Housing, Infrastructure and Communities Canada
Logement, Infrastructures et Collectivités Canada

Baseline Assessment of Climate-Resilient Infrastructure Guidance Implementation in Canada

Canada

Prepared by WSP for Housing, Infrastructure and Communities Canada.

Ce rapport est disponible en français sous le titre *Évaluation de base de la mise en œuvre des documents d'orientation sur la résilience aux changements climatiques des infrastructures au Canada*.

Important: This report refers to the Inventory of Existing Guidance for Climate-resilient Infrastructure in Canada (Excel). To obtain a copy of this Inventory, please contact info@infc.gc.ca.

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Executive Summary

OBJECTIVES AND METHODOLOGY

Housing, Infrastructure and Communities Canada (HICC) has developed and supported a wide range of climate-resilient guidance for infrastructure projects across Canada. In this context, climate resilient infrastructure is predictable, reliable, and secure, meeting the needs of communities fairly and equitably, including those with existing gaps in infrastructure and those with infrastructure at highest risk of climate impacts [1]. As HICC continues to develop and support programs and guidance for climate-resilient infrastructure, these initiatives must complement existing efforts, drive climate risk assessment and treatment, and incentivize the development of housing and infrastructure that is sufficiently resilient to a rapidly changing climate.

WSP completed a baseline assessment of available guidance for climate-resilient infrastructure in Canada (the "project") to achieve the following five objectives:

1. Create an inventory of Canadian guidance for climate-resilient infrastructure.
2. Identify target end-users, their level of awareness, and their use of the climate-resilient guidance.
3. Assess the most frequently used and effective guidance, and any existing gaps and challenges.
4. Demonstrate the benefit of the guidance through evidence and examples of how it has increased climate resilience.
5. Provide case studies of municipalities that have adopted climate-resilient codes and standards for their infrastructure work.

The project scope included the following infrastructure asset types:

- Buildings, including residential housing
- Water, including drinking water, wastewater, and stormwater
- Transit, prioritizing roads, highways, bridges, light rail, and rapid transit infrastructure when part of a public transportation system (e.g., subways, buses) or active transportation system[1]
- Protective infrastructure, built specifically to protect people and property (e.g., berms, dykes, and embankments)

[1] Ferries and air transportation are essential modes of public transportation in many remote communities; however, these modes of transportation typically sit within Transport Canada's scope and are therefore excluded from this assessment. Public transit fleets are also excluded from the project scope.

The project scope also included nature-based solutions (NBS), which have been considered across the four infrastructure categories listed above.

To achieve the project objectives, WSP developed an approach to identify and solicit climate guidance information. WSP conducted a literature review of existing guidance that was publicly available online, distributed an online survey to targeted stakeholders[2], and hosted subject-matter expert workshops to gather end-user experience and observations.

ANALYSIS AND OBSERVATIONS

In total, WSP assembled an inventory of 158 guidance documents for climate-resilient infrastructure across different jurisdictions and asset types in Canada. Of the 158 documents, 47 apply to all sectors, 63 to buildings, 35 to water, 20 to transit, 8 to protective infrastructure, and 10 to natural assets. The project also identified an ancillary list of 156 related resources, including relevant documents, tools, platforms, hubs, and databases, that did not meet all the criteria for inclusion in the inventory. The inventory and ancillary lists of resources were compiled in an Excel workbook. Each entry provides multiple fields of metadata including the title, publication year, URL, author name, jurisdiction and jurisdiction type, end-users, asset type, considerations of nature-based solutions, applicable climate hazard(s), and brief description.

Available Guidance

There has been an upswell of guidance published in recent years, most of the guidance documents are national in scope, and there are more guidance documents with considerations pertaining to flooding than other hazards. Despite the abundance of guidance documents, there is a notable lack of guidance for operations and maintenance, and gaps for guidance in some regions (e.g., prairies) by some jurisdictions (e.g., municipal guidance in coastal and northern regions). The inclusion of climate resilience considerations in many guidance documents that are not primarily focused on climate issues adds to a complex landscape of guidance that is challenging to assess.

In addition to the gaps identified through the inventory, subject matter experts identified the following gaps by asset type:

- Buildings: climate-resilient guidance on specific hazards (e.g., permafrost, floods, heatwaves) and regional guidance (provincial/territorial and municipal)
- Water: climate-resilient water infrastructure guidance with a high level of detail specifically for practitioners and designers
- Transit: climate-resilient transit guidance for cold-weather climates

[2] The survey was originally developed for widespread distribution but ultimately only distributed to experts who were invited to the workshops but could not attend, and to experts that workshop attendees recommended to the project team.

- Protective infrastructure: municipal, regional, and provincial guidance for protective infrastructure and specific data on, for example, permafrost thaw, fires, and flooding in Canadian environments
- NBS: lack of detailed, practical guidance about implementation and long-term operations and maintenance of NBS

Guidance Navigation and Implementation

Experts also identified challenges and opportunities common to all asset types including:

- More support would help end-users navigate the complex environment of climate-resilient guidance and resources that currently exist.
- Regulatory direction would enable climate-resilient projects by justifying additional costs.
- Risk assessments are often required to meet funding requirements but are often not completed early enough in the project lifecycle to influence the design, or there is no requirement to implement the recommendations arising from the risk assessment.

Case Studies

WSP compiled four case studies that showcase successful guidance implementation for each asset category in various communities across Canada:

- Supply System used Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol and Ontario Regulation 588/17: Asset Management Planning for Municipal Infrastructure to adapt water infrastructure to their communities' changing climate. This water infrastructure-focused case study showcases the use of the PIEVC Protocol as a commonly used tool, and the value of requiring climate considerations in asset management, to support the development of resilient infrastructure.
- Providence Health Care used Climate Resilience Guidelines for B.C. Health Facility Planning and Design to integrate climate resilience measures into its facility planning and design. This building-focused case study showcases climate resilience considerations throughout an entire design process.
- Government of Northwest Territories used Transportation Association of Canada (TAC), Guidelines for Permafrost Regions and Government of Northwest Territories, Department of Transportation's Erosion and Sediment Control Manual (ESCM) to develop a permafrost protection plan for the Prohibition Creek Access Road. This transit infrastructure-focused case study showcases climate resilience for complex hazards in a northern context and includes consideration for infrastructure operations and maintenance.
- Annapolis Royal used the PIEVC Protocol and CLIMAtlantic's *Climate Risk, Responsibility, and Liability for Municipalities* to develop climate-resilient infrastructure actions to protect the community from

coastal flooding. This protective infrastructure-focused case study showcases the use of novel funding strategies and adaptive planning in supporting the development of climate-resilient infrastructure.

CONCLUSION AND RECOMMENDATIONS

Gaps in Guidance Availability

The assessment found that, although existing guidance produced for specific regions and asset types is beginning to integrate climate change consideration, in many cases there is also new guidance focused specifically on climate-resilient infrastructure. End-users are still becoming familiar with new and updated guidance that reflects these changing conditions. Over the last two decades, there has been marked evolution in guidance to assess climate risk; however, greater emphasis is now needed to ensure robust guidance for asset and/or hazard-specific climate risk reduction measures.

No guidance documents qualitatively stand out within or across infrastructure types as 'top' or most-used guidance. No guidance document was mentioned repeatedly in the expert workshops or case studies; however, the PIEVC Protocol is a widely used climate risk assessment tool.

Overall, review of the guidance inventory and expert insights found that there are gaps in available guidance, a lack of awareness of guidance, and barriers to guidance uptake and implementation. To overcome these gaps, WSP recommends to:

- Integrate climate considerations into existing guidance rather than developing new stand-alone documents because integration represents a favourable cost-benefit investment and may support greater uptake in projects by practitioners familiar with previous versions of the guidance.
- Continue supporting guidance development for regions and topics for which no or insufficient guidance exists (e.g., northern regions where permafrost thaw, fire, and flooding are rapidly changing the environment).

Challenges in Navigating the Guidance Landscape

There are many other supports beyond technical 'guidance' that are used and important in building climate-resilient infrastructure. These items are included in the ancillary list and highlighted in the case studies. Despite calls from subject matter experts and practitioners for more guidance specific to some asset types and climate hazards, there is a substantial amount of guidance for climate-resilient infrastructure in Canada.

The landscape of guidance can be difficult to navigate because there is a high volume of documents, there are updates and new guidance documents developed over time, users employ guidance as well as other supports (such as manuals and best practices) in supporting climate resilient infrastructure, and guidance is authored and provided by many parties across jurisdictions with no central repository. Further, more guidance does not always equate to better quality of guidance or easier implementation of resilience measures. WSP recommends the following strategies to manage the complexity of the guidance landscape and support end-users:

- Provide education and outreach to key stakeholders, such as municipal associations and provincial engineering organizations, to help navigate the guidance environment.
- Continue developing the guidance inventory by adding more resources, as they become available, to create a centralized collection, aiding end-users in navigating evolving guidance. Consider making the inventory available on the Climate Insight platform to enhance accessibility and ultimately understanding, use, and efficacy of guidance.

Challenges in Implementation of Guidance

In addition to developing improved guidance and assisting end-users in navigating the guidance landscape, more support is needed for end-users to finance and implement climate resilient infrastructure projects. To date, most funding requirements are connected to climate risk assessments and not to the actual development of climate-resilient infrastructure. To be effective, asset owners, planners, and designers need a clear understanding of the cost-benefit of integrating resilience measures throughout project phases and asset lifecycles. Explicit requirements for climate considerations enable resilience actions in instances where climate considerations may not otherwise occur due to funding or other resource limitations.

Realities of limited budgets at the provincial, territorial, municipal levels, and particularly small, rural and Indigenous communities, can hinder implementation of climate-resilience in infrastructure projects, especially when the long-term cost-benefit is uncertain. WSP recommends that HICC:

- Ensure funding programs require projects to demonstrate how climate resilience has been incorporated into planning and design phases.
- Support better understanding and reduction of implementation barriers for end-users. This may include conducting broader surveys or additional focus groups with end-users focused on the cost-benefit analyses and business cases to implement guidance and enable development and maintenance of climate-resilience infrastructure.
- Consult with municipal and Indigenous governments, provinces and territories to align government funding structures and regulations with municipal realities.
- Support owners in conducting the cost-benefit analyses to identify the long-term value and avoided costs associated with climate-resilient infrastructure. Simplified or accessible cost-benefit analyses can support the value proposition for municipal councils or funding programs, for example, to justify the up-front costs of climate-resilient infrastructure.
- Work with regulators to develop and implement more regulatory mechanisms that support climate resilient infrastructure. This approach can make it easier for stakeholders to justify adherence to regulations, even with limited funds.

Looking forward, it is important that guidance documents and climate-resilient infrastructure initiatives keep pace with the changing climate as well as the needs of end-users and communities across Canada. It is recommended that HICC continue understanding and validating the perspectives presented in this assessment through further engagement with end-users and those involved in all phases of supporting climate-resilient infrastructure. By addressing these limitations and implementing these recommendations, Canada can enhance the effectiveness of its climate-resilient infrastructure initiatives.

Case Studies

The case studies included in this report showcase the practical application of existing guidance documents for both climate risk assessment and climate resilient infrastructure development. They outline national, provincial, territorial, and regional guidance supporting communities facing acute and chronic climate change hazards, particularly for aging infrastructure crucial to community services and safety. The case studies underscore the value of tailored guidance and support to incentivize and implement climate-resilient projects effectively. They showcase communities and organizations that have moved beyond short-term thinking focused on initial capital construction costs.

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ACRONYMS

Acronym	Definition
AAMA	American Architectural Manufacturers Association
ACASA	Atlantic Climate Adaptation Solutions Association
ACEC	Association of Consulting Engineering Companies Canada
AMO	Association of Municipalities Ontario
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance-of-way Association
ASCE	American Society of Civil Engineers
ASLA	American Society of Landscape Architects
BARC	Building Adaptive & Resilient Communities
BNQ	Bureau de Normalisation du Québec
BOMA	Building Owners and Managers Association Canada
CCRN	Canadian Coastal Resilience Network
CEC	Commission for Environmental Co-operation
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
CRBCPI	Climate-Resilient Buildings and Core Public Infrastructure
CRI	Climate Risk Institute
CSA	CSA Group
CVC	Credit Valley Conservation
DHI	Dansk Hydraulisk Institut
DVE	Design Value Explorer
ECCC	Environment and Climate Change Canada
EECA	Prince Edward Island Department of Environment, Energy and Climate Action
ESCM	Erosion and Sediment Control Manual
FCM	Federation of Canadian Municipalities

Acronym	Definition
FEMA	Federal Emergency Management Agency
FNNBOA	First Nations National Building Officers Association
GCC	Green Communities Canada
GNWT	Government of Northwest Territories
GPR	Guidelines for Permafrost Regions
HICC	Housing, Infrastructure, and Communities Canada
HVAC	Heating, Ventilation, and Air Conditioning
IBWG	Infrastructure and Buildings Working Group
ICLEI	International Council for Local Environmental Initiatives
ICLR	Institute for Catastrophic Loss Reduction
IDF	Intensity-Duration-Frequency
IFRS	International Financial Reporting Standards
IISD	International Institute for Sustainable Development
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
MNAI	Municipal Natural Assets Initiative
NAI	Natural Assets Initiative
NAS	National Adaptation Strategy
NBDELG	New Brunswick Department of Environment and Local Government
NBS	Nature-Based Solutions
NEHRP	National Earthquake Hazards Reduction Program
NGO	Non-Governmental Organization
NRC	National Research Council
PCAR	Prohibition Creek Access Road
PCIC	Pacific Climate Impacts Consortium
PEI	Prince Edward Island
PIEVC	Public Infrastructure Engineering Vulnerability Committee
PT	Provincial/Territorial

Acronym	Definition
SCC	Standards Council of Canada
SNBSC	Southwest New Brunswick Service Commission
SSRIP	Standard to Support Resilience in Infrastructure Program
SUDS	Sustainable Urban Drainage Systems
TAC	Transportation Association of Canada
TCFD	Task Force on Climate-related Financial Disclosures
TDR	Technical Design Requirements for Alberta Infrastructure Facilities
TMU	Toronto Metropolitan University
TRCA	Toronto and Region Conservation Authority
USACE	United States Army Corps of Engineers
U.S.	United States
UWSS	Union Water Supply System
WDMA	Window & Door Manufacturers Association
WUI	Wildland-Urban Interface

1. Introduction and Background

The *National Adaptation Strategy* (NAS) is the first strategy in Canada that outlines a collective approach toward building a country that is better equipped to handle the impacts of climate change [1]. The NAS defines "climate-resilient infrastructure" as "predictable, reliable, and secure infrastructure services [..that] meet the needs of all communities fairly and equitably, including those with existing gaps and those with infrastructure at highest risk of climate impacts" [1].

Public Services and Procurement Canada (PSPC) and Housing, Infrastructure and Communities Canada (HICC) have supported the development of climate-resilient guidance for infrastructure projects across Canada. In 2016-2021, HICC funded the *Climate Resilience Building and Core Public Infrastructure* (CRBCPI) initiative, and the Standards Council of Canada (SCC) delivered, in parallel, the *Standards to Support Resilience in Infrastructure Program* (SSRIP) [2]. These two initiatives are now in their second phases (2021-2026) and will contribute to meeting HICC's objectives under the NAS and Action 40 "Climate-Informed Codes and Standards for Resilient Infrastructure" of the *Government of Canada Adaptation Action Plan* [3]. For PSPC, HICC and their partners to meet their commitments to increase climate-resilient infrastructure under the NAS, the current landscape and implementation of guidance must be understood, and any new guidance development must build on existing efforts to fill current needs and gaps.

To inform resilient infrastructure guidance and the ongoing use and evolution of funding requirements, PSPC and HICC contracted WSP to develop a report (the "project") that provides a baseline inventory of guidance and assess the current level of guidance implementation and how it is used in the Canadian context. The project aims to achieve the following five objectives:

1. Create an inventory of Canadian guidance for climate-resilient infrastructure.
2. Identify target end-users, their level of awareness, and their use of the climate-resilient guidance.
3. Assess the most frequently used and effective guidance, and any existing gaps and challenges.
4. Demonstrate the benefit of the guidance through evidence and examples of how it has increased climate resilience.
5. Provide case studies of municipalities that have adopted climate-resilient codes and standards for their infrastructure work.

The project scope included the following infrastructure asset types:

- buildings, including residential housing
- water, including drinking water, wastewater, and stormwater

- transit, prioritizing roads, highways, bridges, light rail, and rapid transit infrastructure when part of a public transportation system (e.g., subway, buses) or active transportation system[3]
- protective infrastructure, built specifically to protect people and property (e.g., berms, dykes, and embankments)

Project scope also included nature-based solutions (NBS), which are considered across the four infrastructure categories.

The report is structured as follows:

- A streamlined guidance inventory provides a list of Canadian guidance documents for climate-resilient infrastructure that reduces climate risk at national, provincial/territorial, regional, municipal, and international levels. The inventory includes codes, standards, guidelines, guides, and technical circulars. Items that were identified in the review and engagements but did not fully meet inclusion criteria for the inventory are included in an ancillary list. A full inventory of guidance documents and ancillary items is available as an accompanying Excel file.
- A qualitative analysis of expert input outlines end-user understanding of key gaps in existing guidance as well as challenges and opportunities in adopting guidance to support climate-resilient infrastructure projects.
- Four case studies demonstrate how communities have implemented existing guidance for climate-resilient infrastructure projects across Canada.

HICC can leverage the results of this report to understand the current landscape and use of guidance for climate-resilient infrastructure in Canada, inform the ongoing development of guidance and funding requirements, and ultimately progress toward achieving the objectives of the NAS.

[3] Ferries and air transportation are essential modes of public transportation in many remote communities; however, these modes of transportation typically sit within Transport Canada's scope and, therefore, are excluded from this assessment. Public transit fleets are also excluded from the project scope.

2. Method and Approach

WSP used a mixed-methods approach (online review, expert workshops, surveys, and case studies) to develop an inventory of guidance for climate resilient infrastructure across Canada, to broadly characterize how the guidance is used, and to identify the benefits and challenges associated with the current state of guidance. The team conducted an online review to develop the inventory of existing guidance (Objective 1) and conducted expert workshops and a survey to supplement the guidance inventory and to gather insights about its use, benefits, challenges, and gaps (Objectives 1-4). Case studies were developed based on information collected through the online review, the expert workshops, and the survey responses to demonstrate guidance implementation (Objective 5).

