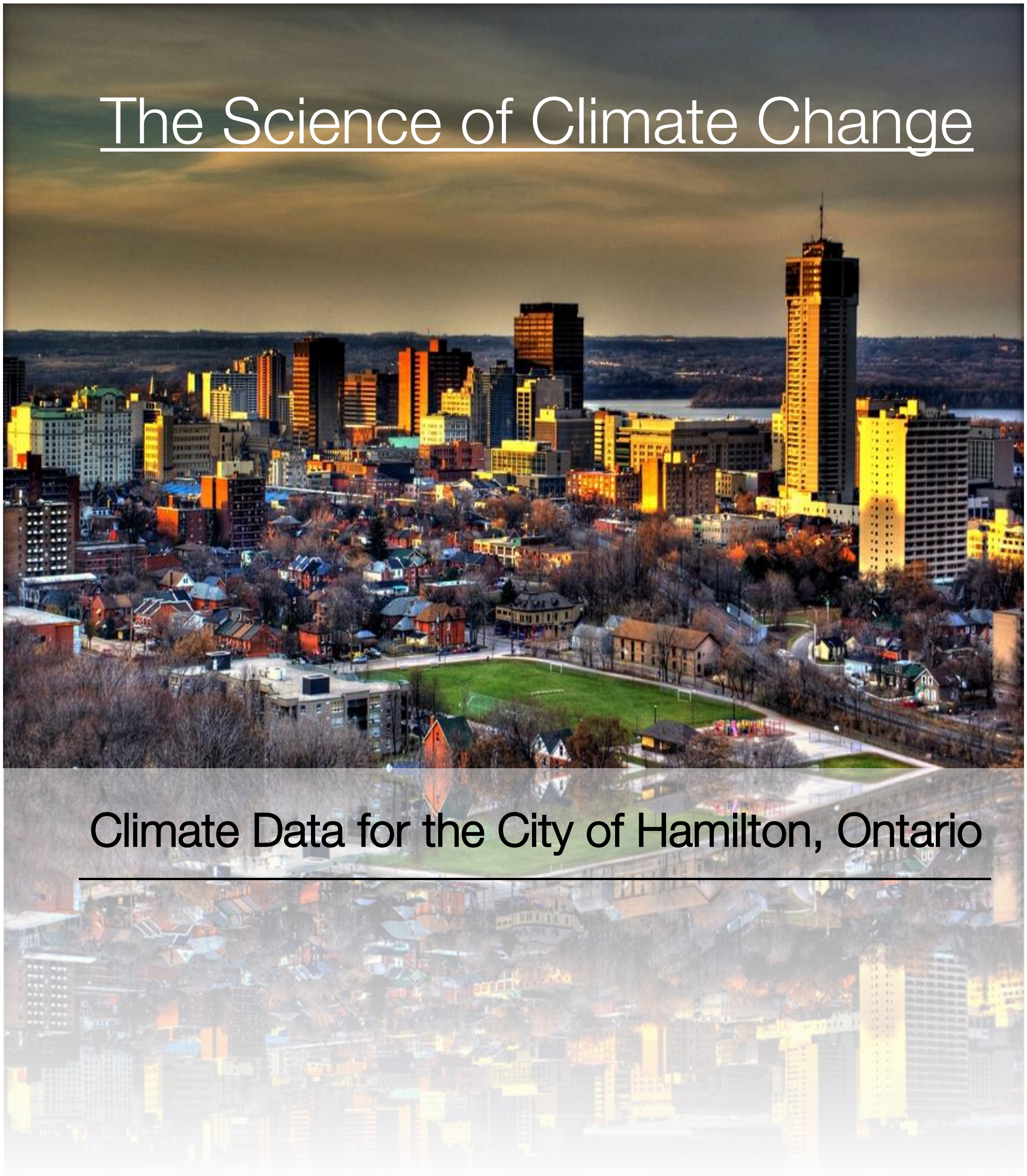
The Science of Climate Change



Climate Data for the City of Hamilton, Ontario

Report generated by ICLEI Canada

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ICLEI Local Governments for Sustainability

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Glossary of Terms

Definitions have been taken from the Intergovernmental Panel on Climate Change (IPCC) (http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf), Environment Canada (http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=B710AE51-1).

Baseline

A climatological baseline is a reference period, typically three decades (or 30 years), that is used to compare fluctuations of climate between one period and another. Baselines can also be called references or reference periods.

Climate Change

Climate change refers to changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the build-up of greenhouse gases which trap heat and reflect it back to the earth's surface.

Climate Projections

Climate projections are a projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols. These projections depend upon the climate change (or emission) scenario used, which are based on assumptions concerning future socioeconomic and technological developments that may or may not be realized and are therefore subject to uncertainty.

Climate Change Scenario

A climate change scenario is the difference between a future climate scenario and the current climate. It is a simplified representation of future climate based on comprehensive scientific analyses of the potential consequences of anthropogenic climate change. It is meant to be a plausible representation of the future emission amounts based on a coherent and consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships.

Ensemble Approach

An ensemble approach uses the average of all global climate models (GCMs) for temperature and precipitation. Research has shown that running many models provides the most realistic projection of annual and seasonal temperature and precipitation than using a single model.

Extreme Weather Event

A meteorological event that is rare at a place and time of year, such as an intense storm, tornado, hail storm, flood or heat wave, and is beyond the normal range of activity. An extreme weather event would normally occur very rarely or fall into the tenth percentile of probability.

Global Climate Models (GCM)

Global Climate Models are based on physical laws and physically-based empirical relationships and are mathematical representations of the atmosphere, ocean, ice caps and land surface processes. They are therefore the only tools that estimate changes in climate due to increased greenhouse gases for a large number of climate variables in a physically-consistent manner.

Greenhouse Gas (GHG) Emissions

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation, emitted by the Earth's surface, the atmosphere itself, and by clouds. Water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs) are the six primary greenhouse gases in the Earth's atmosphere in order of abundance.

Heavy Rainfall

Heavy rainfall is defined as rainfall that is greater or equal to 50mm an hour, or is greater or equal to 75mm in three hours.

Hot Days

A hot day occurs when temperatures meet or exceed 30°C.

Radiative forcing

The change in the value of the net radiative flux (i.e. the incoming flux minus the outgoing flux) at the top of the atmosphere in response to some perturbation, in this case, the presence of greenhouse gases.

Relative Sea Level Rise

Relative sea level rise is a local increase in the level of the ocean relative to the land, which can be due to ocean rise and/or land level subsidence.

Representative Concentration Pathways

Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. It supersedes Special Report on Emissions Scenarios (SRES) projections published in 2000.

Storm Surge

The temporary increase, at a particular location, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). A storm surge is defined as being the excess above the level expected from the tidal variation at that time and place.

Temperature anomaly

A departure from a reference value or long-term average. A positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that the observed temperature was cooler than the reference value.

Introduction

Climate change is an increasingly critical issue both at the international and local level. Recent events in the City of Hamilton, ON, such as the July 2009 flood event and other occurrences of extreme weather over the past several decades have highlighted the need to be prepared for ongoing challenges. This report will inform and educate readers on some of the climate change impacts that are projected to occur in the region over the next century. It will primarily focus on changes in temperature and precipitation, while also touching on changes to lake levels and temperature, which all pose a significant threat to Hamilton at the community level. The information provided will develop a base for deeper and more thorough understanding of climate change impacts in the municipality, and will illuminate the realities of Canadian climate change more generally.

Background

The data presented in this report is based on global climate models and emission scenarios defined by the Intergovernmental Panel on Climate Change (IPCC), drawing from both the Fourth Assessment Report (AR4) and Fifth Assessment Report (AR5) publications. Tables and charts showing temperature and precipitation change data have been constructed using Environment Canada's newly developed Canadian Climate Data and Scenarios (CCDS) tool, which has replaced the Canadian Climate Change Scenarios Network *Localizer Reports,* and the Institute for Catastrophic Loss Reduction's *Intensity-Duration-Frequency Climate Change Tool.*

It is important to note that uncertainty is an integral component in the study of climate change. Uncertainty is factored into climate change scenarios, models, and data, and reflects the complex reality of environmental change and the evolving relationship between humans and the planet. Climate change cannot be predicted with absolute certainty in any given case, and all data must be considered with this in mind. While it is not possible to anticipate future climactic changes with absolute certainty, climate change scenarios help create plausible representations of future climate conditions. These conditions are based on assumptions of future atmospheric composition and on an understanding of the effects of increased atmospheric concentrations of greenhouse gases (GHG), particulates, and other pollutants.

A number of different methods exist to construct climate change scenarios, however global climate models (GCMs) are considered to be the most conclusive tools available for simulating responses to increasing greenhouse gas concentrations, as they are based on mathematical representations of atmosphere, ocean, ice cap and land surface processes.[1]

Wherever possible, this report uses an ensemble approach, which refers to a system that runs multiple climate models at once. Research has shown that this provides a more accurate projection of annual and seasonal temperatures and precipitation than a single model would on its own. In cases where an ensemble approach was unavailable, this report uses the CGCM3T47 model, which is the third version of the Canadian Centre for Climate Modelling and Analysis' (CCCma) Coupled Global Climate Model. This model has a well established track record for simulating current and future climates, and has been used in all IPCC exercises pertaining to GCMs.[2]

Climate Change Scenarios

Climate change scenarios are based on models developed by a series of international climate modeling centers. They are socioeconomic storylines used by analysts to make projections about future greenhouse gas emissions and to assess future vulnerability to climate change. Producing scenarios requires estimates of future population levels, economic activity, the structure of governance, social values, and patterns of technological change. In this report, climate change scenarios from both the Fourth (SRES Scenarios) and the Fifth (RCP Scenarios) IPCC Assessments are considered.

