PLANNING FOR RESILIENCY

Toward a Corporate Climate Adaptation Plan

September 2017

METROLINX

ACKNOWLEDGMENTS

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Report Authors

Dr. Quentin Chiotti

Kevin Chan

Ersoy Gulecoglu

Antoine Belaieff

Geoff Noxon (editing)

Internal Contributors and Reviewers

Finance – Internal Audit; Strategic Business Planning & Enterprise Risk Management

Capital Projects Group – Program Management

Operations - Transit Operations

Planning & Policy – Regional Planning

External Reviewers

The Prince's Accounting for Sustainability (A4S)

Ontario Ministry of Transportation

Ontario Ministry of Environment and Climate Change

Toronto and Region Conservation Authority

Zizzo Strategy

www.metrolinx.com/sustainability

For questions or comments please contact:
sustainability@metrolinx.com

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MESSAGE FROM THE CHIEF FINANCIAL OFFICER

We are experiencing an unprecedented time of transit growth with over $34 billion in projects planned or underway across the Greater Toronto and Hamilton Area (GTHA). With this investment, it is imperative for Metrolinx to strengthen its resiliency and adaptive capacity to climate-related hazards and mitigate the risks associated with our changing climate.

Becoming climate resilient is one of the five goals in our *Sustainability Strategy (2015-2020)*, while in the Metrolinx *Five-Year Strategy (2015-2020)*, we committed to establish a *Corporate Climate Adaptation Plan*.

The effects of climate change are already apparent, and we need to prepare for hotter temperatures, more intense rainfall events, and increasingly severe and frequent storms. The science to support climate change is sound and cannot be ignored. It presents us with new information that we must consider in order to make better capital investment decisions. We need to move forward in a systematic and structured way to bring the organization and our assets to a higher level of climate resiliency and adaptive capacity.

To be resilient and adaptive to extreme weather and climate change means taking actions and adopting measures that protect and secure the people and communities that rely on our assets and services, as well as the assets themselves. This requires us to consider all facets of our operations and planning procedures, recognizing that resiliency is best achieved when it is applied across the system as a whole, rather than in specific areas.

Metrolinx currently spends nearly $500 million annually maintaining our assets in a State of Good Repair. As we plan for our assets to further grow from the $19.5 billion of our existing assets, to another $43 billion of investment for new infrastructure over the next decade, we are working to integrate climate resiliency into how we plan, build, operate and help connect people across our network. There is an opportunity to build upon existing business practices already in place such as Enterprise Asset Management, Business Continuity Planning, Design Excellence, Planning and Construction, Emergency Response Planning, and Risk Assessment procedures. We also recognize the need to implement effective climate resiliency measures that reflect best practices from around the world. Our efforts to date include:

- a staff position dedicated to climate resiliency and adaptation within our Planning and Policy group;
- a cross-organizational Climate Resiliency Working Group;
- a Climate Risk Assessment of key assets against 12 climate parameters;
- an Extreme Weather Advisory Plan;
- enhanced emergency response and operating procedures;
- increased levels of redundancy on generators and power systems;
- installation of early weather and flood detection systems and controls across the transit network;
- an embankment failure monitoring pilot project; and
- a winter readiness plan to help prepare for the impacts of increased snowfall, ice, and more extreme winter temperatures.

Metrolinx recently became a founding member of the Canadian Chapter of The Prince of Wales' Accounting for Sustainability (A4S) CFO Leadership Network – a global initiative led by Chief Financial Officers committed to sustainability. This report supports our commitment to A4S to work together to transform finance through the development of tools, methodologies and approaches that enable sustainability to be integrated into decision making.

We know that Metrolinx needs to be prepared to take on the challenge of climate change and address associated financial and operational risks. This report is the next step towards completing our Corporate Climate Adaptation Plan, and helps define how we need to move forward to protect our customers and secure the sustainable development of our region.

Sincerely,

Robert Siddall, FCPA, FCA
President and CEO (Acting)
Chief Financial Officer
Metrolinx

EXECUTIVE SUMMARY

E1. INTRODUCTION

About Metrolinx. Metrolinx is an agency of the Government of Ontario, and is responsible for coordinating and integrating transportation in the Greater Toronto and Hamilton Area (GTHA). Its operations consists of GO Transit regional bus and rail services, and UP Express, and its extensive assets include bus and train fleets, rail lines, stations, parking structures, maintenance facilities, and PRESTO, the electronic payment system. A long-term capital investment plan will see those assets expand substantially over the coming decades.

Our challenge. Metrolinx's Passenger Charter commits to delivering safe, on-time services while keeping customers comfortable and informed. However, our changing climate poses a serious risk to our ability to deliver on that promise, as illustrated by recent extreme weather events that caused unexpected and undesirable delays and cancellations to GO Transit services across the GTHA. The inevitability of future climate change means that preserving safety and minimizing costs requires Metrolinx to integrate resiliency across the organization.

Our approach. In response to the threat of climate change, Metrolinx has added staff resources, created a Resiliency Working Group, begun to assess risks and vulnerabilities, and strengthened a number of plans and procedures. However, much work lies ahead to completely integrate resiliency, and Metrolinx will develop a Corporate Climate Adaptation Plan within 2017 that identifies key actions related to stakeholder engagement, monitoring and surveillance, education, and partnership building.

About this report. This report provides a foundation for the Corporate Climate Adaptation Plan. It explains why climate change matters to Metrolinx, gives an overview of possible responses, reviews Metrolinx's efforts to date, and suggests key areas of future work.

E2. THE RISKS AND IMPLICATIONS OF CLIMATE CHANGE

Climate change is a global phenomenon with implications for Metrolinx's assets and operations that warrant a concerted response.

Climate change: A global crisis. The burning of fossil fuels and land use changes have released large amounts of greenhouse gases (GHGs) into the atmosphere, that trap heat, and affect weather patterns and climate. The earth's atmosphere today contains 40 percent more carbon dioxide (CO_2) than 200 years ago. As atmospheric GHG concentrations continue to rise at an alarming rate, some degree of climate change seems inevitable, and extreme weather events such as droughts and rainstorms will become more frequent and intense worldwide. As a northern country, Canada will see its climate change more than the global average. The economic costs of more extreme weather in Canada are considerable, and are estimated to grow from $5 billion annually in 2020 to as much as $43 billion by the 2050s. As part of international efforts to slow climate change, Canada and Ontario have each committed to dramatically reduce GHG emissions in their jurisdiction.

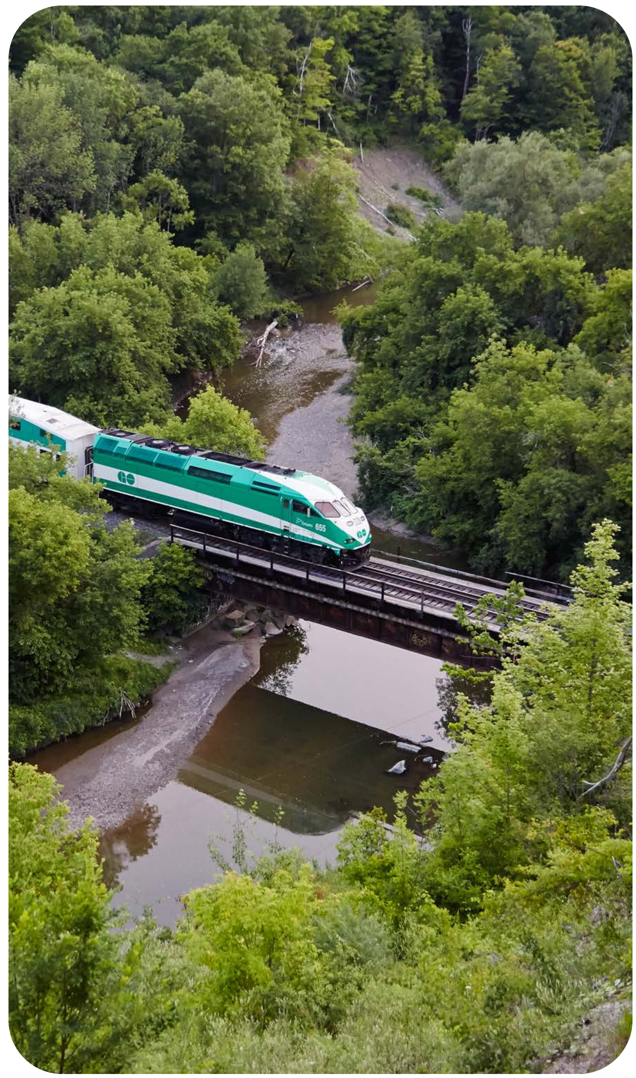
Expectations and responsibility to respond to climate change. There have been growing expectations for corporations and governments to take responsibility to reduce GHG emissions and to reduce vulnerability to a changing climate. In the case of new infrastructure this includes greater attention to the carbon footprint from the construction and lifecycle of the asset, as well as taking action to reduce its vulnerability to extreme weather events and climate change impacts. Taking climate change into account is becoming a requirement to receive infrastructure funding, as well as a growing concern in terms of liability over the inadequate design or mismanagement of infrastructure that causes impacts and effects that should otherwise be avoidable.

Implications for the GTHA. Climate change in the Great Lakes Basin and the GTHA is generally expected to bring increases in temperature, precipitation, drought, wind gust events, and freezing rain frequency by the end of this century. There is high confidence that: (i) temperature increases are expected to be greater in the winter than in the summer; (ii) minimum temperatures will increase greater than maximum temperatures; (iii) annual precipitation will increase, while changes in snowfall will be variable; (iv) extreme weather events will increase in frequency and severity; and (v) the number of hot days, heat waves and drought during the summer will increase significantly.

For example, the annual average temperature could rise faster in the future than in the past, and could be 4°C warmer compared to the 1960s by mid-century. As a result the number of "hot days" with temperatures above 32°C are projected to double by the 2020s (13 days/year), quadruple by the 2050s (25.5 days/year), and increase almost 8X by the 2080s (50.5 days/year), compared to the 1981-2010 average (6.5 days/year). Extreme precipitation events, including freezing rain and convection storms, could also increase in frequency and severity. Flood events that occurred in Peterborough (2002 and 2004), Toronto (2005 and 2013), and Burlington (2014) could also occur more often.

GTHA municipalities already face significant challenges in managing infrastructure assets to perform acceptably in today's climate. Infrastructure assets that were designed to function within an expected range of past climatic conditions may not perform as well under future climate conditions, especially in response to more extreme weather events.

Metrolinx's vulnerabilities and the need to act. Many elements of Metrolinx's infrastructure and operations are vulnerable to extreme weather. Heat can warp rail tracks, rainstorms can cause floods or washouts, snow and ice can obstruct track switches, freeze-thaw cycles can cause pavements and other materials to deteriorate, freezing rain can cause blackouts that interrupt communications, and storms and heat waves can exhaust staff. As a result, bus and train trips can be delayed or cancelled, sections of rail corridors can be closed or have speeds reduced, and customers can be inconvenienced or even stranded.



Existing infrastructure assets may need to be maintained, and in some cases upgraded, so that they are less vulnerable and more resilient to extreme weather events and climate change. New standards that are based on future climate conditions may need to be applied to new infrastructure and capital projects that have extended lifecycles. New protocols regarding maintenance, monitoring, reporting, and emergency response planning may be needed for managing existing and future infrastructure assets.

For Metrolinx, improving resilience is a necessity, not an option. The operational, financial and public risks of inaction are unacceptable, while timely action could bring secondary benefits. GTHA residents and their communities expect Metrolinx to proactively consider the impacts of climate change when planning, building and operating infrastructure.

E3. RESILIENCY INITIATIVES AT METROLINX

Metrolinx has acted in a number of areas related to resiliency, although these actions have generally been taken to "harden" assets in response to particular weather events, rather than as part of a methodical and proactive plan.

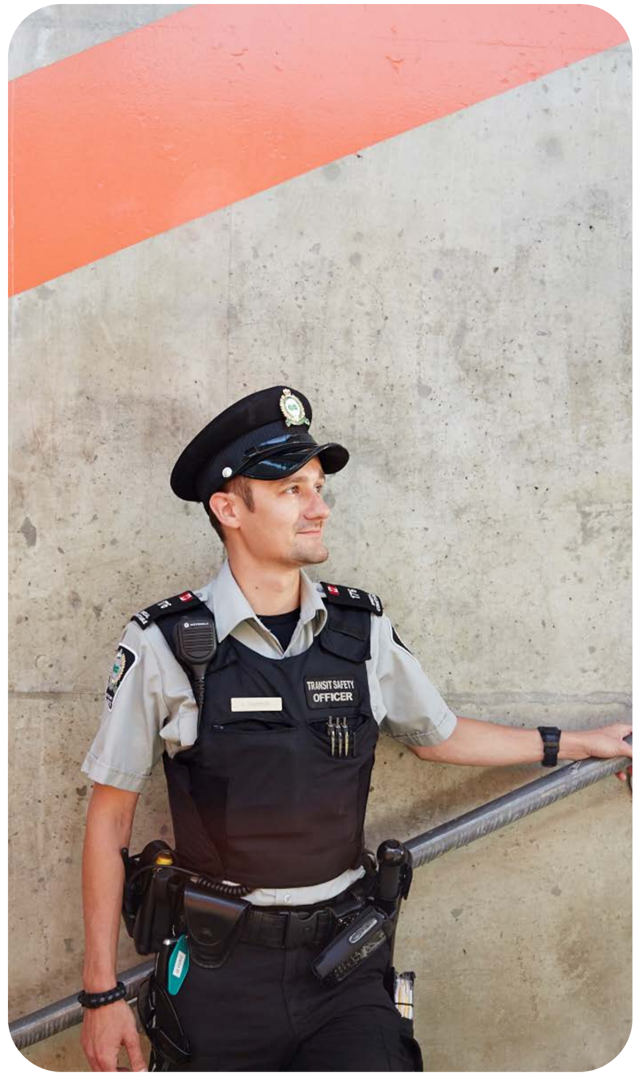
Vulnerability assessment pilot project. A Resiliency Working Group was created at Metrolinx, with representatives from different business units across the organization (e.g. bus, rail, stations, and planning). The group engaged a consulting team and led a test application of Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol to six representative infrastructure assets. The exercise improved Metrolinx's understanding of the vulnerability and risk of its assets to extreme weather events and climate change. Some areas have considerable adaptive capacity and are quite robust, but there are concerns in other areas where critical thresholds may be exceeded by mid-century, with implications for operations and safety.

The key issues relate to hot weather and flooding, but other issues including freezing rain, high wind gusts and lightning remain concerns for Metrolinx assets and for interdependent assets (e.g. municipal stormwater management systems and electrical distribution) that can affect the delivery of transit services. The results of this study are: informing planning and decision making that helps enhance the resiliency of the assets examined; being considered for application across Metrolinx's entire asset portfolio; highlighting needed improvements in monitoring and maintenance protocols; and informing climate resiliency requirements for new capital projects.

Asset management. Metrolinx conducted a formal review of its asset management capabilities against the international (ISO) standard. The review found both strengths and opportunities for improvement, and identified weather and climate change as key risks. In response, Metrolinx launched an enterprise-wide asset management (EAM) program in 2016. The five-year EAM program is shaped by a set of guiding principles, and pursues objectives in seven key areas. One EAM tool that supports climate resiliency is a new enterprise Geographic Information System (GIS) platform that provides an inventory of Metrolinx's assets and enables the sharing of spatial data across the organization.

Design practices. Design guidelines and standards are important tools to embed resiliency in Metrolinx's assets at an early stage. Metrolinx is developing new Design Excellence Guidelines for future capital projects that will apply resiliency and adaptation principles related to flooding, drought, low-impact development and the urban heat island effect. Metrolinx has increased its preferred rail laying temperature to 37.7°C to reduce the risk of track bending or buckling in hot weather; this was an initial reaction to recent heat events, and further data collection and analysis may indicate the need for additional change. Metrolinx has also upgraded its standards for providing back-up generators at GO stations and facilities, and proposed a new vegetative clearance zone along railway tracks to protect future electrification infrastructure from interference by vegetation due to heavy winds or precipitation.

Emergency response planning and preparedness. Metrolinx has aggregated more than 60 emergency response plans (one for each major asset) into a single coordinated plan. That plan features numerous protocols for different asset types and emergency events, some of which address extreme weather. This includes service disruption protocols that redirect trains, or provides local transit alternatives for customers whose journey is delayed or cancelled. Experience has shown that Metrolinx operations are also vulnerable to significant snow or ice accumulation during winter storms, and has created a Snow Plan as part of a Winter Readiness Plan to guide communications, schedule modifications, crewing decisions, and rail and bus service adjustments when severe winter weather is forecast.



Regional and strategic planning. Metrolinx is working in several other areas to address resiliency. It has collaborated with local, regional, provincial and federal partners, both governmental and non-governmental and particularly across the GTHA, to improve collective knowledge and best practices. It is integrating resiliency principles into the current review and update of its Regional Transportation Plan, and into selected procurement processes.

E4. OPPORTUNITIES FOR ACTION

Metrolinx can boost its resiliency and adapt to the risks of climate change by working in several key areas, based on best practices in other agencies and jurisdictions.

Evidence-based decision making. It is important that decisions on climate risk and resiliency measures are based on credible and up to date information, most notably for climate change projections. How one manages uncertainty around climate change scenarios and projections should follow best practices. Evidence-based decision making can inform the cost of taking action today, vis-à-vis the future costs of inaction, and use accepted models and tools for estimating and valuing the environmental, as well as social benefits.

Building knowledge. Metrolinx will be working to improve its understanding in several key areas— the nature of threats, degrees of risk, areas of vulnerability, types of possible responses, and their expected effectiveness—before it can effectively embed resilience across the organization. The Province of Ontario aims to improve the reliability of climate modelling and decision-making, by supporting research, providing data, and sponsoring training sessions. Metrolinx is working with Conservation Authorities and municipalities to determine flood risk across the GTHA from both riverine and overland/urban flooding, as well as aiming to determine credible and defensible projections of Intensity-Duration-Frequency (IDF) Statistics under different climate scenarios. Metrolinx aims to engage with peer organizations and outside experts to learn about vital subjects related to climate change and resiliency.

Managing risk. A strategic approach to risk management treats climate change adaptation as a business issue, and could be considered as an overall framework for action in terms of planning, building, and operations. It considers the risks to assets and services in assessing the potential costs of a "do-nothing" scenario, and weighs them against the costs and benefits of spontaneous or proactive actions. When action is warranted, it is usually easier, less costly and less disruptive to build resiliency into capital projects in the planning stages, rather than during or after construction. New infrastructure provides an attractive opportunity to embed resilience into an entire life cycle. When considering an entire base of assets, some of which already exist and some of which do not, knowing how to distribute actions over time in order to maximize overall outcomes and minimize overall costs is a complex challenge—particularly when (as with climate change) future risks and their rate of change are not precisely known. With this challenge in mind, Metrolinx is continuously seeking an optimal pathway to adaptation that considers current and future costs.

Managing assets. Asset management optimizes the allocation of resources over the lifecycle of an asset base, from planning through construction, operation, rehabilitation and replacement. Asset management plans and practices are a critical channel for the implementation of resiliency strategies. For example, maintaining the state of good repair by considering changing climate conditions may be a prudent asset management option during decadal capital investment cycles.

Planning capital improvements. The Governments of Canada and Ontario have provided legislative and regulatory guidance for planning capital projects, as well as directions for policy and practice, that will inform Metrolinx's climate adaption work. Those directions include intergovernmental working groups, funding for new knowledge and tools, cross-cutting jurisdictional strategies, progressive land use policy, and best practice guides. Ontario's environmental assessment (EA) process is in the process of being updated to consider climate change, and it is expected that Metrolinx's planning processes will be consistent with future guidance and changes. Metrolinx can also share information and join forces with regional and local governments, many of which struggle with similar challenges, and with industry associations such as Engineers Canada which developed the PIEVC Protocol that Metrolinx has used to assess the vulnerability of key assets.

Designing capital improvements. Work has begun on the integration of climate adaptation into codes and standards for buildings and other infrastructure, which are important channels for embedding resiliency into Metrolinx's asset base. This is occurring parallel with national efforts to develop climate change standards for buildings and infrastructure led by the Standards Council of Canada, the Canadian Standards Association, and the National Research Council So far, well known international certification and rating programs like ISO and LEED offer limited guidance on infrastructure resiliency. However, new rating programs such as ENVISION and ISCA IS do offer guidance for decision-making around climate resiliency and adaptation for individual projects. In Ontario, the area of greatest progress in updating standards is in stormwater management—but even those updates address recent climate changes without considering the impact of continued climate change on future weather expectations.

Operations and maintenance. Improved monitoring and inspection practices and protocols will help assess asset condition and the potential for critical failure before, during, and after extreme weather events. Planning for emergencies such as extreme weather events is critical to resiliency preparedness, and many public-sector organizations are improving their emergency management capabilities and protocols. When disruptions do occur, business continuity plans can further guide an organization in resuming or continuing acceptable levels of service.

E5. THE WAY AHEAD

This report is a step towards Metrolinx's development of a Corporate Climate Adaptation Plan. The Adaptation plan will aim to answer key questions, adhere to guiding principles, and build upon four key pillars in order to put climate resiliency into practice.

Overview. The plan will address key questions that pertain to GTHA climate projections, Metrolinx's infrastructure vulnerabilities, protocols and standards that require strengthening, cost-effective measures that could be implemented, and priority areas for action. Guiding principles that could help answer those questions acknowledge the threats posed by climate change, the existence of different pathways toward resiliency, and the potential for secondary benefits from adaptation measures. Further, it is important to acknowledge the possible need for transformative measures, and the desirability of taking rapid action under conditions of uncertainty. Metrolinx's supportive policy setting, internal culture, investment plan, current understanding and prior experience are all strengths that the organization can work from.

Pillar 1: Awareness, education and communication.