2.1 Online Review

The online review was conducted to develop an inventory of the existing guidance to reduce climate risk for infrastructure related to buildings, water, public transport, and protection across Canada (Objective 1). The following criteria were used to target guidance documents most relevant to increasing climate resilience or climate change adaptation in infrastructure design and management:

- publicly available
- published as guidance
- published no earlier than 2019[4]
- authored by a reputable body (including governments and non-government bodies)
- issued by and applicable to national, provincial/territorial, municipal, and international jurisdictions
- applicable to at least one of the four infrastructure categories (buildings, water, public transport, protective)
- explicitly referencing climate change adaptation and/or resilience
- applicable to any phases of infrastructure lifecycles (e.g., location, design/build, operate/maintain)

[4] 2019 was set as a publication cut-off date, in agreement with the client, to capture recent guidance. Some exceptions were made; guidance documents that were identified by subject matter experts to be highly used or important provincial/territorial Climate Adaptation Plans or CSA Group guidance documents were included in the inventory, as well as guidance documents identified in case studies.

- either required or voluntary[5]
- applicable to adaptation measures and interventions, including nationally applicable climate risk assessment methods

WSP developed an ancillary list to capture relevant items (e.g., documents, tools, platforms, hubs, databases), that were identified through the assessment but did not meet all the criteria needed to be included in the inventory. For example, WSP and consulted experts may have deemed the items included in the ancillary list relevant; however, they were:

- published before 2019[4]
- not published as guidance (e.g., research or studies making recommendations for design requirements but not "guidance")
- climate change risk assessment guidance documents

WSP used four reference sources as starting points for identifying guidance to review:

1. HICC websites:
    a. Codes, standards and guidance for climate resilience: https://www.infrastructure.gc.ca/climate-resilience-climatique/codes-standards-normes-guidances-eng.html
    b. Standard and Guidance: Assets and Hazards: https://www.infrastructure.gc.ca/climate-resilience-climatique/hazards-dangers-eng.html
2. Standards Council of Canada (SCC). 2022. Guidance Document on Using Climate Information in Standards Development
3. Credit Valley Conservation (CVC) Authority and WSP. 2023. National Infrastructure and Buildings Climate Change Adaptation State of Play Report (report for Housing, Infrastructure and Communities Canada)
4. International Institute of Sustainable Development (IISD). 2021. Advancing the Climate Resilience of Canadian Infrastructure. https://www.iisd.org/system/files/2021-07/climate-resilience-canadian-infrastructure-en.pdf

WSP then conducted a gap analysis to identify search criteria (outlined above) for other potential guidance documents, which were retrieved through an online search. These guidance documents formed the initial

[5] A guidance is considered 'required' if adhering to the guidance is referenced in legislation or required for funding, permits or design. It is voluntary or not required if it is a recommended approach. Please note that this a grey area with different approaches and challenges across the country and this designation may change over time depending how guidance is used and how it evolves.

inventory. As the expert workshops were conducted and surveys responses were received, WSP verified existing guidance documents and added new guidance documents to the inventory.

WSP used an Excel spreadsheet to compile the inventory to support tailored sorting and simplify updates to the list. For each guidance identified, WSP included the following information:

- Publication Data
  - Title
  - Year of Publication
  - URL Link for Access
  - Author and Stakeholder Information
  - Author
  - Author Jurisdiction
  - End-users
- Asset and Hazard Information
  - Asset Type
  - Inclusion of Nature-Based Solutions (NBS)
  - Applicable Climate Hazards
  - Guidance Description and Use Information
  - Description
  - Document Type
  - Required[5]
  - Action Specified or Required

WSP acknowledges that the inventory represents existing guidance at a moment in time and likely does not include all guidance documents, especially documents in development and those from municipalities and smaller jurisdictions, given that there are over 3,500 municipalities in Canada.

2.2 Primary Research

WSP conducted workshops with subject matter experts and developed a survey to support and validate the initial guidance inventory and gather expert insight about guidance use, benefits, challenges, and needs (Objectives 1-4).

2.2.1 Expert Workshops

In July and August 2024, five, 1-hour, virtual workshops were conducted on Microsoft Teams using Jamboard, a virtual collaboration platform. One workshop was held for each infrastructure category (buildings, water, transit, and protective infrastructure) and one for NBS. The workshops aimed to identify gaps in the guidance inventory and provide high-level insights into any challenges implementing climate-resilient guidance in infrastructure projects.

WSP identified expert invitees to the workshops using HICC's Infrastructure and Buildings Working Group (IBWG), a list of provincial and territorial staff specializing in climate-resilient infrastructure, online searches, and professional networks. WSP confirmed the outreach list with HICC prior to sending invitations. As aligned with best practice, WSP aimed to source seven to ten participants for each workshop [4]. In total, WSP sent workshop invitations to 195 subject matter experts to attend a workshop on guidance for climate-resilient infrastructure for their infrastructure type. Table 1 and Table 2 show that a total of 63 participants attended the workshops (32% of participants invited). Each workshop included six to sixteen participants, as outlined in Table 1. To promote even representation across regions, WSP invited at least two experts from each of the regions outlined in Table 2.

Table 1: Expert Count by Asset Type

Asset Type	Focus Group Count (#)	Survey Count (#)	Interview Count (#)	TOTAL
Buildings	9	2	-	**11**
Water	9	1	-	**10**
Transit	16	2	-	**18**
Protective	6	-	-	**6**
NBS	10	-	-	**10**
Multi-Asset	-	6	2	**8**
TOTAL	**50**	**11**	**2**	**63**

Note: the "Multi-Asset" category includes interviewees and survey respondents who provided input for more than one asset type.

Table 2: Expert Count by Region

Region	Focus Group Count (#)	Survey Count (#)	Interview Count (#)	TOTAL
Atlantic	7	1	1	**9**
Northern	9	3	-	**12**
Prairies	3	2	-	**5**
Ontario	12	2	-	**14**
Quebec	2	-	1	**3**
British Columbia	6	3	-	**9**
Multiple Jurisdictions	11	-	-	**11**
TOTAL	**50**	**11**	**2**	**63**

Note: the "Multiple Jurisdictions" category includes workshop attendees, interviewees, and survey respondents who provided input for more than one region.

Using the virtual facilitation platform, WSP provided workshop attendees with a list of guidance documents sourced via the online literature review and asked experts to identify any missing guidance documents. Experts identified various documents, which are included in the guidance inventory in Section 0 and in the accompanying Excel document. Then, WSP facilitators asked open-ended questions, allowing participants to highlight key points:

- What gaps exist in current guidance for climate-resilient infrastructure for [insert relevant asset type]?
- What are the key challenges you face to develop and implement guidance for climate-resilient infrastructure projects for [insert relevant asset type]?

WSP facilitators used a semi-structured group interview method for these questions, enabling open-ended discussions and insights. Although the workshops were facilitated, the open-ended nature of the workshop questions means the absence of certain topics in one focus group compared to another does does not imply they were not relevant, only that the item was not prioritized by attendees in the discussion. Semi-structured group interviews (i.e., expert workshops or focus groups) are effective for gathering diverse ideas and perceptions in a setting that encourages varied viewpoints without requiring consensus. Group discussions often elicit rich information, as participants' insights can prompt others to share their experiences and perspectives, revealing the nuances of complex topics [4].

Semi-structured individual interviews were hosted in instances where an expert contributor was not able to attend the workshop or preferred to contribute in French rather than English. WSP facilitators also asked

participants to identify any guidance for climate-resilient infrastructure implementation success stories. Expert input from this question is incorporated into the case studies outlined in Section 6.0.

2.2.2 Surveys

WSP developed and circulated two versions of a survey to specific stakeholders who were not able to attend the expert workshops or additional experts who were recommended by workshop contributors. The survey supported the development of the guidance inventory and gathered expert insight about guidance use, benefits, challenges, and needs (Objectives 1-5).

One version of the survey focused on regional differences and the other focused on differences among infrastructure categories/asset types. Respondents were asked to identify which documents they used from a list that was auto-generated from WSP's online review. Differences between the two versions of the survey are outlined below.

- **Survey by region**: Options were categorized by province/territory and region. For example, if respondents selected Nova Scotia, they would see an auto-generated list of guidance documents for Nova Scotia and Atlantic Canada. Survey respondents could select options for two provinces/territories.
- **Survey by asset type**: Options were categorized by asset type (i.e., buildings, water, transit, protective). For example, if respondents selected buildings, they would see an auto-generated list of guidance documents for buildings. Survey respondents could select options for two asset types.

Following the questions on guidance document usage, respondents were asked to identify case studies that demonstrate the successful implementation of guidance in climate-resilient infrastructure projects.

Survey respondent asset type and regional data is outlined in Table 1 and Table 2, respectively.

2.3 Case Studies

Although experts identified numerous successful climate-resilient infrastructure projects across asset types and community contexts in Canada, WSP faced challenges in finding case studies that specifically demonstrated the effective use of climate resilience guidance. This issue likely stemmed from gaps in guidance and data identified during the inventory analysis and workshops and implementation challenges highlighted by experts.

Despite these limitations, four case studies are highlighted to showcase the application of guidance for climate-resilient infrastructure across Canada and a range of community sizes and types. One case study was developed for each infrastructure category using input from expert workshops, surveys, and literature identified in the online review. Priority was given to case studies identified through workshops. When workshop attendees did not provide suitable case studies, WSP reviewed publicly available online information to find appropriate examples and connected with authors of the materials for more information.

3. Guidance Inventory

The primary objective of this assessment was to inventory existing guidance for climate-resilient infrastructure across Canada. At the time of submission, WSP identified 158 guidance documents, and included 156 additional items in the ancillary list. Table 3 lists the number of guidance documents with specific features. The numbers listed do not add up to the total number of guidance documents in the inventory because some guidance documents are applicable to multiple categories and jurisdictions. Figure 1 shows the number of provincial/territorial guidance authored by each province or territory. It also shows the number of guidance authored for multiple provinces/territories (Atlantic and Northern, in grey on right). Figure 2 shows the number of guidance for climate hazard types. For presentation in this figure, some climate hazard types are grouped together. Figure 3 shows the number of documents, included in both the inventory and the ancillary, published each year. Documents included in both the inventory and ancillary are included to capture the range of supports published over time.

Table 3: Guidance Inventory Summary

		Jurisdiction				
		National	Provincial / Territorial	Regional	Municipal	International
Asset Type	All	19	15	2	5	6
	Buildings	39	9	2	10	3
	Water	20	10	2	3	0
	Transit	9	10	0	1	0
	Protective	4	2	1	1	0
	NBS	4	0	3	1	2
TOTAL		84	41	6	16	11

The total numbers listed do not add up to the total number of guidance documents in the inventory because some guidance documents are applicable to multiple categories, jurisdictions, and/or environment types.

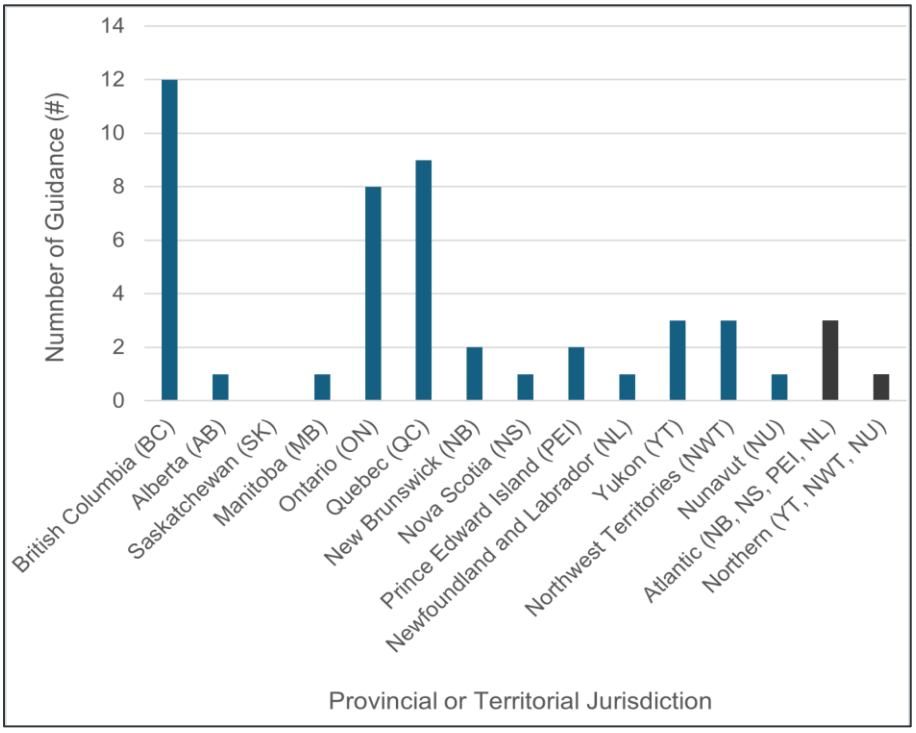

Figure 1: Provincial/Territorial Guidance in Inventory

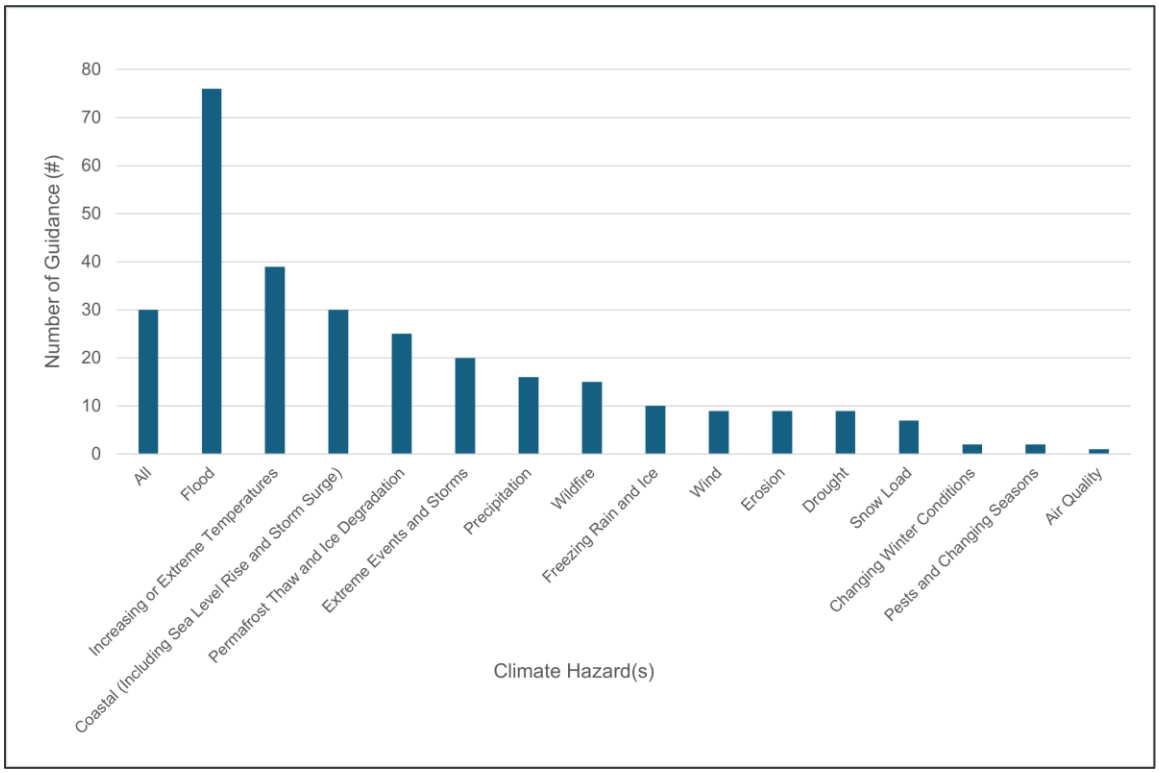

Figure 2: Guidance for Climate Hazard Types

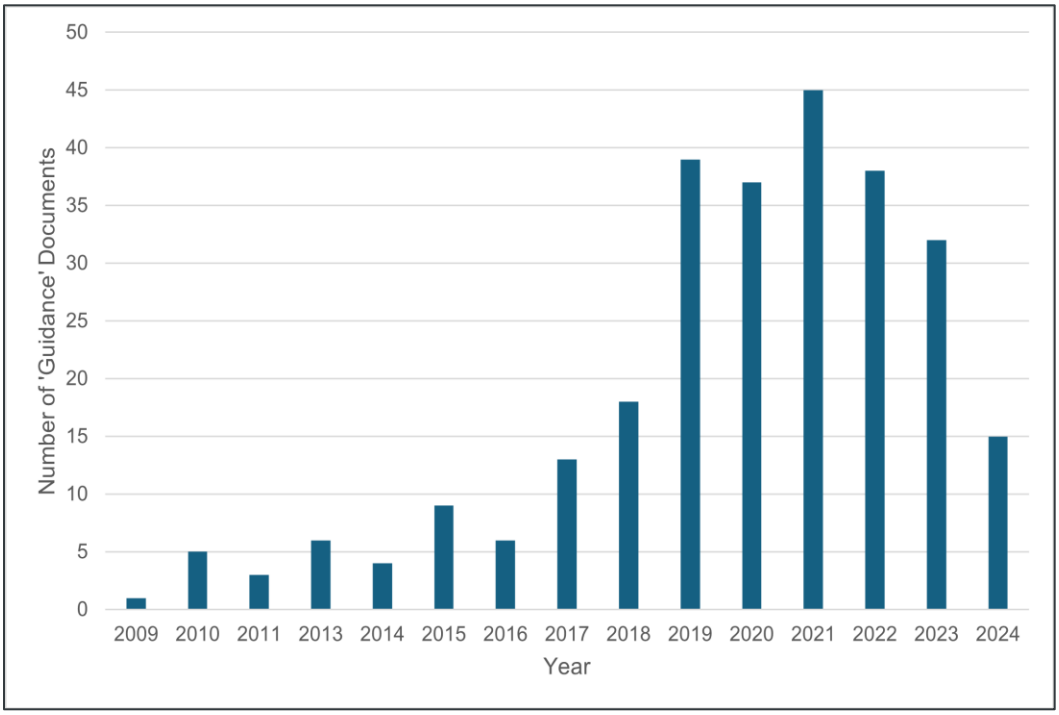

Figure 3: Number of Guidance (Inventory and Ancillary) Published Each Year

The full inventory of guidance documents and ancillary items is available as an Excel file. A simplified inventory of the guidance is included below, arranged by jurisdiction type (national, provincial/territorial, regional, municipal, international), which is the clearest way of organizing the guidance, given that jurisdiction type does not overlap (i.e., guidance only has one main author although it can apply to multiple infrastructure types or hazards).

Within each table, guidance documents are ordered by asset type, author jurisdiction, alphabetical order of authors, and year. As noted in the methods a 2019 cut-off date was applied to avoid the inclusion of outdated guidance. However, some documents published prior to 2019 are included in the inventory because they were identified by subject matter experts to be highly used or important provincial/territorial Climate Adaptation Plans or CSA Group guidance documents or were guidance documents identified in case studies.

