

**CLIMATE CHANGE
ADAPTATION
PLAN FOR THE
MONTRÉAL URBAN
AGGLOMERATION
2015-2020**

SUMMARY VERSION
2017 EDITION

A WORD FROM YOUR REPRESENTATIVES



All over the world, people are recognizing the key role that cities play in both fighting and adapting to climate change. Densely populated urban centres are the first to feel the adverse consequences of climate change. But cities are also places conducive to innovation and action. This is why we are taking up our responsibilities, and planning as

of now to ensure better quality of life for Montréalers and secure the future of coming generations.

The Montréal Urban Agglomeration committed to reducing its greenhouse gas (GHG) emissions by adopting, in 2013, the *Plan de réduction des émissions de GES de la collectivité montréalaise 2013-2020*. Despite our mitigation efforts, we are already seeing some of the climate disturbances we feared: heat waves, heavy rainfalls, ice storms and more. A strategy that aims to limit their negative effects is crucial for our administration and for our citizens. This is why I am very proud to present this first Climate Change Adaptation Plan for the Montréal Urban Agglomeration 2015-2020.

With this adaptation plan, Central Services, the boroughs and the municipalities have made many ambitious commitments. The measures we are announcing aim, among other things, to reduce heat islands, protect biodiversity, manage runoff water, increase infrastructure resilience, and adopt new practices in regard to the range of recreational activities on offer, to name just a few.

This plan is the first step in a very concrete process that will not only consolidate our accomplishments and strengthen our ability to respond to all these disturbances, but that will also show our desire to help maintain and improve the quality of our citizens' living environment.



Denis Coderre
Mayor of Montréal and President of
the Communauté métropolitaine de Montréal



Heat waves, heavy rains, freezing rain... the extreme events of recent years show that climate change is already having an effect on us. These new conditions pose a challenge, but they also provide opportunities that we can seize to make Montr  al a city at the forefront of sustainable development.

This first adaptation plan spotlights our region's vulnerability in regard to climate change. We can't deny the impacts we have seen, and those we anticipate, on the population, the infrastructures, the natural environment and all the activities that happen on the island. The wealth of information brought together in this plan provides solid arguments about the importance of moving from strategy to action, and that's what we commit to doing.

This adaptation plan presents concrete measures for tackling the climate hazards that are already affecting us and whose impacts will most certainly be exacerbated in the coming years. Climate projections confirm that episodes of oppressive heat, intense rain and destructive storms will happen more frequently. This adaptation process is an opportunity for us to change and improve our approaches to mitigate the impacts of climate change.

This plan is the result of a fruitful collaboration among various players in the Montr  al Urban Agglomeration. Specialists in the environment, water management, infrastructures, buildings, green spaces and land use planning, along with representatives from every borough and city in the Agglomeration, helped to develop this tool. Thanks to this, our Agglomeration will become more resilient in the coming five years.



R  al M  nard
Member of the executive committee responsible for sustainable
development, the environment, large parks and green spaces

MONTREAL IS ADAPTING TO CLIMATE CHANGE

Recent decades have marked a turning point in regard to the climate. We have seen countless extreme weather events all over the world and witnessed their impacts. The scientific community, including the Intergovernmental Panel on Climate Change (IPCC), has attested to climate change and its amplification.

This changing climate has been felt in the Montréal agglomeration. Just think of the heat waves we have experienced for the past few years, or the flooding and freezing rain that have caused a great deal of property damage and incurred financial costs as well as inconveniencing the population in its everyday activities.

The Montréal agglomeration is already dealing with the changes that affect our natural environment, our built environment, the population and our socioeconomic activities. A range of non-climate factors, such as the age of our infrastructures, land use planning and sociodemographic characteristics, have the effect of amplifying or, in contrast, limiting the repercussions of climate change.

Two types of joint action are possible when it comes to managing climate change: mitigation (also called reduction) and adaptation.

Mitigation consists of reducing the intensity of change by reducing greenhouse gas emissions caused by human activity. To this end, the Ville de Montréal developed a *Plan de réduction des émissions de gaz à effet de serre de la collectivité montréalaise 2013-2020* (Montréal's 2013-2020 community plan to reduce GHG emissions). **Adaptation** consists, in turn, of assessing the effects of climate change on the agglomeration and putting into place the required measures to minimize its impacts. Adaptation measures help make the agglomeration more **resilient** to climate change, meaning capable of reacting and reorganizing while keeping its essential functions and identity intact.

This first climate change adaptation plan, the fruit of a collaboration between municipal services, local administrations and the Service de l'environnement, is the starting point of an iterative process that will be expanded over the years as data accumulate about the changing climate and its risks, and as the effectiveness of the actions we undertake is demonstrated.



Credit: © Denis Labine, Ville de Montréal

ADAPTATION AND RESILIENCE

Climate change **adaptation** is a process by which communities and ecosystems adjust in order to limit the negative consequences and enjoy the potential benefits of the changing climate.

Resilience is the capacity of a community's economic, social, political and physical infrastructure systems to absorb shocks and stresses and still retain their basic function and structure.*

* Source: Craig Applegath, www.resilientcity.org

PLAN OBJECTIVES

The adaptation plan is designed to achieve three specific objectives:

1. Consolidate all the adaptation measures already in place which contribute to climate change adaptation, even if they do not refer to it.

Many of the climate impacts that relate to health issues and the protection of natural and built environments are already considered in a number of other Montréal Urban Agglomeration plans and strategies. We have catalogued more than 30 strategies, policies, plans and regulations that, to a greater or lesser extent, relate to climate change adaptation. As such, this adaptation plan rests on initiatives that have already been announced, and provides solid arguments showing that it is important to move from strategy to action.

2. Provide relevant information regarding climate change risks to the all the agglomeration's municipalities.

While climate projections are the same throughout the agglomeration, vulnerability factors and risk levels vary depending on the geographic location on the island of Montréal. So it is crucial to know not only the risks, but also the local variations in vulnerability, in order to target actions based on local realities and focus efforts on the places with greater vulnerability.

3. Plan the agglomeration's development as well as maintenance and repair operations while taking into account the constraints associated with climate change.

This objective is at the very core of a climate change adaptation plan. It means we need to find ways to update our ways of thinking and doing things within the agglomeration in order to reduce the risks that come with climate change.

PLAN CONTENT

The first volume of the plan sets out a diagnosis of the adaptation challenges the Montréal agglomeration is facing. It includes a vulnerability analysis for the agglomeration in regard to six climate hazards:

- higher average temperatures;
- heavy rainfalls;
- heat waves;
- destructive storms;
- droughts;
- river floods.

For each of these hazards, we provide a description of the meteorological observations and climate projections. Next, we review the hazard's impacts on the built environment, the population, the natural environment and municipal activities. Lastly, we present a vulnerability analysis for the Montréal agglomeration, when possible in the form of a map.

The second volume is dedicated entirely to adaptation measures. It presents the actions we must consolidate or develop and the commitments made by the Montréal agglomeration's various entities.



Credit: © Denis Labine, Ville de Montréal

TERRITORY COVERED BY THE PLAN

Located where the St. Lawrence River meets the Ottawa River, the island of Montréal is about 50 km long and 16 km across at its widest point. Surrounded by Rivière des Prairies, the St. Lawrence River and Lac Saint-Louis, it has 266.6 km of shoreline and covers an area of 483 km² (499 km² counting the small nearby islands).

This territory brings together 16 municipalities that form the Montréal Urban Agglomeration, which is made up of 15 municipalities and the Ville de Montréal (subdivided in turn into 19 boroughs). It is home to nearly two million residents, or 24% of Québec's population.²⁰

The Montréal Urban Agglomeration features many green spaces classified under various terms, including 19 large parks, 10 ecoterritories, and protected spaces that cover 21.3% of the land. These green spaces are mostly located at both ends of the agglomeration, except for Mount Royal Park, which acts as a lung at the centre of downtown Montréal, and Parc Jean-Drapeau, also steps away from the business core. There are nearly 1.2 million trees on public land.¹⁹

THE MONTRÉAL AGGLOMERATION IN NUMBERS

90%	of the territory is urbanized
1.9 million	people lived on the island of Montréal in 2011
3,780	people per square kilometre (2011) ¹⁸
45%	of the population is concentrated in the centre of the island
10%	of the population lives at the island's extremities
15%	of the population is between 0 and 14 years old
16%	of the total population is aged 65 and up
33%	of the population are immigrants, or 1 out of 3 residents ¹⁸
3%	of the population speaks neither French nor English
39%	of households are made up of one single person ⁴
42%	of housing was built before 1961
6,200 km	of streets and arteries
18	bridges provide access to the island
68	metro stations on four lines stretch across 71 km
5	commuter train lines

AGGLOMERATION OF MONTRÉAL



CLIMATE PROJECTIONS

The *Climate Change Adaptation Plan for the Montréal Urban Agglomeration* is based on climate projections from Ouranos.¹³ These projections were made for the southern Québec region, including Montréal. We also performed a historical analysis on Montréal's meteorological and hydrological observations for the last few decades. The historical trends for Montréal are in line with the climate projections for southern Québec as a whole, which makes it relevant to use these projections.

Ouranos is a research and development consortium that brings together more than 450 scientists and professionals working in regional climatology and climate change adaptation.

For **temperatures**, the projections indicate an increase of about 2 to 4 °C for the 2041-2070 period and 4 to 7 °C for the 2071-2100 period. As well, the growing season for plants, which has already lengthened in recent decades, should lengthen still more, by 10 to 30 days from now to 2050 depending on the emissions scenario chosen. As well, the length of the freeze-up period should continue to shorten, losing another two to four weeks as compared to today. It's estimated that, for 2041-2070, the snowy period should shorten by 65 to 45 days compared to the historical period of 1970-1999. The most extreme projections even say it is possible that we may see snow cover lasting fewer than 20 days. Lastly, climate projections indicate that the number of freeze-thaw cycles should increase in winter, but reduce in fall and spring between now and 2050.