1) SRES Scenarios - IPCC Fourth Assessment Report (AR4)

Climate change scenarios from the Fourth Assessment report are referred to as Special Report on Emissions Scenarios (SRES), and use ensembles of more than 20 GCMs to construct a complex storyline of environmental and socioeconomic conditions that follow from predetermined emissions levels over the coming decades[3]. Four different narrative storylines were developed to describe the relationships between emission driving forces and their evolution, adding context for scenario quantification. Each storyline represents different demographic, social, economic, technological, and environmental developments.[4] **This report uses two AR4 scenarios to portray future climate projections for the City of Hamilton- the high emission scenario (A2), and the low emission scenario (B1).**

- ❖ The B1 storyline and scenario family represent a convergent world with a global population that peaks in mid-century and declines thereafter, but with rapid changes in economic structures towards a service and information economy, reductions in material intensity, and the introduction of clean and resource-efficient technologies.[5] Major underlying themes include global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.[6]
- ❖ The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities.[7] Fertility patterns across regions converge very slowly, which results in a continuously increasing global population. Economic development is regionally oriented and per capita economic growth and technological change are more fragmented and slower than other storylines. In addition, this scenario sees relatively slow end-use and supply-side energy efficiency improvements and delayed development of renewable energy, with no barrier to the use of nuclear energy.[8]

2) RCP Scenarios - IPCC Fifth Assessment Report (AR5)

Representative Concentration Pathways (RCPs) are the newest set of climate change scenarios that provide the basis for the Fifth Assessment report from the IPCC.[9] The new RCPs have replaced the Special Report on Emissions Scenarios (SRES) in order to be more consistent with new data, new models, and updated climate research from around the world. The RCPs contain information regarding emission concentrations and land-use trajectories, and are meant to be representative of the current literature on emissions and concentration of greenhouse gases. The premise is that every radiative forcing pathway (defined in glossary) can result from a diverse range of socioeconomic and technological development scenarios.[10] They are identified by their approximate total radiative forcing in the year 2100 relative to 1750, and are labeled as RCP 2.6, 4.5, 6.0 and 8.5. These four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6.0), and one scenario with continued rising greenhouse gas concentrations (RCP8.5).[11] The RCPs also consider the presence of 21st century climate policies, as compared with the no-climate policy assumption of the SRESs in the Third and Fourth Assessment Reports.[12] For this report, data from RCP 6.0 will be omitted, as the remaining three scenarios provide a sufficient range of emissions pathways over the next 100 years. Exhibit 1 displays the general details concerning each RCP, its pathway, projected temperature change and respective air pollutant concentration.

Exhibit 1: AR5 Climate Change Scenario Characteristics

Scenario/RCP	Pathway	Temp Anomaly	PPM
2.6	Peak and decline	+1.5°C	~490
4.5	Stabilizing without overshoot	+2.4°C	~650
8.5	Rising	+4.9°C	>=1370

Note: Due to the recentness of the IPCC Fifth Assessment Report (2014), data from the IPCC Fourth Assessment Report (2007) was substituted in cases where localized AR5 data was unavailable.

Temperature

Ontario

Over the last six decades, Canada has become warmer, with average temperatures over land increasing by 1.5°C between 1950 and 2010.[13] This rate of warming is almost double the global average reported over the same time period.[14] Assuming emissions continue at the current rate of global output, the Province of Ontario is projected to experience an average annual temperature rise of approximately 5.1°C by the end of the century[15]. Other scenarios that assume that action is taken to reduce greenhouse gas emissions project a change of approximately 3.6°C[16].

Exhibit 2, Exhibit 3 and Exhibit 4 display the expected seasonal temperature change in Ontario based on the IPCC Fifth Assessment Report (AR5). Each table represents a different climate change scenario. If current emissions trends continue, the higher emissions scenarios and associated temperature increases will likely apply.[17]

Exhibit 2: Seasonal Temperature Change in Ontario for RCP2.6
Baseline: 1986-2005 with respect to the RCP 4.5 scenario

	RCP 2.6					
	2016-2035		2046-2065		2081-2100	
	Median	Range	Median	Range	Median	Range
Winter	1.4°C	0.8-1.9°C	2.2°C	1.5-2.8°C	2.4°C	1.4-3.0°C
Spring	1.1°C	0.7-1.4°C	1.6°C	1.0-2.1°C	1.4°C	0.8-1.9°C
Summer	1.1°C	0.8-1.5°C	1.4°C	1.0-2.2°C	1.3°C	0.9-2.0°C
Autumn	1.2°C	0.9-1.5°C	1.7°C	1.2-2.5°C	1.6°C	1-2.3.0°C

Exhibit 3: Seasonal Temperature Change in Ontario for RCP 4.5
Baseline: 1986-2005 with respect to the RCP4.5 scenario

	RCP 4.5					
	2020s		2050s		2080s	
	Median	Range	Median	Range	Median	Range
Winter	1.6°C	0.9°-2.0°C	3.2°C	2.4-4.1°C	4.4°C	3.1-5.3°C
Spring	1.1°C	0.6-1.6°C	2.0°C	1.4-2.6°C	2.5°C	1.8-3.7°C
Summer	1.1°C	0.8-1.4°C	2.1°C	1.6-2.8°C	2.9°C	1.8-3.6°C
Autumn	1.3°C	0.9-1.6°C	2.2°C	1.8-2.9°C	2.8°C	2.4-3.8°C

Exhibit 4: Seasonal Temperature Change in Ontario for RCP 8.5
Baseline: 1986-2005 with respect to the RCP4.5 scenario

	RCP 8.5					
	2020s		2050s		2080s	
	Median	Range	Median	Range	Median	Range
Winter	1.9°C	1.2-2.2°C	4.4°C	3.4-5.4°C	8.1°C	6.9-9.7°C
Spring	1.2°C	0.8-1.7°C	3°C	2.3-3.4°C	5.2°C	4.5-6.3°C
Summer	1.3°C	1.0-1.6°C	3.1°C	2.6-3.9°C	6°C	4.7-6.9°C
Autumn	1.4°C	1.1-1.8°C	3.3°C	2.8-4.0°C	5.8°C	4.9-7.0°C

City of Hamilton

Temperatures in the City of Hamilton are expected to rise in congruence with the provincial changes observed in the AR5 data above. The Canadian Climate Change Data and Scenarios (CCDS) tool provides information from a weather stations located within the City of Hamilton (*Hamilton Station A*). The data uses a baseline of 1971-2000, and depicts projected temperature change (not actual temperature) from both A2 (high) and B1 (low) scenarios. At this time, AR5 scenario data for these stations is unavailable.

In Hamilton, you can expect to see a temperature increase of anywhere between **1.3°C** and **4.8°C** depending upon the selected scenario and timeframe. Each of the climate change scenarios are based on different assumptions about future greenhouse gas levels. If current emission trends continue, the higher emissions scenarios and associated temperature increase will likely apply.

Projections are based on increases from the temperature baseline, which is the mean air temperature from 1971-2000. For Hamilton, the annual mean temperature over this period was **7.6°C**. The projections to 2020, 2050, and 2080 reflect the expected future temperature, in degrees Celsius, from the annual and seasonal baselines.

In a high emissions scenario (A2), the City of Hamilton can expect to experience an average annual temperature change of **1.5°C** in the 2020s, **3°C** in the 2050s, and **4.8°C** in the 2080s.

Exhibit 5: Baseline Mean Temperatures (1971-2000) for Station *Hamilton A* (43.17N 79.93W) (All figures are positive, unless noted otherwise)

	Annual	Winter	Spring	Summer	Autumn
°C	**7.6°C**	-4.6°C	6.3°C	19.5°C	9.3°C

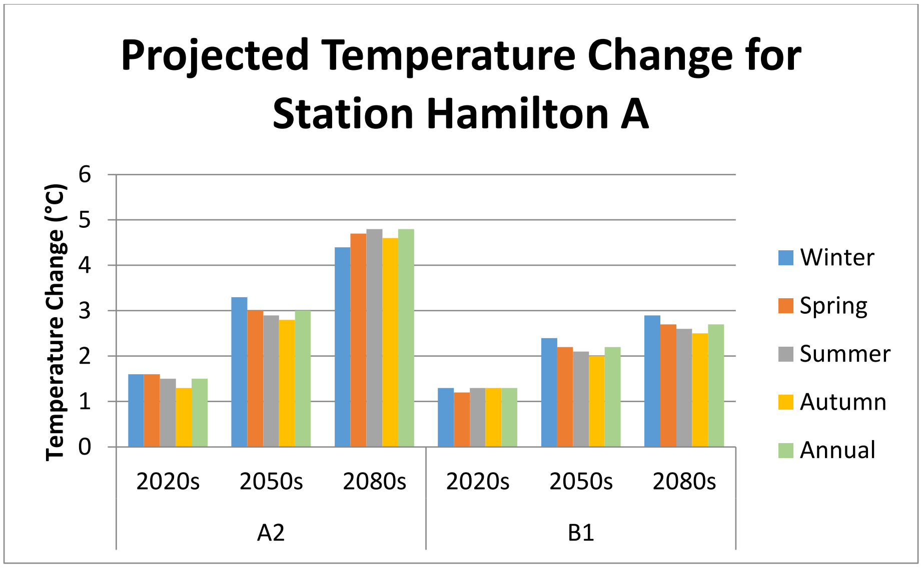
Exhibit 6: Projected Seasonal Temperature Change for *Station Hamilton A* (43.17N 79.93W)
AR4 (2007) - CGCM3T47 (Mean) - SR-A2 (baseline: 1971 - 2000; projection start: 2011)

	2020s	**2050s**	**2080s**
Winter	1.6°C	3.3°C	4.4°C
Spring	1.6°C	3.0°C	4.7°C
Summer	1.5C	2.9°C	4.8°C
Autumn	1.3°C	2.8°C	4.6°C
Annual	1.5°C	3.0°C	4.8°C

Exhibit 7:Projected Seasonal Temperature Change for Station *Hamilton A* (43.17N 79.93W)
AR4 (2007) - GCGCM3T47 (Mean) - SR-B1 (baseline: 1971-2000; projection start: 2011)

	2020s	**2050s**	**2080s**
Winter	1.3°C	2.4°C	2.9°C
Spring	1.2°C	2.2°C	2.7°C
Summer	1.3°C	2.1°C	2.6°C
Autumn	1.3°C	2.0°C	2.5°C
Annual	**1.3°C**	**2.2°C**	**2.7°C**

Exhibit 8: Projected Temperature Change for Station *Hamilton A* (43.17N 79.93W)
AR4 (2007) - GCGCM3T47 (Mean) - SR-B1 & A2 (baseline: 1971-2000; projection start: 2011)



Hot Days

Temperature extremes can pose significant threats to communities across the country. From health impacts to increasing energy demands, "hot days" can be particularly concerning for communities.

