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GUIDANCE ON GOOD PRACTICES IN CLIMATE CHANGE RISK ASSESSMENT

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GLOSSARY

This glossary is derived from *Changing Climate, Changing Communities* (ICLEI Canada 2010). The terms outlined have been used consistently in Sections 1.0 to 3.0 of this document. Throughout Sections 4.0 and 5.0, the terms are used in the same context in which they were used within the good practice or case study presented. In each of these cases, the taxonomy used is specific to the approach, and users should be aware that definitions may differ from one case to another. In cases where this happens, a call-out box has been added for clarification.

Adaptation: Any initiative or action in response to actual or projected climate change impacts that reduces the effects of climate change on built, natural and social systems.

Adaptive Capacity: The ability of built, natural and social systems to adjust to climate change (including climate variability and extremes), moderate potential damages, take advantage of opportunities or cope with the consequences.

Climate: The weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about normal weather, as well as the range of weather extremes for a location.

Climate Change: Changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the buildup of greenhouse gases, which trap heat and reflect it back to the earth's surface.

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

Consequence: Something that occurs as a result of a given climate impact (e.g., basement damage from flooding, increases in respiratory illnesses from heat or damage to buildings).

Exposure: The presence of people, livelihoods, species or ecosystems in places and settings that may be affected by climate change.

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

Hazard: A biophysical event (e.g., drought, rain or wind) that could cause potential impacts.

Impact: The effects of existing or forecast changes in climate on built, natural and human systems, i.e., the effects of climate change on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure. One can distinguish between potential impacts (impacts that may occur given a projected change in climate, without considering adaptation) and residual impacts (impacts of climate change that would occur after adaptation).

Impact Statement: A concise statement that outlines locally relevant projected threats and how those changes are expected to affect the built, natural, social and economic systems of the municipality.

Likelihood: The probability of an event (e.g., a hazard or impact) occurring.

Resilience: The capacity of a system, community or society exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Risk: The combination of the likelihood of an event occurring and its negative consequences. Risk can be expressed as a function where risk = likelihood × consequence. In this case, likelihood refers to the probability of a projected impact occurring, and consequence refers to the known or estimated outcomes of a particular climate change impact.

Risk Assessment: Assesses the vulnerabilities, exposure and climate change hazards and their likelihoods and consequences. One of the key stages of risk management.

Risk Management: A systematic approach to selecting the best course of action in uncertain situations by identifying, assessing, acting on and communicating risk issues.

Sensitivity: Measures the degree to which the community will be affected when exposed to a climate-related impact. Sensitivity reflects the ability of a given system or jurisdiction to function (functionality) normally when an impact occurs.

Vulnerability: The degree to which a system or jurisdiction is susceptible to harm arising from climate change impacts. It is a function of a community's sensitivity to climate change and its capacity to adapt to climate change impacts.

Weather: The day-to-day state of the atmosphere, and its short-term variation in minutes to weeks.

LIST OF ACRONYMS

BARC	Building Adaptive and Resilient Communities
CAC	Community Advisory Committee
CAS	Climate Action Secretariat
CIER	Centre for Indigenous Environmental Resources
GIS	Geographic information system
IBC	Insurance Bureau of Canada
ICLEI	Local Governments for Sustainability (incorporated as International Council for Local Environmental Initiatives)
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
NGO	Non-governmental organization
OCCIAR	Ontario Centre for Climate Impacts and Adaptation Resources
O & M	Operations and Maintenance
PIEVC	Public Infrastructure Engineering Vulnerability Committee
SMDHU	Simcoe Muskoka District Health Unit
TEK	Traditional Ecological Knowledge

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1.0 INTRODUCTION

Canada is warming two times faster than the global average and three times faster in its northern regions, and the impacts of climate change are being felt across the country, from coast to coast to coast (Bush and Lemmen 2019). Some of the related risks manifest through major extreme-weather events such as floods, wildfires and heat waves. For example, wildfires in British Columbia (BC) in 2017 cost the province more than $568 million—more than double the historical average annual cost of $214 million (Lindsay 2018). Heavy rains in May 2017 caused flooding and related infrastructure damage, resulting in more than $233 million in insured damages in eastern Ontario and western Québec (Insurance Bureau of Canada [IBC] 2017). In Canada's Prairies, alternating seasons of flooding and drought have had significant financial consequences for agriculture and agri-services. In 2017, much of southern Saskatchewan experienced the driest July in over 130 years of record-keeping. For farmers in the region, the heat and dryness were especially damaging because they followed a rainy spring that had been so wet, it affected farmers' ability to properly seed fields (Prairie Climate Centre 2017). Furthermore, Canada's North has seen a five to 10 percent reduction in snow cover for every decade since 1981, declines in summer and winter sea ice, and glaciers receding at an unprecedented rate—all of which have resulted in fundamental changes to traditional livelihoods and ways of life (Bush and Lemmen 2019).

