Climate Change Impacts in Windsor:
A Technical Analysis

Supporting information for the 19 possible climate change impacts as identified by the City of Windsor

Version 2: November 2019

A Guide to Understanding the Impact Summary Pages

Impact Statement:

Impact statements consider projected climatic change projections and their effects on built, natural, social and economic systems. Impact statements are intended to capture:

- A climatic threat/change (i.e. increase in temperature)
- The outcome of the climatic change (i.e. heat waves in summer)
- The consequences associated with this outcome (i.e. power outages)

The summary pages were designed to provide more specific information for each of the impact statements identified with a risk assessment rating higher than Medium-Low.

Vulnerability:

Vulnerability was assessed based on the sensitivity and adaptive capacity of the department due to the respective climate impact. The sensitivity was judged on how the climate impact would affect the functionality of the department, whereas the adaptive capacity identifies the resulting cost and disruption if adaptation planning does not occur.

Using the vulnerability matrix shown in Table 1, the vulnerability score was completed. A vulnerability score of V3 or higher moved onto the risk assessment.

Table 1. Vulnerability matrix based on sensitivity and adaptive capacity.

		Sensitivity: Low → High				
		S1	S2	S3	S4	S5
Adaptive Capacity: Low ↓ High	AC1	V2	V2	V4	V5	V5
	AC2	V2	V2	V3	V4	V5
	AC3	V2	V2	V3	V4	V4
	AC4	V1	V2	V2	V3	V3
	AC5	V1	V1	V2	V3	V3

Risk Assessment:

Risk is a function of likelihood and consequence, where likelihood is the probability of the impact occurring and the consequence is the known or estimated consequences to the community if a particular climate change impact occurs.

Likelihood:

The likelihood rating was evaluated based on the estimated recurrence of the climatic impact as shown in Table 2. A likelihood rating of almost certain (5) was given to the impacts where the departments indicated that they are already experiencing the impacts.

Table 2. Chart used to determine likelihood rating.

Likelihood Rating	Recurrent Impact	Single Event
Almost Certain (**5**)	Could occur several times per year	More likely than not – probability greater than 50%
Likely (**4**)	May arise once per year	50/50 chance
Possible (**3**)	May arise once in 10 years	Less likely than not but still appreciable – probability less than 50% but still quite high
Unlikely (**2**)	May arise once in 10 years to 25 years	Unlikely not but not negligible – probability low but noticeably greater than zero
Rare (**1**)	Unlikely during the next 25 years	Negligible – probability very small, closer to zero

Risk Assessment:

The consequence ratings were completed using a community viewpoint lens. Risk was determined through social, economic and environmental factors as seen in Table 3. The factor values were added together to obtain a subtotal risk score for social, economic and environmental risk respectively. These subtotal risk scores were multiplied by the likelihood amount and added together for a final total risk score. The total risk score is boxed, in the top right hand corner of each impact summary page.

The subcategory and total risk scores were further categorized from very low to extreme based on the scale shown in Figures 1 and 2. Impact statements with total risk scores of medium-low and above have had an impact summary page generated.

Table 3. Risk score categories and their corresponding factors.

Social Risk	Economic Risk	Environmental Risk
Public Health and Safety	Property Damage	Air
Displacement	Local Economy and Growth	Water
Loss of Livelihood	Community Livability	Soil and Vegetation
Cultural Aspects	Public Administration	Ecosystem Function
$\boldsymbol{A} = \text{Total } \textbf{Social} \text{ x Likelihood}$	$\boldsymbol{B} = \text{Total } \textbf{Economic} \text{ x Likelihood}$	$\boldsymbol{C} = \text{Total } \textbf{Environmental} \text{ x Likelihood}$
$\text{Total Risk} = \boldsymbol{A} + \boldsymbol{B} + \boldsymbol{C}$		

Figure 1. Scale used to evaluate subcategory risk scores.

Figure 2. Scale used to evaluate total risk scores

Supporting Information:

Where available, the impact summary page includes supporting information that may assist in developing appropriate adaptation actions.

Supporting information may include:

- Historical climate information;
- Climate Change projections;
- Event based data;
- Relevant research papers; and
- Departmental, Community and traditional knowledge.

The supporting information will be refined and expanded overtime as more information is obtained.

The Cost of Doing Nothing:

Where possible, the cost of doing nothing was estimated. Developing cost estimates required either past events, climate change modelling (ex. Sewer Master Plan and East Riverside Flood Risk Study) that may be representative of future events, or published papers (i.e. published papers or government documents) that identified possible costs. Where data was limited, the cost of doing nothing was not estimated or was calculated based on known current costs to the Corporation.

The cost of doing nothing is not to be taken as an absolute cost risk for inaction but should be viewed to provide context into the possible magnitude of costs associated in the event the impact could occur.

Assumptions, limitations, methodology and resources used are included to provide clarity in understanding the estimates provided.

The impact summary pages are considered working documents to be modified as required over the life the project. These pages may also be used to track events over the life of any future climate change adaptation plan.

Total Risk Score:

175

Impact #1: More extreme weather events increasing the health and safety risk to the community

Likelihood	5	Almost Certain
Social	70	High
Economic	70	High
Environmental	35	Medium-Low
Total	175	Medium-High

Vulnerability	Department	Impact Statement
V5	Community Development	Increased demand on emergency social services
V3	Transit	Providing evacuation services
V3	Emergency Preparedness	Increased demand for emergency services and centers
V2	Emergency Preparedness	Lack of adequate notifications at the moment

Links to Community Risk Assessment

Statement	Social	Economic	Environmental	Overall Risk
Increasing risk of public health and safety risks due to lack of public knowledge about climate change	65	75	85	225
Increased frequency of extreme weather events causing strain on emergency responses and community service providers	45	50	20	115
Extreme precipitation and flooding can block access to key roadways and infrastructure throughout the community, leading to isolation of residents and/or challenges for emergency services	40	36	16	92

Supporting Information

Canadian Natural Disasters

The Canadian Disaster Database (CDD) contains detailed disaster information on more than 1000 natural (biological, meteorological, geological), technological and conflict events (excluding war) that have happened since 1900 at home or abroad and that have directly affected Canadians.

The figure below outlines the total number of meteorological disasters for a given decade (Figure 1). The last update to the Database was in 2016 and as such the last decade shown in the figure represents only 6 years.

The CDD tracks "significant disaster events" which conform to the Emergency Management Framework for Canada definition of a "disaster" and meet one or more of the following criteria:

- 10 or more people killed
- 100 or more people affected/injured/infected/evacuated or homeless
- an appeal for national/international assistance
- historical significance
- significant damage/interruption of normal processes such that the community affected cannot recover on its own

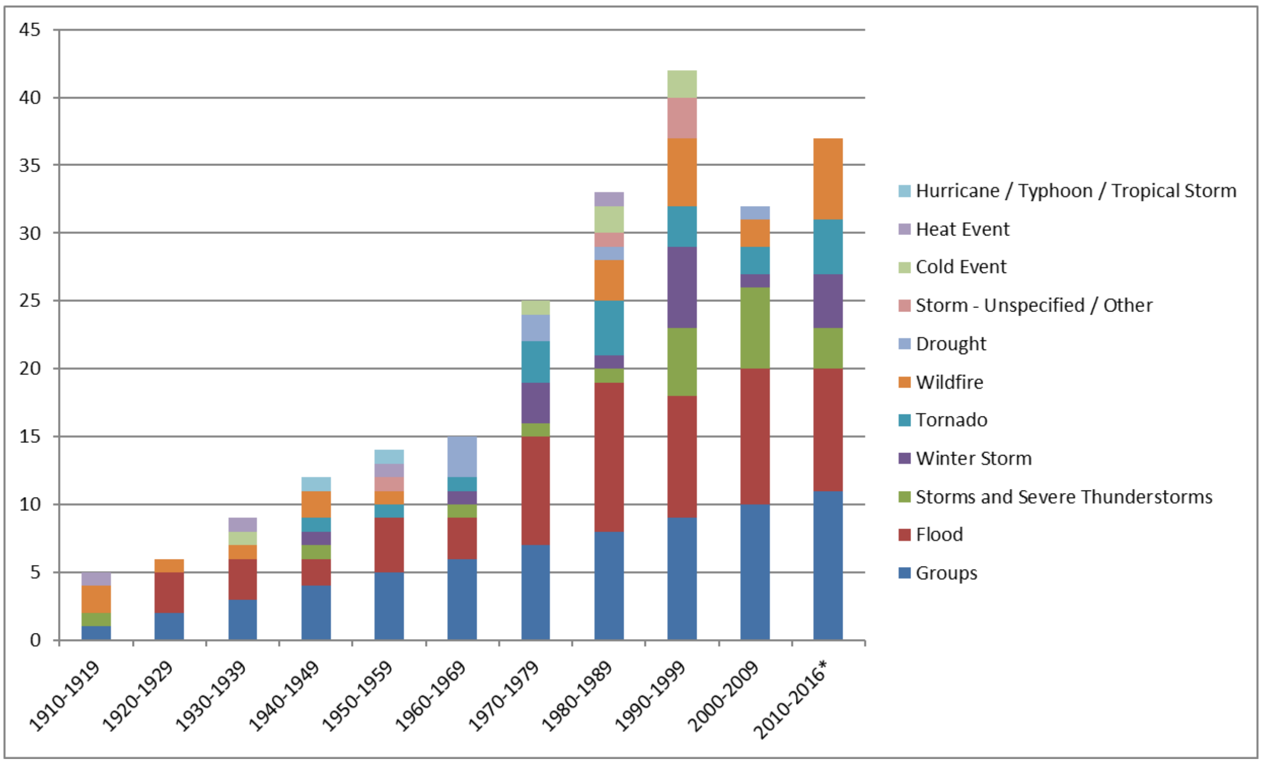


Figure 1: Number of Natural Disasters as documented in the Canadian Disaster Database (source: Public Safety Canada)

Figure 2 below shows the exponential growth in the number of insurance claims as wind threshold gust increases to over 90 km/hour.

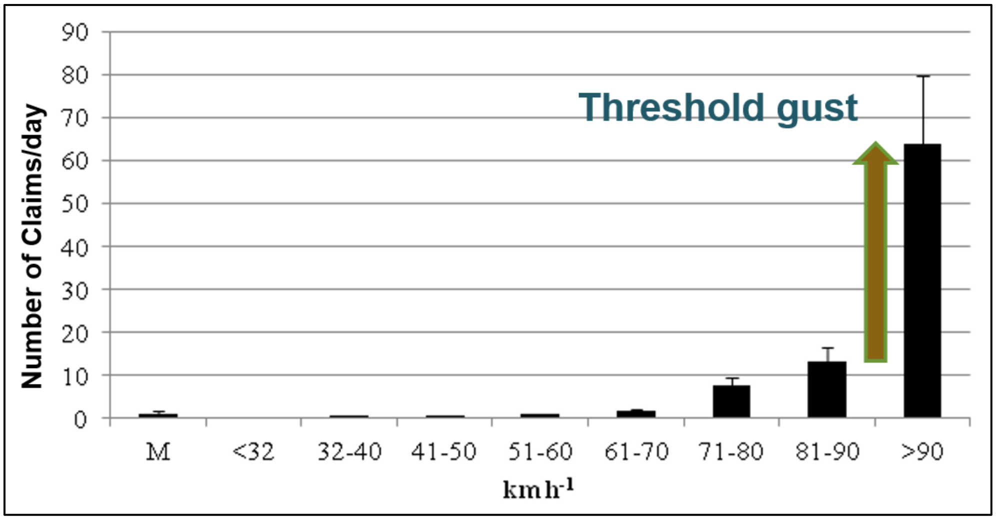


Figure 2: Southern Ontario Insurance Claims for Housing and Building from Severe Wind Events (source: Auld, 2015)

Lightning flashes per square kilometer per year as determined by the government of Canada show Windsor to Guelph as having more lightning than many other areas in Ontario (Table 1).

Table 1. Greatest Single Year lightning flash density (flashes per square kilometer per year) for Southern Ontario (source: Government of Canada)

Area	Average Flash Density (flashes per square kilometer per year)
Simcoe-Delhi-Norfolk	8.0+
Windsor to Guelph	5.0
Lake Simcoe to Belleville	3.5
Guelph to Lake Simcoe	3.0
Lake Simcoe to Belleville North	1.75

Local Events

The following natural disasters have occurred in Windsor and Essex County with resulting public safety risk to City of Windsor residents:

Table 2. Natural Disasters in Windsor Essex County

Date	**Area**	**Type of natural disaster**
August 6 2018*	Windsor	Severe Windstorm
August 27/28 2017*	Windsor	Flood
March 2017*	Windsor	Severe Windstorm
September 29 2016	Windsor	Flood
August 2016	Windsor/LaSalle	Tornado
June 6, 2010	Leamington	Tornado
August 25 2009	Windsor, Toronto, Ottawa	Severe Thunderstorms

August 20 2009	Windsor, GTA	Tornados
July 19 1989	Essex County	Flood
May 30 1985	Windsor	Severe Thunderstorms
April 3 1974	Windsor	Tornados/Extreme wind
June 17 1946	Windsor/Tecumseh	Tornados

*Events not captured in the Canadian Disaster Database (figure 1)

Weather-related disasters pose a threat to human life, health and well-being in a variety of ways (Table 3). Some events result in more direct and more immediate impacts than others. For example, flooding, drought, severe storms and other weather-related natural hazards can damage health by leading to an increase risk of injury, illness, stress-related disorders and death. Other impacts on health are less direct and longer-term, such as mould in buildings as the result of flooding or vector borne diseases (Canada, 2008).

Table 3: Key weather-related natural hazards in Canada and their associated health impacts.

Extreme Weather Event	**Examples: Health Impact Pathway(s)**	**Examples: Potential Health Effects**	**Populations at Higher Risk**
Extreme Heat	• Body temperatures are elevated beyond normal range • Increased growth and abundance of disease-causing organisms and/or vectors • Air quality is negatively impacted	• Dehydration • Heat-related illnesses (heat stroke, fainting, heat cramps, heat rash) • Existing medical problems made worse, such as asthma and allergies • Physical and mental stress • Respiratory and cardiovascular disorders • Food-borne diseases • Vector-borne infectious diseases	• Younger children • Seniors (especially those who are bedridden, unable to care for themselves or socially isolated) • Chronically ill individuals • People with compromised health status • People living in areas with poor air quality • People working or exercising outdoors • People without access to air conditioning • People on certain medications
Extreme Cold	• Body temperature is reduced below normal range	• Frostbite • Hypothermia • Death • Increased risk of injury due to accidents (car, slipping on ice, shovelling snow)	• People without shelter • People who play or work outdoors • Children • Seniors
Extreme rain or snowfall	• Flooding and its after-effects (e.g. poor indoor	• Physical injury, shock and trauma • Death by drowning	• Children • Seniors

	air quality from growth of moulds) • Increase in populations of mosquitos and other disease carriers • Contamination of drinking water by chemicals or wastes in surface runoff • Failure of essential infrastructure (e.g. sewers, water treatment facilities) • Algal blooms and other changes in aquatic ecology	• Respiratory illnesses • Outbreaks of vector borne infectious diseases • Outbreaks of crytosporidiosis, giardiasis, amoebiasis, typhoid and other water-borne infections	• People living along coasts or waterways • People with chronic illnesses • People with compromised health status • People with impaired immune systems • People with inadequate or no housing
Extreme drought	• Water shortages • Crop failures • Reduced water quality • Wildfires • Air pollution due to dust and smoke	• Respiratory illnesses from dust and smoke from fires • Outbreaks of water-borne illness due to increase concentration of contaminants • Hunger, malnutrition and associated stress disorders due to crop failures and economic hardship • Injury or death (in extreme causes) • Stress from loss of property, livelihood, displacement and community disruption	• People living in drough-prone areas • Agriculturally dependent communities • People without insurance • People without resources (e.g. financial and social)
Severe storms	• High winds • High waves and storm surges • Flooding • Property damage • Damage to essential infrastructure (e.g. power lines, hospitals, water treatment plants) • Damage to personal property • Increased risk of automobile accidents	• Physical injuries or death from falls, collapsing buildings, wind blown debris, house fires, motor vehicle accidents, etc. (especially head injuries, fractures and lacerations) • Hypothermia • Electrocution • Food-borne disease	• People living in storm-prone areas • People living in low-lying coastal areas or in regions prone to flooding • People living in areas where environmental degradation has created hazardous condition.

		• Respiratory illness and asthma due to pollen and spores • Drowning • Stress disorders from loss of loved ones, property and livelihoods	

Source: Canada, 2008.

The Cost of Doing Nothing

A 2011 report by the National Round Table on the Environment and Energy estimated that climate change could cost Canada from $21 billion to $43 billion per year by 2050, equivalent to 0.8% to 1% of GDP, depending on what future global emissions occur and how Canada grows in the meantime (NRTEE, 2011). A portion of these costs are contributed to human health and safety.

During a review of Windsor's vulnerability and risk assessment under a changing climate process, three possible impacts were identified as posing a direct risk to human health and safety, including:

- Impact 4: An increase in extreme heat causing health issues
- Impact 6: Increasing summer temperatures will cause a decrease in air quality
- Impact 7: Increasing temperature risk increasing risk for vector borne disease and new infectious disease

Several additional climate change impacts identified also may pose a risk of injury to the public, including:

- Impact 2: An increase in extreme precipitation leading to basement flooding
- Impact 3: Increasing intense storms impacting the tree canopy through stress and damage
- Impact 8: Increasing winter precipitation leading to an increase risk of ice conditions
- Impact 9: An increase in water levels leading to overland flooding from the Detroit River/Little River/Lake Ontario/Lake Erie
- Impact 10: Increasing intensity storms leading to damage to infrastructure, power outages, safety and additional clean up costs
- Impact 12: Increase in winter and spring temperatures leading to quicker thawing and snowmelt contributing to overland flooding

Where data was available, costs associated with these impacts have been estimated and can be found under the corresponding impact summary sheet.

Suggested Adaptation Actions:

Action 1.2 Increase community level of knowledge on Climate Change.

- ☐ Enhance climate change education and awareness initiatives for Windsor residents and City staff;
- ☐ Collaborate with the University, College and local school boards to enhance climate change training and development;
- ☐ Engage with professional agencies to develop and enhance local climate change knowledge and experience;
- ☐ Continue to share relevant climate change data on Open Data Catalogue
- ☐ Investigate the creation of a City Lab in Windsor - an innovation hub bringing together students, academia and civic leaders to work towards climate action.

Action 2.1 Update Community Development and Health Services (CDHS) Emergency Response Plan

- ☐ Consult with County stakeholders to discuss regional approaches;
- ☐ City of Windsor staff training for emergency response;
- ☐ Conduct exercises to test opening emergency shelters in times of crisis;
- ☐ Develop a notification system for the public on what to do and where to go in an emergency.

Action 2.3 Enhance public education to increase personal preparedness & reduce health risks associated with extreme weather

- ☐ Produce targeted messaging for at risk populations including seniors and persons with limited mobility as well as their caregivers;
- ☐ Enhance supports for Community Development and Health Services clients;
- ☐ Educate the public on when to call 911 or 311.

Action 6.1 Improve communications from Transit Windsor to the public

- ☐ Hire a social media/communications coordinator for Transit Windsor;
- ☐ Develop a social media presence for Transit Windsor and use this to alert riders of changes to routes due to extreme weather events.

Action 6.2 Develop extreme weather contingency plans for Transit Windsor

- ☐ Identify priority risk areas and develop a Plan to respond to flooding of transit infrastructure, disruption of service and infrastructure damage to terminals, shelters, benches, bus stop pads etc.;
- ☐ Invest in back up power sources for all key Transit Windsor infrastructure including fuel pumps;
- ☐ Explore storing Transit Windsor buses in more than one location

References:

1. Government of Canada, retrieved online March 2019 from https://www.publicsafety.gc.ca/cnt/rsrcs/cndn-dsstr-dtbs/index-en.aspx
2. Auld, Heather. Risk Sciences International (2015) Climate Information for Infrastructure Decision Making.

3. Government of Canada, retrieved online March, 2019 from https://www.canada.ca/en/environment-climate-change/services/lightning/statistics/maps-hotspots.html
4. Her Majesty the Queen in Right of Canada, represented by the Minister of Health, 2008. *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity* online at http://publications.gc.ca/collections/collection_2008/hc-sc/H128-1-08-528E.pdf.
5. Canada. National Round Table on the Environment and the Economy. (2011). Paying the Prince: The Economic Impacts of Climate Change for Canada.

Last updated: November 1, 2019

Total Risk Score:

170

Impact #2: An increase in extreme precipitation leading to basement flooding

Likelihood	5	Almost Certain
Social	50	Medium
Economic	85	Very-High
Environmental	35	Medium-Low
Total	170	Medium-High

Vulnerability	Department	Impact Statement
V5	Operations	Basement flooding response
V5	Pollution Control	Basement flooding and private property damage
V4	ROW & Development	More interest in the basement flooding subsidy program
V4	ROW & Development	Increase in 311 calls
V4	Engineering	Basement flooding
V4	Community Development	Funding pressure on social housing providers to repair
V4	Community Development	Stress on tenants resulting in negative health implications
V4	Building	Management of storm water, increasing requests for building permits
V4	Windsor Public Library	Roof and basement leakage
V2	CAO	Harder to obtain insurance
V2	Building	Waste generation
V2	Essex Region Conservation Authority	Anxiety and fear of flooding from the community
V1	Building	Change to dwellings

Links to Community Risk Assessment

Statement	Social	Economic	Environmental	Overall Risk
Increased frequency of precipitation causing flooding and resulting in financial strain due to personal property loss and high replacement costs	40	56	48	144
Increased frequency of extreme weather events leading to basement flooding and without proper restoration, allowing mold growth	44	56	40	140
Continued risk of basement flooding, causing anxiety and fear as community anticipates flooding	35	25	20	80

Supporting Information

Climate Projections

In 2015, Essex Region Conservation Authority with the support of Windsor Essex municipalities retained researchers to undertake a review of intensity-duration-frequency (IDF) curves for the region. The study *A Comparison of Future IDF Curves for Southern Ontario* (Coulibaly, 2015) predicts a 25% increase in the 10-year return storm intensity and a 40% increase in the 100-year return storm intensity by the 2090s (see figure 1). The solid bar in the box plots indicates the 50th percentile of the results while the outer bars indicate the 10 % and 90% range.

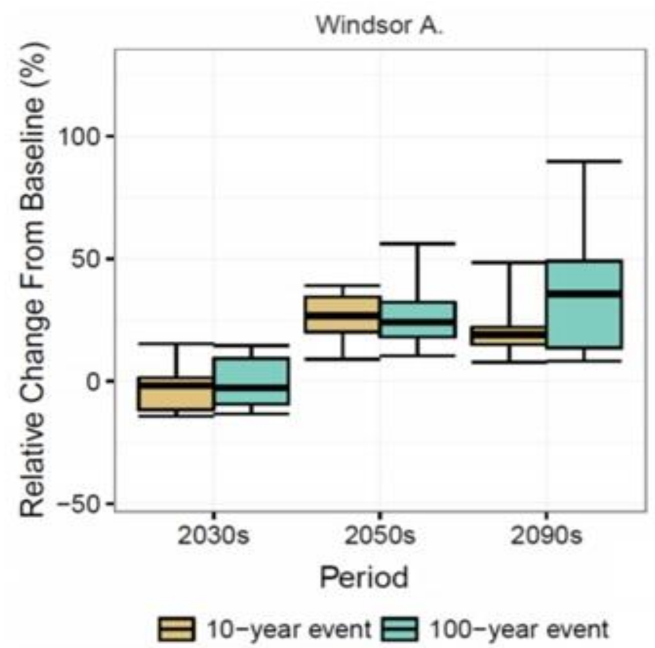


Figure 1. Relevant change from baseline in 10 year and 100 year flooding events over time (source: Coulibaly et al.)

As shown in figure 2 below, a 1-in-100 year storm today in the City of Windsor is projected to be a 1-in-20 year storm by mid-century.

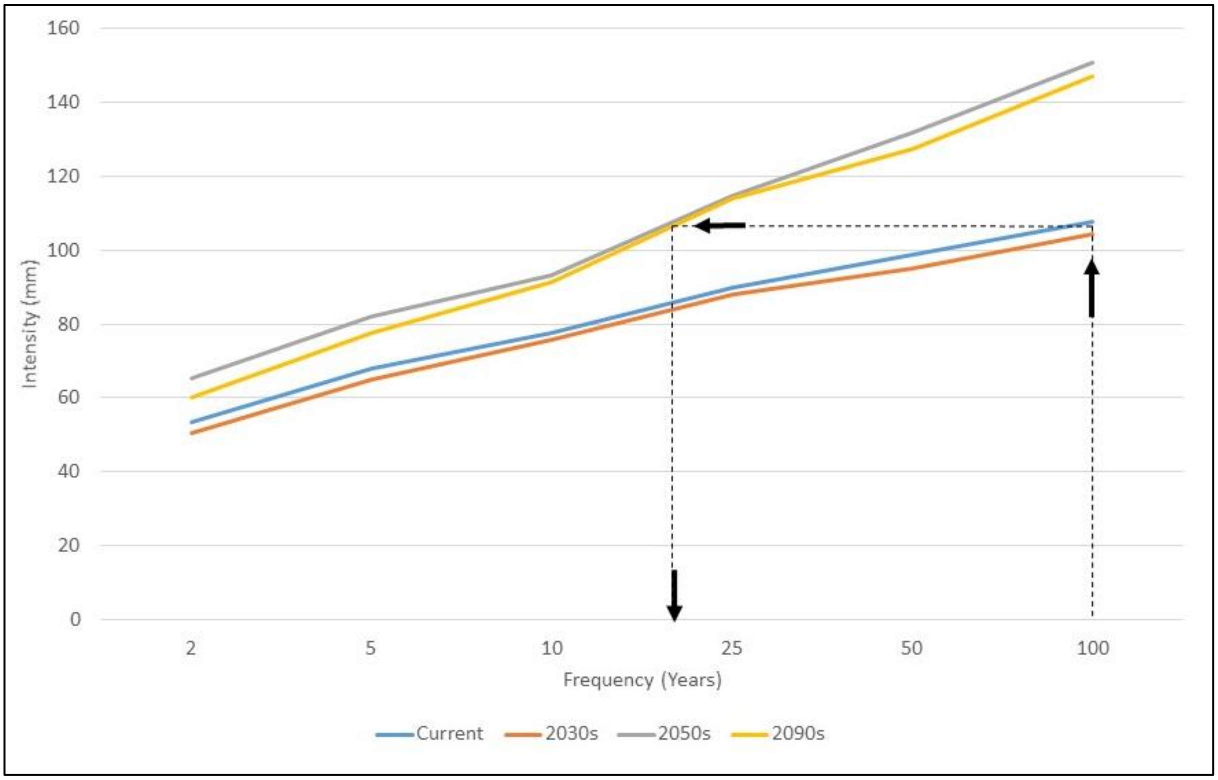


Figure 2. Current and Future Rainstorm Intensity Projections (source: Coulibaly et al.)