Exhibit 9 contains temperature data for station *Hamilton A* based on both a high (A2) and low (B1) emission scenarios. The figures are based on historical records from 1971-2000. It is evident from this graph that the City of Hamilton can expect an increase in the number of hot days (days where the temperature exceeds 30°C), with the annual amount almost doubling in the A2 scenario.

Exhibit 9: Current and projected number of days exceeding 30°C for Station *Hamilton A* (43.17N 79.93W)
AR4 (2007) - GCGCM3T47 (Mean) - SR-B1 & A2 (baseline: 1971-2000; projection start: 2011)

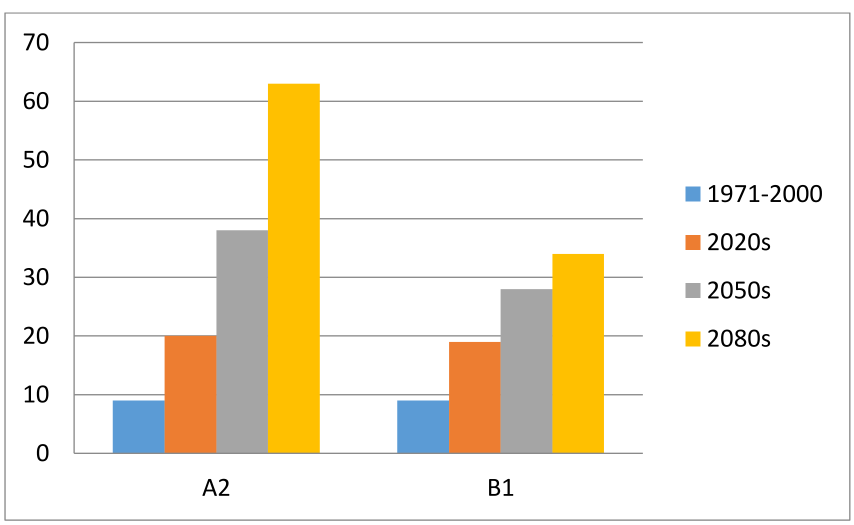


Exhibit 10 shows the predicted number of days with extreme temperatures for Hamilton into the 2080s.

Exhibit 10: Projected number of days with extreme temperature for Station *Hamilton A* (43.17N 79.93W)
AR4 (2007) - GCGCM3T47 (Mean) - SR-B1 & A2 (baseline: 1971-2000; projection start: 2011)

	A2			B1		
	Days with Maximum Temperature >30°C	Days with Maximum Temperature >35°C	Days with Maximum Temperature <-10°C	Days with Maximum Temperature >30°C	Days with Maximum Temperature >35°C	Days with Maximum Temperature <-10°C
1971-2000	9	0	5	9	0	5
2020s	20	1	3	19	1	3
2050s	38	3	1	28	1	2
2080s	63	10	1	34	2	2

Precipitation

Ontario

Canada has, on average, become wetter during the past half century, with average precipitation across the country increasing by approximately 13%.[18] Although other parts of the country can expect to see a significant percentage increase in precipitation, particularly Northern Canada, projections for Southern Ontario show less dramatic changes to precipitation patterns.

Below are the projected precipitation change for the province of Ontario under the three different RCP scenarios (RCP2.6, RCP4.5 and RCP8.5). Changes will vary depending on different greenhouse gas concentration assumptions in each scenario (see Exhibit 1 for scenario description). If current emissions trends continue, the higher emissions scenarios will likely apply.

Exhibit 11: Seasonal Precipitation Change (%) in Ontario - RCP2.6
Baseline: 1986-2005 with respect to the RCP4.5 scenario

	RCP2.6					
	2020s		2050s		2080s	
	Median	Range	Media	Range	Median	Range
Winter	3.70%	0.2-10.8%	6.50%	3.2-14.9%	5.50%	2.7-13.4%
Spring	1.10%	(-)1.6-8.4%	1.40%	0.7-12.8°C%	1.30%	0.1-11.2%
Summer	0.50%	(-)3.8-10.8%	2.60%	(-)2.6-14.9%	1.20%	(-)3.4-13.4%
Autumn	3.6%	(-)1.4-8.2%	5.0%	0.8-9.7%	6.0%	0.2-11.1%

Exhibit 12: Seasonal Precipitation Change (%) in Ontario - RCP4.5
Baseline: 1986-2005 with respect to the RCP4.5 scenario

	RCP4.5					
	2020s		2050s		2080s	
	Median	Range	Median	Range	Median	Range
Winter	5.90%	0.6-10.8%	10.80%	5.7-15.2%	11.60%	5.7-17.6%
Spring	7.10%	0.8-13.7%	10.70%	3.7-19.4%	13.10%	6.6-21.4%
Summer	2.30%	(-)3.5-10.8%	2.30%	(-)4.2-15.2%	4.10%	(-)2.9-17.6%
Autumn	3.70%	(-)1-8.5%	7.50%	1.5-13.4%	7.90%	1.6-13.7%

Exhibit 13: Seasonal Precipitation Change (%) in Ontario - RCP8.5
Baseline: 1986-2005 with respect to the RCP4.5 scenario

	RCP8.8					
	2020s		2050s		2080s	
	Median	Range	Median	Range	Median	Range
Winter	4.00%	1.6-12.1%	13.10%	10.9-23.9%	24.20%	21.6-21.7%
Spring	1.30%	(-)0.8-9.7%	3.10%	5.3-21.5%	6.00%	14.1-36.9%
Summer	0.70%	(-)3.5-12.1%	1.30%	(-)3.8-23.0%	(-)0.5%	(-)8.2-41.7%
Autumn	3.1%	(-)1.1-7.9%	7.7%	1.7-13.6%	13.6%	6.3-19.9%

City of Hamilton

Precipitation in Hamilton is expected to rise in congruence with the provincial changes observed in the AR5 data above, with some decreases in precipitation during the summer months. The Canadian Climate Change Data and Scenarios (CCDS) tool provides information from a weather station located within the City of Hamilton (*Hamilton A*). The data uses a baseline of 1971-2000, and depicts projected precipitation change (not total precipitation) from both A2 (high) and B1 (low) scenarios. At this time, AR5 scenario data for these stations is unavailable.

Projections are based on increases from the precipitation baseline, which is the average amount of precipitation from 1971-2000. For Hamilton, the annual precipitation average over this period was **912.2 mm**. The projections to 2020, 2050, and 2080 reflect the projected amount of precipitation, in millimetres, from the annual and seasonal baselines.

In a high emission scenario (A2), Hamilton can expect to experience an average annual precipitation increase of **24.9 mm** in the 2020s, **66.7 mm** in the 2050s, and **99.9 mm** in the 2080s.

Exhibit 14: Baseline Mean Precipitation (1971-2000) for *Station Hamilton A (43.17N 79.93W)*

	Annual	Winter	Spring	Summer	Autumn
Millimeters (mm)	**912.2 mm**	197.5 mm	230.4 mm	251.0 mm	233.2 mm

Exhibit 15: Projected Seasonal Precipitation <u>Change</u> for *Station Hamilton A (43.17N 79.93W)**
AR4 (2007) - CGCM3T47 (Mean) - SR-**A2** (baseline: 1971 - 2000)

	2020s	2050s	2080s
Winter	18.2 mm	36.1 mm	56.5 mm
Spring	11.1 mm	29.7 mm	50.4 mm
Summer	(-)6.5 mm	(-) 14.1 mm	(-) 10.9 mm
Autumn	2.3 mm	15.1 mm	4.9 mm
Annual	**24.9 mm**	**66.7 mm**	**99.9 mm**

* All figures are positive, unless noted otherwise.

Exhibit 16: Projected Seasonal Precipitation <u>Change</u> for *Station Hamilton A (43.17N 79.93W)**
AR4 (2007) - CGCM3T47 (Mean) - SR-**B1** (baseline: 1971 - 2000)

	2020s	2050s	2080s
Winter	9.0 mm	21.0 mm	27.9 mm
Spring	10.6 mm	21.3 mm	29.2 mm
Summer	(-)6.5 mm	(-) 7.3 mm	(-) 10.8 mm
Autumn	4.6 mm	4.5mm	8.8 mm
Annual	**17.6 mm**	**44.4 mm**	**55.0 mm**

* All figures are positive, unless noted otherwise.

