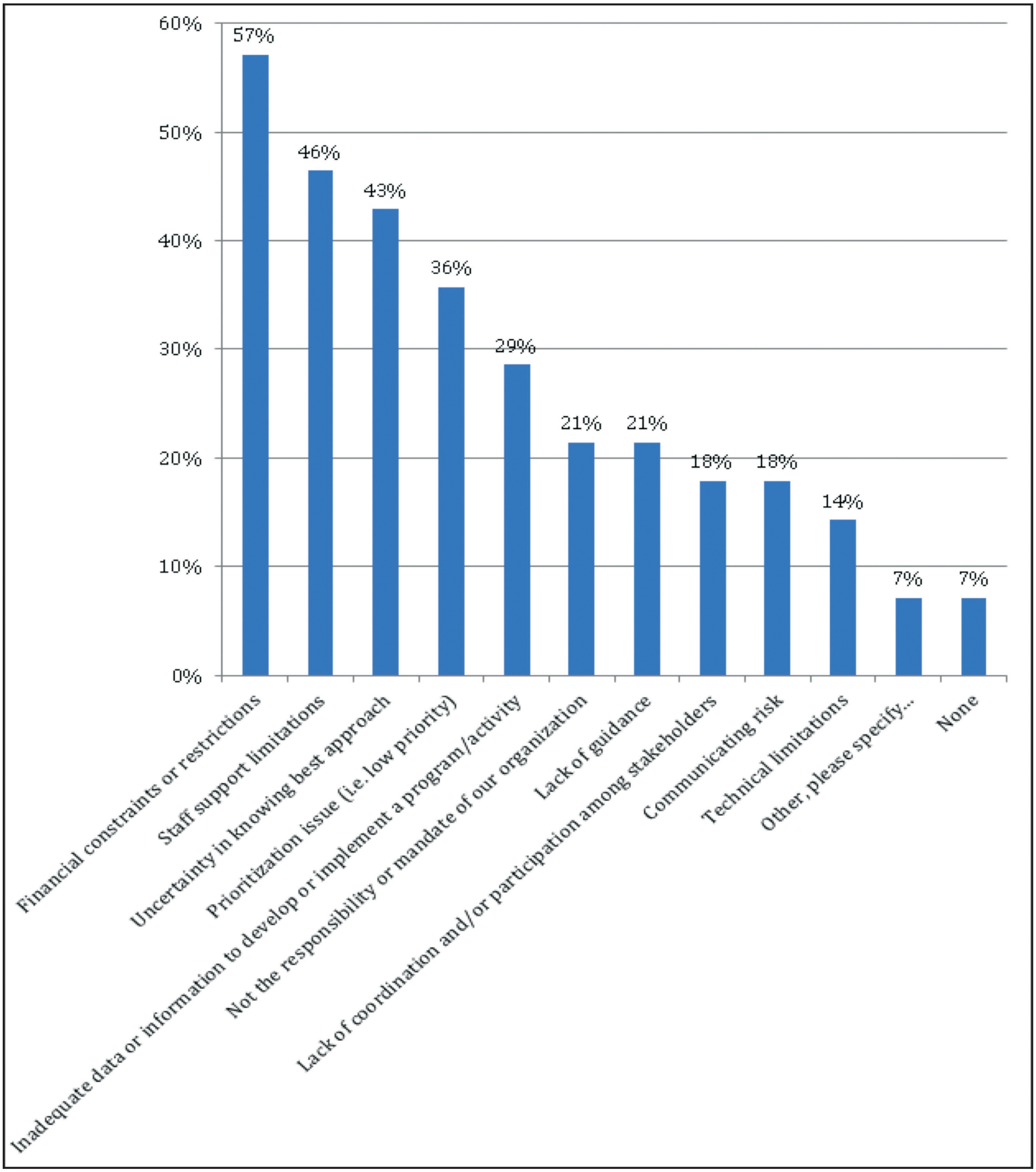
Stakeholder consultation revealed initiatives such as the sun safety program and the tracking of food-borne illnesses that are thought to be effective public health programs having important climate change adaptation functions. Key areas where efforts could be expanded to increase adaptive capacity include increasing awareness of the population to risks to health from climate change and needed protective measures. Adaptation benefits may also be derived by making health services more accessible through decentralization in order to more effectively reach vulnerable people. Regular monitoring of adaptation progress and evaluations of the effectiveness of programs (e.g. monitoring air pollution over time coincident with implementation of programs) will increase adaptive capacity. However, a challenge exists in monitoring and evaluating adaptations due to the difficulty in linking program outputs with health impacts from climate change that may increase or decrease gradually over the longer-term but also very quickly through discrete/acute disasters or events. In this regard, the burden of climate change on health is unknown due to inadequate surveillance and monitoring of impacts.

