



Climate Resilience and Canadian Water Infrastructure

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Report on Advancing the Climate Resilience of Canadian Infrastructure

- Compile latest information on **climate hazards and impacts** on Canadian infrastructure;
- Take stock of **resilience options** for addressing these climate risks; and
- Capture the range of **policies, practice guidance, and financing options** that have emerged in recent years at the federal level in Canada and internationally.



CANADA'S CHANGING CLIMATE

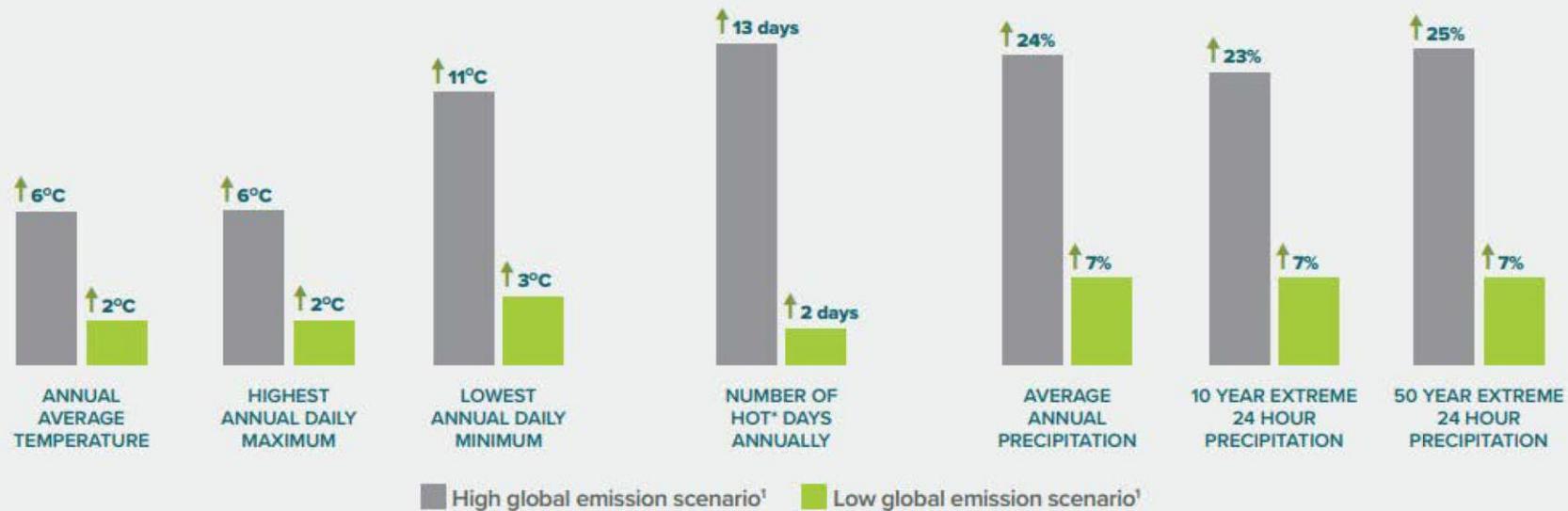
PROJECTED CHANGES THIS CENTURY



Canada's climate has warmed and will warm further in the future, driven by human influence. Global emissions of carbon dioxide from human activities will largely determine how much warming the country—and the world—will experience in the future.

HIGH VS LOW EMISSION PROJECTIONS

TWO VERY DIFFERENT FUTURES FOR CANADA



Median values. Changes are for 2081-2100 relative to the 1986-2005 reference period.

¹ High and low global emission scenarios. The high emission scenario RCP 8.5 is associated with an increase in global average temperature of about 3.7 °C by late century relative to the 1986-2005 reference period. The low emission scenario RCP 2.6 is associated with an increase in global average temperature of about 1.0 °C by late century relative to the 1986-2005 reference period.