Event Based Data

Table 1: Historical 311 calls to Report Flooding in the City of Windsor

Year	Number of Calls
2010	2,320
2011	660
2012	32
2013	217
2014	911
2015	
2016	2,850
2017	5,982

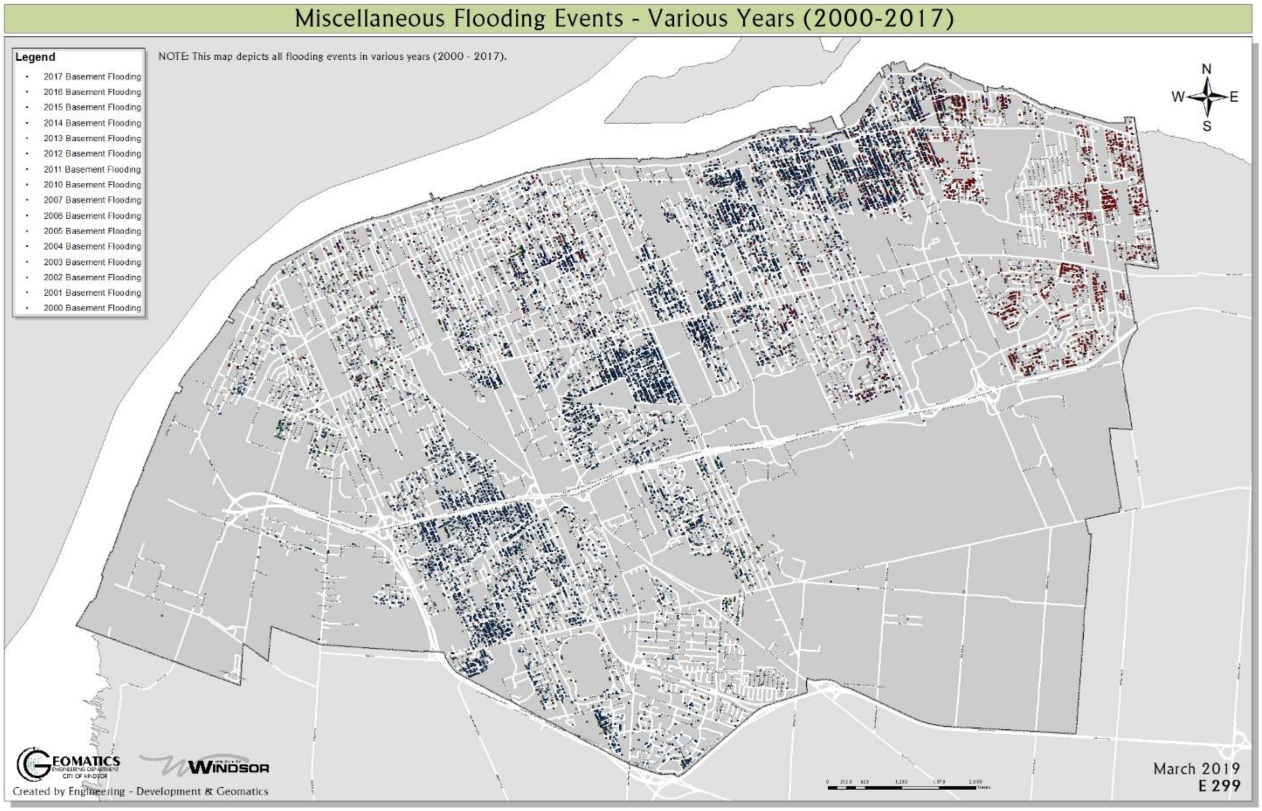


Figure 3. Map of City of Windsor flooding locations reported through 311 since 2000.

Departmental Impacts

Operations

During and after the 2016 and 2017 flooding events in Windsor, major expenses were incurred by various departments for their response as well as the cleanup. These costs are outlined in Table 3.

Table 3. City of Windsor Operational Costs for Response and Clean-Up of Flooding Events

Top Expenses	2016	2017
Contracted/Purchased Services	$143,957	$1,240,785
Salaries/Overtime/Benefits	$71,679	$145,735
Landfill Tipping Fees	$57,725	$163,091
Other Costs	$7,869	$140,475
Total	**$281,230**	**$1,690,086**

Development, Projects & Right of Way

The table below shows the number of basement flooding subsidy applications received and the number of subsidy payments issued in the City of Windsor from 2012 to 2018. Currently 100% of the cost of the program to the homeowner is covered by the City.

Table 4. Number of applications and subsidy payments issued as part of the basement flooding subsidy program over time.

	2012	2013	2014	2015	2016	2017	2018
# of Applications Received	576	443	579	437	1158	5100	2200
# of Subsidy Payments Issued	380	289	403	299	781	2121	535

Community Development

Conversations with Community Development and Health Services has brought to attention costs of recent flooding incurred by social housing providers. CDHS staff time was required to provide guidance to social housing providers regarding repairs and relocating tenants when units were flooded and deemed uninhabitable. The City of Windsor is the sole share holder of social housing units operated by the Windsor Essex Community Housing Corporation, which may be at risk to flooding.

Windsor Public Library

During the 2017 flooding event, both Riverside and Budimir libraries flooded closing the libraries for three days, and the basements were inaccessible for several months. Budimir library also flooded in 2012.

Community Impacts

Insurance Bureau of Canada

The Insurance Bureau of Canada has reported that the insured losses in our region from the 2016 and 2017 flooding events totalled $108 million and $124 million respectively.

Partners for Action Results

In 2018, the City of Windsor partnered with Partners for Action and the Canadian Red Cross to undertake a flood risk and awareness survey of Windsor residents. The online survey was available from April 5 to May 15th, 2018. A total of 420 residents in the City of Windsor responded to the survey.

Key findings:

Flood risk awareness in Windsor is almost nine times the national average – 51% of respondents in Windsor believe they live in an area at risk for flooding, comparted to only 6 % of Canadians (Silver, A, 2018).

The economic impact of flooding since 2010 is substantial. Sixty-nine percent of respondents who provided details faced over $10,000 in damages, with 17 % having $50,000 or more in damages (figure 4). Windsor residents paid for these damages with personal savings (42 %) and insurance (44 %), but some indicated that they could not pay for the damages to their homes and property, and only 0.6% received government assistance (Figure 5).

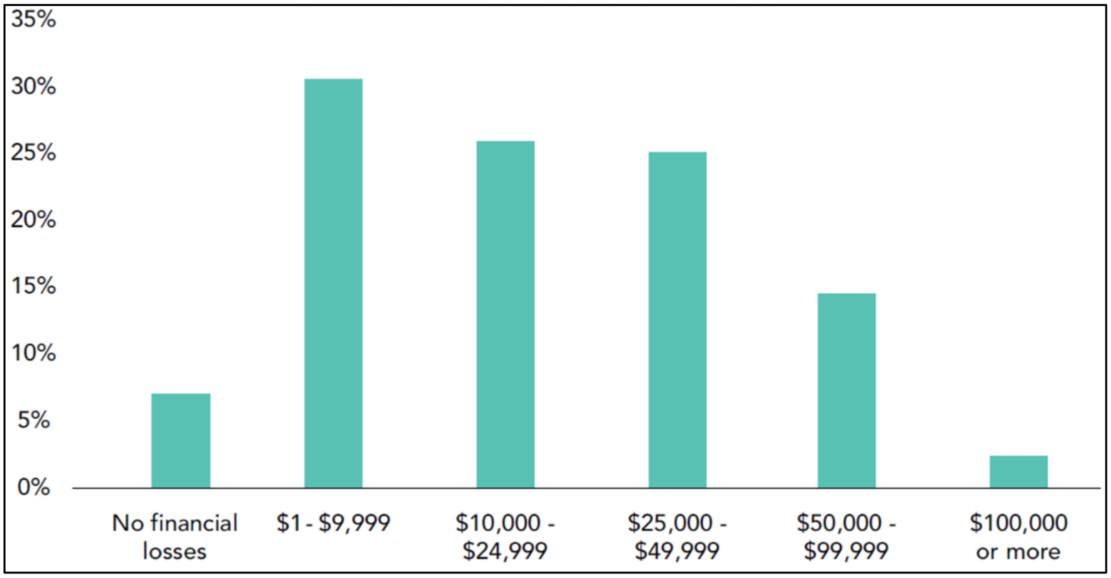


Figure 4. Financial losses from flooding as expressed by Windsor residents in 2018 survey (source: Silver and Peddle)

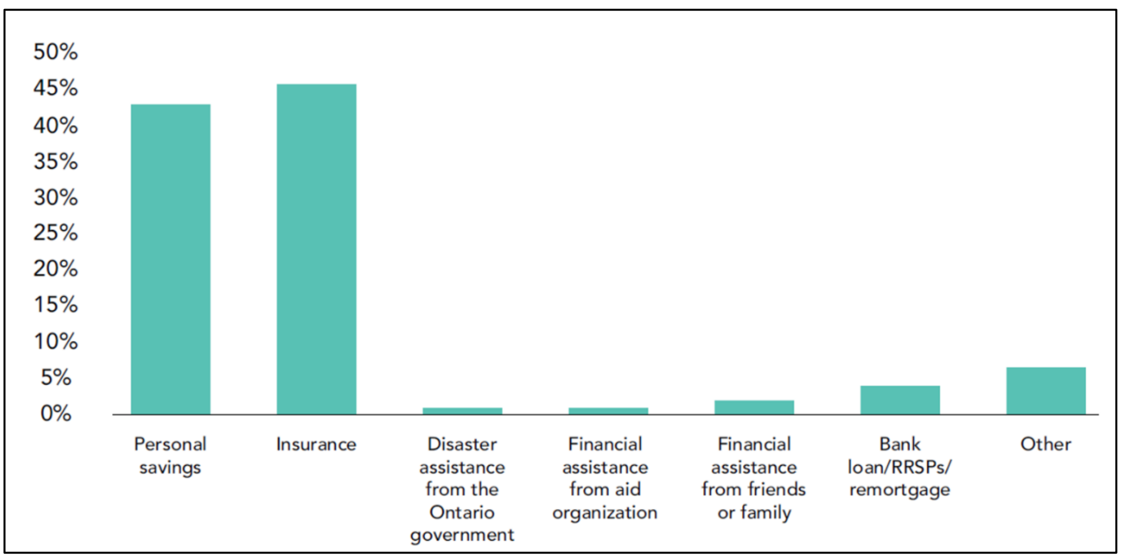


Figure 5. How Windsor residents paid for flooding damages they have incurred in recent years (source: Silver and Peddle)

The Cost of Doing Nothing

As mentioned above, the 2016 and 2017 flood events resulted in $108 and $124 millions dollars of insured losses. Based on the results of the Partners 4 Action survey only 44% of those affected paid for the damages through insurance (Silver, A, 2018). Therefore the estimate overall costs are likely closer to $245 and $281 million, respectively.

Through the development of the Sewer Master Plan, computer modelling of the City's sewer system was used to estimate the basement flooding potential under various rain events. Figure 6 illustrates the modelling results of the Sewer Master Plan under current conditions for the 1:5 year, 1:25 year and 1:100 year storm event. Using the Rainstorm Intensity Projections in Figure 2, the current 1:5, 1:25 and 1:100 year storms are predicted to have a return period of 1:3, 1:8 and 1:20 year in the 2050s.

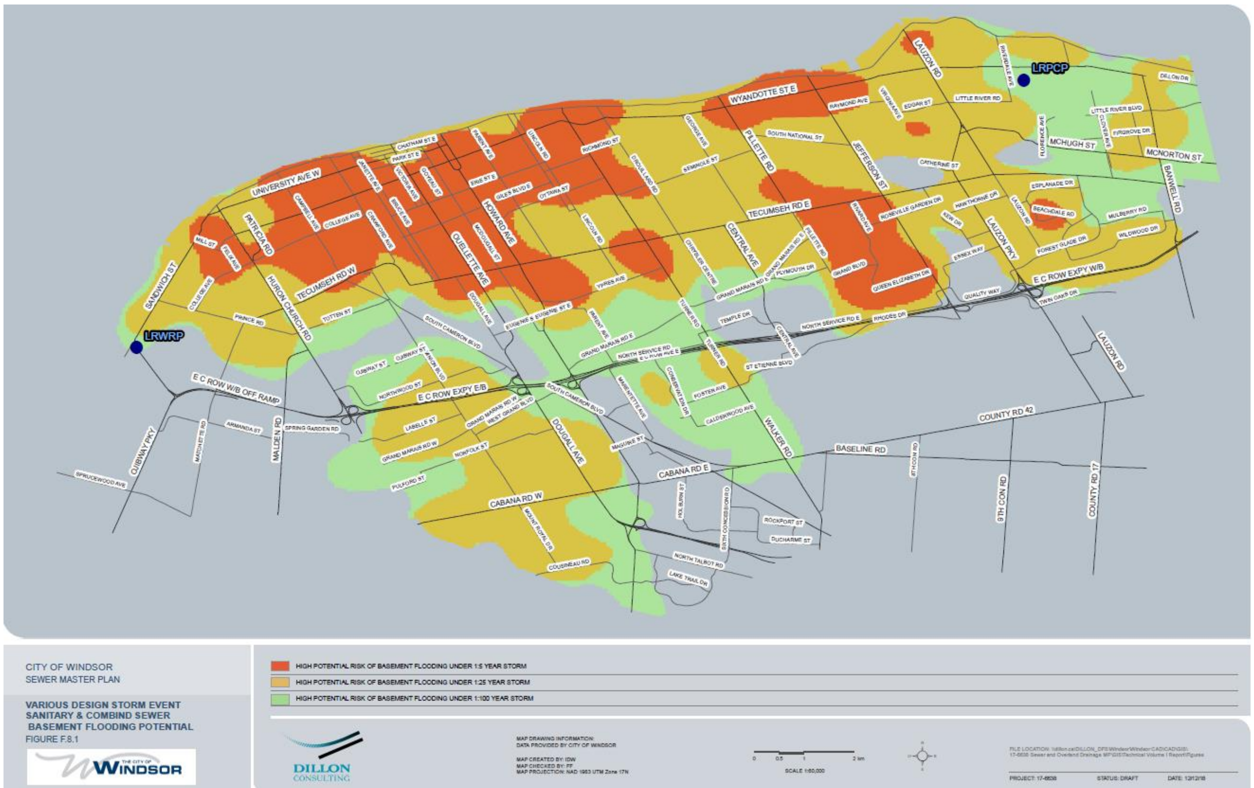


Figure 6: Various Design Storm Event Sanitary and Combined Sewer Basement Flooding Potential (Dillon, 2019)

Table 5 estimates the number of properties at risk under the various storm conditions. However, these scenarios would occur if that intensity of storm covered the whole City. In the past, when the City has experienced extreme precipitation events they have usually been concentrated on an area of the City and did not cover the whole City. Therefore, these numbers can be seen as worst case scenario, that is, a 1:5, 1:25 or a 1:100 year storm hitting the whole City at once.

Table 5: Number of Possible Properties Affected under Various Storm Intensities

Current Storm Intensity	Future Storm Intensity	Estimated Number of Properties affected
1:5 year	1:3 year	22,364
1:25 year	1:8 year	55,284
1:100 year	1:20 year	68,306

In 2018, the Insurance Bureau of Canada estimated that the average cost to repair a flooded basement was $43,000. As previously noted, not all these damage costs are always covered by insurance, especially if the property in question has flooded before. Additional costs not included in this cost is an individuals lost time at work, personal stress and other mental health issues that may occur when dealing with an emergency. However, in order to estimate a cost for the do nothing scenario the $43,000 was applied to each property affected. Table 6 shows the possible worst case scenario, i.e. a City wide storm at those storm intensities.

Table 6: Estimated Losses under Various Storm Intensities

Current Storm Intensity	Future Storm Intensity	Estimated Losses under Various Storm Intensities for a Single Storm
1:5 year	1:3 year	$961,652,000
1:25 year	1:8 year	$2,377,212,000
1:100 year	1:20 year	$2,937,158,000

These estimated costs do not include damages that would occur to City owned infrastructure or emergency response nor does it include economic losses from business closures, productivity losses, or environmental damages.

Suggested Adaptation Actions:

Action 3.1 Increase education to the public on how to reduce their personal risk of basement flooding

- ☐ Hire a coordinator to conduct public education and outreach to highlight responsibilities of the property owner and promote lot level storm water controls. These include but are not limited to rainbarrels, rain gardens and down spout disconnections;
- ☐ Develop outreach programs to teach residents what they can do to reduce snowmelt flooding on their property;
- ☐ Provide education to private market and social housing landlords and business owners outlining precautions, insurance options and responsibilities for tenants and landlords;
- ☐ Provide education on cleaning and fixing damaged property after a flooding event to prevent mould growth.

Action 3.2 Develop a media notification system to prepare residents for large storm events

- ☐ Provide information on what to do before, during and after extreme rain events in real time.

Action 3.3 Continue and enhance the Basement Flooding Subsidy Program and incentivize other methods of protecting property

- ☐ Include a subsidy for sewer lateral video surveillance and subsequent repair or replacement as part of the Basement Flooding Subsidy Program;
- ☐ Continue to subsidize rainbarrels.

Action 4.1 Implement the Sewer Master Plan overall recommendations (including but not limited to)

- ☐ Identify infrastructure most at risk for extreme weather impacts;
- ☐ Continue to implement sewer infrastructure replacement and improvements;
- ☐ Install rain guards in sanitary manholes;
- ☐ Design and installation of curb inlet flow restrictors;
- ☐ Introduce city-wide mandatory downspout disconnection;
- ☐ Explore feasibility of a retention treatment basin (RTB) on the riverfront trunk sewer near the Lou Romano Water Reclamation Plant;
- ☐ Explore opportunities for stormwater storage near the Little River Pollution Control Plant.

Action 4.2 Increase City of Windsor staff resources to respond to infrastructure issues during extreme weather

- ☐ Review staff resources required for flooded infrastructure response during extreme rain events;
- ☐ Promote skilled trades as an important and rewarding career to address future gaps in trained personnel.

Action 4.6 Complete infrastructure projects that received funding as part of the Disaster Mitigation & Adaptation Fund grant

- ☐ Implement the Pontiac/St. Paul pump station study;
- ☐ Implement stormwater management improvements to Tranby Park;
- ☐ Complete the Upper/Lower Little River Flood Plain mapping study

Action 5.2 Investigate the potential for natural areas to enhance flood attenuation

- ☐ Identify where flood attenuation is needed within the City of Windsor;
- ☐ Review water retention possibilities in natural areas including lands adjacent to Provincially Significant Wetlands and other wetland associated habitats (e.g. swamp forest, wet prairie, meadow marsh).

Action 7.1 Improve stormwater design standards for future climate change precipitation projections

- ☐ Require new developments to follow the new Windsor Essex Region Stormwater Management Standards Manual including climate change considerations;
- ☐ Design new public areas to accommodate future rainfall intensity and increased stormwater demand and where possible consider providing additional resiliency to neighbouring areas;
- ☐ Investigate changes to new building structures in flood prone areas such as limiting basement depth, enhancing lot grading and building elevation requirements;

- ☐ Use the City's Zoning By-law and Site Plan Control process to limit hard surface areas in new developments;
- ☐ Re-evaluate the defined flood plains in Windsor considering climate change and restrict development in those areas to low population and recreational uses.

Action 7.3 Enhance the use of low impact development in both private and public areas to reduce storm water impacts

- ☐ Develop opportunities for increased stormwater management in parks.
- ☐ Incorporate low impact development into infrastructure projects such as roads, sewers and public spaces development.
- ☐ Continue to monitor and showcase current City of Windsor low impact development projects.
- ☐ Promote and incentivize the use of low impact development to developers, private landowners and the community.

Action 7.5 Develop communications campaign with messaging to residents on lot-level resiliency actions

- ☐ Including but not limited to green and cool roofs, rain gardens, native plants, rainbarrels etc.

References:

1. Coulibaly, P. Burn, D. and Switzman, H. (2015). *Technical Report: A Comparison of Future IDF Curves for Southern Ontario* (prepared for the Essex Region Conservation Authority and the Toronto Region Conservation Authority).
2. Insurance Bureau of Canada, online http://www.ibc.ca/on/resources/media-centre/media-releases/windsor-floods-cause-close-to-108-million-in-insured-damage (retrieved March 25, 2019).
3. Insurance Bureau of Canada, online http://www.ibc.ca/on/resources/media-centre/media-releases/late-august-flooding-in-windsor-region-caused-more-than-124-million-in-insured-damage/ (retrieved March 25, 2019).
4. Silver, A. and Peddle, S. (2018). *Voices of Flooding In Windsor, Ontario: Results of a survey on flood experiences and preparing for the future*.

Last updated: November 1, 2019

Total Risk Score:
140

Impact #3: Increasing intense storms impacting the tree canopy through stress and damage

Likelihood	5	Almost Certain
Social	50	Medium
Economic	50	Medium
Environmental	40	Medium-Low
Total	140	Medium

Vulnerability	Department	Impact Statement
V4	Forestry	Impact on tree canopy through stress and damage
V3	Forestry	Damage to private tress
V2	ERCA	Tree damage leading to property damage and personal injury

Links to Community Risk Assessment

Statement	Social	Economic	Environmental	Overall Risk
Changes in weather patterns and extremes can cause damage to Windsor's natural features (terrestrial and aquatic) leading to decreased summer tourism and a shift in the tourism industry	20	70	85	175
Increasing damage to nature trails, parks and green spaces due to high winds and other extreme weather events will lead to temporary or permanent closures of outdoor public spaces	55	50	55	160
Increased temperatures and precipitation causing damage to trees and natural features, leading to loss of ecosystem good and services	40	48	64	152

Supporting Information

Event Based Data

On August 6, 2018 a severe windstorm hit Windsor and LaSalle. This storm had a significant impact on the City owned trees along the right of way and in our parks and was reported as the having the largest negative impact on City trees and resources over the last 5 years.

The Ojibway Nature Centre had to close for several days to allow clean up crews to remove fallen trees. Street trees were also affected thereby reducing the urban tree canopy in Windsor.

The immediate clean up costs from this storm was $86,730 while the costs to remove 130 trees and trim 270 was $119,550. Due to limited budget, not all trees removed were replaced in 2018.

Trees have multiple benefits including:

- Improving air quality;
- Sequestering carbon (climate change mitigation);
- Energy Conservation;
- Water filtration and retention;
- Wildlife Habitat; and
- Economic benefits including increased home values.

Suggested Adaptation Actions:

Action 3.4 Continue and enhance tree pruning programs to develop proper tree health and limit future damage

- ☐ Enhance tree pruning and maintenance programs on City of Windsor trees using the City's updated Tree Inventory;
- ☐ Implement an outreach program for private tree care and maintenance.

Action 5.1 Protect and enhance the management of natural areas to improve climate change resilience

- ☐ Evaluate and prioritize natural areas restoration opportunities;
- ☐ Develop high level policies to inform the development of Natural Areas Management Plans;
- ☐ Develop Natural Areas Management Plans;
- ☐ Prioritize the preservation of unprotected natural properties especially for consolidation of existing natural areas;
- ☐ Increase implementation of natural areas restoration and maintenance;
- ☐ Conduct restoration using appropriate zone specific plants focusing on those identified to be able to withstand extreme weather events;
- ☐ Monitor, protect and advocate for species at risk;
- ☐ Enhance communication and coordination with other agencies;
- ☐ Enhance recognition of Trees as assets in all rehabilitation, development and remediation issues.

Action 5.5 Complete an Urban Forest Management Plan

- ☐ Complete the City of Windsor Street Tree and Park Tree Inventories;
- ☐ Complete a Canopy Cover Study & Benefits Assessment and develop a Tree Canopy Cover goal for the Windsor community to benefit the environment and human health;
- ☐ Work towards achieving the Tree Canopy Cover goal through increased quality tree planting, maintenance and replacement;
- ☐ Continue to protect the urban forest through enforcement of the public tree by-law (By-law 135-04);

- ☐ Explore additional tree protection measures to limit the removal of trees in Windsor;
- ☐ Increase awareness of the air pollution and greenhouse gas reduction benefits provided by trees.

Action 5.6 Improve climate resilience of trees in urban forests, parks and in the public right-of-way

- ☐ Ensure tree and plant species established are native where possible, diverse, disease resistant and have high climate adaptability;
- ☐ Where appropriate, identify safe opportunities for assisted tree migration from more southern regions;
- ☐ Use an integrated pest management approach to park and urban forest maintenance;
- ☐ Enhance tree maintenance programs to mitigate damage due to heat and extreme events;
- ☐ Review and update new tree irrigation procedures to improve establishment success and therefor long-term survival and performance of trees

Last Updated: November 1, 2019

Total Risk Score:

130

Impact #4: An increase in extreme heat causing health issues

Likelihood	5	Almost Certain
Social	55	Medium-High
Economic	45	Medium
Environmental	30	Medium-Low
Total	130	Medium

Vulnerability	Department	Impact Statement
V4	Forestry	Heat stress on employees leading to injury and/or illness
V4	Community Development	Impacts homeless individuals living in emergency shelters, and housing support homes
V4	Parks Operations	Require splash pads to run longer
V4	Recreation	Increase in pool use requiring increased energy and chemical use
V4	Recreation	Change in outdoor programming
V3	Forestry	Increase need for shelter (tree cover)
V3	Recreation	Providing cooling centers
V3	Transit Windsor	Strain on air conditioning and heating in buses
V3	Transit Windsor	Heat stress on employees leading to injury and/or illness
V3	Parks Operations	Play surfaces heat up causing health concern
V3	Windsor Essex County Health Unit	Reduction in outdoor fitness activities decreasing physical activity
V2	Transit	Individuals becoming more aggravated
V2	Transit	Individuals becoming more aggravated
V2	Facilities	Heat stress on employees leading to injury and/or illness
V2	Emergency Preparedness	Community health issues and death
V2	Operations	Heat stress on employees leading to injury and/or illness
V2	Human Resources	Overwhelmed AC demand leading to worker absenteeism
V2	Human Resources	Heat stress on employees leading to injury and/or illness
V2	Recreation	Increase in indoor programming increasing costs to low income individuals
V2	Emergency Preparedness	Increased need to cancel training
V2	CAO	Require planning needs for more green space
V2	Pollution Control	Heat stress on employees leading to injury and/or illness

V2	Windsor Essex County Health Unit	Increase in health illness and disorders
V2	ERCA	Heat stress on employees leading to injury and/or illness
V2	Windsor Public Library	Cause more people to visit libraries as cooling centers
V1	Transit Windsor	Use buses as cooling stations or to move to cooling centers
V1	Transportation Planning	Increased demand for shade trees, increasing competition for ROW capacity
V1	Transportation Planning	Reduce ability for active transportation
V1	Essex Region Conservation Authority	People will spend less time outside in conservation areas

Links to Community Risk Assessment

Statement	Social	Economic	Environmental	Overall Risk
Increasing spring and fall temperatures causing hot schools, leading to heat related illnesses in children and staff creating inhospitable conditions	50	40	45	135
Health risks and discomfort caused by increasing heat and precipitation could lead to decreased used of public transit/bus stops	30	30	25	85

Supporting Information

Climate Projections

Research has shown a large change in the number of hot days Windsor will experience in the coming decades. Figure 1 below shows projections to the 2080's as reported by the Canadian Climate Data and Scenarios Network. Climate Atlas has also detailed historical observed and future modelled annual mean number of very hot days (above 30 degrees Celsius) and very warm nights (above 20 degrees Celsius) as shown in Figures 2 and 3.