The observed trend toward increased **precipitation**, and heavy rainfalls in particular, is confirmed by Ouranos's climate projections. By 2050, annual precipitation should increase by 3 to 14%. Projections also show an accentuation of rain in winter of 2 to 27% and in spring of 3 to 18%. We can also expect a significant increase in the frequency and intensity of heavy rainfalls; their intensity should increase by 10 to 25% by 2100. As well, a rainfall of a given intensity whose return period was of 20 years in the 1986-2005 range could come back more frequently in the 2046-2065 range with a return period of seven to 10 years.



Credit: © Yves Provencher, *Journal Métro*

As they do for the planet as a whole, climate models predict strong increases in the duration of **heat waves** and in the frequency of hot nights (with a low temperature of > 20 °C). According to these same projections, extreme high temperatures in summer will increase more than average summer temperatures. This means longer and more intense heat waves in the coming decades.

When it comes to **destructive storms** (freezing rain, heavy snow, hail and wind), climate projections show major uncertainties. But despite the lack of precision about the future of destructive storms in Montréal, the trends we have already observed, and their significant impacts, demand consideration and tailored measures to help the agglomeration prepare to better handle them in the future.

Looking forward to 2081-2100, the majority of climate projections agree that periods of meteorological **drought** will be shorter year-round and during the winter (December to February), but longer during the summer season (June to August). As for soil drought, the projections for anomalous soil humidity levels indicate drier conditions year-round and even more so for the summer season in the 2081-2100 range.

For Rivière des Prairies, a study recently simulated the average daily flow for 2042-2070. It observed that the spring **river flood** should move even earlier in the year than it was during the historical period of 1972-2000. According to an Ouranos study, the levels of the St. Lawrence River should drop in the Montréal area by 20 to 120 cm by 2050. In short, we can expect that spring river floods from Rivière des Prairies will come increasingly early in the year. However, it is not clear whether future floods will be more intense than in the past. Hydrological models do not yet have the ability to take into account frazil ice, which currently limits their predictive power for this type of river flood.

CLIMATE EVOLUTION FOR THE VARIOUS HAZARDS*

 HIGHER AVERAGE TEMPERATURES	Extended summer season ➤ freeze-up and snowy periods ➤ number of freeze-thaw cycles
 HEAVY RAINFALLS	➤ frequency and intensity
 HEAT WAVES	➤ frequency and length
 DESTRUCTIVE STORMS	➤ frequency of heavy snowfalls ➤ frequency of freezing rain
 DROUGHTS	➤ length during the summer season
 RIVER FLOODS	➤ spring river floods occurring earlier in the year

* The results in this table are based on both meteorological and hydrological observations for Montréal and on projections for the future produced for southern Québec. The only exception is the "destructive storms" hazard, as here we present only the analysis of meteorological observations for Montréal.



HIGHER AVERAGE TEMPERATURES

On the territory of the Montréal agglomeration, there is a clear trend toward increased temperatures (by about 1 °C) between the decades 1970-1980 and 2000-2010, which is in keeping with the trend observed for the rest of Québec.

Higher average temperatures have an impact on all the seasons. They cause a longer summer and a shorter winter, among other things, which in turn have repercussions on various parameters related to climate. For example, from the periods of 1955-1984 to 1985-2014, we observed:

- a nine-day increase in the length of the plant growing season;
- a five-day reduction in the freeze-up period;
- a marked reduction in the length of the snowy period, which moved from an average of 103 days to an average of 73.

Lastly, we noted a 29% increase in freeze-thaw cycles in the winters of 1942 to 2015.

IMPACTS

On the territory of the Montréal agglomeration, we mostly see the impacts of higher average temperatures on the built environment in winter. The higher number of freeze-thaw cycles accelerates the degradation of the road arteries in Montréal and causes a higher number of potholes. It also helps accelerate the degradation of some bridges, tunnels and overpasses.

Higher average temperatures also have environmental impacts. Insects, whose metabolisms depend directly on climate conditions, are heavily influenced by temperature. These changes can bring about an increased growth rate for some pest insects and multiply the number of generations produced each season. The changing climate could change the geographical distribution area for insects. It could also lead to an increased frequency of infestations and to more severe pest insect damage to plants.

An increase of just a few degrees can be enough to bring about drastic changes in plant biology. This has already caused a change in plant hardiness zones for Montréal. The territory moved from being a 5B zone to being a 6 zone, which implies changes in the distribution area for certain species and could favour the appearance of certain undesirable plant species.

Plant hardiness zones for Québec are determined using Canadian data such as lowest winter temperatures, the length of the freeze-free period, summer precipitation, highest temperatures, snow, January rains and maximum wind speeds.²



Pothole on boulevard Saint-Laurent, near rue Sherbrooke (February 25, 2013)
Credit: © Dario Ayala, *Montreal Gazette*



Tar spots on a maple leaf
Credit: © Équipe de lutte intégrée, Ville de Montréal

Pathogens (fungi, bacteria, viruses and nematodes) that can cause infections in plants also feel the impacts of higher temperatures. Higher winter temperatures could allow a larger number of pathogenic agents to survive and in so doing, expand their distribution area. Pathogen species that cannot survive in current climate conditions could begin to attack plants in our region.

Higher average temperatures in the summer mean a longer pollen production season. This is particularly worrisome in the case of allergenic plant species. For example, in Montréal, the emission period for ragweed pollen (*Ambrosia artemisiifolia* L.) expanded by three weeks between 1994 and 2002.^{4, 10}

The longer pollen season brought on by higher average temperatures is leading to growing health problems among people who are sensitive to these allergens.

We also expect an increased prevalence of vector-borne and zoonotic diseases caused, among other things, by the northward movement of animal populations that are pathogen vectors. Some vector-borne diseases, such as Lyme disease and West Nile fever caused by the West Nile Virus (WNV), have been on the rise in Québec in recent years.

Higher average temperature in winter and the increased frequency of freeze-thaw cycles have major impacts on city operations within the agglomeration. Generally speaking, this results in increased operating costs due to higher labour force needs and increased resource consumption (such as abrasives used during spreading operations).

The higher temperatures, which extend the summer season, also have some positive impacts, such as a higher number of days with weather conditions appropriate for construction work, and a longer season for using the bicycle path network.

NUMBER OF REPORTED CASES OF LYME DISEASE AND WEST NILE FEVER CAUSED BY THE WEST NILE VIRUS (WNV) IN QUÉBEC SINCE 2002

PERIOD	NUMBER OF CASES REPORTED	
	Lyme disease*	West Nile fever**
2002 – 2003	Info not available	Approx. twenty per year
2004 – 2010	< 15 per year	< 5 per year
2011	32	42
2012	43	132
2013	141	32

*Ministère de la Santé et des Services sociaux. *Maladie de Lyme - Évolution de la maladie au Québec*, [online]. [www.msss.gouv.qc.ca/professionnels/maladie-lyme.php#evolution-de-la-maladie-au-quebec] (Accessed May 25, 2015.)

**Ministère de la Santé et des Services sociaux. *Virus du Nil occidental (VNO) - Surveillance de cas humains de VNO au Québec*, [online]. [www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?virus_du_nil#quebec] (Accessed May 25, 2015.)

VULNERABILITY TO HIGHER AVERAGE TEMPERATURES

The Montréal agglomeration’s vulnerability to higher average temperatures is difficult to map. There are no specific zones that will be more heavily affected than others by this hazard. As such, we must consider that the entire territory is targeted and will be impacted by these changes.

Some elements are nevertheless identified as sensitive to the impacts of higher average temperatures. For instance, concrete infrastructures are sensitive to freeze-thaw cycles. The road network and its related structures, such as bridges and tunnels, are considered to be vulnerable.

Plants and insects have very complex interrelations. They will definitely be affected in a number of ways, but a deeper analysis of all the factors would require a very fine-tuned understanding of the environment. As such, for this first plan, we chose to provide a summary look at the issues without targeting any one area more than the others. It would be useful to deepen certain aspects as needed when putting local projects into place.

Lastly, we identified certain groups of people as being particularly sensitive to the extended pollen season (children, young adults, people with asthma, etc.), but we did not carry out an analysis of their distribution on the territory.

MAIN IMPACTS ON MUNICIPAL OPERATIONS IDENTIFIED FOR THE MONTRÉAL URBAN AGGLOMERATION DUE TO HIGHER AVERAGE SUMMER AND WINTER TEMPERATURES

WINTER ↑ average temperature ↑ frequency of freeze-thaw cycles	Road salt spreading operations aiming to make street surfaces and sidewalks safer will multiply because the temperature will hover around the freezing point more often. In freeze-thaw cycles, bridges, overpasses, tunnels, retaining walls and other related road structures located on the Montréal territory are inspected in order to prevent falling fragments. The probable increase in the number of freeze-thaw cycles could lead to a rise in the number of these verification and structural safety inspections. We are already seeing difficulties with maintaining outdoor skating rinks due to fluctuations around the freezing point. In the future, we will see a reduced number of outdoor skating days.
SUMMER Extended summer season ↑ average summer temperature	The demand for access to splash pads, pools and outdoor sports areas will increase. Citizens will expect an opening or access period starting earlier in the spring and finishing later in the fall. Maintenance and monitoring staff needs for these facilities must be adapted. The extended summer season will lead to increased demand for resources for park management, green space management and plant maintenance.