*Hot day = daily maximum temperature is above 30°C

West Coast - too wet



<https://www.cbc.ca/news/canada/british-columbia/bc-flood-watch-road-closures-1.6249154>

West Coast - too dry



<https://thenarwhal.ca/bc-climate-disasters-2021/>

East Coast - too wet



<https://www.cbc.ca/news/canada/newfoundland-labrador/nl-rain-storm-wednesday-1.6260478>

The Middle - too dry...too wet



<https://winnipeg.citynews.ca/2022/05/15/manitoba-flood-mitigation-aerial-tour/>

<https://www.cbc.ca/news/canada/manitoba/manitoba-drought-forecast-1.6288588>

The North - too warm



<https://www.bbc.com/future/article/20210303-the-unsure-future-of-roads-and-buildings-on-melting-ground>



Key Observation #1

Considerable activity over the past decade, as evidenced by the sheer volume of literature available on resilience options for infrastructure.

This applies to all infrastructure types reviewed:

- Wastewater and stormwater
- Buildings
- Water supply
- Transportation
- Marine
- Energy and ICTs

Three categories of resilience options:

1. Risk-informed planning and assessment
2. Structural changes
3. Enhanced monitoring and maintenance

Climate Change Risks and Resilience Options for Canada's Built Infrastructure



CLIMATE HAZARD	EXAMPLES OF INFRASTRUCTURE IMPACTS	EXAMPLES OF RESILIENCE OPTIONS
	Higher temperature streams and decreased streamflow lead to more concentrated influent flows that are harder to disinfect	Apply natural infrastructure solutions (green roofs, urban forests) to increase assimilative capacity of receiving streams

Climate Change Risks and Resilience Options for Canada's Built Infrastructure

CLIMATE HAZARD	EXAMPLES OF INFRASTRUCTURE IMPACTS	EXAMPLES OF RESILIENCE OPTIONS
Wastewater and Stormwater Infrastructure	<ul style="list-style-type: none"> Exceeding capacity Increase cracking Damaged efficiency 	
Buildings	<ul style="list-style-type: none"> Increase systems Acceleration Increase Roof collapse Foundations freeze/thaw Subsidence Loss of structural integrity Erosion of foundations Increase wind damage Loss of power 	
Water Supply Infrastructures	<ul style="list-style-type: none"> Power outages Reduced deterioration Rupture Flooding Reduced Cracking 	
Energy and Information and Communications Technologies (ICTs)	<ul style="list-style-type: none"> Overheating in ICT data centres, exchanges, base stations Water level fluctuations and drier soils can increase internal erosion of embankment dams Displaced transmission tower foundations and damage to underground vaults and cable chambers Flooding of energy generation plants and substations and dam spillway gate performance issues Damage to copper and fibre-optic cables Snapped power lines, broken or fallen utility poles, ice buildup on wind turbine blades Damage and/or destruction of lines and transmission poles Annealed or damaged conductors 	<ul style="list-style-type: none"> Increase cooling system capacity Enhanced dam safety monitoring and management Modify structural designs to permit adjustment of towers when displacement due to permafrost thaw occurs Elevate substations and electrical infrastructure components and enhance dam safety monitoring and management Bury transmission and distribution lines Install microgrids to enable communities to run on secondary sources when central grids fail Bury electrical grid to avoid damage from extreme heat and fire Keep fire-prone areas clear of brush
Land Transportation	<ul style="list-style-type: none"> Pavement softening, rutting, and bleeding Thermal rail expansion (buckling) Increased risk of critical events (e.g., washouts) Increased ice accretion on cable-stayed bridges Shortened winter ice road season Soil and slope instability plus ground movement/settlement Causeways, bridges, and low-lying roads inundated or damaged Blocked roads, bridges, and railways due to debris or snow 	<ul style="list-style-type: none"> Use heat-tolerant pavement mixtures Use low-solar absorption rail coatings Increase culvert capacities Use of cable coverings to shed accreted ice Transform ice roads into all-season roads Install geotextiles Build riprap and dikes Update vegetation management-related standards (e.g. plant different tree species along roads)
Marine Infrastructure	<ul style="list-style-type: none"> Soil and slope instability and ground movement/settlement due to permafrost melt Inundation of ports and other coastal infrastructure Increased wave damage to docks and other mooring structures Increased shipping traffic in Arctic waters due to less sea ice increasing demand for Northern ports Lower water levels leading to reduced vessel capacity 	<ul style="list-style-type: none"> Thicken embankments and new infrastructure design suited to permafrost environments Build flooding considerations into building and infrastructure design Actively restore shoreline habitat (i.e., dunes, salt marshes) Demand forecasting and planning for Arctic shipping and port facilities Invest in flow augmentation technologies, and increase dredging of channels