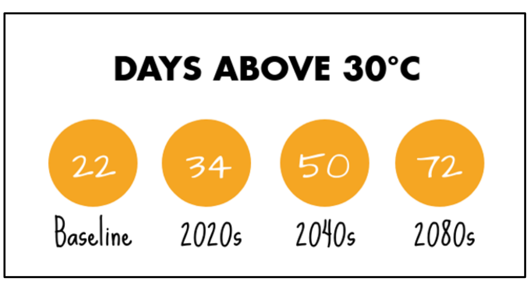


Figure 1: Temperature Extreme Projections Days above 30 degrees Celsius (ICLEI, 2018)

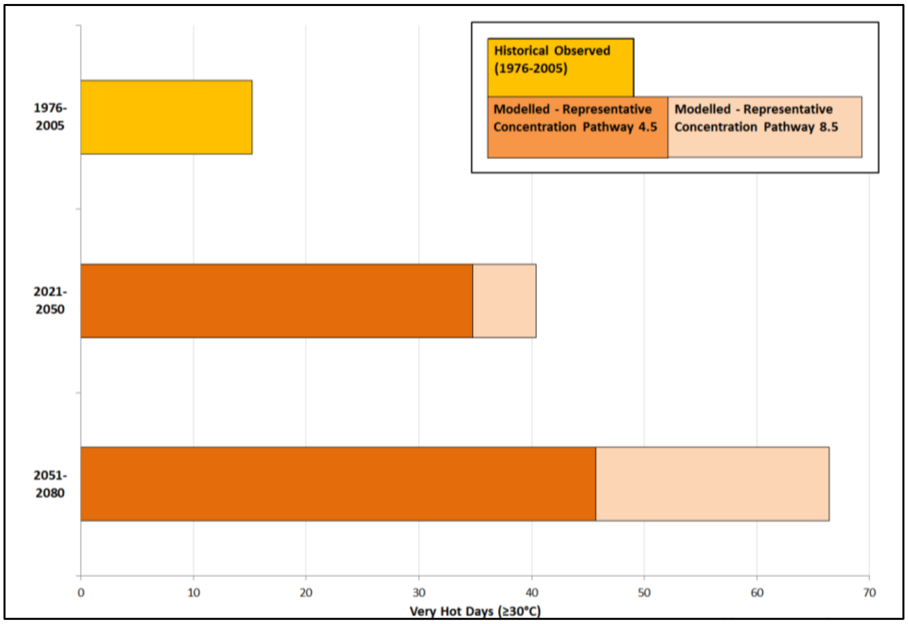


Figure 2: Historical Observed and Future Modelled Annual Mean Number of Very Hot Days (>30°C) (Climate Atlas)

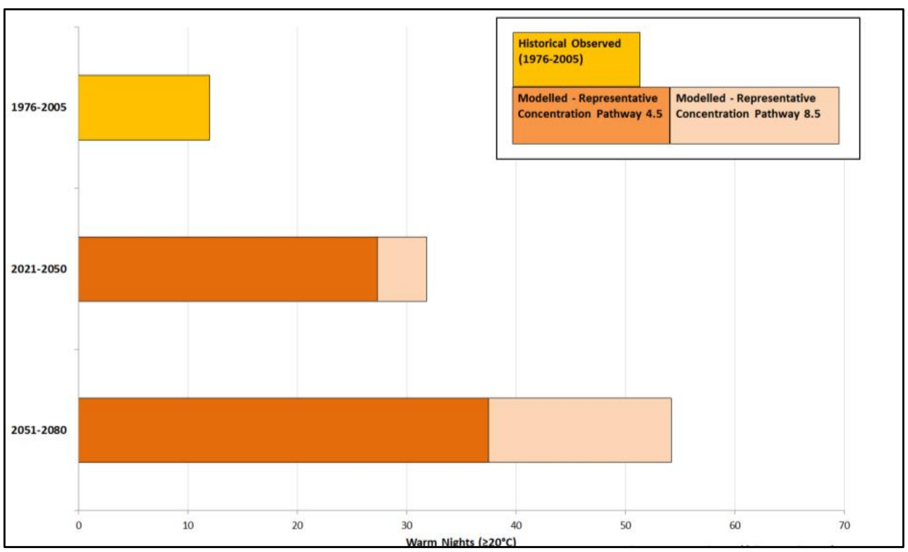


Figure 3: Historical Observed and Modelled Future Annual Mean Number of Very Warm Nights (>20°C) (Climate Atlas)

Event Based Data

The Windsor-Essex County Health Unit issues heat warnings based on weather forecasts from Environment Canada as part of the Stay Cool Windsor Essex program. As of 2016, the heat warning criteria is described below (Figure 4).

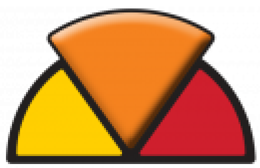
Heat Warning Level	Warning Icon	Heat Warning Criteria
Heat Warning		A heat warning is issued when two consecutive days are forecasted to have a daytime high temperature greater than or equal to 31°C and a nighttime temperature greater than or equal to 21°C or a humidex greater than 42 degrees Celsius.
Extended Heat Warning		An extended heat warning is issued when three or more than three consecutive days are forecasted to have a daytime high temperature greater than or equal to 31°C and a nighttime temperature greater than or equal to 21°C or a humidex greater than 42 degrees Celsius.
Heat Emergency		Heat Emergencies are declared during extenuating circumstances (i.e., large scale power outage or drinking water emergency) during a heat event.
Special Weather Statement		While heat warning criteria is not expected to be reached, this is the first very warm and humid weather of the season.

Figure 4. Heat Warning Criteria as outlined as part of the Stay Cool Windsor Essex program.

As a result of these criteria, heat warnings are issued by the health unit. The number of heat warnings and extended heat warnings issued since 2016 are shown in Table 1.

Table 1: Number of Heat Warnings and Extended Heat Warnings issued for Windsor-Essex

Year	Heat Warnings issued	Extended Heat Warnings issued	Total number of days	Additional Comments
2016	2	5	23	Special weather statement was issued for May 27 and 28
2017	1	2	12	No Special weather statement issued
2018	1	4	22	Special weather statement issued May 28

Extreme Heat and Human Health

An assessment of vulnerability to the health impacts of extreme heat was completed in partnership with Health Canada and the City of Windsor. This study found that a strong association exists between temperature and excess mortality in Windsor. At approximately 29°C excess mortality begins to increase as ambient temperatures increase (Figure 5) (Berry, P. 2011).

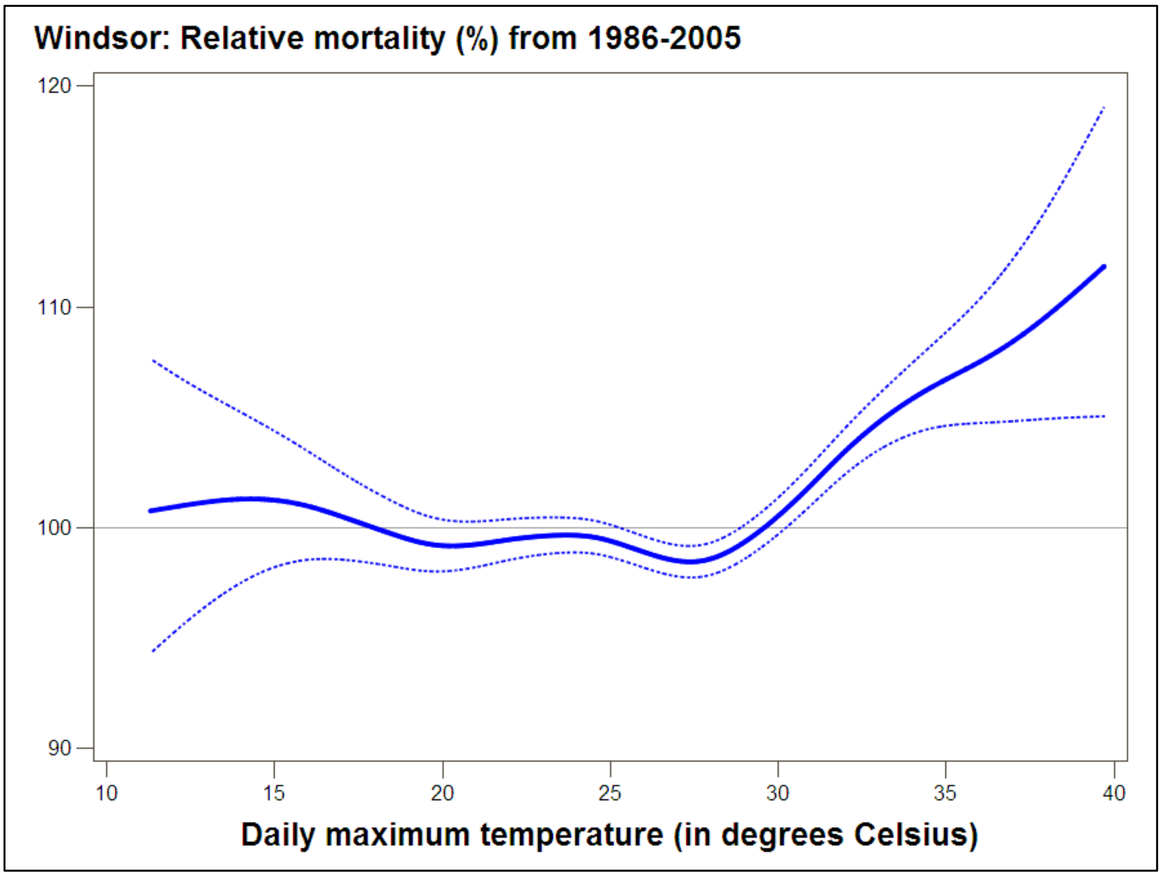


Figure 5: Association between non-traumatic daily deaths and maximum daily temperatures in Windsor (Berry *et.al,* 2011)

The recently completed Community Needs Assessment notes that from 2007 to 2017, the rate of heat-related emergency room visits in Windsor Essex ranged from 6.8 to 13.8 cases per 100,000 residents. Additionally, heat-related emergency room visits consistently affected males between the age of 25 to 44 years with a rate of 25.2 visits per 100,000 residents in 2016 (WECHU, 2019) Figure 6 illustrates a correlation between the rate of emergency room visits and the number of days over 30 degrees Celsius.

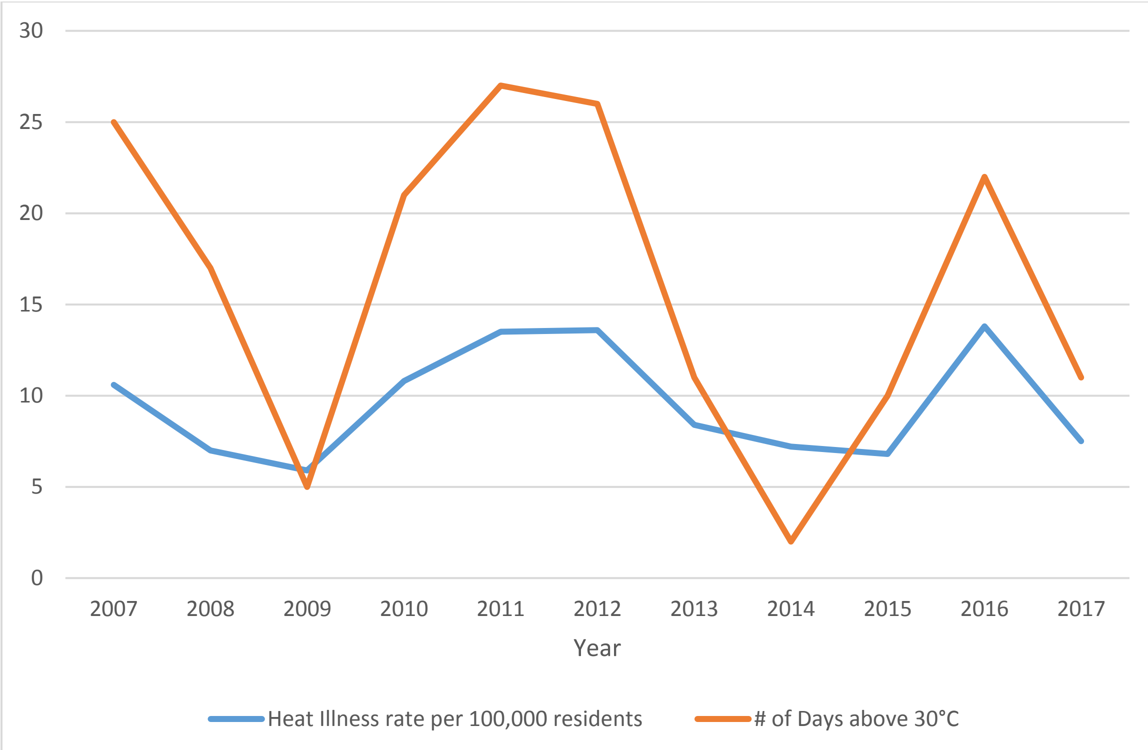


Figure 6: Correlation between the rate of heat illness and the number of hot days

Based on this information, the rate of heat illnesses in Windsor is expected to rise with the predicted increases of days over 30 degrees Celsius (Figures 1 – 3).

The Cost of Doing Nothing

Climate change in Canada could be responsible for roughly five to ten additional deaths per 100,000 people by the 2050s and seven to seventeen by the 2080s due to increases in extreme heat and air pollution (NRTEE, 2011). Cities where temperatures are expected to increase the most will be more adversely affected. A National Round Table on the Environment and Economy (2011) examined four cities across Canada - Vancouver, Calgary, Toronto and Montreal, and estimated annual costs of premature mortality risk attributed to heat and air quality impacts from Climate Change using the "*value of a statistical life*".

The value of statistical life (VSL) is defined as the additional cost that individuals would be willing to pay for small reductions in risks that, in the aggregate reduce the expected number of fatalities by one. The VSL is therefore a valuation of anticipated mortality risk reductions, not the valuation of an identifiable life (Canada, 2018). The VSL was established by Treasury Board of Canada Secretariat in 2004 and was set at $6.11 million.

Based on the VSL, the willingness to pay to avoid premature death in the four Cities are in the order of billions dollars per year for each city and growing over time with cumulative costs as highlighted in Table 2.

Table 2: Willingness to Pay to Avoid Premature Mortality Attributed to Heat and Air Quality Impacts form Climate Change (NRTEE, 2011)

City	Cost	
	Low Climate Change Scenario	High Climate Change Scenario
Toronto	$65 Billion	$96 Billion
Montreal	$52 Billion	$77 Billion
Vancouver	$36 Billion	$48 Billion
Calgary	$11 Billion	$17 Billion

Using the results of the NRTEE study, estimates were made to determine the cost risk of premature mortality attributed to heat and air quality in Windsor in the years 2050 and 2080.

Table 3: Increased Annual Cost of Premature Mortality Risk Attributed to Heat and Air Quality Impacts from Climate Change in Windsor

	Death rate per 100,000 residents – Low end estimate	Death rate per 100,000 residents – High end estimate	Low end Estimated Cost	High end Estimated Cost
2050	5	10	$224 million	$448 million
2080	7	17	$721 million	$1.750 billion

Possible Adaptation Actions:

Action 2.4 Review the 2011 Heat Alert and Response Plan and Update as required

- ☐ Determine emergency conditions that require opening community reception centres or emergency shelters;
- ☐ Ensure all public facilities have access to an air conditioned space;
- ☐ Encourage the public to seek relief from extreme heat in public spaces;
- ☐ Identify privately owned places that could be used as cooling centres during Heat Alerts;
- ☐ Promote access to free tap water through programs such as Blue W or the Windsor Essex County Health Units Water app;
- ☐ Increase access to water bottle re-fill stations in public washrooms;
- ☐ Review the 2011 Vulnerability to Extreme Heat in Windsor report and update where possible.

Action 2.5 Enhance protection of outside workers during extreme heat conditions

- ☐ Identify opportunities for targeted education to at risk workers and their employers (e.g. Factory and greenhouse workers, farmers, roofers, landscapers and construction workers);
- ☐ Identify options to modify outdoor staff work schedules and/or tasks to earlier in the day, or in shaded or indoor areas;
- ☐ Investigate alternatives for cooler clothing options and hats for outside workers;
- ☐ Provide sun protection options such as sunscreen or hats to staff;
- ☐ Promote the importance of hydration to staff.

Action 5.5 Complete an Urban Forest Management Plan

- ☐ Complete the City of Windsor Street Tree and Park Tree Inventories;
- ☐ Complete a Canopy Cover Study & Benefits Assessment and develop a Tree Canopy Cover goal for the Windsor community to benefit the environment and human health;
- ☐ Work towards achieving the Tree Canopy Cover goal through increased quality tree planting, maintenance and replacement;
- ☐ Continue to protect the urban forest through enforcement of the public tree by-law (By-law 135-04);
- ☐ Explore additional tree protection measures to limit the removal of trees in Windsor;
- ☐ Increase awareness of the air pollution and greenhouse gas reduction benefits provided by trees

Action 7.5 Develop communications campaign with messaging to residents on lot-level resiliency actions

- ☐ Including but not limited to green and cool roofs, rain gardens, native plants, rainbarrels etc.

Action 7.6 Consider Thermal Comfort and the Urban Heat Island effect in development project design

- ☐ Encourage and implement more natural surface low impact development treatments instead of hard surfaces;
- ☐ Enhance landscaping and tree coverage in new public space and public right-of-way development;
- ☐ Continue to consider thermal comfort in park design and incorporate shade sails, tree planting, shade structures, splash pads etc.
- ☐ Use cooler and lighter hard surfaces in parks and public spaces;
- ☐ Include requirements for Urban Heat Island and Thermal Comfort considerations in Requests for Proposals for road class environmental assessments

Action 7.7 Enhance protections from heat and UV rays at sport fields and outdoor pools

- ☐ Increase shade options for all users and spectators at sports fields as well as outdoor pools by using trees, shade structures, shade sails etc.;
- ☐ Explore a field closure policy during extreme heat events;
- ☐ Explore rearranging outdoor swimming schedules to avoid peak heat times of day;
- ☐ Investigate installing stadium lighting for sports fields so usage can shift to cooler parts of the day;

- ☐ Increase education with recreation user groups about the risks of extreme heat

Action 7.8 Provide UV Protection in public spaces and at public events

- ☐ Locate public transportation bus stops where shade is available;
- ☐ Consider installation of sunscreen dispensers in washroom facilities in public spaces and public pools, Sandpoint beach and the Marina;
- ☐ Promote cooling options for festival organizers such as temporary shade sails, misting stations, the Hydration Station etc.;
- ☐ Provide and promote education about the risks of extreme heat

Action 7.9 Enhance communication and education around the impacts of extreme heat on human health

- ☐ Increase community understanding of heat illness signs and symptoms and associated health risks;
- ☐ Collaborate with the Windsor-Essex County Health Unit to communicate heat warnings via email, website, social media, text, app etc.;
- ☐ Collaborate with partners to produce and implement a targeted heat education program for vulnerable populations including migrant workers, international students and new Canadians

References:

1. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
2. Climate Atlas retrieved March, 2019 from (https://climateatlas.ca/map/canada/plus30_2060_85#grid=416)
3. Berry, P., Richters, K., Brisbois, M. (2011). *Assessment of Vulnerability to the Health Impacts of Extreme Heat in the City of Windsor.*
4. WECHU (2019). *Community Needs Assessment, 2019 Update.*
5. Canada. National Round Table on the Environment and the Economy. (2011). Paying the Prince: The Economic Impacts of Climate Change for Canada.
6. Her Majesty the Queen in Right of Canada, represented by the President of the Treasury Board, [2018], from https://www.canada.ca/en/treasury-board-secretariat/services/federal-regulatory-management/guidelines-tools/policy-cost-benefit-analysis.html

Last Updated: November 2, 2019

Total Risk Score:
120

Impact #5: An increase in extreme weather causing a diversion of resources

Likelihood	5	Almost Certain
Social	30	Medium-Low
Economic	55	Medium-High
Environmental	35	Medium-Low
Total	120	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Finance	Diversion of resources to address issues

Supporting Information

Operational Costs for Response and Clean-Up of Various Recent Events in the City of Windsor

Events	**Total Costs**
2016 Tornado	$101,109
2016 Flood	$285,674
2017 Severe Winds	$70,546
2017 Flood	$1,690,086
2018 Wind Storm	$251,780
2019 High Water Levels*	$192,870

Note *: Costs incurred as of October 31, 2019

As a result of the various natural events listed above, the City incurred costs exceeding $2.5 million since 2016.

Possible Adaptation Actions:

Action 1.3 Build financial support for unforeseen impacts of climate change

- ☐ Develop a Municipal severe weather reserve fund to address funding deficits due to emergency response.

Action 4.3 Incorporate climate change considerations into infrastructure design, development, maintenance and renewal

- ☐ Continue to consider climate change when implementing the City of Windsor's Asset Management Plan;
- ☐ Continue to implement the Triple Bottom Line approach considering financial, social and environmental costs and benefits when making infrastructure decisions.

Last Updated: November 2, 2019

Total Risk Score:
120

Impact #6: Increasing summer temperatures will cause a decrease in air quality

Likelihood	5	Almost Certain
Social	40	Medium-Low
Economic	35	Medium-Low
Environmental	45	Medium
Total	120	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V3	Human Resources	More air pollution leading to increased absenteeism

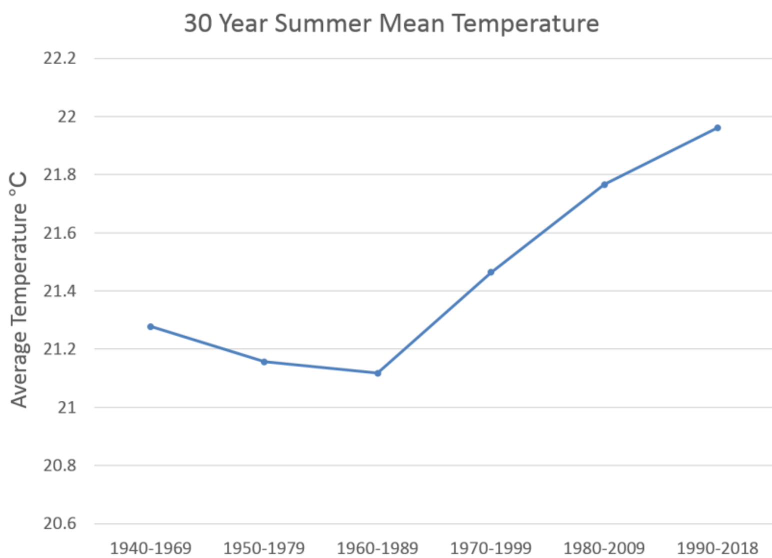
Links to Community Risk Assessments

Statement	**Social**	**Economic**	**Environmental**	**Overall Risk**
Increasing summer temperatures contributing to increased air quality health advisories	60	50	55	165
Increasing summer temperatures and poor air quality will decrease opportunities for active transportation and outdoor recreation	35	20	25	80

Supporting Information

Historical Climate Trends

Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent summer mean temperatures over 30-year timeframes (Figures 1)



	30 Year Summer Mean Temperatures (°C)
1940 - 1969	21.3
1950 - 1979	21.2
1960 - 1989	21.1
1970 - 1999	21.5
1980 - 2009	21.8
1990 - 2018	22.0
2000 - 2018*	22.2
2010 - 2018*	22.2

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Summer Mean Temperatures as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean summer temperatures over time (Figure 2).

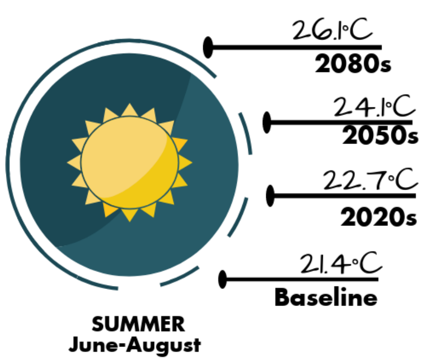


Figure 2: Summer Mean Temperatures Projections (ICLEI 2018)

Explanation

Over the past few decades, the air in Canada has been getting steadily cleaner, as considerable efforts have been made to reduce air pollution. In many parts of Canada, including Windsor, we often have days with clean air followed by heavy smog, and then a return to clean air. The amount of pollutants released into the air does not usually change so quickly, so what is happening? The answer, the weather.

How the Weather Affects Air Quality

Hot sunny days in the summer may be accompanied by smog. The intense summer sun causes chemical reactions among the pollutants that are already in the air, leading to the formation of ground-level ozone a major component of smog.

Other weather factors that can affect air quality in Windsor include:

The Wind – The wind can carry pollutants towards us or away from us.

Temperature Inversions – In a temperature inversion, the temperatures are upside down – the cooler air is at the ground and the warmer air is higher up. When this happens the cooler air cannot rise, and the warmer air above acts like a lid, trapping pollutants at the ground where we live and breathe.

Rain and Snow – Rain and snow clean the air, removing most of the pollutants.

Event Based Data

Historically, Windsor has experienced a large number of poor air quality days, with the peak occurring in 2007 when 38 smog advisories were issued. Since this time, air quality in the region has improved.