8.1.3 Existing Barriers to Adaptation and Opportunities for Action

Community stakeholders identified a number of barriers to public health adaptation in Middlesex-London. The top barriers identified through the questionnaire were (1) financial constraints, (2) staff support limitations, (3) uncertainty about the best risk management approaches and (4) low prioritization of the issue (Figure 19).

8.0 Adaptive Capacity

Figure 19 – Barriers to implementing programs, activities or measures to reduce health risks from climate change



Source: MLHU, 2014c

8.0 Adaptive Capacity

Estimating Costs of Impacts, Adaptation and Inaction

An important challenge for moving forward with further adaptation initiatives in Middlesex-London relates to the limited information on the health costs of climate change. Economic analysis of climate change and health adaptation which can be presented to decision-makers to illustrate costs of adaptation (e.g., the costs of implementing a HARS), and of inaction, would benefit preparedness efforts. This information would aid in consideration of the value of undertaking preventative actions to reduce climate change risks to health against more urgent or acute health concerns in the community. Quantifying the costs of big disasters and making this information available provides the opportunity to raise awareness of climate change and health issues and obtain support for adaptive measures. Post-disaster or extreme event studies may be undertaken to estimate costs saved if preventative mitigation measures were implemented.

Uncertainty About Future Climate Change, Weather Variability and How to Respond

A significant barrier to taking actions to protect people in Middlesex-London identified by stakeholders was the uncertainty about future climate change, weather variability and how to respond. However, it was noted at the workshop that current adaptive actions should be based on all available information and not delayed due to uncertainty. In this regard, a useful strategy is to implement cost-effective measures that achieve co-benefits and address current and foreseen issues. Policies and programs that address multiple risks (e.g. plant trees to reduce air pollution, enhance flood prevention and drought mitigation and reduce the UHI) are beneficial as are actions that target both adaptation and greenhouse gas mitigation goals at the same time (e.g., increasing active transportation).

Adaptation Governance and Avoiding Silos

Effective institutional arrangements to support climate change and health adaptation are a fundamental component of adaptive capacity. Efforts to reduce health risks in Middlesex-London would benefit from greater clarity on roles and responsibilities of provincial and regional health organizations (e.g. LIHNs) for addressing climate change hazards at municipal and community levels. This would support needed efforts to bring a climate change and health lens to existing efforts to adapt to impacts within the community. For example, climate change and health considerations (e.g., future risks) and messages should be inputted to planning and program development in other sectors (e.g. forestry, parks, environment, city planning etc.) to achieve co-benefits and to avoid maladaptation. A climate change action plan that includes all key sectors would benefit the residents of Middlesex-London.

Communications Challenges

Stakeholders working directly with the public in Middlesex-London indicated that awareness and communication are the key to successful adaptation. Efforts are needed to change how we talk about climate change with partners and the public. It may be helpful to nuance terminology when communicating climate change issues. Instead of describing GHG-induced climate change or global warming it is useful to describe the phenomenon as *changing climate, climate variability* or *changing weather patterns.* It may also be helpful to take advantage of past climate-related disasters to drive home messages on the need to prepare for climate change and to garner support for adaptation actions.

However, direction is needed about how to effectively communicate climate change and health risks to the public. Should health authorities be more proactive in terms of messaging on climate change and health? How explicitly should issues related to exposures to current hazards (e.g. floods, drought, air pollution,

8.0 Adaptive Capacity

extreme heat) be communicated through a climate change lens? Current messaging on climate-related health risks does not generally consider or include information about the effects of climate change. A useful approach may be to employ messaging initially related to specific health issues and then discuss them from a climate change perspective – start at the root of the issue that is immediately meaningful to public.