HEAVY RAINFALLS

Under the effect of climate change, the air trapped in the atmosphere warms up. Warmer air can hold more humidity. As a result, the air carries more water from the tropics toward boreal regions. Sub-polar regions like Québec become wetter. Another consequence is more frequent and more intense heavy rainfalls, which can cause floods, sewer backups and damages. This trend was observed for southern Québec between 1950 and 2010.

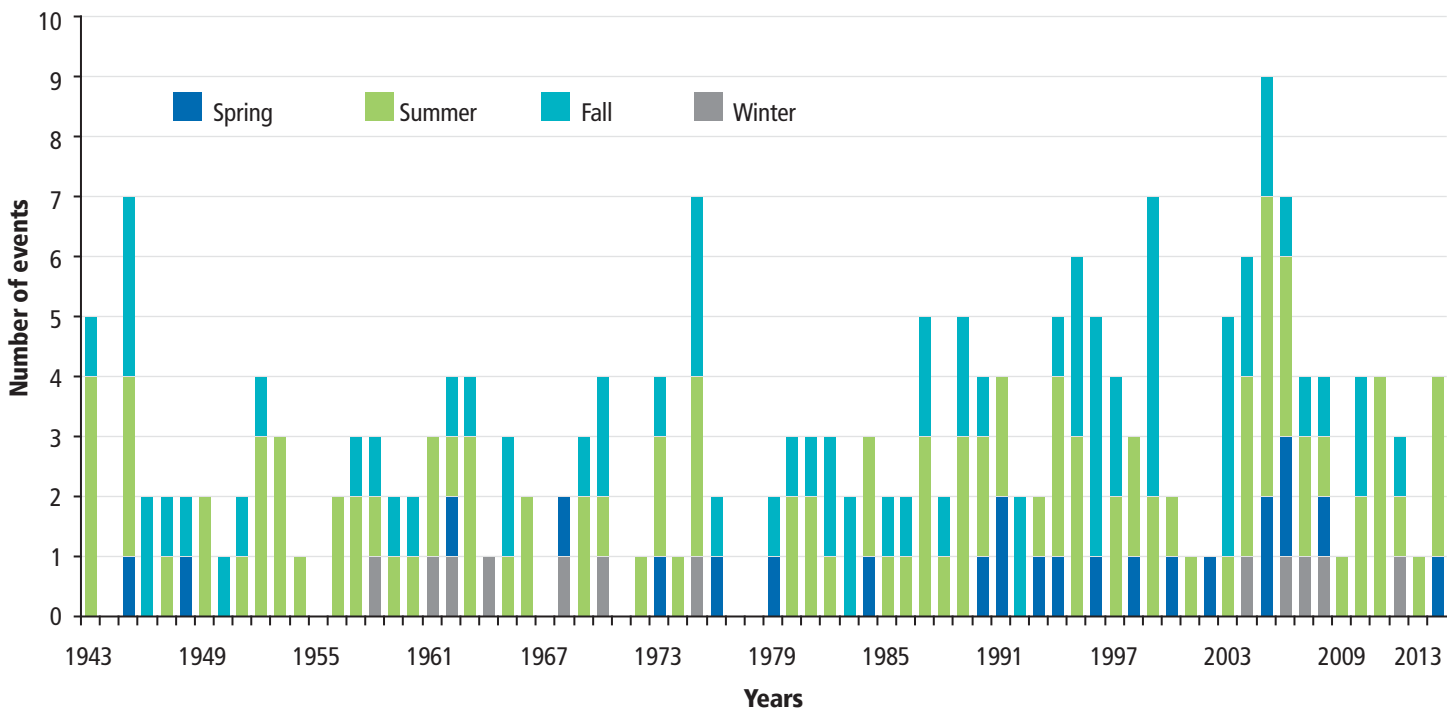
Heavy rainfalls, both short and long-lasting, are a real issue for the Montréal agglomeration. The figure below shows the increase in the number of heavy rainfalls over the years on the territory from 1943 to 2014.



Street flooded during the violent storm of May 29, 2012.
Credit: © Olivier Pontbriand, *La Presse*

NUMBER OF DAYS DURING WHICH RAINFALL EXCEEDED 30 MM

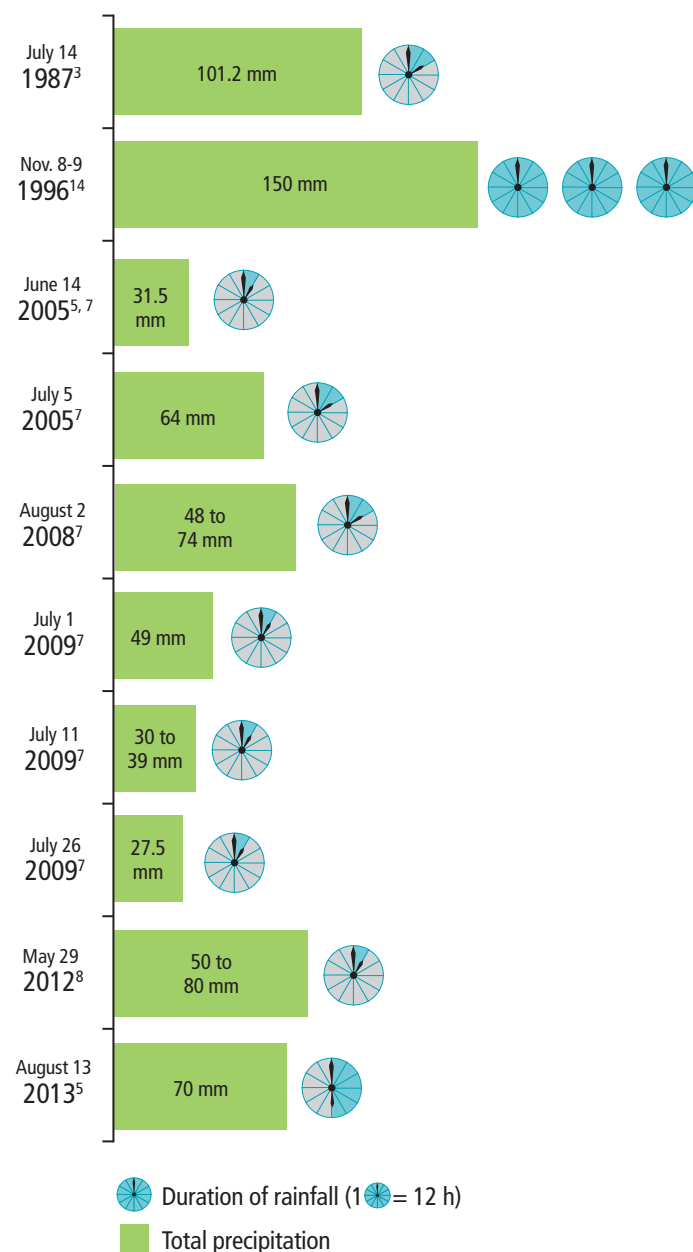
Data from the weather station at the Montréal-Trudeau international airport.



NOTABLE EVENTS

Over the last three decades, a number of heavy rainfalls have occurred on the island of Montréal, causing a wide range of inconveniences. For example, on May 29, 2012, downpours drenched Montréal. The rain that fell in less than an hour caused flooding in various areas of the city, which led to numerous road and tunnel closures. As well, a number of Montréal underground

SOME NOTABLE RAINFALL EVENTS IN THE MONTRÉAL AGGLOMERATION (1983-2013)



shopping centres had to be quickly evacuated and closed, along with metro stations on the orange line between Berri-UQAM and Lionel-Groulx stations. Nearly 15,300 homes lost power.¹²

IMPACTS

At times of intense rain, often localized and brief, the wastewater flow in sewers can rise drastically and cause overflows. Once the network is saturated, runoff water can no longer get in, so it accumulates at low points, which can cause flooding.

Basements are especially at risk of flooding, whether due to water infiltration, runoff water, or sewer backflow. Factors such as poor ground levelling and the presence of a downward slope leading to the garage entrance, without a saddle, put homes at risk of flooding. Water can also back up into buildings that are not protected by a well-maintained backwater valve or whose plumbing systems are in poor repair.²²



Floods may lead to health problems and economic losses.
Credit: © Olivier Pontbriand, *La Presse*

Building floods generate major economic losses. First, they occasion costs related to destroyed and damaged goods. Second, they are a source of concern for insurance companies, which may reduce flood risk coverage.

Major material losses may cause psychological distress among disaster victims. As well, if no adequate protection and cleaning measures are taken, flooded buildings are at higher risk of developing mould problems. When these develop to a significant degree, it can lead to serious health problems such as asthma and allergic reactions.

The heavy flow of stormwater runoff and floods in urban settings also cause damage to the road network, sewer systems made of brick, and underground utilities, which can in turn lead to outages depending on the service that is affected (for instance, electricity or telephone). For example, during the heavy rainfalls of July 14, 1987, many homes lost power, and the authorities had to evacuate people who were trapped in their vehicles

on boulevard Décarie.¹⁵ The high volume of precipitation led municipal authorities to create the Bureau des mesures d'urgence (emergency measures bureau) in 1988, which later became the Centre de sécurité civile (civil safety centre).⁶

Overall, heavy rainfalls have relatively few impacts on the environment. Vegetation and ecosystems in temperate zones are fairly resilient to intense precipitation in summertime. However, wastewater overflows into watercourses raise the quantity of pathogenic and pollutant organisms.

The operational impacts identified in Montréal due to the increased frequency and intensity of heavy rainfalls affect public works, drinking water production activities and wastewater treatment. For example, heavy rains may delay works on some construction sites, which may cause delays for each successive step of the project.