In 2015, the Air Quality Index (AQI) was replaced with the Air Quality Health Index (AQHI). The AQHI differs from the traditional AQI (i.e. Smog Alerts) as it reports on the health risk posed by a mixture of pollutants including ground-level ozone, particulate matter and nitrogen dioxide as opposed to the air quality of the single worst pollutant. The AQHI further breaks down the risk to low, moderate, high or very high. Under the high and very high risks, the general population is recommended to modify their activities and are notified as such under the issuance of an air quality statement. Special Air Quality Statements are issued if the AQHI is forecasted at a high risk for 1 to 2 hours, however, if the duration of the event is expected to last at least 3 hours a Smog and Air Health Advisory is issued. Table 1 show the number of Air Quality advisories issued for the region since 2007.

Table 1: Number of Air Quality Advisories per year for Windsor-Essex

Year	Smog Advisory Days	Special Air Quality Statement Days	Smog and Air Health Advisory Days
2007	38	-	-
2008	12	-	-
2009	5	-	-
2010	10	-	-
2011	8	-	-
2012	24	-	-
2013	0	-	-
2014	0	-	-
2015	-	1	0
2016	-	1	0
2017	-	1	0
2018	-	0	0

The AQHI also provides separate recommendations for at risk populations including; people with diabetes, lung disease (such as chronic bronchitis, asthma, emphysema, lung cancer) or heart disease (such as angina, a history of heart attacks, congestive heart failure, arrhythmia, or irregular heartbeat). Seniors are at higher risk because of weakening of the heart, lungs and immune system and increased likelihood of health problems such as heart and lung disease. Children are also more vulnerable to air pollution; they have less-developed respiratory and defence systems and often spend more time outdoors being physically active, which can increase exposure. This population is recommended to modify daily activities when a moderate risk is expected. Table 2 shows the number of days when Windsor reached a moderate risk.

Table 2: Number of Days with an AQHI reading of a Moderate Risk

Year	Downtown Windsor	West Windsor
	(# of days)	(# of days)
2015	86	89
2016	72	71
2017	129	117
2018	74	58
2019*	50	52

* as of September 9, 2019

The Cost of Doing Nothing

Recently, Windsor has seen an overall improvement in air quality, however, air quality can still pose a risk especially to at risk populations. Estimates state that air pollution costs more than $1 billion a year in hospital admissions, emergency room visits, and absenteeism (Environment and Climate Change Canada 2013). An OECD working paper report attributed 197 premature deaths per million in Canada annually (OECD, 2017). This would represent 45 premature deaths in Windsor.

A report by the National Round Table on the Environment and the Economy (NRTEE, 2011) found that under a changing climate poorer air quality will also increase the number of days people present with respiratory problems resulting in a roughly three-fold increase under a high climate change scenario and roughly two-fold increase under a low climate change scenario between 2020s and 2080s. The consequences of these health impacts include reduced quality of life, employee absenteeism, and costs to the health care system.

Health care spending accounted for about 10% of Canada’s gross domestic product in 2008, with 70% of spending coming from public sources. Using health care costs estimated for Toronto, under a low climate change scenario, the economic burden, on average, grows from 20 cents to 80 cents per person, while under a high climate change scenario, the economic burden, on average, grows from 60 cents to over $5.3 per person by the 2080s (NRTEE, 2011).

Using the NRTEE study results for the City of Toronto, estimates were made to determine the health care costs due to poor air quality in Windsor in the years 2020, 2050 and 2080.

Table 3: Annual Health Care Costs from to Poor Air Quality under various Climate Change Scenarios or

	Slow Climate Change Scenario	High Climate Change Scenario
2020	$48,169	$144,507
2050	$162,312	$519,399
2080	$350,035	$2,318,986

Air quality and extreme heat can compound the economic costs. For more information about the costs of premature mortality in Windsor due to extreme heat and air quality refer to Impact #4.

Possible Adaptation Actions:

Action 2.6 Continue to protect indoor air quality

- ☐ Continue to monitor the indoor air quality of corporate work places and public places;
- ☐ Encourage residential and business property owners to monitor air quality.

Action 2.7 Develop an Air Quality Health Index (AQHI) Response Plan

- ☐ Communicate AQHI warnings via email and a website link to the public as well as community partners (e.g. Windsor- Essex Housing Connections WEHC);
- ☐ Identify actions to limit pollution produced during AQHI warnings as well and limit staff and community exposure to poor air quality;
- ☐ In collaboration with the Windsor-Essex County Health Unit increase education about the Air Quality Heat Index (AQHI).

Action 2.8 Decrease public and private contributions to air quality contaminants

- ☐ Enhance the City of Windsor's Anti-Idling Bylaw;
- ☐ Improve education and awareness of the Anti-Idling Bylaw;
- ☐ Investigate the feasibility of replacing gas and diesel burning equipment with cleaner technologies such as electric powered equipment;
- ☐ Promote the benefits of public and private trees including carbon dioxide capture and improved air quality.

Action 5.5 Complete an Urban Forest Management Plan

- ☐ Complete the City of Windsor Street Tree and Park Tree Inventories;
- ☐ Complete a Canopy Cover Study & Benefits Assessment and develop a Tree Canopy Cover goal for the Windsor community to benefit the environment and human health;
- ☐ Work towards achieving the Tree Canopy Cover goal through increased quality tree planting, maintenance and replacement;
- ☐ Continue to protect the urban forest through enforcement of the public tree by-law (By-law 135-04);
- ☐ Explore additional tree protection measures to limit the removal of trees in Windsor;
- ☐ Increase awareness of the air pollution and greenhouse gas reduction benefits provided by trees.

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Environment Canada online (https://www.canada.ca/en/environment-climate-change/services/air-quality-health-index/publications.html#X-2017062912494131) retrieved March 13, 2019.
4. Environment and Climate Change Canada online (https://www.canada.ca/en/environment-climate-change/services/air-pollution/quality-environment-economy/economic-issues/human-health-costs.html) retrieved Sept 11 2019.
5. Ministry of Environment, Conservation, and Parks online http://airqualityontario.com/aqhi/index.php retrieved September 9, 2019.
6. Organisation for Economic Co-operation and Development (OECD). 2017. The Rising Cost of Ambient Air Pollution thus far in the 21st Century online https://read.oecd-ilibrary.org/environment/the-rising-cost-of-ambient-air-pollution-thus-far-in-the-21st-century_d1b2b844-en#page1
7. Canada. National Round Table on the Environment and the Economy. (2011). Paying the Prince: The Economic Impacts of Climate Change for Canada.

Last Updated: November 2, 2019

Total Risk Score:
115

Impact #7: Increasing temperature increases risk for vector borne disease and new infectious disease

Likelihood	5	Almost Certain
Social	50	Medium
Economic	40	Medium-Low
Environmental	25	Low
Total	115	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Building	More standing water and vegetation growth leading to increased requirements in by-law enforcement
V4	Windsor Essex County Health Unit	Risk for vector borne disease and new infectious disease
V2	Environmental Sustainability and Climate Change	Increase in larviciding program

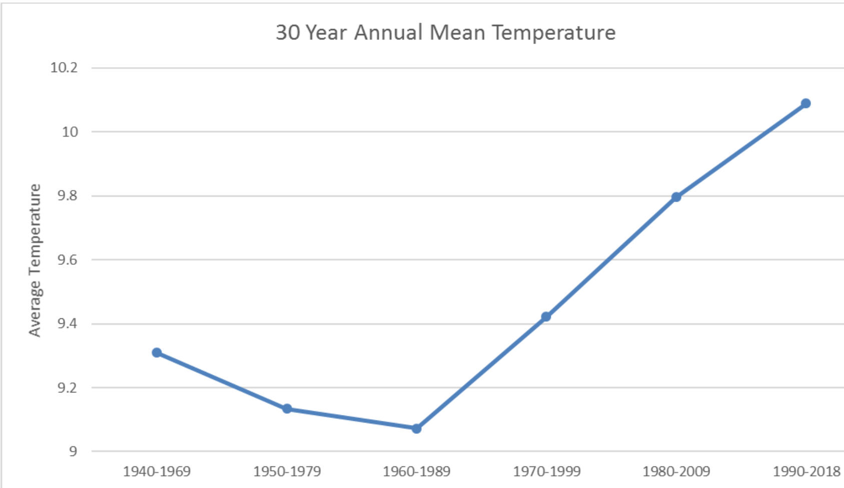
Links to Community Risk Assessment

Statement	**Social**	**Economic**	**Environmental**	**Overall Risk**
Increasing annual temperatures can increase the risk for vector and food borne diseases	50	50	50	150

Supporting Information

Historical Climate Trends

Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent annual mean temperatures over 30-year timeframes (Figure 1).



	30 Year Annual Mean Temperature ºC
1940 - 1969	9.3
1950 - 1979	9.1
1960 - 1989	9.1
1970 - 1999	9.4
1980 - 2009	9.8
1990 - 2018	10.1
2000 - 2018*	10.2
2010 - 2018*	10.3

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Annual Mean Temperatures as Reported at Windsor Airport (Source: Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean annual temperatures as well as seasonal mean temperatures over time (Figures 2 and 3).

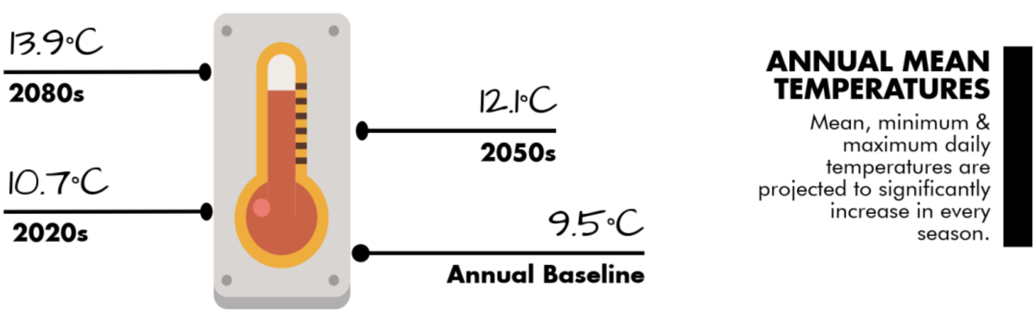


Figure 2: Annual Mean Temperature Projections (source: ICLEI 2018)

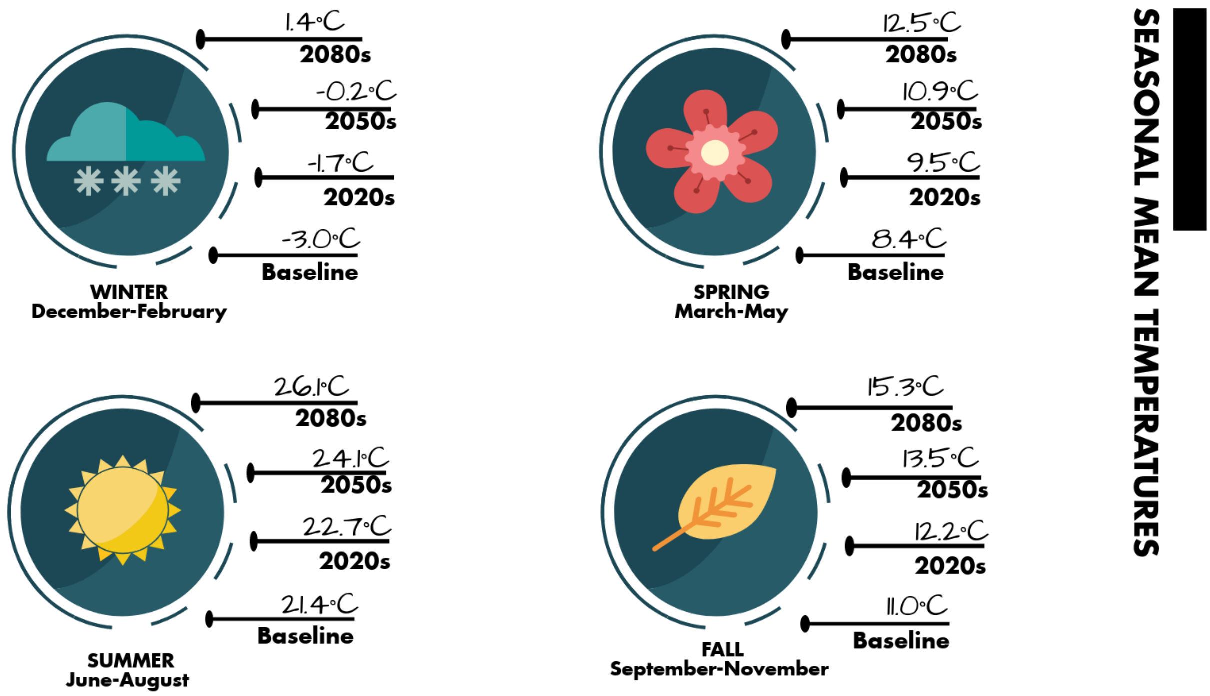


Figure 3: Annual Seasonal Mean Temperature Projections (source: ICLEI, 2018)

Explanation

Vector-borne diseases are transmitted to humans through the bites of insects (vectors) carrying disease-causing pathogens. Common vectors include mosquitos, ticks and flies. Currently in Windsor, there are known human cases of West Nile (carried by mosquitos) and Lyme-disease (carried by Black-legged ticks).

Increasing temperatures can lengthen the living season and broaden the geographic range of disease-carrying vectors. For example, as winters become warmer, there is more opportunity for vectors to over winter in Windsor. In addition, seasonal average temperatures are projected to increase in the spring, summer and fall which will increase optimal breeding conditions for vectors.

Increasing rainfall, flooding and humidity can also create and enhance viable areas for vector breeding and allows breeding to occur more quickly, as eggs hatch faster in hotter climates.

West Nile virus in Windsor/Essex

West Nile virus is transmitted through a bite from an infected mosquito. The Windsor Essex County Health Unit (WECHU) working in collaboration with local municipalities began larviciding for mosquitos in 2003. WECHU monitors yearly the number of mosquito pools that test positive for the virus as well as the number of human cases of West Nile virus (Table 1). West Nile virus causes an asymptomatic infection in 80 % of cases, but in less than 1 % of cases severe illnesses occur that affect the nervous system, such as aseptic meningitis, encephalitis, or acute flaccid paralysis. The remaining cases likely are associated with West Nile Fever (Ouhoummane, et al. 2019). In Table 1 below it is assumed that the number of human cases indicates individuals that presented with symptoms warranting medical treatment, and therefore this number represents only 20 % of the overall number of individuals infected each year. Individuals with West Nile Fever may also not require medical treatment and may be under-reported. Between 2012 and 2018, there were 6 West Nile Virus related deaths in Windsor Essex.

Table 1: Cases of West Nile virus in Windsor/Essex

Year	Number of positive mosquitos pools for WNV	Number of Human Cases
2012	25	22
2013	7	5
2014	1	1
2015	15	4
2016	10	4
2017	29	20
2018	27	13

Lyme Disease in Windsor/Essex

Lyme disease is a potentially serious infection transmitted to humans bit by an infected black-legged tick (also called a deer tick). Not all black-legged ticks carry the bacteria that causes Lyme disease, and not everyone who is bitten by an infected tick will develop signs and symptoms of Lyme disease. The WECHU occasionally drags nets over parkland areas to catch ticks for testing, and individuals that have been bit by a deer tick are encouraged to take the tick to WECHU for testing. Data on the number of infected ticks and human cases of Lyme disease as reported by the Health Unit can be found in Table 2.

Table 2: Cases of Lyme Disease in Windsor/Essex

Year	Number of ticks submitted carrying lyme-disease	Number of Human Cases
2012	0	0
2013	2	3
2014	0	5
2015	4	6
2016	1	2
2017	2	7
2018	2	9

Emerging Concerns

In the last couple of years there has been an influx of new mosquito types to Windsor Essex County (Table 3). These include: *Ae. Albopictus* and *Ae. aegypti*, which are known carriers of the zika virus, chikungunya virus and dengue virus. Fortunately to date, the captured mosquitos have not been carriers of any of the aforementioned viruses.

In October 2019, The Windsor-Essex County Health Unit's (WECHU) routine mosquito surveillance program identified one mosquito pool that tested positive for Eastern Equine Encephalitis (EEE) virus in the community.

Table 3: Number of new Mosquito species captured in Windsor/Essex

Year	Number of Ae. albopictus captured	Number of Ae. aegypti captured
2016	17	0
2017	5	6
2018	1,129	0

In addition, between 2015 and 2018 fourteen Lone Star ticks were submitted to WECHU by the public. A Lone Star tick bite can lead to an alpha-gal allergy (meat allergy) (WECHU, 2019). Any human cases in Windsor?

The Cost of Doing Nothing

West Nile Virus

A recent study reviewed the direct and indirect costs of West Nile virus cases in Quebec during the 2012-2013 season. These costs included medical expenses (ie. emergency room visits, hospitalizations, follow-up appointments, etc.) as well as costs associated with absences from work. The costs were the largest for individuals with West Nile Encephalitis with a median cost of $21,332 per person compared to $8,124 for West Nile Meningitis and $192 for West Nile Fever (Ouhoummane, et al. 2019). In 2013, the economic burden attributed to West Nile Virus in Quebec for 31 symptomatic patients was approximately $430,000 or an average of $13,871 per person (Ouhoummane, et al. 2019). Using this average, the estimated economic burden based on the number of historical human cases in Windsor Essex are provided in Table 4.

Table 4: Estimated Economic Burden from West Nile Virus in Windsor/Essex

Year	Number of Human Cases	Estimated Economic Burden from West Nile
2012	22	$305,162
2013	5	$69,355
2014	1	$13,871
2015	4	$55,484
2016	4	$55,484
2017	20	$277,420
2018	13	$180,323

The Government of Canada uses the value of a statistical life (VSL) in cost benefit analysis calculations as a means to putting a cost to reduce risk of a human life. The value of statistical life (VSL) is defined as the additional cost that individuals would be willing to pay for small reductions in risks that, in the aggregate reduce the expected number of fatalities by one. The VSL is therefore a valuation of anticipated mortality risk reductions, not the valuation of an identifiable life (Canada, 2018). The VSL established by the Treasury Board of Canada Secretariat in 2004 was set at $6.11 million.

Between 2012 and 2018, there were 6 West Nile Virus related deaths in Windsor Essex. Using the VSL, the additional cost that individuals would be willing to pay for a reduction in 6 deaths over 6 years would be of $44.0 million.

Lyme Disease

Two known publications have sought to estimate the economic burden of Lyme Disease. Unfortunately, neither of these studies included economic costs in Canada.

The first publication estimated that the average total health care costs associated with the treatment of Lyme Disease was $2,968 for patients in the US (Adrion et al, 2015). Early detection and treatment can greatly reduce these costs. Using these projected costs, Table 5 shows the estimated health care cost for treatment of Lyme Disease in Windsor/Essex since 2012.

Table 5: Estimated Health Care Costs for Treatment of Lyme Disease

Year	Number of Human Cases	Estimated Health Care Costs
2012	0	0
2013	3	$8,904
2014	5	$14,840
2015	6	$17,808
2016	2	$5,936
2017	7	$20,776
2018	9	$26,712

The second publication identified studies from six countries that assessed the economic burden of Lyme Disease from a societal perspective and included direct (health care costs) and indirect costs (out-of-pocket drug costs, caregiving, travel, work loss, restricted activities, loss of healthy time). Using this information a per capita cost in US dollars was estimated for the 6 countries along with the annual total economic burden based on population: $0.14 per capita cost resulting in an annual total economic burden of $735,550 for Scotland; $0.014 per capita and $142,562 annually for Sweden; $0.51 per capita and $40,880,000 annually for Germany; $1.36 per capita and $23,120,000 annually for the Netherlands; and $2.41 per capita and $786,000,000 annually for the US (Mac, et al., 2019). In order to estimate the economic burden of Lyme Disease from a societal perspective for Windsor the average per capita cost for the 6 countries was used. This results in an estimated societal cost of $216,000 per year for Windsor in 2020.

The World Health Organization has made Lyme Disease a priority disease, as experts predict escalating climate change to play a significant role in the proliferation of the disease. Recently, WECHU has also noted a spread of black-legged ticks. Black-legged ticks were captured in May and October 2018 through WECHU's active surveillance (tick dragging) program. This finding was alarming since no black-legged ticks had been captured in previous years and additionally, no ticks had been captured after the month of May in previous years (WECHU, 2019).

In endemic areas in Europe (eg. Slovenia) and the United States (eg. Maine) studies have reported Lyme Disease incidence rates in ticks of 130 per 100,000 populations in 2010, and 86.4 per 100,000 populations in 2016, respectively (Mac, et al., 2019). Based on these reported incidences of Lyme Disease, the estimated incidence rates in ticks in Windsor Essex is 2.3 per 100,000 populations. If under a changing climate, Windsor was to reach an endemic status or 86.4 per 100,000 populations, the health care costs could climb to $641,088 per year.

Possible Adaptation Actions:

Action 2.9 Enhance monitoring for vector borne diseases and new infections diseases

- ☐ Continue to work in collaboration with the Windsor-Essex County Health Unit (WECHU) to undertake tick and mosquito surveillance programs;
- ☐ Promote the WECHU Fight the Bite public awareness campaign;
- ☐ Continue to participate in larviciding programs to decrease the spread of vector borne diseases;
- ☐ Provide personal protection for outside workers against vector borne disease;
- ☐ Enhance Bylaw Enforcement and response to standing water complaints.

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Ouhoummane N, Tchouaket E, Lowe A-M, Fortin A, Kairy D, Vibien A, et al. (2019) *Economic Burden of West Nile Virus Disease, Quebec, Canada, 2012-2013*, Emerg Infect Dis. 2019 Oct.
4. WECHU (2019). *Community Needs Assessment, 2019 Update.*
5. Adrion E, Aucott J, Lemke K, Weiner J. (2015) Health Care Costs, Utilization and Patterns of Care following Lyme Disease, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0116767
6. Mac S, da Silva S, Sander B. (2019) The economic burden of Lyme disease and the cost-effectiveness of Lyme disease interventions: A Scoping Review, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6319811/
7. Her Majesty the Queen in Right of Canada, represented by the President of the Treasury Board, [2018], from https://www.canada.ca/en/treasury-board-secretariat/services/federal-regulatory-management/guidelines-tools/policy-cost-benefit-analysis.html

Last Updated: November 2, 2019

Total Risk Score:

115

Impact #8: Increasing winter precipitation leading to an increased risk of ice conditions

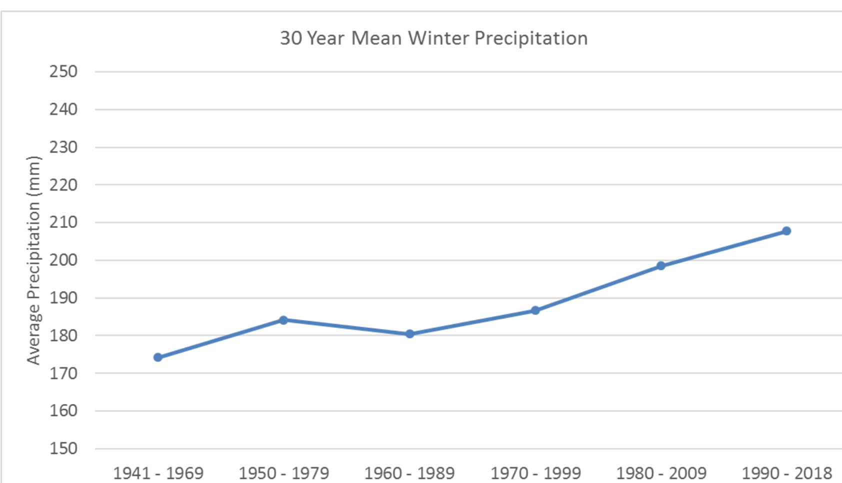
Likelihood	5	Almost Certain
Social	45	Medium
Economic	40	Medium-Low
Environmental	30	Medium-Low
Total	115	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Building	Slip and fall risks to the public and employees
V3	Human Resources	Slip and fall risks to public and employees
V3	Library	Increase in salt use and clearing of snow
V2	Parks Operations	Increase in salt use

Supporting Information

Historical Climate Trends

Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent winter mean precipitation over 30-year timeframes (Figure 1).



	30 Year Mean Winter Precipitation (mm)
1940 - 1969	174.2
1950 - 1979	184.2
1960 - 1989	180.4
1970 - 1999	186.7
1980 - 2009	198.5
1990 - 2018	207.8
2000 - 2018*	210.9
2010 - 2018*	201.8

Note: *indicates not a complete 30-year timeframe

Figure 1: Historical Annual Average Winter Precipitation reported at Windsor Airport (Government of Canada)

As the winter temperatures warm, the risk of freezing rain will increase as well as increasing the conditions allowing the snow to melt and than freeze again.

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean winter precipitation over time (Figure 2).

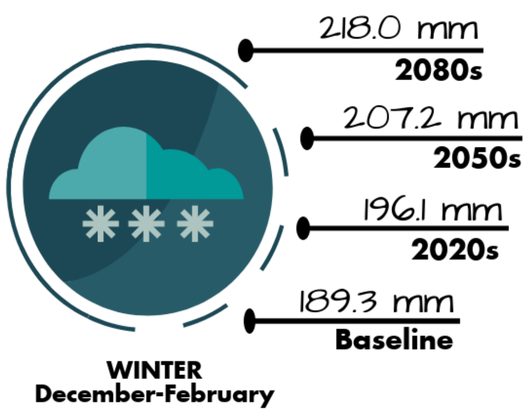


Figure 2: Annual Mean Winter Precipitation Projections (ICLEI, 2018)

As temperatures warm under future climate scenarios, models predict that Windsor could experience less freezing rain in the warmer months (November, March and April); however, during the colder months of December, January and February the area could experience more freezing rain events in the middle to late part of this century. The results show that Windsor could increase the number of freezing rain events from the 40-year average of 3.9, 1.0, and 0.5 (freezing rain events with a duration of >1, 4 and 6 hours a day) to 4.5, 1.4 and 0.8 respectively by the 2080s (Cheng, 2007).

Cost of Doing Nothing

This impact includes too many variables to estimate the cost of doing nothing. For example, there are varying Operational procedures depending if snow or ice occur and how much at a time. Therefore a cost was not estimated for this impact. However, tracking the changes in winter precipitation along with damage claims may provide insight in the future.

Possible Adaptation Actions:

Action 2.10 Enhance community safety during icy conditions

- ☐ Investigate enhancement to winter maintenance and snow ploughing of sidewalks and public spaces;
- ☐ Enhance Bylaw Enforcement and response to public and private snow and ice complaints;
- ☐ Identify and address areas where snow melt water accumulates and increases the likelihood of ice formation;
- ☐ Enhance education to the public about ice and snow hazards;
- ☐ Improve communications to private businesses and landowners on their roles and responsibilities for the maintenance of sidewalks during freezing rain or snow events.