Metrolinx has a solid foundation for engaging various partners, stakeholders and audiences in a dialogue about how to achieve resiliency. Previous actions and current initiatives represent a "good news" story and a learning opportunity for others, while it can acquire valuable lessons from a range of ongoing efforts across Canada and on a global scale. Metrolinx will continue to learn from the best practices of others, collaborate with other partners and stakeholders where it is strategic to do so, and inform internal and external audiences regarding the progressive measures that it is implementing to enhance climate resiliency. Metrolinx participation in the Canadian Chapter of The Prince of Wales' Accounting for Sustainability (A4S) CFO Leadership Network -- a global initiative led by Chief Financial officers committed to sustainability, ARISE Canada -- the Canadian Chapter of an International initiative dedicated to disaster risk reduction, and the City of Toronto Resilient City Working Group (which includes interaction with Toronto's Chief Resiliency Officer supported through the Rockefeller Foundations 100 Resilient Cities Initiative) that adopts a collaborative approach to addressing climate change vulnerability and resiliency needs are examples of our international, national, and regional engagement activities. Internal engagement that increases awareness, educates key personnel, and builds partnerships within Metrolinx to effectively manage extreme weather events and climate change risks will continue to be an important requirement of the plan.

Pillar 2: Assessing vulnerability, risks and opportunities.

Meaningful assessments of risk and vulnerability require relevant and reliable information about a changing climate (both historical trends and future projections), as well as the ability to interpret and extend that information for specific weather risks, asset types and locations.

A variety of climate data sources are available through government and private sector portals (e.g. the Ministry of the Environment & Climate Change's (MOECC) Ontario Climate Change Data Portal and Risk Sciences International's Climate Change Hazards Information Portal), which provide science-based climate projections constructed from an ensemble of global climate models. Various climate vulnerability and risk tools exist that can be applied to individual assets or a system-wide basis. They also require supportive statistical data and mapping tools to understand the threats posed by precipitation events, flooding and the urban heat island effect. The goal is to enable a system-wide vulnerability assessment that leads to the identification of cost-effective resiliency measures.

Pillar 3: Building resiliency across the enterprise.

Metrolinx will aim to address resiliency in several key functional areas. These include planning, design and construction; enterprise asset management; environmental assessment; design standards; and operations, including weather readiness and emergency response protocols. Building resiliency across the enterprise extends beyond any single business unit, and is cross cutting that touches upon numerous aspects of the organization. Decisions should be evidence based, informed by climate science and credible projections of climate change, adhere to policy and regulatory requirements, and be informed by best practices. This applies to managing and improving existing assets as necessary and when opportunities emerge, and also planning, designing, and constructing future assets. While design standards may need to be enhanced to withstand more extreme weather conditions brought on by climate change, engineering design and solutions may not be the only effective response possible, as changes in operational protocols and processes may also result in an increase in resiliency and adaptive capacity.

Pillar 4: Monitoring and adaptive management.

Efforts to build resiliency would benefit from a common reporting protocol and information repository, as well as ongoing monitoring of relevant developments in science, policy, technology, best practices and the parallel efforts of Metrolinx's peers and partners. This will also require applying suitable tools and methods to evaluate the effectiveness of resiliency measures, including cost-benefit analysis and triple bottom line. As a result, the Corporate Climate Adaptation Plan should be treated as a living document, to be reviewed and updated on an ongoing basis. Through effective monitoring and adaptive management, continuous improvement can be achieved by implementing resiliency measures that ranges from incremental to transformative change.

1 INTRODUCTION

1.1 About Metrolinx

Mandate

Metrolinx is an agency of the Government of Ontario. Its creation through the *Metrolinx Act, 2006* was intended to better coordinate and integrate transportation in the Greater Toronto and Hamilton Area (GTHA). [1] Its mission is to champion, develop and implement an integrated transportation system that enhances prosperity, sustainability and quality of life in the region. Metrolinx understands that to deliver high quality services to our customers and stakeholders we must, among other things, be innovative, engage the communities in which we operate, and ensure the safety of our employees, customers, and the communities in which we build and operate.

Current infrastructure assets

Metrolinx provides GO Transit regional rail and bus services across the GTHA. In 2015, it carried more than 225,000 passengers by rail each day, and almost 70,000 by bus. Figure 1 summarizes the key services provided by Metrolinx, and the Metrolinx-owned infrastructure used to provide these services including rail corridors, bus and rail fleets, maintenance facilities and parking structures.

Figure 1: **Selected Metrolinx infrastructure and services (March 31, 2017)**[2]

Asset Group	Quantity	Asset
GO train service	7	Lines
	65	Stations
	458	Route-kilometres
	1,699	Weekly train trips
	58	Weekday trainsets in use
	75	Locomotives
	685	Bi-level passenger railcars
GO bus service	22	Terminals (plus numerous stops and ticket agents)
	2,785	Route-kilometres
	14,099	Weekly bus trips
	326	Single-level buses
	186	Double-decker buses
UP Express	4	Stations
	25	Route kilometres
	1,089	Weekly tran trips
	5	Active trainsets (typical weekday)
	18	Diesel multiple unit railcars
Network-wide	10	Parking structures
	71.168	Rail Parking spaces
	3,418	Park and Ride lot spaces
	590	Carpool parking spaces
	6	Green power installations

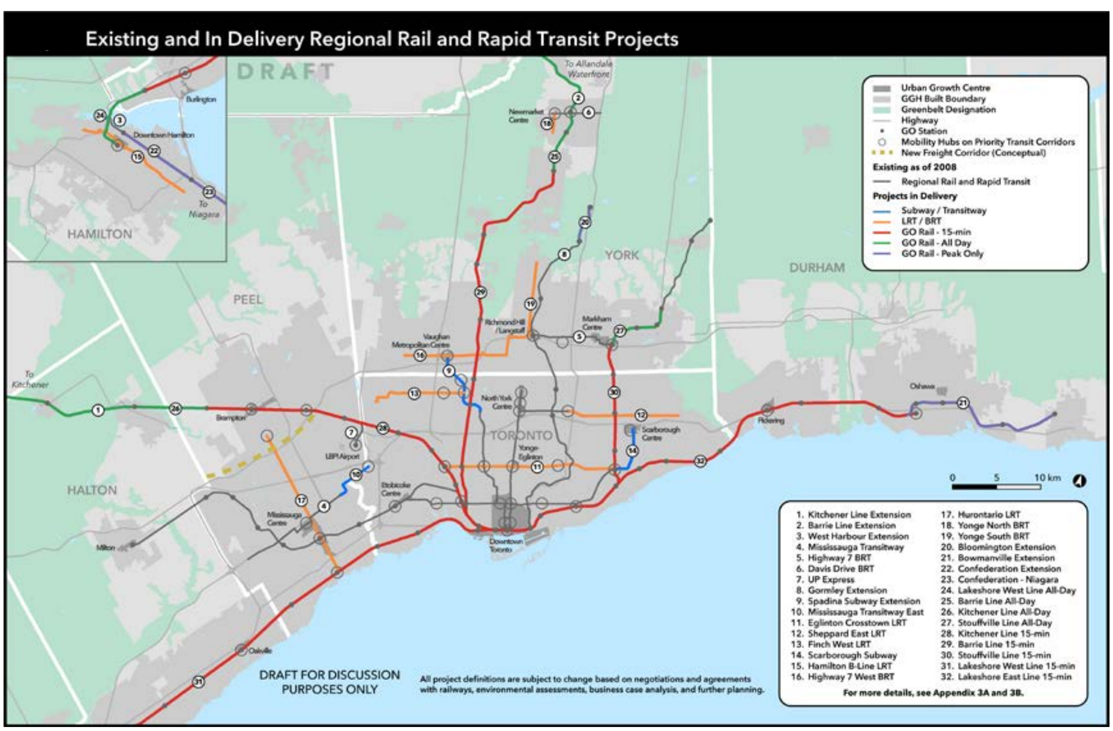
Each year, Metrolinx makes capital investments to maintain its assets in a state of good repair; in the 2014-2015 fiscal year these totalled more than $470 million.[3] It also invests in expanding and improving its assets. In 2015-2016 those projects cost $2-billion, and included renovating Union Station, building the UP (Union Pearson) Express, improving the Georgetown South section of the Kitchener rail corridor, adding new bus rapid transit (BRT) segments in Mississauga and Vaughan, and excavating the Eglinton Crosstown tunnel.

Future infrastructure assets

Today's investments are just the beginning of a longer-term commitment of more than $43 billion over the next 10 years, as described in the Metrolinx 2017/2018 Business Plan.[4] Future rapid transit projects (see Figure 2) include Regional Express Rail (RER), which is a plan to provide faster and more frequent service on the GO Transit Rail network with electrification on core segments, including the Union-Pearson (UP) Express. This work will include new stations, tracks, bridges, signals and fleet, will enable the doubling of peak period GO train service, and quadrupling of off-peak service by 2024.

Other future rapid transit work across the GTHA include the Finch West LRT to Humber College, the Hurontario LRT, the Hamilton LRT, and the Sheppard East LRT. Each LRT line includes track, stops and stations, and maintenance and storage facilities. When completed, the GTHA will enjoy over 1,200 kilometres of rapid transit (more than triple what existed in 2008) and over 80 percent of the GTHA's projected 10 million residents will live within two kilometres of rapid transit by 2031.[5] Currently the Regional Transportation Plan for the GTHA is undergoing a review and staff will report back to the Board at its meeting of December 2017 to present a Draft Final RTP for consideration.

Figure 2: **Existing and In Delivery Regional Frequent Transit Network**[6]



1.2 Our challenge

Recent severe weather impacts

In Metrolinx's GO Passenger Charter, we promise to do our best to be on time, always take your safety seriously, keep you in the know, make your experience comfortable, and help you quickly and courteously. Our ability to keep this promise was severely tested in 2013, when two extreme weather events caused significant service disruptions.

On July 8, 2013 more rain fell during the evening rush hour than during an entire typical July—leading to more than $1 billion in insured damages across the GTHA, and making it the costliest weather event in Ontario's history.[7] The deluge caused washouts along the Lakeshore West and Richmond Hill Corridors, and partly submerged a GO train with about 1,400 passengers on board, near Pottery Road along the Lower Don Transportation Corridor. Images of the GO train and its passengers spread quickly across social media, and the event has become an iconic example of how Canada's infrastructure may be vulnerable to extreme weather events and climate change.

On December 21–22 of the same year, an ice storm left about 300,000 households without power for hours or days, and caused widespread delays on GO trains and GO buses, Toronto Transit Commission (TTC) subways and streetcars, and other municipal bus systems.[8] The storm highlighted the interdependencies between transit and electricity infrastructure as ice accretion, power outages, and fallen trees affected track, roads, switches, traffic lights and stations.

These two events, along with others that were less catastrophic but still costly and disruptive, provided a strong impetus for Metrolinx to take decisive actions in both the short and long terms.

Preparing for an uncertain future

It is widely accepted that the extreme weather events of 2013 were neither the beginning nor the end of what climate change means for Metrolinx. Continued change is inevitable, even if projections vary as to the likelihood and severity of the possible impacts and effects. Metrolinx is thus working to integrate climate resiliency across the organization in order to preserve public safety and provide essential services across the GTHA, while minimizing overall costs. It will not be working in isolation, and is collaborating with a range of partners and stakeholders, both governmental and non-governmental, as they forge their own paths toward resiliency.

1.3 Our approach

A proactive response

Following the events of 2013, Metrolinx initiated a proactive approach to preparing for climate change. In 2014 we created a senior advisor position focused on resiliency and adaptation, and published our *Five Year Strategy 2015-2020* which committed the organization to establish a Corporate Climate Adaptation Plan covering facilities, practices and protocols.[9] By May 2015 an internal Resiliency Working Group had been formed, with a dozen representatives of Metrolinx business units, and began working towards an adaptation plan. Its initial steps included applying a nationally recognized vulnerability and risk assessment tool to a selection of critical infrastructure assets, overseeing the development of credible GTHA climate change projections, and building stakeholder awareness around the urgency of taking action on climate change. In 2016, the *Metrolinx Sustainability Strategy (2015-2020)* committed the organization to becoming climate resilient, and to completing the Corporate Climate Adaptation Plan within 2017.[10]

The goal of becoming climate resilient requires taking actions to protect and secure existing and future assets, which in turn helps build the resiliency of the communities that we serve. Metrolinx has already taken a number of related steps, such as developing an extreme weather advisory plan, enhancing emergency response procedures, installing early weather and flood detection systems and controls, and launching a snow plan to prepare for extreme winter weather. However, these are only the beginning of a more intensive future strategy that will include assessing the vulnerability of our infrastructure and services, strengthening our tools and processes for planning and designing new infrastructure, developing adaptation and resiliency plans for high-risk assets, and working with governments and service providers across the GTHA to build knowledge about risks and effective adaptation measures.

Toward a Corporate Climate Adaptation Plan

Metrolinx aims to manage its Corporate Climate Adaptation Plan as a living document, with periodic review and update, beginning with the state of knowledge on climate science, policy landscape, and climate change projections. In addition, the review and update should include key performance indicators as we report on progress, as well as benchmarking to global best practices. The plan provides a mechanism to test resiliency measures, practices, and protocols, on a regular basis, including exercises to ensure emergency preparedness.

Reducing Metrolinx's vulnerability to climate change and extreme weather will require actions to be applied across the organization, because any system is only as resilient as its least resilient part. We aim to embed resiliency measures into the maintenance and repair of existing infrastructure; the planning, design and construction of new infrastructure; and our operational practices and protocols. By doing so, we will successfully protect and secure not just our assets, but will also be taking actions that enhances the resiliency of the people and communities that we serve. This will require us to improve our knowledge in several key areas:

- Rely upon probable future climate and extreme weather conditions in the GTHA, based on various emission scenarios and climate model projections;
- Determine which infrastructure assets are vulnerable to hotter temperatures, increased snowfall, and more frequent and intense storm events, where they are, and what condition they are in;
- Prioritize areas of resiliency investment, and identify which specific measures would be most cost-effective; and
- Update design standards for infrastructure assets, and protocols for operations and maintenance procedures to consider climate change and resiliency.

Based on a review of the literature and the actions of leading peer organizations, a Climate Adaptation Plan should include, and build upon, the following, which are reflected in the Pillars for Resiliency (p. 51):

- *Stakeholder engagement*—Engaging key stakeholders is critical to identifying research priorities, assessing the effectiveness of current actions in adapting to future conditions, and determining the most appropriate response actions based on best practices.
- *Monitoring and surveillance*—Data related to climate, infrastructure asset conditions, ecosystem function, social conditions and economic impacts, including those derived from community-based monitoring, are needed to inform effective adaptation decision making.
- *Education*—Increased awareness of the social, economic and environmental impacts of climate change at local to regional scales will help facilitate the development and public acceptance of adaptation measures.
- *Partnership building*—Effective adaptation measures will require cooperation and coordination between all orders of government, industry, communities, universities and colleges, voluntary organizations, public interest groups and individuals.[11]

1.4 About this report

The purpose of this report is to provide a foundation for the development of a Corporate Climate Adaptation Plan. It explains why climate change matters to Metrolinx, gives an overview of possible responses based on best practices, reviews Metrolinx's efforts to date (many of which have gone undocumented), and suggests key areas for future work. The remaining sections of this report are:

- **Chapter 2—The Risks and Implications of Climate Change** summarizes the scientific evidence for climate change, the potential implications for severe weather patterns in the GTHA, the ways in which Metrolinx is vulnerable, and the rationale for a proactive approach.
- **Chapter 3—Resiliency Initiatives at Metrolinx** presents actions that Metrolinx has taken to respond to extreme weather and climate change over the past few years.
- **Chapter 4—Opportunities for Action** discusses key concepts, best practices and government policy and guidance that could inform Metrolinx's approach to becoming more resilient through planning, designing, operating and maintaining its assets and services.
- **Chapter 5—The Way Ahead** identifies a vision for a more resilient Metrolinx, and four principal pillars to support the development of a Corporate Climate Change Adaptation Plan.

2 THE RISKS AND IMPLICATIONS OF CLIMATE CHANGE

2.1 Climate change: A global crisis

Understanding the science

In 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that "[the] warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level."[12] Since then, there has been growing acceptance among scientists and policy-makers that in order to stabilize atmospheric greenhouse gas (GHG) concentrations at a level that would prevent dangerous human interference with the climate system, global annual average temperatures should not rise more than 2°C compared to pre-industrial levels.[13]

GHG concentrations continue to increase at an alarming rate, with atmospheric carbon dioxide (CO_2) levels in 2016 exceeding 400 parts per million throughout the entire year for the first time in millions of years.[14] In fact, 2016 was the hottest year ever recorded—with a global average temperature about 1.3°C warmer than the pre-industrial era, and about 0.9°C warmer than the 1951-1980 average.[15] Of the 17 hottest years on record, 16 have occurred since 2000 (and the other was 1998). Recent climate changes are so significant that while our planet's past climate might help us understand our vulnerabilities and prepare for impacts, we can no longer view it as a reliable indicator of what will happen in the future—especially for extreme weather events that are likely to be more severe and frequent.

GHG concentrations in the atmosphere have reached a point where we cannot prevent some degree of climate change from occurring. Current levels of CO_2, combined with the storage of heat in the world's oceans and the melting of permafrost in arctic regions, may be taking us on a path towards warming of more than 2°C by 2050. In fact, a failure to slow the growth of GHG emissions could lead to CO_2 concentrations that are four times pre-industrial levels by 2100 (exceeding 1,000 parts per million), and global average temperature could increase by 4-5°C.[16]

Climate change experts confidently predict that average temperatures will increase in the northern hemisphere, during wintertime more than in summertime, and at night more than during the day. They also expect moderate increases in total annual precipitation, with more frequent and intense extreme weather events, and more prolonged periods of drought, although there is less confidence predicting changes in precipitation.

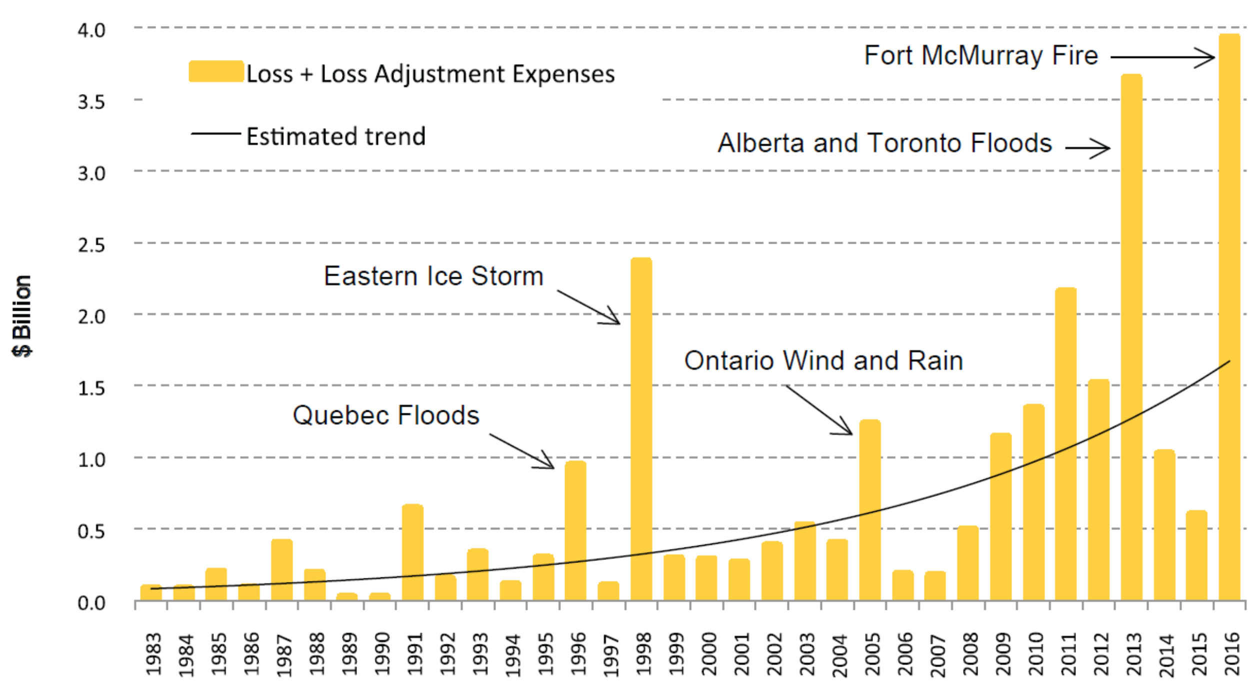
Climate change could also make our weather more variable from year to year, season to season, and even from week to week, compared to what we have experienced in the past. Recent and future changes to the climate are so significant that while past climate can help us to understand our vulnerabilities and prepare for impacts, it is no longer as reliable an indicator about what will happen in the future.

Economic implications of extreme weather events

Across Canada, catastrophic losses from weather-related events have been growing since 1983 (see Figure 3). While future losses will depend on the growth rates of global carbon emissions and changes in Canada's population and economy, the National Roundtable on the Environment and the Economy (NRTEE) has estimated that, under a 2°C global warming scenario, the annual costs of climate change to Canada could grow from about $5 billion in 2020 to between $21 billion and $43 billion by the 2050s (with a 5 percent chance that costs could exceed $90 billion).[17] These numbers are likely underestimated, because the assessment only considered selected sectors across Canada.