Youth in Middlesex-London are often not aware of climate change issues and their implications for health. It would be of benefit to work with schools to develop effective ways to get the messages about climate change impacts and protective measures to this part of the population. Integrating guidance information and solutions to address climate change into the education curriculum would help to begin to change the culture. A greater use of social media may be particularly effective in this regard. As well, people in rural areas may not be receiving adequate information on how to adapt to health impacts of climate change. Health authorities should ensure that climate change and health information is disseminated to rural residents and rural decision-makers.

Through the Middlesex-London workshop a number of ideas for mobilizing the community to reduce climate change risks to health were identified (Table 11).

Table 11 - Options for organizing community partners in Middlesex-London to reduce climate change risks to health

Area	Suggested Actions
Collaboration, decision-making and planning	*Collaboration* • Pursue opportunities for ongoing collaboration with regional organizations – e.g. create steering committee or ongoing working group on regional climate change and health issues o Identify areas of overlap and consolidate information, experiences, strategies and best practices; o Bring together a comprehensive network of community partners (e.g. have all the vulnerable populations been identified and represented?); o Include representatives from the public; o Use the progress made on the water climate change strategy in London as a building block and incorporate the health piece into it. • Multi-agency involvement is needed as relying on one agency as a point of entry is limiting • Health professionals should collaborate with planners on healthy and climate resilient community design *Decision-making* • A steering committee could assist in making effective climate change resiliency decisions at the regional and lower-tiered municipal levels • City planners should develop a framework for planning and decision- making across sectors o Include consideration of a broad range of climate change risks to health o Provide the opportunity for public input regarding implementation of actions that achieve climate resiliency • Evidenced based decision-making is needed o Decision-making should focus not only on costs and short-term gains *Planning* • Middlesex-London would benefit from creation of an adaptation action plan for the region o However, need to reference and address adaptation through a larger process of collaboration and integration between health and other initiatives and services o Adapt over the long term to become more resilient o Some LTCHs, community groups, etc. have action plans • Organize around four key aspects: hospitals, schools, urban areas (London), rural areas (county)

8.0 Adaptive Capacity

Area	Suggested Actions
Stakeholder and community engagement	• Increase outreach and involvement to/of the student community • Use social media initiatives to increase engagement and awareness • Multi-sector and stakeholder engagement including public outreach and engagement is needed • There are many opportunities (e.g., conferences) to support engagement – there is a need for work at the community level through multidisciplinary efforts • A community adaptation plan can be taken back to individual organizations
Development of knowledge sharing capacities	• Pursue opportunities for sharing knowledge, expertise and adaptation approaches and creating broader institutional networks o Great interest in sharing best practices and lessons learned • Strengthen and expand partnerships to identify duplication and redundancy, and combine efforts to save resources • Coalesce around common issues and concerns (e.g., similarities in characteristics of vulnerable populations and how to identify and support them better) • Provide policy makers with knowledge required to make informed decisions on effective climate change greenhouse gas mitigation and adaptation strategies that are not maladaptive and that achieve co-benefits
Integration of climate change and health issues with other sector policies	• Need to consider green transportation solutions for rural areas as it is difficult to travel without dependency on vehicles – need to consider this when planning and zoning in rural areas is being undertaken • Engineers need to integrate climate change considerations into infrastructure design including waste-water and water treatment facilities • A community energy action plan for London would engage diverse stakeholders to advocate on different issues related to energy. Hydro needs to be aware of climate change risks and measures needed to increase resiliency of power generation and distribution systems • Involve industry leaders, including insurance companies by identifying corporate interests and advocating for their involvement to promote greenhouse gas mitigation and adaptation to reduce costs

Source: Fook, 2014

8.2 Individual Level Adaptive Capacity

Social Capital

Ebi and Semenza (2008), Keim (2011) and Cheng and Berry (2013) indicate the importance of social capital and strong relationships at the community level for adapting to disasters. Building a culture of trust and reciprocity throughout a community can help enhance its resilience to disasters. Households with multiple people in close proximity to other residents can also aid in disaster response by sharing resources and helping where necessary. Volunteerism and the proportion of single person or lone-parent households can be important indicators of vulnerability. In addition, people who live alone and lone-parent families may also be particularly vulnerable to climate-related disasters, due to a limited ability to remove oneself from a disaster-affected area (Keim, 2011). People who have lower levels of social support (e.g., living alone) may be less able to adequately access or comprehend heat alert warnings and appropriate health promotion messaging to protect themselves during extreme heat events (Health Canada, 2011b; O'Neill and Ebi, 2009; Ebi et al., 2006).