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Cheng et al. 2007. Possible impacts of climate change on freezing rain in south-central Canada using downscaled future climate scenarios. Natural Hazards and Earth System Sciences. Online at https://www.nat-hazards-earth-syst-sci.net/7/71/2007/nhess-7-71-2007.pdf

Last updated: November 2, 2019

Total Risk Score:

114

Impact #9: An increase in water levels leading to overland flooding from the Detroit River/Little River/Lake St. Clair/Lake Erie

Likelihood	3	Possible
Social	39	Medium-Low
Economic	48	Medium
Environmental	27	Low
Total	114	Medium-Low

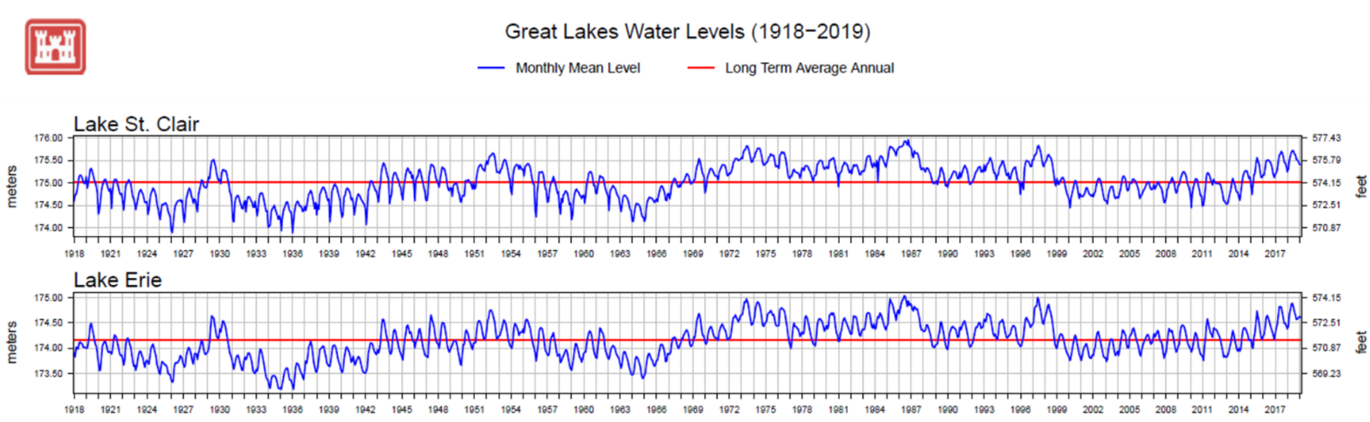
Vulnerability	**Department**	**Impact Statement**
V4	Engineering	Overland flooding from Detroit River/Little River
V4	ERCA	Intense storms leading to reverse flooding
V4	Recreation	Affects marina infrastructure

Supporting Information

Historical Climate Trends

The US Army Corps of Engineers have been monitoring Great Lakes levels in coordination with Canada since 1918. All levels are referenced to the International Great Lakes Datum of 1985 (IGLD 85). The red line represents the long term average annual water level (Figure 1). For the last couple of years both Lake St. Clair and Lake Erie are above this long term average.

Figure 1: Historical Great Lakes Water Levels (US Army Corps of Engineers)



Climate Projections

The US Army Corps of Engineers forecasts show above average water levels in Lake Erie and Lake St. Clair through 2020 (Figure 2). The projections show the probability that the water levels in Lake Erie and Lake St. Clair may be higher in 2019 than in 2018.

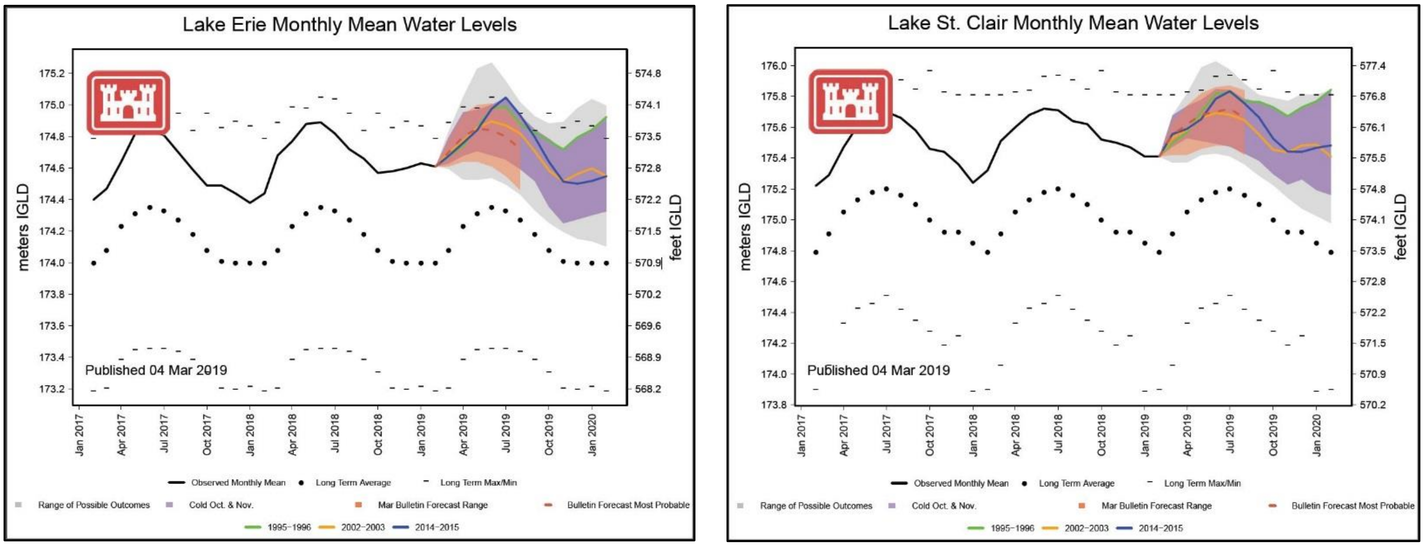


Figure 2: Short-term Lake Erie and Lake St. Clair Forecast (US Army Corps of Engineers)

National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory provides both short-term forecasts and longer term climate change projections for the Great Lakes. The short term forecasts and long-term climate change projections for Lake Erie are provided in Figure 3. The long-term water level projections are informed by four recent studies on the Great Lakes.

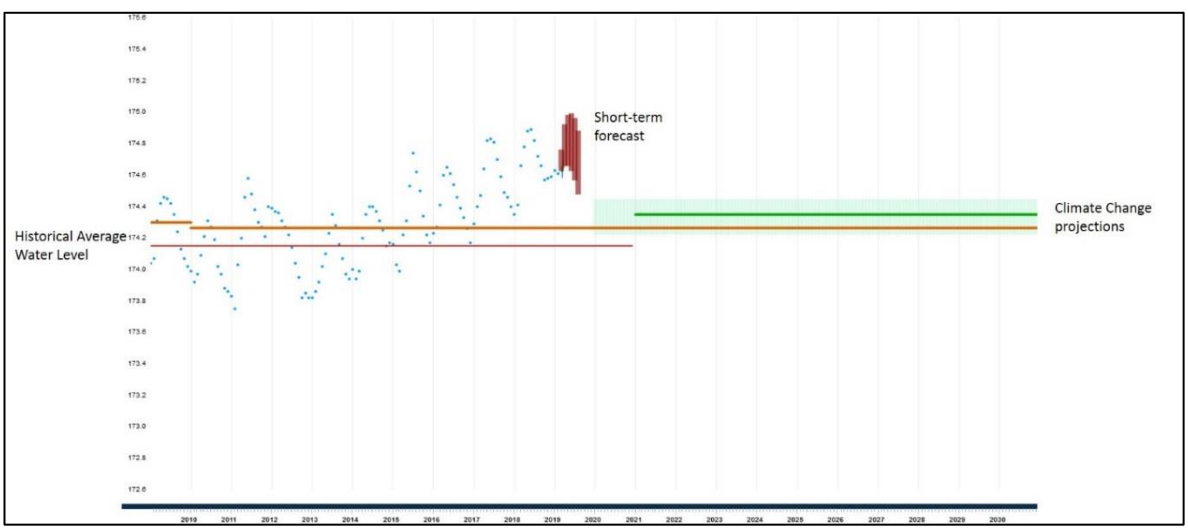


Figure 3: Short-term Great Lakes Level Forecast and Longer Term Climate Change projections for Lake Erie (NOAA) over time

Note: Long-term projections for future Great Lakes water levels are highly uncertain. Many studies have been published in the past several decades that use global climate models to assess the impact that future climates will have on Great Lakes water levels

In 2019, in support of the East Riverside Flood Risk Study, RWDI Consultants were retained to provide climate projections for the current and future 1:100 year instantaneous water level elevations for Lake St. Clair. The 1:100 year instantaneous water levels as determined in this study are 176.5 m, 176.6 m and 176.8 m for 2018 (current climate), 2030 and 2050, respectively. The impacts of these high water levels are noted below.

Departmental Impacts

In 2019, Lake St. Clair peaked at an all time high of 176.08 m. As a result of the high water level the City of Windsor undertook a number of emergency response actions including sandbagging of catch basins and installation of rain catchers in sanitary manholes along Riverside Drive to protect residents from overland flooding. Sand bags were also offered free of charge to homeowner in high risk areas.

The high water levels also resulted in the closure of Lakeview Marina docks as well as contributed to significant erosion of the Peche Island Shoreline. In response to these impacts City Council reallocated money to construct floating docks at Lakeview Marina and to secure the Peche Island Shoreline.

In addition some sewer outfalls were also noted at risk including at: Prospect; Brock, Mill and Huron Church.

Table 1 summarizes the response costs for the 2019 high water levels.

Table 1: 2019 Costs associated with High Water Levels

Emergency Response Costs	$134,010
Cost to reconstruct City owned Marina	$3,000,000
Emergency Repairs to Peche Island Shoreline	$2,500,000
Total as of July 30, 2019	**$5,634,010**

In addition to the financial costs to respond to the high water levels, a revenue loss of $300,000 for the 2019 season is also expected due to the closure of the marina docks.

Essex Region Conservation Authority

Essex Region Conservation Authority monitors the risk flooding and when warranted will issue flood warnings and watches to affected areas (Table 2).

Table 2: Number of Flood Messages issued by ERCA (ERCA, 2019)

	2016	2017	2018	2019 to date
Watershed Conditions Statements – provide flood outlook (an early notice of potential for flooding based on heavy rain, snow melt, etc. and water safety information.	2	17	17	13
Flood Watches – there is potential for flooding	7	15	21	23 (189 days)
Flood Warnings – flooding is imminent or already occurring	2	5	13	11

Note: These flood messages are for all of Essex County and are not limited to the City of Windsor
*: As of October 31, 2019

In 2018, severe flooding in Essex County (not within the City of Windsor) resulted in ten homes being put under an Order to Remedy (not habitable until fixed) and five were put under an Order to Prohibit the Use (not-habitable).

In 2019, Essex Region Conservation Authority issued a long-term flood watch from April 10 to October 15, approximately 189 days.

The Cost of Doing Nothing

In 2019, Landmark Engineers Inc. was retained to complete the East Riverside Flood Risk Study. Using the Lake St.Clair climate projections developed by RWDI (above), properties at risk of flooding under the various water levels were identified (Figures 4 – 6).

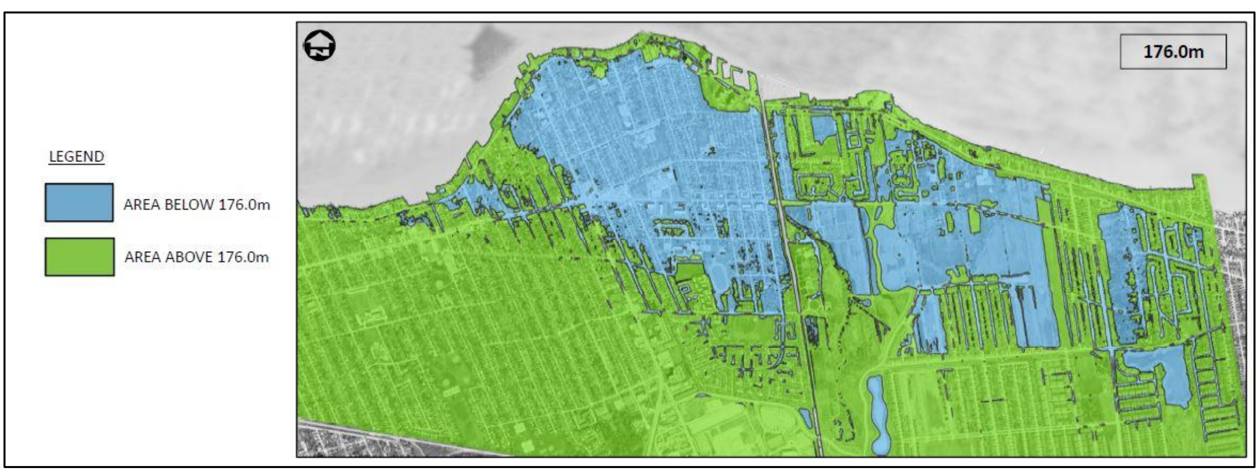


Figure 4: Area at Risk for Overland Flooding at current high water level of 176.0 m (Landmark Engineers, 2019)

At this water level, the existing dike system with some emergency modifications is currently protecting the properties to the south. This is shown by the green band of land along Riverside drive (Figure 4).

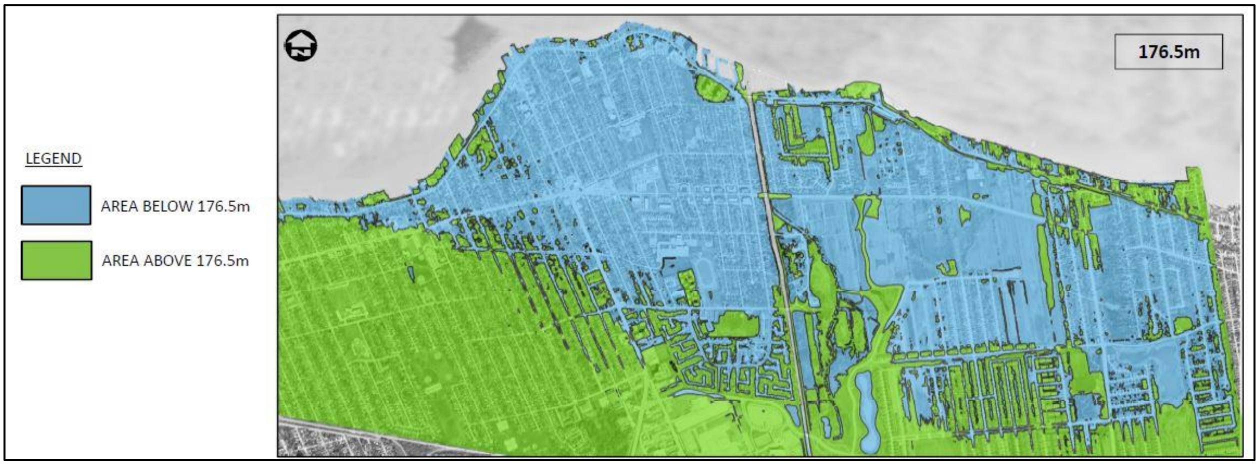


Figure 5: Area at Risk for Overland Flooding at a high water level of 176.5 m (current 1:100 year level) (Landmark Engineers, 2019)

At this level, sections of the existing dike would be exceeded. The original dike design was set at a 176.4 m flood level.

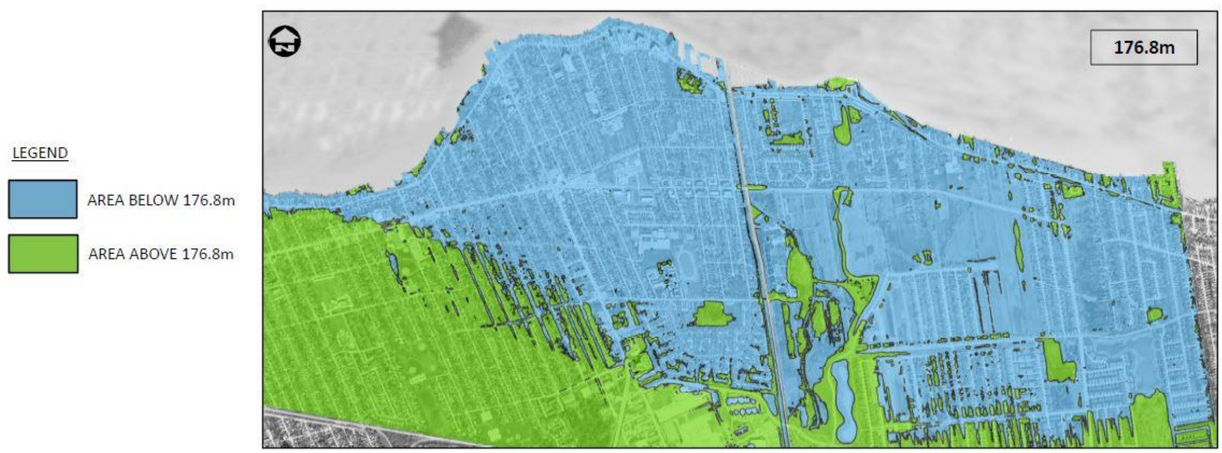


Figure 6: Area at Risk for Overland Flooding at a high water level of 176.8 m (1:100 year water level - 2050s) (Landmark Engineers, 2019)

At this level, the majority of the dike would be breached.

Using the figures above and current zoning for the properties, an estimate was made on the total number of properties that could be affected by overland flooding (Table 3).

Table 3: Total Number of Properties at Risk under Various High Water Levels

Property type	**2019 water level 176.0m**	**1:100 yr event Current 176.5m**	**1:100 yr event 2050s 176.8m**
Residential	3907	6916	7764
Commercial	63	90	102
Institutional	6	8	9
Industrial	5	13	15
Green District	60	71	72
Development	20	20	20
Total Land Parcels	4,061	7,118	7,982

In 2018, the Insurance Bureau of Canada estimated that the average cost to repair a flooded basement was $43,000. In order to estimate a cost for the do nothing scenario the $43,000 is used regardless of property type. This will provide a very conservative estimate as commercial, institutional and industrial properties would likely result in much larger losses. In addition, residential losses would likely be above $43,000 as overland flooding may result in repairs to main level living areas. Under this estimate no losses were assumed for green district or development parcels although losses are also likely under these property classes.

In the event that the scenarios illustrated in Figures 4 through 6 occur the estimated losses are shown in Table 4.

Table 4: Estimated Losses on Private Property for Overland Flooding under various high water levels

1:100 Year Water Level	Estimated Losses on Private Property for Overland Flooding	Comments
176.0 m	$171,183,000	Current dike was designed at a 176.4 m elevation. However, some risk still exists under a 176.0 m water level as wind driven waves can increase water level height by 0.34 m for the Detroit River shoreline and 1.5 m for the Lake St. Clair Shoreline.
176.5 m	$302,161,000	The Little River Pollution Control plant may be impacted.
176.8 m	$339,270,000	The Little River Pollution Control plant will be impacted.

Under the 176.5 m scenario there is a threat of overland flooding to the Little River Pollution Control Plant that would seriously jeopardize the facility. Under such a scenario, the plant would be forced to shut down to protect critical components. The loss of critical components at the plant could result in the loss of sewage treatment to all properties within the Little River Pollution Control Plant drainage area. In 2018, there were 26,928 households in Windsor and Tecumseh connected to the plant. Of these properties, 19,164 are not already at risk of overland flooding but due to a plant shut down would now be put at risk of basement flooding. This could result in an addition $824 million in losses for private property owners.

These estimated costs do not include damages that would occur to City owned infrastructure such as roads, playgrounds, pump stations and the Little River Pollution Control Plant nor does it include economic losses from business closures, productivity losses, or environmental damages. However, to put some context around the cost if the Little River Pollution Control Plant was to flood, can be estimated by the cost experienced by the City of Thunder Bay. In 2012, the City of Thunder Bay's sewage treatment plant experienced flooding to tunnels, and much of it machinery and extensive emergency repairs were needed. The cost of those repairs is about $58 million. That figure included plant-related repairs, emergency response to the facility as well as operating and capital costs.

Possible Adaptation Actions:

Action 3.5 Review and improve policies and procedures to prepare for overland flooding

- ☐ Identify vulnerable roads and areas prone to overland flooding and have appropriate plans in place to address them;
- ☐ Continue to provide sandbags to vulnerable properties when required;
- ☐ Continue to sandbag critical infrastructure when required;
- ☐ Install high water detection equipment at critical infrastructure to monitor surface water levels

Action 4.4 Implement the recommendations of the East Riverside Flood Risk study to reduce overland flooding risk

- ☐ Assess vulnerable areas and properties along the Detroit River;
- ☐ Share the findings with the public and conduct public education on flooding risks, responsibilities and emergency response;
- ☐ Enhance the barrier landform where required;
- ☐ Ensure protection of the St. Paul Pump Station.

Action 4.5 Continue to monitor Little River overland flooding risk

- ☐ Inspect the landform along the Little River channel and provide enhancements as required;
- ☐ Enhance the berm around the Little River Pollution Control Plant to protect critical infrastructure

Action 4.7 Continue to invest in stormwater and sewer infrastructure

- ☐ Conduct vulnerability and risk assessments for critical infrastructure including pump stations;
- ☐ Invest in municipal drain and stormwater pond improvements;
- ☐ Where warranted, enhance stormwater infrastructure operations and maintenance;
- ☐ Increase drawdown rates for storm water ponds;
- ☐ Enhance phragmites control to maintain capacity of drains and ponds.

Action 5.7 Enhance Detroit River shoreline protection measures along Windsor's riverfront and Peche Island

Action 6.6 Evaluate and enhance recreational uses along Windsor's shoreline

- ☐ Enhance shoreline protection for Sandpoint Beach;
- ☐ Enhance shoreline protection for Peche Island;
- ☐ Evaluate where pathways and trails should be set back from surface water bodies to protect public safety and limit closures when water levels are high.

Action 6.7 Replace Lakeview Marina docks with floating docks that are more resilient to varying water levels

Action 7.4 Enhance education to the public about the risk of high surface water levels

- ☐ Communicate with the media and use social media to update the public on current or changing conditions;
- ☐ Collaborate with other organizations such as ERCA to help spread similar messaging;
- ☐ Use various educational tools and resources to help illustrate overland flooding to the public;
- ☐ Provide door-to-door visits to vulnerable properties as required;
- ☐ Educate the public on the risks of driving on flooded roads

References

1. US Army Corps of Engineers (online) https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Information-2/Water-Level-Data/
2. NOAA, Great Lakes Environmental Research Laboratory (online) https://www.glerl.noaa.gov/data/dashboard/GLHCD.html
3. ERCA, 2019. 2018 Annual Report (online at https://essexregionconservation.ca/wp-content/uploads/2019/01/ERCA_AnnualReport_2018_WEB.pdf)

Last Updated: November 2, 2019

Total Risk Score:
112

Impact #10: Increasing intensity storms leading to damage to infrastructure, power outages, safety and additional clean up costs

Likelihood	4	Likely
Social	40	Medium-Low
Economic	48	Medium
Environmental	24	Low
Total	112	Medium-Low

Vulnerability	Department	Impact Statement
V5	Operations	Damage to infrastructure, power outages and additional cleanup costs
V3	Parks Operations	Increase in operating maintenance
V3	Transit	Damage to buses and facilities, removing buses(at least three) from fleet
V3	Facilities	Property damage
V2	Building	Waste generation
V1	Library	Property damage due to more moisture

Links to Community Risk Assessment

Statement	Social	Economic	Environmental	Overall Risk
Increased frequency of extreme weather events can lead to more power outages	45	85	30	160

Supporting Information

Operational Costs for Response and Clean-Up of Various Recent Events in the City of Windsor

Events	Total Costs
2016 Tornado	$101,109
2016 Flood	$285,674
2017 Severe Winds	$70,546
2017 Flood	$1,690,086
2018 Wind Storm	$251,780
2019 High Water Levels*	$192,870

Note *: Costs incurred as of October 31, 2019

As a result of the various natural events listed above, the City incurred costs exceeding $2.5 million since 2016.

Community Impacts

Insurance Bureau of Canada

The Insurance Bureau of Canada (IBC) has reported that the insured losses in our region from the 2016 and 2017 flooding events totalled $108 million and $124 million respectively. Community costs associated with the other events noted above are not available as IBC only publishes events that exceed $25 million or more in insured losses.

The Cost of Doing Nothing

The City of Windsor carries insurance to mitigate losses due to extreme weather with a deductible of $100,000 per occurrence. The policy also includes business interruption and loss of revenue. However, similar to insurance covered by the public, repeat occurrences can drive up the City's insurance premium.

Possible Adaptation Actions:

Action 4.3 Incorporate climate change considerations into infrastructure design, development, maintenance and renewal

- ☐ Continue to consider climate change when implementing the City of Windsor's Asset Management Plan;
- ☐ Continue to implement the Triple Bottom Line approach considering financial, social and environmental costs and benefits when making infrastructure decisions.

Action 6.2 Develop extreme weather contingency plans for Transit Windsor

- ☐ Identify priority risk areas and develop a Plan to respond to flooding of transit infrastructure, disruption of service and infrastructure damage to terminals, shelters, benches, bus stop pads etc.;
- ☐ Invest in back up power sources for all key Transit Windsor infrastructure including fuel pumps;
- ☐ Explore storing Transit Windsor buses in more than one location

References:

1. Insurance Bureau of Canada, retrieved online March 25, 2019 at http://www.ibc.ca/on/resources/media-centre/media-releases/windsor-floods-cause-close-to-108-million-in-insured-damage
2. Insurance Bureau of Canada, retrieved online March 25, 2019 at http://www.ibc.ca/on/resources/media-centre/media-releases/late-august-flooding-in-windsor-region-caused-more-than-124-million-in-insured-damage/

Last Updated: November 2, 2019

Total Risk Score:

110

Impact #11: An increase in extreme precipitation leading to an overwhelming of City infrastructure

Likelihood	5	Almost Certain
Social	30	Medium-Low
Economic	45	Medium
Environmental	35	Medium-Low
Total	110	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V5	Operations	Flooding of roads, sewers etc.
V5	Pollution Control	Flooding, infrastructure, building and vehicle damage
V3	Engineering	Municipal drain capacity to be exceeded
V3	Facilities	Flooding forcing building closures and reduction of services
V3	Parks Operations	Increase in operating maintenance
V2	Engineering	Increase in sewer pipe size, pump size, pond sizes to maintain level of service
V2	Transit Windsor	Overland flooding leading to transit terminal closures
V2	Transit Windsor	Flooding contributing to rerouting of buses
V2	Emergency Preparedness	Flooding, infrastructure, building and vehicle damage
V2	Pollution Control	Overland flooding of storm water facilities
V2	Pollution Control	Increase in sewer pipe size, pump size, pond sizes to maintain level of service
V1	Transportation Planning	Requiring larger ponds reducing population density, increasing trip length for transit and active transportation

Links to Community Risk Assessment

Statement	Social	Economic	Environmental	Overall Risk
Overland flooding can cause closure of businesses, schools and disruptions to community services	40	56	48	144

Supporting Information

Climate Projections

In 2015, Essex Region Conservation Authority with the support of Windsor Essex municipalities retained researchers to undertake a review of intensity-duration-frequency (IDF) curves for the region. The study *A Comparison of Future IDF Curves for Southern Ontario* (Coulibaly, 2015) predicts a 25% increase in the 10-year return storm intensity and a 40% increase in the 100-year return storm intensity by the 2090s (see figure 1). The solid bar in the box plots indicates the 50^{th} percentile of the results while the outer bars indicate the 10 % and 90% range.