Boulevard Décarie on July 14, 1987, after 101.2 mm of rain fell in two hours.
Credit: © La Presse

VULNERABILITY TO HEAVY RAINFALLS

The Montréal agglomeration's vulnerability to heavy rainfalls was obtained through a geographic analysis of areas with the potential for water accumulation, as well as of the infrastructures and groups of people who are sensitive to this hazard's impacts.

Topography is the factor with the greatest influence on the potential for water accumulation. The other parameter with a heavy influence is urbanization. Older neighbourhoods, located in the centre of the island and home to a high density of inhabitants, buildings and streets (Ahuntsic-Cartierville, Côte-des-Neiges–Notre-Dame-de-Grâce, Côte-Saint-Luc, Hampstead, Plateau-Mont-Royal, Rosemont–La Petite-Patrie, Saint-Laurent, Sud-Ouest, Verdun, and Villeray–Saint-Michel–Parc-Extension) feature areas with water accumulation potential on a large portion of their territory. The island's west end and part of its east end are less mineralized areas with more vegetation, which helps the soil absorb some of the rainwater, reducing the accumulation of water in basins.

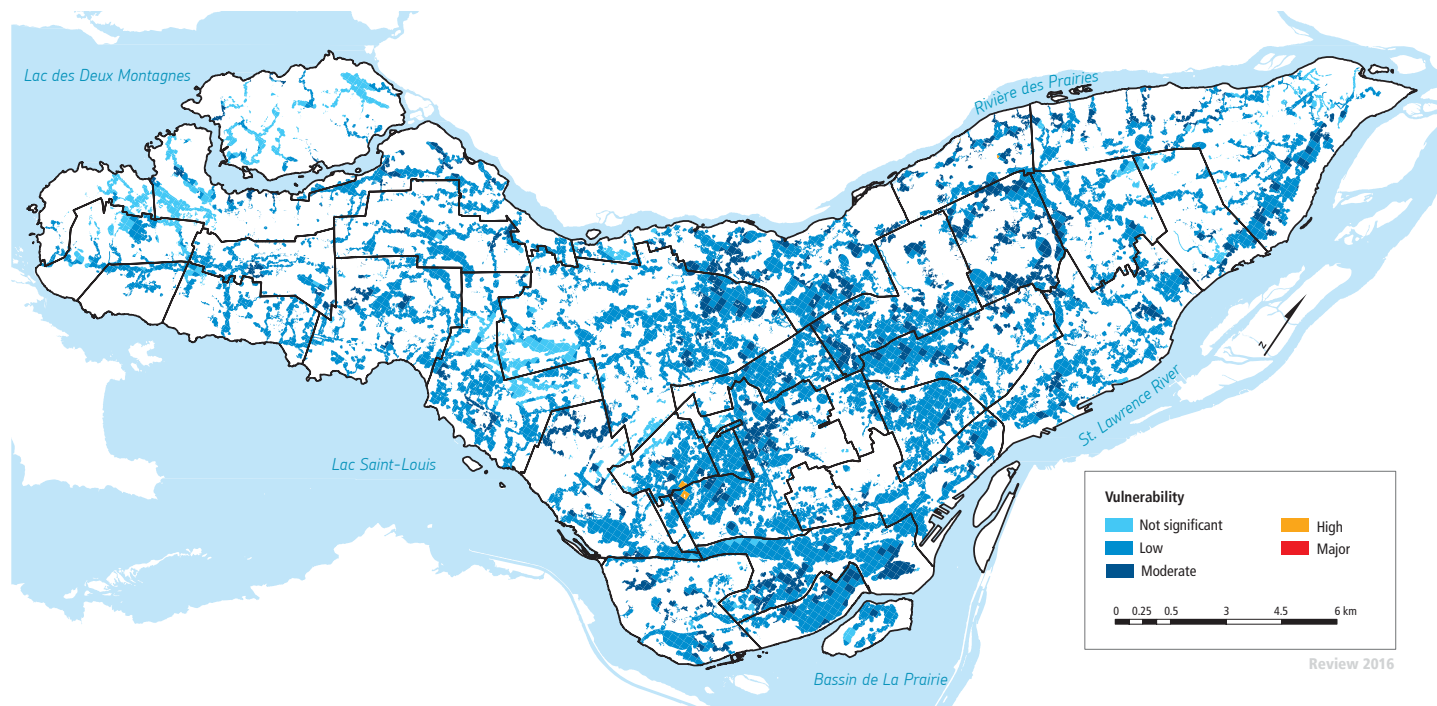
Lastly, other factors, such as vegetation, soil type and soil usage influence rainwater runoff speed, absorption and accumulation.

Many infrastructures are sensitive to heavy rainfalls, including sewer systems, underground utilities, the road network and buildings—especially critical sites, such as hospitals, police stations, drinking water plants and so on, and places of interest such as schools, metro stations, bridge entrances and exits, and so forth.

Many groups of people are sensitive to the impacts of heavy rainfalls, particularly children, people aged 65 and up, and underprivileged people.

The map below shows that a good part of the agglomeration presents low or moderate vulnerability to heavy rainfalls, and that the most vulnerable areas are in the central and eastern parts of the island. Only a few zones are highly vulnerable, because they are located in areas that risk accumulating runoff water and due to the presence of vulnerable infrastructures and populations.

VULNERABILITY TO HEAVY RAINFALLS IN THE MONTRÉAL AGGLOMERATION





HEAT WAVES

Heat waves, extreme heat, oppressive heat... there are many ways to talk about a weather phenomenon that translates into abnormally high air temperatures both day and night. Heat that accumulates faster than it moves along can last over several days and come with high humidity, which can cause serious discomfort.

We need to consider a number of aspects when studying heat waves: their duration, the humidity level, and the day/night contrast. A heat wave that lasts for a long time or has a high humidity level (high humidex) will be especially uncomfortable for the population. The same is true when nights don't cool down enough (night temperature that stays above 20 °C).

In Montréal, we have seen an upward trend in heat waves, in particular with a 58% increase in high-humidex nights, for the period of 1953-2012.



High traffic in the Parc Laurier pool, Plateau-Mont-Royal
Credit: © Marco Campanozzi, La Presse

NOTABLE EVENTS

The Montréal agglomeration has experienced many heat waves in the last 70 years, some of which have been particularly notable, even causing deaths.

SOME NOTABLE HEAT WAVE EVENTS FOR THE MONTRÉAL AGGLOMERATION

DATE	AVERAGE TEMPERATURE	NUMBER OF DEATHS ^{1, 5}
July 9-13, 1987	32.6 °C	169
June 16-18, 1994	33.1 °C	103
July 1-3, 2002	33.2 °C	30
August 14-18, 2009	30.7 °C	Not available
July 5-10, 2010	33 °C	106
July 20-23, 2011	32.9 °C	13
July 14-19, 2013	32 °C	6

IMPACTS

In a densely populated urban area like the agglomeration's, heat waves are a serious issue for public health. Oppressive heat provokes heat stress in people, causing cramps, fainting, heat stroke and more. Extreme heat causes a range of discomforts, leading to many hospitalizations, and can also aggravate the fragile health of people suffering from various diseases and cause premature deaths. On the territory of the Montréal agglomeration, more than 400 deaths have been attributed to heat waves over the last 30 years.¹

Heat waves can also lead to and accentuate the effects of air pollution. Reduced air quality aggravates the symptoms of many health problems and can limit people's ability to practice outdoor activities and sports.

Vegetation, so important in urban settings, is also vulnerable to heat waves. While trees and other plants are equipped with defense mechanisms, heat waves can shock them, causing water stress that can render them quite fragile. We then observe an increase in plant sickness. Plants affected this way require more care or may need to be completely replaced. These elements have impacts on the resources required and on maintenance costs.

Extreme heat episodes, even short ones, can reduce the populations of a number of insects. The impact can of course be positive when we're dealing with harmful species, but not when species such as pollinators are affected.

Aquatic environments can also be affected by heat waves, since heat waves cause a fast and massive increase in cyanobacteria blooms. The proliferation of blue algae can have a number of repercussions, including the eutrophication of water bodies, which disrupts their balance by reducing biodiversity as well as reducing access to the water for swimming.

High temperatures can affect or weaken the agglomeration's infrastructures, particularly roads and arteries. Road surfaces with high traffic and many heavy vehicles may soften and deform under their weight, forming ruts. High heat can also cause premature damage to the expansion joints of civil engineering works.

Lastly, heat waves affect municipal operations and services. They often lead to an increased demand for services, such as pools, wading pools and splash pads, and for extended opening hours at air-conditioned public spaces such as libraries and community centres. Because of this, we are seeing an increased number of interventions and a higher need for staff to provide services, maintain infrastructure and, as needed, enact emergency measures.

VULNERABILITY TO HEAT WAVES

Heat islands cover about 28% of the island of Montréal's surface. They are mainly found in the northern and eastern parts of the agglomeration. The boroughs of Ville-Marie, Plateau-Mont-Royal, Sud-Ouest, Mercier-Hochelaga-Maisonneuve, Villeray-Saint-Michel-Parc-Extension, Montréal-Nord and Saint-Léonard are home to the largest heat island areas.

Of all the factors that contribute to the vulnerability of certain areas of the territory (see the table below), we must above all consider the presence of populations that are particularly sensitive to this hazard, meaning young children and seniors, especially those who live alone or suffer from chronic illnesses. As well, some immigrants may be more vulnerable to heat waves if they are unable to speak or understand French and English; it is not possible to reach them with awareness-raising messages, warnings and emergency measures directives, and, as is true of all people living in social isolation, they may also be less inclined to ask for help. As well, income levels influence the vulnerability of citizens in the agglomeration because lower-income people generally have less access to air conditioning.