Climate change impacts magnify existing stressors or challenges (e.g., aging infrastructure, income inequity and population growth) and may create new ones, such as areas becoming newly vulnerable to sea-level rise and coastal inundation. The social, economic and environmental costs of climate change can be high. For example:

- **Social:** Climate change can have significant social impacts that affect the health of Canadians and disrupt communities. For example, in 2018 throughout Québec there were approximately 90 premature deaths related to extreme temperatures and the resulting heat waves. Other impacts on health and well-being (physical and mental) include the increased spread of ticks and Lyme disease, air pollution, and food insecurity (e.g., reduced access to traditional food); threats to kinship connections, the passing on of environmental knowledge, social cohesion, and cultural and archaeological sites; and increased safety risks. Infrastructure damage (including built infrastructure and changes in the natural environment) can impact travel safety; for example, changing sea-ice conditions can impact the ability to travel at key times of year and increase risks associated with traveling on the ice.
- **Economic:** The growing exposure of built assets (e.g., houses, bridges, roads, rails, etc.) to climate risks is resulting in increasing economic damage from storms, floods and other natural disasters. Canadian insurers report claims on natural catastrophes—floods, forest fires and other extreme weather events—of approximately $2 billion annually, up from $400 million annually in previous decades (IBC 2019). Additionally, changes in temperature and precipitation patterns have led to dramatic impacts on the tourism and recreation sectors across the country, as well as traditional economies, growing seasons and transportation corridors.
- **Environmental**: The capacity of natural ecosystems to respond to climate change is compounded by other pressures on natural resources, such as land clearing, invasive species and shifting land-use patterns. The impacts of climate change on natural

ecosystems are already being observed, and include increases in species extinction, changes in the range and spread of native and invasive species (including the health of animals and plants harvested for food and fur), coastal erosion, permafrost melt and changes to ice conditions.

Climate change risk assessments are the foundation of adaptation action and can help all orders of government understand existing sensitivities to climate change impacts, as well as the likelihood and consequence of future risks.

1.1 Purpose of this Guidance Document

Federal, provincial and territorial governments in Canada have an opportunity and obligation to lead by example through addressing climate change risks and building their institutional resilience to them. Climate change risk assessments can inform such strategies by providing a location-specific understanding of climate impacts and the risks they pose. This document is intended to serve as a guide to inform good practices in conducting climate risk assessments across jurisdictions.

The information contained within this guidance document was developed through a literature review on climate change risk assessment methodologies that have been used at various scales in Canada and internationally. The literature review was followed by a series of expert interviews with both developers and users of climate change risk assessment frameworks. The guiding principles for climate change risk assessment, as well as the good practices in climate change risk assessment presented herein, were established through this research.

1.2 How to Use this Guidance Document

This guidance document was designed for federal, provincial and territorial governments to inform their climate change risk assessment processes, including the selection of the most appropriate approach (e.g., top-down versus bottom-up) and supporting framework (e.g., International Organization for Standardization [ISO] 31000:2018 versus the *Ontario Climate Change and Health Toolkit*) to achieve their goals. The document begins with an introduction to the fundamentals of climate change risk assessment, including an explanation of the various approaches and their advantages and disadvantages. The document then outlines six questions users should consider prior to undertaking a climate change risk assessment. Next, the document presents six good practices and explains the extent to which they meet the guiding principles of effective climate change risk assessments. For each good practice, a case study demonstrates how this framework was applied at a given scale or jurisdiction.

2.0 FUNDAMENTALS OF CLIMATE CHANGE RISK ASSESSMENT

Understanding how future climate scenarios will impact a given government or jurisdiction can take many forms and involve a range of activities. Users can choose from various methods to assess climate change impacts and their consequences, and each method has unique elements and features. The following section outlines some of the fundamental concepts around climate change risk assessment, including definitions, differences between vulnerability and risk, and the role of risk assessments within broader adaptation planning processes.