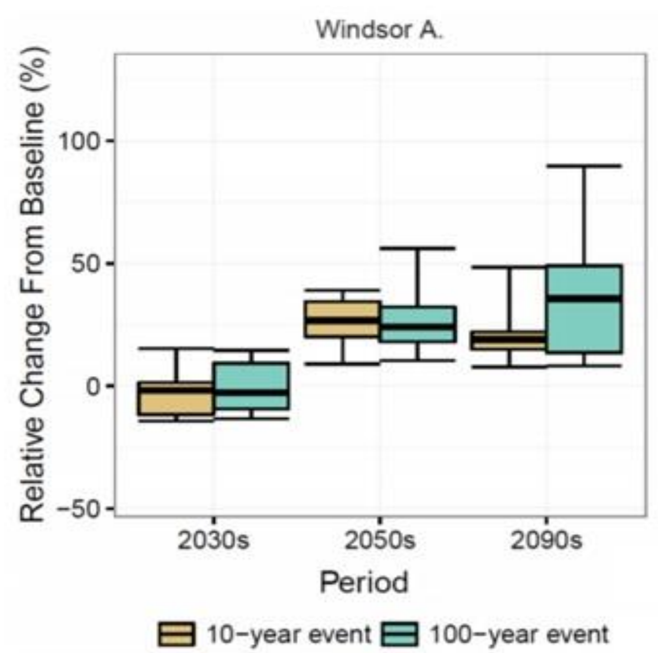


Figure 1. Relevant change from baseline in 10 year and 100 year flooding events over time (Coulibaly et al.)

As shown in Figure 2 below, a 1-in-100 year storm today in the City of Windsor is projected to be a 1-in-20 year storm by mid-century.

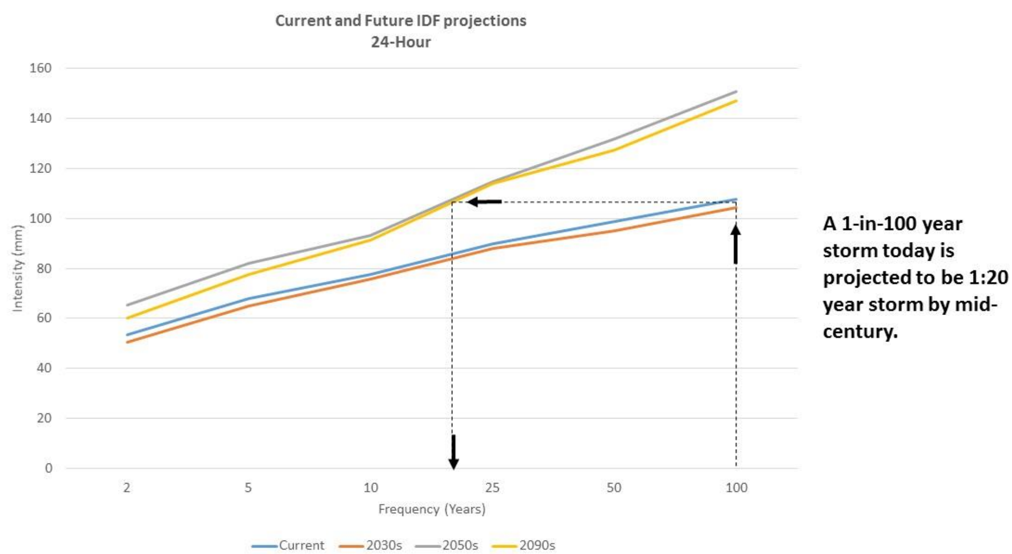


Figure 2. Current and Future Rainstorm Intensity Projections (Coulibaly et al.)

Departmental Impacts

Transit Windsor: During the 2016 flood event, Transit Windsor had to temporary divert services away from the Tecumseh Mall Transit Terminal as Tecumseh Mall Parking lot was overwhelmed.

During flood events, Transit Windsor still operates but often has to temporary reroute buses to avoid any flooded streets.

Lou Romano Water Reclamation Plant: Site drainage at the Lou Romano Water Reclamation Plant drains to the front of the plant for treatment. Under heavy rainfall events, the inlet capacity often is exceeded which may restrict flow from the site. On a number of occasions this has caused the site drainage to backup into the plant's grit building. Depending on the extent of the back-ups repair costs can range from $10,000 to close to $100,000.

Windsor Public Library: The 2017 Flood event lead to the temporary closure (3 days) of Budimir and Riverside libraries. Basement spaces were closed for longer in order for repairs to be made.

Capri Centre: The Capri Centre was also damaged during the 2017 flood event.

The Cost of Doing Nothing

The City of Windsor carries insurance to mitigate losses due to extreme weather with a deductible of $100,000 per occurrence. The policy also includes business interruption and loss of revenue. However, similar to insurance covered by the public, repeat occurrences can drive up the City's insurance premium.

Possible Adaptation Actions:

Action 2.2 Develop an emergency response procedure for extreme flooding events

- ☐ Ensure open communication among City of Windsor staff and first responders before, during and after the event;
- ☐ Identify vulnerable roads and areas prone to overland and extreme rain event flooding and have appropriate plans in place to address them;
- ☐ Consult and collaborate with first responders to prepare road closure protocols;
- ☐ Develop a safe access standard for road evaluations;
- ☐ Continue to coordinate emergency response with the Local Health Integration Network (LHIN) to decrease risk to vulnerable populations.

Action 4.1 Implement the Sewer Master Plan overall recommendations (including but not limited to)

- ☐ Identify infrastructure most at risk for extreme weather impacts;
- ☐ Continue to implement sewer infrastructure replacement and improvements;
- ☐ Install rain guards in sanitary manholes;
- ☐ Design and installation of curb inlet flow restrictors;
- ☐ Introduce city-wide mandatory downspout disconnection;
- ☐ Explore feasibility of a retention treatment basin (RTB) on the riverfront trunk sewer near the Lou Romano Water Reclamation Plant;
- ☐ Explore opportunities for stormwater storage near the Little River Pollution Control Plant.

Action 4.7 Continue to invest in stormwater and sewer infrastructure

- ☐ Conduct vulnerability and risk assessments for critical infrastructure including pump stations;
- ☐ Invest in municipal drain and stormwater pond improvements;
- ☐ Where warranted, enhance stormwater infrastructure operations and maintenance;
- ☐ Increase drawdown rates for storm water ponds;
- ☐ Enhance phragmites control to maintain capacity of drains and ponds.

Action 4.8 Protect and improve roads from flooding damage

- ☐ Assess frequently flooded roads and consider road improvements

Action 4.9 Promote green infrastructure options for drainage issues on public and private property

- ☐ Research and implement the use of green infrastructure as part of municipal projects;

- ☐ Encourage the use of French drains, dry wells, bioretention stormwater ponds or raingardens to enhance rear yard drainage as opposed to connecting to a storm sewer;
- ☐ Promote, encourage and protect the use of urban forests as Green Infrastructure for rainwater interception and erosion control benefits.

Action 5.2 Investigate the potential for natural areas to enhance flood attenuation

- ☐ Identify where flood attenuation is needed within the City of Windsor;
- ☐ Review water retention possibilities in natural areas including lands adjacent to Provincially Significant Wetlands and other wetland associated habitats (e.g. swamp forest, wet prairie, meadow marsh).

Action 7.2 Explore options to implement stormwater financing mechanisms

- ☐ Complete the Stormwater Financing Study
- ☐ Effectively communicate and educate the public of any stormwater financing implementation decisions

Action 7.3 Enhance the use of low impact development in both private and public areas to reduce storm water impacts

- ☐ Develop opportunities for increased stormwater management in parks.
- ☐ Incorporate low impact development into infrastructure projects such as roads, sewers and public spaces development.
- ☐ Continue to monitor and showcase current City of Windsor low impact development projects.
- ☐ Promote and incentivize the use of low impact development to developers, private landowners and the community.

References:

1. Coulibaly, P. Burn, D. and Switzman, H. (2015). *Technical Report: A Comparison of Future IDF Curves for Southern Ontario* (prepared for the Essex Region Conservation Authority and the Toronto Region Conservation Authority).

Last Updated: November 2, 2019

Total Risk Score:
110

Impact #12: Increase in winter and spring temperatures leading to quicker thawing and snowmelt contributing to overland flooding

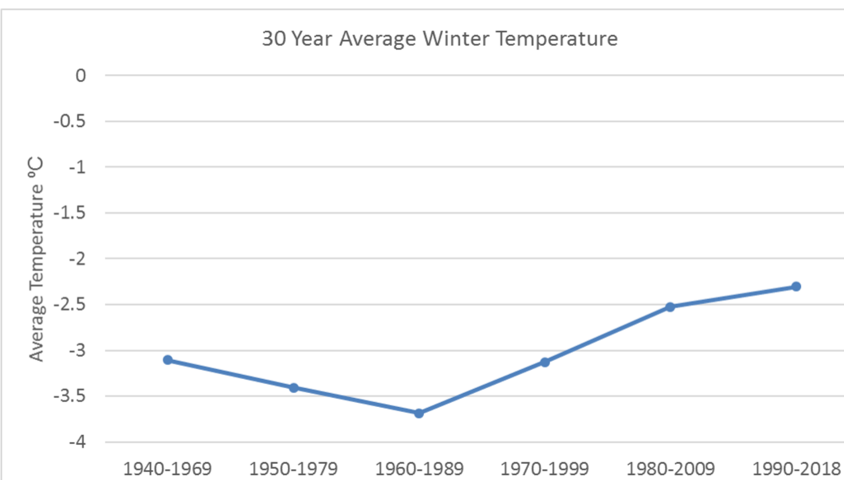
Likelihood	5	Almost Certain
Social	25	Low
Economic	55	Medium-High
Environmental	30	Medium-Low
Total	110	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Operations	Overland flooding
V2	Pollution Control	Overland flooding

Supporting Information

Historical Climate Data

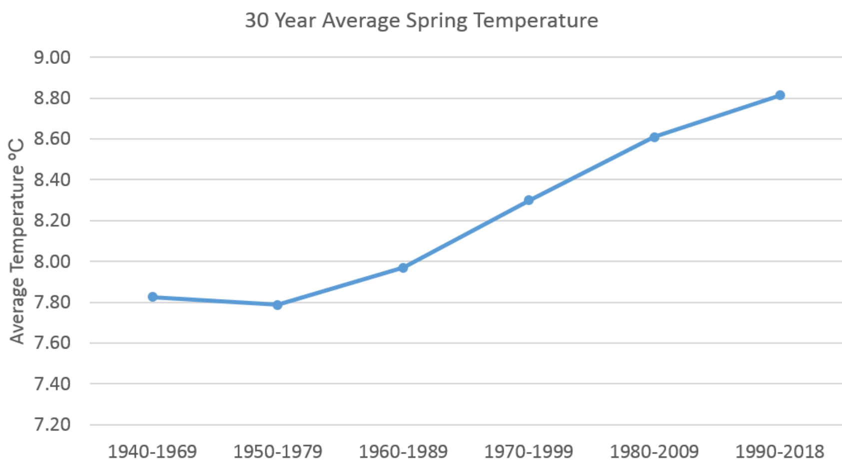
Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent winter and spring mean temperatures over 30-year timeframes (Figures 1 and 2).



	30-Year Winter Mean Temperatures °C
1940 - 1969	-3.1
1950 - 1979	-3.4
1960 - 1989	-3.7
1970 - 1999	-3.1
1980 - 2009	-2.5
1990 - 2018	-2.3
2000 - 2018*	-2.4
2010 - 2018*	-2.5

Note: * Indicates not a complete 30-year timeframe

Figure 1: Historical Winter Mean Temperatures as Reported at Windsor Airport (Government of Canada)



	30-Year Spring Mean Temperatures °C
1940 - 1969	7.8
1950 - 1979	7.8
1960 - 1989	8
1970 - 1999	8.3
1980 - 2009	8.6
1990 - 2018	8.8
2000 - 2018*	9
2010 - 2018*	9.1

Note: * Indicates not a complete 30-year timeframe

Figure 2: Historical Spring Mean Temperatures as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean winter and spring temperatures over time (Figure 3).

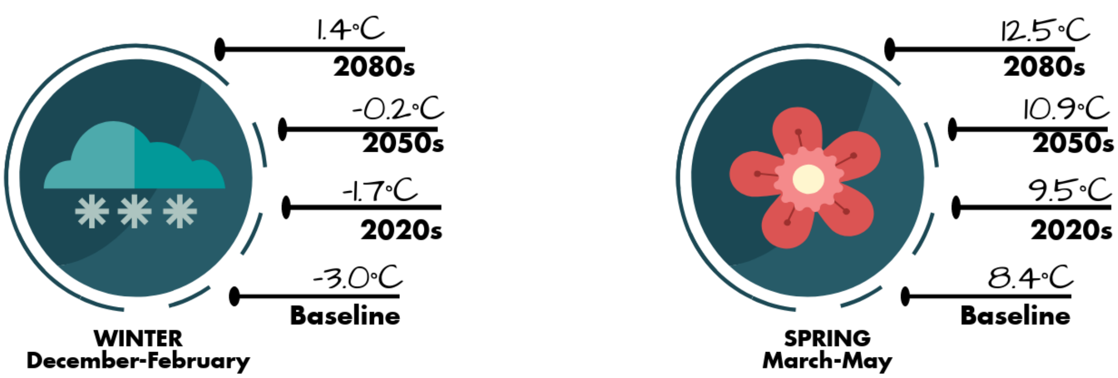


Figure 3: Winter and Spring Mean Temperature Projections (ICLEI, 2018)

Warming winter temperatures can contribute to faster snowmelts, which can also be exacerbated by rain. Quick snowmelts can reduce capacity in the sewer system but can also lead to localized overland flooding in areas where the snowmelt can not drain effectively.

Cost of Doing Nothing

Melting snow should drain to nearby catchbasins or infiltrate into the unfrozen ground. A quick snow melt becomes a concern based on the speed of the melt, frozen ground conditions and can also be exacerbated by heavy rains. Overwhelming of the City's sewer system can lead to basement flooding (Impact 2), while poor drainage can lead to overland flooding. In the scenarios discussed during impact identification, this Impact was identified for the risk posed to properties (basement flooding, overland flooding), flooding of roads as well as environment concerns (salt runoff, waste water plant bypasses).

The economic costs associated with overland flooding from snowmelt is considered minor in comparison to the costs associated with basement flooding (Impact 2) and overland flooding from the Detroit River/Little River (Impact 9) as the extent of the flooding from snowmelt conditions is expected to be limited to very localized areas. That being said, in 2018, the Insurance Bureau of Canada estimated that the average cost to repair a flooded basement was $43,000. Not all damages are covered by insurance, especially if the property in question had flooded previously and overland flood insurance is not common yet.

Possible Adaptation Actions:

Action 3.1 Increase education to the public on how to reduce their personal risk of basement flooding

- ☐ Hire a coordinator to conduct public education and outreach to highlight responsibilities of the property owner and promote lot level storm water controls. These include but are not limited to rainbarrels, rain gardens and down spout disconnections;
- ☐ Develop outreach programs to teach residents what they can do to reduce snowmelt flooding on their property;
- ☐ Provide education to private market and social housing landlords and business owners outlining precautions, insurance options and responsibilities for tenants and landlords;
- ☐ Provide education on cleaning and fixing damaged property after a flooding event to prevent mould growth.

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.

Last updated: November 2, 2019

Total Risk Score:

108

Impact #13: An increase in annual temperature can increase plant pests, disease and invasive species

Likelihood	4	Likely
Social	28	Low
Economic	36	Medium-Low
Environmental	44	Medium
Total	108	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V5	Forestry	Increase risk of invasive species
V4	Forestry	Change pest cycles increasing pest control problems
V4	Forestry	Shift in plant hardiness zones providing new opportunities for new species
V3	Forestry	Stress leading to tree loss
V3	ERCA	A loss of frozen conditions leading to the spread of invasive species and disease contributing to a loss of species at risk and overall biodiversity

Links to Community Risk Assessment

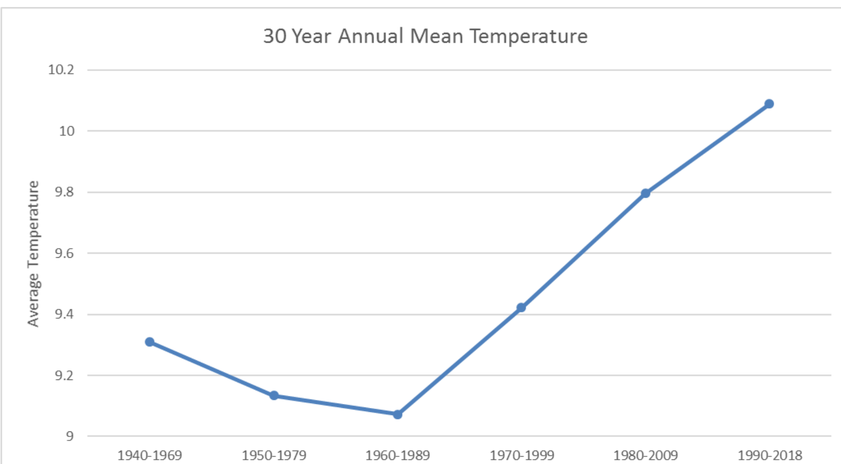
Statement	**Social**	**Economic**	**Environmental**	**Overall Risk**
Increase in temperatures may lead to increase in tree pests/viruses and loss of urban tree canopy	50	65	80	195
Changes in weather patterns and extremes can cause damage to Windsor's natural features (terrestrial and aquatic) leading to decreased summer tourism and a shift in the tourism industry	20	70	85	175
Increase in annual temperatures can support longer pest lifecycles, and contribute to spread of diseases and pests affecting natural systems	70	50	50	170

Increased temperatures and precipitation causing damage to trees and natural features, leading to loss of ecosystem good and services	40	48	64	152
Shifting temperature patterns and ecoregions can lead to inhospitable habitat for sensitive plant and animal species, changing the community's biodiversity	40	45	50	135

Supporting Information

Historical Climate Trends

Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent annual mean over 30-year timeframes (Figures 1).



	30 Year Annual Mean Temperature °C
1940 - 1969	9.3
1950 - 1979	9.1
1960 - 1989	9.1
1970 - 1999	9.4
1980 - 2009	9.8
1990 - 2018	10.1
2000 - 2018*	10.2
2010 - 2018*	10.3

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Annual Mean Temperatures as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the annual mean and seasonal temperatures over time (Figures 2 and 3).

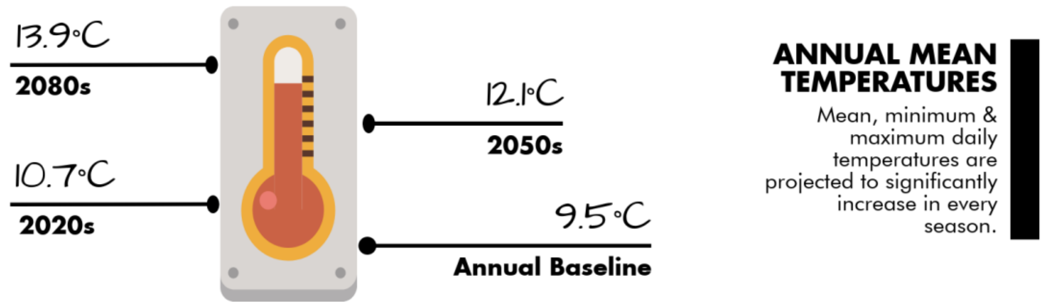


Figure 2: Annual Mean Temperature Projections (ICLEI, 2018)

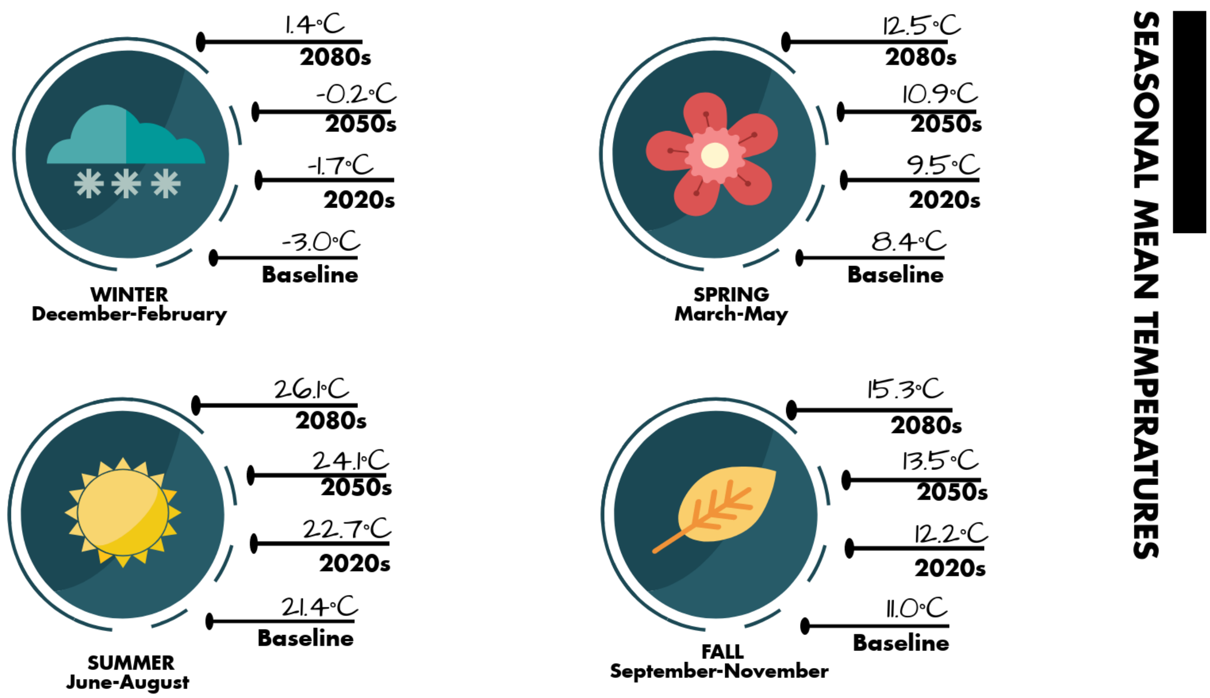


Figure 3: Annual Seasonal Mean Temperature Projections (ICLEI, 2018)

Explanation:

Local ecosystems are facing a number of threats from a changing climate including survival in a quickly changing climate and the introduction of invasive alien species that are able to survive in the new climate.

As the local climate warms, species will migrate further north. In recent decades, in both land and aquatic environments, plants and animals have moved to latitudes at a median rate of 16.8

kilometres per decade. As the climate continues to change, models and long-term studies project even greater shifts in species ranges. However, many species may not be able to keep pace with climate change for several reasons, for example because their seeds do not disperse widely or because they have limited mobility, thus leading, in some places, to local extinctions of both plants and animals (Groffman et al. , 2014).

Invasive alien species and pests can be transported unknowingly by humans to the region through international trade, shipping/boating (ex. Zebra mussels), movement of wood (ex. Emerald Ash Borer), horticulture/landscaping (ex. Phragmites). There is also the intentional release of pets (ex. Red Eared Slider Turtles).

Invasive alien species have had a profound impact on Ontario's most fragile and threatened natural ecosystems. Climate Change is likely to increase the rate of invasions into the region and lead to a spread of already-established species. While a warming climate will increase environmental stresses, and may result in less resilient ecosystems that are unable to combat invasive species. (MNR, 2012) For example, warmer winter temperatures may allow invasive species to over-winter and therefore establish in the region.

Forestry:

Impacts to Ash Tree by the Emerald Ash Borer

It was estimated that Windsor/Essex lost over 1 Million Ash trees to the Emerald Ash Borer. This included losing our local population of the very rare Pumpkin Ash. Blue Ash populations (listed as 'Threatened'), while showing some signs of resistance, have also been negatively affected.

The loss of Ash in our riparian areas have now become vulnerable as some of these areas are being dominated by other invasive species like Phragmites. This has resulted in a loss of biodiversity in these areas/wetlands and their storm water retention capabilities have now been negatively affected.

Ash trees also had a major role to play in the integrity of the City's Urban Forest. A very popular shade tree, Ash were widely planted for their fast growing attributes and attractiveness. The City lost 7,000 Ash trees along the Right of Way and in City Parks at a removal and replacement cost of over $4 Million dollars. Ash once made up 10% of our Street Tree Inventory.

Other Invasive species

Oak Wilt. Knocking on the doorstep of Canada has recently been found on Belle Isle in the Detroit River. Rare and Endangered Black Oak/Pin Oak savana are at risk (1,000 acres). Natural areas typically consist of 10-20% Oak species.

Shumard Oak which are listed as Special Concern are also at risk. The City's Street Tree Inventory consists of 3 % Oak trees

Asian Long Horned Beatle. This destructive beatle prefers Maple, Poplar and Elm trees among a few others. Maples comprise of approximately 18 % of our street tree inventory alone (~12,500 trees)

Bag Worm prefers Honeylocust, Maples and conifers. Mild winters promote the survival of overwintering larvae in bags. Hard cold winters will kill these off and help keep populations in check.

The Linden Bark Borer attacks all species of Lindens and Basswood. Lindens make up 10% of our Street Tree Inventory

The Spotted Lantern Fly attacks fruit trees and Crab Apples which are popular ornamental tree in most City's/rural areas

In 2018, The City of Windsor's Forestry division spent over $900,000 on managing invasive species including: Emerald Ash Borer; Phragmites; Oak Wilt; Japanese Knotweed; Garlic Mustard; Wild Parsnip; European Buckthorn; Linden Bark borer; Autumn Olive and others. Expenditures for phragmites alone was $320,000.