FACTORS CONTRIBUTING TO THE FORMATION OF INTRA-URBAN HEAT ISLANDS

Type of materials: Some materials absorb a lot of heat during the day (such as bricks, stone, asphalt, tar, etc.) and emit it when night falls. This is why the temperature stays high at night in intra-urban heat islands during heat waves.

Lack of vegetation: In addition to absorbing some of the heat that would otherwise be stored by buildings and objects, plants cool down the surrounding air thanks to their sweating process.

Soil sealing: Permeable soils let some of the water they contain evaporate during high heat. This evaporation works by absorbing the energy from the surrounding air, which cools it down.

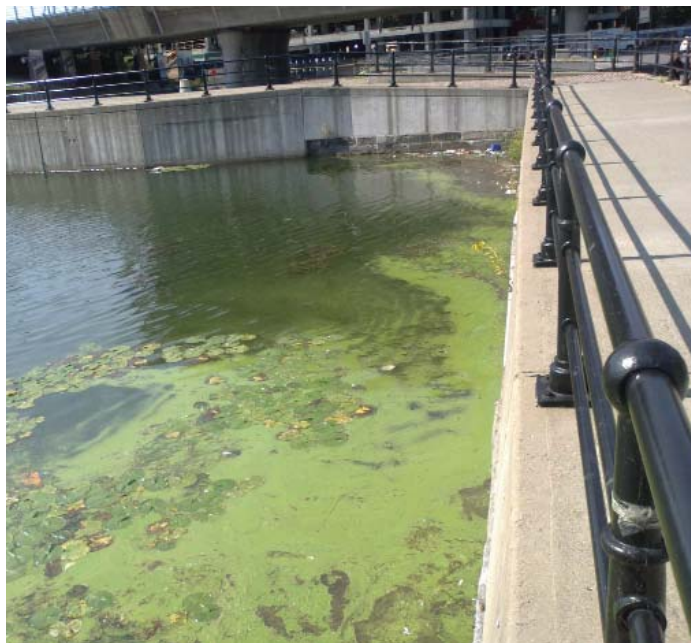
Human activities: Many human activities give off heat, including air conditioning, vehicle engines and some industrial activities.

Urban morphology: An urban geometry that combines narrow streets and tall buildings contributes to forming intra-urban heat islands.

Plants are also sensitive to heat waves, particularly when they are located in heat islands. While intra-urban heat islands generally have little vegetation, any vegetation present in an intra-urban heat island (IUHI) is much more vulnerable during a heat wave, because the temperature there is even higher than elsewhere on the territory.

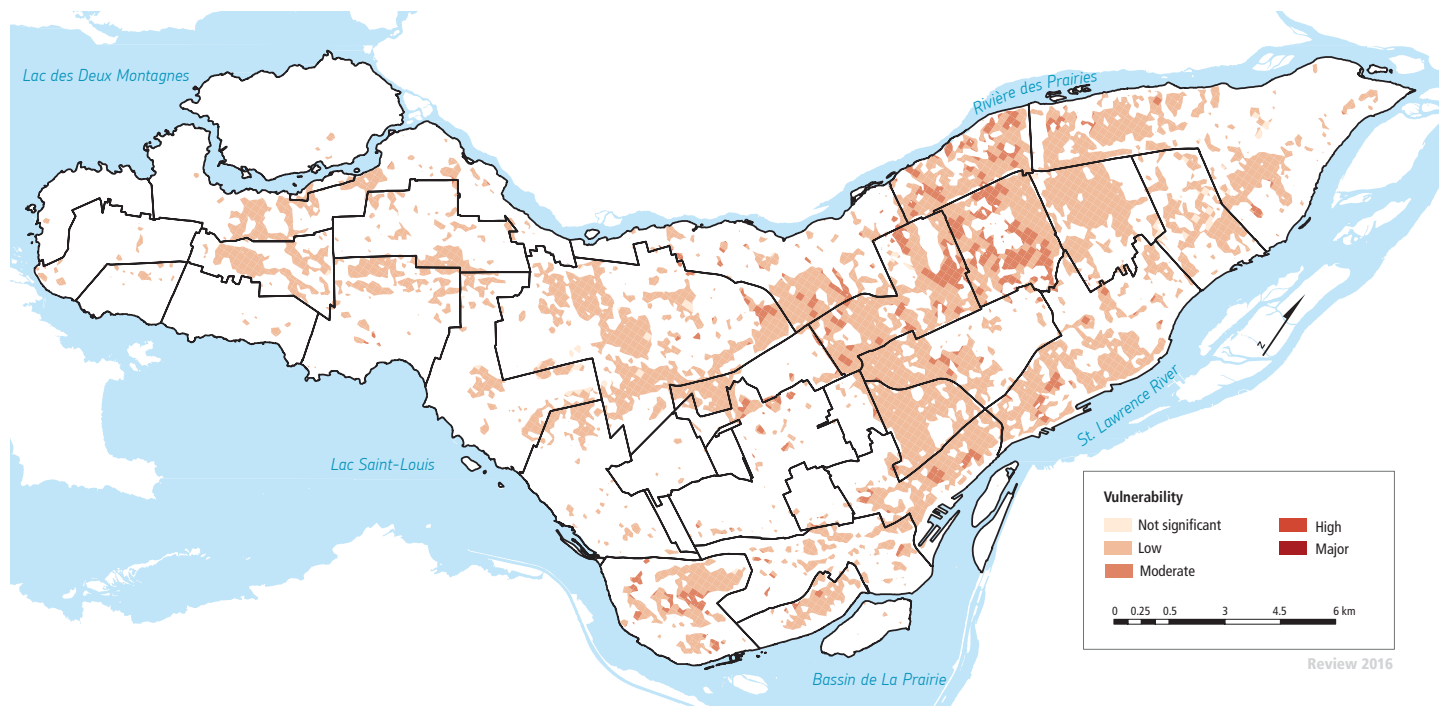
Lastly, since roads and arteries are likely to be affected by oppressive heat, they are identified as infrastructures that are sensitive to this hazard.

We produced a heat wave vulnerability map using all these factors in order to illustrate the areas most sensitive to heat waves. The map is a very useful way to target vulnerable areas and choose the most appropriate adaptations strategies for them.



Cyanobacteria bloom in summer 2012 at the last lock of the Lachine canal, with its mouth in the Vieux-Port de Montréal
Credit: © Réseau de suivi du milieu aquatique, Ville de Montréal

VULNERABILITY TO HEAT WAVES IN THE MONTRÉAL AGGLOMERATION





DESTRUCTIVE STORMS

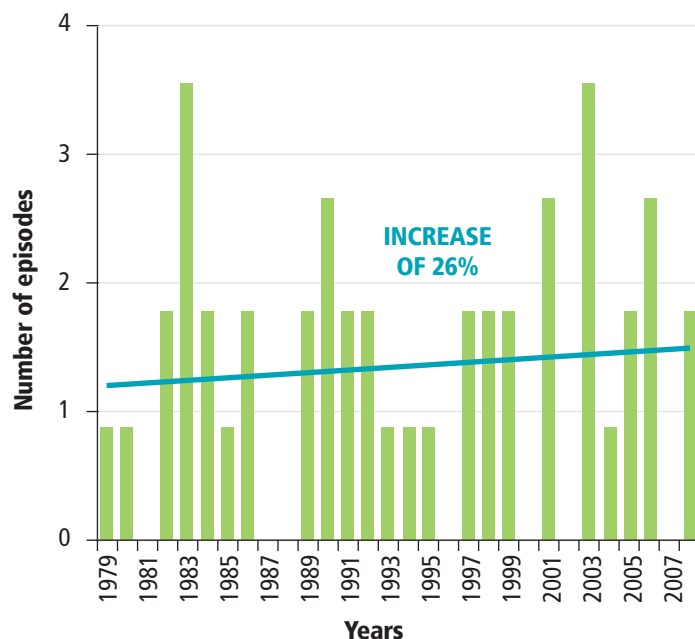
The destructive storms hazard includes several types of storms: windstorms, hailstorms, heavy snowfalls and freezing rain. We grouped these together by taking into account, above all, the devastating impacts that such events can bring about.

The meteorological data currently available for Montréal do not allow us to evaluate the evolution of wind speeds or hail episodes over the last few decades.

As for freezing rain, a team of researchers from McGill University recently gathered data from 1979 to 2008¹⁶ showing an increase of about 26% in the number of events across the Montréal agglomeration. As well, the number of heavy snowfalls has increased over the last 70 years. In fact, between 1994 and 2014, the island of Montréal experienced 13 days during which more than 30 centimetres of snow fell, whereas this phenomenon only occurred nine times between 1942 and 1993.