Single person households comprise roughly 28% of all households in Middlesex-London relative to the provincial average of 24% (Statistics Canada, 2006a) and the proportion of older adults living alone was 29.1%.

8.0 Adaptive Capacity

Additionally, lone parent households comprised 16.5% of all census families in Middlesex-London relative to 15.8% for Ontario (Statistics Canada, 2006a). In 2006, 19% of the population aged 15 and over reported providing unpaid care or assistance to older adults (20% for Ontario on average), and 40% reported providing unpaid care to children (relative to approximately 42% for Ontario on average) (Statistics Canada, 2006a). Gathering more information about volunteerism and developing a comprehensive action plan to mobilize volunteers in the event of an emergency, including encouraging residents to check-in on their neighbours, can be effective strategies to enhancing the adaptive capacity of communities (Health Canada, 2005). However, the current data indicates that Middlesex-London has a higher proportion of single-person households and slightly lower levels of volunteerism when compared with the rest of the province which may result in relatively higher vulnerability to disasters.

Income Levels

Kovats, Wilkinson and Menne (2010) found that disasters and extreme weather will have greater impacts on socially and economically marginalized communities. For example, persons with relatively lower incomes may have increased difficulty recuperating from the financial impacts associated with home repairs following a storm (Keim, 2011), and income and education may also play key roles in adapting to the effects of extreme weather. Social status has also been linked to the mental health impacts associated with disaster, and the loss of life or home (Haines et al., 2006). With respect to extreme heat events, people may be at higher exposure to hot temperatures if they lack financial resources or education (Kovats, Wilkinson and Menne, 2010). Those with lower incomes may have less ability to engage in adaptive behaviours such as accessing cool, air conditioned places, and may lack access to health and social services relative to other individuals with greater income (Balbus and Malina, 2009; Vescovi et al., 2009). The homeless may have higher levels of exposure to heat and may be particularly vulnerable under climate change.

People with lower incomes may also be at higher risk of food insecurity due to a reduced ability to purchase healthy and nutritious foods. In addition, people with a lower education may lack an understanding of dietary requirements (Kirkpatrick and Tarasuk, 2003). In Middlesex-London, the cost of a nutritious food basket—a basket containing the necessary dietary requirements to feed a family of four for one week—has increased over time. Between 2009-2011, the cost of a basket increased from $160/week to $170/week.