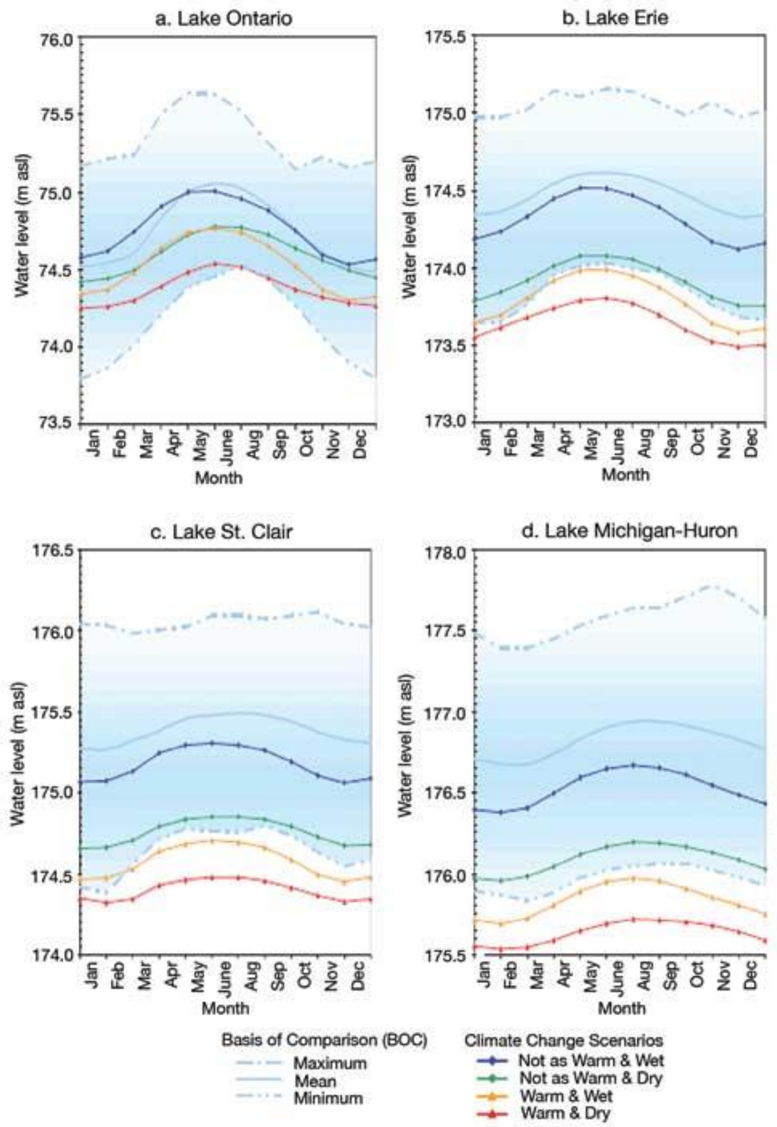
Water Levels and Water Temperature

Due to recent increases in the volume of glacial melt water, precipitation changes and increased evaporation, water resources across much of Canada have been altered. In the Great Lakes, a 1°C in mean annual air temperature has been associated with a 7-8% increase in the actual evaportranspiration (AET) rates, resulting in a decrease in water availability.[19] Changing water levels in the Great Lakes will have significant impacts for all of Southern Ontario and climate is the key determining factor affecting lake levels. Analysis of long-term regional climate data suggests that precipitation accounts for 55% and temperature accounts for 30% of the variability in lake levels.[20]

Water shortages have been documented in regions of Southern Ontario and projections indicate that shortages will occur more frequently as summer temperatures and evaporations rates increase.[21] Ice cover break-up dates are expected to advance in the range of 1 to 3-1/2 weeks, while freeze-up dates are expected to be delayed by up to 2 weeks[22]. The resulting ice cover duration is expected to decrease by up to a month depending on the depth of the lake, with greater reductions found for deeper lakes[23]

Projected warming in the region, particularly in winter months, is expected to further change the duration and extent of ice cover on the lakes. Less ice cover results in great loss of water through evaporation and enhanced shoreline erosion during winter storms.[24]

Exhibit 17: Projected changes in Great Lakes Water Levels based on a 50-year average

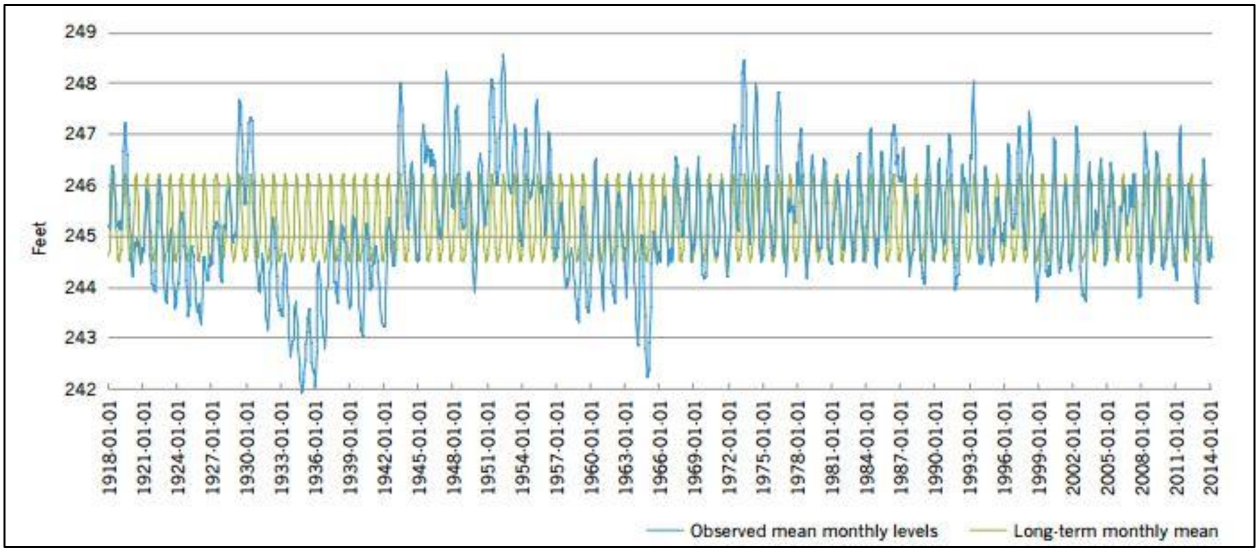


Lake Ontario is expected to see its water levels decrease by 0.5 meters by 2050.[25] Exhibit 17 shows the results from studies that have modeled future changes in water levels of Lake Ontario, Erie, St. Clair and Michigan-Huron. Projections are measured in meters above sea level (m asl).

Increases in nearshore temperatures have been recorded at several locations around the Great Lakes since the 1920s. They are most pronounced in the spring and fall and are positively correlated with trends in global mean air temperature.[26]

The graph below illustrates the historical monthly water levels for Lake Ontario between 1918 and 2014.

Exhibit 18: Lake Ontario mean monthly levels and long-term monthly means (1918-2014)[27]



Lake Ontario has not shown a persistent low water levels pattern, however it has on several occasions been at its lowest since the early years of regulation.

Extreme Weather Events: Heavy or Extreme Rain

Canada has seen more frequent and intense extreme events over the last 50-60 years than ever before. These events come in the form of extreme heat days, more instances of extreme precipitation and flooding, wind storms, and ice storms. In Canada, models show shorter return periods of extreme events – that is, the estimated interval of time between occurrences – in the future[28].

Extreme and heavy rain events are expected to become more intense and more frequent.[29] As Southern Ontario is the most intensely urbanized area of the province, the magnitude and costs associated with flooding is significantly higher than elsewhere in the province.

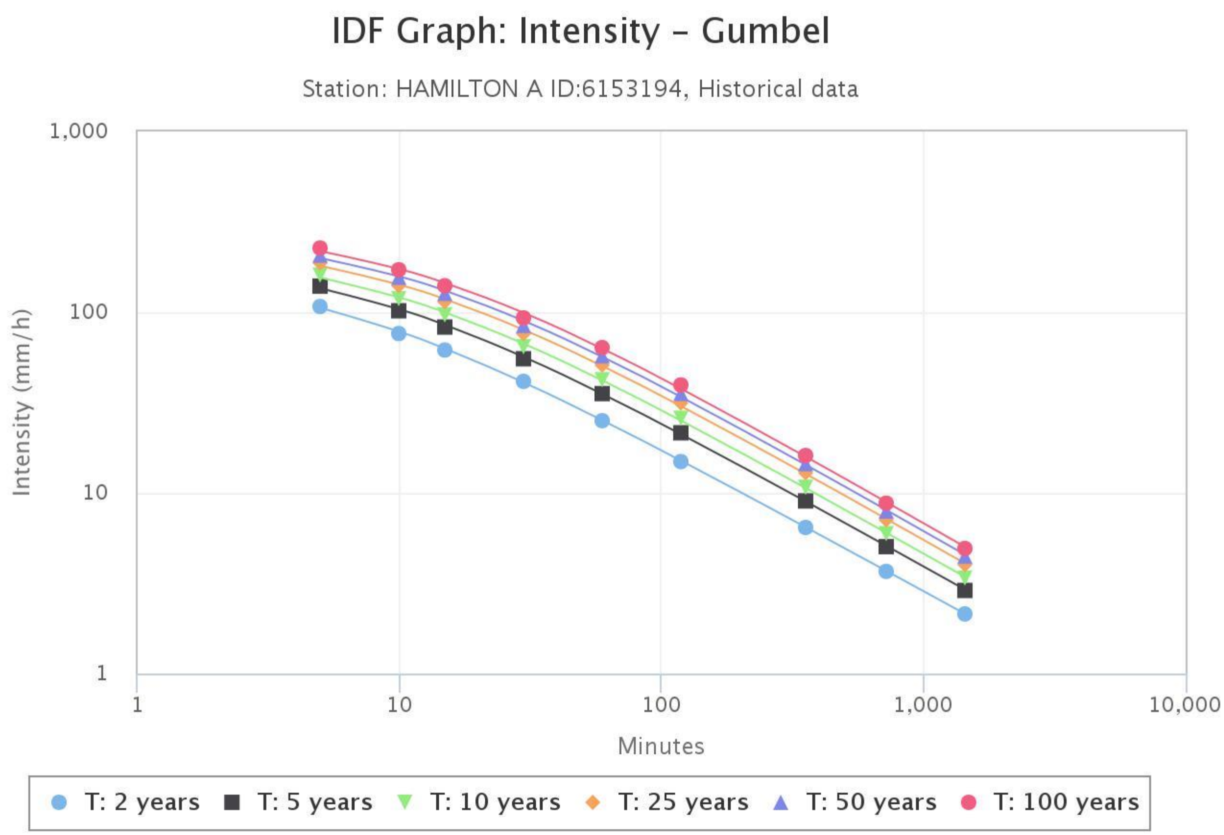
The Institute for Catastrophic Loss Reduction (ICLR) has developed a tool that assists users in developing and updating IDF curves using precipitation data from existing Environment Canada hydro-meteorological stations. Available precipitation data is integrated with predictions obtained from Global Climate Models to assess the impacts of climate change on IDF curves. GCM models developed for IPCC Assessment Report (AR) 5 (IPCC,2013) are used to provide future climate scenarios for the various RCPs.