EVOLUTION OF FREEZING RAIN EPISODES IN THE MONTRÉAL AGGLOMERATION

Data from Ressler *et al.* (2012)¹⁶



Violent winds made a huge tree branch fall onto a vehicle in the Hochelaga-Maisonneuve neighbourhood. (01/11/2013)
Credit: © Patrick Sansfaçon, *La Presse*

NOTABLE EVENTS

In the last 30 years, a number of destructive storm events have occurred on the island of Montréal, causing many inconveniences and accidents. For example, on January 5, 1998, we saw 5 to 80 mm of freezing rain, extending from the Maritimes to the Outaouais and Saint-Laurent valleys. It was the second most expensive disaster in the entire history of Canada, with 28 deaths, 945 injuries and 600,000 people evacuated.^{9, 11}

SOME NOTABLE DESTRUCTIVE STORM EVENTS IN THE MONTRÉAL AGGLOMERATION

DATE	TYPE OF STORM	DETAILS
November 16, 1983	Snow and freezing rain	20 cm of snow
December 13, 1983	Freezing rain	Not available
December 3, 1984	Snow	21 cm of snow
May 29, 1986	Hail	Hailstones up to 8 cm in diameter
June 29, 1986	Hail	Hailstones from 0.5 to 1.5 cm in diameter
November 20-22, 1986	Snow	30 cm of snow
January 22-23, 1987	Snow	30 cm of snow
May 29, 1987	Hail	Hailstones from 1 to 1.2 cm in diameter
July 18, 1987	Hail	Not available
February 12-13, 1988	Snow	20 cm of snow
January 5, 1994	Snow	25 cm of snow
January 5, 1998	Freezing rain	Depending on the source, 5 to 80 mm of freezing rain
January 18, 2012	Wind	Not available
December 27, 2012	Snow	45 cm of snow in less than 24 hours
July 19, 2013	Wind	Winds above 100 km/h



Ice storm crisis of 1998
Credit: © Denis Labine, Ville de Montréal



Snowstorm of December 27, 2012
Credit: © Matias Garabedian, Flickr (CC BY-SA 2.0)

IMPACTS

High winds, freezing rain accumulations, hail and heavy snowfalls all cause deformation, accelerated wear and breakage to infrastructures and vegetation. The scope of damages depends on how powerful the storm is (wind speeds, ice or snow accumulation thickness, size of hailstones). The impacts of destructive storms directly affect the population because of the consequences they have on people's lives and health and on the smooth operation of various activities that take place in the city.

In the Montréal agglomeration, destructive storm damages mainly include fallen trees or tree branches, broken roofs and other broken building envelope components. Major gusts can tear off or lift pieces of a home, such as the roof. They can not only compromise a building's integrity, but can also cause serious damages around the building, because debris can fly around and pierce windows, glass storefronts and façades as well as being a danger to pedestrians. Also, heavy snowfalls and freezing rains can load down a roof structure and cause breakage.

The damages caused to residences may lead to costs related to destroyed and damaged goods. This may be a source of concern for insurance companies, which may reduce risk coverage for individuals. Damages may also cause psychological distress for disaster victims.

Destructive storms often lead to electricity outages. Electrical cables may be broken by high winds and ice accumulations, among other things. When power outages happen in winter, they may force people to leave their homes in search of warmth. They can also lead to carbon monoxide poisoning if people make indoor use of heating or cooking equipment that's designed for outdoor use. The shutdown of in-home medical equipment and an increase in food poisoning due to fridge and freezer shutdowns are also direct consequences of power outages in all seasons.

Above-ground utilities other than electricity can also be damaged. Damages caused to traffic lights and traffic signs and the presence of snow, ice and debris on the ground may seriously impede road traffic. Health problems may be aggravated when people's mobility is limited.

The environmental impacts of destructive storms in urban settings mostly affect plants, and trees in particular. When snow or ice accumulates and is accompanied by violent winds, trees may be uprooted or their trunks may be split. In addition to affecting trees' normal growth and shape, the injuries that freezing rain inflicts on trees may make them more vulnerable to insect-related damages and illnesses.

The operational impacts of destructive storms in Montréal are related to increased operating costs, particularly for snow removal, pruning, and the increased deployment of first responders and staff to handle snow removal and spread salt and abrasives to make roads and sidewalks safer.



Snow removal in Montréal
Credit: © Martin Chamberland, *La Presse*

VULNERABILITY TO DESTRUCTIVE STORMS

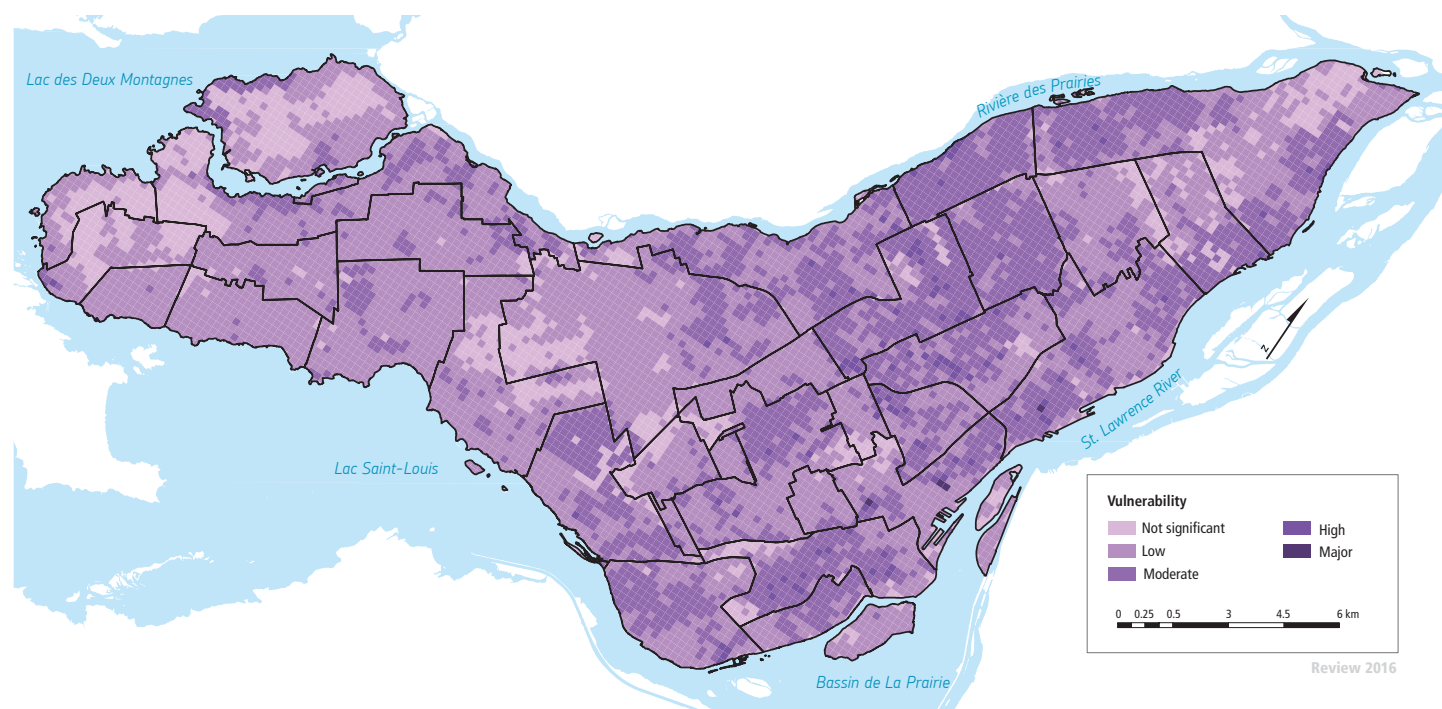
The Montréal agglomeration's vulnerability to destructive storms was obtained by geographically identifying the infrastructures and groups of people who are sensitive to the impacts of this hazard, starting from the hypothesis that all sectors of the Montréal agglomeration are equally likely to be hit by a storm.

Buildings, critical sites and places of interest (such as hospitals, police stations and metro stations) are considered to be vulnerability factors when they are located in a place affected by a destructive storm. Whether because of direct damages caused to buildings or due to the impacts resulting from restricted access to places of interest, considerable impacts are associated with these elements' presence on the territory.

As for social susceptibility factors, the three groups of people identified as being the most vulnerable to storms are underprivileged people, people living alone and seniors. As a result, the areas that are home to people who fall into several of these categories present especially high vulnerability.

The map shows that more vulnerable areas are scattered throughout the island of Montréal, with a light concentration in more densely populated neighbourhoods, because sensitive people and infrastructures are focused in these areas.

VULNERABILITY TO DESTRUCTIVE STORMS IN THE MONTRÉAL AGGLOMERATION





DROUGHTS

The literature contains various definitions of drought. Each definition describes a distinct reality, and their usage depends on the set of issues being considered. If we look at the number of consecutive days without rain, we're talking about meteorological drought. If we focus on a water deficit in the soil, then we're talking about soil moisture drought (also called agricultural drought). Hydrological drought concerns an especially low watercourse and water table level. Lastly, socioeconomic drought includes humankind's pumping of water resources. All these types of drought are of course interrelated. For the most part, in this adaptation plan, we discuss soil moisture drought, because of the more marked impacts it can have on the agglomeration's territory.