Since the new millennium Ontario has experienced its own costly extreme weather events, including intense rainfall and associated flooding (e.g. in Peterborough, Toronto, and Burlington), tornadoes (e.g. Goderich and Vaughan), frost (e.g. damaging the province's apple crop), ice storms (e.g. in December 2013), algal blooms (e.g. in Lake Erie), and both low and high water levels in the Great Lakes (e.g. record lows in January 2012, and record high levels in May 2017). Projected low water levels in the Great Lakes could cost the region almost $20 billion by 2050, by impacting hydroelectricity, commercial shipping, recreational boating and fishing, and property values near the shores.[18]

Figure 3: **Catastrophic losses in Canada ($Billions, 1983-2016)**[19]



Canada's commitment

At the 2015 Conference of the Parties (COP 21) in Paris, 196 countries agreed to reduce GHG emissions by 2030 and prevent global average warming of 2°C.[20] Canada's federal government has committed to exceed its previous 2030 target of a 30 percent emissions reduction from 2005 levels.[21] Ontario, the only province in Canada to meet its emissions reduction target for 2014, has committed to go even further: it has set emission targets of 15 percent below 1990 levels by 2020, 37 percent below 1990 levels by 2030, and 80 percent below 1990 levels by 2050.[22]

2.2 Implications for the GTHA

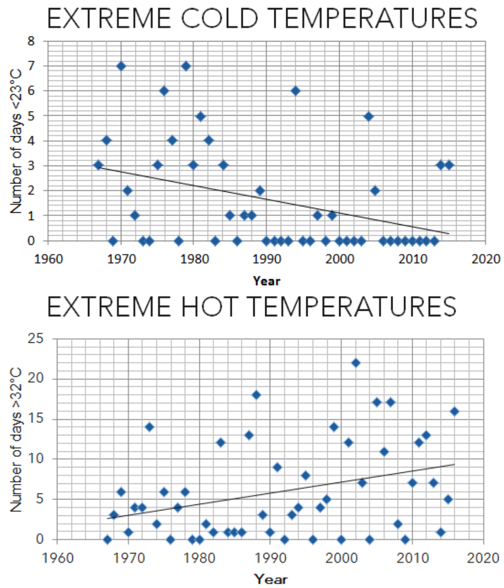
Regional climate trends since 1967: A historical perspective

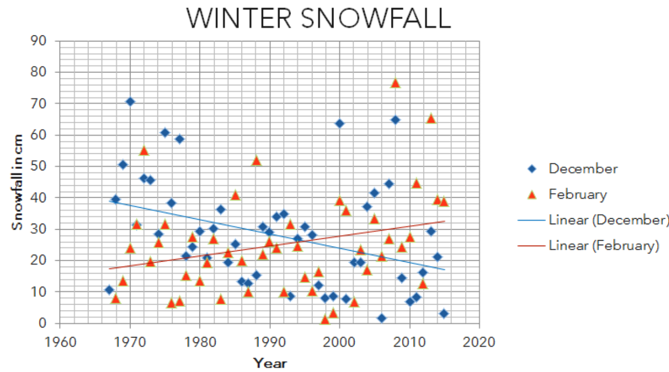
The GTHA's climate has already undergone considerable change since GO Transit began operations in May, 1967 with implications for our region and Metrolinx's operations. For example, in recent years flooding along the Lower Don River has disrupted rail service once or twice per year on the Richmond Hill Line (which entered service in 1978).

Data from the weather station at Toronto Pearson International Airport provides an indication about the regional change that has taken place since 1960 (Figure 4). Some notable changes in key climate trends include:

- The number of days with extreme cold temperatures (less than -23°C) have become less frequent;
- The number of days with extreme hot temperatures (greater than 32°C) have become more frequent;
- The amount of precipitation that is falling as rain rather than snow during the winter season has increased; and
- The month of December has experience the steepest decline in snowfall (close to 50%), while the month of Februrary is the only month where snowfall has increased.

Figure 4: **Climate Trends at Toronto Pearson International Airport, 1967 - 2016**[23]





RECORDED FLOOD EVENTS SINCE 1978
ALONG THE LOWER DON RIVER

1981, 2000, 2011, 2013, 2014, 2015 and 2017

Regional Climate Change Projections to 2050 and 2080

Over the last decade, the GTHA has experienced numerous record-breaking weather events, some of which (e.g. heat waves) covered the whole region while others (e.g. intense rainstorms) were very local in nature (see Appendix I). However, these events all occurred at a time when the global average temperature has been rising to 1.2°C above pre-industrial conditions; much more frequent and intense extreme weather should be expected as increases in global average temperatures reach or exceed 2°C.

Figure 5 summarizes the current consensus predictions for climate change in the Great Lakes Basin, and the level of confidence behind them. There is general agreement that the region will see increases in temperature, precipitation, drought, wind gust events, and freezing rain by the end of this century; however, the level of confidence and quality of supporting evidence for these projections vary considerably.

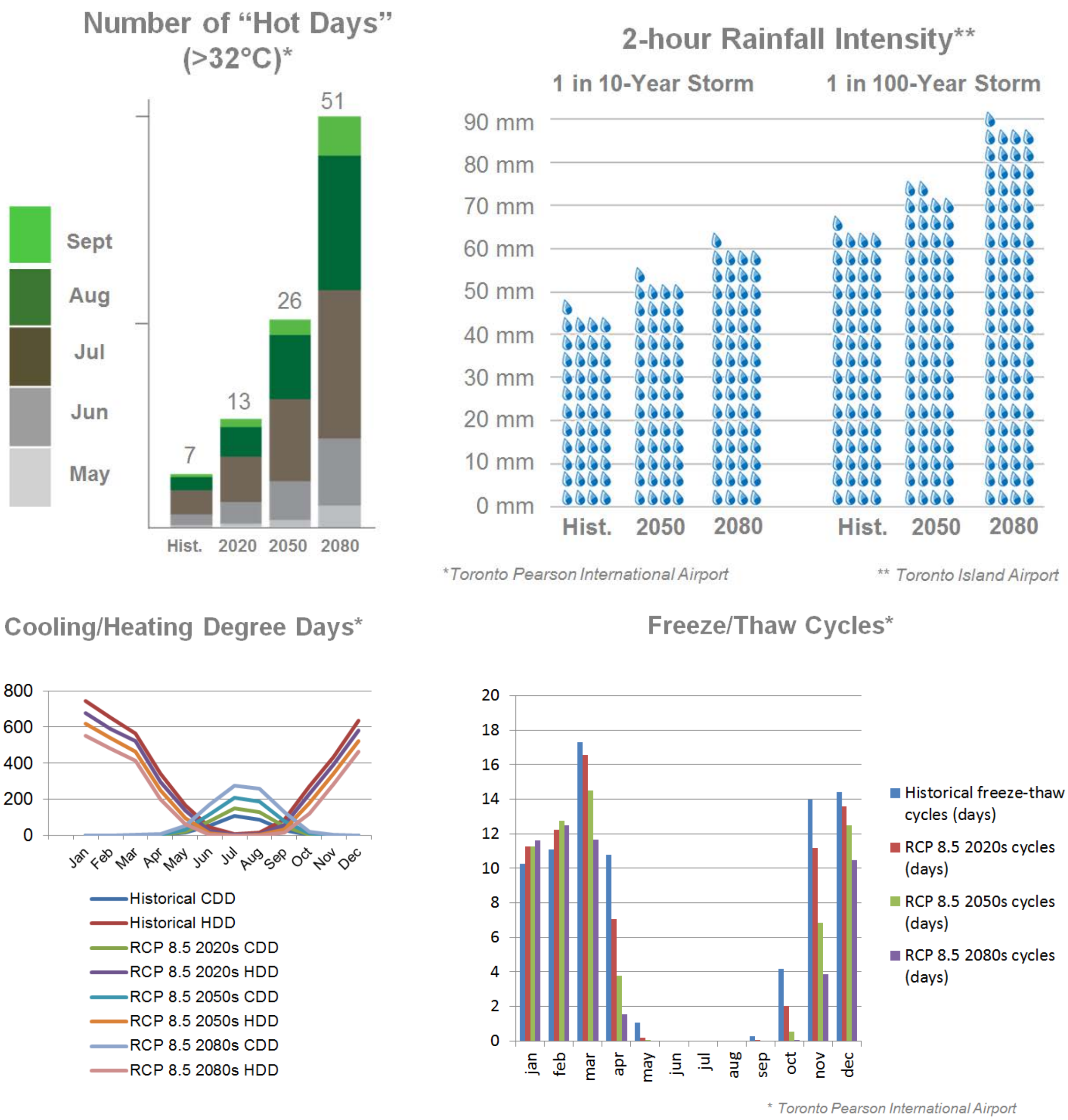
Figure 5: **Climate change projections for the Great Lakes Basin**[24]

Theme	General projections	Trend	Data Confidence
Air temperature	• 1.5°C-7°C increase by 2080s depending on climate scenario and model used • Greater increases in the winter • Increased frost-free period and growing season	↑	High evidence High agreement
Precipitation	• 20% increase in annual precipitation across the Great Lakes Basin by 2080s under the highest emission scenario • Increases in rainfall, decreases in snowfall • Increased spring precipitation, decreased summer precipitation • More frequent extreme rain events	↑	High evidence Medium agreement
Drought	• Projected increases in frequency and extent of drought	↑	Low evidence High agreement
Wind	• Increased wind gust events	↑	Low evidence Low agreement
Ice storms	• Greater frequency of freezing rain events	↑	Low evidence Low agreement

Projections for the GTHA's climate by 2050 generally align with those for the Great Lakes Basin with effects that may be viewed positively or negatively. For example, projections for Toronto expect that (Figure 6):

- The number of "hot days" above 32°C will quadruple by 2050 and increase almost 8x by 2080, compared to the historical (1981-2010) baseline;
- Rainfall events (e.g., 2-hour events) will increase in intensity for 1-10 year storms and 1-100 year storms;
- Heating degree days will decline, lowering winter heating requirements, but cooling degree days will increase significantly, resulting in increased demand for summer air conditioning; and
- Changes in freeze/thaw cycles on a monthly basis will be variable, with significant declines during the "shoulder" months in April and November, modest declines in March and December, and slight increases during January and February.

Figure 6: **Selected Climate Change Projections for Toronto – 2020s, 2050s and 2080s**[25]



Municipal readiness to respond

When considering the likely impacts of climate change, the climate itself is only one part of the equation. Of equal importance is the vulnerability of human systems, and our capacity to adapt and become more resilient to whatever the climate brings our way. Municipalities need to improve their own adaptive capacity and act to make their infrastructure less vulnerable. This is relevant to Metrolinx given that our infrastructure assets are interdependent with the assets of municipalities (e.g. stormwater management systems) and other agencies (e.g. hydro utilities).

Infrastructure and adaptation deficit. The infrastructure challenges of Canadian municipalities can be described in terms of an *infrastructure deficit* and an *adaptation deficit*. The infrastructure deficit reflects an ongoing failure to repair or replace physical assets that exhibit unacceptable condition or performance; in 2007, the Federation of Canadian Municipalities estimated that Canada's municipalities faced an infrastructure deficit of $123 billion[26], and in 2015 the Auditor General of Ontario raised concerns about the state of good repair for existing public infrastructure and the need for additional spending for maintenance and renewal.[27] Further, the 2016 Canadian Infrastructure Report Card that found a similar situation with public transit systems, reporting that more than half of their fixed assets were in either fair, poor or very poor condition.[28] The adaptation deficit reflects an additional gap between the infrastructure improvements needed to ensure acceptable performance in today's climate, and those needed to ensure acceptable future performance in the face of climate change impacts; the value of the adaptation deficit of Canadian municipalities is unknown, but is likely immense.[29]

Flood risk. Flood risk is one area where the readiness of GTHA municipalities to deal with current and future climate risks has been studied. In 2015, the cities of Toronto and Mississauga were surveyed about their level of preparedness to limit potential flood damage from current (2015) and anticipated (2030) extreme precipitation events; they received B- and C+ scores, respectively.[30] Both fared well in areas of flood plain mapping and land use planning, but were below average in water drainage capacity and the ability to keep watercourses clear of debris at key times during the year. Another recent report assessed the flood risk and preparedness of small- and medium-sized communities in Ontario including several in Metrolinx's service area (e.g. Guelph, Oakville, Barrie, Oshawa, Brampton, Kitchener, and Burlington), as well as Conservation authorities including three in the GTHA (i.e. Kawartha Region Conservation Authority, Credit Valley Conservation Authority, and the Toronto and Region Conservation Authority).[31] Since most municipalities currently lack the expertise to assess climate change risks and adaptation costs and benefits, they may be unable to justify and prioritize adaptation measures, even though they recognize flood risks as a significant concern.

Knowledge building. The capacity of municipalities and transit agencies to respond to climate change is supported by their involvement in associations that focus on building and sharing knowledge. From a municipal perspective, the Federation of Canadian Municipalities (FCM) and the International Council for Local Environmental Initiatives (ICLEI) offer training and guidance to identify and assess the potential impacts of climate change on infrastructure.[32] From a transit perspective, the Canadian Urban Transit Association (CUTA) and the Transportation Association of Canada (TAC) are both raising awareness of the importance of resiliency and adaptation to climate change. Building sustainability and resiliency is a core theme of CUTA's long-term vision for the transit industry[33], while TAC initiated a Climate Change Task Force in 2008 that was tasked with ensuring that all of the association's research and communication activities give appropriate consideration to climate change mitigation and adaptation; the task force has recently been given permanent committee status.[34] TAC is also in the process of having the City of Toronto's Climate Change Risk Assessment Tool redesigned so that it can be applied to transportation systems.

2.3 Metrolinx's vulnerabilities and the need to act

Areas at risk due to extreme weather

A significant proportion of Metrolinx's infrastructure and operations functions well under most weather conditions, but some have been known to be vulnerable to extreme weather events. A selection of Metrolinx's vulnerabilities based on anecdotal evidence are summarized as follows. Note that resiliency and adaptation measures that reduce vulnerability are already being implemented for many of these assets:

Rail tracks. Extreme temperatures, intense rainfall and strong wind gusts can significantly impact track integrity. Hot temperatures above 32°C can cause track warping and sun kinks, while severe cold (<-23°C) can cause tracks to break. Long stretches of high heat (e.g. three days or more) increase the risks to track integrity, and prolonged drought conditions increase the risk of grass fires along rail corridors. Intense rainstorms can lead to flooding, embankment erosion and slope instability, which in extreme cases can lead to track washouts. Wind gusts can blow large amounts of vegetation and other debris onto tracks, resulting in delayed or cancelled rail services. Snowfalls of more than 20 centimetres are a concern, and rainfall of more than 10 millimetres while snow is also melting can create flooding problems.

Track switches and train doors. Freeze-thaw cycles or heavy snowfalls can cause ice and snow to accumulate between moving rails, blocking and freezing the switches that allow trains to move from one track to another. Ice and rocks frozen to the bottom of trains can also fall into switches and prevent them from closing properly. Switch heaters or snow clearing devices have been installed along key segments of our rail corridors, mostly fueled by natural gas, although the newly constructed East Rail Maintenance Facility has electric heaters. Generally natural gas heaters are more resilient (less vulnerable to power failure than electric heaters), but generate more GHGs than electric heaters. Ice and snow build-up can also cause train doors to stick or become inoperative.

Stream crossings and culverts. Intense rainfall and overland flooding can cause instability of embankments, and can compromise the integrity of ballast. Flood events are often a function of culvert size, and whether there is debris blocking and redirecting overland flows seeking streams and rivers. On July 8, 2013, an intense storm dropped 126 millimetres of rain at Pearson International Airport; more rain fell during the evening rush hour than during an entire average July. Along the Lower Don River portion of the Richmond Hill Corridor, flooding was extensive. It partly submerged a GO train, and caused a partial washout at track level. The situation could have been worse if the upstream G. Ross Lord Dam and reservoir had not held back additional water that otherwise would have increased flows.

Other washouts happened on the same day along the Lakeshore West, Richmond Hill, Barrie and Kitchener Corridors. In these cases, the washout of ballast was caused by overland stormwater flows that either exceeded the capacity of culverts, or were blocked by debris preventing the normal flow of water under the tracks.

Additional impacts on July 8, 2013, included flooding at Union Station that affected customers and knocked out power and vital communication systems, and flooding at TTC's Kipling subway station that restricted access to the Kipling GO station and stranded customers. All told, these events impacted Metrolinx's reputation for safe and reliable transit services. Strategic Communications, for example, received 56 media calls related to service disruptions, while the Customer Contact Centre received 154 comments including 55 complaints. About 1,400 customers had to be evacuated by Toronto Marine Rescue Services from the partly submerged train along the Lower Don River. Finally, 17,500 passengers along the Lakeshore West route used a "bus bridge" between the Long Branch and Port Credit GO stations during the recovery period from July 9 to 11, requiring 259 bus trips.[35]

Stations and facilities. Intense rainstorms, extreme heat and freeze-thaw cycles affect GO stations and other facilities. Roofs are also vulnerable to high wind gusts, and in some cases heavy snow-loads. Cracking and deterioration of many different materials are possible. Pedestrian tunnels and elevator pits can be vulnerable to flooding, and tunnels are also vulnerable to premature deterioration due to freeze-thaw cycles.

Union Station, the main hub of the Metrolinx rail and bus network, has been vulnerable to intense rainfall events and flood conditions, and power outages caused by freezing rain events. However, preserving Union Station operations is critical to keep the entire network functioning. There is limited redundancy in the main electricity feed from Toronto Hydro, and in 2013 the station only had back-up generator capacity to provide four hours of electricity supply in case of a power outage. In response to the July 8th, 2013 storm and the December 2013 ice storm, a number of measures have been introduced by the City of Toronto that greatly enhances the climate resiliency of Union Station, notably the installation of two diesel generators that supply back-up power for longer time periods (10 hours at 100% load; more than 24 hours for emergency load), and the inclusion of a rainwater collection and cistern storage system in the new York Concourse that increases the station's stormwater management system capacity.[36]

Snow clearing and removal are also an ongoing problem at Stations, especially on surface parking lots and platforms. Some stations have glycol-based platform snow melting systems installed, which generate GHGs but reduces the application of rock salt on our platforms.

Electrical power. Recent power outages have been caused by intense rainfall, flooding and freezing rain, and pose significant problems for Metrolinx operations and infrastructure. For locomotives and coaches, way-side power is needed during blackouts to start trains and their electrical components. Although not all GO stations have back-up generators, those that do typically generate enough power to last four hours—enough time to evacuate passengers, but insufficient to maintain operations during prolonged blackouts. Segregated power can help to operate elevators and other essentials, and to pump out elevator pits in flood conditions. Power is also needed to operate communication systems that keep customers informed on trains and in stations. Metrolinx expects its power demands to increase significantly in the coming years as it both expands and electrifies its rail services.

Communications. Communication systems, including large infrastructure (e.g. radio towers and antennas, and their electronic equipment sheds) are vulnerable to intense rainfall, flooding, extreme heat and freeze-thaw cycles. This applies to systems owned and operated by Metrolinx, in addition to those owned and operated by others (e.g. Rogers, Bell, Telus, etc.). Some sheds/cabinets (e.g. for Radio Towers, Signals) have had back-up systems installed, such as air conditioning units, and back-up power (battery and diesel generators). It is critical that customer communication be preserved during extreme weather events, as well as before them (i.e. to give advance warnings).

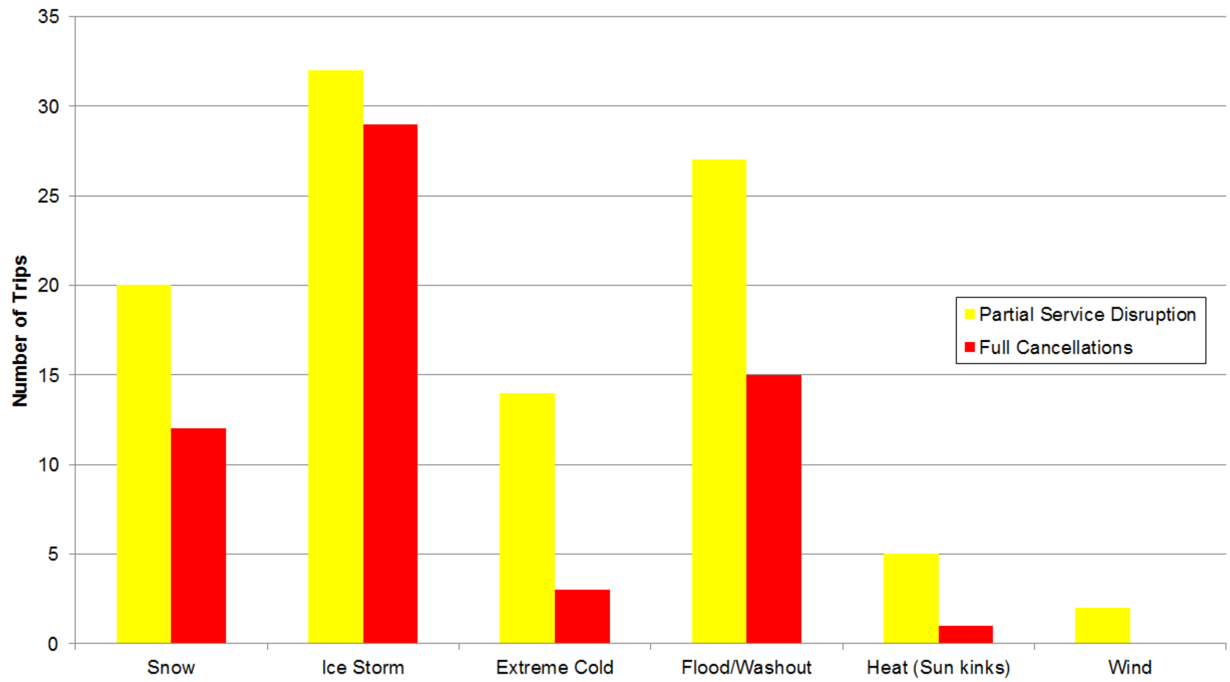
Crews, staff and customers. Intense rainfall and flooding, freezing rain and ice storms, and extreme heat events can pose problems for crews and staff. Extreme heat can lead to heat exhaustion and cause delays in work completion. Extreme weather can impact staff arrival times and service levels. Customers can also be impacted by extreme weather events, from having mobility choices disrupted or severely limited to being stuck on stranded or flooded vehicles.

Impacts of extreme weather on rail infrastructure and services

We can obtain a more complete understanding of the vulnerability of Metrolinx's rail infrastructure assets and services by examining the impacts of actual past weather events on on-time performance.

Overall effects. Information about the on-time performance of scheduled GO rail trips between January 2013 and August 2015 shows which extreme weather conditions caused service delays and cancellations, and which corridors are more vulnerable to extreme weather conditions (see Figure 7). The December 2013 ice storm caused the greatest number of partial and full cancellations, exceeding those from floods or washouts, extreme heat or cold, snow and wind. More than 800 trips arrived at least five minutes late over this period, with winter events causing more delays than floods, heat or other non-winter events. It should be noted that summer daily maximum temperatures during this period were relatively cooler compared with those that occurred in 2016, as well as compared to hotter years that occurred earlier this millennium.