Extreme heat, heat waves
 Seasonal temperature increases resulting in permafrost degradation and changing freeze-thaw cycles

Changing precipitation patterns
 Drought
 Wildfires

Sea ice changes
 Winter storms, ice storms, high velocity windstorms
 Permafrost degradation

Storm surges, high tides, rising sea levels
 Fluctuations in inland water levels
 High winds

Water Supply Infrastructure

Climate hazard	Examples of infrastructure impacts	Examples of resilience options
Changing precipitation patterns	<ul style="list-style-type: none"> • Power outages due to electrical storms affecting pumping stations • Reduced structural integrity and/or accelerated deterioration of dams 	<ul style="list-style-type: none"> • Enhanced and redundant backup power supplies • Adopt structural adaptations to dams, weirs, and drainage canals
Permafrost degradation	<ul style="list-style-type: none"> • Rupture of water lines and storage tanks 	<ul style="list-style-type: none"> • Use of polystyrene insulation beneath roads
Storm surges and sea level rise	<ul style="list-style-type: none"> • Flooding of treatment plant infrastructure 	<ul style="list-style-type: none"> • Seawalls, dikes, floodwalls, levees, local surge barriers, etc.
Drought	<ul style="list-style-type: none"> • Reduced source of potable water • Cracking of earthen dams, increasing flood risk 	<ul style="list-style-type: none"> • Demand management and use of natural infrastructure such as bioswales, constructed wetlands, rain gardens, and bioretention systems • Structural adaptations to dams, weirs, and drainage canals

Sources: ¹Bush & Lemmen, 2019; ²ECCC, 2016; ³ECCC, 2020; ⁴Melillo et al., 2014; ⁵Clavet-Gaumont et al., 2017; ⁶Amec Foster Wheeler & Credit Valley Conservation, 2017; ⁷Lemmen & Warren, 2004; ⁸McClearn, 2020; ⁹Felio, 2015; ¹⁰EPA, 2021.

Wastewater and Stormwater Infrastructure

Climate hazard	Examples of infrastructure impacts	Examples of resilience options
Heat	<ul style="list-style-type: none"> Higher temperature streams and decreased streamflow lead to more concentrated influent flows that are harder to disinfect 	<ul style="list-style-type: none"> Apply natural infrastructure Install effluent cooling systems
Changing precipitation patterns	<ul style="list-style-type: none"> Exceeding stormwater/drainage systems 	<ul style="list-style-type: none"> Increased capacity of stormwater and drainage collection systems Reduce or green up impervious surfaces (e.g., roofs, parking areas)
Seasonal temperature changes	<ul style="list-style-type: none"> Increased frequency, duration, and severity of thermal cracking and rutting 	<ul style="list-style-type: none"> Use phase-change materials to reduce the number of freeze/thaw cycles
Storm surges	<ul style="list-style-type: none"> Damaged or flooded structures that reduce treatment efficiency 	<ul style="list-style-type: none"> Hybrid built and natural infrastructure solutions (e.g., terraced berms, drainage improvements, bulkheads, beach nourishment, reinforced dunes, offshore breakwaters, living shorelines)