Projections are based on increases from the precipitation intensity rate baseline, which is the average amount of precipitation from 1962-2007. The projections to 2020, 2050, and 2080 reflect the projected amount of precipitation, in millimetres, from the annual and seasonal baselines.

Exhibit 19: Baseline Precipitation Intensity Rates (mm/h) (1971-2003) for Station Hamilton A (43.17N 79.93W)

T (years)	2	5	10	25	50	100
5 min	107.49	139.37	160.48	187.14	206.93	226.57
10 min	76.17	101.77	118.72	140.14	156.03	171.80
15 min	61.72	82.71	96.60	114.15	127.17	140.09
30 min	41.41	55.22	64.36	75.91	84.48	92.99
1 h	25.09	35.42	42.26	50.90	57.31	63.67
2 h	14.90	21.50	25.87	31.40	35.50	39.57
6 h	6.43	9.02	10.73	12.90	14.50	16.10
12 h	3.68	5.04	5.94	7.08	7.93	8.77
24 h	2.14	2.88	3.38	4.00	4.46	4.92

Exhibit 20: Baseline Precipitation Intensity Rates (mm/h) (1971-2003) for Station Hamilton A (43.17N 79.93W)



The complete collection of projected rainfall IDF tables and graphs for the City of Hamilton can be found in Appendix A.

Conclusion

The information provided in this report provides a clear indication that climate change is affecting Canada, and specifically the City of Hamilton. Rising annual temperatures as well as increases in precipitation and extreme events are major climate impacts that can have tremendous ecological, infrastructural, economic, and sociological effects for the community. This report is meant to act as a background and an introduction to climate change in this area, and additional research should be conducted to retrieve more precise downscaled climate projections where available.

Appendix A

The following 18 exhibits were generated by The Institute for Catastrophic Loss Reduction (ICLR) Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change (www.idf-cc-uwo.ca).

2020s

Exhibit 21: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP2.6 (baseline: 1971 - 2003; projection start: 2011-2040)

T (years)	2	5	10	25	50	100
5 min	119.80	153.85	175.82	204.04	224.64	244.97
10 min	86.07	113.06	130.50	152.88	169.21	185.32
15 min	69.75	91.95	106.29	124.69	138.13	151.39
30 min	46.63	61.31	70.78	82.95	91.84	100.61
1 h	28.67	39.76	46.86	56.08	62.85	69.48
2 h	16.96	24.20	28.69	34.72	39.01	43.31
6 h	7.20	10.04	11.84	14.21	15.95	17.65
12 h	4.08	5.58	6.52	7.77	8.69	9.59
24 h	2.35	3.17	3.70	4.39	4.90	5.39

Exhibit 22: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP2.6 (baseline: 1971 - 2003; projection start: 2011-2040)

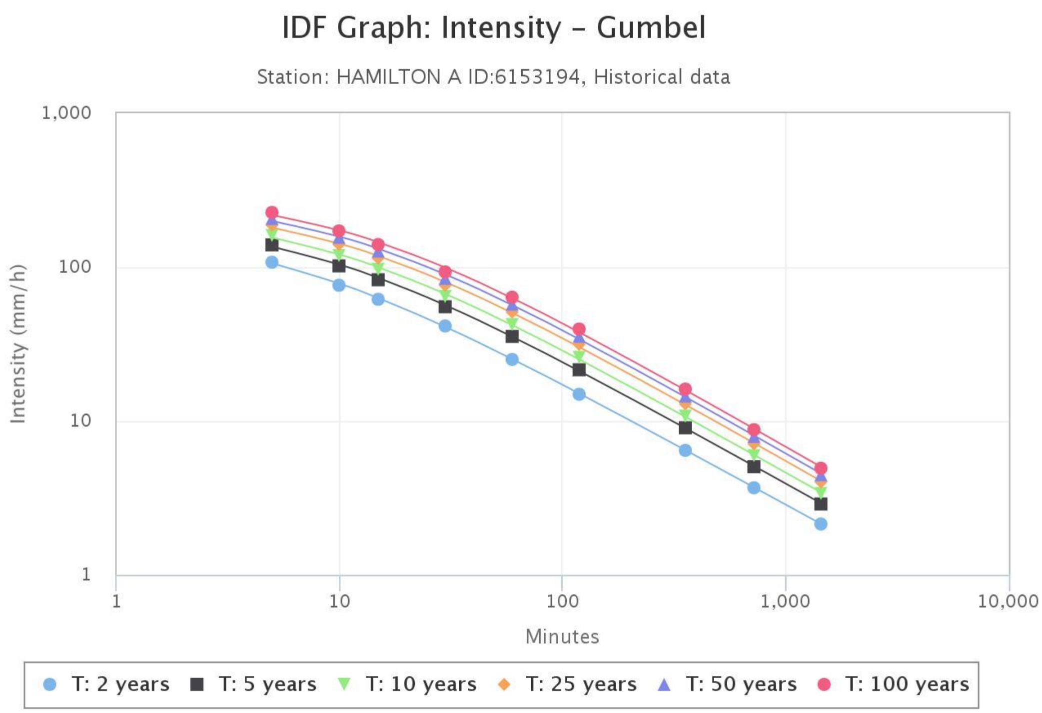


Exhibit 23: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP4.5(baseline: 1971 - 2003; projection start: 2011-2040)

T (years)	2	5	10	25	50	100
5 min	121.22	154.53	178.12	206.94	228.45	249.97
10 min	87.21	113.62	132.35	155.22	172.29	189.37
15 min	70.68	92.40	107.80	126.61	140.63	154.68
30 min	47.24	61.60	71.77	84.20	93.47	102.75
1 h	29.31	39.96	47.64	57.02	63.98	70.98
2 h	17.37	24.28	29.26	35.34	39.85	44.36
6 h	7.36	10.09	12.05	14.44	16.22	17.99
12 h	4.14	5.60	6.63	7.90	8.83	9.77
24 h	2.38	3.19	3.76	4.46	4.97	5.49

Exhibit 24: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP4.5(baseline: : 1971 - 2003; projection start: 2011-2040)