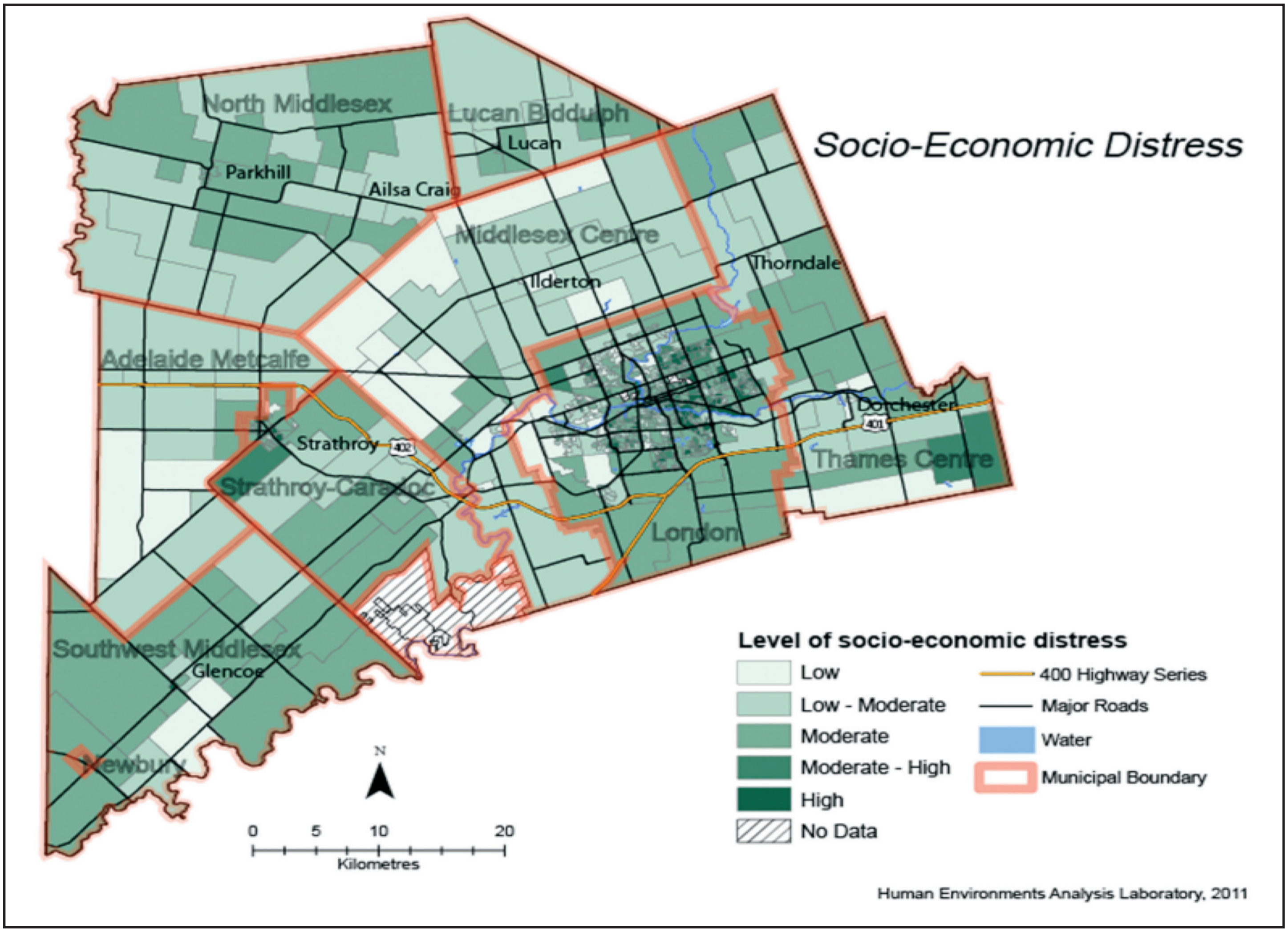
In 2006, 10.4%, or just under 50,000 people in Middlesex-London were classified as low-income relative to 11.1% of Ontarians. As well, 12.5% of people less than the age of 18 years old were low-income relative to 13.7% of Ontario's youth population. In 2006, approximately 21.3% of the region's population aged 15 years and older had not received a high school diploma (lower than the provincial proportion of 22.2%). While it is difficult to assess the exact number of people who are experiencing homelessness in Middlesex-London, a 2003 study carried out on behalf of the Salvation Army found that shelters in the City of London serve an estimated 4,000 people per year through the provision of temporary housing and food (De Bono, 2003). Low socioeconomic status (SES) in the London Census Metropolitan Area (CMA) is associated with a higher prevalence of some illnesses and conditions that may be exacerbated by climate change. For example, within the London CMA, the group with the lowest SES had 4.7 times the rate of hospitalizations for chronic obstructive pulmonary disease, 4.5 times the rate of anxiety disorders and 3.5 times the rate of diabetes than those with the highest SES (MLHU, 2014d). Consequently, the area served by the MLHU has large numbers of people

[2] The socioeconomic distress index is a composite of data on the highest level of completed education, unemployment rate, lone parenthood rate and low income rate (MLHU, 2014e).

that are potentially highly vulnerable to extreme weather events and disasters by virtue of their low income, education or because of other personal circumstances (living alone, lack of caregiver during emergency).

For the past several years, unemployment rates in London and surrounding areas have been among the highest in Canada, and recent Statistics Canada data indicate that unemployment reached 9.5% in March, 2013 (up from 8.3% in March, 2012) (Statistics Canada, 2013a). Individuals with low incomes or persons experiencing homelessness may be at higher risk of being affected by flood conditions and resulting health risks can be exacerbated during a disaster. People who are street-involved or experiencing homelessness may lack quality shelter, thereby increasing their exposure to weather events (McMichael, Woodruff and Hales, 2006; Greenough et al., 2001). People living in overcrowded accommodation may also be particularly vulnerable to extreme weather events if indoor environments become compromised by storm water or high winds (Vardoulakis, Thornes and Lai, 2012). Figures 21 and 22 provide information on levels and spatial distribution of socioeconomic distress within Middlesex County and the City of London[2].