Figure 7: **Full and partial cancellations by weather event, January 2013 to August 2015**[37]



The need to act

The U.K.'s *Stern Review on the Economics of Climate Change* (2006) clearly outlined the global economic costs of climate change's potential impacts, relative to the costs of mitigating emissions.[38] It concluded that investing 1 to 2 percent of global Gross Domestic Product (GDP) could reduce GHG emissions sufficiently to avoid a doubling of atmospheric carbon levels, whereas the cost of impacts could be up to 20 percent of GDP. The report also emphasized, "Adaptation to climate change—that is, taking steps to build resilience and minimise costs—is essential. It is no longer possible to prevent the climate change that will take place over the next two to three decades, but it is still possible to protect our societies and economies from its impacts to some extent—for example, by providing better information, improved planning and more climate-resilient crops and infrastructure."[39]

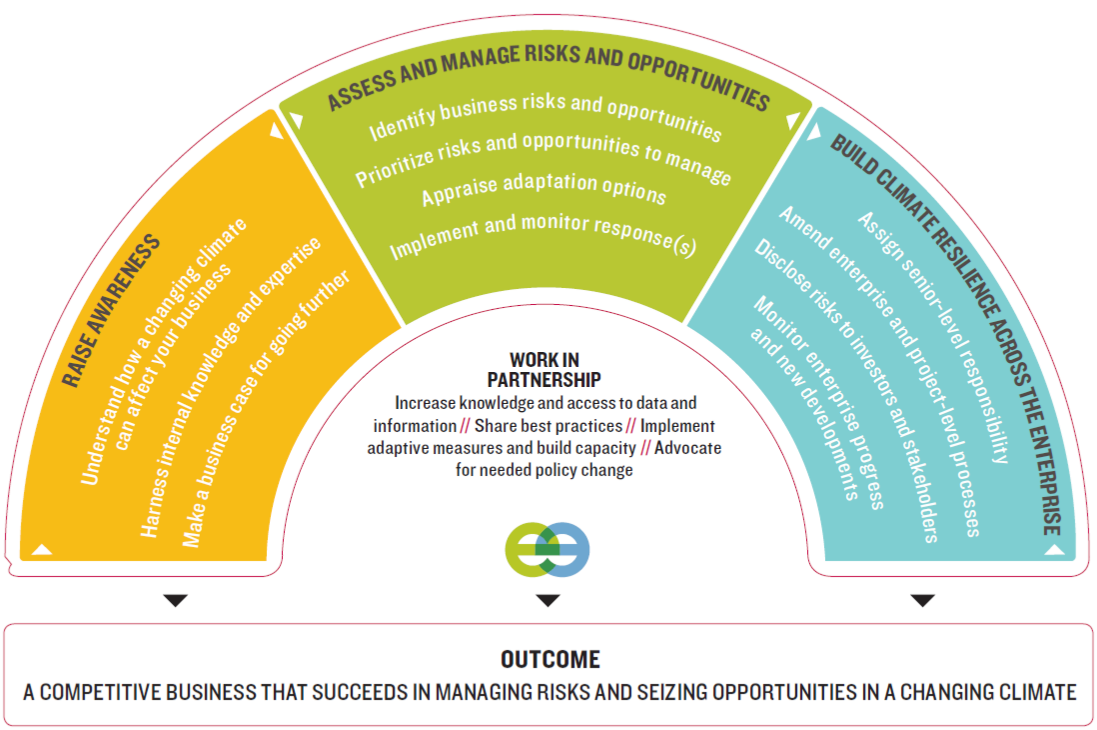
There are many reasons for an organization, particularly a public agency, to enhance resiliency and adaptive capacity in the face of climate change. Canada's National Round

Table on the Environment and the Economy (NRTEE) suggested that action is justified for three reasons:

- *First* – Doing nothing would expose an organization's assets, services, customers and employees to the full force of extreme weather events and climate change, and it impede the ability to meet organizational objectives and the expectations of investors, taxpayers, customers and employees.
- *Second* – Canadians who depend on public transit and similar public services have a growing expectation that decision-makers will take climate change into account when planning, building and operating infrastructure.
- *Third* – While significant risks will arise from climate change, adaptation measures could also create new opportunities for job growth and prosperity, such as drought resistant tree breeds, and innovative engineering solutions.[40]

For NRTEE (see Figure 8) the key to success in managing risks and seizing opportunities in a changing climate is an agency's ability to raise awareness, assess and manage risks and opportunities, and build resiliency across the enterprise. While these action areas are largely internal, agencies are encouraged to also share best practices and work in partnership with external stakeholders.

Figure 8: **NRTEE approach to business success in a changing climate**[41]



GTHA residents have already seen first-hand the very real risks of climate change, and the disruption they have caused to Metrolinx's assets, services and reputation. Having reviewed the science and the available evidence, Metrolinx should aim to proactively identify and address the climate vulnerabilities of its infrastructure and operations. In doing so, it strives to balance the required investments against possible risks, while giving priority to its role as a service provider and guardian of public safety.

3 RESILIENCY INITIATIVES AT METROLINX

3.1 Vulnerability assessment pilot project

After its formation in 2015, Metrolinx's Resiliency Working Group conducted an initial review of best practices in vulnerability assessment. Based on the results, it was tasked with engaging a consulting team to apply Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol to six assets that are broadly representative of infrastructure across the regional transit network.[42] This exercise was the first use of the PIEVC Protocol to assess transit infrastructure assets in Canada[43], and made a substantial contribution toward better understanding of the vulnerability and risk of Metrolinx's assets to extreme weather events and climate change.

The project team included internal staff, engineering consultants familiar with Metrolinx assets (AECOM), climate experts (Risk Sciences International), and flood experts (Toronto Region Conservation Authority (TRCA)). The six assets studied were chosen based on factors including ridership, strategic importance, vulnerability history, and system-wide significance. They included a bus maintenance facility, a rail maintenance facility, two GO stations and sections of two rail corridors.

Climate parameters, thresholds and projected probabilities

A key initial step in the study[44] was to identify several key climate-related inputs into the PIEVC protocol:

- Climate parameters that may impact the asset (e.g. high temperature);
- The threshold(s) at which the climate parameter could become a concern for the asset (e.g. extreme temperatures over 40°C); and
- The probability that the climate parameter will exceed the threshold during the study period of 2015-2050.

A total of 12 key climate parameters and 21 different thresholds were established by the project team based on their potential impact on assets, service and the safety of staff and customers, among other considerations (see Appendix II). Future probabilities of meeting each climate parameter threshold were then estimated, including the probability of the event occurring *at least once* during the 35 years between 2015 and 2050. The estimation of probabilities was based on historical data from Toronto Pearson International Airport and a group of more than 40 climate models released by the IPCC AR5 in 2013[45]; the climate change scenario adopted was the highest of the four representative concentration pathways (RCP8.5), reflecting a GHG emissions trajectory comparable to business as usual through 2050. Once identified, the climate parameters, thresholds and probabilities were applied to a suite of infrastructure components (see Figure 9) to determine their vulnerability and risk, including high-level estimates of riverine and urban flood risk as well as future projections of IDF statistics.

Figure 9: **Infrastructure components assessed for PIEVC climate vulnerability and risk assessment**[46]

Rail corridors	Facilities	Stations
Track Rail Road bed Turnouts	*Roofs* Building Roof canopies Green roofs Solar panels	*Roofs* Main building Roof canopies
Structures Culverts Bridge superstructure Bridge substructure Signal bridges	*Walls* Solid Glass	*Walls* Solid Glass Mechanical (elevator, sprinkler systems)
Signals and communications Switches Track circuits Wayside signals Bungalows and cabinets Radio towers Electrical power supply	*Site* Parking lots Street access Back-up power	*Site* Platforms Platform canopies Parking lots Parking structures Street access Back-up power

General findings and vulnerabilities

At a workshop convened to apply the climate parameters, thresholds and probabilities to the selected infrastructure assets, internal and external stakeholders identified about 450 interactions across the six assets. Of these interactions, 47 percent were ranked as low risk, 44 percent as medium risk, and 9 percent as high risk. Overall, the study team determined that Metrolinx has developed good adaptive capacity through its built infrastructure, operating practices and back-up systems in many areas. Well-designed facilities and effective interventions have helped to protect the safety of Metrolinx's staff and passengers during a variety of recent weather events. However, the study also found that improvements could be made in a number of areas to improve confidence in the system's ability to withstand projected future climate conditions and more extreme weather events. Many measures are already under consideration, being planned, or have been implemented that address the high risks identified for rail corridors, stations, and facilities.

Diverse recommendations were developed to enhance resiliency across the organization in the short, medium and long terms. The most obvious effects of climate change were noted as increases in temperature, having potential impacts on track, employee productivity and customer experience, and increases in intense precipitation events and the risk of both riverine flooding (along the Lower Don River Valley) and overland/urban flooding. Additional study and analysis are required to better understand these risks, including their interdependencies with other infrastructure (e.g. stormwater infrastructure and electricity supply), as well as spatial variability across the GTHA. Thunderstorms, wind intensity and freezing rain are other climate parameters where more study is needed; factors to be assessed include ice accretion on rails and (in the future) overhead catenary wires.

This study enables Metrolinx to better address its resiliency needs by establishing a central database for asset conditions and weather-related incidents; assessing vulnerabilities and risks across the entire transit network; adding resiliency measures to future capital projects; enhancing maintenance and inspection practices; and incorporating extreme weather events into emergency response planning. In this context future studies should consider flood risks from intense storms across the entire regional transit network that includes examining the impacts to Municipal infrastructure adjacent to rail corridors, stations and facilities. The relationship between transit infrastructure and municipal infrastructure are interdependent, and in the case of stormwater management systems, undersized culverts can cause significant flooding to transit infrastructure, municipal roads and adjacent areas, or both.

3.2 Enterprise Asset Management

Enterprise-wide asset management program

In 2014, Metrolinx conducted an asset management capability assessment, which led to a roadmap for further developing Metrolinx's asset management capabilities in line with industry best practice.[47] The project consultants applied a proprietary model that is structured around the Federal Transit Administration's (FTA) asset management framework and comparable to ISO 55001, the international asset management standard.[48] The assessment determined that Metrolinx's understanding and application of asset management principles were consistent with other agencies, which are generally early in their stage of development and maturity. The organization had relative strengths in capital planning and new asset delivery, compared to managing existing assets. Weather and climate change were identified as key risks, and suggested that more could be done to integrate short-term weather projections into operations and contingency planning, in addition to integrating long-term climate change projections into capital needs analysis.

In response to the consultant's assessment report and in recognition of the need to transform and improve the way that asset lifecycle is managed across the organization, Metrolinx launched an enterprise-wide asset management (EAM) program in February 2016.[49] This program was required to improve asset management practices and ensure fiscal accountability and sustainability as infrastructure assets, service levels and ridership grow substantially over the next 15 years.

The EAM program offers a platform for measures that enhance resiliency and adaptive capacity to extreme weather and climate change, in a manner consistent with best practices adopted by leading transit agencies. It will be implemented over five years, with objectives for improvement in seven areas: customer experience, risk management, fiscal management and planning, asset performance and utilization, operational and on-time performance, standard practices and organizational alignment across business units, and evidence-based decision making. Its guiding principles include meeting or exceeding regulatory requirements, aligning with industry standards, leveraging common data and processes across Metrolinx, driving program decisions with business cases, optimizing customer needs and safety with lifecycle costs, and implementing quick wins.

Enterprise GIS platform

In assessing climate change risks, leading transit agencies have demonstrated the importance of having a comprehensive GIS dataset that includes a detailed inventory of assets with design standards and state of good repair, and climate change data including flood risks. Metrolinx recently launched an integrated Enterprise GIS Project to manage, share and use spatial data and related information across the organization. The project consolidates GIS data across Metrolinx, and shares information with external governments and agencies. It is a good opportunity to link resiliency-related data from different departments (e.g. stations having back-up generators, service disruption locations, ridership numbers by station), conservation authorities and municipalities (e.g. for riverine and overland/urban flood risk, respectively), and utility providers (e.g. Toronto Hydro). The GIS Enterprise Risk Management system currently offers over 100 layers of data including GO Train routes and stations, GO Bus routes and garages, Mobility Hubs, and many others. In addition, responsibility for the Enterprise GIS platform has recently been consolidated within the Enterprise Asset Management program.

3.3 Design practices

Design Excellence Guidelines

Metrolinx has recently developed new Design Excellence Guidelines to bring design consistency to future capital projects, to enhance the customer experience, and to guide simple, robust solutions that are economically and operationally viable. To minimize the impacts of climate change and extreme weather on station functionality and customers, the guidelines integrate the principles of resiliency and adaptation.[50] They promote design features that help reduce overland/urban flooding and the urban heat island effect at stations. They promote the use of LID best practices as outlined by the Credit Valley

Conservation (CVC) and TRCA[51], including permeable paving and bioswales to ameliorate flood risk both on-site and downstream. Resiliency to flood and drought is a core element of the planting strategy, and takes climate projections into account by promoting species that will thrive as future bioclimatic conditions across the GTHA become comparable to what currently exists in the Carolinas.

Preferred track laying temperature standard

Metrolinx has actively addressed resiliency concerns around the impacts of hot temperatures on railway track integrity (i.e. bending and buckling, as discussed in Section 2.3).[52] When continuous welded rail is installed in a corridor, it is first de-stressed in accordance with regional preferred rail laying temperature (PRLT). The PRLT across Canada has traditionally been 32.2°C (90°F), and virtually all GO Transit track in service at the turn of this century was in this category. However, increasing mean summertime daily temperatures has led Metrolinx to adopt a higher PRLT of 37.7°C (100°F) for all replaced or new track including the UP Express Corridor. This was a direct response to measurable trends, rather than a proactive strategy with long-term climate change in mind.

For historical reasons the track in various rail corridors has varying PRLT, and therefore an uneven spatial pattern of risk to high temperatures although other North American Class 1 freight railroads (e.g. CN track) have also made the change to a higher standard (or are in the process of doing so). Buckling remains a potential threat during times of high or rapidly rising temperatures, typically during late spring and summer and between the hours of 11:00 a.m. and 8:00 p.m. Higher-risk locations include curves, bridge approaches, at-grade crossings, crossings with other railways, rock cuts, areas with a history of lateral instability, and locations with a transition from wood to concrete ties. To ensure that it is always safe to operate trains during days with hot temperatures and heat waves, Metrolinx implements a wide range of remedial measures including increased patrols, speed restrictions (slow orders), and rail adjustments where early problems appear. Slow orders are common during high temperature periods, and in July 2016 a patrol discovered a sun kink along the Barrie Rail Corridor near Newmarket.

The new, higher PRLT has been incorporated into the GO Transit Track Standards (RC-0506-02TRK)[53] that came into effect on June 1, 2016, and applies to all tracks and rights-of-way that are owned or operated by Metrolinx. Implementation of Regional Express Rail and the electrification of key rail corridors will also involve a shift from wooden to concrete ties, which will also make tracks more resilient to high temperatures. When replacing aging or damaged ties, concrete and wooden ties can be interspersed, and a pilot project is under development at Metrolinx that will reduce service disruptions. Further, with Continuously Welded Rail properly de-stressed and maintained, and with minimum temperatures rising, an increase in welded rail pull-a-parts caused by extreme cold temperatures is not anticipated. Regularly scheduled track patrols are expected to be sufficient, along with the railway signal system "fail safe design approach", to help identify a pull-a-part general location in the remote chance when they occur.

Moving forward, more knowledge is needed about the actual rail laying temperature of tracks across Metrolinx's network, especially in high-risk locations. There are also unknowns regarding the spatial variation in high temperatures across the GTHA, which is a key risk factor; while there is considerable confidence in the projection of higher maximum summer temperatures by 2050, historical weather data show that on any given day there can be significant temperature variation between different areas within the GTHA.

Back-up generator standard

During prolonged power outages, Metrolinx's ability to evacuate facilities and maintain service depends on having a reliable system of back-up generators.

For more than a decade, Metrolinx has proactively improved back-up power systems at its rail and bus maintenance facilities. At bus maintenance facilities this includes diesel-powered generators, as well as co-generation and tri-generation systems fueled by natural gas that can operate during power interruptions and during peak electricity pricing periods. The Willowbrook Rail Maintenance Facility has a back-up diesel generator to provide power to its control centre, and a locomotive can provide power for other essential services.

After the storms of July and December of 2013 caused several stations and facilities to completely lose power, Metrolinx undertook a review of emergency power requirements for all GO facilities. At the time, the Design Requirements Manual (DRM) standard allowed a combination of generators and uninterruptible power supply (UPS) systems to provide back-up power for critical facilities and systems; generator back-up was only mandatory at GO station parking structures. The new DRM standard requires back-up power generators for GO rail stations and parking structures, bus terminals, rail layover facilities, and operational support facilities (i.e. Wolfdale, GTCC, Middlefield).[54] Back-up battery systems are required for sheds and cabinets that house computers and electronics for communications and signals, in addition to having provisions to be connected to mobile diesel back-up generators. Infrastructure elements that are covered include passenger elevators, surface parking, bus platform and bus loop lighting, heating for service counter areas, barrier-free doors in buildings and vestibules, automated teller and vending machines, and partial lighting for areas not covered by emergency lighting.

With the DRM standard, 19 new stations committed through the RER will have back-up generators. Existing stations that are planned to be rebuilt or renovated and require additional electrical service, and currently do no have back-up generators, will have them considered on a case by case basis.

While having back-up generation will help enhance resiliency across the Metrolinx network to extreme weather and climate change, as the Province transitions towards a low carbon economy, there is expected to be increased expectation to find alternatives to diesel and natural gas as the fuel source. This is already happening for the Eglinton Crosstown LRT line where Metrolinx is working with Toronto Hydro to build a battery energy storage systems that is capable of providing back-up and emergency power for up to four hours in the event of a wide-spread power outage.[55]

Vegetative clearance zone

Electrification of railway corridors for the RER will require that electrified corridors are free from debris including vegetation. Trees and other vegetation in electrified corridors could be impacted by high wind gusts, heavy rainfall, freezing rain, blowing snow or heavy snowfall. Metrolinx has therefore proposed a vegetative clearance zone along railway tracks to reduce climate change vulnerability, enable installation of the overhead catenary system and feeder lines, and ensure the safety and reliability of rail operations.[56] It is based on a European standard, and will extend seven metres from the centre of the outermost track in order to:

- Minimize the risk that limbs could fall on the track or overhead wires, sparking a fire and/or a catenary dewirement.
- Ensure safety for maintenance workers in an electrified environment.
- Reduce the extent and frequency of vegetation maintenance and any service disruptions it necessitates.

Removal of trees to establish a vegetative clearing zone is contrary to the environmental benefits associated with trees, particularly carbon sequestration. Consequently tree removals will need to be offset by a vegetative protocol that addresses the overall net amount of carbon, and also the additional co-benefits for biodiversity, species at risk, and other ecological indicators.

3.4 Emergency response planning and preparedness

Organization-wide emergency plan

When an extreme weather event causes an asset to fail or overwhelms its functional capacity, the resulting emergency situation may require the evacuation of customers and staff. Being prepared for such a situation is the goal of emergency response planning and preparedness. In the past, each Metrolinx asset (i.e. building or station) had its own emergency response plan; however an initiative is underway to compile more than 60 plans into a single coordinated emergency plan for the entire organization.

Currently there are many Metrolinx protocols that are related to emergency response planning. Some address weather conditions that could become more frequent with climate change; others do not, but could inform emergency response planning in anticipation of climate change. Some protocols provide a mechanism to monitor and report on weather-related incidents that may cause service delays or cancellations.

Service disruption protocols

When extreme weather events cause service disruptions, having protocols in place ahead of time can guide Metrolinx's response and minimize the impacts on its assets, operations and customers. Metrolinx has many protocols in place, however some may need to be improved in order to enhance our resiliency to future climate conditions. A selection of service disruption protocols are:

Flood monitoring. A flood monitoring protocol lessens the impacts of a severe rainstorm on GO commuters. In the morning, this would involve rerouting southbound trains from the Richmond Hill corridor to the Barrie corridor, to avoid flooding in the Lower Don River Valley. The reverse would apply in the afternoon, when northbound GO trains in the Barrie corridor could by-pass Oriole Station and Old Cummer Station before rejoining the Richmond Hill Corridor at Langstaff Station. Other rerouting options exist for portions of other rail corridors, depending on whether the on-board crew is qualified to operate on the alternative route, and depending on securing permission from CN, CP and/or GEXR to use their track.

Bus bridges. When GO train operation is interrupted due to severe weather or other causes, rail services are replaced by enhanced bus services. "Bus bridges" can be established to carry customers between GO stations within a single corridor, between GO stations in different corridors, from a GO station to the Union Station bus depot, or from a GO station to a nearby TTC subway station or service stop. For example, during the storm in July 2013 a "bus bridge" was created between the Long Branch and Port Credit GO stations, in response to the washout at Dixie Road.

Coordination with other transit systems. Another option in response to service disruptions is for the TTC and GO Transit control centres to invoke the GO Transit Service Disruption Protocol, allowing GO customers to use TTC services for no additional charge, although the entire amount for all rides provided will be reimbursed after the disruption is resolved. GO buses may carry customers between GO stations and TTC stations, or customers may be able to use TTC or other local transit services. This protocol applies in all seven GO rail corridors, and also involves Miway and York Region Transit.

Winter readiness and snow plan

GO rail operations can be severely impacted by single snowfalls of more than 20 centimetres, snow accumulation from multiple storms, or blowing snow. Snow cover on tracks can be a hazard, while snow, ice and debris can prevent the proper functioning of rail switches.

Winter storms can therefore reduce the availability and reliability of rail infrastructure, equipment and crews. "Off-schedule" trains can cause congestion and may compound delays to other trains; as a result, attempts to maintain full service in poor weather conditions can actually increase the risk to service delivery. Vulnerable rail transit providers typically implement a snow plan or winter readiness plan when sufficient snowfall is forecast, involving a reduction of service, the use of accurate weather forecasts, internal coordination and decision-making, and communications with customers and the public.