NOTABLE EVENTS

Over the last 30 years, no major droughts have been noted in the Montréal agglomeration. The last major drought dates back to 1957, when, in the month of August, only 2.1 millimetres of rain were recorded for Dorval and 0.6 millimetres at the McGill

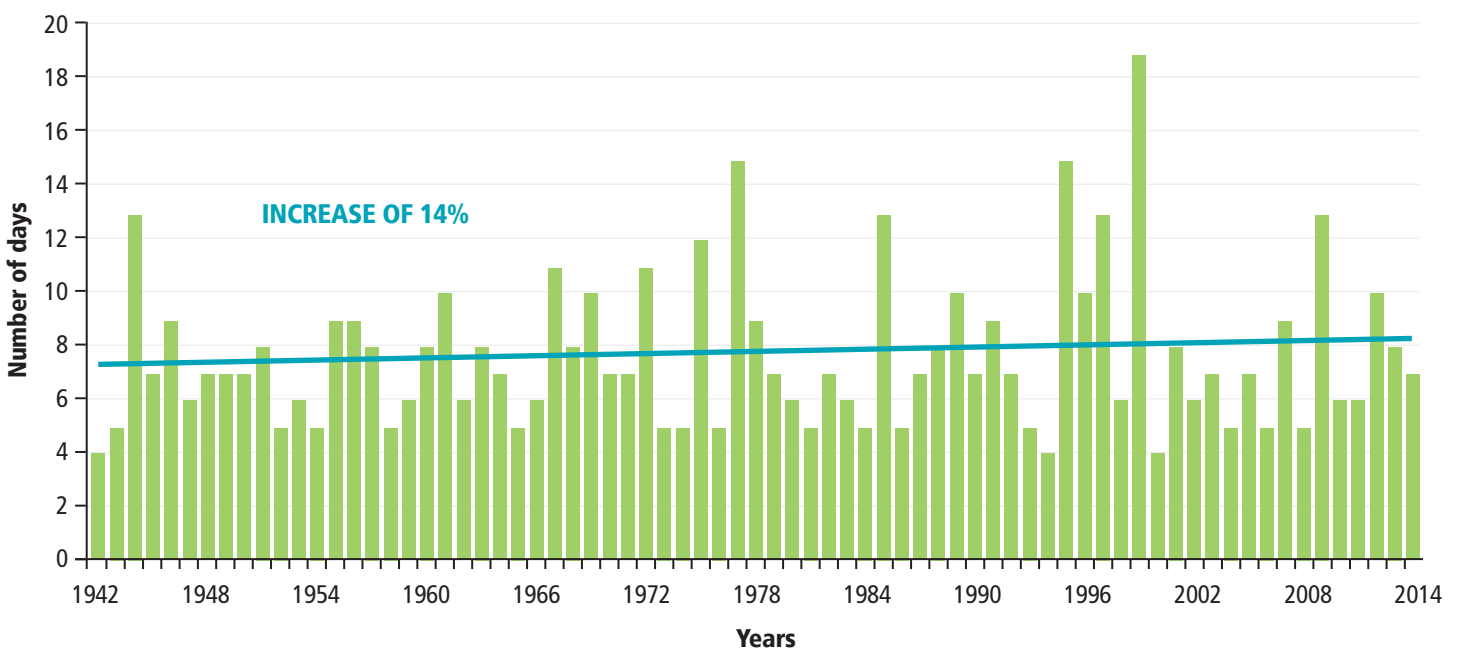
University station. August 1957 is considered to have been the driest month in the history of the greater Montréal area.¹⁷

Nonetheless, we can evaluate whether meteorological droughts have increased in Montréal by calculating the number of consecutive days without rain over time, as illustrated in the figure below. We can observe a very minor trend toward more drought episodes during the summer months. This trend is not significant, though, and it is still too early to attribute it to climate change. As well, on average for southern Québec overall, observations show a slight downward trend when it comes to meteorological drought indicators.

As for soil moisture, hydrological and socioeconomic drought, current historical observations do not permit us to conclude that there is any significant drought increase in Montréal in response to climate change. Despite these uncertainties, the prognosis for change in the long term seems a bit clearer; projections of increased drought are only really reliable starting in 2081-2100. However, there should not be any alarming situations between now and 2020.

EVOLUTION OF THE MAXIMUM NUMBER OF CONSECUTIVE DAYS WITHOUT PRECIPITATION FROM MAY TO SEPTEMBER BETWEEN 1942 AND 2014

Data obtained from the weather station at the Montréal-Trudeau international airport.



IMPACTS

The impacts of drought on the Montréal agglomeration's territory are mostly related to soil moisture drought, which causes damage to buildings and infrastructures built on clay soils when the necessary remedial measures are not applied to constructions. Foundations can collapse when clay soils dry out and shrink. Cracks appear in the foundations and can progress toward the walls (these are known as meandering cracks). From an economic standpoint, these damages can have serious consequences. Since home insurance generally does not cover damage caused to houses by the collapse of clay soil, owners must handle the entire expense of foundation work—often very costly. In the same vein, soil moisture drought can also damage sidewalks, pavement and sewer pipes that are built on clay soil.

The environmental impacts of drought in urban settings particularly affect plants and water bodies. Generally speaking, water quality tends to go down during a drought. This decline can be attributed to various factors: warmer water temperature, reduced concentration of dissolved oxygen, conditions that favour the development of cyanobacteria blooms, eutrophication, and a higher concentration of some pollutants.

Drought is a source of water stress for plants, which can lead to death if the drought is prolonged. This stress can reduce tree vigour and increase their vulnerability to pest insects and pathogens. By affecting plants, drought may reduce the ecological services they provide.

Drought periods are often combined with high heat, which affects the levels of air pollutants. In dry weather, dust and particles, such as pollen, are more easily carried and contribute to poor air quality. The presence of pollutants and pollen in the surrounding air exacerbates the symptoms of respiratory and cardiovascular illnesses, and contributes to degrading health in people who are already weakened.



Fissures in a foundation (meandering cracks)
Credit: © Ville de Montréal

For the Montréal agglomeration, the impacts on municipal operations as related to drought particularly affect drinking water production activities and the maintenance of green spaces and roads.

The increased demand for water that results from drought places pressure on treatment and purification equipment. This increase could lead to shorter reserve time in the network, which would weaken the system in case of problems. This same increase would also lead to additional production costs. Drought could also limit the system's water carriage capacity when water levels are very low, because low water limits the plants' capacity.

As well, we need stronger coordination and more resources to ensure the longevity of landscaping, green spaces and street trees.

Lastly, when it doesn't rain for a long period, street cleanliness tends to degrade, which requires an increase in road cleaning operations.

VULNERABILITY TO DROUGHT

The Montréal agglomeration's vulnerability to drought was obtained by taking into account buildings constructed in areas where the soil contracts when it dries and groups of people that are sensitive to the impacts of drought, particularly degraded air quality.

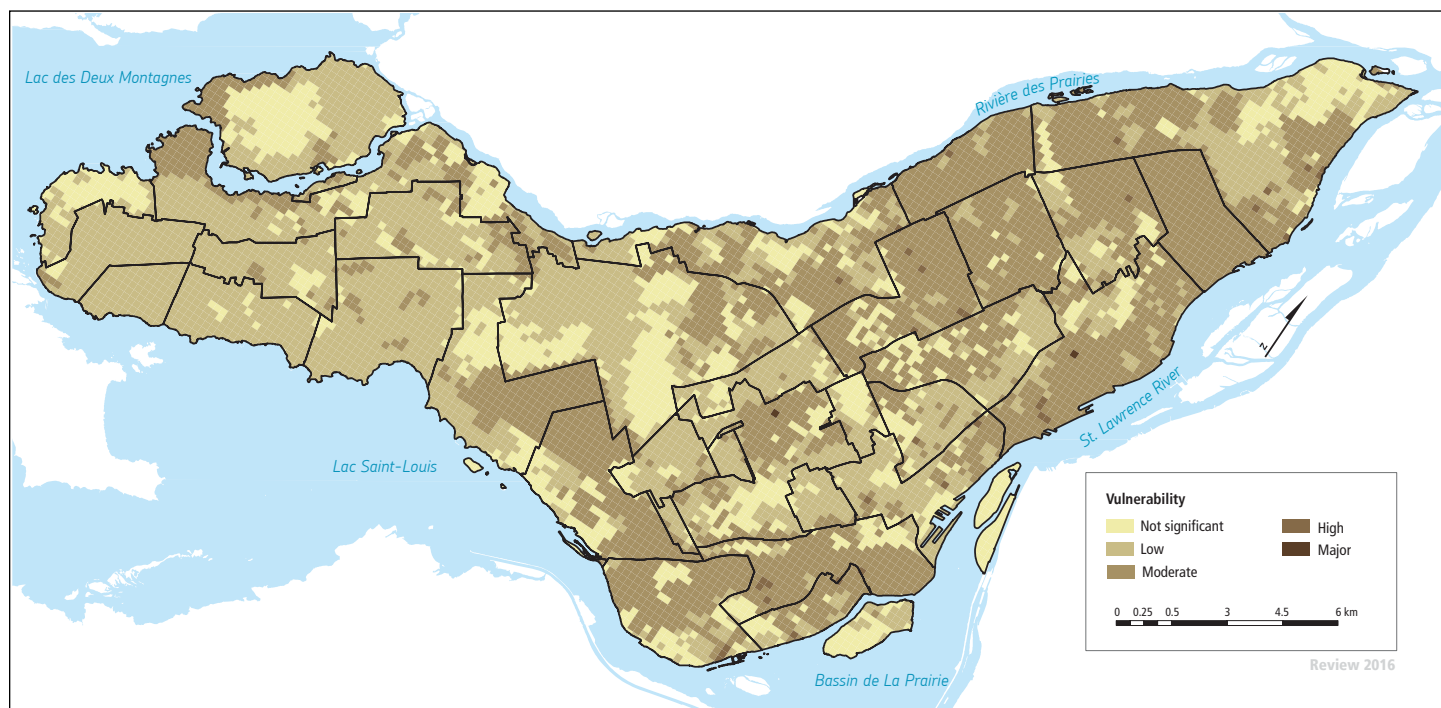
We used only soil type as a factor in determining the areas susceptible to soil contraction in the Montréal agglomeration. Clay soils shrink when they dry out. However, factors such as the soil's water retention potential and soil occupation also influence soil moisture drought. For example, roads, parking lots and buildings are sealed infrastructures that prevent the soil from absorbing rainwater.

As described previously, buildings and sidewalks are vulnerable to soil contraction when the soil dries out. The Montréal agglomeration is particularly vulnerable to this phenomenon because a good part of our soils are made of clay. As such, building density is a determining factor in the vulnerability analysis.

As for the social aspect, the groups of people most sensitive to the impacts of drought are underprivileged people and people living alone.