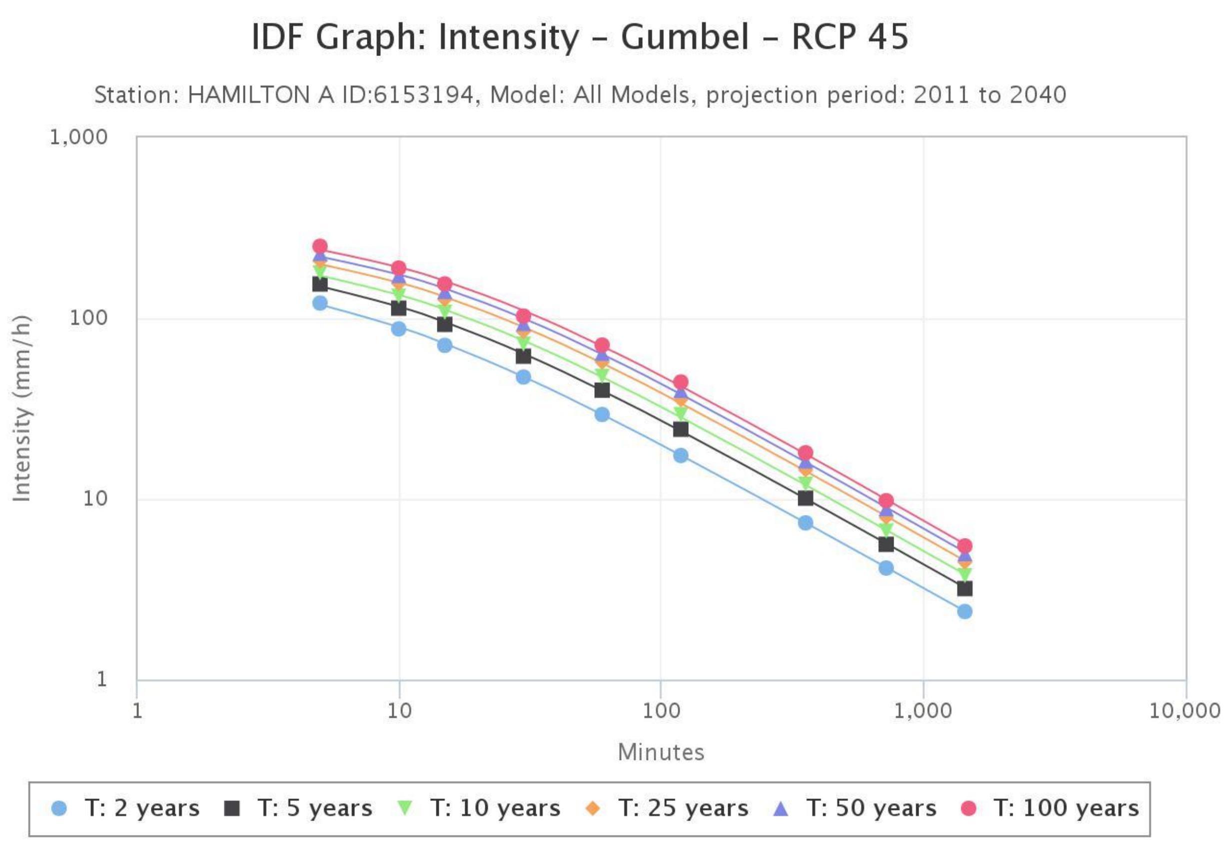
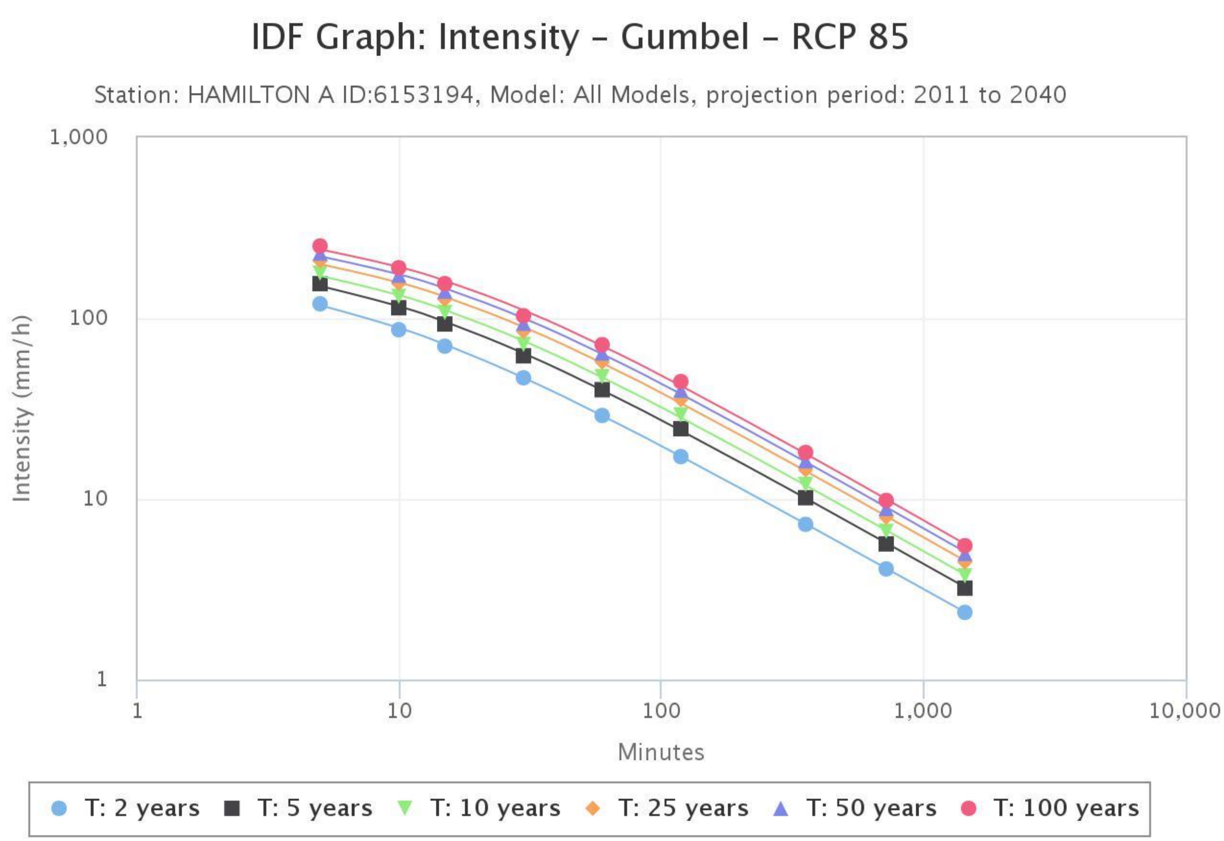


Exhibit 25: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP8.5(baseline: : 1971 - 2003; projection start: 2011-2040)

T (years)	2	5	10	25	50	100
5 min	120.12	155.20	177.56	207.17	229.16	250.93
10 min	86.32	114.16	131.92	155.43	172.91	190.18
15 min	69.95	92.85	107.44	126.77	141.12	155.35
30 min	46.76	61.89	71.53	84.31	93.77	103.19
1 h	28.93	40.19	47.45	57.09	64.18	71.37
2 h	17.13	24.43	29.15	35.37	39.96	44.58
6 h	7.23	10.15	12.01	14.45	16.26	18.07
12 h	4.09	5.63	6.61	7.90	8.86	9.81
24 h	2.35	3.21	3.75	4.46	4.98	5.51

Exhibit 26: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP8.5(baseline: : 1971 - 2003; projection start: 2011-2040)



2050s

Exhibit 27: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP2.6(baseline: : 1971 - 2003; projection start: 2041-2070)

T (years)	2	5	10	25	50	100
5 min	122.35	157.63	180.20	206.97	226.03	245.22
10 min	88.11	116.12	134.00	155.18	170.26	185.50
15 min	71.42	94.45	109.18	126.64	139.08	151.57
30 min	47.73	62.95	72.70	84.28	92.52	100.74
1 h	29.47	40.99	48.37	57.29	63.58	69.77
2 h	17.48	24.95	29.75	35.59	39.77	43.85
6 h	7.40	10.35	12.24	14.56	16.22	17.84
12 h	4.19	5.74	6.74	7.96	8.83	9.68
24 h	2.40	3.26	3.82	4.49	4.98	5.46

Exhibit 28: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP2.6 (baseline: : 1971 - 2003; projection start: 2041-2070)

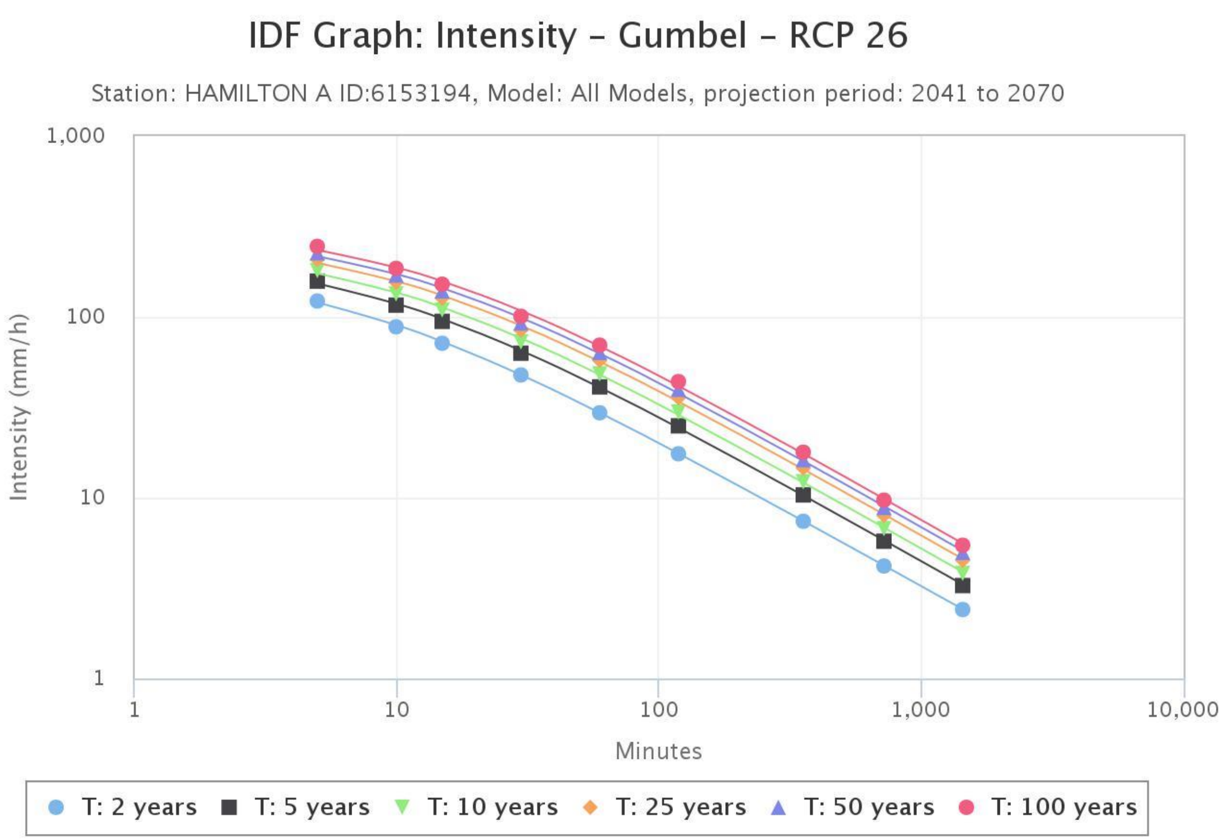


Exhibit 29: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP4.5(baseline: : 1971 - 2003; projection start: 2041-2070)

T (years)	2	5	10	25	50	100
5 min	125.29	162.49	186.97	217.15	239.28	261.83
10 min	90.48	120.05	139.50	163.47	181.08	199.00
15 min	73.36	97.67	113.67	133.40	147.85	162.59
30 min	49.00	65.07	75.64	88.70	98.23	107.97
1 h	30.42	42.57	50.60	60.53	67.71	75.04
2 h	18.08	25.96	31.18	37.64	42.34	47.04
6 h	7.64	10.75	12.81	15.36	17.22	19.06
12 h	4.31	5.95	7.03	8.38	9.36	10.33
24 h	2.47	3.38	3.98	4.72	5.27	5.80

Exhibit 30: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP4.5(baseline: : 1971 - 2003; projection start: 2041-2070)