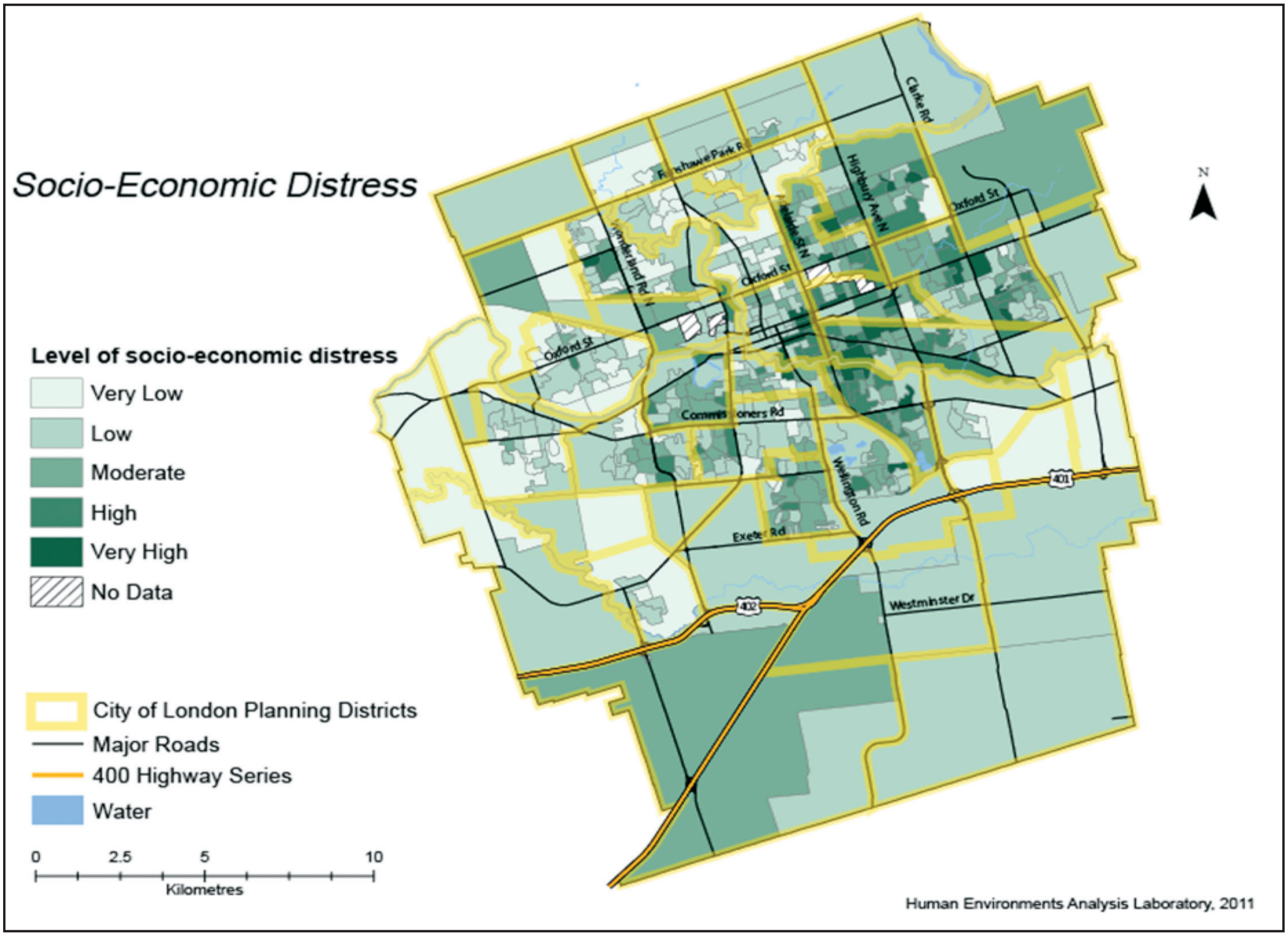
Figure 20 – Socioeconomic distress within Middlesex County



Source: MLHU, 2014e

8.0 Adaptive Capacity

Figure 21 – Socioeconomic distress within the City of London



Source: MLHU, 2014e

Air conditioner ownership

Data on individual air-conditioner ownership, access or use is not currently available for the region, but Natural Resources Canada (2010) estimates air conditioner ownership to be at approximately 80% in Ontario—the highest proportion of ownership among all Canadian provinces. However, relying solely on air conditioning is a problematic intervention for extreme heat. Increased air conditioning use can exacerbate energy insecurity and climate change by increasing GHG emissions, and can acclimatize people to narrow ranges of temperatures potentially making them more sensitive to extreme heat events in the future (Maller and Strengers, 2011; Richardson, Kagawa and Nichols, 2008).