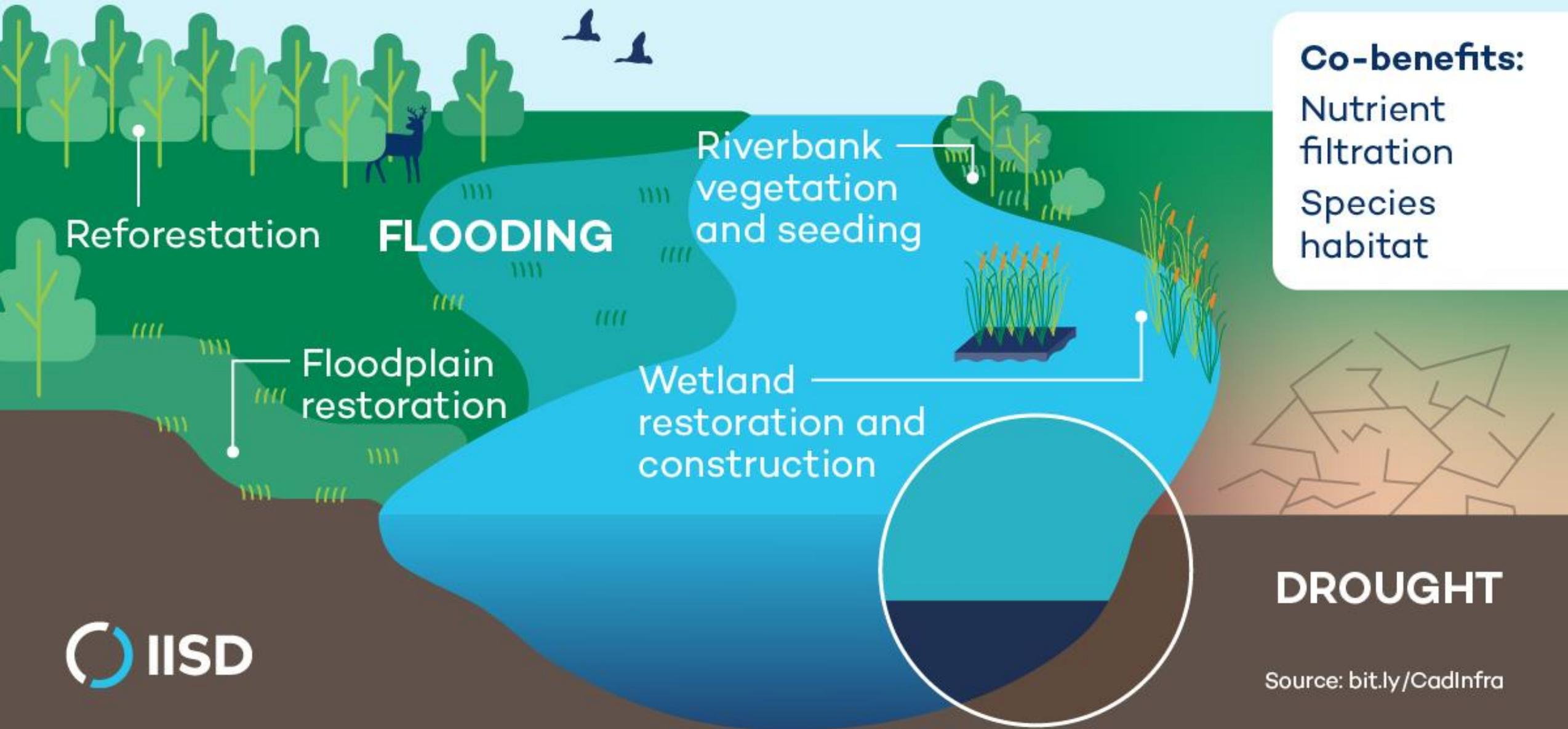
Sources: ¹Bush & Lemmen, 2019; ²ECCC, 2016; ³ECCC, 2020; ⁴Amec Foster Wheeler & Credit Valley Conservation, 2017; ⁵Mercer Clarke & Clarke, 2018; ⁶Melillo et al., 2014; ⁷EPA, 2021.

An aerial photograph of a lush green mangrove forest. The dense canopy of trees is punctuated by a network of winding, shallow water channels that create a complex, organic pattern. The water in the channels has a slightly different hue, appearing more teal or light blue-green compared to the surrounding foliage. The overall scene is vibrant and natural.

Key Observation #2

Natural infrastructure is becoming a mainstream option for enhancing the resilience of built infrastructure and communities.