2.1 What Is a Climate Change Risk Assessment?

Risk management is a systematic approach to selecting the best course of action in uncertain situations by identifying, assessing, acting on and communicating risk issues. In the context of adapting to climate change, risk management provides a framework for developing adaptation strategies in response to potential climatic changes that create or increase risk (ISO 2019). Risk assessments are part of this broader risk management framework.

A climate change risk assessment is the cornerstone of broader risk management and, as such, should include the consideration of vulnerabilities, exposure and climate change hazards and the consideration of likelihoods and consequences. The results of the climate change risk assessment can then be used to identify the appropriate courses of action to respond to the identified risks.

It is important to understand that assessing climate change risks should be an iterative process, as risks will evolve and change over time. Risk assessments provide a snapshot of risk at a given time, whereas climate change is not a linear process and what was (or was not) identified at a given point in time may not be valid at a later date. In order to be meaningful in the long term, risk assessments need to be repeated, following an iterative process that assists participants in understanding how climate change has and/or could impact a given jurisdiction, as well as the effects of adaptation work and/or actions that have been undertaken.

2.2 Considerations for Working with Indigenous Peoples on Climate Change Risk Assessments

Note: Indigenous Peoples were not engaged as part of developing this guidance document. This is a limitation of this report. The considerations below are meant to act as a starting point for working with Indigenous Peoples in a risk assessment process, and do not replace the need to meaningfully engage with First Nations, Inuit and Métis peoples.

Many Indigenous Peoples have a close relationship with the land and water, and can therefore contribute vital knowledge, experience and leadership to understanding climate change impacts and advancing adaptation efforts. At the same time, First Nations, Inuit and Métis communities have distinct and diverse climate change adaptation needs and priorities.

Working with Indigenous Peoples and considering distinctions-based approaches to climate change adaptation is an important step in developing a comprehensive understanding of climate risks, and one that supports the objectives of reconciliation. As such, when conducing a climate change risk assessment, approaches should create space to meaningfully include Indigenous Knowledge, as well as Indigenous ways of knowing, doing and being, alongside Western scientific methods.

Indigenous Knowledge is grounded in generations of place-based observations and experiences expressed through stories, values, ways of knowing and beliefs that define how climate change is perceived, understood and responded to (Expert Panel on Climate Change Adaptation and Resilience Results 2018). As such, Indigenous Knowledge offers perspectives that stand independently of, and can be considered alongside, scientific knowledge to broaden our understanding of climate risks.

Meaningful collaboration with Indigenous Peoples requires significant and ongoing investment of resources, including adequate time to build trust and relationships. It is important to consider how risk assessment methodologies can include culturally appropriate approaches that respect locally or regionally relevant research ethics and engagement protocols for working with Indigenous communities.

Risk assessment project teams can also consider how to include representation from Indigenous governments, organizations, co-management bodies and communities in their projects' governance structures, and how to contract research support from teams that have experience working with Indigenous Peoples in the relevant regions.

Please see case study 4.4, Climate Change Planning Tools for First Nations, for one example of how a risk assessment methodology has been applied in a First Nations community.

2.3 Elements of Climate Change Risk Assessment

A range of elements can be included as part of a climate change risk assessment, including vulnerability, hazard or impact assessment. Each user should include the elements that are best suited to their needs, objectives and capacities related to completing a climate change risk assessment and should document each step of the process to support replicability in the future. Key activities can include:

- identifying climate impacts, including slow-onset impacts and acute hazards
- completing a vulnerability assessment, including assessments of sensitivity, adaptive capacity and exposure
- determining the probability and potential consequences of events arising from climate change impacts or hazards
- understanding stakeholders' perceptions of the nature of climate impacts, probabilities and consequences
- engaging in continuous communications with partners and stakeholders (e.g., subject matter experts, local governments, Indigenous organizations, residents).

These elements can be integrated and, when done together, present the most comprehensive understanding of climate change risk, including the projected changes in climate, the resulting hazards and impacts, and the perceptions and attitudes toward their consequences and likelihoods. The information generated through this type of comprehensive assessment presents the most robust and best available information on climate change risk for a given jurisdiction or organization.

Understanding your objectives in completing a climate change risk assessment (see Section 2.6 on the decision-making processes risk assessment can support), along with the capacities to complete the assessment (e.g., financial, timelines and personnel), will help you determine which elements could and should be included.