8.0 Adaptive Capacity

Visitors and Newcomers, Socioeconomic Status and Social Isolation

Visitors and newcomers may be more vulnerable to extreme weather events (e.g., extreme heat events, flooding) due to cultural differences in dress, limited knowledge of health services and weather warnings, and language barriers which may prevent the effective communication of health messaging during heat alerts. In 2010, the City of London had many visitors—1,414,000 people from other parts of Canada; 164,000 people from the United States; and 31,000 people from other international destinations (Tourism London, 2010). Additionally, between 2001-2006, Middlesex-London became home to 12,350 new immigrants to the region. According to the most recent census information, about 1.1% (or 4,970 people) of the region's population speaks neither French nor English, which is lower than the 2.3% of the provincial population that speaks neither official language (Statistics Canada, 2006a).

Middlesex-London has a large proportion of the population who immigrated to the region (approximately 83,450 people) (Statistics Canada, 2011a). In the United States, research has demonstrated that racialized communities tend to experience greater exposure to heat events and have relatively poorer health status as a result of pre-existing socio-economic inequalities and by virtue of where they are located in particular towns or cities (O'Neill and Ebi, 2009). More research is required to understand if communities in Middlesex-London with higher proportions of new immigrants have higher exposure to extreme heat events.

9.0 Knowledge Gaps

Future efforts to adapt to the growing health risks from climate change in the Middlesex-London Region will benefit from improving knowledge of individual and community level vulnerabilities to the impacts. This assessment report provides baseline information that can inform subsequent research activities. Knowledge and data gaps related to vulnerabilities in the region include:

Extreme Weather and Natural Disasters

- Temperature /mortality curves for identification of heat alert triggers;
- Number of workers employed in high heat environments or outdoors;
- Heat-related morbidity and mortality attributed to outdoor physical activity and participation in outdoor events;
- Air conditioner usage;
- Relationship between violent crime and domestic violence and temperature;
- Morbidity and mortality associated with a range of extreme weather events (e.g., flooding, drought, tornadoes, etc) including the mental health impacts;
- The number of buildings with higher floors and whether large numbers of vulnerable populations reside in those buildings;
- Exposure and health impacts of extreme heat on new immigrants;
- Why there was not a significant increase in the number of heat alerts called or heat alert days although there was an increase in the number of hot days over the last decade.

Air Quality

- Modelling of air quality morbidity and mortality;
- Indoor air quality and impacts of rising temperatures;
- The number of seasonal allergy sufferers;
- Impacts on indoor air quality after flood events;
- Exposure to poor air quality by socially or economically marginalized groups and visitors and newcomers;
- Whether climate change is lengthening the pollen season.

Vector-borne Diseases

- Possible vector breeding sources and surveillance of novel or emerging diseases;
- Exposure pathways such as stagnant water sites and the use of outdoor recreation facilities to better understand risks from mosquito-borne diseases as the climate changes;
- Health risks to people living in Middlesex-London from climate-related vector-borne and zoonotic diseases becoming endemic in other regions of the world.

Food, Water and Food Insecurity

- Morbidity and mortality related to food and water-borne diseases caused by climate hazards (e.g., floods, algal blooms etc);
- Improved monitoring of local food sourcing capacity and inspection;
- Extent of food security.

9.0 Knowledge Gaps

Adaptive Capacity

- Data on health and social services utilization during extreme weather events and disasters;
- Evaluation of the effectiveness of existing risk management/adaptation measures (e.g., natural disasters, heat, cold, air quality, infectious diseases, water- and food-borne contamination, food insecurity) including effects on behavioural change in the population;
- Perceptions of decision makers and the general public about risks to health from climate change and the need to take proactive adaptations;
- Evaluation of the capacity of health, social and emergency services to prepare for and respond to an expected increased health burden associated with climate change;
- Challenges and opportunities faced by rural and urban communities in Middlesex-London to adapt to climate change.