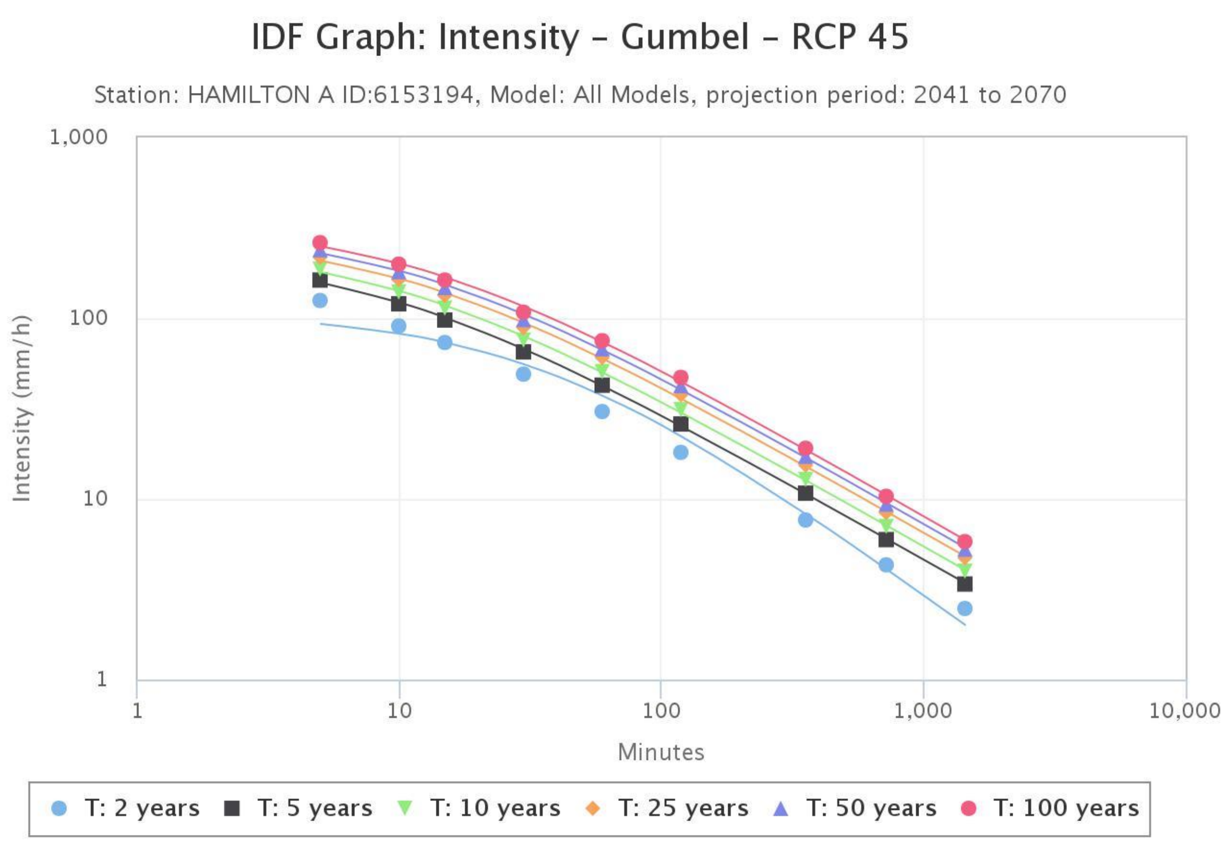
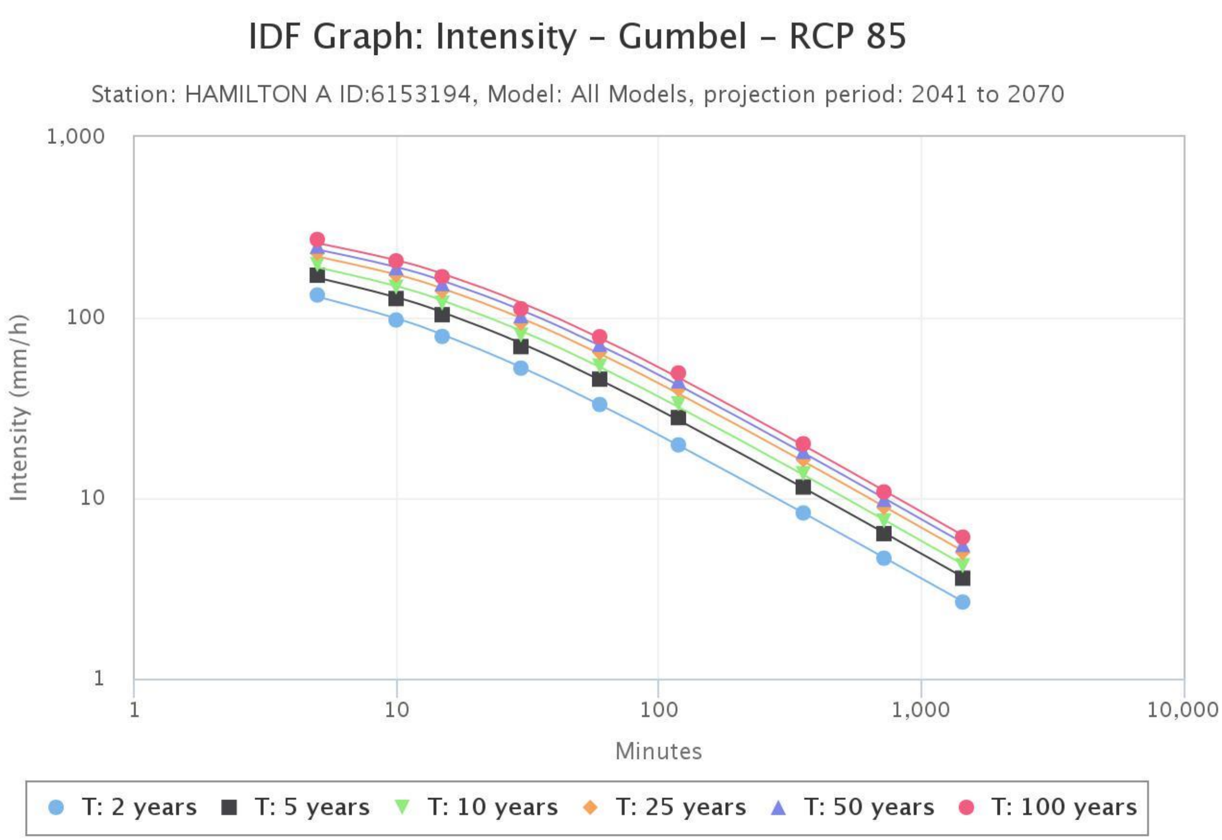


Exhibit 31: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP8.5(baseline: : 1971 - 2003; projection start: 2041-2070)

T (years)	2	5	10	25	50	100
5 min	133.19	171.47	196.60	226.68	248.58	270.32
10 min	96.81	127.27	147.27	171.15	188.55	205.83
15 min	78.55	103.60	120.05	139.73	154.06	168.28
30 min	52.42	68.98	79.85	92.89	102.37	111.78
1 h	32.96	45.55	53.81	63.82	71.06	78.25
2 h	19.70	27.90	33.28	39.87	44.60	49.31
6 h	8.27	11.51	13.64	16.25	18.13	19.99
12 h	4.65	6.35	7.47	8.85	9.84	10.82
24 h	2.66	3.60	4.22	4.99	5.53	6.08

Exhibit 32: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP8.5(baseline: : 1971 - 2003; projection start: 2041-2070)



2080s

Exhibit 33: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP2.6(baseline: : 1971 - 2003; projection start: 2071-2100)

T (years)	2	5	10	25	50	100
5 min	121.81	156.82	180.36	209.42	230.08	250.60
10 min	87.68	115.46	134.18	157.21	173.60	189.87
15 min	71.06	93.91	109.30	128.27	141.76	155.15
30 min	47.49	62.60	72.76	85.32	94.24	103.10
1 h	29.30	40.73	48.37	57.97	64.74	71.46
2 h	17.51	24.79	29.72	36.02	40.42	44.80
6 h	7.36	10.29	12.23	14.71	16.46	18.19
12 h	4.16	5.71	6.73	8.04	8.96	9.87
24 h	2.39	3.25	3.81	4.53	5.05	5.55

Exhibit 34: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP2.6(baseline: : 1971 - 2003; projection start: 2071-2100)