Windsor Utilities Commission:

To eliminate taste and odour problems associated with Zebra Mussels, WUC added an activated charcoal treatment at a cost of $400,000 to $450,000 per year. (MNR, 2012)

The Cost of Doing Nothing

In Canada, the annual cost of invasive alien species is estimated to be as much as $20 billion to the forest sector, $7 billion for aquatic invasive species in the Great Lakes and $2.2 billion for invasive plants alone in the agricultural sector (Canada, 2012). A second study estimated the potential economic impacts of invasive alien species to be approximately $3.6 billion per year in Ontario (Vyn, 2018).

Based on the 2018 survey results for expenditures for invasive species programs, the total expenditure by municipalities and Conservation Authorities in Ontario range from $16.8 million to $29.6 million annually. It is estimated that total expenditures could increase by 10 times to effectively control invasive species in the province and there would still be a net benefit to the province (Vyn, 2018).

Possible Adaptation Actions:

Action 5.1 Protect and enhance the management of natural areas to improve climate change resilience

- ☐ Evaluate and prioritize natural areas restoration opportunities;
- ☐ Develop high level policies to inform the development of Natural Areas Management Plans;
- ☐ Develop Natural Areas Management Plans;
- ☐ Prioritize the preservation of unprotected natural properties especially for consolidation of existing natural areas;
- ☐ Increase implementation of natural areas restoration and maintenance;
- ☐ Conduct restoration using appropriate zone specific plants focusing on those identified to be able to withstand extreme weather events;
- ☐ Monitor, protect and advocate for species at risk;
- ☐ Enhance communication and coordination with other agencies;
- ☐ Enhance recognition of Trees as assets in all rehabilitation, development and remediation issues.

Action 5.3 Enhance linkages between and among natural heritage features

- ☐ Ensure land retention of natural heritage linkages;
- ☐ Investigate increased land connectivity options including land acquisition and landscaped or below grade Eco passages to enhance natural areas linkages.

Action 5.4 Implement an Invasive Species Program

- ☐ Hire an invasive species coordinator for the City of Windsor;
- ☐ Monitor Windsor’s natural areas for invasive species such as Phragmites, Oak Wilt, the Asian long horned beetle etc.;
- ☐ Increase invasive and woody species control measures such as prescribed burns, cutting and physical removal;
- ☐ Enhance targeted education to the public regarding best management practices for protecting private trees from invasive species.

Action 5.6 Improve climate resilience of trees in urban forests, parks and in the public right-of-way

- ☐ Ensure tree and plant species established are native where possible, diverse, disease resistant and have high climate adaptability;
- ☐ Where appropriate, identify safe opportunities for assisted tree migration from more southern regions;
- ☐ Use an integrated pest management approach to park and urban forest maintenance;
- ☐ Enhance tree maintenance programs to mitigate damage due to heat and extreme events;
- ☐ Review and update new tree irrigation procedures to improve establishment success and therefor long-term survival and performance of trees.

Action 5.8 Increase community level of knowledge on the benefits of natural areas

- ☐ Enhance support for the Ojibway Nature Center;
- ☐ Continue to provide education to the public about the importance of natural areas, invasive species and endangered species;
- ☐ Utilize Citizen Science Programs such as iNaturalist to help monitor and collect information on species at risk and invasive species.

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Groffman, P.M., Kareiva, S. Carter, N.B. Grimm, J. Lawler, M. Mack, V. Matzek, and H. Tallis, 2014: *Ch. 8: Ecosystems, Biodiversity and Ecosystem Services. Climate Change Impacts in the United States: The Third National Climate Assessment,* J.M. Melillo, Terese (T.C.) Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 195-219, online at https://nca2014.globalchange.gov/downloads.
4. Ontario Ministry of Natural Resources. July 2012. *Ontario Invasive Species Strategic Plan*. Toronto: Queens's Printer for Ontario
5. Her Majesty the Queen in Right of Canada, represented by the Minister of the Environment, 2012. *Invasive Alien Species Partnership Program*, online at http://publications.gc.ca/collections/collection_2012/ec/En11-12-2010-eng.pdf
6. Vyn R. 2018. *Updated Expenditure Estimates on Invasive Species in Ontario: 2018 Survey Results* online https://www.invasivespeciescentre.ca/Portals/0/Final%20Report%20-%202018%20Survey%20Results.pdf?ver=2018-05-31-182438-190.

Last Updated: November 2, 2019

Total Risk Score:
96

Impact #14: An increase in rainfall and temperature causing an increase in algae growth

Likelihood	4	Likely
Social	28	Low
Economic	36	Medium-Low
Environmental	32	Medium-Low
Total	96	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Pollution Control	Algae and plant growth in storm water ponds
V3	ERCA	Algae and plant growth in rivers, lakes and recreational areas

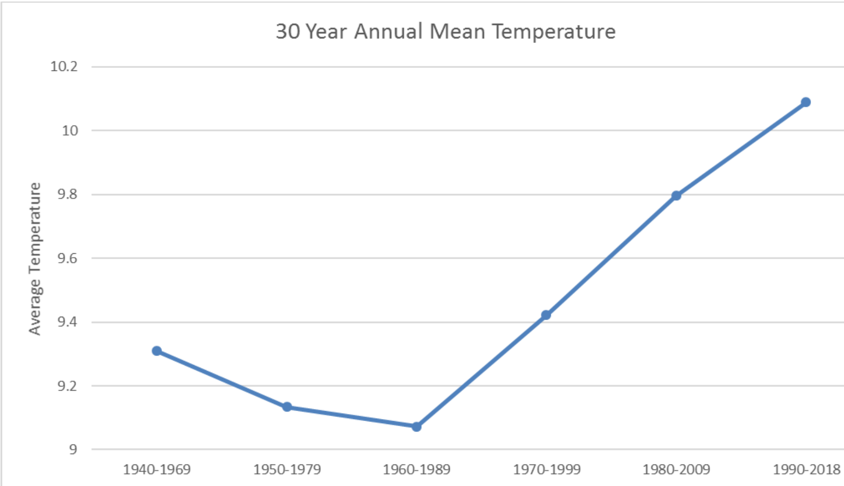
Links to Community Risk Assessment

Statement	**Social**	**Economic**	**Environmental**	**Overall Risk**
Warmer temperatures will allow for increased growth of algae and other water plants affecting surface water quality	55	50	55	160

Supporting Information

Historical Climate Trends

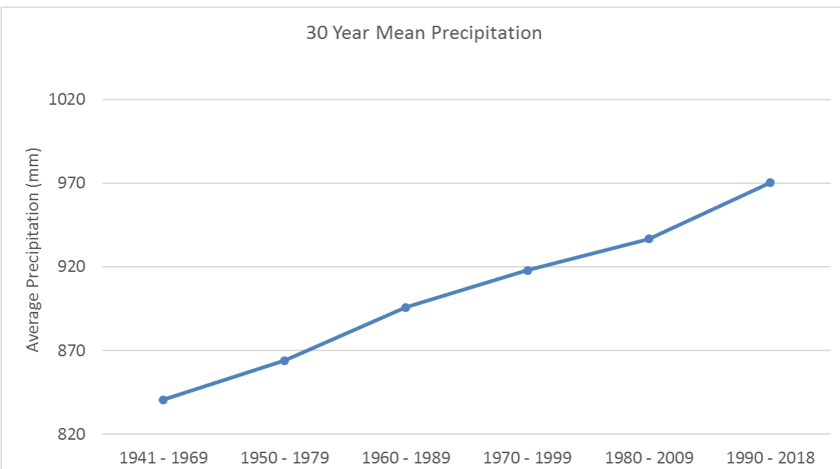
Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in annual mean temperatures and precipitation over 30-year timeframes (Figures 1 and 2).



	30 Year Annual Mean Temperature °C
1940 - 1969	9.3
1950 - 1979	9.1
1960 - 1989	9.1
1970 - 1999	9.4
1980 - 2009	9.8
1990 - 2018	10.1
2000 - 2018*	10.2
2010 - 2018*	10.3

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Annual Mean Temperatures as Reported at Windsor Airport (Government of Canada)



	30 Year Mean Precipitation (mm)
1940 - 1969	840.6
1950 - 1979	864.1
1960 - 1989	895.7
1970 - 1999	918.0
1980 - 2009	936.8
1990 - 2018	970.3
2000 - 2018*	993.6
2010 - 2018*	1047.0

Note: * indicates not a complete 30-year timeframe

Figure 2: Historical Precipitation as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the annual mean temperatures and precipitation over time (Figures 3 and 4).

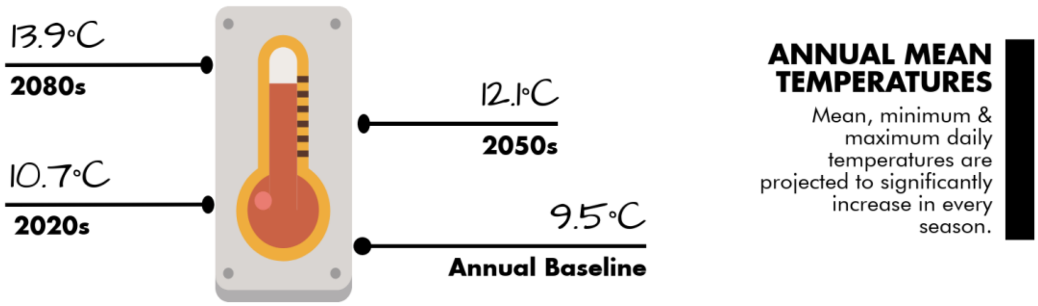


Figure 3: Annual Mean Temperature Projections (ICLEI, 2018)

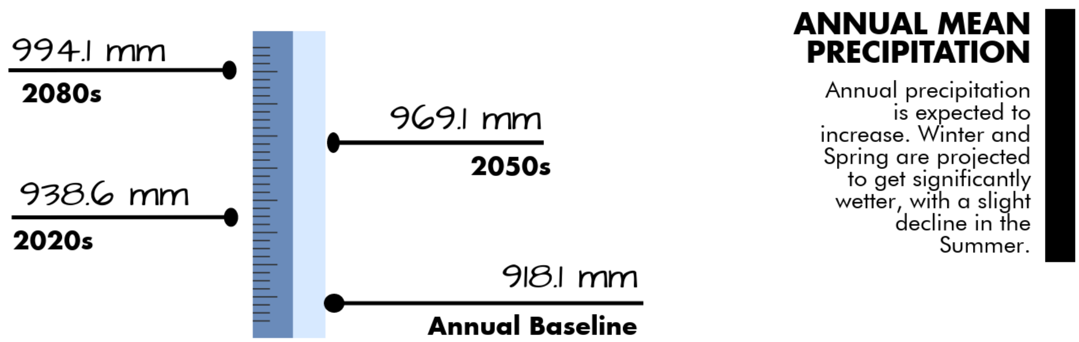


Figure 4: Annual Mean Precipitation Projections (ICLEI, 2018)

Discussion

Increasing precipitation amounts and storm intensities are major drivers of water pollution in the form of excess nutrients, sediments, and dissolved organic carbon. Rising air temperatures can also lead to declines in water quality as warmer surface waters can stimulate blooms of harmful algae, which may include toxic cyanobacteria (also known as blue-green algae) (Groffman et al., 2014).

Exposure to blue-green algae blooms can cause health effects in people and animals when the water is touched, swallowed, or when airborne droplets are inhaled. Exposure to high levels of blue-green algae and their toxins can cause diarrhea, nausea or vomiting; skin, eye or throat irritation; and allergic reactions or breathing difficulties.

The Cost of Doing Nothing

A study recently published estimates the economic costs of algal blooms in the Canadian Lake Erie Basin. The results suggest that algal blooms will impose equivalent annual costs equal to $272 million in 2015 prices over a 30-year period if left unchecked. The largest market impact will be to the tourism industry at an estimated economic loss of $110 million annually. While the inherent value lost by recreational users is estimated at $115 million annually (Smith et al., 2019).

Possible Adaptation Actions:

Action 2.11 Enhance surveillance for blue-green algae in our surface water bodies

- ☐ In collaboration with the Windsor-Essex County Health Unit enhance education about the dangers of blue-green algae for water users;
- ☐ Develop an education campaign targeting fertilizer use and washing cars around storm water ponds;
- ☐ Develop a regional plan to reduce phosphorus levels in our environment.

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Groffman, P.M., Kareiva, S. Carter, N.B. Grimm, J. Lawler, M. Mack, V. Matzek, and H. Tallis, 2014: *Ch. 8: Ecosystems, Biodiversity and Ecosystem Services. Climate Change Impacts in the United States: The Third National Climate Assessment,* J.M. Melillo, Terese (T.C.) Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 195-219, online at https://nca2014.globalchange.gov/downloads.
4. Smith R, Bass B, Sawyer D, Depew D, Watson S, 2019. *Estimating the economic costs of algal blooms in the Canadian Lake Erie Basin.* Harmful Algae journal, v. 87. Online at https://www.sciencedirect.com/science/article/pii/S1568988319300915

Last updated: November 2, 2019

Total Risk Score:

95

Impact #15: An increase in summer temperatures increasing energy demand

Likelihood	5	Almost Certain
Social	35	Medium-Low
Economic	35	Medium-Low
Environmental	25	Low
Total	95	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V5	Recreation	Damage and melting to indoor ice surfaces
V4	Asset Planning	Increase in electrical loads and greenhouse gas emissions
V2	Human Resources	Cooling systems overwhelmed, leading to worker absenteeism
V2	Community Development	Strain on residents for air conditioning costs, or repair leading to financial hardship
V2	Facilities	More cooling requirements contributing to higher energy use
V1	Parks Operations	Increased energy use

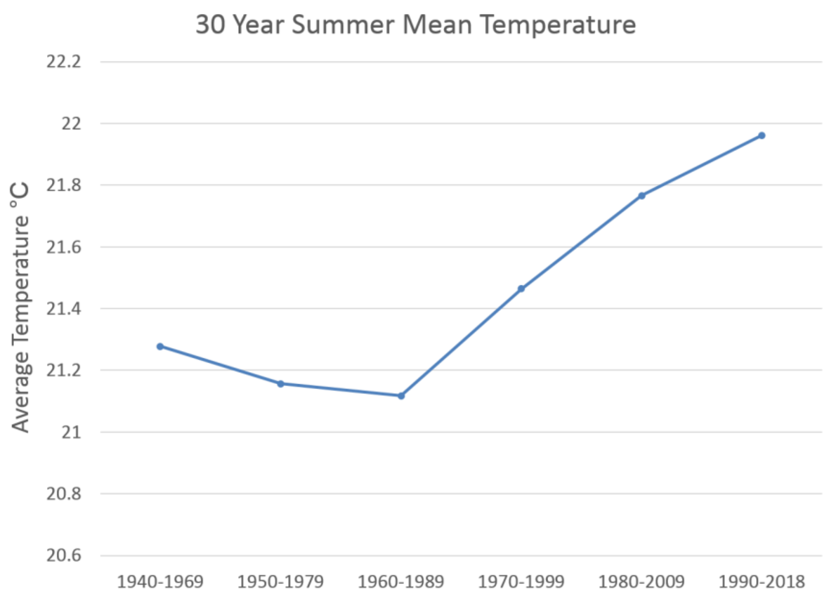
Links to Community Risk Assessment

Statement	**Social**	**Economic**	**Environmental**	**Overall Risk**
Increased summer temperatures and hot days can cause increased demand on grid for cooling	55	40	85	180

Supporting Information

Historical Climate Trends

Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent summer mean temperatures over 30-year timeframes.



	30 Year Summer Mean Temperatures (°C)
1940 - 1969	21.3
1950 - 1979	21.2
1960 - 1989	21.1
1970 - 1999	21.5
1980 - 2009	21.8
1990 - 2018	22.0
2000 - 2018*	22.2
2010 - 2018*	22.2

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Summer Mean Temperatures as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean summer temperatures over time.

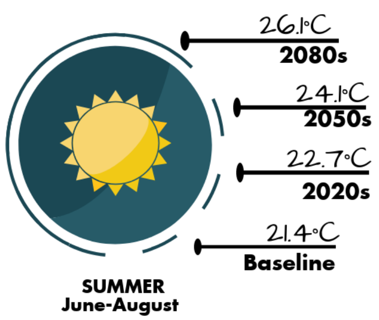


Figure 2: Summer Mean Temperatures Projections (ICLEI, 2018)

The Climate Atlas provides climate change projections for the number of cooling degree days. Cooling degree days are often used to estimate how much air-conditioning is required in a year. An increase in projected cooling degree days implies that the area will experience hotter or longer summers.

Cooling degree days are equal to the number of degrees Celsius a given day's mean temperature is above 18°C. For example, if the daily mean temperature is 21°C, the cooling degree day value for that day is equal to 3. If the daily mean temperature is below 18°C, the cooling degree day value for that day is zero. The following table summarizes the cooling degree day projections for the Windsor area.

Table 1: Cooling Degree Days Projections (Climate Atlas, 2019)

	Number of Cooling Degree Days Predicted	
	Low Carbon Scenario	High Carbon Scenario
Baseline 1976 - 2005	375.9	
2021 - 2050	564.1	612.3
2051 - 2080	683.2	877.5

Cost of Doing Nothing

As climate change continues to increase the mean summer temperatures for Windsor-Essex there will be an increased demand for cooling to maintain comfortable indoor temperatures, which will result in an increase in energy demand. A recent study published in the journal of Nature entitled "Amplification of future energy demand growth due to climate change" determined that under a low climate change scenario energy demand is expected to increase 11-27% while a high climate change scenario may result in a 25-58% increase (Bas et al. 2019).

By applying the expected increase in energy demand for Windsor the increase in greenhouse gas emissions and energy expenditure can be estimated (Table 2).

As the cooling demand is met with electricity, historic electricity usage for the City of Windsor can be used to calculate the cost of doing nothing. In terms of expenditure, it is very challenging to accurately predict what the cost of electricity will be for 2050. Current on-peak electricity prices are used to calculate future expenditure.

Table 2: Expected increase in electricity use, expenditures and emissions for the Community

	Low Climate Change Scenario (11% increase)	High Climate Change Scenario (25% increase)
Additional electricity usage	268,237,761 kWh	609,631,276 kWh
Additional expenditure	$35,943,860	$81,690,591
Additional Emissions	4,639 Tonnes	10,545 Tonnes

Table 3: Expected increase in electricity use, expenditures and emissions for the Corporation

	Low Climate Change Scenario (11% increase)	High Climate Change Scenario (25% increase)
Additional electricity usage	8,298,828 kWh	18,860,972 kWh
Additional expenditure	$1,112,042	$2,527,370
Additional Emissions	143 Tonnes	326 Tonnes

Possible Adaptation Actions:

Action 7.10 Implement the Community Energy Plan (including but not limited to the following)

- ☐ Develop and implement home and building retro fit programs;
- ☐ Encourage a modal shift towards Public Transit and Active Transportation;
- ☐ Foster the adoption of electric vehicles;
- ☐ Continue to retrofit City of Windsor buildings to increase energy efficiency;
- ☐ Incentivize the use of energy efficiency technologies to decrease building energy demand;
- ☐ Designate and plan district energy areas;
- ☐ Promote and implement renewable energy generation such as solar photovoltaic energy systems

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Climate Atlas Retrieved March 18, 2019 https://climateatlas.ca/map/canada/cooldd_2060_85#grid=416&z=8&lat=42.59&lng=-82.75
4. Bas J. van Ruijven, Enrica De Cian, Ian Sue Wing. **Amplification of future energy demand growth due to climate change**. *Nature Communications*, 2019; 10 (1) DOI: 10.1038/s41467-019-10399-3

Last Updated: November 2, 2019

Total Risk Score:	**95**

Impact #16: An increase in winter temperatures will reduce the length of time outdoor rinks can operate

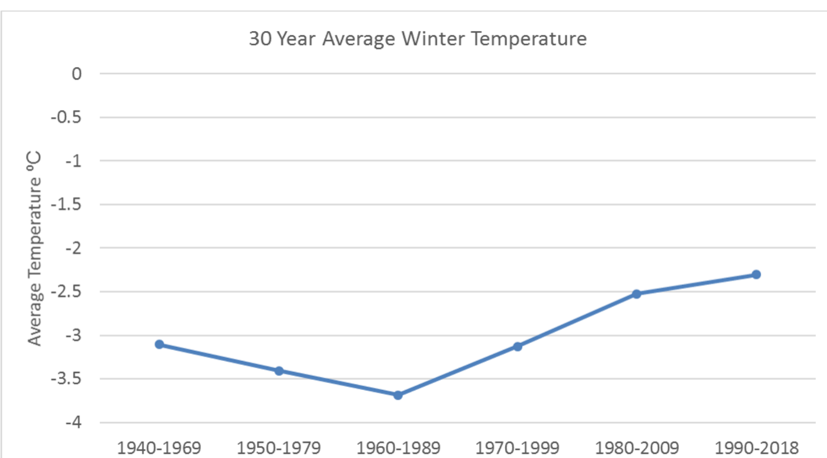
Likelihood	5	Almost Certain
Social	35	Medium-Low
Economic	40	Medium-Low
Environmental	20	Low
Total	95	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Recreation	Reduce the length that outdoor rinks can operate
V3	Parks Operations	Reduce the length that outdoor rinks can operate

Supporting Information

Historical Climate Data

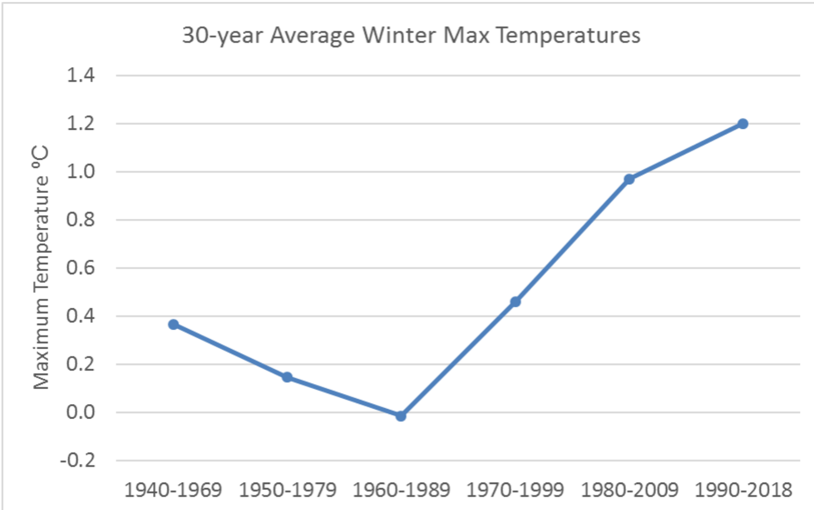
Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent winter mean and maximum temperatures over 30-year timeframes (Figures 1 and 2).



	30-Year Winter Mean Temperatures °C
1940 - 1969	-3.1
1950 - 1979	-3.4
1960 - 1989	-3.7
1970 - 1999	-3.1
1980 - 2009	-2.5
1990 - 2018	-2.3
2000 - 2018*	-2.4
2010 - 2018*	-2.5

Note: * Indicates not a complete 30-year timeframe

Figure 1: Historical Winter Mean Temperatures as Reported at Windsor Airport (Government of Canada)



	30-Year Winter Mean Max Temperatures °C
1940 - 1969	0.4
1950 - 1979	0.1
1960 - 1989	0.0
1970 - 1999	0.5
1980 - 2009	1.0
1990 - 2018	1.2
2000 - 2018*	1.1
2010 - 2018*	1.1

Note: * indicates not a complete 30-year timeframe

Figure 2: Historical Winter Mean Maximum Temperatures as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean winter temperatures over time (Figure 3).

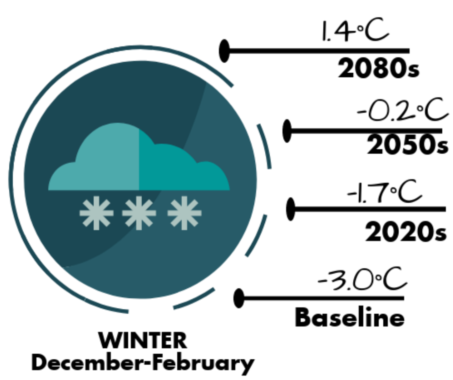


Figure 3: Winter Mean Temperature Projections (ICLEI, 2018)

"The NHL represents the highest level of hockey in the world. But before many of our players ever took their first stride on NHL ice, they honed their skills on the frozen lakes and ponds of North America and Europe. Our sport can trace its roots to frozen freshwater ponds, to cold climates. Major environmental challenges, such as climate change and freshwater scarcity, affect opportunities for hockey players of all ages to learn and play the game outdoors." NHL Commissioner Gary Bettman

Departmental Impacts

Though the above quote from Gary Bettman speaks to unrefrigerated ice rinks (e.g. ponds, backyard rinks, etc.), the same is true for the City's maintained outdoor ice surfaces.

Recreation

The City of Windsor currently operates two outdoor skating surfaces: Lanspeary Lions Rink and Charles Clark Square. Lanspeary is a covered ice surface, which is rented out to the public at a cost between $103 and $118 per hour. Charles Clark Square is an uncovered ice surface available for free public skating. Generally, Lanspeary is open longer due to the ice surface being covered reducing impacts from rain, heat and sun (Table 1). However, Lanspeary has also seen a decrease in the average number of weeks open over time (Table 2).

Table 1: Length of Outdoor Skating Season for Lanspeary and Charles Clark Square

Winter	Lanspeary Lions Rink		Charles Clark Square	
	Number of Weeks Open	Days Closed due to Weather	Number of Weeks Open	Days Closed to Weather
2004/2005	15			
2005/2006	13			
2006/2007	18			
2007/2008	17			
2008/2009	18			
2009/2010	17			
2010/2011	14		14	
2011/2012	11.5		14.5	
2012/2013	15		12	12
2013/2014	13		3*	
2014/2015	16		14	
2015/2016	14		7	2
2016/2017	12	4	10	8
2017/2018	12	4	10	19
2018/2019	13	5	12	8

Note: * Charles Clark Square was only open for 3 weeks due to the artificial ice surface

Table 2: Average Number of Weeks Lanspeary Lions Rink is Open

5 Winters	Average Number of Weeks Open during 5 year timeframes
2004/2005 – 2008/2009	16.2
2009/2010 – 2013/2014	14.1
2014/2015 – 2018/2019	13.4

The closure of the Lanspeary Lions rink results in the cancellation of rented ice time, under these conditions, the City of Windsor returns collected revenues. Table 3 shows the revenue rebates due to the closure of the Lanspeary Lions rink.