Addressing these information gaps will be important for efforts to more fully understand health vulnerability in the region and institute appropriate risk management activities. Having access to appropriate baseline information will also be important to developing iterative evaluation processes to monitor changes in population health and the impact of future public health adaptation programs and policies. However, some basic adaptations including evaluations of existing programs using the lens of climate change can be implemented without new data sources.

Updating the information in this report with data from new tools for assessing climate change vulnerability would also be useful. For example, adaptation efforts would benefit from climate modelling and health outcome projections with better resolution, specific to the Middlesex-London region. This report characterizes future climatic shifts according to broad regional climate projections and models; model results specific to Middlesex-London or the province of Ontario would aid in forecasting future health impacts. Additionally, new technologies that employ satellite photography (i.e., heat maps), when coupled with GIS mapping resources, can create informative graphics about priority neighbourhoods and communities with relatively higher degrees of vulnerability (e.g., due to a high proportion of older adults, children, or areas which are socio-economically marginalized). Finally, a more formal evaluation of health services throughout the region would benefit adaptation efforts as climate change continues. For example, the Canadian Coalition for Green Health Care has developed a toolkit for hospitals to use to assess their resilience to climate change (Paterson et al, in press). Resilient health services will ensure rapid response in the event of emergencies, or during periods with increasing incidence of morbidity or mortality.

Glossary

A2 Modelling Scenario: The IPCC's Special Report on Emissions uses several emissions projections to estimate future climate change scenarios. The A2 scenarios assume a continued trend of a divided world with increasing global population, regionally oriented economic development, and self-reliant nation states with relatively stable increases in greenhouse gas emissions for the foreseeable future.

Adaptation: The process of enhancing, developing, or implementing strategies and measures to moderate or cope with the consequences of probable climatic changes. In public health, adaptation can be considered to be synonymous with prevention.

Adaptive capacity: The ability of individuals, communities, and institutions to prepare for and cope with the consequences of climate variability and change.

Climate: "Average weather" in a particular place over a particular time period; typically refers to statistically 'average' variability of weather variables (i.e., temperature, precipitation) over a pre-defined time period.

Climate-related risk: Likelihood of exposure or the consequence(s) of exposure arising from a health hazard.

Climate change: Statistically significant variation of observed climate behaviour in either the mean state of the climate or in its variability. Climate change results from natural processes and persistent anthropogenic (i.e. human induced) changes to the composition of the planet's atmosphere with resulting shifts in regional weather patterns.

Exposure (to climate-related hazards): The differential degree to which a person or group is in contact with a factor and the extent to which this level of exposure causes impacts to health; can also capture locations where exposure tends to occur or areas where exposure is greatest.

Greenhouse Gas Emissions (GHGs): Any gas in that atmosphere that absorbs and emits thermal infrared radiation which is the fundamental process involved in the greenhouse effect. Notable gases include carbon dioxide, water vapour, ozone and methane.

Health: A state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.

Intergovernmental Panel on Climate Change (IPCC): An intergovernmental body of scientists established by the United Nations, the World Meteorological Organization and the United Nations Environment Programme to provide scientific assessments on the worldwide risk of global climate change and associated implications for humans and natural environments.

Mitigation: Actions or measures (e.g. policy) taken to reduce greenhouse gas emissions and/or enhance the capture of greenhouse gas emissions through green space initiatives.

Glossary

Population health: Population health describes an approach to health promotion that aims to improve the health status of an entire population and to reduce health inequity/inequality among and between population groups. A population health perspective considers a broad range of social, environmental, economic, and biological factors and conditions that influence human health and wellness.

Public health: Promote the health of populations by preventing morbidity and mortality through a broad range of research, programming and policy activities.

Sensitivity: Refers to how individuals and/or populations are influenced by factors such as physiology, biology, genetic endowment, gender or age in ways that make them more susceptible to the health impacts of climate change.

Socioeconomic status (SES): A relative measure of social status, typically understood as a function of an individual's education, income, and occupation.

Vulnerability: The degree to which a system is susceptible to or unable to cope with the adverse effects of climate change. Vulnerability a function of a population's exposure to climate hazards, sensitivity to those impacts, and adaptive capacity.

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