2.3.1 Hazard and Impact Assessment

It is important to understand the relationship between hazards and impacts. A hazard is a biophysical event (e.g., drought, rain or wind), whereas an impact is what occurs as a result of a specific hazard (e.g., irrigation challenges, flooding or damage to buildings). The key to understanding the relationship between climate hazards and their associated impacts is the consequences of a given climatic change (e.g., changes in precipitation leading to flooding). While it is likely that there will be some common hazards across a given sector or region, it is important to understand how climatic changes will affect local conditions and to view these as unique impacts.

Whether positive or negative, impacts should be recorded consistently and should each address a similar scale. A description of an impact should include an identification of the “someone” or “something” that will be impacted, the specific way it will be impacted and the reason the impact may occur. For example, “summer drought” defines a hazard and is not a strong impact statement, but “summer drought causing increased demand on water supply” is an impact statement as it outlines what will occur (increased demand on water supply) as a result of the hazard (summer drought). The latter description answers the “what,” “why” and “how” questions, and specifies that the impact is a result of changes to climatic conditions, namely precipitation. Information should be as specific as possible.

A hazard or impact assessment considers each relevant climate change–induced hazard or impact for a specific sector or region. Users can assess the risk of the hazard itself or of the resulting impacts. Both types of assessment typically include the likelihood of occurrence of a given hazard or impact and its spatial extent.

2.3.2 Vulnerability Assessment

Climate change vulnerability is typically characterized by three factors:

- **Sensitivity:** the degree to which a system or sector is adversely affected by climate-related stimuli.
- **Exposure:** the receptors, e.g., the people, livelihoods, species or ecosystems in places and settings that may be affected.
- **Adaptive capacity:** the degree to which an organization and/or jurisdiction has financial, human or technical resources to adapt to climate change impacts.

In short, a vulnerability assessment generally looks at current or past experience and the ability to cope with climate change and adverse weather-related impacts. It often includes the identification of the exposure of an entity and its activities, products and services to observed changes in climate and related hazards; the identification of climate impacts; and the ability of the entity to manage the impacts of these changes.

2.4 Why Is Climate Change Risk Assessment Important?

Adaptation to climate change is characterized by uncertainty and complexity. Projections of future climate and other important variables are uncertain, the related outcomes are debatable, and there may be numerous adaptation actions to choose from. Adaptation involves multiple decision-makers, partners and stakeholders, often with conflicting values and competing interests. Climate change risk assessments are an integral part of any climate change adaptation effort as they can help to reduce some of the inherent uncertainties through the identification, analysis and evaluation of climate risks.

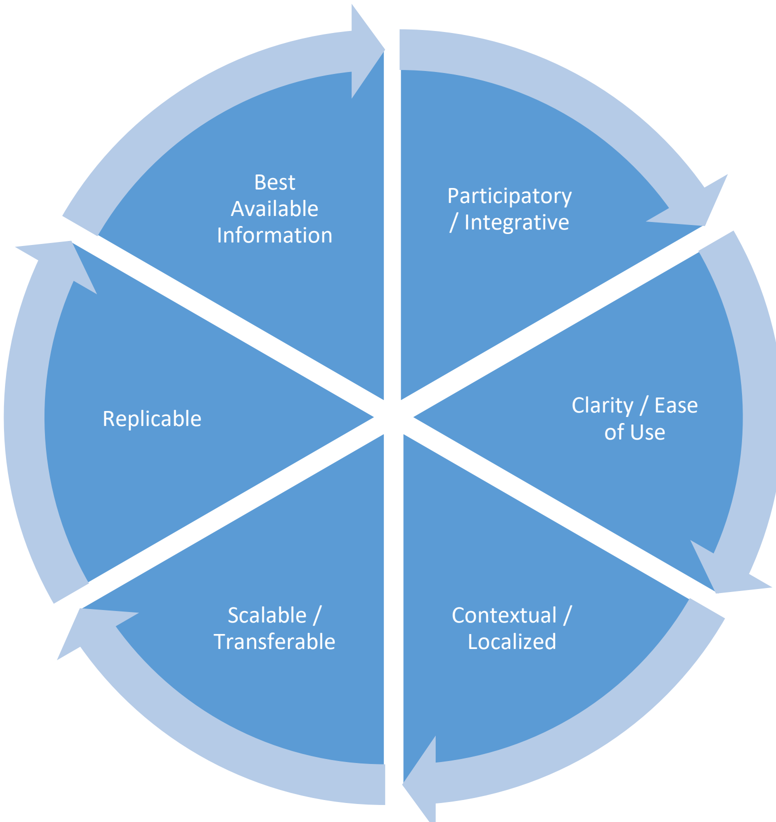
Risk assessment and management offer a framework to identify, understand and prioritize climate change risks, and ultimately to support the selection of adaptation responses to reduce the identified risks. Risk assessment, as part of a broader risk management process, offers a practicable and credible approach for prioritizing complex risk issues and for ultimately selecting the most suitable risk-reduction strategies in order to achieve societally acceptable levels of risk. It also provides a means for balancing a range of considerations and for using predictive information.