In the event of a severe snowstorm, Metrolinx implements a *snow plan schedule* to provide safe and reliable transportation for customers. Its key principles include:

- Optimize advanced notification for all internal and external stakeholders to implement related procedures.
- Modify schedules, focusing on sustainable service delivery without triggering more serious delays.
- Crews start and end in their normal location, thereby reducing crewing issues.
- Right-hand running only, in order to reduce crossovers, trains passing trains, and issues with signals and switches.
- Bus services that connect to train services will be adjusted accordingly.

Successful implementation of Metrolinx's snow plan is somewhat contingent on the accuracy of weather forecasts, as well as on coordination with the various snow plans being implemented simultaneously by the companies and agencies that operate across Metrolinx's rail system (e.g. CN, CP, Toronto Terminal Railways, and Pacific Northern Railway).

In some cases, weather conditions can deteriorate quickly and significant snowfall can occur without a snow plan being issued; this occurred on February 2, 2015 when a severe storm dumped 20 to 40 centimetres of snow across the GTHA. Operational problems were exacerbated by communication and website breakdowns, and numerous GO trains were delayed or cancelled.[57] The storm prompted an external review of Metrolinx's winter readiness, which concluded that key elements of the snow plan were consistent with best practices but some improvement could be made. Those included more consistent use of weather forecasting information, the creation of a comprehensive Winter Readiness Plan, the annual review of the snow plan's effectiveness, and the collection of performance data during severe weather conditions. There have been other occurrences of the *clear skies phenomenon* when snowstorms occur overnight and then pass by the following day, resulting in clear sky conditions when the snow plan is actually enacted. Uncertainty in duration and intensity of snowstorms requires Metrolinx to make a calculated decision in implementing the adjusted schedule, which involves all of the effort and actions that lead up to that decision.

3.5Collaboration with partners and stakeholders

Metrolinx has worked with many stakeholders to learn about, and share information on, climate change vulnerability, risks and resiliency. This has given Metrolinx an opportunity to communicate its progress and to keep abreast of best practices in climate change modeling, vulnerability assessment, and measures to enhance resiliency and adaptive capacity. Metrolinx staff have attended meetings and learning events on climate change science and data, vulnerability and risk, and flood resiliency. They also contributed to a national assessment report on climate change risks and adaptation practices in the transportation sector, led by Transport Canada.[58]

City of Toronto's Resilient City Working Group. Metrolinx is an invited member of the City of Toronto's Resilient City Working Group, which also includes many City divisions, agencies and corporations, as well Hydro One and other stakeholders. The Working Group provides knowledge and technical support to senior decision-makers, and facilitates action on resiliency within the City's operations. In 2015, it was asked to review previous actions regarding extreme weather, to identify planned activities that would make the City's assets and services more resilient, and to identify other needs to ensure the safety and security of assets and services under extreme weather conditions. The Working Group identified ten themes for a high-level risk assessment, giving highest priority to utilities, transportation and water/wastewater. Metrolinx participated in the risk assessment of major assets in response to two hypothetical events: a severe heat wave affecting the Kitchener Rail Corridor, and a rainstorm comparable to that of July 2013 that affected the financial district, Union Station and the Union Station Rail Corridor. Some key conclusions of the overall exercise included:

- the importance of looking at vulnerability and risk at the level of the overall system as well as individual assets;

- the value of looking at the worst-case scenario where the most severe weather conditions could occur, and when asset failure may result;
- the importance of collaborating with other stakeholders to reduce flood risks and enhance emergency response and recovery;
- the essential nature of adequate pumping systems and back-up power systems as resiliency measures;
- the need for riverine and overland urban flood mapping to better understand current and future flood risk;
- the potential of integrating climate change risks and resiliency measures into procurement contracts, in order to enhance the ability of transportation infrastructure to withstand future extreme climatic events;
- the need for a robust and coordinated communication plan and system to alert the public of measures being implemented in response to extreme weather;
- the importance of managing public expectations, and clearly articulating that some risks and service disruptions are unavoidable;
- the highly interconnected nature of regional transportation systems, and the need for more coordination and synchronization (including higher design standards) to enhance resiliency;
- the benefits of increased information sharing (e.g. GIS data), collaboration (e.g. joint projects) and integration (e.g. service disruption protocols) between transportation agencies for enhanced resiliency; and
- the need for better understanding of interdependent risks between transportation, utilities and water management to enhance resiliency.[59]

The City of Toronto Resilient City Working Group is also a useful conduit to

The Toronto and Region Conservation Authority (TRCA). The Toronto and Region Conservation Authority (TRCA) has a service agreement with Metrolinx, and along with other Conservation Authorities who manage watersheds that overlap with Metrolinx assets, provides flood risk information as part of the Environmental Assessment process. Metrolinx also works with the TRCA and the City of Toronto through the Lower Don Transportation Corridor Working Group, which shares information and provides opportunities for collaboration to reduce flood risk. Metrolinx and the TRCA are also members of the City of Toronto Resilient City Working Group.

International and Corporate Opportunities. There are various international and corporate opportunities for Metrolinx to learn from other agencies and companies, and share our own knowledge, experiences, and key lessons learned that are vital to effectively advancing climate resiliency across an organization. Metrolinx recently became a founding member of the Canadian Chapter of the Prince of Wale's Accounting for Sustainability (A4S) CFO Leadership Network – a global inititiative led by Chief Financial Officers who are committed to sustainability. Metrolinx has also recently joined ARISE Canada (Private Sector Alliance for Disaster Resilient Societies) as an associate member – the Canadian Chapter of an international initiative through the United Nations International Strategy for Disaster Reduction (UNISDR), that is geared towards the private sector. Participation through both of these initiatives may provide opportunities for corporate collaboration on climate resiliency initiatives on a national and international scale.

On a regional scale the City of Toronto Resilient City Working Group continues as a key mechanism to share information and develop collaborative partnerships with municipal departments and other agencies who own and manage major infrastructure assets (e.g. TTC, Toronto Hydro, and the Greater Toronto Airport Authority). The Rockefeller Foundation's 100 Resilient Cities program, and the recently hired Chief Resilient Officer for the City of Toronto, represents a two-year opportunity to address resiliency in a broader sense, noting that climate is one of three key drivers to this initiative.

3.6 Planning and procurement

Planning Context

Metrolinx is in the process of reviewing and updating its Regional Transportation Plan (RTP).[60] The RTP is related to climate resiliency in the GTHA in two key ways: first, by providing integrated multimodal options, the RTP will enhance connectivity across the region and hence their resiliency to potential disruptions in travel and service caused by extreme weather events; second, by ensuring that the infrastructure assets owned and operated by Metrolinx and its partners are resilient to extreme weather and climate change, this will help support the resiliency of the communities across the GTHA that rely upon a safe and reliable regional transit system. Further, in the future it may be through the RTP that different future scenarios, involving various variables such as population growth, demographic change, and climate change projections, can be assessed to determine the effectiveness of a climate adaptation plan.

Procurement

Metrolinx has examined ways of improving procurement processes to integrate language and requirements around resiliency. This has been done on a case-by-case basis, and is moving towards a more proactive and coordinated approach.

For Project Agreements, Transit Project Assessment Process (TPAP) requirements, and Project Specific Output Specifications, there are a number of areas where extreme weather and climate change could be considered and in some cases incorporated into the procurement process for new capital projects, such as the Consultant Scope of Services:

- Certain resiliency criteria are incorporated for each climate parameter of concern.
- Stormwater management report and design aim to take into account climate change precipitation projections including future changes in IDF statistics.
- Consultant scope of service should include a climate change specialist that has knowledge of methods, tools and approaches to evaluating and mitigating the risks and vulnerability of infrastructure to climate change.
- TPAP will include consideration of climate change resiliency.
- The risk registry will include risk to climate change for various projections and time periods.
- Project management requirements will include consideration of a workplan that outlines how climate change risks and resiliency are being taken into account.

Similarly, for Technical Advisors, the following areas could be taken under consideration:

- Reference Concept Design for new projects. If further hydrogeological study is required, it should consider climate change impacts on precipitation and flood risk.

- As part of the Reference Concept Design a climate change risk assessment could be conducted for high value assets, and provide recommendations for measures that enhance resiliency.
- Compliance with environmental commitments and approvals may include through the TPAP that Metrolinx can demonstrate that new capital projects consider climate change when assessing/designing for stormwater management.

For Schedule 17: Environmental Obligations, the following areas could be considered:

- Include a climate change specialist in the list of environmental specialists within their multi-disciplinary team.
- The climate specialist should have knowledge of methods, tools and approaches to evaluating and mitigating the risks and vulnerability of infrastructure to climate change.
- Commit under the sustainability strategy to become climate resilient.
- ProjectCo's sustainability plan should identify climate change risks and vulnerabilities, and include the implementation of climate adaptation and resiliency measures where practicable. Climate change risks and vulnerabilities include, but are not limited to, riverine and overland flooding, high winds (over 120 km/hour), wind gusts, freeze-thaw cycles, snow accumulation, lightning strikes, tornadoes and ice storms.

4 OPPORTUNITIES FOR ACTION

4.1 Evidence-based decision making

It is important that decisions on climate risk and measures that enhance resiliency and adaptive capacity are based on credible and up to date information, most notably for climate change projections. The IPCC represents the most accepted evidence-based science on climate change, including GCM projections, and is updated on a regular basis. The use of ensembles of GCMs has become the established method for climate projections for over a decade.[61] The AR5 is the most recently published assessment, with the Sixth Assessment Report due out in 2020/2021.

How one manages uncertainty around climate change scenarios and projections should also follow best practices. Using the median (50th percentile) is typically adopted to inform policy decisions, while a broader range of uncertainty that falls in between the 25th and 75th percentiles may be preferred to inform design and investment decisions.[62] In some cases the lowest or highest percentiles could also be used (e.g. 10th or 90th percentile), such as when applied to specific extreme cases (e.g. considering worst case scenarios for disaster planning).

Evidence-based decision making can also inform the cost of taking action today, vis-à-vis the future costs of inaction, and should use accepted models and tools for estimating and valuing the environmental, as well as social benefits.

Adopting evidence-based decision making to manage climate change risks is consistent with Metrolinx's strong track record and corporate culture to use evidence-based planning methods and business case analysis.

4.2 Building knowledge

It is clear that progress toward resiliency will require us to develop a clearer understanding of many subjects: the nature of threats, the degrees of risk, the areas of vulnerability, the types of possible responses, and their expected effectiveness. This will require all stakeholders to work together to acquire, share and refine knowledge (an area discussed in greater detail in Section 3.5).

Climate modelling

Informed decisions around risk and adaptation require access to credible, defensible and reliable climate projections. The Environmental Commissioner of Ontario has recognized that a knowledge gap exists in this regard—namely that while climate data is generally abundant and freely available in Ontario, it generally does not always meet the needs of end users.[63]

Many end users, both in government and the private sector, also vary in their understanding of climate data and their capacity to choose and apply data appropriately. The Commissioner acknowledged that some end users require more guidance or customized data; one example is a guide to using climate information for adaptation research and decisions, produced by the Ouranos Climate Consortium, a Quebec-based non-profit organization.[64] MOECC has been addressing these concerns by funding projects to: (i) consolidate the available dataset and disseminate the data on a centralized data portal (the Ontario Climate Change Data Portal (OCCDP)); and (ii) host training sessions to improve practitioners skills in understanding and using the available climate data.

The 2017 update to Ontario's *Climate Change Action Plan and Adaptation Strategy* is expected to establish a new climate modelling collaborative to help decision-makers understand potential climate impacts, and make more informed and effective climate-resilient decisions.[65] The modelling collaborative will provide a one-window repository for information about current climate change impacts and future projections, and will offer expertise on climate change's possible impacts on different activities (e.g. farming, infrastructure, public health) and how those areas can plan for and manage risks. Until then the OCCDP provides climate change projections based on the AR4 and AR5 IPCC Assessment, while private sector portals are an additional source of information such as RSI's Climate Change Hazards Information Portal (CCHIP).

As part of the PIEVC climate vulnerability study Metrolinx engaged RSI to develop climate change projections for 12 climate parameters to 2050, which are consistent with those available through the OCCDP and CCHIP. This data set could be expanded upon to include other time periods and a broader range of projections, but otherwise what was produced for the PIEVC study should be sufficient for most decision-making needs until there is additional data provided through the new Ontario one-window repository, or if the projections are in need of updating after the release of the IPCC Sixth Assessment Report in 2020/2021.

Floodplain mapping and IDF curves

While Ontario has the most stringent floodplain land use regulations in Canada, there are many buildings, critical infrastructure assets (including sections of rail corridors), and other types of development that are located within the regional storm (Hurricane Hazel) floodplain. Determining which assets are at flood risk with climate change is a challenge. Riverine floodplain data based on the regional storm exists for most, if not all, of the watersheds across the GTHA, but there is no central repository for this data in GIS format. Neither does this data coincide with the flood conditions that have occurred as a result of events greater than the historical 100-year storm, which in the new millennium seems to be occurring more frequently across the GTHA (e.g. Peterborough in 2002 and 2004; Burlington in 2014; Black Creek (2005) and the Lower Don River (2013), in Toronto), with each causing significant social and economic costs.

Many of these extreme flood events have resulted from a combination of both riverine and overland/urban/stormwater flows, and in Ontario our understanding of municipal stormwater capacity and flood risk is relatively poor. On a micro- or site-specific scale, two-dimensional hydrologic modelling and LIDAR-based mapping can improve our understanding of flood risk, but their application can be costly and time consuming, especially on a system-wide or watershed basis. Even then flood mapping data would also need to be coupled with climate change projections that take into account future intense storms and resulting changes in flood depth and spatial extent.

The design of stormwater management systems are typically informed by locally based IDF statistics, and the MTO and Environment Canada have updated this data to 2007.[66] For infrastructure with extended lifecycles, decision makers in Ontario can use updated historical data or draw from three data portals that take into account future increases in the intensity, duration, and frequency of precipitation events.[67] While these three data portals provide viable options to consider future IDF Statistics, others have recommended that adopting a risk based approach is also a viable alternative, where the focus is directed at determining an agency's risk tolerance level.[68] This could involve engaging expert advice to determine which projections are most appropriate for informing decision-making, including flood risk assessment. In the GTHA this would likely involve consideration of flood plains for the regional storm, the 100-year storm and lesser events, and future storms projected to occur with climate change.

4.3 Managing risk

Risk management overview

A strategic approach for building resiliency across an enterprise is to frame the issue of climate change adaptation within a risk management context—in essence, making it an economic or business issue rather than an environmental one. Another consideration would be to apply a safety lens, through the perspective of emergency response planning and preparedness. Managing risks to climate change is becoming more common within business management practices, initially in terms of GHG emissions and reduction plans, and more recently to include disclosure of vulnerability and risk to extreme weather and climate change. In Ontario carbon emission reporting is a requirement to be eligible for securing Green Bond funding, but the need to consider resiliency measures that reduces vulnerability and risk to extreme weather and climate change is still relatively limited.[69]

Using a vulnerability and risk -lens, businesses might see possible climate change impacts in at least three key areas: supply chain, physical threats to operations, and reputation. In the case of public transit agencies, the impacts of greatest concern would include:

- *Disruptions to service operations*—Including harm to assets leading to service delays or temporary shutdowns, resulting in a loss of ridership and revenue.
- *Threats to assets and infrastructure*—Requiring adaptive investments to safeguard against climate change, and improve existing networks. Since lifespan/lifecycle over infrastructure is 10 years or more, strategic investment cycles present critical opportunities to make transportation systems more secure and climate resilient.[70]

While adapting to climate change may be a departure from the business-as-usual approach, it can make good economic sense. The challenge is to inform risk management decisions by demonstrating the costs of inaction (the "do-nothing" scenario), and by determining why and when anticipatory actions (rather than reactive ones) makes economic sense. While an organization's interest in risk and resiliency is often *spontaneous* (e.g. driven by a particular extreme weather event), it is more prudent—as trends become clearer and the uncertainty around the speed and magnitude of climate change is reduced—that organizations implement *proactive* adaptation measures, rather than waiting for a catastrophic event to occur. Even taking a proactive approach, in the face of small risks (e.g. low-probability events with negligible impacts) doing nothing may be an appropriate and cost-effective response. However, more significant probabilities and/or impacts might tip the scale in favour of investing in adaptation measures that leads to incremental or transformative change.

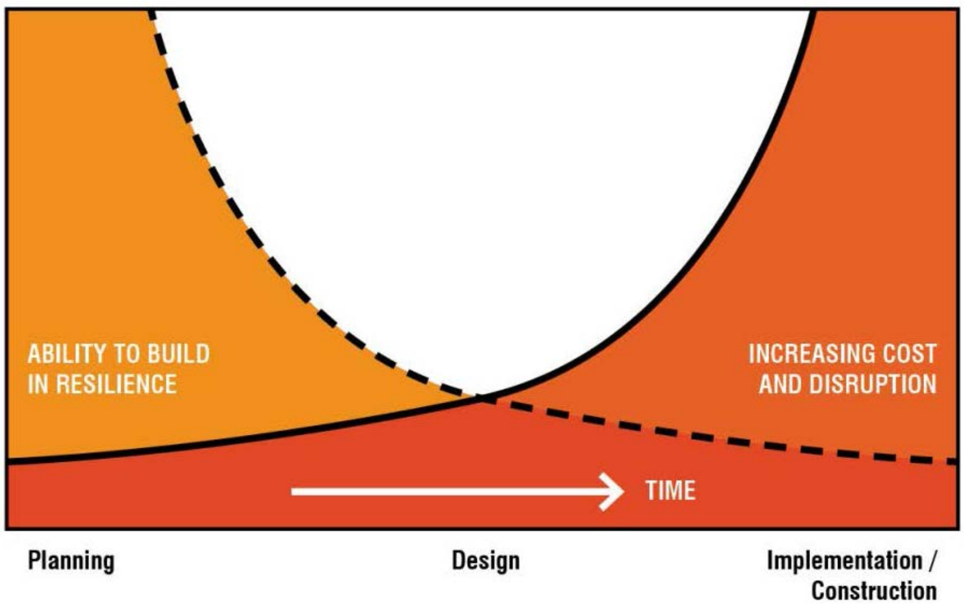
Managing risk for capital projects

There are many opportunities to embed resiliency measures through business planning, investment and operating cycles. Managing risks when resources are constrained involves balancing the expense of higher design standards against the costs of an asset failing. Investment decisions require integration of risk trade-offs, and may be constrained by the status of a given project (i.e. between conception and construction). Figure 10 shows that it is generally easier, less costly and less disruptive to build resiliency into a capital project in the planning stages, compared to incorporating resiliency into the more costly, and potentially more disruptive, construction phase.

Many countries are advocating climate-proofing of infrastructure as a priority, and recognize the need to address the design life of existing and new infrastructure as well as the need for changes in operating and maintenance practices.[71] Existing infrastructure can be problematic because it has been designed and constructed for a past or present climate, and may not be resilient to future climate conditions. New infrastructure provides an opportunity to embed lifelong resiliency into its design, operation and maintenance; doing so may require designing and building to higher standards, or embedding flexibility into the design so future adjustments can be made cost-effectively when climate conditions change.

Managing risks for capital projects is becoming more common on a Global level, where large businesses are exploring opportunities to integrate sustainability and climate resiliency considerations into finance and business practices in a way that improves efficiency and risk management. In the case of the A4S CFO Leadership Network, for example, emphasis is on sharing best practices in the optimal lifecycle management of an organization's physical assets, including long-term capital investment decisions.[72]

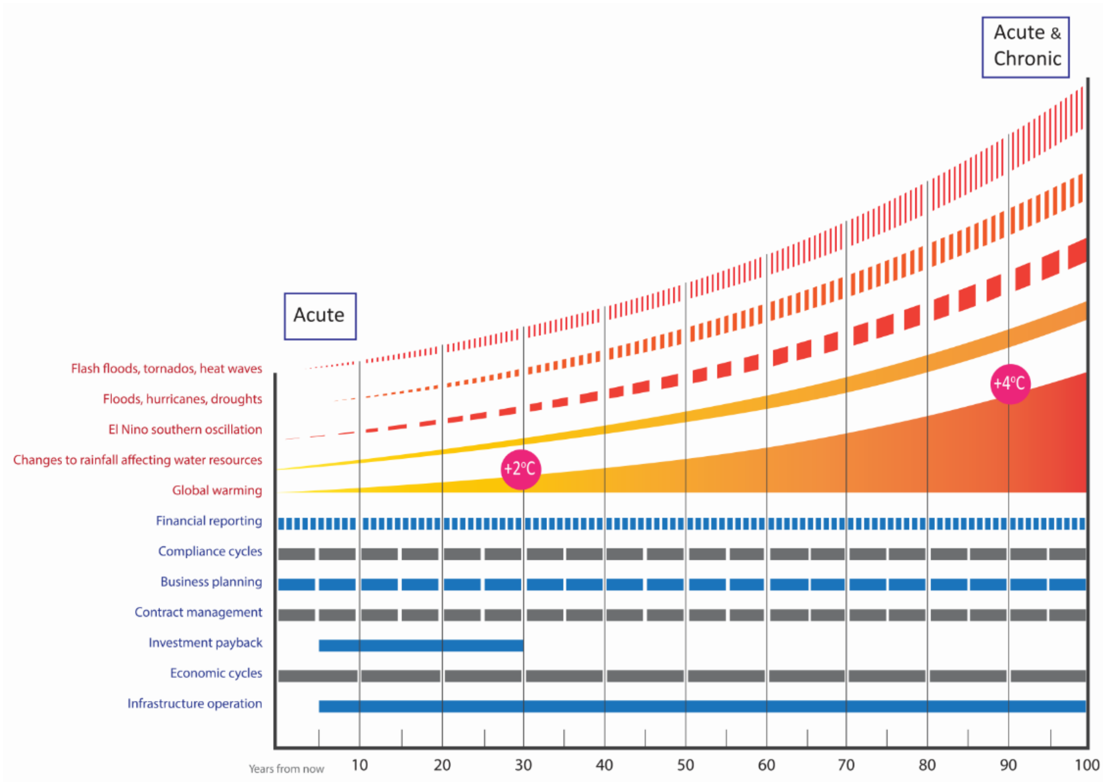
Figure 10: **Opportunities to build resilience in planning and design**[73]



Seeking a pathway to adaptation

In developing a strategy for adaptation and resiliency, Metrolinx will endeavor to consider its large base of assets through a very long-term lens of climate change that overlaps with various business management cycles such as lifecycle management, maintaining the state of good repair, and capital investment planning (Figure 11). Allocating budgets and directing resources into business management cycles could follow a number of approaches, ranging from: incremental decisions and improvements on a continuous basis; transformative, proactive and anticipatory measures that result in an immediate upgrade in design standards; or delaying transformative change until monitoring determines that such action is necessary. In an ideal case, budgets and resources would be applied where a combination of design and operations over the planning horizon would generate the most cost-effective outcome to reduce risk and increase resiliency and adaptive capacity.