The full inventory with more information, including an online link to the guidance, a description of the guidance, and more details is included in the Excel document. A simplified ancillary list is included in Appendix A.

3.1 National Guidance

The inventory includes 84 guidance documents developed by a national author and applicable across Canada (Table 4). Guidance documents are ordered by asset type, author jurisdiction, alphabetical order of authors, and year. In the Climate Hazard(s) column, 'Extreme Events' is a generalized term to represent acute climate events, such as storms and heat waves, that have been grouped together in the documents or referenced generally. The full inventory with more information, including an online link to the guidance, a description of the guidance, and more details are included in the Excel document.

Table 4: National Guidance Documents

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Guidance on Good Practices in Climate Change Risk Assessment	2021	Canadian Council of Ministers of the Environment	All	All	No	No
CSA W205:19 Erosion and sedimentation management for northern community infrastructure	2019	CSA Group	All	Permafrost Thaw, Erosion	No	Yes
CSA W224:24 Coastal flood risk assessment for buildings and infrastructure	2024	CSA Group	All	Flood, Coastal	Yes	No
Nature-based solutions for coastal and riverine flood and erosion risk management	2021	CSA Group (Vouk, I. et al.)	All	Flood, Erosion	Yes	No
A Guide to Implementing Systems-Based Approaches to Climate Resilient Infrastructure	2021	Engineers Canada	All	Flood, Extreme Heat	Yes	No
ECCC Climate-Resilient Buildings and Core Public Infrastructure: An assessment of the impact of climate change on climatic design data in Canada	2019	Environment and Climate Change Canada (ECCC)	All	Extreme Temperature, Precipitation, Wind, Snow Load, Ice	No	No
Adaptation & Resilience Planning Guides	2016	Government of Canada	All	Flood, Extreme Heat, Storm	Yes	No
The Climate Lens: Investing in Canada Infrastructure Program	2023	Housing, Infrastructure and Communities Canada (HICC)	All	All	Yes	Yes

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Climate-Resilient Infrastructure: Adaptive Design and Risk Management	2021	Housing, Infrastructure and Communities Canada (HICC)	All	Flood, Extreme Heat, Storm, Permafrost Thaw	Yes	No
Building Adaptive and Resilient Communities (BARC)	2023	International Council for Local Environmental Initiatives (ICLEI) Canada	All	All	Yes	No
IDF_CC Tool 7.0	2021	Institute for Catastrophic Loss Reduction (ICLR) and Western University (Simonovic et al.)	All	Precipitation	No	Yes
Risk-Based Land-Use Guide by the Geological Survey of Canada	2015	Natural Resources Canada	All	All	No	No
Federal Land Use Guide for Flood Risk Areas	2022	Natural Resources Canada	All	Flood	Yes	No
Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure (Version 1.0)	2021	Natural Resources Canada and Public Safety Canada	All	Flood	No	Yes
Design Value Explorer (DVE)	2015	Pacific Climate Impacts Consortium (PCIC) in collaboration with Environment and Climate Change Canada (ECCC) and National Research Council of Canada (NRC)	All	All	No	No
Planned retreat approaches to support resilience to climate change in Canada	2020	Natural Resources Canada	All (Coastal)	Coastal	No	No

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Development of Climate Change Adaptation Solutions Within the Framework of the CSA Group Canadian Electrical Code Parts I, II and III	2019	CSA Group and Mantle	All (Electrical)	Flood, Ice, Wind, Snow Load, Wildfire, Permafrost Thaw	No	Yes
Standard CAN/BNQ 9701-500 Risk-Based Approach for Community Planning in Northern Regions — Requirements and Guidance	2023	Bureau de Normalisation du Québec (BNQ)	All (Northern)	Increasing Temperature, Permafrost Thaw, Sea Ice Degradation	No	Yes
BNQ 9701-500 Risk-based Approach to Community Planning in Northern Regions	2017	Bureau de Normalisation du Québec (BNQ)	All (Northern)	Permafrost Thaw, Extreme Cold, Ice Degradation	No	No
BOMA Canada Climate Resilience	2022	Building Owners and Managers Association (BOMA) Canada	Buildings	Flood, Extreme Temperature	No	No
BNQ 2501-500 Geotechnical Site Investigations for Building Foundations in Permafrost Zones	2017	Bureau de Normalisation du Québec (BNQ)	Buildings	Increasing Temperature, Permafrost Thaw	No	No
User's Guide – National Energy Code of Canada for Buildings 2017	2019	Canadian Commission on Building and Fire Codes and National Research Council of Canada	Buildings	Extreme Temperature, Precipitation, Wind, Snow Load, Ice	No	Yes
CSA Group's Basement Flood Prevention Guideline Helps Canadians Adapt to a Changing Climate	2018	Canadian Standards CSA Group	Buildings	Flood	No	No
CSA PLUS 4011:19 - Technical guide: Infrastructure in Permafrost: A Guideline for Climate Change Adaptation	2019; 2021	CSA Group	Buildings	Permafrost Thaw	No	No
CSA Z240.10.1:19 - Site preparation, foundation, and installation of buildings	2019	CSA Group	Buildings	Flood	No	Yes

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
CSA S478:19 Durability in buildings	2019	CSA Group	Buildings	All	No	Yes
CSA A440.4-19 - Window, Door and Skylight Installation	2019	CSA Group	Buildings	Precipitation	No	Yes
CSA S504:19 Fire resilient planning for northern communities	2019	CSA Group	Buildings	Wildfire	No	Yes
CSA A440.6:20 High exposure fenestration installation	2020	CSA Group	Buildings	Storm, Wildfire, Extreme Temperature	No	Yes
CSA S505:20 Techniques for considering high winds and snow drifting and their impact on northern infrastructure	2020	CSA Group	Buildings	Wind, Snow Load	No	Yes
CSA A123.26:21 Performance requirements for climate resilience of low slope membrane roofing systems	2021	CSA Group	Buildings	Permafrost Thaw	No	No
CSA W210:21 Prioritization of Flood Risk in Existing Communities	2021	CSA Group	Buildings	Flood	No	No
CSA S502:21 - Managing changing snow load risks for buildings in Canada's North	2021	CSA Group	Buildings	Snow Load	No	Yes
CSA S500:21 Thermosyphon foundations for buildings in permafrost regions	2021	CSA Group	Buildings	Permafrost Thaw	No	Yes
CSA S501:21 Moderating the effects of permafrost degradation on existing building foundations	2021	CSA Group	Buildings	Permafrost Thaw	No	Yes
CSA S520:22 Design and Construction of low-rise residential and small buildings to resist high wind	2022	CSA Group	Buildings	Wind	No	No
CSA A440.2:22, Fenestration energy performance	2022	CSA Group	Buildings	Extreme Heat, Increasing Temperature	No	Yes

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
CSA A440S1-19 - Canadian Supplement to American Architectural Manufacturers Association (AAMA) / Window & Door Manufacturers Association (WDMA) / CSA 101 / I.S.2 / A440-17, North American Fenestration Standard / Specification for windows, doors, and skylights	2022	CSA Group	Buildings	Flood, Wind, Snow Load	No	Yes
Managing Flooding and Erosion at the Watershed Scale: Guidance to Support Governments Using Nature-Based Solutions.	2023	CSA Group	Buildings	Flood, Erosion	Yes	No
Climate Adaptation and Resilience in Commercial Real Estate	2023	CSA Group	Buildings	Flood, Extreme Heat	No	No
CSA Z800-18 - Guideline on Basement Flood Protection	2023; 2018	CSA Group	Buildings	Flood	No	No
Ahead of the Storm: Developing flood-resilience guidance for Canada's commercial real estate	2019	Intact Centre on Climate Adaptation	Buildings	Flood	No	No
National Building Code of Canada, 2020	2020	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes (developed by)	Buildings	Flood, Wildfire	No	Yes
National Fire Code of Canada, 2020	2020	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes (developed by)	Buildings	Fire	No	Yes

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
National Plumbing Code of Canada, 2020	2020	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes (developed by)	Buildings	Flood	No	Yes
National Energy Code of Canada for Buildings, 2020	2020	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes (developed by)	Buildings	Extreme Heat	No	Yes
Practical Guidance for Private-side Drainage Systems to Reduce Basement Flood Risk: Addressing Critical Information Gaps	2021	National Research Council of Canada (NRC)	Buildings	Flood, Extreme Heat, Precipitation, Wind, Tornado	No	No
Climate Resilience Buildings: Guideline for management of overheating risk in residential buildings	2021	National Research Council of Canada (NRC)	Buildings	Extreme Heat	No	No
National Guide for Wildland-Urban Interface (WUI) Fires	2021	National Research Council of Canada (NRC)	Buildings	Wildfire	No	No
Guide for design of flood-resistant buildings	2021	National Research Council of Canada (NRC)	Buildings	Flood	No	No
Guidelines for improving flood-resistance for existing buildings	2021	National Research Council of Canada (NRC)	Buildings	Flood	No	No
CSA Plus 4011.1 Technical Guide: Design and Construction Considerations for Foundations in Permafrost Regions	2019	CSA Group	Buildings (Northern)	Increasing Temperature, Permafrost Thaw	No	No

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Coastal Flood Risk Assessment Guidelines for Building and Infrastructure Design: Supporting Flood Resilience on Canada's Coasts	2019	Canadian Coastal Resilience Network (CCRN)	Buildings (Coastal)	Flood, Sea Level Rise, Storm Surge	Yes	No
FireSmart Development Best Practices Checklist	2024	FireSmart Canada	Buildings, Protective	Wildfire	No	No
CSA R111 Solid Waste Sites in Northern Communities: From Design to Closure	2019	CSA Group	Buildings, Water (Northern)	Permafrost Thaw, Extreme Temperature	No	No
CSA W210:21 Prioritizing flood resiliency in existing residential communities	2017	CSA Group	Buildings, Water, Transportation	Flood	No	No
CSA W204-19 Flood Resilient Design for New Residential Communities	2019	CSA Group	Buildings, Water, Transit	Flood, Sea Level Rise	No	No
Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol	2021	Public Infrastructure Engineering Vulnerability Committee (PIEVC) Program Alliance	Buildings, Water, Transit	All	No	No
Nature-based Climate Solutions Siting Tool	2021	Canadian Climate Institute	Natural Assets	Flood, Extreme Heat, Erosion	Yes	No
CSA W218:23 Specifications for natural asset inventories	2023	CSA Group	Natural Assets	Extreme Events	Yes	Yes
Integrating Natural Assets into Asset Management	2017	Municipal Natural Assets Initiative (MNAI)	Natural Assets	Flood, Erosion, Drought	Yes	No
Natural and Nature-Based Solutions – Design Standard for Natural Coastal Features	2023	CSA Group	Natural Assets (Coastal)	Storm Surge, Wave Action, Erosion	Yes	Yes
Nature-Based Infrastructure for Coastal Flood and Erosion Risk Management: A Canadian Design Guide	2024	National Research Council of Canada (RC. Murphy, E., Cornett, A., van Prosodic, D., & Mulligan, R. P. (Eds.))	Protective	Coastal	Yes	No

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Guide normatif BNQ 3019-190 Reducing the Urban Heat Island Effect - Parking Lot Development - Design Guide	2013	Bureau de Normalisation du Québec (BNQ)	Transit	Extreme Heat, Flood	Yes	No
CSA S7 - Design of pedestrian, cycling and multi-use bridges	2019	CSA Group	Transit	Permafrost Thaw, Seismic Events	No	Yes
CSA S6:19 Canadian Highway Bridge Design Code	2019 and 2023	CSA Group	Transit	Permafrost Thaw, Seismic Events	No	Yes
Climate Change and Asphalt Binder Selection: Resilient Roads of the Future	2020	National Research Council of Canada (NRC)	Transit	Extreme Heat, Increasing Temperature	No	No
Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions	2010	Transportation Association of Canada (TAC)	Transit	Permafrost Thaw	No	No
BNQ D 3682-320-9, Mitigation of the Risks of Inflow and Infiltration in New Sanitary Sewer Systems	2016	Bureau de Normalisation du Québec (BNQ)	Water	Flood, Precipitation	No	No
CAN / BNQ 3682-320 Mitigation of the Risks of Inflow and Infiltration in New Sanitary Sewer Systems	Ongoing	Bureau de Normalisation du Québec (BNQ)	Water	Flood	No	No
BNQ 3660-004 Manuel de conception des réseaux d'égout pluvial et sanitaire	Ongoing	Bureau de Normalisation du Québec (BNQ)	Water	Precipitation, Flood	Yes	Yes
CSA S900.1:18 Climate Change Adaptation for Wastewater Treatment Plants	2018	CSA Group	Water	Flood	No	No

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
CSA PLUS 4013-19 - Technical Guide: Development, Interpretation and Use of Rainfall Intensity-Duration-Frequency (IDF) Information: Guideline for Canadian Water Resources Practitioners	2019	CSA Group	Water	Flood	No	No
CSA W203:19 - Planning, design, operation and maintenance of wastewater treatment in northern communities using lagoon and wetland systems	2019	CSA Group	Water	Flood, Permafrost Thaw, Water Quantity and Quality	No	No
CSA S503:21 - Community drainage system planning, design, and maintenance in northern communities	2020	CSA Group	Water	Changing Winter Conditions	No	No
CSA W211:21 Management standard for stormwater systems	2021	CSA Group	Water	Flood	No	No
The Municipal How-To Guide for CSA Community Water Standards	2022	CSA Group	Water	Flood, Extreme Precipitation	No	No
CSA W200-18 - Design of bioretention systems.	2023	CSA Group	Water	Flood	No	No
CSA W201-18 Construction of bioretention systems	2023	CSA Group	Water	Flood	No	No
CSA W200:F18 (C2023) Conception des systèmes de biorétention	2023; 2018	CSA Group	Water	Flood	No	No
Guidelines on undertaking a comprehensive analysis of benefits, costs and uncertainties of storm drainage and flood control infrastructure in a changing climate	2022	National Research Council of Canada (NRC)	Water	Flood	No	No
CSA S910.1 Climate Change Vulnerability Assessment for Dams in Canada	2021	CSA Group	Water, Protective	Flood, Extreme Precipitation, Drought	No	No

Title	Year	Author	Asset Type	Climate Hazard(s)	NBS Considerations	Required
A Flood Risk Check-Up for Canadian Municipalities: Tackling Flooding Together	2024	Intact Centre on Climate Adaptation	Water, Protective	Flood, Extreme Precipitation	Yes	No
Coastal flood risk assessment guidelines for building and infrastructure design: supporting flood resilience on Canada's coasts	2020	National Research Council of Canada (NRC)	Water, Transit	Flood	No	No

3.2 Provincial/Territorial Guidance

The inventory includes 41 guidance documents developed by an author with provincial or territorial jurisdiction and applicable to a Canadian province or territory (Table 5). Guidance documents are ordered by asset type, author jurisdiction, alphabetical order of authors, and year. In the Climate Hazard(s) column, 'Extreme Events' is a generalized term to represent acute climate events, such as storms and heat waves, that have been grouped together in the documents or referenced generally. The full inventory with more information, including an online link to the guidance, a description of the guidance, and more details is included in the Excel document.

Table 5: Provincial/Territorial Guidance Documents

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Technical Design Requirements for Alberta Infrastructure Facilities (TDR)	2022	Alberta Infrastructure	Alberta	All	All	No	Yes
Systems Based Approaches for Climate Resilient Infrastructure Guidebook	2023	Arcadis, Housing, Infrastructure and Communities Canada (HICC) and the British Columbia Ministry of Transportation and Infrastructure (BC MoTI)	British Columbia	All	All	Yes	No

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Preliminary Strategic Climate Risk Assessment for British Columbia	2019	British Columbia Ministry of Environment and Climate Change Strategy	British Columbia	All	All	No	Yes
A Guide for Climate Change Adaptation Planning for New Brunswick Communities	2013	Government of New Brunswick	New Brunswick	All	Flood, Sea Level Rise, Storm	Yes	No
Government of Newfoundland and Labrador Climate Lens: Guidance Document	Not found	Government of Newfoundland and Labrador	Newfoundland and Labrador	All	All	No	Yes
Weathering What's Ahead: Climate Change Risk and Nova Scotia's Well-being	2022	Nova Scotia Department of Environment and Climate Change	Nova Scotia	All	Increasing Temperature, Precipitation, Storm, Sea Level Rise, Ocean Conditions	No	Yes
Upagiaqtavut Setting the Course: Climate Change Impacts and Adaptation in Nunavut	2010	Government of Nunavut	Nunavut	All	Increasing Temperature, Extreme Events, Precipitation, Sea Level Rise, Permafrost Thaw, Ice Degradation	No	No
O. Reg. 588/17: Asset Management Planning for Municipal Infrastructure	2018	Government of Ontario	Ontario	All	Flood	Yes	Yes

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Ontario Provincial Climate Change Impact Assessment Technical Report	2023	Ontario Ministry of the Environment, Conservation and Parks	Ontario	All	Extreme Heat, Extreme Temperature, Precipitation, Changing Winter Conditions, Drought, Wildfire	No	Yes
Coastal Hazard Assessment	Not found	Government of Prince Edward Island	Prince Edward Island	All	Coastal	No	No
Prince Edward Island (PEI) Climate Change Risk Assessment	2021	Prince Edward Island Department of Environment, Energy and Climate Action (EECA)	Prince Edward Island	All	Flood, Coastal Erosion, Storm, Extreme Heat, Precipitation, Ice, Freezing Rain, Drought, Earlier and Warmer Springs	No	No
Assessing Climate Change Risk and Resilience in the Yukon Main Report	2022	Government of Yukon	Yukon	All	Wildfire, Permafrost Thaw, Snow Load, Ice	Yes	No
CLIMAtlantic Nature-Based Solutions for Coastal and Riverine Flood and Erosion Risk Management	2021	CLIMAtlantic	Atlantic (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador)	All (Coastal)	Coastal	Yes	No
CLIMAtlantic Coastal Adaptation Toolkit	2024	CLIMAtlantic	Atlantic (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador)	All (Coastal)	Coastal	Yes	No
Assessing Climate Change Risk and Resilience in the Yukon: Main Report	2018	Government of Yukon	Yukon	All (Northern)	Flood, Permafrost Thaw, Wildfire	Yes	No