In sum, drought vulnerability varies greatly from one place to another within the agglomeration, mainly based on building density and the concentration of people who are sensitive to the impacts of poor air quality.

VULNERABILITY TO DROUGHT IN THE MONTRÉAL AGGLOMERATION





RIVER FLOODS

Climate change modifies the water cycle, creating more episodes of heavy rain and meteorological drought. This change to the water cycle also has an impact on river floods. We call it a river flood when the flow or level of a river rises above a critical threshold.

The risk of river floods in the Montréal agglomeration mainly concerns the boroughs and municipalities that border Rivière des Prairies. Those whose territory touches the edges of the St. Lawrence River are less likely to be affected by this hazard.

NOTABLE EVENTS

The last notable river floods for the island of Montréal took place in April 2004 and April 2008, and both occurred in Rivière des Prairies.

KEY FACTS ABOUT THE NOTABLE RIVER FLOODS OF 2004 AND 2008

DATE	DETAILS
April 2004	A frazil ice accumulation in Rivière des Prairies in the Pierrefonds area led to rising water levels. An ice jam* downstream also worsened the river flood. A few homes were flooded.
April 2008	Heavy snowfalls in the winter of 2007-2008 and the regular melting of the snow cover in the entire Outaouais drainage basin led to a major flow of water into Rivière des Prairies in spring 2008. Many areas were affected, including Ahuntsic-Cartierville, Pierrefonds, Île-Bizard, Sainte-Anne-de-Bellevue and Senneville.

*According to the Environment Canada definition, an ice jam is "an accumulation of broken river ice or sea ice which is not moving, due to a physical restriction and its resistance to pressure."



Ice from Rivière des Prairies broke down the rear fence of Résidence Berthiaume-du-Tremblay in the Ahuntsic-Cartierville borough. (18/04/2014)
Credit: © Philippe Rachiele – journaldesvoisins.com

When we consider the data since 1942, we see that spring river flooding episodes are happening earlier in the year. Not only do they seem to be happening earlier, but the maximum flows for 1972-2000 reached levels that were never reached before that. Flows of over over 3,550 m³/s were reported, far above the alert threshold of 2,550 m³/s set by the Centre de sécurité civile.

The shortened winter season leads to an earlier spring thaw, which explains the earlier timing of spring river floods. The higher number of freeze-thaw cycles in winter indicates milder periods in winter that encourage ice jams to form, which create an obstacle to drainage and can cause flooding. The Montréal agglomeration was accustomed to having ice jams from early April to late May, but for a number of years now, ice jams have been observed in January and February.

IMPACTS

When a river's flow or water level rises above a critical threshold, its water overflows the riverbed and causes flooding. In an urban setting, flooding causes damage to the built environment, particularly to buildings located in flood-prone areas. They also affect sewer systems and underground utility networks.

During a river flood, the sewer system may saturate very quickly, causing sewer backups in some buildings. Heavy river floods may weaken infrastructures by placing too-heavy demands on them, which can lead to more breakages (such as components of the sewer system). Flooding due to river floods can also damage the underground utility network (ex.: electricity, telephone), which can cause outages.

River floods also cause premature bank erosion and destabilization. Bank erosion draws sediment into the water, which can negatively affect water quality.

Flooding caused by river floods also has a number of incidences on population health. In addition to increasing the risk of gastrointestinal diseases linked to people's direct contact with the water in the flooded area, flooding can cause psychological distress for people who experience major material losses. As well, mould proliferates in flooded basements, which can lead to serious health problems including asthma and allergic reactions.

Urban floods hamper transportation, leading to the closure of some road sections and to traffic slow-downs. Submerged tunnels and overpasses, in addition to causing traffic problems, can endanger the lives of people caught in their vehicles.

Lastly, river floods require the heavy mobilization of the people responsible for implementing emergency measures.



The Amphibex machine works in Rivière des Prairies. (27/01/2009)
Credit: © Ivanoh Demers, *La Presse*

VULNERABILITY TO RIVER FLOODS

The areas vulnerable to river floods are identified on the map below. They are located on the territory of the following cities and boroughs: Pierrefonds-Roxboro, Ahuntsic-Cartierville, Montréal-Nord, Rivière-des-Prairies–Pointe-aux-Trembles and Senneville.

Any infrastructure or population located within a flood-prone area is considered vulnerable. The breadth of this vulnerability depends on a number of factors: building density; the presence of critical sites such as hospitals, police stations and drinking water plants; and the presence of places of interest such as schools and bridge exits.

The presence of roads is also a factor that can make an area more vulnerable to flooding. When water accumulates under road foundations, it contributes to their premature wear and breakage.

Lastly, areas with a high population density are evidently more vulnerable to the impacts of river floods.

VULNERABILITY TO RIVER FLOODS IN THE MONTRÉAL AGGLOMERATION



ADAPTATION MEASURES

The adaptation measures constitute the heart of this first plan for the Montréal agglomeration. They aim to reduce vulnerabilities on the territory and they express how all the municipal players are adjusting, or will be adjusting, in order to deal with an evolving climate.

The measures set out in this first plan aim to consolidate the experiences we have acquired and to strengthen our ability to include climate issues in every sphere of activity within the municipal administration.

For each hazard, three to six key measures were chosen by means of a collaboration between Central Services, the cities and boroughs, and specialists in the fields of land use, green spaces, buildings, water management, sports and more. These key measures in turn translate into a range of actions that will be put into effect by Central Services, the cities and the boroughs (see the table on the next page).

The actions for this first climate change adaptation plan were chosen according to the following criteria:

- **Implementation already begun or planned**
Some plans, strategies and by-laws already include measures that contribute to climate change adaptation. The adaptation plan represents an opportunity to consolidate these actions.
- **Short-term feasibility, between now and 2020**
Implementing these measures requires relatively little time, so it can be done by the end of the period covered by this plan.
- **Potential for adaptation to more than one climate hazard**
Some actions have co-benefits that allow them to boost resilience to more than one hazard.

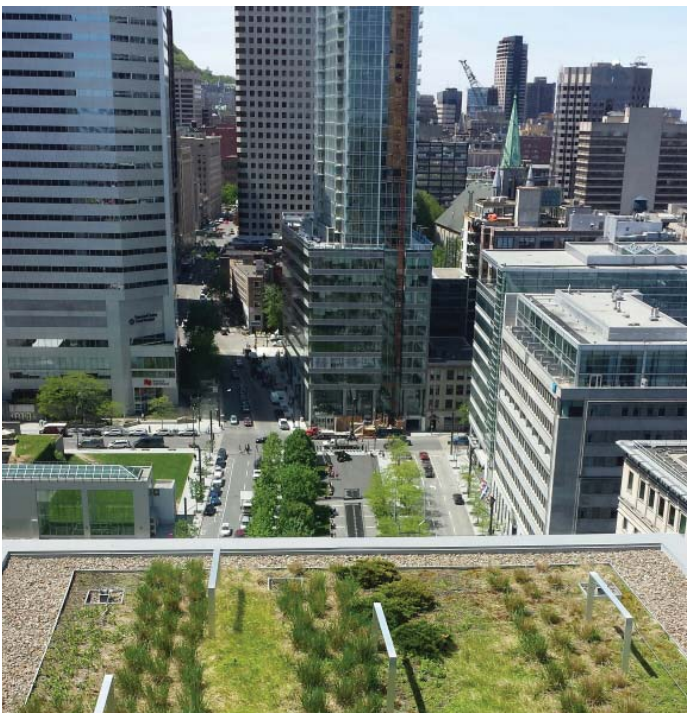
Lastly, another criterion was added for adaptation measures that will be implemented locally by the boroughs and cities: they **must be in line with the local vulnerability diagnosis** that was presented to them.

FOLLOW-UP MECHANISMS

We plan to carry out a mid-term report for the climate change adaptation plan in 2017-2018. This evaluation will also constitute an opportunity to make changes and additions to the plan as needed.

A final report on this first adaptation plan will be published at the end of the plan's period, which is 2015-2020.

To ensure the most precise monitoring possible, the commitments written into this plan are accompanied, in most cases, by a specific goal and a monitoring indicator. Each department, city and borough will be responsible for providing the Service de l'environnement (environment department) with the data about their progress in implementing their measures for the mid-term and final reports.



Greened roof on one of the towers of the Québecor Média head office
Credit: © Philippe Aubry

CATEGORIES OF ADAPTATION MEASURES FOR EACH CLIMATE HAZARD

 HIGHER AVERAGE TEMPERATURES	– Protect biodiversity – Increase infrastructures' resilience to the freeze-thaw cycle – Adapt the slate of winter recreational activities and maintenance operations – Broaden the slate of summer recreational activities and maintenance operations – Control undesirable plant species
 HEAVY RAINFALLS	– Harvest rainwater – Increase infrastructures' and buildings' resilience to runoff water – Minimize sealed surfaces – Ensure the capacity of stormwater and combined sewer systems – Increase and preserve tree and plant cover – Develop emergency measures for heavy rainfalls
 HEAT WAVES	– Mitigate heat islands – Provide spaces for people to cool off and avoid exposure to oppressive heat (cooling islands) – Protect biodiversity against heat waves – Develop emergency measures for heat waves
 DESTRUCTIVE STORMS	– Increase infrastructures' and buildings' resilience to wind and freezing rain – Develop emergency measures in case of prolonged power outage (winter conditions) – Increase plants' resilience to wind and freezing rain
 DROUGHT	– Ensure the quality and quantity of drinking water – Increase infrastructures' and buildings' resilience to soil drying – Increase plants' resilience to drought
 RIVER FLOODS	– Increase infrastructures' and buildings' resilience to river floods – Develop emergency measures for flood-prone areas – Increase the stability of river banks facing erosion

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