Figure 11: **Climate change timeline corresponding with business planning, investment and operating cycles**[74]



4.4 Managing assets

Asset management is the systematic deployment, operation, maintenance, upgrading and disposal of assets in a manner that optimizes their lifetime cost and performance while providing service that is safe, reliable and cost-effective. Good asset management practices will result in informed and strategically sound decisions that optimize investments, better manage risk (including the risk of infrastructure failure), and take into account the potential impacts of extreme weather events and climate change. By incorporating lifecycle costs, risks and performance trade-offs in capital, operating and maintenance budgets, asset management can optimize the allocation of scarce resources.

In Ontario, the provincial Municipal Infrastructure Strategy requires municipalities to maintain Municipal Asset Management Plans that consider climate change vulnerability and resiliency; and view infrastructure expenditures through the lens of lifecycle costs, direct and indirect costs and benefits, and vulnerability to climate change impacts.[75] However, the Province provides only limited guidance on how to address climate change risks and adaptation. In Metro Vancouver, TransLink commissioned a 2012 report to assess climate change vulnerability and risk to its assets, as an initial step towards incorporating climate change into its asset management plans.[76]

The U.S. FTA requires transit agencies to prepare a transit asset management plan, and has produced a detailed guide to support this process.[77] A supplement to that guide includes information for decision-makers on how to take climate change into account with a focus on asset classes and lifecycle management. The FTA has identified 7 key opportunities to integrate climate change adaptation into asset management systems.[78] For example, in terms of condition assessment and performance monitoring, there is an opportunity to monitor asset condition in conjunction with climatic conditions (e.g. temperature, precipitation, winds) to determine if extreme weather events affects performance. This information could be used for other beneficial purposes, such as identifying high-risk areas and vulnerable assets.

In the UK, the effects of extreme weather events on on-time performance of rail service have been incorporated into climate change planning.[79] In this case, historical records for on-time performance have been monitized to determine the costs of service delays and disruptions caused by extreme weather events. Future costs are then estimated based on climate change projections, and the results are used to inform decision making for asset management and capital improvements.

This approach takes the work done by Metrolinx (see section 2.3) a step further, monetizing the effects of extreme weather on on-time performance, applying this through a climate change lens, and using this information to inform decision making for asset management and capital improvements.

4.5 Planning capital improvements

Federal and Provincial guidance

National Directions on Resiliency and Adaptation. In March 2016, Canada's federal, provincial and territorial leaders met to map out the *Vancouver Declaration on Clean Growth and Climate Change*.[80] The First Ministers made a commitment for stronger action on adaptation and climate resiliency, including adaptation policies to address climate risks faced by Canada's populations, infrastructures, economies and ecosystems, and pledged to support climate-resilient and green infrastructure.They also agreed to work together to develop a pan-Canadian framework on climate change that was implemented in 2017. The Working Group on Adaptation and Climate Resilience was tasked with identifying options for a comprehensive approach to adapt to climate change, support affected communities and build greater resilience.

Infrastructure funding is another avenue through which the federal government is aiming to enhance the resiliency and adaptive capacity of public transit infrastructure. Budget 2016 committed $500 million towards enhancing the adaptive capacity of infrastructure, while a new approach to public transit funding will focus on modernization and expansion; the first phase ($3.4 billion over three years) supports modernization and maintaining a state of good repair, while the second phase will help municipalities transition to a low-carbon economy.[81]

Public Safety Canada administers the Disaster Financial Assistance Arrangements (DFAA) program, created in 1970, that reimburses the provinces for expenses and damages resulting from natural and manmade disasters. Over the past five years, the DFAA's liabilities have increased substantially due to damages caused by extreme weather events. The Parliamentary Budget Officer has estimated that over the next five years the DFAA can expect annual costs of almost $1 billion.[82] In recognition of this, the National Disaster Mitigation Program (NDMP) was established in 2014 and earmarked $200 million over five years to help build safer and more resilient communities. The NDMP, which supports provincial and territorial cost-shared projects, should help governments, communities and individuals better understand flood risks and employ effective measures to enhance resiliency.[83]

Provincial approaches to adaptation and mitigation. While the Ontario government has focused more on reducing GHG emissions, it has also addressed the need for resiliency and adaptation in several different ways.

From 2007 through 2009, Ontario's Expert Panel on Climate Change Adaptation engaged many stakeholders including 17 provincial ministries and agencies. The panel was tasked with helping provincial and municipal governments to prepare and plan for the impact of climate change in key areas including public health, environment, infrastructure and the economy. The panel's advice[84] was eventually integrated by Ministry of the Environment into its *Climate Ready: Ontario's Adaptation Strategy and Action Plan 2011-2014*, which outlined a vision and strategy, along with five goals and 37 actions to help Ontario prepare for climate change.[85] One of the actions focused on transportation infrastructure, and concerned winter roads in Northern Ontario. Ten other actions were cross-cutting and included transportation issues in their scope; they included important recommendations to promote business approaches to risk management, undertake infrastructure vulnerability assessments, update the environmental assessment process,

develop guidance for stormwater management, increase awareness of land use planning tools, and update rainfall intensity-duration-frequency (IDF) curves.

The Ministry of the Environment and Climate Change (MOECC) recently released *Ontario's Five Year Climate Change Action Plan 2016-2020* which focused on GHG emission reductions.[86] Ontario's plan for adapting to climate change and becoming more resilient will be released later in 2017. The new *Climate Change Adaptation Action Plan* will build on *Climate Ready: Ontario's Adaptation Strategy and Action Plan*, and will also include new actions focusing on increasing adaptive capacity in key areas of the province at risk from a changing climate, including infrastructure and remote communities. The updated plan will also provide details of a new Climate Modelling Collaborative that will help decision makers understand potential climate impacts to support effective, climate-resilient decision-making.

Provincial land use policy. Ontario has taken steps to integrate climate change resiliency in its land use policies. The 2014 *Provincial Policy Statement* (PPS), which sets an overall vision for land use planning in Ontario, considers how planning for new development, including infrastructure and public service facilities, could take into account potential climate change impacts. It calls for infrastructure and land use to be planned in a coordinated, integrated manner so that they can meet current and projected needs while also being financially viable over their lifecycle, as demonstrated through asset management planning.

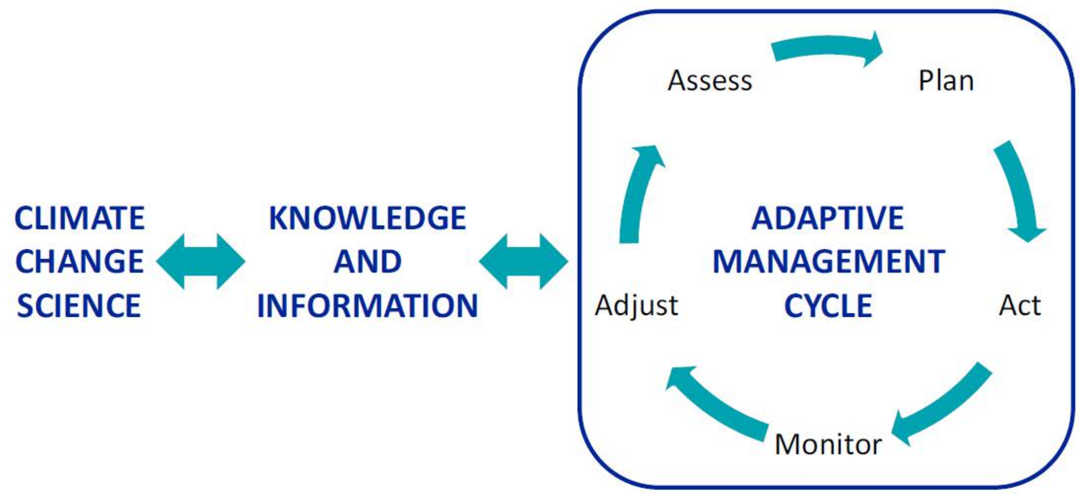
The PPS also addresses the need to protect public health and safety from natural hazards, and directs development (with some exceptions such as historic areas) to remain outside zones affected by flooding or erosion hazards. It also directs planning authorities to consider how climate change impacts could increase the risks associated with natural hazards.[87]

While the PPS applies across Ontario, planning in the Greater Golden Horseshoe (which includes much of Metrolinx's service area) is guided by four legislated plans: the *Niagara Escarpment Plan*, the *Oak Ridges Moraine Conservation Plan*, the *Greenbelt Plan* and the *Growth Plan for the Greater Golden Horseshoe*.[88] The Government of Ontario has recently completed an integrated review of all four plans, which were released in May, 2017. Upper- and single-tier municipalities in the Greater Golden Horseshoe are required to: develop policies in their official plans to identify actions that will reduce greenhouse gas emissions and address climate change adaptation; assess infrastructure risks and vulnerabilities and identify actions and investments to address these challenges; and undertake stormwater management planning in a manner that assesses the impacts of extreme weather events. To support municipalities, the province has committed this year to develop guidance on watershed planning and on addressing climate change.

Provincial infrastructure planning guidance. The *Infrastructure for Jobs and Prosperity Act, 2015* is Ontario's key legislation concerning infrastructure and resiliency to climate change.[89] It provides a planning and implementation framework for public investment in infrastructure, including $130 billion the Province has budgeted for projects across Ontario over the next decade. The Act establishes mechanisms to encourage principled, evidence-based and strategic long-term infrastructure planning to support a variety of sustainability goals. It lists 14 principles for public sector agencies to integrate in transportation infrastructure planning decisions, including the objective that "Infrastructure should be designed to be resilient to the effects of climate change."[90]

While the Act itself lacks further detail on how to approach resiliency, other provincial documents offer some relevant guidance. For example, in its *Discussion Paper on Climate Change* (2015), the MOECC supported the adoption of a risk assessment approach, the application of assessment tools such as Engineers Canada's PIEVC Protocol to evaluate climate risks for infrastructure assets, and the use of up-to-date climate change projections for Ontario.[91] The approach has been applied to municipal infrastructure by ICLEI and others, as well as to ecosystems.[92] It supports the use of the "adaptive management cycle" (see Figure 12) that has been applied to environmental issues across Ontario, including by the International Joint Commission regarding the management of the Great Lakes Basin in response to climate change.[93]

Figure 12: **The relationship between climate change science and adaptive management**[94]



Environmental assessment. Environmental assessment is a comprehensive and systematic process used to identify, analyze and evaluate the environmental effects of proposed projects, and to ensure that they are factored into decision-making. In Canada, climate change is not specifically cited in the Canadian Environmental Assessment Act, 2012, but in 2016 the Federal Government introduced an interim approach that required the assessment of upstream GHG emissions related to certain pipeline projects.[95] In their review of the Federal environmental assessment process, an Expert Panel recommended in April, 2017, that Canada develop a mechanism on the *Pan-Canadian Framework on Clean Growth and*

Climate Change to provide direction on how to consider climate change in future federal project and regional Impact Assessments.[96]

Some provinces have produced guidance dealing with climate change in environmental assessments, although to date only Nova Scotia requires it.[97] Quebec mandates the use of climate change projections for 2050 in the design and construction of stormwater infrastructure, and a 15 to 20 percent increase in stormwater culvert capacity for all return periods as part of their environmental assessment process for new roads and highways.[98]

In Ontario, in 2014 the Environmental Assessment Codes of Practice were updated to include the interrelationships between alternatives and a changing climate in descriptions of environmental effects.[99] The MOECC has subsequently prepared a draft guide *Consideration of Climate Change in Environmental Assessment in Ontario,* to describe how projects can address climate change adaptation needs.[100] This guide was briefly posted through the EBR website for public comment in 2016, and it is expected to be formalized sometime in 2017 into the Environmental Assessment program's Guides and Codes of Practice.

At present, Metrolinx uses TPAP as prescribed in Ontario Regulation 231/08 (the Regulation) as the primary process to ensure Environmental Assessment for Metrolinx transit infrastructure projects.[101] The Regulation exempts Metrolinx from the Environmental Assessment Act, provided it follows the TPAP when assessing impacts (both positive and negative) from planned transit infrastructure projects. Generally, Metrolinx has proactively included considerations for Climate Change.

Regional and local government context

A growing number of municipalities and conservation authorities are assessing vulnerability and risk to extreme weather and climate change, and are implementing policies to enhance infrastructure resiliency. Regional and local governments, and other agencies, are also eligible to participate in the NDMP, conditional upon meeting Provincial criteria and providing 50 percent of the funding. These initiatives are focal points for collaboration on issues of common interest, as well as opportunities to share information and best practices.

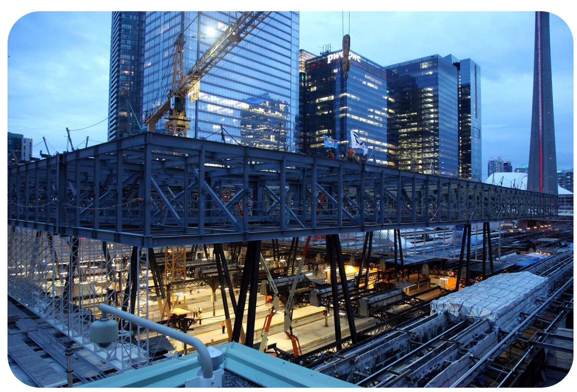
Regional and local communities across Canada are using a number of land use policy and decision-support tools to prepare for climate change, build resiliency and increase adaptive capacity. These tools include official plans, zoning by-laws, subdivision and development controls, covenants and easements, design guidelines, and environmental review processes for new developments. Many GTHA municipalities have introduced climate change resiliency into by-laws and policies addressing stormwater flooding and the urban heat island effect, and promote measures that benefit both climate change mitigation and climate change adaptation such as green roofs, permeable surfaces and district energy systems. In particular, the *Low Impact Development Stormwater Management Planning and Design Guide* (2010), developed by the Toronto and Region Conservation Authority (TRCA) and the Credit Valley Conservation Authority (CVC), is a best practice that is beginning to be applied by municipalities to improve resiliency to extreme weather and climate change.[102] CVC research has demonstrated that LID measures can be very effective in dealing with 90 percent of rainfall events (e.g. one- and two-year floods), and in reducing peak flow runoff from larger events. The LID guide is in the process of being updated, and is expected to include information on climate change.

PIEVC Protocol. In August 2005, Engineers Canada established a committee to help public agencies assess the climate change vulnerability of Canada's infrastructure. The resulting Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol has now been used in more than 40 case studies including for transportation assets (e.g. highways, airports, and bridges), water resource and management systems (e.g. stormwater, wastewater and potable water systems), and buildings.

Section 3.1 of this report discusses Metrolinx application of the PIEVC Protocol in assessing the climate change vulnerability of six representative assets. Other GTHA agencies that have used the PIEVC Protocol include the TRCA, City of Toronto, Greater Toronto Airport Authority, and Toronto Hydro.[103]

4.6 Designing capital improvements

Resiliency and standards in Canada



In Canada, many codes and standards for buildings and other infrastructure take climate into account, but tend to be based on historical climate data and assume that the past is a good indicator of the future. However, climate change will bring changes in both average conditions and the frequency and severity of extreme weather events. In the past, efforts to update national building codes and standards have focused on permafrost, snow loads in northern regions, and measures in tornado-prone regions; progress in areas relevant to transit assets in the GTHA has been limited to-date. Much remains to be done.[104]

Within the climate change community, the issue of standards has largely been addressed indirectly; work has focused on improving methods and approaches to assess vulnerability and risk, rather than on prescribing specific design changes. Other key areas of work include forensic investigations after extreme weather events that yield important insights into vulnerabilities (knowledge of infrastructure "breaking points" for a given weather hazard can inform changes that enhance resiliency), and improved understanding of climate parameters, including climate change projections, that clarify risk.

The Standards Council of Canada recently received $11.7 million over five years to address new standards in response to climate change. This work will address three interrelated streams: (i) the standardization of weather data collection and how the data are used; (ii) climate change information and projections, and how they can be used to inform new infrastructure standards and codes; and (iii) building on past efforts to develop new standards in the north.[105] The National Research Council has also received $40 million over four years to address infrastructure standards, although the precise areas of focus are still under development. Stakeholder engagement will be a key aspect of this work; in March 2017, Metrolinx was invited to participate in a workshop (jointly sponsored by the National Research Council and Canadian Urban Transit Association) on new climate change transit standards. The Canadian Standards Association (CSA) Group is also part of this program, and is leading a series of seven climate change adaptation projects, including the development of solutions within the framework for the Canadian Electrical Code, the Canadian Highway Bridge Design Code, and for the Durability of Buildings.

Certification and rating programs

Certification and rating programs have made only limited progress toward addressing resiliency. Within the International Organization for Standards (ISO), for example, standards pertaining to climate change have generally focused around the emissions rather than adaptation. The United Nations Office for Disaster Risk Reduction (UNISDR) is helping to pioneer a new ISO Standard in 45 cities already recognized for their commitment to safety from natural hazards including floods, storms and earthquakes; the new ISO standard for resilient and sustainable cities (ISO 37120) is based on 100 indicators that steer and measure the performance of city services and quality of life.[106] However, it does not directly address infrastructure resiliency.

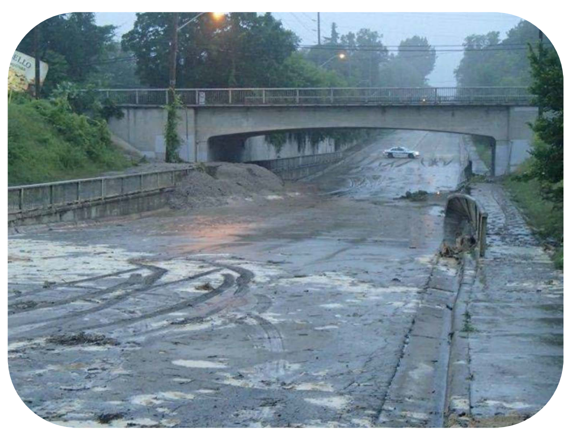
The certification program Leadership in Energy and Environmental Design (LEED) provides a comprehensive rating system for the design, construction, operation and maintenance of green buildings, homes and neighbourhoods. LEED's climate considerations have been on existing weather risks (e.g. sea level rise, storm surges, stormwater management, urban heat island) and no direct climate change criteria have been developed. Recently updated LEED standards do not directly consider climate change, but there is a new credit for addressing rainwater (e.g. by adopting green infrastructure and low impact development) that goes beyond one- or two-year storms to consider more infrequent (e.g. 95^{th} and 98^{th} percentile) storm events and Heat Island Reduction.[107] LEED also offers guidance on measures that have an adaptation function, even though do not receive credit in LEED scoring. BOMA BEST takes a similar approach, and is developing its own standard for resiliency and/or adaptation.[108]

Other certification programs are beginning to consider climate change risks and resiliency. Two notable examples are ENVISION and ISCA IS (the Infrastructure Sustainability Council of Australia's Infrastructure Sustainability certification program).[109] Both programs are meant to guide decision-making, both are capable of assessing individual project performance as well as long-term community sustainability, and both consider climate change resiliency and adaptation within their sustainability criteria.

ENVISION represents a "best practice" in evaluating physical infrastructure for sustainability performance and resiliency. It considers the planning, design, construction and operation of many different kinds of infrastructure, and offers five levels of achievement—improved, enhanced, superior, conserving and restorative—that can be attained over a project's lifecycle.

ISCA IS promotes infrastructure that is "planned, designed, constructed and operated to optimise environmental, societal and economic outcomes over the long term." The program's 15 sustainability categories can be rated according to three levels of performance: (1) Good—measuring and implementing initiatives; (2) Excellent—no net impact; and (3) Leading—restoration and enhancement. The program has received widespread acceptance, and is being applied to a wide range of transit projects in Australia and New Zealand including stage one of Australia's Gold Coast Light Rail system. Lessons learned from its application to operational practices, as well as design and construction protocols, could be of benefit to Metrolinx, especially in relation to procurement contracts.

Design for stormwater management



In Ontario, watershed management has been the field of greatest progress toward linking climate change science with policy and adaptation practices. However, the Province has focused primarily on source water protection rather than on riverine and stormwater flood management. Current standards and guidance for flood management do not incorporate the implications of climate change risks for flood frequencies and magnitudes.

Ontario's primary policy instrument for planning, designing, operating and maintaining stormwater management infrastructure is the *Stormwater Management Planning and Design Manual* (2003).[110] Because it does not take climate change into account, any new projects that simply meet these guidelines may be inadequate to manage extreme weather events that are expected to grow more frequent and intense. The Ontario Expert Panel on Climate Change Adaption and the Environmental Commissioner of Ontario have both identified the need to address this gap.

In February 2015 the MOECC released an *Interpretation Bulletin* expressing the expectation that a site's stormwater management system should mimic its natural hydrology before development.[111] The main approach to doing so is to control precipitation as close as possible to where it falls, by employing lot level and conveyance controls referred to as low impact development (LID). In 2017, the Ministry is expected to produce a LID stormwater management guide for new development, infill, retrofits and redevelopment. The 2015 Bulletin also noted that future IDF statistics are available through the Ontario Climate Change Data Portal.

MTO has updated IDF statistics for Ontario, and has been working with the University of Waterloo to develop future projections based on historical trend data. In October 2016, MTO issued two Provincial Engineering Memorandums: "Implementation of the Ministry Updated IDF Curves Online Application Version 3" and "Implementation of the Ministry's Climate Change Consideration in the Design of Highway Drainage Infrastructure."[112] With these two memorandums, culvert design for new highway development will need to be based on this data set. These requirements do not extend beyond new highways, for example to address buildings or other linear infrastructure such as rail corridors.