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Climate Resilience Framework & Standards for Public Sector Buildings	n.d.	British Columbia (B.C.) Climate Action Secretariat	British Columbia	Buildings	All	No	Yes
Climate Resilience Guidelines for BC Health Facility Planning & Design	2024	British Columbia Ministry of Health	British Columbia	Buildings	Extreme Heat, Flood, Wildfire	No	No
BC Housing Design Guidelines and Construction Standards	2019	British Columbia Housing	British Columbia	Buildings	All	No	No
Building for Climate Change: A Quick Guide for Homeowners and Builders	2018	Southwest New Brunswick Service Commission (SNBSC), with aid from the Province of New Brunswick's Environmental Trust Fund	New Brunswick	Buildings	All	No	No
Good Building Practice for Northern Facilities (Fourth Edition, March 2021)	2021	Government of Northwest Territories	Northwest Territories	Buildings	All	No	Yes
Code de construction du Québec	2015	National Research Council of Canada (NRC)	Quebec	Buildings	Flood, Wildfire	No	Yes
Government of Yukon 2022 Design Requirements and Technical Standards	2022	Government of Yukon	Yukon	Buildings	All	No	Yes
Flood Hazard Area Land Use Management Guidelines	2018	Government of British Columbia	British Columbia	Buildings, Water, Protective	Flood, Sea Level Rise	Yes	Yes

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Low Impact Development Stormwater Management Guidance Manual; ERO number: 019-4971	2022	Government of Ontario	Ontario	Buildings, Water, Transit	Flood	Yes	No
Technical Circular: T04-19 Resilient Infrastructure Engineering Design - Adaptation to the Impacts of Climate Change and Weather Extremes	2019	British Columbia Ministry of Transportation and Infrastructure	British Columbia	Transit	Extreme Events	No	No
Developing climate change-resilient designs for highway infrastructure in British Columbia	2020	Engineers and Geoscientists British Columbia	British Columbia	Transit	Extreme Events	No	Yes
Standard Specifications for Highway Construction	2021	Government of Manitoba	Manitoba	Transit	Flood, Extreme Temperature	No	Yes
Manuel de conception des ponceaux	2020	Ministère des Transports et de la Mobilité durable	Quebec	Transit	Flood	No	Yes
Manuel d'inventaire et d'inspection des enrochements, édition 2022	2022	Ministère des Transports et de la Mobilité durable	Quebec	Transit	Storm Surge, Wave Action	No	No
Tome 1 - Conception routière	2023	Ministère des Transports et de la Mobilité durable	Quebec	Transit	Flood, Extreme Heat	No	No
Manuel de conception des structures	2024	Ministère des Transports et de la Mobilité durable	Quebec	Transit	Flood	No	Yes

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Government of the Northwest Territories, Department of Transportation - Erosion and Sediment Control Manual	2013	Government of the Northwest Territories (GNWT)	Northwest Territories	Transit (Northern)	Extreme Temperature, Ice Degradation	Yes	Yes
Guidelines For Safe Ice Construction	2014	Government of the Northwest Territories (GNWT)	Northwest Territories	Transit (Northern)	Permafrost Thaw	No	Yes
One Water System Risk Management Planning Guide	2024	Engineers and Geoscientists British Columbia	British Columbia	Water	Flood, Wildfire, Drought, Water Scarcity	Yes	No
Ministry of Health: Design Guidelines for Drinking Water Systems in British Columbia V. 1.0	2023	Government of British Columbia and WSP	British Columbia	Water	All	No	Yes
Developing an Efficient and Cost-Effective Inflow and Infiltration (I/I) Reduction Program	2017	Sustainable Technologies Evaluation Program (STEP)	Ontario	Water	Flood, Precipitation	No	No
Guide technique sur le traitement des eaux usées des résidences isolées	2015	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs	Quebec	Water	Flood	No	No
Guide de conception des petites installations de production d'eau potable	2019	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs	Quebec	Water	Flood	No	Yes

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Guide de conception des installations de production d'eau potable	2021	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs	Quebec	Water	Flood	No	Yes
Exploitation des installations de distribution d'eau potable	2023	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs	Quebec	Water	Flood	No	No
Low Impact Development Stormwater Management Planning and Design Guide	2010	Sustainable Technologies Evaluation Program (STEP)	Ontario	Water, Protective	Flood	Yes	No

3.3 Regional Guidance

The inventory includes six (6) guidance documents developed by a regional author and/or applicable to a region, such as Atlantic Canada or northern Canada (Table 6). Guidance documents are ordered by asset type, author jurisdiction, alphabetical order of authors, and year. The full inventory with more information, including an online link to the guidance, a description of the guidance, and more details is included in the Excel document.

Table 6: Regional Guidance Documents

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Climate Risk, Responsibility, and Liability for Municipalities (November 2022)	2022	Atlantic Climate Adaptation Solutions Association (ACASA)	Atlantic (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador)	All	Flood, Coastal Erosion, Storm Surge	Yes	No
Green Bylaws Toolkit	2020	Stewardship Centre for British Columbia	British Columbia	All, Natural Assets	Flood, Extreme Heat	Yes	No
Technical Guide for Northern Housing	2020	First Nations National Building Officers Association (FNNBOA)	Northern (Yukon, Northwest Territories, Nunavut)	Buildings	Permafrost Thaw	No	No
Green Shores for Shoreline Development	2021	Stewardship Centre for British Columbia	British Columbia	Buildings, Natural Assets (Coastal)	Coastal, Shoreline	Yes	No
Sustainable Technologies Evaluation Program (STEP)	2020	Toronto and Region Conservation Authority (TRCA)	Ontario	Water, Natural Assets	Flood	Yes	No
Low Impact Development Guidelines Module 2 - Bioretention and Bioswales	2010	Credit Valley Conservation Authority (CVC)	Ontario	Water, Protective	Flood	Yes	No

3.4 Municipal Guidance

The inventory includes 16 guidance documents developed by a municipal author (Table 7). Guidance documents are ordered by asset type, author jurisdiction, alphabetical order of authors, and year. The full inventory with more information, including an online link to the guidance, a description of the guidance, and more details is included in the Excel document.

Table 7: Municipal Guidance Documents

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
City of Calgary Climate Resilience Strategy	2018	City of Calgary	Calgary, Alberta	All	Flood, Extreme Heat, Storm	Yes	Yes
Climate Change Adaptation Plan for Saint John	2021	City of Saint John	Saint John, New Brunswick	All	Flood, Sea Level Rise, Storm Surge	Yes	Yes
City of Vancouver Climate Change Adaptation Strategy	2018	City of Vancouver	Vancouver, British Columbia	All	All	No	No
Guide for Integrating Climate Change Considerations into Municipal Asset Management	2020	Federation of Canadian Municipalities (FCM)	Municipal	All	All	No	No
Operations & Maintenance for Climate Resilience: Six Strategies for Your Municipality	2022	Federation of Canadian Municipalities (FCM)	Municipal	Buildings	All	Yes	No
City of Calgary Sustainable Building Guidance Document Version 2.0	2024	City of Calgary	Calgary, Alberta	Buildings	All	No	Yes
City of Edmonton Climate Resilience Home Guide	2022	City of Edmonton	Edmonton, Alberta	Buildings	All	No	No
Toronto Green Roof Construction Standard	2009	City of Toronto	Toronto, Ontario	Buildings	Flood, Extreme Heat	Yes	Yes

Title	Year	Author	Author Jurisdiction	Asset Type	Climate Hazard(s)	NBS Considerations	Required
Toronto Green Standard	2022	City of Toronto	Toronto, Ontario	Buildings	All	Yes	Yes
Vancouver Building By-law	2019	City of Vancouver	Vancouver, British Columbia	Buildings	All	No	Yes
Green Buildings Policy for Rezonings	2018	City of Vancouver	Vancouver, British Columbia	Buildings	Extreme Heat	No	Yes
Sustainable Infrastructure & Buildings Design Guide for Metro Vancouver	2021	Metro Vancouver	Vancouver, British Columbia	Buildings	Extreme Heat, Wildfire, Drought, Precipitation, Wind, Storm, Sea Level Rise	Yes	Yes
Rain City Strategy	2019	City of Vancouver	Vancouver, British Columbia	Buildings, Water	Flood	Yes	No
City of Vancouver's Guidelines on Flood Plain Standards and Requirements	2023	City of Vancouver	Vancouver, British Columbia	Buildings, Water, Protective	Flood, Sea Level Rise	Yes	Yes
City of Moncton Green Development Guidelines	2023	City of Moncton	Moncton, New Brunswick	Buildings, Water, Transit	All	No	No
The Natural Assets Initiative's Guidebook	2024	Natural Assets Initiative (NAI) (Amy Taylor and Jeff Wilson of Green Analytics and Donna Chiarelli as the project lead)	Ontario	Natural Assets	Flood, Extreme Temperature, Wildfire, Drought, Invasive Species, Pests and Diseases	Yes	Yes

3.5 International Guidance

International items included in the inventory were identified by subject matter experts as important guidance applicable in Canada. The inventory includes eleven (11) guidance documents developed by an author with international jurisdiction and applicable internationally (Table 8). Guidance documents are ordered by asset type, author jurisdiction, alphabetical order of authors, and year. In the Climate Hazard(s) column, 'Extreme

Events' is a generalized term to represent acute climate events, such as storms and heat waves, that have been grouped together in the documents or referenced generally. The full inventory with more information, including an online link to the guidance, a description of the guidance, and more details is included in the Excel document.

Table 8: International Guidance Documents

Title	Year	Author	Asset type	Climate hazard(s)	NBS considerations	Required
ASCE / COS 73-23 Sustainable Practice for Sustainable Infrastructure	2023	American Society of Civil Engineers (ASCE)	All	Flood, Extreme Heat, Storm	Yes	No
C40 Cities - General Guidance and Knowledge Hub for Climate Change Adaptation of Cities	Ongoing	C40 Cities Climate Leadership Group	All	Flood, Extreme Heat, Air Quality, Sea Level Rise, Storm	Yes	No
IFRS S2 General Requirements for Disclosure of Sustainability-Related Financial Information	2022	International Financial Reporting Standards (IFRS) Foundation	All	All	No	Yes
ISO 14090:2019 Adaptation to climate change: Principles, requirements and guidelines	2019	International Organization for Standardization (ISO)	All	All	No	No
ISO 14091:2021 Adaptation to climate change: Guidelines on vulnerability, impacts and risk assessment	2019	International Organization for Standardization (ISO)	All	All	No	No
ISO 14092:2020 Adaptation to climate change — Requirements and guidance on adaptation planning for local governments and communities	2020	International Organization for Standardization (ISO)	All	All	Cannot access	No
REDi Rating System	2017	Arup	Buildings	Extreme Events (Including Seismic Events)	No	No
Global Building Resilience Guidelines	2022	The Global Resiliency Dialogue	Buildings	All	No	No
Pathways to Living Cities Framework	2022	Living Cities	Buildings, Natural Assets	Flood, Extreme Heat	Yes	No

Title	Year	Author	Asset type	Climate hazard(s)	NBS considerations	Required
Guide to Storm Surge Forecasting	2011	World Meteorological Organization (WMO)	Coastal	Coastal	Cannot Access	Cannot Access
USACE Natural and Nature-Based Features Guide	2021	United States Army Corps of Engineers (USACE)	Natural Assets (Coastal)	Flood, Coastal Erosion, Sea Level Rise	Yes	No

3.6 Qualitative Assessment of the Guidance Inventory

3.6.1 Observations

There are several observations about the guidance in the inventory that are worth noting but not identified as clear gaps or advantages:

- There is an **upswell of guidance published in recent years** (Figure 3), which occurs alongside HICC initiatives to support guidance development, beginning in 2016. This relatively recent increase in guidance may indicate that Canada is not only in the early stages of developing guidance for climate-resilient infrastructure, but also in the early stages of using the guidance and integrating it into practice effectively.
- Most technical guidance documents in the inventory are **national in scope** and authored by agencies with national jurisdiction (Table 3). The number of technical codes, standards, and circulars at the provincial/territorial or municipal levels does not match the national level. This difference may be due to a greater amount of federal funding and capacity for climate resilient guidance compared to lower levels of government and other organizations.
- At the local government level, **most guidance is focused on buildings**, followed by water. Similarly, at the national level, most guidance is for buildings, but the difference is not as pronounced compared to the local level. Guidance authored by and applicable to **provinces and territories spans the asset types more evenly**. These differences in the number of guidance documents at different jurisdictional levels do not necessarily represent true gaps in the availability or quality of guidance.
- The inventory identified **only ten guidance documents specifically for nature-based solutions (NBS) or natural assets**; however, ~45 items include mention of NBS. Most of these ~45 items are applicable to **flood and/or extreme heat**, which is likely not a gap in the applicability of NBS for other hazards and, rather, reflects how NBS are commonly used in Canada for water management and mitigation of extreme heat, including the urban heat island effect. The amount of guidance available does not necessarily reflect the quality of the guidance or the ability to implement solutions.
- There are substantially **more guidance documents with considerations pertaining to flooding than other hazards (**Figure 2**)**. This may represent the multiple types of flooding and the potential design options to address flooding across multiple asset types. It could also reflect the biggest return on investment for flood-related action that is widely applicable across the country. Again, the amount of guidance available does not necessarily reflect the quality of the guidance or the ability to implement solutions.
- An inclusion criterion for guidance in the inventory was documents needed to specifically reference action to address climate resilience. **Most of the technical codes and standards included in the inventory are not authored specifically for climate resilience** but mention it as a consideration.

Including considerations of climate change in technical codes, standards, and circulars for infrastructure types and engineering systems is a logical and valuable approach to mainstreaming climate resilience into guidance because it represents a favourable cost-benefit investment and may support greater uptake in projects by practitioners familiar with previous versions of the guidance.

- Another criterion for inclusion in the inventory was guidance needed to be published within the last five years (2019 or later). However, many guidance documents identified by subject matter experts and used in case studies were **published prior to 2019**, likely indicating they are established and valuable pieces of guidance.

3.6.2 Gaps and Challenges

Gaps and challenges were identified through a qualitative gap analysis:

- **Lack of guidance specific to operations and maintenance**. The inventory includes guidance primarily intended for practitioners involved in the design and construction of infrastructure, reflecting limited guidance available for the operations and maintenance (O&M) of infrastructure over time. Guidance for O&M may be integrated into the existing codes and standards; however, limited resources to support O&M is identified as a gap. One available O&M resource for climate resilience is *Operations & maintenance for climate resilience: Six strategies for your municipality* [5].

- **Limited guidance for some regions.** Guidance was identified in the inventory for most provinces and territories; however, not all provinces and territories have guidance in each sector. Although not specifically considered or integrated into the inventory development, there were no documents identified for infrastructure specific to alpine or prairie regions (Figure 1).

  Although some documents were available, the least amount of guidance was identified for the prairie region. This lack of guidance identified does not necessarily indicate a lack of climate supports available; groups like the Prairie Adaptation Research Collaborative (PARC), the Prairie Climate Centre, and Climate West offer resources for climate data, training and understanding climate impacts and adaptations. Further, guidance from local governments within the prairies are included in the inventory (e.g., City of Calgary Resilience Strategy (2018) and City of Edmonton Climate Resilience Home Guide (2022)). This limited amount of guidance identified for the region may also be a limitation of the online review methodology and/or a limitation in the expert workshops if users of guidance for the prairie region were not able to attend.

- **No local guidance for coastal or northern infrastructure.** There is no guidance authored by local governments in the inventory for coastal or northern infrastructure. This 'gap' in municipal guidance for coastal and northern infrastructure may reflect the more regional nature of coastline management and northern affairs.

4. Climate-Resilient Infrastructure Expert Input

The sections below outline a thematic analysis of qualitative insights provided by experts in the buildings, water, transit, protective infrastructure, and NBS workshops. The objectives of the workshops were to identify gaps in the guidance inventory and provide high-level insights into any challenges implementing climate-resilient guidance in infrastructure projects.

4.1 Gaps in Existing Guidance

Experts were prompted by facilitators to discuss gaps in existing guidance for their asset type. Detailed insights from individuals in the working groups are organized by asset type in Table 9.

Table 9: Gaps in Existing Guidance for Climate-Resilient Infrastructure

Asset Type	Guidance Gap Summary	Specific Guidance Gaps
Buildings	Although the guidance inventory identified many documents pertaining to buildings, experts identified a need for more climate-resilient buildings guidance on specific climate hazards (e.g., for permafrost, flood zones, heatwaves), and more guidance at a regional level (i.e., provincial/territorial or municipal).	Experts identified gaps in: ▪ guidance for developing durable building pads in permafrost areas ▪ permafrost mitigation and adaptation guidance specific to northern contexts ▪ guidance managing existing facilities located in flood zones ▪ guidance managing residential heat wave responses ▪ guidance to identify areas for buildings that are less at risk for adverse impacts for climate hazards (e.g., how to identify low flood risk areas for building)
Water	Experts noted water, wastewater, and stormwater is a best practice-oriented field and as such, requested more known and/or required standards and guidance documents for water practitioners and designers. The discussion focused on the need for more regulatory direction to necessitate compliance with guidance. Discussion	Experts identified gaps in: ▪ detailed instructions on how to implement climate-resilient water infrastructure projects ▪ direction on climate-resilient water infrastructure geared to practitioners and designers ▪ required compliance with guidance. If climate hazard-related design decisions are not

Asset Type	Guidance Gap Summary	Specific Guidance Gaps
	noted that it is challenging to pursue climate-resilient design decisions if it is only recommended but not required by a guidance or funding program.	required and, instead, 'nice to have', it is challenging to include them in infrastructure
Transit	Experts identified a need for climate-resilient transit guidance for cold-weather climates.	Experts identified gaps in: ▪ Canadian transit and rail standards that account for specific natural environments across the country (e.g., northern regions with permafrost) ▪ transit design guidance that accounts for cold weather and snow
Protective	Experts identified a need for municipal, regional, and provincial/territorial guidance for protective infrastructure, and specific types of data to support climate-resilient infrastructure analysis.	Experts identified gaps in: ▪ protective infrastructure guidance on hazards such as strong winds and flooding in a Canadian context ▪ baseline Canadian information to support adaptation actions in the Arctic, where permafrost thawing, fires, and flooding are rapidly changing the landscape ▪ contextualization of United States (U.S.) guidance for local Canadian environments, starting with understanding local hazards ▪ climate change data including, aggregated, gridded Intensity-Duration-Frequency (IDF) curves to support resilience for large watersheds with non-uniform rainfall ▪ guidance documents that coalesce the lessons learned and best practices from climate-resilient protective infrastructure projects across Canada
Nature-Based Solutions	Experts highlighted that NBS is a nascent field. Many guidance documents are in early development stages, with municipalities working on practices for individual projects to support climate-resilient infrastructure. Due to the field being in development, research and data gaps can hinder the creation of detailed	Experts identified gaps in: ▪ direction on climate-resilient NBS infrastructure geared to practitioners ▪ practical guidance tools with a high level of technical detail about implementation (e.g., City of Toronto Green Infrastructure suite of

Asset Type	Guidance Gap Summary	Specific Guidance Gaps
	guidelines and guidance for advanced technical aspects.	resources that are a good example of sufficient technical detail) ▪ research that provides essential equations and technical guidance ▪ case studies that focus on long-term operations and maintenance data, not the immediate post-construction period

Although each workshop focused on the gaps in guidance for their specific infrastructure types, experts across all workshops identified the value of and need for specific guidance. As one expert noted: "*guidance documents need to be specific - not high-level statements.*" Buildings, transit, and protective infrastructure experts focused on the need for guidance that is applicable to Canadian environments and climate hazards, which often include cold conditions and the relatively unique challenges that accompany degrading permafrost. It was noted that experts often turn to international guidance to fill gaps; however, that international guidance does not capture the unique Canadian context. Although the guidance inventory identified many documents pertaining to buildings, the gaps identified for guidance with respect to permafrost, managing facilities in flood zones, managing heat wave responses, and siting buildings in low-risk areas by the experts in the buildings group are highlighted as gaps for HICC to potentially address by supporting end-users in navigating the guidance and/or providing specific guidance.