Table 3: Loss Revenue due to Cancelled Ice Time

Winter	Revenue Returned
2015/2016	$12,208
2016/2017	$10,093
2017/2018	$13,859

The Cost of Doing Nothing

Operation of both outdoor ice surfaces is greatly dependent on winter conditions. As, mentioned above the average mean winter temperature in Windsor is expected to increase from a baseline of -3°C to 1.4°C in the 2080s (Figure 3). Higher temperatures, along with more winter precipitation will lead to further closures of the ice rinks. Without interventions, further revenue loss is expected as well as the loss of a traditional Canadian past-time.

Possible Adaptation Actions:

Action 6.3 Improve design standards for new recreational facilities to ensure they are more climate resilient

- ☐ Ensure any future outdoor rinks developed consider warmer winter temperature protection measures which may include a full cover and extra cooling capacity;
- ☐ Ensure all new sports fields developed have sufficient shade amenities and additional drainage designed to reflect Windsor's climate projections;
- ☐ Ensure any new indoor recreational facilities are designed to withstand Windsor's climate projections

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Bettman. 2014. *2014 NHL Sustainability Report* **http://ice.nhl.com/green/report/**

Last Updated: November 2, 2019

Total Risk Score:

95

Impact #17: Increase in extreme hot days leading to infrastructure wear and tear

Likelihood	4	Likely
Social	35	Medium-Low
Economic	40	Medium-Low
Environmental	20	Low
Total	95	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V5	Recreation	Damage and melting to indoor ice surfaces
V3	Operations	Buckling of roads and sidewalks
V3	Emergency Preparedness	Increasing costs to main fleet and buildings
V2	Facilities	Decrease in material longevity
V2	Building	Exterior elements of building requiring replacement sooner

Links to Community Risk Assessments

Statement	**Social**	**Economic**	**Environmental**	**Overall Risk**
Increase in extreme hot days leading to buckling of roads leading to failure	44	60	68	172

Supporting Information

Historical Numbers

Since 2016, the Windsor Essex County Health Unit has been issuing a heat warning when two consecutive days are forecasted to have a daytime high temperature greater than or equal to 31 C and a nighttime temperature greater than or equal to 21 C or a humidex greater than 42 degrees. Table 1 shows the total number of days where this criteria was exceeded.

Table 1: Number of Heat Warnings/Extended Heat Warnings (2016-2018) (Windsor Essex County Health Unit, 2019)

Year	Total number of days under Heat Warnings or Extended Heat Warnings
2016	23
2017	12
2018	22

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the number of days that will exceed 30 C (Figure 1).

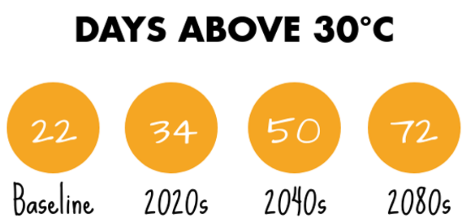


Figure 1: Temperature Extreme Projections Days above 30 C (ICLEI, 2018)

Similarly, climate change modelling completed by the Climate Atlas also predicts an increase to the number of days that will exceed 30 C (Figure 2).

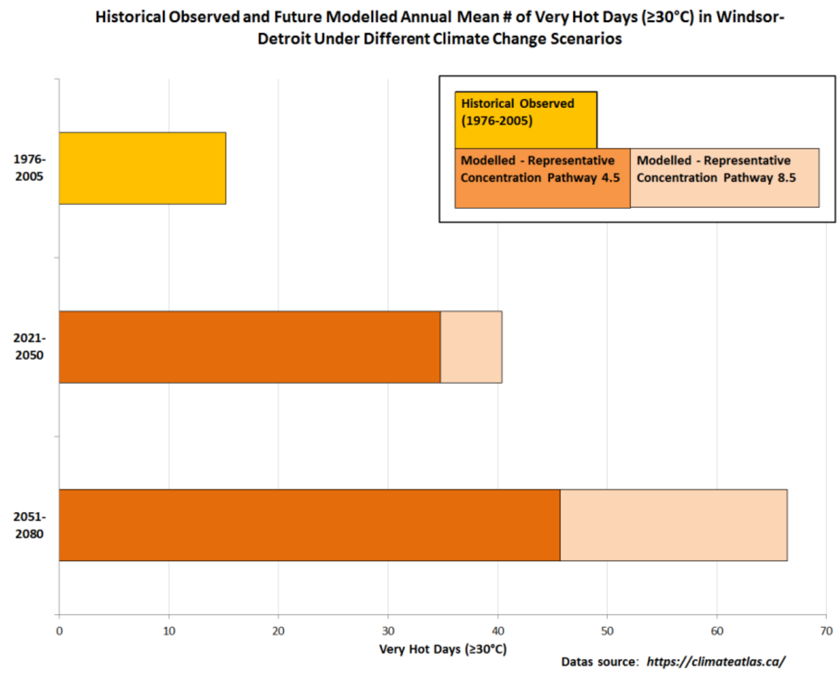


Figure 2: Annual Mean Number of Very Hot Days (>30°C) (Climate Atlas)

Extreme heat can significantly impact the operation and life cycle of infrastructure, as is evident from the recent bucking of Highway 3. Table 2 below summarizes some of the known impacts on various types of infrastructure due to higher temperatures.

Table 2: Impacts on various types of infrastructure due to high temperatures

Highways, Roads	Bridges	Buildings
• Pavement softening causing rutting • Increased flushing and bleeding of older pavement • Reduction in maximum loads that can be safely transported • Buckling of roads and sidewalks • Shortened life expectancy of highways, roads and rail	• Cracking of bridge decks due to limits of expansion joints being exceeded • Drier conditions can affect the life cycle of bridges and culverts	• Building damage has been observed when clay soils dry out • Premature weathering • Increased indoor air temperature and reliance on cooling systems

The sensitivity of infrastructure to climate hazard is affected by a number of factors (both climatic and non-climatic). The three main factors influencing the sensitivity of infrastructure to climate hazards are namely: age, composition and design (IISD, 2013).

An analysis of pavement deterioration-relevant climate indicators across Canada suggests that, over the next 50 years, low temperature cracking will become less problematic; however, higher extreme in-service pavement temperatures will raise the potential for rutting and cracking (longitudinal and alligator). In general, maintenance, rehabilitation or reconstruction will be required earlier in the design life (Mills et al., 2007).

Fortunately, none of the potential impacts fall beyond the normal range of conditions experienced in North America. Performance grade binders and other material properties can be adjusted and structure designs can be strengthened for new asphalt pavements. Maintenance schedules can be advanced (or deferred) (Mills et al. 2007).

The Cost of Doing Nothing

One study examined the economic costs of projected temperature changes on asphalt roads across the United States using low and high climate change scenarios. The study found that maintaining status quo for pavement design will add approximately $19.0 and $21.8 Billion (US$) to pavement costs by 2040 and 2070 under a low climate change future, but could be as high as $26.3 and $35.8 billion under a high climate change future. The study further stated that failing to update engineering standards in practice in light of climate change therefore significantly threatens pavement infrastructure (Underwood et al., 2017).

Using an infrastructure predictive modelling tool, a service level analysis report was completed for the current state of the City of Windsor's road network. Currently, approximately 10 % of the roads in the City of Windsor are at the end of their intended life. Using the predictive modelling tool, life cycle variables can be applied to model various conditions that may change the end of life for assets. In this case, the tool was run to determine the percent of roads that would be at the end of their intended life if climate change reduced the life cycle of the roads by one, two and three years (Table 3)

Table 3: Changes in Road Condition under Reductions in Life Cycle

Expected Service Life	Percent of Roads at End of Life (%)
Current Conditions	10.56
Reduction of 1 year	12.90
Reduction of 2 years	13.51
Reduction of 3 years	14.33

Roads are not the only infrastructure facing impacts due to extreme heat; buildings will have high cooling demand leading to stress of chillers, exterior components to buildings may also age prematurely, while vehicles and electrical systems may experience heat stress on various components.

Possible Adaptations Actions:

Action 3.6 Promote public and private building standards and maintenance practices which protect buildings and HVAC units from damage due to increased cooling demand

- ☐ Consider new design and replacement standards for building Heating, Ventilation and Air Conditioning (HVAC) units;
- ☐ Enhance preventative maintenance for building HVAC units.

Action 4.10 Review design standards and maintenance practices as they relate to newest climate projections

- ☐ Review engineering design, construction and maintenance for surface pavements;
- ☐ Review engineering design, construction and maintenance for sewer and stormwater management infrastructure;
- ☐ Enhance preventative maintenance for HVAC units;
- ☐ Identify cooling options for electrical and mechanical components susceptible to high heat and equipment wear and tear.

Action 4.11 Explore options for increased electrical power generation from City of Windsor infrastructure (generators) to supplement Ontario's electrical grid as warranted

References:

1. Windsor Essex County Health Unit, 2019. Personnel Correspondence.
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.
3. Climate Atlas Retrieved March 2019 from https://climateatlas.ca/map/canada/plus30_2060_85#grid=416
4. The International Institute for Sustainable Development, 2013. *Climate Change Adaptation and Canadian Infrastructure.* Online https://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf
5. Mills B, Tighe S, Andrey J, Smith J, Parm S, Huen, K. 2007. *The Road Well-Traveled: Implications of Climate Change for Pavement Infrastructure in Southern Canada*. Online at http://www.bv.transports.gouv.qc.ca/mono/0970582.pdf
6. Underwood B, Guido Z, Gudipudi P, Feinberg Y. 2017. *Increased Costs to US Pavement Infrastructure from Future Temperature Rise.* Nature Climate Change volume 7. Online at https://www.nature.com/articles/nclimate3390

Last Updated: November 2, 2019

Total Risk Score:
90

Impact #18: Increasing hot days and summer drought causing stress on landscaping and park lands

Likelihood	5	Almost Certain
Social	25	Low
Economic	35	Medium-Low
Environmental	30	Medium-Low
Total	90	Medium-Low

Vulnerability	**Department**	**Impact Statement**
V4	Forestry	Increase in irrigation required
V3	Parks Operations	Increase in irrigation required
V2	Engineering	Landscaping following construction
V2	ERCA	Stress on new plantings

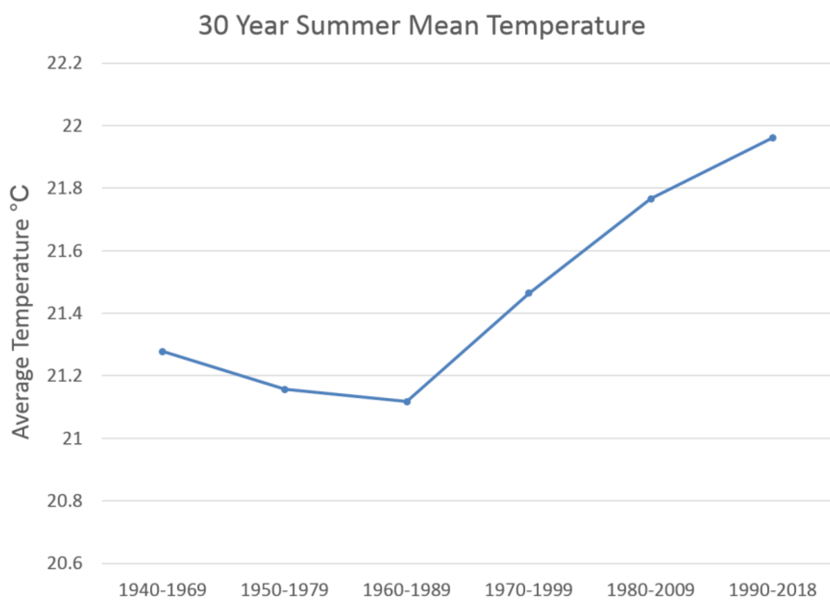
Links to Community Risk Assessments

Statement	Social	Economic	Environmental	Overall Risk
Warmer temperatures and changes in precipitation patterns can cause hot and dry conditions, leading to more heat and water stress on crops and livestock	55	80	80	215

Supporting Information

Historical Numbers

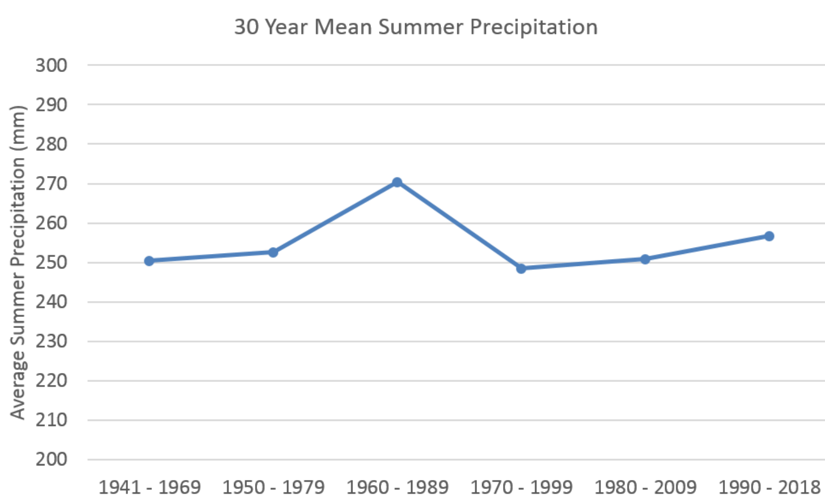
Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in recent summer mean temperatures over 30-year timeframes (Figures 1) while showing fairly consistent summer precipitation over 30 year timeframes (Figure 2).



	30 Year Summer Mean Temperatures (°C)
1940 - 1969	21.3
1950 - 1979	21.2
1960 - 1989	21.1
1970 - 1999	21.5
1980 - 2009	21.8
1990 - 2018	22.0
2000 - 2018*	22.2
2010 - 2018*	22.2

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Mean Summer Temperatures (Government of Canada)



	30 Year Mean Summer Precipitation (mm)
1940 - 1969	250.5
1950 - 1979	252.6
1960 - 1989	270.4
1970 - 1999	248.4
1980 - 2009	250.9
1990 - 2018	256.8
2000 - 2018*	266.2
2010 - 2018*	296.4

Note: *indicates not a complete 30-year timeframe

Figure 2: Historical Mean Summer Precipitation (Government of Canada)

Climate Projections

No Canada-wide studies of projected future droughts are currently available. Drought studies to date have been focused on the prairie provinces. However, a look at Canada-wide trends in actual evapotranspiration from 1960 to 2000 showed significant increasing values at 35%, mainly on the Pacific and Atlantic coasts and the Great Lakes region (Bonsal et al., 2019). Evapotranspiration is one factor impacting soil moisture and drought conditions.

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts increases to the mean summer temperatures over time (Figure 3) which will impact evapotranspiration rates and a reduction in summer precipitation in the long term (Figure 4).

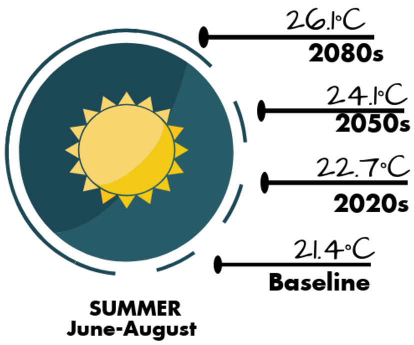


Figure 3: Mean Summer Temperatures Projections (ICLEI, 2018)

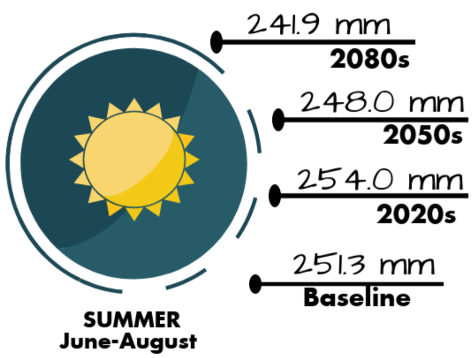


Figure 4: Summer Mean Precipitation Projections (ICLEI, 2018)

Possible Adaptation Actions:

Action 5.6 Improve climate resilience of trees in urban forests, parks and in the public right-of-way

- ☐ Ensure tree and plant species established are native where possible, diverse, disease resistant and have high climate adaptability;
- ☐ Where appropriate, identify safe opportunities for assisted tree migration from more southern regions;
- ☐ Use an integrated pest management approach to park and urban forest maintenance;
- ☐ Enhance tree maintenance programs to mitigate damage due to heat and extreme events;
- ☐ Review and update new tree irrigation procedures to improve establishment success and therefor long-term survival and performance of trees.

Action 7.11 Incorporate native and/or drought tolerant plants into public and private landscaping

- ☐ Educate the public about the benefits of native plants including drought tolerance; water retention attracting pollinators etc.
- ☐ Review and encourage the selection of species more resilient to a changing climate;
- ☐ Encourage the selection of plants that are more mature and larger with deeper root systems;
- ☐ Explore native plant demonstration gardens in public spaces

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. Bonsal, B.R., Peter, D.L., Seglenieks, F., Rivera, A., and Berg, A (2019): Changes in freshwater availabilty across Canada; Chapter 6 in Canada's Changing Climate Report, (ed) E. Bush and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p. 261-342
3. ICLEI (June 2018). Future Climate Projects for the City of Windsor.

Last updated: Saturday, November 02, 2019

Total Risk Score:
90

Impact #19: Increasing precipitation leading to closure of recreational amenities

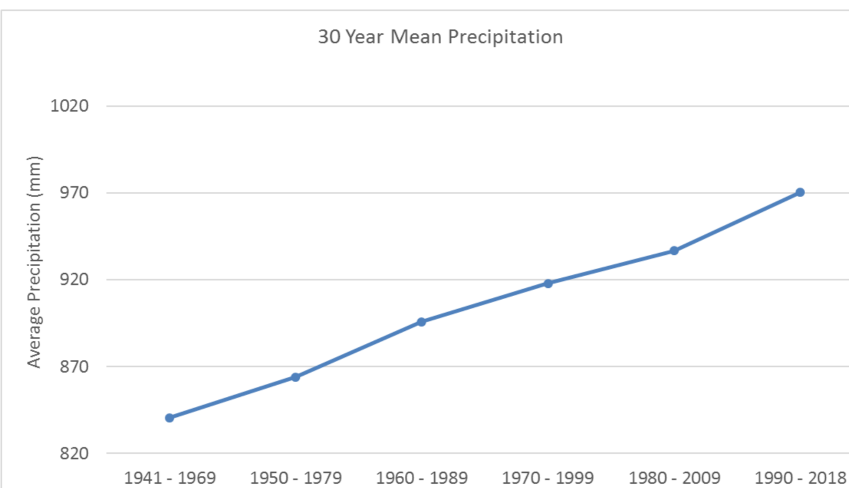
Likelihood	5	Almost Certain
Social	25	Low
Economic	40	Medium-Low
Environmental	25	Low
Total	90	Medium-Low

Vulnerability	**Departments Affected**	**Impact Statement**
V4	Parks Development	Saturated sports fields

Supporting Information

Historical Climate Trends

Since 1940, the Government of Canada has maintained a weather station at Windsor Airport. This data is fully available through a historical weather data base. Analysis of this data shows an increasing trend in mean precipitation (Figures 1)



	30 Year Mean Precipitation (mm)
1940 - 1969	840.6
1950 - 1979	864.1
1960 - 1989	895.7
1970 - 1999	918.0
1980 - 2009	936.8
1990 - 2018	970.3
2000 - 2018*	993.6
2010 - 2018*	1047.0

Note: * indicates not a complete 30-year timeframe

Figure 1: Historical Precipitation as Reported at Windsor Airport (Government of Canada)

Climate Projections

Climate change modelling completed by Canadian Climate Data and Scenarios Network predicts annual mean precipitation to continue to increase over time (Figure 2) as well as increases in winter, spring and fall mean precipitation totals (Figure 3).

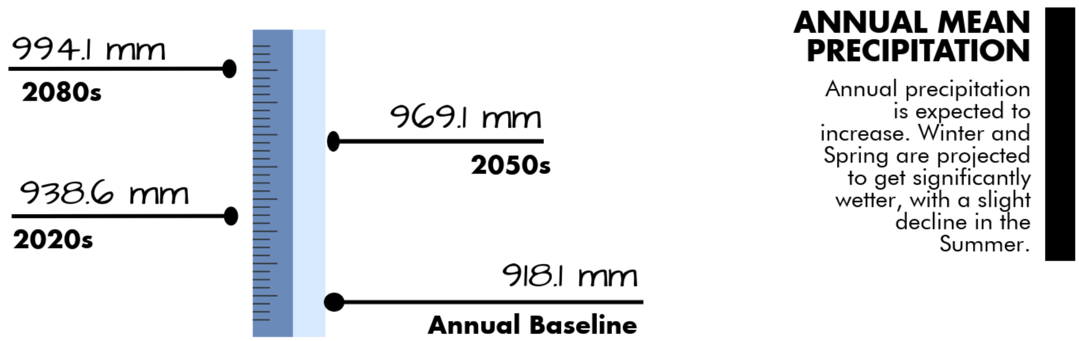


Figure 2: Annual Mean Precipitation Projections (ICLEI, 2018)

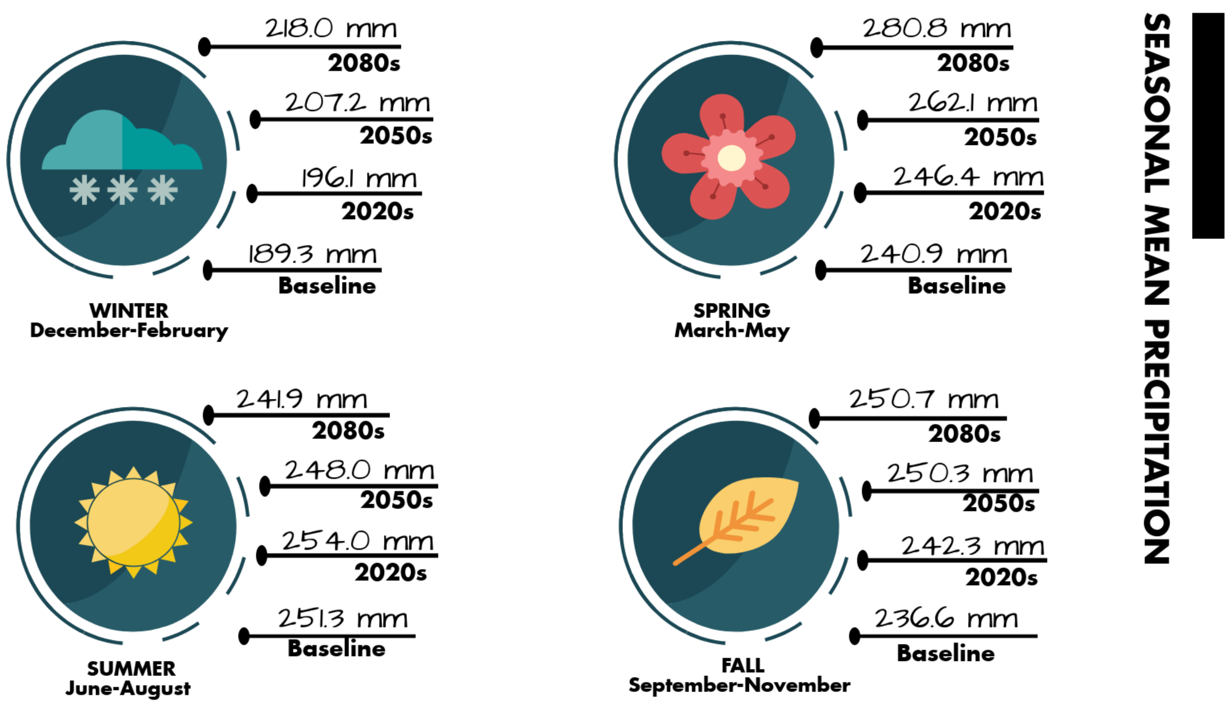


Figure 3: Annual Mean Seasonal Precipitation Projections (ICLEI, 2018)

Event Based Data

The City of Windsor's Recreation department operates and maintains a number of recreational sports amenities including baseball diamonds and soccer fields. These recreational amenities are rented to various sports groups throughout the year. Unfortunately, heavy precipitation can cause unsafe playing conditions, as well as, allowing play can cause damage to playing surfaces. In the event, that the City of Windsor closes a sports field, the renter is rebated their fees. Table 1 shows the total revenue returned due to the closure of sports fields. Sports fields may be closed for reasons other than precipitation, unfortunately, the reasons are not closely tracked. In most cases, a sports field will be closed due to inclement weather or damage to fields (that are likely caused by weather).

Table 1: Loss of Funds Due to Inclement Weather

	2016	**2017**	**2018**	**2019**
Baseball Diamonds	$26,779	$21,344	$14,885	$177,292
Soccer Fields	$8,499	$12,852	$20,445	$54,846
Total	$35,278	$34,196	$35,300	$232,138

Cost of Doing Nothing

Windsor's climate projections indicate an increase in spring precipitation followed by drier summers. It is expected that without drainage improvements to sports fields the loss of revenue will continue into the future.

It is important to note, that as summer temperatures continue to rise, there will be an increasing demand for outdoor sports to occur earlier and later in the year to allow for breaks during hot summer days. However, this push for longer shoulder seasons is hampered by resources and precipitation affecting sports fields.

Possible Adaptation Actions:

Action 5.2 Investigate the potential for natural areas to enhance flood attenuation

- ☐ Identify where flood attenuation is needed within the City of Windsor;
- ☐ Review water retention possibilities in natural areas including lands adjacent to Provincially Significant Wetlands and other wetland associated habitats (e.g. swamp forest, wet prairie, meadow marsh).

Action 6.3 Improve design standards for new recreational facilities to ensure they are more climate resilient

- ☐ Ensure any future outdoor rinks developed consider warmer winter temperature protection measures which may include a full cover and extra cooling capacity;
- ☐ Ensure all new sports fields developed have sufficient shade amenities and additional drainage designed to reflect Windsor's climate projections;
- ☐ Ensure any new indoor recreational facilities are designed to withstand Windsor's climate projections

Action 6.4 Identify strategies to minimize cancellations of recreational rentals at existing recreation facilities

- ☐ Investigate modifying season start, end and duration dates as well as general schedules for recreational programming to try to avoid spring flooding and summer heat;
- ☐ Identify recreational facilities such as trails and sports fields at risk of flooding and prioritize additional drainage measures where possible;
- ☐ Continue to add air conditioning and dehumidifiers to indoor arenas as necessary
- ☐ Investigate developing service agreements with private facilitates or neighbouring towns to share recreational facilities in the event of flooding

Action 6.5 Enhance inspections of Special Events Facilities and roads to identify infrastructure deficiencies for upcoming events

References:

1. Government of Canada. Historical Data. Retrieved March 2019 from http://climate.weather.gc.ca/historical_data/search_historic_data_e.html
2. ICLEI (June 2018). Future Climate Projects for the City of Windsor.

Last Updated: November 2, 2019