4.7 Operations and maintenance

Monitoring

Credible, accurate short-term forecasts for local heat waves and storm warnings are crucial to maintaining service. The quality of current forecasts for sudden, localized rainstorms that could lead to flooding and/or washouts, as well as for freezing rain, are among the best available, but the timing and intensity of some events cannot be accurately predicted.

Flood warning systems also important, especially along the Lower Don River. Flood events have been growing more frequent, and will continue to do so (e.g. storms that were once expected every five years or so now seem to occur almost annually).

Other efforts to ensure rail infrastructure functions safely can include monitoring of railway tracks for buckling and sun kinks during heat waves, monitoring of rail corridors and track ballast after severe rainfall and flood events, and springtime inspection and clearance of culverts that direct stormwater under tracks.

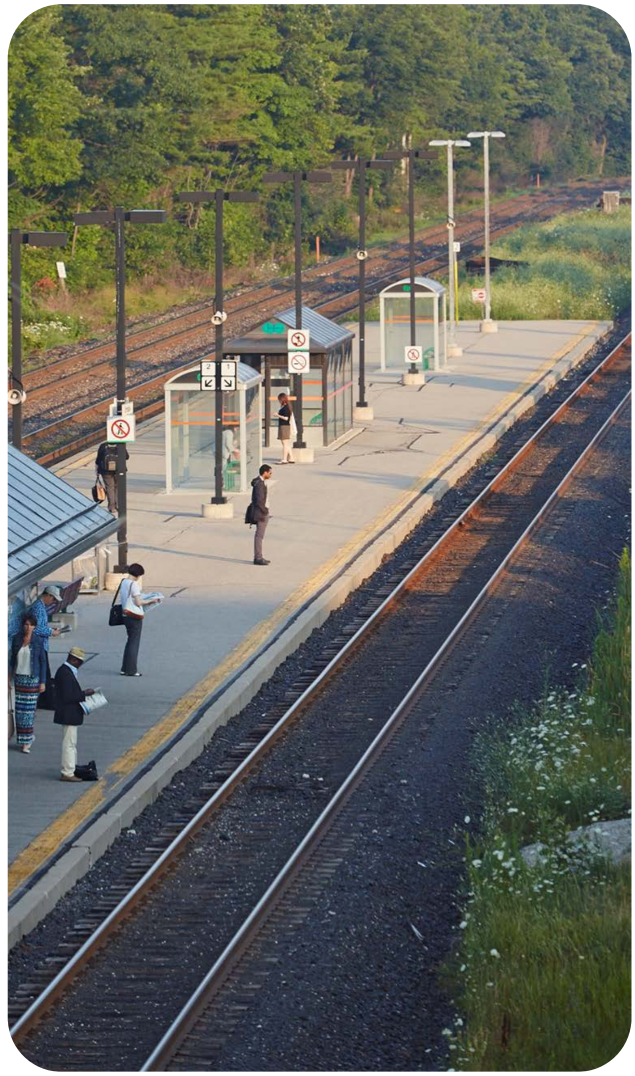
Emergency response planning and preparedness

One effect of climate change is an increase in the frequency and intensity of extreme weather events. An uptick in the need for emergency response, and the cost of providing it, is causing stakeholders to reassess their emergency management capabilities and protocols. Outside Ontario, some of those efforts include:

- Extreme weather events including hurricanes and coastal storm surges have raised concerns within the U.S. Federal Highway Administration about the transportation sector's vulnerability to climate change, and have led to extensive flood risk mapping in many coastal regions.[113]
- A growing number of public-private collaborations are focused on reducing disaster risk, such as a joint initiative between Price Waterhouse Cooper and the UN Office for Disaster Risk Reduction to create a disaster risk management platform (e.g. ARISE), support its use in the private sector and beyond, and ultimately create risk-resilient societies.
- In 2010, Public Safety Canada produced a guide on emergency management planning, followed by a guide for business continuity planning.[114]
- A 2012 report of the Nova Scotia Emergency Management Office outlined how to better incorporate future climate change impacts into emergency planning and management.[115]
- A 2012 study by the U.S.-based Center for Clean Air Policy in partnership with the Environmental and Energy Study Institute examined how extreme weather events and climate change might influence transportation investment and asset management decisions.[116]

In Ontario, the 2012 *Emergency Management and Civil Protection Act* and *Ontario Regulation 380/04* set out requirements for the development, implementation and maintenance of emergency management programs by municipalities and Provincial ministries, with a focus on emergency preparedness and response. Requirements include the designation of an emergency management coordinator, the writing of an emergency response plan and the formation of a program committee. Emergency Management Ontario (EMO) monitors compliance, and supports ministries and municipalities in maintaining their programs including an Incident Management System and their use of a Hazard Identification and Risk

Assessment (HIRA) protocol. In 2011, a GTHA workshop on climate change adaptation in the emergency management and critical infrastructure sector, organized by the Clean Air Partnership, concluded that few municipalities in Ontario consider climate change in their HIRA applications, even though extreme weather events are their biggest concern.[117]



Business continuity planning

Business continuity is the ability of an organization to resume or continue acceptable, predefined levels of service following a disruption. The goal of business continuity management is to make organizations more resilient to potential threats by adopting plans and strategies that allow them to respond and recover from threats that cannot be controlled. In the U.K., business continuity management for organizations has grown to include climate change adaptation. Public Safety Canada supports business continuity planning from a disaster management perspective, and in the GTHA the York Region Rapid Transit Corporation has adopted a business continuity plan that identifies actions in response to a crisis, but does not specifically address climate change risks.[118]

5. THE WAY AHEAD

5.1 Overview

Responding to climate change impacts and threats is not an option. This report has provided a comprehensive assessment of how Metrolinx has addressed the challenge to date, with some comparisons to best practices elsewhere. To move forward on resiliency, Metrolinx aims to adopt a more comprehensive, proactive stance that methodically addresses a range of short-term and long-term needs.

Key questions. A Corporate Climate Adaptation Plan should address seven key questions:

- How are climate conditions projected to change across the GTHA, based on various emission scenarios and for different timelines?
- How is Metrolinx's infrastructure vulnerable to extreme weather conditions?
- Which assets are most vulnerable to these changes, and what condition are they in?
- Which operations and maintenance protocols need to be strengthened?
- What increases in design standards are required to reduce vulnerability and enhance resiliency?
- What are the most cost-effective resiliency measures to implement, and where?
- What are the priority areas for investing in and implementing resiliency measures across the regional network?

Knowledge gaps, challenges and barriers. There are a number of knowledge gaps and challenges that can act as barriers to action. These include:

- Uncertainty around some climate change parameters, especially future IDF projections;
- A lack of localized data, including flood risk from riverine and urban/overland flows;
- National and provincial design standards and codes for buildings and infrastructure that are based on historical climate, and may be inadequate for future extreme weather conditions;
- Cost estimates for capital projects that haven't initially considered the added investment that may be required to include resiliency and adaptation measures;
- Inconsistent consideration and application of lifecycle costing for asset management and capital budgets; and
- Balancing between measures that reduce vulnerability and enhance resiliency and adaptive capacity, that are consistent with the transition towards a low carbon economy.

Guiding principles. The application of guiding principles could help determine the level of effort and resources required to answer the preceding questions and address many of the knowledge gaps, challenges and barriers noted above. It may be worthwhile for the Resiliency Working Group and its partners across the organization to consider several conclusions of the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change, restated here to apply to Metrolinx[119]:

- Climate change poses a moderate threat to Metrolinx's current efforts to become sustainable, and is a serious threat to achieving future sustainability.
- Climate-resilient pathways include strategies, choices and actions to reduce climate change impacts, in addition to actions to ensure that effective risk management and adaptation can be implemented and sustained.
- The integration of mitigation and adaptation measures can in some cases generate mutual benefits, as well as help Metrolinx achieve many of its sustainability goals.
- Prospects for climate-resilient pathways are fundamentally related to what others across the province, the country and the globe are able to accomplish in achieving their GHG emission reduction targets, but mitigation and adaptation measures will remain essential for climate change risk management through the rest of this century.
- To promote sustainability within the context of climate change, climate-resilient pathways may require Metrolinx to consider not just measures involving incremental change, but decisions that lead to transformational outcomes.
- Delayed action in the present may reduce options for implementing climate-resilient pathways in the future.

- More research is needed to determine the trade-offs between investing in measures that produce transformational rather than incremental changes, to achieve and maintain desired levels of sustainability.

Current strengths. The good news is that Metrolinx will benefit from several existing positive attributes as it embarks down a resiliency pathway:

- A strong culture of sustainability, resiliency and innovation, including a sustainability strategy and a commitment to establish a corporate Climate Adaptation Plan;
- Growing institutional support for resiliency at the Provincial level;
- Considerable investment commitments in new capital projects over the next two decades;
- Numerous existing initiatives and protocols to build on;
- Solid knowledge of best practices;
- Prior experience with assessment of climate change risks and infrastructure vulnerability;
- Strong internal expertise across the organization, gathered in the Resiliency Working Group; and
- Strong knowledge of, and relationships with, external stakeholders and subject matter experts.

Pillars for Action. The path toward a Corporate Climate Adaptation Plan involves four main areas of work that are informed by, and consistent with, best practices: awareness, education and communication; assessing vulnerability, risks and opportunities; building climate resiliency across the enterprise; and monitoring and adaptive management.

5.2 Pillars of Climate Resiliency

I. Awareness, education and communication

Increasing internal and external awareness through education is an essential component of an adaptation action plan, and ensures that Metrolinx is both on top of best practices and showcasing where it is leading on climate resiliency. Developing collaborative relationships with external partners and agencies are essential as Metrolinx may be unable to address resiliency needs on its own. Engagement that increases awareness, educates key personnel, and builds partnerships within Metrolinx and externally to effectively manage extreme weather events and climate change risks will continue to be an important requirement of the *Adaptation Plan*. Metrolinx has a solid foundation from which to engage various partners, stakeholders and audiences in a dialogue about how to achieve resiliency. Previous actions and current initiatives represent a solid foundation for further progress and a learning opportunity for others, while Metrolinx can acquire valuable lessons from a range of ongoing efforts across the GTHA, Ontario, Canada and on a global scale. Metrolinx will continue to learn from the best practices of others, collaborate with partners and stakeholders where it is strategic to do so, and inform internal and external audiences regarding the progressive measures that it is implementing to enhance climate resiliency.

II. Assessing risks and opportunities

Understanding vulnerability and risks of infrastructure assets, people and services to various climate parameters is essential for managing climate risks and capitalizing upon opportunities effectively. This requires having relevant and reliable information about a changing climate (both in regards to historical trends, and future projections). Further, having the ability to interpret and apply this information for specific climate parameters, asset types and locations will be needed. There are a variety of climate data sources available through government and private sector portals which provide science-based climate projections based on an ensemble of global climate models. It is important to remain up to date on the state of climate science and climate change model projections, as well as the climate risk tools that can be applied to individual assets or on a system-wide basis. Assessing risks and opportunities will also require having access to supportive statistical data and mapping tools to understand the threats posed by extreme weather events, as well as flood risk and the urban heat island effect. Being able to quantify the cost effectiveness of resiliency measures in relation to the costs of inaction will also need to be an important component of the *Adaptation Plan*.

III. Building climate resiliency across the enterprise

Metrolinx will aim to address resiliency in several key functional areas. These include planning, design and construction; enterprise asset management; environmental assessment; design standards; risk management and insurance; communications; and operations, including extreme weather readiness and emergency response protocols. Building resiliency across the enterprise extends beyond any single business unit, and touches upon numerous aspects of the organization. Decisions should be evidence-based, informed by climate science and credible projections of climate change, adhere to policy and regulatory requirements, and be informed by best practices. This applies to managing and improving existing assets as necessary and when opportunities emerge, and also planning, designing, and constructing future assets. While design standards may need to be enhanced to withstand more extreme weather conditions brought on by climate change, engineering design and solutions may not be the only effective response possible, as changes in operational protocols and processes may also result in an increase in resiliency and adaptive capacity.

IV. Monitoring and adaptive management

Efforts to build resiliency would benefit from a common reporting protocol and information repository, as well as ongoing monitoring of relevant developments in science, policy, technology, best practices and the parallel efforts of Metrolinx's peers and partners. As a result, the *Adaptation Plan* should be treated as a living document, to be reviewed and updated on an ongoing basis. Through effective monitoring and adaptive management, continuous improvement can be achieved by implementing resiliency measures that ranges from incremental to transformative change.

While Metrolinx accepts and is concerned about climate change, the organization has a more limited understanding of how the climate is changing, what the climate may be like in 2050 or 2080, and what impacts it might have on the agency's infrastructure assets. This report and the PIEVC vulnerability study report provide a solid foundation for internal and external engagement, awareness and partnership building, and can inform future dialogue about assessing risks and opportunities, and embedding resiliency into planning practices and protocols.

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[42] *PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate, Principles and Guidelines*, Version PG-10.1, (Ottawa: Engineers Canada), 54 p.

[43] Engineers Canada has posted their PIEVC case studies online: https://pievc.ca/assessments

[44] AECOM, Risk Sciences International, and the Toronto and Region Conservation Authority (2016) *Metrolinx PIEVC Climate Change Vulnerability Assessment – Final Report*, Metrolinx RQQ-IN-021 (Markham: AECOM), 194 p.

[45] see AECOM et al. (2016) "Appendix A: Detailed Historical and Future Projections Methodology", Table A1. Countries and Models used in this AR5 Ensemble.

[46] summarized from AECOM et al. (2016)

[47] Parsons Brinckerhoff (2014) *Metrolinx Asset Management Review: Capability Assessment and Asset Management Improvement Program*, Vrsion 1, 109 p.

[48] see Rose, D., Isaas, L., Shah, K., and T. Blake (Parsons Brinckerhoff) (2012) *Asset Management Guide: Focusing on the Management of Our Transit Investments* (Washington, D.C.: Federal Transit Administration), FTA Report No. 0027, 268 p. The International Organization for Standardization has ISO 55001:2014 Asset Management, Management Systems that specifies requirements for an asset management system within the context of an organization.

[49] In Metrolinx (2015) *2015-2016 Business Plan*, to ensure that Metrolinx remains a trusted organization with the capacity and flexibility to deliver *The Big Move*, a deliverable is to develop an Enterprise Asset Management Plan and a Prioritization Framework.

[50] GO Transit Design Excellence Guidelines: Urban, Architecture and Landscape Design, Version: 1.2, 217 p. Section 2.7 "Integrated Sustainable Design and Climate Resiliency" outlines a station and landscape design to create a comprehensive approach to sustainability that is resilient now and in the future, with an emphasis on minimizing energy use, managing storm water, and minimizing regional environmental impact.

[51] The Credit Valley Conservation Authority and the Toronto and Region Conservation Authority published *Low Impact Development Stormwater Management Planning and Design Guide*, version 1.0 in 2010.

[52] See Case Study 2: Preparing for Higher Temperatures and Rail Buckling at GO Transit, p. 165, in Woudsma, C., and W. Towns (2017) "Ontario", in K. Palko and D.S. Lemmen (Eds.) *Climate risks and adaptation practices for the Canadian transportation sector 2016* (Ottawa: Government of Canada), pp. 139-179.

[53] See Table 6 – Preferred Rail Laying Temperature, p. 3-20, in *GO Track Standards*, RC-0506-02TRK, June, 390 p.

[54] Back-up system requirements are outlined in Section F: Technical Requirements, in Metrolinx (2016) GO Design Requirements Manual, GO-DRM-STD-2017-REV1, February 3, 2017.

[55] This was announced for the Eglinton Crosstown LRT on March 28th, 2017 (http://www.thecrosstown.ca/fr/node/1625)

[56] Metrolinx is establishing a Vegetation Compensation Protocol for Regional Express Rail projects. Vegetation that is removed due to construction will be compensated for in accordance with the provisions of this Protocol.

[57] Kalinowski, T. (2015) "GO Transit vows to improve after snow woes; Commuters fume over delays, website outage on Monday", *Toronto Star*, p. GT2

[58] see K. Palko and D.S. Lemmen (Eds.) *Climate risks and adaptation practices for the Canadian transportation sector 2016.*

[59] City of Toronto Resilient City Update and Next Steps, Staff Report: *Resilient City – Preparing for a Changing Climate, Status Update and Next Steps* (City of Toronto, Chief Corporate Officer), 125 p.

[60] *Draft 2041 Regional Transportation Plan for the Greater Toronto and Hamilton Area* (Toronto: Metrolinx), 137 p.

[61] IPCC (2007) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

[62] For example see NYC Mayor's Office of Recovery & Resiliency (2017) *Preliminary Climate Resiliency Design Guidelines*, 30 p. and The Port Authority of NY & NJ, Engineering Department (2015) *Design Guidelines Climate Resilience*, 10 p.

[63] See Environmental Commissioner of Ontario (2015) *Connecting the Dots on Climate Data in Ontario* (Toronto: ECO), 65 p.

[64] Charron, I. (2016) *A Guidebook on Climate Scenarios: Using Climate Information to Guide Adaptation Research and Decisions, 2016 Edition* (Montreal: Ouranos) 94 p.

[65] Ministry of the Environment and Climate Change (2016) *Ontario's Five Year Climate Change Action Plan 2016-2020* (Toronto: Ministry of the Environment and Climate Change), 85 p.

[66] see Highway Standards Branch, Ministry of Transportation, Provincial Engineering Memorandum, Design and Contract Standards Office #2016-13, October 28, 2016: *Implementation of the Ministry Updated IDF Curves Online Application Version 3*, 4 p.

[67] Three IDF statistics data portals are available in Ontario. MTO and University of Waterloo (http://www.mto.gov.on.ca/IDF_Curves/terms.shtml); MOECC and the Institute for Energy, Environment and Sustainable Communities, University of Regina (http://www.ontarioccdp.ca/); and Western University and the Canadian Water Network (http://idf-cc-uwo.ca/).

[68] Coulibaly, P., Burn, D.H., Switzman, H., Henderson, J. and E. Fausto (2016) *A Comparison of Future IDF Curves for Southern Ontario. Addendum – IDF Statistics, Curves and Equations*. Toronto and Region Conservation Authority and Essex Region Conservation Authority, 244 p.

[69] In 2014, Ontario became Canada's first province to develop and sell green bonds to encourage investment in environmentally friendly projects and attract new investors. Ontario's third green bond issued has raised $800 million that will be used to help build clean transportation and environmentally friendly infrastructure projects in communities across the province. This includes the York VivaNEXT Bus Rapid Transit Expansion in York Region; and GO Transit Regional Express Rail in the GTHA.

[70] Findley, T. and R. Schuchard (2011) *Adapting to Climate Change: A Guide for the Transportation Industry.* BSR (Business for Social Responsibility), 7 p.

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[72] The A4S (Accounting for Sustainability Project) was established by the HRH The Prince of Wales in 2004. See A4S CFO Leadership Network (2017) *Essential Guide to Social and Human Capital Accounting*, 106 p.

[73] Figure 2.2 from Hughes, J.F. and K. Healy (2014) *Measuring the resilience of transport infrastructure*, report prepared by AECOM New Zealand Ltd., NZ Transport Agency research report 546, p. 16.

[74] Viner, D., Rawlins, M., Allison, I., Howarth, C. and A. Jones (2015) *Climate change and business survival: The need for innovation in delivering climate resilience*. Mott MacDonald, p. 10-11.

[75] Ontario Ministry of Infrastructure (2016) *Building Together – Guide for Municipal Asset Management Plans. https://www.ontario.ca/page/building-together-guide-municipal-asset-management-plans*

[76] AECOM (2012) *Regional Transportation Strategy – Asset Management Project: Climate Change Vulnerability Study* (Burnaby, BC: AECOM), report prepared for TransLink – South Coast British Columbia Transportation Authority, Report: 60222615, 47 p.

[77] Rose, D., Isaas, L., Shah, K., and T. Blake (Parsons Brinckerhoff) (2012) *Asset Management Guide: Focusing on the Management of Our Transit Investments* (Washington, D.C.: Federal Transit Administration), FTA Report No. 0027, 268 p.

[78] Table 5.1, in Office of Budget and Policy, Federal Transit Administration, U.S. Department of Transportation (2011) *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation,* FTA Report No. 0001 (Washington, DC: Federal Transit Administration, U.S. Department of Transportation), p. 85.

[79] Network Rail owns, operates and develops railway infrastructure in England, Wales and Scotland. Their network is divided into 10 routes, many which have developed climate change adaptation plans. See, for example Network Rail (2014) *Route Weather Resilience and Climate Change Adaptation Plans, South East* (London: Network Rail), 25 p.

[80] The First Minister's met in Vancouver, British Columbia, on March 3, 2016, and agreed to the *Vancouver Declaration on clean growth and climate change* http://www.scics.ca/en/product-produit/vancouver-declaration-on-clean-growth-and-climate-change/

[81] *Growing the Middle Class*, Tabled in the House of Commons by the Hon. William Frances Morneau, P.C., M.P., Minister of Finance, March 22nd, 2016, 269 p.

[82] Office of the Parliamentary Budget Officer (2016) *Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangement due to Weather Events* (Otawa: Office of the Parliamentary Budget Officer), 46 p.

[83] The National Disaster Mitigation Program was established in 2014, and has $200 million over five years, of which $183 million is allocated as contribution funds for projects that are cost-shared with provinces and territories. https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/prgrm-gdlns-en.aspx#a01

[84] Expert Panel on Climate Change Adaptation (2009) *Adapting to Climate Change in Ontario* – Report of the Expert Panel on Climate Change Adaptation (Toronto: Ministry of the Environment), 88 p.

[85] Ministry of the Environment (2011) *Climate Ready: Ontario's Adaptation Strategy and Action Plan, 2011-2014* (Toronto: Ministry of the Environment), 120 p.

[86] Ministry of the Environment and Climate Change (2016) *Ontario's Five Year Climate Change Action Plan 2016-2020* (Toronto: Ministry of the Environment and Climate Change), 85 p.