Experts in buildings and protective infrastructure called for guidance at the sub-national level and experts in water infrastructure noted gaps in regulations and documents written at the practice level for water practitioners and designers. Experts in NBS highlighted that the relatively new nature of NBS as suitable options for resilience may explain the lack of detailed guidance.

4.2 Implementation Challenges and Opportunities

Along with the unique challenges and opportunities for supporting climate-resilient infrastructure across different asset types and environments, several common themes emerged when experts were asked to identify challenges implementing guidance in climate-infrastructure projects. As one expert noted, *"I suspect the challenges with climate-resilient infrastructure in my province are probably the same ones as everywhere else."*

Table 10 outlines the implementation challenge and opportunity themes across four workshops with buildings, water, transit, and protective infrastructure experts. Input from a fifth workshop on nature-based solutions is incorporated throughout these sections, where applicable.

Table 10: Guidance for Climate-Resilient Infrastructure Implementation Challenges and Opportunities

Challenge	Individual Insights	Opportunities and Recommendations for HICC
Guidance documents can be helpful, but more regulatory direction is needed to incentivize climate-resilient projects.	▪ More provincial/territorial support for climate-resilient infrastructure standards is needed. ▪ To support uptake, standards considering climate change need to be incorporated into legislation or be made mandatory to receive funding. ▪ If funds are limited, it is easier to justify adhering to regulations than implementing guidance.	▪ Incentivize guidance adoption via regulatory mechanisms. ▪ Develop and implement enforcement and compliance tools to ensure adherence to climate resilience standards. ▪ Coordinate with provinces / territories and municipalities to ensure new regulatory and enforcement mechanisms fit within existing systems.
Provincial/territorial and municipal deficits and limited budgets can act as barriers to climate-resilient infrastructure projects.	▪ Early adoption and support of climate-resilient infrastructure can be challenging due to associated costs.	▪ Support municipalities in justifying the capital expenditure ▪ Consider making incorporation of climate change considerations in infrastructure development or renewal a mandatory requirement ▪ Consider providing additional funding support for climate-resilient infrastructure projects.
Encouraging long-term thinking and conducting business case cost-benefit analyses for every system is challenging within the time limits and financial constraints of the annual budget cycle for municipalities.	▪ Short-term thinking often highlights immediate construction costs over long-terms benefits. ▪ Prioritization of immediate infrastructure needs can hinder the integration of climate-resilient solutions, despite awareness of long-term cost-benefit. ▪ There is often insufficient understanding and evidence concerning the lifecycle costs of climate-resilient infrastructure projects.	▪ Enable municipalities to conduct cost-benefit analyses of climate-resilience infrastructure initiatives ▪ This may be achieved through the support of stream-lined processes and guidance to match the availability of municipal resources.

Challenge	Individual Insights	Opportunities and Recommendations for HICC
	▪ For interlinked or complex systems, like stormwater, it can be particularly difficult to find the time to conduct cost-benefit analyses. ▪ It can be challenging to select appropriate and cost-effective mitigation and adaptation techniques for permafrost, as costly methods like thermal siphoning may be necessary. ▪ Most case studies focus on the immediate post-construction period, lacking long-term data. This gap hinders understanding of long-term performance and is often tied to funding constraints. ▪ Municipal budgeting often allocates more funds for capital expenditures, with less available for operations and maintenance.	
Existing government funding structures and regulations sometimes do not align with municipal realities and can act as a barrier to adopting climate-resilient projects.	▪ Qualifying for the federal Disaster Mitigation and Adaptation Fund is challenging because it is difficult to quantify avoided costs or savings, making it hard to justify renewing necessary infrastructure. ▪ While the Municipal Climate Change Action Centre in Alberta successfully initiated climate-resilient projects due to easy application and quick turnaround, the lack of funding for subsequent implementation steps has stalled these projects. ▪ The building code can impede adaptation projects for public transit facilities. Without a defined structure type for renewable energy canopies, retrofitting small-scale canopies with solar panels required overbuilding,	▪ Consult with municipalities and provinces to determine key actions to improve uptake and implementation of existing federal funding mechanisms and regulations for climate-resilient infrastructure projects.

Challenge	Individual Insights	Opportunities and Recommendations for HICC
	making the project cost-prohibitive for municipalities.	

Input from experts discussing guidance by asset type indicates the value of and need for guidance that is specific for Canadian natural environments and climate hazards (e.g., regions with permafrost degradation and northern coastlines). Combined, these findings highlight the complex landscape of climate-related guidance for infrastructure in Canada. Insights about implementation suggest that guidance documents alone are not sufficient to drive the necessary changes and actions to support climate-resilient infrastructure projects. Challenges lie in implementing, for example, additional features, design considerations, or different solutions to support climate resilience if they are not required or mandated. This is especially true in instances where financial resources are limited, which is a common reality across the country for all asset types. For example, in one of the focus groups and in the Union Water Supply System case study, mention was made of *O. Reg. 588 / 17: Asset Management Planning for Municipal Infrastructure*, which is asset management legislation in Ontario requiring local governments to adopt a strategic asset management policy that includes climate change considerations. This regulation is a tool that assists in pursuing climate change action because it requires climate change considerations despite potential added costs.

Further key challenges that were identified by experts include conducting cost-benefit analyses, timing risk assessments and the implementation of suitable resilience measures in a project with the proper stage of procurement and development, and accessing funding programs that can support the full lifecycle of infrastructure.

5. Case Studies

Four case studies were developed to illustrate how existing guidance can support climate-resilient infrastructure projects spanning asset types and contexts across Canada's provinces and territories.

Each case study outlines an instance where guidance for climate resilience was successfully applied to assets and showcases how the guidance was implemented. Each case study includes a high-level roadmap outlining the steps that led to the successful application of the guidance, providing a model for others to follow. Guidance documents referenced in each case study are included in the inventory. A summary of case studies is provided in Table 11.

Table 11: Summary of Case Studies

Project	Infrastructure Type	Community	Province or Territory	Community Type (Population)	Relevant Climate Hazards
Union Water Supply System Adapts Water and Wastewater Infrastructure to Communities' Changing Climate	Water	Essex County (Leamington, Kingsville, Essex, Lakeshore)	Southwestern Ontario	180,000 people	Extreme weather events
Providence Health Care's Use of Climate Resilience Guidelines for the New St. Paul's Hospital Planning and Design	Buildings	Vancouver, Sechelt, Squamish, Powell River	British Columbia	15,000 people	Extreme weather events (heatwaves, floods), sea level rise
Prohibition Creek Access Road Permafrost Protection Plan	Transit	Colville Lake Dene, Deline Dene, Fort Good Hope Dene, Fort Good Hope Metis, Norman Wells Metis, Tulit'a Dene, and Fort Norman Metis	Northwest Territories	Northern, 2,500 people	Permafrost degradation
Developing Climate-Resilient Infrastructure Actions to Protect Annapolis Royal from Coastal Flooding	Protective	Annapolis Royal	Nova Scotia	Coastal, 500 people	Flooding

5.1 Case Study 1: Union Water Supply System Adapts Water and Wastewater Infrastructure to Communities' Changing Climate

5.1.1 Overview and Highlights

Asset type: Water Infrastructure

Status: Project complete

Climate hazard: Extreme weather events

Geography: Essex County, Southwestern Ontario

Communities: Leamington, Kingsville, Essex, Lakeshore

Challenges: Extreme weather events compromising water supply; increasing severity and frequency of tornadoes, thunderstorms, heavy rainfall, and drought; algal blooms affecting water quality

Guidance documents: Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol and O. Reg. 588/17: Asset Management Planning for Municipal Infrastructure

Outcomes: Infrastructure Climate Risk Assessment conducted; adaptation measures implemented including communication system upgrades, portable generators, staff training, and real-time algae monitoring

5.1.2 Background: Extreme Weather and Algal Blooms in Essex County, Ontario

Climate change can hinder water infrastructure operations due to, for example, more severe droughts, storms, and impacts on source water quality, such as more frequent algal blooms [6]. Union Water Supply System (UWSS) delivers potable water from Lake Erie to approximately 66,800 residents in Essex County, as well as commercial, industrial, and agricultural consumers, including several large food processors and hydroponic greenhouses [7]. Extreme weather events and algal blooms have become and are likely to continue becoming more frequent and severe in Essex County, challenging UWSS's ability to supply water to its customers [8].

Essex County Climate

The climate of Essex County is generally temperate, featuring cold winters, warm summers, and high levels of precipitation. However, extreme weather events such as tornadoes, severe thunderstorms, heavy rainfall, and drought, have occurred historically in this region, have been increasing in severity and frequency in recent years, and are projected to continue to increase. In the fall of 2017, the region attracted national attention for their significant rainfall events and flooding, which resulted in algal blooms that impacted the taste and smell of water being distributed through the UWSS.

Table 12 outlines the key impacts of climate change on UWSS [8].

Table 12: Impacts of Climate Change on UWSS

Impacts of Climate Change on UWSS	
Physical	▪ High-speed winds from tornadoes and thunderstorms damage infrastructure and have resulted in power outages that threaten public safety. ▪ Service lines and other underground infrastructure have frozen, resulting from low temperatures, and breakage has occurred during the freeze-thaw cycle. ▪ Flooding can damage pipes and cause debris blockages.
Social	▪ Water distribution has been impacted as a result of damaged infrastructure. ▪ Thunderstorms cause power outages that have resulted in failed communication services and disabled water treatment and monitoring. ▪ Algal growth in Lake Erie can affect the taste and quality of drinking water. ▪ Customer complaints about the taste of treated water have increased in recent years.
Economic	▪ Climate events have increased costs for unplanned repairs and updates to protect infrastructure from extreme weather.
Ecological	▪ Prolonged periods of high temperature and stagnant water promote algae growth. ▪ Local drinking water quality and aquatic ecosystems have been impacted by increases in algal blooms.

5.1.3 Using Climate-Resilient Guidance

In 2011, UWSS partnered with Engineers Canada to conduct an Infrastructure Climate Risk Assessment of their physical infrastructure assets using the *Public Infrastructure Engineering Vulnerability Committee's (PIEVC) Protocol* [8]. The PIEVC Protocol is a five-step process that analyses engineering vulnerabilities of physical assets to current and future climate parameters. The PIEVC Protocol was updated in 2023-2024, with funding support provided by HICC.

UWSS saw this assessment as an opportunity to better understand potential climate impacts and to integrate the resulting information into future asset management risk assessments (Table 13). Further, the Infrastructure Climate Risk Assessment is in compliance with *O. Reg. 588/17: Asset Management Planning for Municipal Infrastructure* (O. Reg. 588/17), which requires all Ontario municipalities to gather data on core municipal infrastructure assets, including their age, materials, replacement costs, condition assessment, and lifecycle, and requires local governments to adopt a strategic asset management policy that includes climate change considerations [8]. Given that O.Reg 588/17 requires climate change considerations in asset management plans, it was used as an important tool to drive climate change risk assessment.

UWSS, Engineers Canada, and the Ontario Ministry of the Environment collaborated to assess the vulnerability of the water system infrastructure to local climate change impacts. The water system infrastructure included in the assessment were the drinking water treatment plant and the distribution network [8]. Table 13 outlines

the results of PIEVC's five-step process completed for UWSS, which was used to inform the asset management plan.

Table 13: Applying PIEVC Protocol to UWSS

Step 1: Project Definition	▪ Climate parameters were determined based on climate conditions and trends relevant to the region and is known seasonal variability. Gaps in data were filled using archival data. ▪ Climate conditions considered for the risk assessment were elevated temperatures, heavy rainfall, drought or dry period, lightning, hurricane, tornado, sub-zero temperatures, freezing rain, heavy snow, heavy fog, freeze-thaw, and fluctuating Lake Erie water levels.
Step 2: Data Gathering and Sufficiency	▪ Gathering sufficient data on physical elements and condition of the water system infrastructure, including operation and maintenance practices, posed challenges as records were not available. ▪ A workshop was organized to bring together past and present officials from the four municipalities with ownership in UWSS, other stakeholders, and interested citizens, to discuss the project and share anecdotal information.
Step 3: Risk Assessment	▪ Risk was calculated based on the probability of the climate event/hazard multiplied by the severity of the event/hazard. ▪ Each element of the water system infrastructure was evaluated based on probability and the severity of the impact, resulting in a ranking of low, medium, or high risk. ▪ The risk assessment indicated that certain climate events/hazards were found to pose higher risk to certain elements of UWSS infrastructure (lightning strikes, blowing snow and blizzards, and lower lake water levels). The assets determined to be at highest risk were the communication system, transformers and transmission lines, chemical storage, and emergency intake, respectively.
Step 4: Engineering Analysis (optional)	▪ No data

Step 5: Conclusion and Recommendations	▪ Short- to medium-term recommendations based on the climate impacts to UWSS's infrastructure include: ▪ Extreme weather procedures for operations personnel should be reviewed and updated. ▪ Operating procedures should be reviewed to account for potential power disruptions. ▪ Storage systems for data should be modified to account for potential power disruptions. ▪ In response to drought and sustained heat, which can cause lower lake levels, there is a need to renew and potentially modify the emergency intake. ▪ Older elevated storage tanks should be modified sooner than originally planned to ensure adequate circulation and minimize water quality issues caused by warm weather.

5.1.4 Outcomes

The outcomes of UWSS's work to support climate-resilient infrastructure include [8]:

- **Integration of climate data:** UWSS was working towards integrating climate data into the asset management plans of Leamington, Kingsville, Essex, and Lakeshore, prior to completing the Infrastructure Climate Risk Assessment. Upon completing the Infrastructure Climate Risk Assessment, UWSS was empowered to include climate risk assessments in their infrastructure and operation planning process and received endorsement from the UWSS Board to implement the full list of PIEVC's recommendations.
- **Successful adaptation efforts:** As of 2019, UWSS's adaptation efforts were:
  - a change to the communication system from land lines to radios
  - creating communications system redundancies in case of power failure
  - purchasing four large portable generators in case of power failure
  - staff training sessions on climate-related risks
  - installing real-time instrumentation to measure algae on raw water intakes to predict water quality and alter water treatment as necessary
- **Ongoing climate risk assessment work:** UWSS is planning on pursuing a Climate Risk Assessment of Linear Asset Conditions to complement this initial Infrastructure Climate Risk Assessment, towards their ultimate goal of integrating climate data into their asset management plans for select jurisdictions within Essex County.

- **A shift in internal decision-making processes:** UWSS notes that the most significant impact of their initial Infrastructure Climate Risk Assessment has been a shift in their internal decision-making processes, as staff are now regularly considering the impacts of climate change in operations and planning.

5.1.5 Take-Aways for Other Communities and Utilities

The experience of UWSS provides several key take-aways for other communities and utilities aiming to leverage existing guidance to enhance climate resilience [8]:

- **Use Available Frameworks and Expertise:** The PIEVC Protocol and Engineers Canada consulting expertise were provided to UWSS at no cost. This protocol and its case studies are freely available to municipalities across Canada, making it accessible for other communities to conduct climate risk assessments, providing a basis for climate-resilient infrastructure.
- **Leverage Existing Asset Management Plans:** UWSS benefited from having a smaller and less diverse asset inventory focused on drinking water. The existence of asset management plans for member municipalities made assessing vulnerabilities more manageable.

By learning from the experiences of UWSS, other communities and utilities can take steps to improve the consistent delivery of potable water despite increased risks of extreme weather events and algal blooms.

5.2 Case Study 2: Providence Health Care's Use of Climate Resilience Guidelines for the New St. Paul's Hospital Planning and Design

5.2.1 Overview and Highlights

Asset type: Building Infrastructure

Status: Project under construction (set to open in 2027)

Climate hazard: Coastal flooding, extreme heat, wildfire smoke

Geography: Lower Mainland, British Columbia

Communities: Vancouver

Challenges: Extreme weather events, rising sea levels, infrastructure wear and tear

Guidance documents: Climate Resilience Guidelines for BC Health Facility Planning and Design, PIEVC Protocol, Climate Resilience Framework & Standards for Public Sector Buildings

Outcomes: Climate risk assessment conducted; adaptation strategies developed and implemented; community and staff engaged; updated facility design

5.2.2 Background

This case study highlights Providence Health Care's application of climate resilience principles in planning and designing the new St. Paul's Hospital and Health Campus. By leveraging climate resilience guidance, this project demonstrates leadership in integrating climate adaptation measures into health facility infrastructure to address evolving climate challenges.

Heat waves and cold snaps, storms, wildfires, drought, and flooding can cause critical system failures that lead to service disruptions, temporary evacuations, and even facility closures, resulting in health emergencies for individual patients and the broader community [9]. Canadian health systems have been addressing the adverse effects of climate change on human health, including surging demand for health services and disruptions to service delivery. For instance, the 2021 heat dome over Western Canada had devastating impacts, severely straining health services as demand surged due to heat-related illnesses and other health complications. Tragically, this extreme weather event resulted in 619 confirmed deaths directly linked to heat in British Columbia—a stark reminder of the deadly consequences of climate change [10].

Heat-related impacts are just one example of the negative effects climate hazards pose to the health system. Table 14 highlights key climate hazards and their potential effects, as identified by Climate Change and Health Innovation Bureau in the *Health in a Changing Climate* report [11].