Riverine Natural Infrastructure Solutions



Source: bit.ly/CadInfra

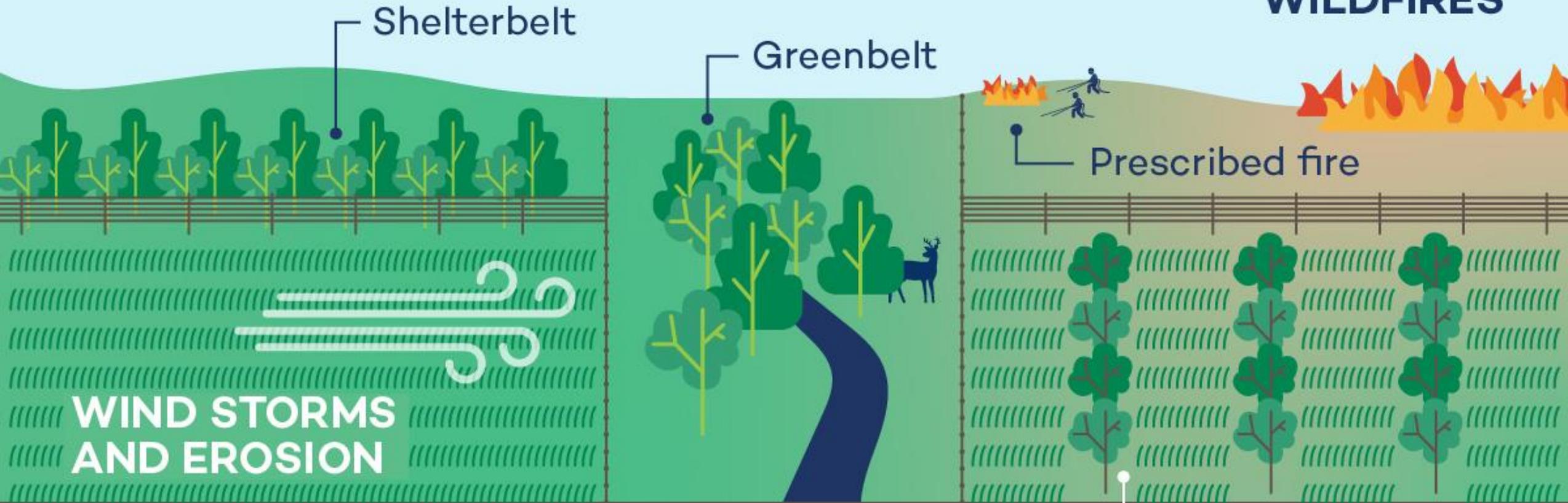
Floating Treatment Wetlands



Rural Natural Infrastructure Solutions

Source: bit.ly/CadInfra

WILDFIRES



Co-benefits:

Food production
Species habitat

Engineered Wetlands

Source: IISD.org





Key Observation #3

A diverse range of strategies, policies, guides, standards, codes, and financing programs have emerged to help inform resilience options for infrastructure.

For example, at the federal level in Canada:

- Climate Lens General Guidance (and Public Infrastructure Engineering Vulnerability Committee - PIEVC risk assessment guidance)
- Climate-Resilient Buildings and Core Public Infrastructure Initiative
- Investing in Canada Infrastructure Program and the Disaster Mitigation and Adaptation Fund
- Municipalities for Climate Innovation and Asset Management programs implemented by the Federation of Canadian Municipalities

OUTCOMES OF THE INITIATIVE

FACTORS TO CONSIDER

- One third of core public infrastructure is in poor condition

ECONOMIC BENEFIT

- \$170 billion cost for repair and upkeep of core public infrastructure
- \$12 saved for every \$1 invested in new construction or retrofits adapted to climate change

FORWARD-LOOKING CLIMATIC DESIGN DATA

DECISION SUPPORT TOOLS

- BUILDINGS**: Design durable buildings that prevent overheating and have roofs resilient to extreme weather events.
- BRIDGES**: Build new bridges to withstand future climate conditions, last longer, with extended service life. Satellite monitoring for inspection and proactive maintenance.
- ROADS**: Adapt existing pavement and construction to climate change. New flexible roads and materials that require less maintenance and contribute less to greenhouse gases.