[87] See Part V: Policies, 1.8 Energy Conservation, Air Quality and Climate Change, section 1.8.1 in Ministry of Municipal Affairs and Housing (2014) *2014 Provincial Policy Statement Under the Planning Act* (Toronto: Ministry of Municipal Affairs and Housing), p. 20.

[88] See Ministry of Municipal Affairs (2017) *Growth Plan for the Greater Golden Horseshoe* (Toronto: Ministry of Municipal Affairs), 109 p.; Ministry of Municipal Affairs (2017) *Greenbelt Plan (2017)* (Toronto: Ministry of Municipal Affairs), 76 p.; Ministry of Municipal Affairs (2017) *Oak Ridges Moraine Conservation Plan (2017)* (Toronto: Ministry of Municipal Affairs), 76 p.; and Niagara Escarpment Commission (2017) *Niagara Escarpment Plan (2017)* (Peterborough: Ministry of Natural Resources and Forestry), 176 p.

[89] Infrastructure for Jobs and Prosperity Act, 2015, S.O. 2015, Chapter 15.

[90] See the section on Infrastructure Planning Principles, subsection 11.

[91] Ministry of the Environment and Climate Change (2015) *Ontario's Climate Change Discussion Paper 2015* (Toronto: Ministry of the Environment and Climate Change), 42 p.

[92] Gleeson, J., Gray, P., Douglas, A., Lemieux, C.J., and G. Nielsen (2011) *A Practitioner's Guide to Climate Change Adaptation in Ontario's Ecosystems* (Sudbury: Ontario Centre for Climate Impacts and Adaptation Resources), Version 1.0, 74 p.

[93] McDermid, J.L., Dickin, S.K., Winsborough, C.L., Switzman, H., Barr, S., Gleeson, J.A., Krantzbert, G. and P.A. Gray (2015) *State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrological and Ecological Effects.* Prepared jointly by the Ontario Climate Consortium and Ontario Ministry of Natural Resources and Forestry to advise Annex 9 – Climate Change Impacts under the Great Lakes Water Quality Agreement, October 2015.

[94] Figure 3, from McDermid, J.L., et al. (2015) *State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrological and Ecological Effects*, p. 4.

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[97] See Nova Scotia Environment (2011) *Guide to Considering Climate Change in Environmental Assessments in Nova Scotia* (Halifax: Nova Scotia Environment), 18 p.; Nova Scotia Environment (2011) *Guide to Considering Climate Change in Project Development in Nova Scotia* (Halifax: Nova Scotia Environment), 48 p.; and Nova Scotia Environment (2017) *A Proponent's Guide to Environmental Assessment* (Halifax: Nova Scotia Environment), 37 p.

[98] Personal correspondence with Alain Bourque, Executive Director, Ouranos – Consortium sur les changements climatiques, Montreal and Alain Mailhot, Institut national de la recherché scientifique, Centre – Eau Terre Environnement, Québec.

[99] Ministry of the Environment (2014) *Code of Practice: Preparing and Reviewing Environmental Assessments in Ontario* (Toronto: Ministry of the Environment), 83 p.

[100] Ministry of the Environment and Climate Change (2016) *Consideration of Climate Change in Environmental Assessment in Ontario* (Toronto: Ministry of the Environment and Climate Change), 40 p.

[101] See *Guide to Environmental Assessment Requirements for Transit Projects,* https://www.ontario.ca/page/guide-environmental-assessment-requirements-transit-projects

[102] Credit Valley Conservation Authority and the Toronto and Region Conservation Authority (2010) *Low Impact Development Stormwater Management Planning and Design Guide*, version 1.0.

[103] These studies are posted on Engineers Canada's PIEVC website: https://pievc.ca/assessments

[104] see Section 3.2 Codes, Standards and Related Instruments, in Boyle, J., Cunningham, M. and J. Dekens (2013) *Climate Change Adaptation and Canadian Infrastructure: A review of the literature* (Winnipeg: International Institute for Sustainable Development), 35 p.

[105] Roy, P., Fournier, E. and D. Huard (2017) *Standardization Guidance for Weather Data, Climate Information and Climate Change Projections* (Montreal: Ouranos), 44 p. + Appendixes *Draft*

[106] ISO 37120:2014 is the first ISO International Standard on city indicators: Sustainable development of communities – indicators for city services and quality of life.

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[108] see BOMA Toronto: Commercial Property Resilience to Climate Change, and papers by: Hay, A. (2015) "Commercial Property Resilience to Climate Change", pp. 2-11; Veres, C. (2015) "Commercial Property Resilience to Climate Change: An Architectural Perspective", pp. 1-6; McGillivary, G. (2015) "Commercial Property Resilience to Climate Change: An Insurance Perspective", pp. 1-5; Duffy, R. (2015) "Commercial Property Resilience to Climate Change: An Energy Management Services Company Perspective", pp. 1-7; and Bristow, D. (2015) "Commercial Property Resilience to Climate Change: An Academic Perspective", pp. 1-5.

[109] For information on ENVISION, see https://sustainableinfrastructure.org/envision/; for information on ISCA (Infrastructure Sustainability Council of Australia) and their Infrastructure Sustainability (IS) tool see https://isca.org.au/is-rating-scheme/about-is

[110] Ministry of the Environment (2003) *Stormwater Management Planning and Design Manual* (Toronto: Ministry of the Environment), 379 p.

[111] Ministry of the Environment and Climate Change (2015) *Interpretation Bulletin: Ontario Ministry of Environment and Climate Change Expectations, Re. Stormwater Management* (Toronto: Ministry of the Environment and Climate Change), 7 p.

[112] See Highway Standards Branch, Ministry of Transportation, Provincial Engineering Memorandum, Design and Contract Standards Office #2016-13, October 28, 2016: *Implementation of the Ministry Updated IDF Curves Online Application Version 3*, 4 p.; and Highway Standards Branch, Ministry of Transportation, Provincial Engineering Memorandum, Design and Contract Standards Office #2016-14, October 28, 2016: *Implementation of the Ministry's Climate Change Consideration in the Design of Highway Drainage Infrastructure*, 4 p.

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[116] Winkelman, S., Mueller, J. and E. Jue (2012) *Climate Adaptation & Transportation: Identifying Information and Assistance Needs – Summary of an Expert Workshop held November 2011* (Centre for Clean Air Policy and the Environmental and Energy Study Institute), Prepared for the NOAA Sector Apllications and Research Program, 60 p.

[117] See MacIver, D., S. Butt, H. Auld and J. Klaasse (2009) "Severe weather is the #1 risk to Ontario municipalities", *Municipal World*, December: 17-19.

[118] York Region, Rapid Transit Corporation, Business Continuity Plan, Version 0.6, HZX Business Continuity Planning, 130 p.

[119] Denton, F., T.J.Wilbanks, A.C. Abeysinghe, I. Burton, Q. Gao, M.C. Lemos, T. Masui, K.L. O'Brien, and K.Warner (2014) "Climate-resilient pathways: adaptation, mitigation, and sustainable development" In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1101-1131.

APPENDIX I: SELECTION OF EXTREME WEATHER EVENTS IN THE GTHA, 2004-2016

Date	Location	Event	Additional detail	Loss plus loss adjustment expenses (2014$)
July 15, 2004	Peterborough	Severe rainfall from 100 mm to 240 mm	1-in-200 year event.	$104 million
Summer 2005	Toronto	Hot temperatures and smog episodes	6-months from June to November was the warmest on record across parts of Ontario. 44 days above 35°C humidex, and record 25 'tropical' nights in which the temperature did not drop below 25°C. Excessive heat and frequent smog days occurred. 42 smog advisory days issued across Ontario between May 1-September 30. Power use at record levels, requiring voltage to be dimmed by 5%. Record breaking number of smog days.	
August 19, 2005	Southern Ontario	Severe storm event with thunderstorms, tornadoes and torrential rainfall.	103 mm of rain fell in one hour in North York, with 154 mm of rain in 3 hours. Record one-hour rainfall double of Hurricane Hazel in 1954. Greater than one-in-one hundred year storm. Insured losses were the highest recorded in the province's history. There were 3,600 reported basement flooding occurrences.	$731.8 million
August 1, 2006	Toronto and southern Ontario	Hot maximum and minimum temperature	Maximum temperature at Toronto Pearson Airport was 36.6°C with a humidex of 45°C. Nighttime heat record for Toronto Pearson Airport at 26.3°C. Maximum temperature records set at Windsor and Hamilton. Record power consumption of 27,005 megawatts.	
Summer 2008	Southern Ontario	Wet summer	Toronto Pearson Airport recorded 396.2 mm of rain with more than three weeks left in the summer season, shattering former high water mark by more than 60 mm. Hamilton experienced thunderstorms on 28 days and for 77 hours, well above the average of 16 days and 23 hours.	
March 2009	Hamilton, London, Kitchener and Toronto, ON	Snow-free March	Hamilton experienced 42 consecutive days -- February 23rd to April 6th -- with no measurable amount of snow. Kitchener and Toronto were also practically snow-free.	
Summer 2009	Southern Ontario	29 tornadoes	Record number of tornadoes in one year, tying 2006. On August 20th, there were 18 tornadoes, a record for the most tornadoes in one day in Canada, including four F0; ten F1; and four F2. Property losses around $100 million.	$88 million in insured damages.
July 26, 2009	Hamilton, ON	Rainstorm and flood	Hamilton and Stoney Creek experienced a midday downpour, flooding 7,000 basements and shutting power to thousands of customers. Radar estimates confirmed rainfall amounts totaling 109 mm in two hours -- worse than a 100-year storm. Conditions were exacerbated by super-saturated ground. 1,850 damage claims.	Insured losses estimated between $200 and $300 million.
November 2009	Toronto, ON	Snow and storm free November	First snow-free November recorded at Toronto Pearson International Airport since 1937. In downtown Toronto, at Canada's oldest weather station, there was no trace of snow (less than 0.2 cm) for the first time ever since snowfall observing first began in 1847.	

Date	Location	Event	Additional detail	Loss plus loss adjustment expenses (2014$)
Summer 2011	Southern Ontario	Drought	Long bouts of dry, hot weather. In Hamilton, in a 28-day period from the last week of June until the third week of July, 0.2 mm of rain fell. Crops hard hit included wheat, corn, soybeans and Niagara's fruit producing region.	
Winter 2011 - 2012	Southern Ontario	Warm temperatures with little snow	Toronto had 5 times more rain than snow from November to March. Only 9 days had more than 1 cm of snow from November to April. The average temperature was the warmest ever (since 1840 when record-keeping began).	
Summer 2012	Southern Ontario	Hot temperatures	Number of hot days above 30°C numbered 38 in Hamilton, and 25 in Toronto. Toronto had 4x than normal more nights above 20°C (16 nights).	
July 8, 2013	Toronto, ON	Intense rainstorm following 38 mm of rain on July 7th and an abnormally wet spring and early summer	Two separate storm cells stalled over Toronto, dumping: 126.0 mm on Toronto Pearson International Airport, 96.8 mm on Toronto City, 85.5 mm on Toronto Island, 65.8 mm on Downsview, and 51.5 mm on East York. Toronto Pearson International Airport's 126.0 mm was new daily rainfall record at the airport, and a record for any date, exceeding Hurricane Hazel's October 15th, 1954 total of 121.4 mm. The July 8th storm also set a record for 30-minute, and 1, 2, 6 and 12-hour rainfall totals, all in excess of 100-year return periods. Estimated to be the most expensive natural disaster ever in Toronto and Ontario. About 500,000 households were without power for a few hours to days, while 3,000 basements were flooded.	$940 million
December 22 – 23, 2013	Southern Ontario - Toronto, ON	Ice storm	Ice storm causing 830,000 customers to lose power, some for more than a week. Additional costs from worker overtime, spoiled food, and damaged homes, vehicles and public infrastructure estimated to exceed hundreds of millions of dollars.	$164.2 million
Winter 2013-2014	Southern Ontario	Severe cold and snow	Toronto experienced its coldest winter in 20 years; 36 extreme cold alerts were issued by Toronto Public Health; snow accumulation was recorded on the ground for more than 100 consecutive days	
June 17, 2014	Angus, Ontario (18 km sw of Barrie)	Tornado (high end of an EF2)	Peak winds between 200 and 220 km/h, a width of 300 m at its widest point and tracked over 20 km; 102 homes damaged, 14 beyond repair, 300 persons displaced.	$30 million
August 4, 2014	Burlington, Ontario	Extreme rain	191 mm rain in < 4 hours. Over 2,300 homes flooded.	$90 million
February 2, 2015	Southern Ontario	Severe snow storm	20-40 cm of snow from Hamilton to Toronto	
Summer 2016	Southern Ontario	Hot temperatures, and drought	At Toronto Pearson International there were 39 days with maximum temperatures at or above 30°C, compared to a normal 14. Temperatures above 35°C occurred in June, July, August and September, a first for Toronto	

Source: Environment and Climate Change Canada: Canada's Top Ten Weather Stories (2004-2014); Canadian Meteorological and Oceanographic Society (CMOS): Canada's Top Ten Weather Stories for 2015; The Weather Network: 10 weather stories that defined Canadians in 2016. Note that the total rainfall for the regional storm for southern Ontario, Hurricane Hazel that occurred on October 15th, 1954, was larger in scale than the high intense short duration thunderstorm events that occurred on August 19th, 2005, and July 8th, 2013. Over 48 hours, more than 200 mm of rain fell in some locations during Hurricane Hazel.

APPENDIX II: SELECT CLIMATE PARAMETERS, PROBABILITIES AND SCORES FOR TORONTO PEARSON INTERNATIONAL AIRPORT

Climate parameter	Threshold	Annual probability		Probability of occurrence for study period (2015-2050)
		Historical	2050s	
Extreme temperatures	40°C	~0.01 per year	1-7 days per year	~100%
	32°C	6.5 days per year	27.5 days per year	100%
	-30°C	0.05 days per year	<0.01 days per year	<70%
	-23°C	1.1 days per year	0.1 days per year	100%
Temperatures range	60°C in one year	0.1 days per year	<0.01 events per year	<90%
Reduced visibility *(e.g., fog, blowing snow)*	400 m (or ¼ mile)	49 hours per year, 15.1 days per year	strong trend ↓, stable recent period	100%
	200 m	33 hours per year, 11.9 days per year	strong trend ↓, stable recent period	100%
Frost penetration	1.2 m or below	0.17 per year	Trend ↓ but some conflicting factors	>90%
High winds (gusts)	90 km/h	2 per year	>2.5 per year	100%
	120 km/h	0.05 days per year	Likely ↑	~85% or higher
Tornadoes	EF1 +	1-in-6,000	Unknown	~0.6%
Overland flood/heavy rainfall	≥25 mm in 2 hour	~ 0.8 events per year	Very likely ↑	100%
	≥60 mm in 2 hours	≤ 0.03 events or less per year	Very likely ↑	~70%
Freezing rain	≥ 10 mm	~0.2 days per year	~0.3 days per year	~100%
	≥ 25 mm	0.06 days per year	>0.09 days per year	>95%
Snow	Blowing snow	7.8 days per year	Trends not significant to scoring	100%
	≥ 20 cm in one day	0.1 days per year	Conflicting trends, likely remaining similar	>95%
	Design Loads (snow-water-equivalent)	184 mm (Asset A and B)	No observed trend, some factors indicate ↑	~20%
		153 mm (Asset C)		~40%
		133 mm (Asset D)		~40%
Hail *(Mississauga area example)*	"Golf ball" / 45 mm or larger	0.07 per year	Unknown	>90%
Horizontal rain	Gusting 50 km/h + >25 mm rain	1.8 days per year	Slight trend ↑	100%
Lightning	Direct strikes	~0.3% per year	Likely ↑	>99%

Source: Table 6: Climate Parameters List: Probabilities and Scores, from AECOM, Risk Sciences International, and the Toronto and Region Conservation Authority (2016) *Metrolinx PIEVC Climate Change Vulnerability Assessment – Final Report,* Metrolinx RQQ-2015-IN-021, p. 29.

APPENDIX III: ACRONYMS

BART: Bay Area Rapid Transit

BOMA BEST: Building Owners and Managers Association, Building Environmental Standards

CN: Canadian National [Railway]

CO_2: Carbon dioxide

CP: Canadian Pacific [Railway]

CSA: Canadian Standards Association

CVC: Credit Valley Conservation [Authority]

EAM: Enterprise asset management

FTA: Federal Transit Administration

GEXR: Goderich-Exeter Railway (GEXR)

GHG: Greenhouse gas (or gases)

GIS: Geographic information systems

GTHA: Greater Toronto and Hamilton Area

HIRA: Hazard identification and risk assessment

IDF: Intensity-duration-frequency

IPCC: Intergovernmental Panel on Climate Change

ISO: International Standards Organization

LA Metro: Los Angeles County Metropolitan Transportation Authority

LEED: Leadership in Energy and Environmental Design

LID: Low impact development

LRT: Light rail transit

MARTA: Metropolitan Atlanta Rapid Transit Authority

MOECC: Ministry of the Environment and Climate Change

MTO: Ministry of Transportation

NDMP: National Disaster Mitigation Program

NRTEE: National Round Table on the Environment and the Economy

PIEVC: Public Infrastructure Engineering Vulnerability Committee

PPS: Provincial Policy Statement

PRLT: Preferred rail laying temperature

RCP: Representative Concentration Pathway

RER: Regional Express Rail

RTP: Regional Transportation Plan

SRES: Special report emissions scenarios

TPAP: Transit Project Assessment Process

TRCA: Toronto and Region Conservation Authority

TTC: Toronto Transit Commission

UNISDR: United Nations Office for Disaster Risk Reduction

UP: Union-Pearson

APPENDIX IV: GLOSSARY OF TERMS

Adaptation. The process of adjustment through the application of soft (operations) or hard (infrastructure) measures to actual or expected climate and its effects, in order to moderate harm or reduce vulnerability and to capitalize upon beneficial opportunities.

Adaptive capacity. The combination of the strengths, attributes, and resources available to an individual, communities that we serve, the GTHA region, or Metrolinx itself as an organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities.

Adaptive management. Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Adaptive management also provides a framework for actively responding to any inaccurate forecasts and ineffective mitigation measures.

Baseline/reference. The baseline (or reference) is the state against which change is measured. It might be a 'current baseline', in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.

Carbon dioxide (CO_2). A naturally occurring gas fixed by photosynthesis into organic matter. A by-product of fossil fuel combustion and biomass burning, it is also emitted from land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured, thus having a Global Warming Potential of 1.

Climate. Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate change. Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. See also *climate variability*.

Climate change impacts. A series of changes within the overall global climate system, brought about as a result of increased atmospheric concentrations of GHGs. These impacts may have far-reaching and unpredictable environmental, social, and economic consequences, and may include: global sea level rise, increases in severe weather events, and changes in precipitation.

Climate model. A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity (i.e., for any one component or combination of components a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterisations are involved. Coupled atmosphere/ocean/sea-ice General Circulation Models (AOGCMs) provide a comprehensive representation of the climate system. More complex models include active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and inter-annual climate predictions.

Climate change parameters. The measurable physical properties of climate. Where climate is the average pattern of weather for a particular region, this average is commonly taken over a 30-year time period. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, hail storms, etc.

Climate projection. The calculated response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Climate projections are distinguished from climate predictions, in that the former critically depend on the emissions/ concentration/radiative forcing scenario used, and therefore on highly uncertain assumptions of future socio-economic and technological development.

Climate (change) scenario. A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A climate change scenario' is the difference between a climate scenario and the current climate.

Ensemble. A group of parallel model simulations used for climate projections. Variation of the results across the ensemble members gives an estimate of uncertainty. Ensembles made with the same model but different initial conditions only characterise the uncertainty associated with internal climate variability, whereas multi-model ensembles including simulations by several models also include the impact of model differences.

Extreme weather event. An event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10^{th} or 90th percentile. By definition, the characteristics of what is called 'extreme weather may vary from place to place. Extreme weather events may typically include floods and droughts.

Greenhouse gas. 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 infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. As well as CO_2, N_2O, and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Heat island. An urban area characterised by ambient temperatures higher than those of the surrounding non-urban area. The cause is a higher absorption of solar energy by materials of the urban fabric such as asphalt.

(climate change) Impact assessment. The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.

(climate change) Impacts. The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts.

Potential impacts. All impacts that may occur given a projected change in climate, without considering adaptation.

Infrastructure. The basic equipment, utilities, productive enterprises, installations and services essential for the development, operation and growth of an organisation, city or nation.

Representative Concentration Pathways. The IPCC AR5 presents a new way of looking at GHG emission scenarios with a range of GHG emission 'pathways' that is wider than earlier scenarios, reflecting a general shift in outlook to more extreme future emissions trajectories than were expected a decade ago. There are four Representative Concentration Pathways: RCP8.5, PCP6, PCP4.5, and PCP2.6, with each defining a specific emissions trajectory and subsequent radiative forcing (a radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system, measured in watts per square metre).

Resilience. The ability of Metrolinx, its infrastructure assets, and the component parts of its regional transit system to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions**.**

Scenario. A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a 'narrative storyline'. See also climate (change) scenario, emissions scenario and SRES.

SRES. The storylines and associated population, GDP and emissions scenarios associated with the Special Report on Emissions Scenarios (SRES), and the resulting climate change and sea-level rise scenarios. Four families of socio-economic scenario (A1, A2, B1 and B2) represent different world futures in two distinct dimensions: a focus on economic versus environmental concerns, and global versus regional development patterns.

Triple Bottom Line. Triple Bottom Line (TBL) is a concept which seeks to broaden the focus on the financial bottom line to include social and environmental responsibilities. A triple bottom line measures a company's degree of social responsibility, its economic value, and its environmental impact.

Uncertainty. An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgement of a team of experts).

Vulnerability. The propensity or predisposition to be adversely affected. Vulnerability to climate change is the degree to which Metrolinx infrastructure assets, our passengers, employees and contractors, and the region within which we provide transit services, are susceptible to, and unable to cope with, the adverse impacts of climate change.

Planning for Resiliency
Towards a Corporate Climate Adaptation Plan

www.metrolinx.com/sustainability
sustainability@metrolinx.com

97 Front St West,
Toronto, Ontario
M5J 1E6

METROLINX