Table 14: Example Impacts of Climate Change on Health Facilities [11]

Hazard	Description of Potential Impacts
Heave waves, hotter nights, high humidity	▪ temporary closure or disruption of specific services and departments (e.g., operating rooms) ▪ patient transfers ▪ surge in patient admissions ▪ increased energy costs to provide cooling
Cold snaps, including ice storms and extreme snowfalls	▪ temporary closure or disruption of specific services and departments (e.g., operating rooms) ▪ power outages ▪ patient transfers ▪ surge in patient admissions ▪ staff shortages ▪ increased energy costs to provide heating ▪ disruption to transportation networks and/or supply chains
Flooding caused by extreme rainfall, river flooding, freezing water pipes, and storm surges resulting from hurricanes	▪ internal flooding, including basements ▪ damage to medical equipment ▪ power outages ▪ closure or disruption of specific departments (e.g., emergency, clinics) ▪ patient transfers from impacted healthcare facilities ▪ staff shortages due to health issues and transportation disruptions ▪ mental health impacts on staff ▪ boil water advisories ▪ blood supply shortages
Wildfires	▪ infrastructure damage from wildfires ▪ closure or disruption of specific departments due to air contamination (e.g., emergency, clinics) ▪ relocation of patients from impacted healthcare facilities ▪ staff shortages caused by health issues and transportation disruptions ▪ mental health impacts on staff ▪ boil water advisories
Melting permafrost	▪ destabilized building infrastructure ▪ damage to pipelines and power lines ▪ unstable transportation routes (including airstrips) on permafrost; less reliable winter ice roads

While efforts to support climate-resilience in British Columbia were already underway, extreme weather events in 2021 underscored the urgency of this work. The unprecedented heat dome was followed by an intense wildfire season, which then gave way to a series of atmospheric rivers in the fall, causing devastating flooding across the Lower Mainland. These cascading climate hazards starkly highlighted the vulnerabilities of health systems and reinforced the critical need to enhance the climate resilience of health facilities [12].

With this in mind, guidance documents that support the development of climate resilient health facilities in British Columbia include:

- *Climate Resilience Guidelines for B.C. Health Facility Planning and Design* (Health Facilities Climate Resilience Guidelines): These guidelines were first launched in 2020 to provide adaptable recommendations for enhancing healthcare infrastructure resilience against climate-related hazards. The Health Facilities Climate Resilience Guidelines offer a framework for integrating climate-resilient measures into facility design. They outline thorough guidance throughout all project stages, from high-level planning and detailed project planning to design, construction document development, and beyond [13].
- *Climate Resilience Framework & Standards for Public Sector Buildings*: This guidance was first launched in 2022 by the British Columbia Ministry of Environment and Climate Change Strategy. It is intended for health authorities, school districts, post-secondary institutions, publicly funded crown corporations and agencies, and the Government of British Columbia. It provides a climate resilience framework for early project planning to assess climate risks and integrate resilience strategies into building designs using minimum climate resilience standards. These standards are delivered through the province's updated Environmental, Social, and Governance Framework for Capital (ESGFC) [14].

In 2024, the Health Facilities Climate Resilience Guidelines were updated (Version 2.0) to align with the latest provincial requirements in the *Climate Resilience Framework & Standards for Public Sector Buildings*, ensuring they remain relevant and effective in addressing evolving climate challenges and regulatory landscape [13].

5.2.3 Using Climate-Resilient Guidance

Climate resilience in healthcare infrastructure is critical to ensuring reliable services amid increasing climate hazards. Recommendations from Health Facilities Climate Resilience Guidelines have been applied to over 20 acute and long-term care infrastructure projects, embedding climate resilience as a core principle [12].

Providence Health Care, a Catholic non-profit health organization, operates 17 facilities across Vancouver and the

Guideline End-users

The Health Facilities Climate Resilience Guidelines cater to a wide audience involved in healthcare infrastructure design, construction, and management, including project teams, facility staff, and health system collaborators.

coastal region of BC, including hospitals, clinics, long-term care homes, assisted living facilities, and hospices. Since 2020, Providence Health Care has embraced the Health Facilities Climate Resilience Guidelines on projects such as the new St. Paul's Hospital and Health Campus, Mount St. Joseph Hospital, and St. Vincent's Heather Long Term Care Facility [13].

The new St. Paul's Hospital and Health Campus represents a groundbreaking application of the guidelines, becoming the first acute care facility in British Columbia to integrate climate resilience throughout its design process [12]. Table 15 illustrates the steps outlined in the Health Facilities Climate Resilience Guidelines and their application to this transformative project. This work exemplifies a proactive approach to safeguarding healthcare delivery in a changing climate (outcomes and considerations in Table 15 and Table 16).

Table 15: Providence Health Care Implementation of Health Facilities Climate Resilience Guidelines for the New St. Paul's Hospital and Health Campus [13] [12] [15] [16]

Project Stage	Step	Providence Health Care implementation	Outcome
Early Project Planning	▪ understand the building's criticality ▪ conduct an exposure screen and identify building impact	▪ completed an initial assessment of all potential climate change related hazards and a screening process to assess specific site and building scale vulnerabilities to the selected hazards	▪ identified key hazards such as flooding, heatwaves, and air quality issues
Detailed Project Planning	▪ determine the climate risks ▪ identify relevant minimum climate resilience standards and any additional resilience strategies	▪ completed a detailed consequence scoring exercise evaluating impacts across multiple categories including patient health, staff safety, and asset replacement costs	▪ assessment work guided the design team in the development of design strategies that responded to and mitigated the associated climate risks

Project Stage	Step	Providence Health Care implementation	Outcome
Design and Construction	▪ identify and track design measures that meet established climate resilience requirements ▪ confirm that climate resilience requirements have been met	▪ identified measures to increase climate resilience, including design features to increase flexibility and disaster-readiness (e.g., flood, earthquake, heat)	▪ facilities designed to withstand climate impacts and ensure service continuity

5.2.4 Outcomes

Providence Health Care's implementation of the Health Facilities Climate Resilience Guidelines in the new St. Paul's Hospital project resulted in design decisions and strategy measures that will support the health facility's climate-resilience, as outlined in Table 16.

Table 16: New St. Paul's Hospital and Health Campus Climate Resilient Measures [16]

Type of Intervention	Examples of Climate-Resilient Measures
Flood Ready	▪ The new St. Paul's will be built five metres above the sea-level rise predicted by the year 2100 so it can continue operating in the event of a major flood. Critical systems, including mechanical, electrical, and communications equipment, will be placed on the 5th floor, following best practices from disasters like Hurricane Sandy. Habitable spaces and storage areas for flood-sensitive goods are above potential flood levels. ▪ The service parkade and cycling centre entrances will be designed to accommodate emergency watertight floodgates. ▪ Approximately 900 reinforced concrete secant piles will be installed around the new hospital's perimeter, overlapping by 6 inches to form a water-resistant barrier. ▪ The hospital's durable building envelope (exterior walls, foundations, and roof) will feature rainscreen details to allow rainwater and condensation to escape, keeping the building dry and minimizing water damage.
Earthquake Ready	▪ The Station Street site, previously a mud bay, will undergo bulk excavation to remove over 300,000 cubic meters of debris and soil accumulated since the early 1900s, ensuring the hospital is built on solid till (hard, firm clay). ▪ Pipes connected to the hospital will have flexible connections and be seismically resilient.

Type of Intervention	Examples of Climate-Resilient Measures
Extreme Heat Ready	▪ Mechanical systems for air quality and cooling are based on temperatures predicted by the year 2080. Chilled water and ventilation systems will ensure a cool environment. ▪ The hospital will feature green roofs and landscapes to capture rainwater, which will be treated and reused for cooling processes. ▪ Chilled water and ventilation systems will maintain a cool environment. ▪ Over 200 trees will be planted at the hospital and in the surrounding area to enhance shade and reduce heat.
Emergency Ready	▪ The hospital will have four generators capable of powering the entire facility with a 30% surplus. If one generator fails during an emergency, critical systems like Intensive Care Units and emergency lights will remain operational. This will allow the hospital to serve the community for 72 hours off the power grid. Future expansion space has been provided for two additional generators. ▪ The ambulance garage will be versatile, with a disaster response area for 16 beds and essential equipment. It will include medical gas outlets, power for heating, and water for decontamination. Both the garage and the Primary Care Triage and Access Centre will quickly convert into testing or mass-casualty triage centers during emergencies or pandemics. ▪ Outside connections are provided for emergency heating and process boilers. ▪ Many hospital rooms will be adaptable for various needs, with inpatient rooms capable of serving as intensive care units, equipped for larger critical care teams and more equipment, and medical gases piped into exam and procedure rooms for inpatient care. ▪ In an emergency, a Mobile Medical Unit (MMU) will be deployed on site, providing dedicated space and infrastructure to enhance patient care capacity.

5.2.5 Take-Aways for New Buildings

The experience of Providence Health Care provides several key take-aways for other buildings experts and health authorities aiming to leverage existing guidance to enhance climate resilience:

- **Consider Climate Resilience from the Start**: Initial assessment of climate change hazards and the screening process for site-specific and building scale vulnerabilities were completed during early project planning. As such, this assessment work was able to guide the design team in creating tailored and efficient strategies to address and mitigate climate risks during detailed design. Continued commitments to climate resilience throughout the later stages of the project (i.e., in design and construction) further helped support the successful integration of climate-resilient measures into the new St. Paul's Hospital [15].

- **Be Flexible and Proactive in an Evolving Guidance Landscape:** The project team began by using International Council for Local Environmental Initiatives (ICLEI) Canada's *Building Adaptive & Resilient Communities* (BARC) framework to approach integrating climate-resilient measures into the New St. Paul's Hospital. They then leveraged the PIEVC Protocol to develop a robust assessment, modifying the process for a health-specific context. The Health Facilities Climate Resilience Guidelines were developed during this project, and further informed the design team's approach to identifying and integrating the final climate-resilient design measures. Learnings from this project also informed discussions around a provincial guideline, the *Climate Resilience Framework & Standards for Public Sector Buildings*. By continuously adopting new and customizing existing guidance, the New St. Paul's Hospital successfully built on proven practices in an evolving policy landscape.
- **Leverage Existing Regulatory Requirements**: Many best practices in healthcare design can inherently enhance climate resilience, even if not explicitly intended for that purpose. For example, the CSA Z8000 standard (2018) includes provisions for occupant comfort and infection control that also address the need to adapt to rising temperatures and maintain indoor air quality during wildfire smoke events. Similarly, compliance with post-disaster standards outlined in the National Building Code of Canada (2022) provides opportunities for integrated measures that bolster resilience to both seismic events and climate-related hazards. Note that seismic risk is different from climate risk, but this is a good example of how codes and standards can be leveraged to incorporate climate resilience measures into projects.
- **Engage Stakeholders**: Stakeholder input was gathered through virtual workshops, which significantly strengthened the climate risk assessment process [15]. These sessions included diverse participants, such as municipal representatives, utilities, facilities and clinical staff, representatives from user groups, and the design team. Together, they evaluated potential climate impacts on patient health, occupant safety, and infrastructure. The outcomes of this collaborative effort informed design strategies that responded to and mitigated the associated climate risks.

Providence Health Care's proactive integration of climate-resilient infrastructure guidance into the planning and design of the new St. Paul's Hospital serves as a model for developers aiming to enhance climate resilience at their projects. This approach highlights the value of early action, adaptability, leveraging regulatory frameworks, and meaningful stakeholder engagement in achieving sustainable, community-informed outcomes. By drawing inspiration from Providence Health Care's example, users of climate-resilient building guidelines can take significant steps toward enhancing the resilience of their own communities in the face of an increasingly uncertain climate.

5.3 Case Study 3: Prohibition Creek Access Road Permafrost Protection Plan

5.3.1 Overview and Highlights

Asset type: Transit (Roads) Infrastructure

Status: Project complete

Climate hazard: Permafrost degradation

Geography: Norman Wells, Northwest Territories

Communities: Colville Lake Dene, Deline Dene, Fort Good Hope Dene, Fort Good Hope Metis, Norman Wells Metis, Tulit'a Dene, and Fort Norman Metis

Challenges: Dependence on surface transportation built on frozen ground; unsuitable current practices for permafrost; climate change increasing risks

Guidance documents: Erosion and Sediment Control Manual, and Guidelines for Permafrost Regions

Outcomes: Permafrost Protection Plan developed to minimize construction impacts, mitigate thaw and degradation, and accommodate climate change. PCAR Phase 1 (6.7 km) completed from Canyon Creek to Christina Creek; Phase 2 (6.3 km) to be combined with Mackenzie Valley Highway construction

5.3.2 Background: Permafrost in the Sahtu Region, Northwest Territories

Economic development and quality of life in Canada's northern communities rely on a dependable surface transit system, often built on perennially or seasonally frozen ground. However, current road planning, design, construction, and maintenance practices are often unsuitable for permafrost conditions, and climate change increases the risk of performance issues [17].

The Prohibition Creek Access Road (PCAR) aims to meet infrastructure needs in the Sahtu region and prepare Sahtu communities for future projects like the Mackenzie Valley Highway, while mitigating potential permafrost thaw as a result of PCAR activities in the region. Other benefits will include enhanced access to Sahtu lands for recreation and traditional uses and better inter-community travel/access to services [18].

The PCAR is situated south of Norman Wells in the Sahtu region of the Northwest Territories. It will stretch from Canyon Creek, about 14 km south of Norman Wells, to Prohibition Creek [18].

The PCAR area features extensive discontinuous permafrost, providing unique habitat and vegetation. In the Project area, permafrost varies in depth and thickness, covering 50% to 90% of the ground. This environment features warm ground temperatures and sensitive permafrost conditions.

PROJECTING PERMAFROST DEGREDATION While simulations consistently show that permafrost warming and thawing will persist and may accelerate due to climate change, the extent and timing of these changes vary across models. Better understanding of long-term interactions between permafrost, climate, vegetation, and snow, along with improved subsurface modeling, can help reduce uncertainties about permafrost's future

Projecting localized permafrost changes in the Project Area is challenging due to complex interactions among factors including surface temperature, soil properties, and initial permafrost temperature conditions. Warm permafrost (0 to -1 °C) is prone to thawing from site development and climate change. Despite mitigation efforts, near-surface permafrost along the alignment is expected to degrade over the coming decades due to climate change [18].

SAHTU COMMUNITIES The Sahtu region in the Northwest Territories includes the following communities: Colville Lake Dene, Deline Dene, Fort Good Hope Dene, Fort Good Hope Metis, Norman Wells Metis, Tulit'a Dene, and Fort Norman Metis. It is bordered by the Yukon Territory to the west, Inuvik to the north, the North Slave Region to the east, and Tlicho to the south.

(https://sahtu.ca/sahtu-communities/#)

5.3.3 Using Climate-Resilient Guidance

The Government of Northwest Territories developed a Permafrost Protection Plan (the "Plan") for the PCAR to [18]:

- minimize PCAR construction impacts on permafrost
- mitigate permafrost thaw and degradation over time
- adapt to climate change effects on permafrost

The Plan also outlines how to implement long-term monitoring and mitigation maintenance for permafrost. Potential impacts and mitigation measures in the Plan were developed using best practices from various guidance documents, including Government of Northwest Territories Department of Transportation's *Erosion and Sediment Control Manual* and the Transportation Association of Canada's *Guidelines for Permafrost Regions (GPR)* [18]. Table 17 describes the guidance documents and how these documents were used to inform the Permafrost Protection Plan for the PCAR [18].

Table 17: Permafrost Protection Plan Guidance Documents

Guidance Name	Guidance Description	Guidance Implementation
Transportation Association of Canada (TAC), Guidelines for Permafrost Regions	The GPR covers planning, route investigation, materials, drainage, erosion control, construction, maintenance, and emerging technologies for northern Canadian roads. It serves as a guide for those involved in infrastructure lifecycles; a tool for project managers, engineers, and maintenance staff; and reference for senior managers on road infrastructure challenges in permafrost areas [19]. A scoping study is underway to update this guidance document [17].	**Risk**: potential permafrost thaw due to altered drainage patterns, erosion, or ponding along the embankment, potentially resulting from increasing temperatures and climate change. **Project activities**: This thaw could occur because of the following PCAR activities: mobilizing and demobilizing construction equipment to and from work sites, site preparation, road construction, construction of watercourse crossing and drainage structures, quarry operations, as well as temporary workspaces and laydowns. **Mitigation measures**: Mitigation measures identified instruct readers to refer to and follow guidance in the GPR, among other documents. Measures informed by the GPR include: ▪ Runoff control methods are needed to protect permafrost soils, including diverting water entering the site, modifying slope surfaces, reducing slope gradients, controlling flow velocity, providing adequate drainage, and diverting flows away from exposed soil areas to mitigate permafrost degradation. ▪ Culvert design will include bedding materials and geotextile to prevent permafrost thaw, and rip rap to prevent erosion around the culverts.
Government of Northwest Territories, Transportation's Erosion and Sediment Control Manual (ESCM)	The ESCM offers guidelines for analyzing, designing, constructing, and maintaining erosion and sediment control systems for transportation projects in the Northwest Territories. It serves as a resource for design consultants, contractors, and	**Risk**: increased ponded surface water and potential erosion and drainage issues associated with permafrost thaw due to increase in mean seasonal temperatures. **Mitigation measures**: Identify climate-vulnerable areas within the right-of-way, especially those with ice-rich permafrost. Avoid construction in these areas if possible; otherwise, use methods to minimize thermal disturbance.

	field personnel, providing a rational basis for system design [18].	Methods can include: ▪ Implement effective road design by stabilizing slopes and installing culverts. ▪ Minimize ground disturbance to the project footprint. ▪ Ensure adequate cross drains along the roadway to maintain natural drainage patterns.

5.3.4 Outcomes

The outcomes of the PCAR Permafrost Protection Plan show the positive impact of integrating climate resilience guidelines into northern road planning, which include [18]:

- **Resilient Road Maintenance Practices**: PCAR staff are now better equipped to identify permafrost issues, maintain culverts, observe drainage and thawing related infrastructure performance problems, complete road inspections after extreme weather events, address potholes and rutting quickly, and address any road settlement issues.
- **Adaptive Permafrost Management**: Adaptive management of permafrost along the PCAR will involve linking site observations and ground temperature monitoring with response actions to mitigate degradation. This approach will require triggers and planned responses to address changes in the permafrost regime due to construction and climate. It will also help evaluate the long-term success of preservation efforts and confirm that disturbed areas have stabilized and are performing as expected.
- **A Model for Northern Communities**: The PCAR Permafrost Protection Plan approach serves as a valuable model for other Northern communities seeking to integrate climate resilience into their road planning processes. Data from annual reporting on permafrost monitoring activities can help inform other projects.

The first Phase of the PCAR has been built along the alignment of the existing Mackenzie Valley Winter Road, covering 6.7 kilometers (km) from Canyon Creek to Christina Creek [18]. Since the first phase of the PCAR was completed in September 2024 and no outcomes reports are available for public review, it is difficult to identify more detailed outcomes at the time of writing.

5.3.5 Take-Aways for Other Northern Communities

The experience of the Government of the Northwest Territories creating the Permafrost Protection Plan for the PCAR provides several key take-aways for other northern communities aiming to leverage existing guidance to enhance climate resilience [18]:

- **Conduct Comprehensive Risk Assessments**: Assess local permafrost conditions, including depth, thickness, and temperature. Use available guidance documents, data, local case studies, and engage experts to help identify vulnerable areas and predict future impacts with accuracy.