UPDATES TO CODES AND STANDARDS

- RAIL TRANSIT**: Adapt track systems to counter the effects of climate change: outdoor air temperature extremes, freeze/thaw cycles. Benefit: Improved safety, operation and passenger comfort.
- FLOODING**: Design guidelines for flood-resilient buildings: new buildings, retrofit/improve existing buildings, reduce flood risk in residential communities, basement flood protection and risk reduction. Benefit: reduce the risk of flooding in new and established neighborhoods and lessen overall damage.
- COASTAL FLOODING**: Protect against sea level rise and storm surge; guidance for stormwater systems; buoyant foundations, nature-based shore protection systems. Benefit: reduce the risk of coastal flooding and erosion and improve coastal resilience.
- WILDLAND URBAN INTERFACE FIRE**: National Canadian guide: slow the spread of wildland fire through choice of materials, maintenance, landscaping. Hazard/risk mapping information that predicts impacts of climate change. Benefit: (1) benefit to cost ratio and savings of 5000 million/year.
- GUIDE FOR ADAPTABLE HOUSING FOR REMOTE/INDIGENOUS COMMUNITIES**: Benefit: design for different climate conditions; prepare for even greater warming in the North; developed in partnership with the First Nations National Building Officers Association.

DESIGN FOR RESILIENCE FROM THE START

Build back better to help the industry innovate, build capacity in small/remote/Indigenous communities, and to develop tools and education to create a culture of resilience. infrastructure.gc.ca/plan/erbcpi-iccipi-eng.html

CANADA'S CLIMATE CHANGE ADAPTATION PLATFORM
Equipping Canadians for a Changing Climate

INFRASTRUCTURE AND BUILDINGS WORKING GROUP

Adaptation State of Play Report
March 2017

FCM FEDERATION OF CANADIAN MUNICIPALITIES

Municipalities for Climate Innovation Program

But is it all enough?

The Gap

Overall infrastructure gap of \$150 billion to \$1 trillion (First Nations ~\$30 billion)

(Advisory Council on Economic Growth, 2016)

The State

2019 Canadian Infrastructure Report Card: "concerning amount of municipal infrastructure in poor or very poor condition".

(BluePlan Engineering, 2019, p. 9)

The Risk

Physical infrastructure ranked as Canada's most consequential risk area

(Council of Canadian Academies, 2019)

The Consequence

CICC 2021 Report concluding Canada's infrastructure is not prepared for the climate crisis

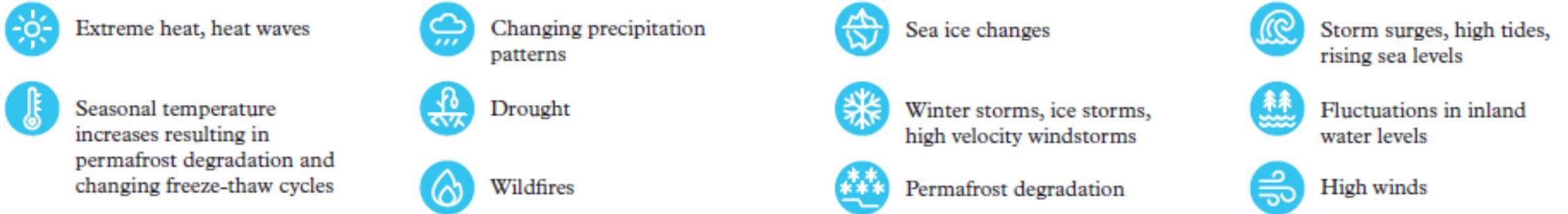
(Canadian Climate Institute, 2021)





While there has been considerable activity to increase the climate resiliency of infrastructure in Canada, greater effort and investment are needed to match the expanding scale of the issue.

Informing the Way Forward



Increased incentive for implementing resilience options

Risk-informed planning and assessment

Structural changes

Enhanced monitoring and maintenance

Integrating natural infrastructure solutions

More and diverse sources of financing

Public-private partnerships and investment

Greater use of innovative financing options

Whole-of-society approach

Systems thinking and policy coherence

Flexible, robust, and redundant options and pathways

Greater consideration of interrelated social factors



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Merci,
Thank you!**

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