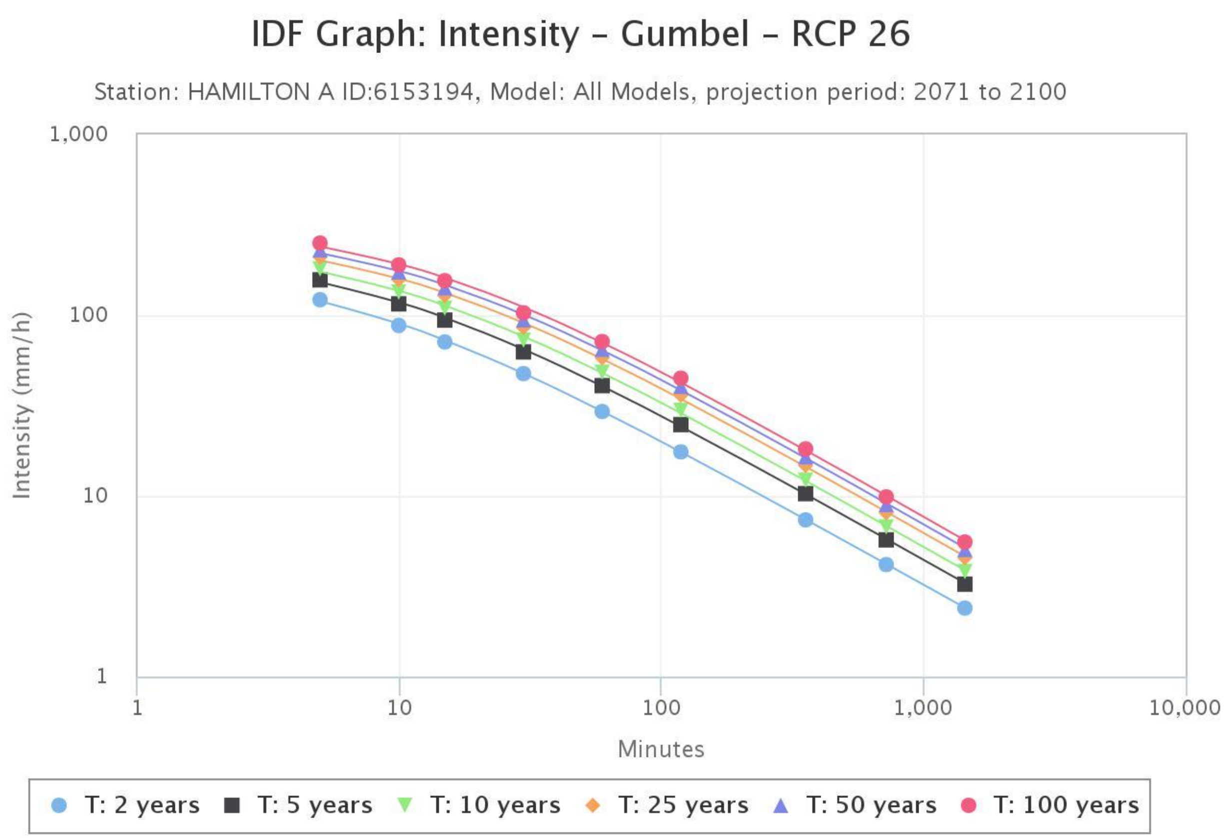


Exhibit 35: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP4.5(baseline: : 1971 - 2003; projection start: 2071-2100)

T (years)	2	5	10	25	50	100
5 min	128.23	160.91	184.75	213.82	234.62	255.13
10 min	92.91	118.76	137.70	160.75	177.30	193.51
15 min	75.20	96.63	112.20	131.19	144.78	158.20
30 min	50.09	64.38	74.71	87.26	96.25	105.15
1 h	31.31	42.09	49.89	59.50	66.37	73.26
2 h	18.68	25.69	30.74	36.95	41.53	45.97
6 h	7.85	10.64	12.64	15.08	16.91	18.67
12 h	4.42	5.89	6.95	8.23	9.20	10.12
24 h	2.53	3.35	3.93	4.64	5.18	5.69

Exhibit 36: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP4.5(baseline: : 1971 - 2003; projection start: 2071-2100)

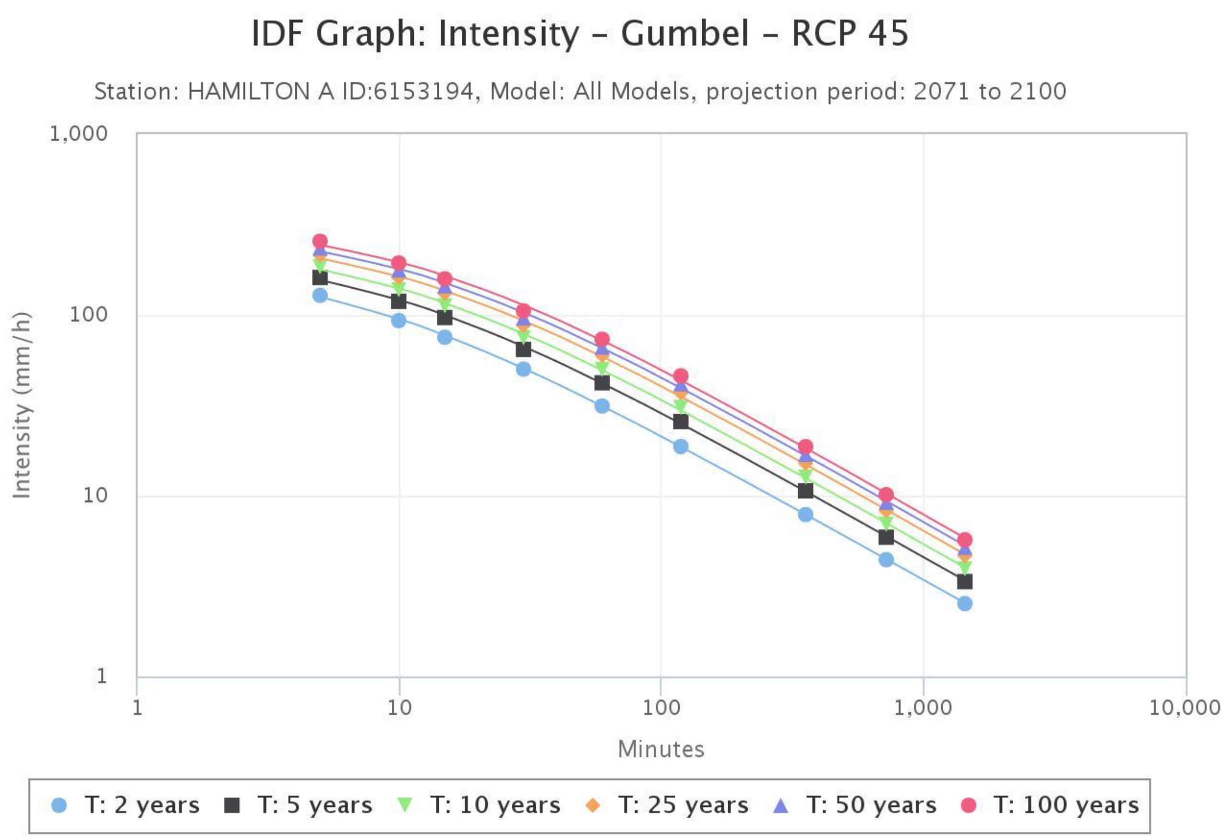
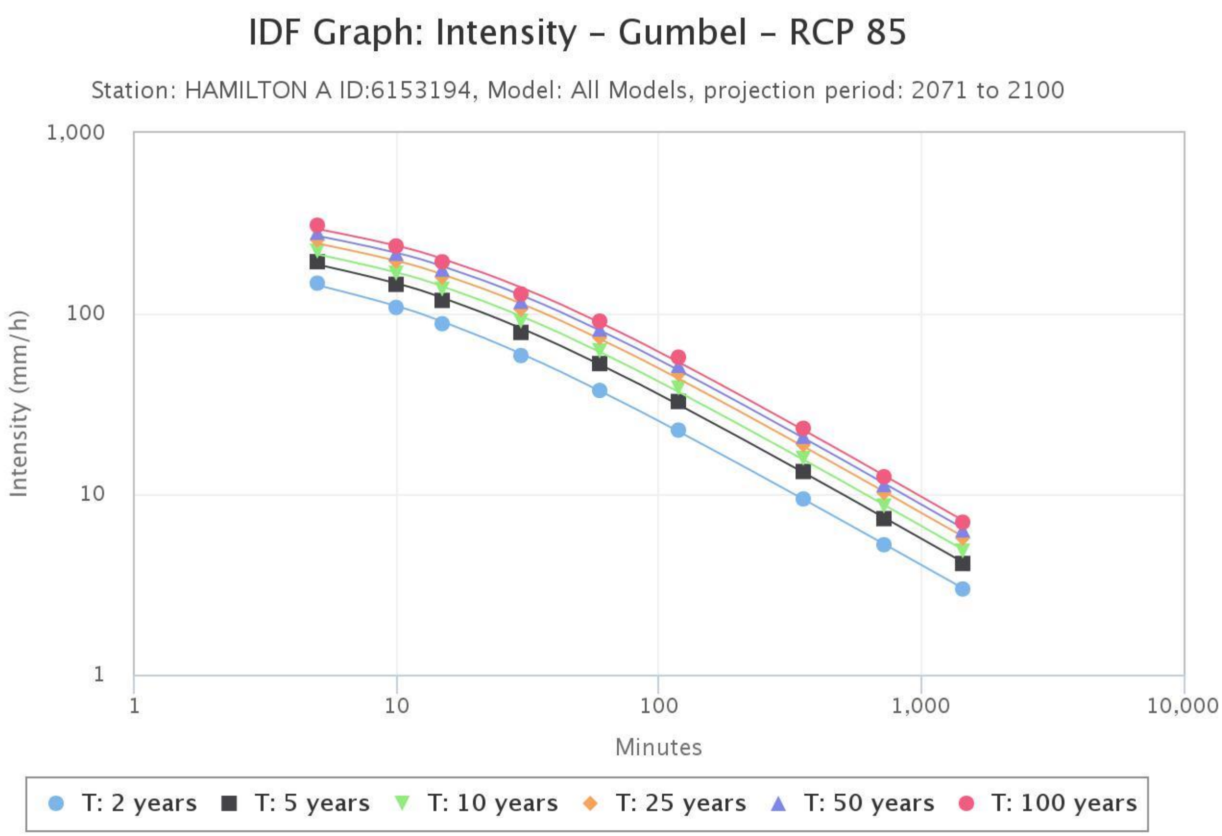


Exhibit 37: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP8.5 (baseline: : 1971 - 2003; projection start: 2071-2100)

T (years)	2	5	10	25	50	100
5 min	147.16	193.51	221.28	255.27	281.77	308.11
10 min	108.03	145.02	167.15	194.23	215.39	236.40
15 min	87.74	118.15	136.38	158.71	176.05	193.34
30 min	58.46	78.56	90.62	105.43	116.84	128.26
1 h	37.47	52.77	62.05	73.42	81.98	90.69
2 h	22.60	32.55	38.65	46.11	51.63	57.32
6 h	9.40	13.34	15.76	18.71	20.89	23.14
12 h	5.24	7.31	8.59	10.15	11.29	12.48
24 h	2.98	4.13	4.84	5.70	6.33	6.99

Exhibit 38: Precipitation Intensity Rates (mm/h) for Station Hamilton A (43.17N 79.93W)
AR5 (2014) – Ensemble Model – RCP8.5 (baseline: : 1971 - 2003; projection start: 2071-2100)



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