- **Use Adaptive Management Strategies**: Implement a system that links site observations and ground temperature monitoring with response actions to mitigate permafrost degradation. Use case studies and guidance to establish specific triggers for action and regularly evaluate the effectiveness of management strategies to support long-term success.
- **Integrate Climate Resilience into Planning and Maintenance**: Incorporate best practices from established guidelines and design infrastructure with resilience in mind. Regular maintenance routines should address issues like drainage, erosion, and road settlement promptly to prevent long-term damage.
- **Share Data and Best Practices with Other Projects**: Document and share findings from permafrost monitoring and management activities. Collaborate with neighboring communities to exchange knowledge and experiences, fostering a collaborative approach to climate resilience. Provide training for local staff and stakeholders on the importance of climate resilience and the specific measures being implemented.

These insights can help northern communities better prepare for and mitigate the impacts of climate change on their infrastructure, supporting sustainable development and improved quality of life for their community members.

5.4 Case Study 4: Developing Climate-Resilient Infrastructure Actions to Protect Annapolis Royal from Coastal Flooding

5.4.1 Overview and Highlights

Asset type: Protective Infrastructure

Status: Project ongoing

Climate hazard: Coastal Flooding

Geography: Annapolis Royal, Nova Scotia

Communities: Annapolis Royal (population ~530)

Challenges: Limited municipal revenue and funding for proactive climate adaptation; aging infrastructure; increased risk of coastal flooding due to climate change

Guidance documents: Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol, CLIMAtlantic's Climate Risk, Responsibility, and Liability for Municipalities

Outcomes: Flood risk assessment conducted by Chair of Town Environmental Advisory Committee and reviewed; identified risks to municipal and private properties; developed adaptation strategies including emergency response planning and a new seawall; cost-benefit analysis supporting proactive adaptation measures

5.4.2 Background: Coastal Flooding in Annapolis Royal

Annapolis Royal, a historic town of about 530 people in Nova Scotia's Annapolis Valley, was the original capital of Nova Scotia. It has the highest density of heritage properties in the province, many situated in a flood plain. Located at the mouth of the Annapolis River, the Town faces flood risks due to coastal storm surges, extreme tides of the Bay of Fundy, and sea level rise. The risk of flooding, especially in the central core and eastern lowlands, is considered a moderate risk under present conditions if a major storm surge event were to coincide with high tide conditions in the Bay of Fundy. A storm surge can persist for an entire tide cycle. Annapolis Royal flooded during the 1976 groundhog day event and this risk is projected to grow as the climate changes [20].

Although awareness of this potential flooding and other climate-related risks is well established through lived experience and multiple reports produced since the late 1990s, Annapolis Royal faces two main barriers to developing coastal flood adaptation and protection measures [20]:

- limited resources, including municipal revenue, to support already-failing infrastructure (due to age and lack of maintenance)

- limited funding for proactive climate adaptation action. Disaster response funding typically follows damaging events.

5.4.3 Using Climate-Resilient Guidance

To address the financial barriers and pursue climate-resilient protective infrastructure, Annapolis Royal is:

- exploring novel funding mechanisms at the municipal level, including aggressive reserve funding, alternative revenue sources, contributions from industry and additional contributions from the community
- applying for federal funding that has been made available to support major capital projects with the goal of climate adaptation (i.e., Flood Risk Infrastructure Investment Program (FRIIP)

As part of the planning and application for funding, Annapolis Royal contracted an assessment of its flood risk and adaptation options to the Atlantic Infrastructure Management (AIM) Network, which is a local non-profit firm [20]. The assessment was provided to municipal government representatives to strategically address the rising coastal climate hazard impacting Annapolis Royal's historic downtown. The assessment considered risk levels based on climate projections over the next eighty years (to 2100), a flexible adaptation pathway considering immediate and feasible actions, and cost estimates to support financing strategies.

Two main guidance documents inform the assessment in addition to the technical design options and a cost-benefit analysis (Table 18) [20].

Table 18: Annapolis Royal Guidance Documents

Guidance Name	Guidance Description	Guidance Implementation
Engineers Canada, PIEVC Protocol	The PIEVC Protocol is freely available to assist engineers in considering climate change effects and risk of failure into plans for design, operations, and maintenance of public infrastructure. It was developed by Engineers Canada, using support from Natural Resources Canada, with early applications beginning in 2007. An updated PIEVC Protocol has been released (V.11, June 2024), building upon the previous Protocol (V.10) used by Annapolis Royal and many others. The PIEVC protocol is currently managed in Canada by the	Conducted a climate risk assessment to evaluate the climate hazard risks, especially coastal risks, to Annapolis Royal's historic downtown. Annapolis Royal used the PIEVC Protocol's Practitioner Risk Assessment approach rather than a fully facilitated approach to consider the cost risk of delaying action ("do-nothing") against the cost of a proposed adaptation solution.

	Climate Risk Institute (CRI) and Institute for Catastrophic Loss Reduction (ICLR).	
CLIMAtlantic, Climate Risk, Responsibility, and Liability for Municipalities: Exploring Municipalities' Responsibilities to Consider, Manage, and Disclose Climate Change Flood Risks	The report outlines five key areas of municipal responsibility for managing and disclosing climate change flood risks in Atlantic Canada: (1) enabling legislation for municipalities, (2) external laws imposing liability for environmental and personal harm, (3) common law, (4) constitutional provisions, and (5) funding agreements and contracts with relevant terms. It then examines these responsibilities in three municipal activities: infrastructure management, land use planning, and development permitting.	Identified legal responsibilities as a municipality and what liabilities Annapolis Royal could face if it failed to meet their responsibilities while upholding other priorities, such as maintaining the historic character of downtown.

Other guidance documents leveraged in the assessment include: the British Columbia Climate Change Adaptation Pathways Framework (2019), which is included in the ancillary list because it is focused on food systems, and the World Meteorological Association's technical document Guide to Storm Surge Forecasting (2011), which is included in the guidance inventory.[6]

5.4.4 Outcomes

The outcomes of Annapolis Royal's work to assess and respond strategically to the increasing coastal climate hazards to its historic downtown include [20]:

- **Assessment of coastal climate hazard risk:** Through the PIEVC assessment, Annapolis Royal identified potential damage to municipal public property as well as private property.
- **Options for flood resilience:** Options for flood resilience that were considered included managed retreat, emergency response measures, adaptive building, a barrier along Goat Island, a storm gate at Digby Gut, a seawall, shoreline restoration, and/or wharf replacement. It was identified that the wastewater treatment facility can be protected by non-structural means including a flood management plan at the former tidal plant causeway crossing. Conversion of the old tidal power generation plant into a storm gate likely would not require any retrofit. Rather, it would require a new way of operating the asset. This storm gate prevents the storm surge from the Annapolis basin from encircling the peninsula and flooding the lagoons. The storm gate would cause runoff from the Annapolis River to

[6] Detailed description of guidance implementation is not available at the time of writing.

build up and increase water levels, but not enough to risk property before being released after surge subsides.

- **Potential adaptive pathways**: Two feasible adaptation strategies were identified: emergency response planning to mitigate consequences of flood events and/or a new seawall and managing upstream impacts at the Highway 1 causeway. If developed using an adaptive pathway approach, the conceptual design of the new seawall can accommodate expansion if required in thirty to forty years without having to remove any of the wall structure. Adaptive pathways accommodate cost-effective design and development at the outset of a project while allowing for future adjustment of a scheme based on evidence of more or less climate change impacts.
- **Legal considerations for the best course of action:** The CLIMAtlantic report prompted and supported Annapolis Royal to proactively identify its legal responsibilities as a municipality in considering, managing, and disclosing climate change flood risks, and what liabilities it could face if it failed to meet its responsibilities. It helped to inform the Town, before it invested in high-cost hard infrastructure without contributions from private sources such as insurance organizations or impacted property owners, that they may consider other feasible pathways to risk mitigation while meeting its duty to inform and deliver robust emergency response measures.
- **Cost-benefit considerations:** A base cost for the proposed seawall concept was calculated at $4.65M. However, a cost-benefit analysis demonstrated that action now would cost less than delaying or taking no action over an eighty-year timeframe. Although the Town will need to consider novel financing strategies such as reserve funding, alternative revenue sources, contributions from industry, and additional contributions from the community, the cost-benefit analysis finds adaptation in this way is a more cost-effective option than responding to a disaster through emergency funding or insurance.

5.4.5 Take-Aways for Other Communities

Annapolis Royal's approach, supported by the PIEVC Protocol and the guidance report from CLIMAtlantic, has laid the foundation for overcoming the Town's existing barriers in constructing coastal flood adaptation and protection measures and supporting climate resilience. Key take-aways for other communities include [20]:

- **Use novel funding strategies**: Funding and resource barriers are common in communities across Canada. Annapolis Royal has identified the next steps and supports required to obtain needed financial resources, it has assessed the financial costs versus benefits to support its chosen course of action, and it has rationale for a sensible adaptive pathway that can minimize potential loss of services, damage to properties, disruption to businesses, and displacement of people. Annapolis Royal has acknowledged that it will require non-conventional infrastructure funding strategies including contributions from the insurance industry and community property owners.

- **Use adaptive planning**: Consider adaptation as a process instead of a one-time intervention or action. The assessments conducted enabled focus on adaptation actions that can be integrated into Annapolis Royal's existing context and initiatives to support long-term sustainable service delivery, including activities to remove the barriers to proper adaptation that currently exist.
- **Consider multiple futures**: The Town's assessments support an adaptive adaptation plan with resilience actions, including actions to remove barriers to adaptation, that can be taken immediately with available financial resources and are not solely based on a worst-case scenario and options that "should" be done. Although understanding the extremes of climate risks is useful knowledge in planning and pursuing risk mitigation, a plan with only actions based on the worst-case scenario is not practical for Annapolis Royal given the Town's limited financial resources.
- **Engage the public**: The assessment included a successful public engagement session attended by approximately 100 community members. Informing the community of key costs and risks allowed for an assessment tailored to local community needs. Although this approach requires major infrastructure investment that will require novel financing strategies, Annapolis Royal now has robust, practical, and community-informed direction for climate-resilience infrastructure to protect the Town from the known high risk of coastal flooding.

6. Conclusion and Recommendations

6.1 Gaps in Guidance Availability

The inventory of climate resilience guidance exceeds 150 documents indicating that there is a rich collection of valuable guidance for climate-resilient infrastructure spanning assets, hazards, and regions across Canada. The codes, standards, and technical circulars authored by bodies at all levels of jurisdiction that form the foundation of guidance are mostly specific to asset types and regions. Although existing guidance produced for specific regions and asset types is beginning to integrate climate change consideration in many cases, there is also new guidance focused specifically on climate-resilient infrastructure. Overall, the volume and range of guidance illustrates the widespread and multi-faceted progress toward, and commitment to, climate-resilient infrastructure, as well as the complex needs and challenges.

In general, climate resilient considerations in guidance are relatively new and there are still many practitioners who are not aware of the rapidly evolving and developing area of interest. For many practitioners, it is difficult to keep up-to-speed and be comfortable with applying new guidance to projects with novel approaches and uncertain results. Over the last two decades, there has been marked evolution in guidance to assess climate risk; however, greater emphasis is now needed to ensure robust guidance for asset and/or hazard-specific climate risk reduction measures. There is a need to advance guidance for risk treatments across scales from singular assets to systems, and to community-scale networks.

There is evidence of growing cohesion in the climate resilience space with established codes and standards integrating climate resilient guidance, such as the National Building Code and the Canadian Highway Bridge Design Code, adopting future climate projection information. This integration of climate considerations into existing standards is considered a valuable approach to mainstreaming climate resilience into design as end-users are more likely to refer to familiar codes and standards rather than stand-alone climate guidance.

No items came to the forefront as 'top' guidance across an infrastructure type or region. An exception to this statement is the wide recognition and use of the PIEVC Protocol as a practical tool to identify climate hazards and risks. However, this is not specifically a guidance document; rather, it is a tool to understand climate risk. The results of the assessment indicated that guidance is most useful when it is written to be specific to the infrastructure sector, asset type, location, and applicable hazards. High level, general guidance is less useful.

Generally, this assessment found that end-users are typically able to access the guidance they need and turn to other jurisdictions to access suitable technical guidance as needed. This ease of access may not be a reality for Indigenous-led projects; however, this consideration is beyond the scope of this assessment. It is recommended that further efforts are supported to consider the needs, challenges, and opportunities for Indigenous communities in accessing and using guidance for climate-resilient infrastructure. Some specific guidance gaps were identified for infrastructure operations and maintenance, for specific regions such as the prairies, and for specific hazards like permafrost thaw and complex coastal hazards.

In reviewing the inventory of guidance, much of the guidance has been developed for buildings, perhaps due to funding directed towards initiatives such as the *Climate-Resilient Buildings and Core Public Infrastructure Initiative* (CRBCPI) and its successor *Climate Resilient Built Environment* Initiative (CRBE), and a strong focus on building sustainability prevalent in the industry over the past 10-20 years (e.g., LEED, Passivhaus, BOMA Best, Green Globes). However, feedback from the buildings subject matter experts highlighted a need for climate-resilient guidance on specific climate hazards such as permafrost, flood zones, heatwaves, and more detailed guidance at a local level (i.e., provincial/territorial or municipal). Therefore, it is possible that some identified gaps may reflect a lack of awareness of available guidance and not necessarily guidance document gaps. This indicates two things: what gets funded is where the momentum grows, and practitioners may not be aware of all the activity in the space.

***WSP recommendations to overcome guidance gaps*:** Incorporating climate resilient considerations into existing codes and standards will support uptake.

- Integrate climate considerations into existing guidance rather than developing new stand-alone documents because integration represents a favourable cost-benefit investment and may support greater uptake in projects by practitioners familiar with previous versions of the guidance.
- There are opportunities to continue supporting guidance development for regions and topics for which no or insufficient guidance exists (e.g., northern regions where permafrost thaw, fire, and flooding are rapidly changing the environment).

6.2 Challenges in Navigating the Guidance Landscape

There are many other supports beyond technical 'guidance' that are used and are important in building climate-resilient infrastructure. The ancillary list exceeding 150 documents as well as the range of resources outlined in the case studies indicates there is a substantial collection of strategies, knowledge hubs, best practices, and manuals that also guide and support climate-resilient infrastructure in Canada. Insights from the expert workshops and case studies highlighted that these supports are important in the critical aspects of developing climate-resilient infrastructure beyond the technical design and delivery. Among end-users, there is no clear delineation between what is considered 'guidance' and the supporting documents included in the ancillary list in this assessment; experts indicated that they rely on these ancillary documents for guidance.

Amid calls for more guidance by subject matter experts and practitioners for more guidance specific to some asset types and climate hazards, there is a substantial amount of guidance for climate-resilience infrastructure in Canada. The landscape of guidance can be difficult to navigate because there is a high volume of documents, there are updates and new guidance documents developed over time, users employ guidance as well as other supports (such as manuals and best practices) in supporting climate resilient infrastructure, and guidance is authored and provided my many parties across jurisdictions with no central repository. Further, more guidance does not always equate to better quality of guidance or easier implementation of resilience measures.

WSP recommendations to support navigation of the guidance landscape: There are strategies for HICC to consider in managing the complexity of the guidance landscape and supporting end-users' understanding of available guidance.

- Provide education and outreach to key stakeholder groups, including associations of municipalities and professional organizations in each province, for example, to assist in the navigation of the guidance environment and how it relates to existing codes and standards.
- Consider continued development of the guidance inventory by adding more resources as they become available to create a centralized collection and support end-users' navigation of guidance as it evolves over time. This initiative may be timely alongside the development of the Climate Insight platform, and its inclusion on the platform may provide opportunities to not only make guidance more easily accessible and understood, but also promote guidance use and efficacy.

6.3 Challenges in Implementation of Guidance

Feedback from the subject matter experts and information in the case studies indicate that guidance is available, but it is often challenging to implement. There is broad recognition of infrastructure funding programs and grants requiring climate risk considerations; however, it is often challenging to align the financial resources and the timing to bring resilient infrastructure projects into fruition.

To date, most funding requirements across Canada are connected to climate risk assessments and not to the actual development of the climate-resilient infrastructure. For example, climate risks assessments are commonly conducted and included in reporting, but they may not be integrated early enough in the project phases to have associated funding and there is often no requirement to implement the assessment's recommendations for resilience. Further, many municipalities have climate resilience requirements at the planning and design stage, but they are not always integrated into the permitting or approvals process and relatively poorly understood by planning, design, and construction teams. This can result in resilience features being eliminated or value engineered out of projects. The status quo will continue unless the value of investing into resilient infrastructure is understood and factored into planning and design. To be effective, asset owners, planners, and designers need a clear understanding of the cost benefits of integrating resilience measures throughout project phases and asset lifecycles.

Another opinion that surfaced in multiple expert workshops was that end-users value the instances where a guidance, funding program, or policy requires, rather than recommends, climate considerations. An explicit requirement enables climate hazard considerations or resilience actions in instances where it may not otherwise occur due to funding or other resource limitations. The workshop participants communicated that funding is nearly always a limiting factor and, therefore, typically spent only on requirements. Narrow focus on capital budgets at provincial, territorial, municipal, and Indigenous community levels can hinder

implementation of climate-resilience in infrastructure projects when the short-term costs are high and the long-term benefits can be challenging to quantify or characterize.

Despite these challenges, the case studies included in this report showcase the practical application of existing guidance documents for both climate risk assessment and climate resilient infrastructure development. The case studies outline national, provincial and territorial, and regional guidance supporting communities facing acute and chronic climate change hazards, particularly for aging infrastructure crucial to community services and safety. Echoing expert insights, the case studies underscore the value of tailored guidance and support to incentivize and implement climate-resilient projects effectively. They showcase communities and organizations that have moved beyond short-term thinking focused on initial capital construction costs.

WSP recommendations to support implementation: Implementing design strategies and guidance for climate resilience requires ongoing support. Requirements for climate resilience are still developing with inconsistencies across local, provincial, and national jurisdictions. It is recommended that HICC:

- Ensure funding programs require projects to demonstrate how climate resilience has been incorporated into planning and design phases.
- Support better understanding and reduction of implementation barriers for end-users. This may include conducting broader surveys or additional focus groups with end-users focused on the cost-benefit analyses and business cases to implement guidance and enable development and maintenance of climate-resilience infrastructure.
- Consult with municipalities, Indigenous governments, and provinces/territories to align government funding structures with municipal realities. Support owners in conducting the cost-benefit analyses to identify the long-term value and avoided costs associated with climate-resilient infrastructure. Simplified or accessible cost-benefit analyses can support the value proposition for municipal councils or funding programs, for example, to justify the up-front costs of climate-resilient infrastructure.

It is recommended that HICC continue understanding and validating the perspectives presented in this assessment through further engagement with end-users and those involved in all phases of supporting climate-resilient infrastructure. By addressing these limitations and implementing these recommendations, Canada can enhance the effectiveness of its climate-resilient infrastructure initiatives and ensure that available guidance is more widely understood and applied.

7. References

Basic reference information for the guidance documents is included in the full inventory.

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APPENDIX A

Simplified Ancillary List

An ancillary list was developed to capture relevant documents, tools, platforms, hubs, databases, etc. that were identified through the assessment but did not meet all criteria to be included in the guidance inventory. The full ancillary list is included in the Excel document; it contains less information about each document than the inventory. It is arranged by asset type. Appendix A is a simplified ancillary list.

Title	Year	Author	Infrastructure Type
Prairie Resilience: A Made-in-Saskatchewan Climate Change Strategy	2017	Government of Saskatchewan	All
2030 NWT Climate Change Strategic Framework: 2019-2023 Action Plan	2018	Government of Northwest Territories	All
Strength, resilience, sustainability: Canada's construction sector recommendations on adapting to climate change	2021	Canadian Construction Association	All
Weathering the storm: Developing a Canadian standard for flood-resilient existing communities	2019	SCC and National Research Council	All
Coastal Hazards Information Platform	2021	Province of Prince Edward Island	All
Building Resilience: Climate Adaptation Plan	2022	Province of Prince Edward Island	All
Made in Ontario Environment Plan	2020	Government of Ontario	All
Policy for Flood Plain Management	2014	Environment and Climate Change, Newfoundland and Labrador	All
Climate Resilient Edmonton: Adaptation Strategy and Action Plan	2018	City of Edmonton	All
Standards to Support Climate Resilience in Infrastructure: Taking stock and mapping the future	2019	CSA Group	All
Using Climate Information in Standards Development Technical Companion to the Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards	2022	CSA Group	All
Canada’s Climate Change Adaptation Platform	2023	Natural Resources Canada	All
Adaptation resource library	n.d.	Federation of Canadian Municipalities	All
CEN-CENELEC Guide 32	2016	European Committee for Standardization (CEN), European Committee for Electrotechnical Standardization (CENELEC)	All

Title	Year	Author	Infrastructure Type
Climate Change and Infrastructure Risk Training for Engineering Professionals	2020	Engineers Canada	All
ISO 31000 Risk Management Guidelines	2018	ISO	All
ICLR and Intact Centre Resources	2020	ICLR, Intact Centre	All
The Canada Green Buildings Strategy	2022	Government of Canada	All
Climate Science 2050: Advancing Science and Knowledge on Climate Change	2020	ECCC	All
The Government of Canada Adaptation Action Plan	2023	Government of Canada	All
Canada's National Adaptation Strategy: Vision Forum	2021	ECCC	All
Achieving a Sustainable Future	2022	ECCC	All
National Infrastructure and Buildings Climate Change Adaptation: State of Play Report	2023	Housing, Infrastructure and Communities Canada (HICC)	All
National Risk Profile: A National Emergency Preparedness and Awareness Tool	2023	Government of Canada	All
Climate Change and Canada's Cities	2024	Climate Atlas	All
Handbook: A toolkit for local elevated climate action adaptation	2024	Climate Caucus	All
Development of a National Standards Strategy	2022	Standards Council of Canada	All
Tip of the Iceberg: Navigating the known and unknown costs of climate change for Canada	2020	Canadian Institute for Climate Choices	All
Enhancing Climate-related disclosure by cities: A guide to adopting the recommendations of the task force on climate-related financial disclosures (TCFD)	2019	Chartered Professional Accountants of Canada	All
Preliminary strategic climate risk assessment for British Columbia	2019	British Columbia Ministry of Environment and Climate Change Strategy	All
Canada in a Changing Climate: Synthesis Report	2023	Changing Climate	All
Canada in a Changing Climate: National Issues	2021	Changing Climate	All
Canada in a Changing Climate: Regional Perspectives	2020	Changing Climate	All
Bridge to the Future: Final Report from the Task Force for a Resilient Recovery	2020	Task Force for a Resilient Recovery	All

Title	Year	Author	Infrastructure Type
Investing in Canada: Canada's long-term infrastructure plan	2020	Housing, Infrastructure and Communities Canada (HICC)	All
A Guidebook on Climate Scenarios: Using Climate Information to Guide Adaptation Research and Decisions	2016	Ouranos	All
Standardization Guidance for weather data, climate information and climate change projections: Overview of Canadian practices, needs, and challenges on integrating climate change into infrastructure design	2017	Ouranos and SCC	All
Climate Data website	n.d.	ECCC	All
CEN-CENELEC Guide 32: Guide for addressing climate change adaptation in standards	2016	CENELEC	All
Pan-Canadian Framework on Clean Growth and Climate Change: Canada's plan to address climate change and grow the economy	2016	Government of Canada	All
Adapting to Climate Change: An Introduction for Canadian Municipalities	2013	Natural Resources Canada	All
Map of Adaptation Actions	n.d.	Canada in a Changing Climate	All
Emergency Management Strategy for Canada: Toward a Resilient 2030	2022	Public Safety Canada	All
Infrastructure and Buildings Working Group: Adaptation State of Play Report	2017	Natural Resources Canada	All
Adapting to Climate Change: Canada's First National Engineering Vulnerability Assessment of Public Infrastructure	2008	PIEVC	All
Risk and Return on Investment tool	2023	Climate Risk Institute	All
Investing in Canada's Infrastructure Program	n.d.	Government of Canada	All
Disaster Mitigation and Adaptation Fund	n.d.	Government of Canada	All
Smart Cities Challenge	n.d.	Government of Canada	All
First Nation Infrastructure Fund	n.d.	ISC	All
Indigenous Community-Based Climate Monitoring Program	n.d.	Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)	All
Flexible Standards-Based Strategies and Solutions	n.d.	Standards Council of Canada	All

Title	Year	Author	Infrastructure Type
Construction and Maintenance Looking Forward	2020	BuildForce	All
Canada Infrastructure Bank	n.d.	Canada Infrastructure Bank	All
A Healthy Environment and a Healthy Economy: Canada's strengthened climate plan to create jobs and support people, communities and the planet	2020	ECCC	All
Resilience Rating System: A Methodology for Building and Tracking Resilience to Climate Change	2021	World Bank Group	All
Top 100 Infrastructure Projects	2022	Renew Canada	All
Infrastructure Statistics Hub	2023	Statistics Canada	All
Climate-Resilient Buildings and Core Public Infrastructure: summary of state-of-practice and knowledge gaps on climate change adaptation of buildings and core public infrastructure	2019	National Research Council of Canada	All
Guidance Document on Using Climate information in Standard Development: Technical Companion to the Guide for Integration Climate Change Adaptation Considerations into Canadian Standards	2022	Standards Council of Canada	All
Guide for Integrating Climate Change Adaptation Considerations into Canadian Standards	2021	Standards Council of Canada	All
Climate-Resilient Buildings and Core Public Infrastructure: An assessment of the impact of climate change on climatic design data in Canada	2020	ECCC	All
Advancing the climate resilience of Canadian infrastructure: A review of literature to inform the way forward	2021	IISD	All
Building a Resilient Canada: The Expert Panel on Disaster Resilience in a Changing Climate	2022	Council of Canadian Academies	All
Municipalities for Climate Innovation Program: Climate Adaptation Maturity Scale	2018	Federation of Canadian Municipalities	All
Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level	2020	Insurance Bureau of Canada and Federation of Canadian Municipalities	All
Summary Report: Estimating budgetary impacts of changing climate hazards in public infrastructure in Ontario	2023	Financial Accountability Office of Ontario	All
Municipal Infrastructure: A review of Ontario's municipal infrastructure and an assessment of the state of repair	2021	Financial Accountability Office of Ontario	All

Title	Year	Author	Infrastructure Type
Provincial Infrastructure: A review of the province's infrastructure and an assessment on the state of repair	2020	Financial Accountability Office of Ontario	All
Standards in Action: Building a Climate-Resilient Future	2021	Standards Council of Canada	All
Climate 2050: Strategic Framework	2019	Services and Solutions for a Livable Region	All
Climate Preparedness and Adaptation Strategy: Actions for 2022-2025	2021	Government of BC	All
Community Resilience Index: Overview and instructions	2021	Justice Institute of British Columbia	All
Emergency Management Strategy for Canada: Toward a Resilient 2030	2019	Public Safety Canada	All
Climate Preparedness and Adaptation Strategy: Actions for 2022-2025	2021	Clean BC	All
A Made-in-Manitoba Climate and Green Plan	2017	Manitoba Sustainable Development	All
Our Pathway Towards Decarbonization and Climate Resilience: New Brunswick's Climate Change Action Plan 2022-2027	2022	Government of New Brunswick	All
The Way Forward: On Climate Change in Newfoundland and Labrador	2018	Government of Newfoundland and Labrador	All
Our Climate, Our Future Nova Scotia’s Climate Change Plan for Clean Growth	2022	Nova Scotia Environment and Climate Change	All
Climate Ready: Ontario's Adaptation Strategy and Action Plan	2016	Government of Ontario	All
Building Resilience: Climate Adaptation Plan	2022	Government of Prince Edward Island	All
Plan2Adapt	2024	Pacific Climate Impacts Consortium (PCIC)	All
Estimating the benefits of Climate Resilient Buildings and Core Public Infrastructure (CRBCPI)	2020	Institute for Catastrophic Loss Reduction	All
Canadian Infrastructure Report Card 2019: Monitoring the State of Canada's Core Public Infrastructure	2019	The Association of Consulting Engineering Companies Canada (ACEC)	All
Incorporating Climate Change into Public Infrastructure Planning and Design (Workshop Series)	2018	Government of Newfoundland and Labrador	All
Climate-Resilient Infrastructure: Adaptive Design and Risk Management	2018	American Society of Civil Engineers (ASCE), Committee on Adaptation to a Changing	All

Title	Year	Author	Infrastructure Type
		Climate, edited by Bilal M. Ayyub	
Adapting Infrastructure and Civil Engineering Practice to a Changing Climate	2015	American Society of Civil Engineers (ASCE), Committee on Adaptation to a Changing Climate, edited by J. Rolf Olsen, Ph.D.	All
City of Calgary Climate Risk Assessment Framework	2019	City of Calgary	All
Climate Change Adaptation Pathways Framework: Supporting Sustainable Local Food in B.C.	2019	B.C. Ministry of Agriculture (by Coulter, L. through 2018-19 Mitacs Science Policy Fellowship)	All (Food Systems)
Climate Resilient Coastal Communities (Funding Program)	2023	Natural Resources Canada (NRCan)	All (Coastal)
Coastal Engineering Manual	2002	U.S. Army Corps of Engineers	All (Coastal)
CEC and DHI Guides on Coastal Nature-based Solutions	2024 (In publication)	Commission for Environmental Co-operation (CEC) and Dansk Hydraulisk Institut (DHI)	All (Coastal)
Health of Canadians in a Changing Climate: Advancing our Knowledge for Action	2022	Health Canada	All (Coastal)
Canada's Changing Climate Report in Light of the Latest Global Science Assessment	2022	Environment and Climate Change Canada	All (Coastal, Northern)
Canada's National Adaptation Strategy: Building Resilient Communities and a Strong Economy	2023	Government of Canada	All (Natural Assets)
Guideline for Wildfire Protection of Institutional Buildings in Forested Regions in Alberta	2013	Alberta Infrastructure	Buildings
Build Better Buildings: A Sustainable Buildings Policy for Government of Newfoundland and Labrador Funded Projects	n.d.	Government of Newfoundland and Labrador	Buildings
British Columbia Building Code	2024	BC Ministry of Housing	Buildings
National Energy Code of Canada for Buildings, 2011	2011	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes	Buildings
National Building Code of Canada, 2015	2015	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes	Buildings

Title	Year	Author	Infrastructure Type
National Fire Code of Canada, 2015	2015	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes	Buildings
National Plumbing Code of Canada, 2015	2015	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes	Buildings
National Energy Code of Canada for Buildings, 2015	2015	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes	Buildings
FEMA P-1019	2014	Federal Department of Homeland Security, Federal Emergency Management Agency (FEMA), National Earthquake Hazards Reduction Program (NEHRP)	Buildings
ASCE 24	2014	American Society of Civil Engineers	Buildings
FEMA 543	2007	FEMA	Buildings
Requirements for the Design and Certification of Dry Floodproofed Non-Residential and Mixed-Use Buildings	2013	FEMA	Buildings
Canadian Highway Bridges Design Code (2025)	2025 (In publication)	CSA Group	Buildings
Best Practices Guide: Laboratory Resilience	2019	International Institute for Sustainable Laboratories	Buildings
Residential Archetyping for Energy Efficiency Programs: A Guide for Canadian Municipalities	2022	Clean Air Partnership	Buildings
Climate-RCI	2021	ECCC and NRC	Buildings
Hygrothermal database of building materials	2021	National Research Council of Canada	Buildings
Delivering Climate Responsive Resilient Building Codes and Standards Findings from the Global Resiliency Dialogue Survey of Building Code Stakeholders in Canada, Australia, New Zealand and the United States	2021	Global Resilience Dialogue Survey Building Code Stakeholders in Canada, Australia, New Zealand and the United States	Buildings
Technical Design Requirements Climate Resilience Study for Alberta Infrastructure	2018	Alberta Infrastructure	Buildings

Title	Year	Author	Infrastructure Type
Buildings: Assessing the financial impacts of extreme rainfall, extreme heat, and freeze-thaw cycles on public buildings in Ontario	2021	Financial Accountability Office of Ontario	Buildings
Climate Change Adaptation Framework Manual	2010	Alberta Sustainable Resource Development	Buildings
Quebec in Action Greener by 2020: 2013-2020 Government Strategy for Climate Change Adaptation	2012	Government of Quebec	Buildings
Resilience-Based Performance: Next Generation Guidelines for Buildings and Lifeline Standards	2019	American Society of Civil Engineers (ASCE), Risk and Resilience Measurement Committee	Buildings
National Energy Code of Canada for Buildings, 2017	2017	National Research Council of Canada (NRC) (publisher), Canadian Commission on Building and Fire Codes	Buildings
Bureau de normalisation du Québec Standards and Guidelines 1809-350 3624-130 3661-500 3680-905 3682-850 3682-901 3682-925 4930-100 9461-100 9825-925 3009-600 3009-610	2024	Bureau de Normalisation du Québec (BNQ)	Buildings
Climate Resilience Guidelines for British Columbia Health Facility Planning and Design	2020	BC Health	Buildings, Healthcare
Permafrost document from EPA	2024	EPA	Buildings, Natural Assets
Combatting Canada's Rising Flood Costs: Natural infrastructure is an underutilized option	2018	Insurance Bureau of Canada	Buildings, Protective
Costing Climate Change Impacts and Adaptation for Provincial and Municipal Public Infrastructure in Ontario	2023	Financial Accountability Office of Ontario	Buildings, Roads, Transit
2023 Multi-year Infrastructure Investment Strategy 5-Year Capital Investment Plan	2023	Manitoba Transportation and Infrastructure	Buildings, Water, Transit
Canada's Changing Climate Report	2019	Government of Canada	Buildings, Water, Transit, Coastal
Climate Change Green Infrastructure Stream	2020	Association of Municipalities Ontario (AMO)	Natural Assets

Title	Year	Author	Infrastructure Type
IUCN NBS Resources	2022	International Union for Conservation of Nature (IUCN)	Natural Assets
GCC Small-Scale GI Training	2021	Green Communities Canada (GCC)	Natural Assets
Non-Governmental Organization (NGO) Resources: David Suzuki Foundation	2021	David Suzuki Foundation	Natural Assets
Tree Equity	2023	Nature Canada	Natural Assets
Green Infrastructure Ontario Coalition Resource Hub	2020	Green Infrastructure Ontario Coalition	Natural Assets
Ecological Design Lab at TMU	2022	Toronto Metropolitan University	Natural Assets
IUCN Resources on Ecosystem-based Adaptation	2021	IUCN	Natural Assets
Green Infrastructure Standards	2020	American Society of Landscape Architects (ASLA)	Natural Assets
Natural Solutions Initiative: Putting Nature back into Nature-based Solutions	2023	Simon Fraser	Natural Assets
Natural Infrastructure Fund	n.d.	Housing, Infrastructure and Communities Canada (HICC)	Natural Assets
Nature Smart Climate Solutions Fund	n.d.	ECCC	Natural Assets
Benefits of adopting natural infrastructure: A comparison of natural and grey infrastructure solutions	2019	Horizon Advisors	Natural Assets
Climate Change Challenges for Flexible Pavement in Canada: An Overview	2021	Maadani et al.	Roads
Investigation of climate change impacts on early-age cracking of jointed plain concrete pavements in Canada	2021	Shafiee et al.	Roads
Climate change and asphalt binder selection across Ontario: A quantitative analysis towards the end of the century	2022	Basit et al.	Roads
Federal Transit Administration	2024	U.S. Department of Transportation	Transit
APTA SUDS (Sustainability and Urban Design Standards) CC-RP-002-11	2011	American Public Transportation Association (APTA)	Transit
American Railway Engineering and Maintenance-of-way Association - Manual for Railway Engineering	2020	American Railway Engineering and Maintenance-of-way Association (AREMA)	Transit

Title	Year	Author	Infrastructure Type
TAC Low Volume Roads Design Guidelines	2019	Transportation Association of Canada (TAC)	Transit
Transit Cooperative Research Program Report 155	2012	Transportation Research Board	Transit
Building a Climate Resilient City: Transportation infrastructure	2017	Prairie Climate Centre	Transit
Transportation- Assessing the financial impacts of extreme rainfall, extreme heat, and freeze-thaw cycles on public transportation infrastructure in Ontario	2022/23	Financial Accountability Office of Ontario,	Transit
Water distribution systems: climate change risks and opportunities	2022	National Research Council of Canada	Water
Minnesota Stormwater Manual	2023	Minnesota Pollution Control Agency	Water
New Brunswick Flood Hazard Maps	2023	Service New Brunswick	Water
Climate Change and Health Vulnerability and Adaptation Assessments: A knowledge to action resource guide	2020	Health Canada	Water, Healthcare
Government of Alberta Stepping Back from the Water	2012	Government of Alberta	Water, Natural Assets
Green Streets Technical Guidelines	2017	City of Portland	Water, Transit
Linear storm and wastewater: Assessing the financial impacts of extreme rainfall on public linear storm and wastewater infrastructure in Ontario	2022	Financial Accountability Office of Ontario	Water, Transit