2.5 Guiding Principles for Climate Change Risk Assessment

Figure 1 provides a set of guiding principles for selecting a framework to support carrying out an effective climate change risk assessment. The principles were developed as part of a literature review that evaluated a variety of climate change risk assessment frameworks against the degree to which they adhered to the set of guiding principles. These were then presented to subject-matter experts and were adapted to reflect expert opinions.

The guiding principles provide a foundation for selecting a framework that can effectively assess climate change risk and should be considered when selecting an organization's climate change risk assessment framework and/or process. They are described in detail below Figure 1.

Figure 1. Guiding principles of frameworks supporting climate change risk assessment



1. **Participatory and Integrative**
   - builds capacity for carrying out a climate risk assessment among its intended users, including necessary leadership and commitment
   - encourages participatory and/or collaborative processes in risk assessment
   - is inclusive and has appropriate and timely involvement of partners and stakeholders.

2. Clear and Easy to Use
- can be tailored for a specific scale (geographic, jurisdictional or organizational)
- uses clear and plain language in its instruction on how to conduct a climate change risk assessment
- includes sufficient and appropriate directions and instruction on carrying out a climate change risk assessment.

3. Contextual and Localized
- identifies best practices and examples of how they have been applied in various contexts

- identifies the use of Indigenous Knowledge and other forms of local knowledge (i.e., anecdotal or cultural) in its development
- integrates or advocates for the use of first-hand technical knowledge and local data (external to the author) in its development (i.e., interviews with subject-matter experts such as public health officers, engineers or planners).

4. Scalable and Transferable

- aligns with, and can be adapted at, various jurisdictional scales (federal, provincial or territorial, or local)
- disseminates experiences and/or lessons learned
- demonstrates success in assessing risk at several scales (time, space, jurisdiction, etc.)
- is capable of anticipating and responding to changes in the capacities of the user in an appropriate and timely manner.

5. Replicable

- clearly highlights how the climate change risk assessment can be replicated for use in future assessments
- provides detailed steps and methods outlining the approach or process
- includes information on the frequency of iteration and approaches for consistent and comparable results.

6. Best Available Information

- ensures inputs into the climate change risk assessment process are based on historical and current information (e.g., Indigenous Knowledge, lived experience, scientific data, etc.)
- considers future projections of climate change
- requires information to be timely, clear and available to all partners and stakeholders.

2.6 Using Risk Assessment to Inform Decision-Making

Risk assessment is part of a systematic approach to selecting the best course of action in uncertain situations by identifying, understanding, acting on and communicating risk issues. In the context of adapting to climate change, risk assessment is generally used within a broader framework of developing adaptation strategies in response to potential impacts from climate change. An abbreviated form of the process can be used to make a rapid assessment of a risk issue to outline the possible scope and its complexity. Risk assessment can also be done on a large scale for a fully comprehensive assessment, which could involve a large number of representatives from many agencies over a longer period of time. Regardless of the scope of the exercise, it is important that users be familiar with the process undertaken and transparent in their documentation and communications.

Risk assessments can support a variety of decisions or organizational processes ranging from the creation of climate change adaptation strategies to securing capital investments in resilient infrastructure. Some of these processes are outlined below:

- **Adaptation strategy and plan development:** Risk assessments provide crucial information that acts as the building blocks or foundation for the development of adaptation strategies in response to the identified and prioritized climate risks.
- **Education and information provision:** Risk assessment findings can be integrated into awareness-raising and educational campaigns on the impacts of climate change (e.g., early-warning and response systems, hazard and vulnerability mapping, participatory action research).
- **Capital investments:** Prioritized risk results can be used to inform the allocation of funding to resilient infrastructure investments (e.g., flood levees, ecological restoration, mechanical and passive cooling in buildings).
- **Outreach and engagement:** Risk assessment results can be used to inform internal/external outreach or behaviour change (e.g., emergency and disaster preparation, livelihood diversification, water conservation).
- **Policy and program development:** Risk assessment results can be used to help update bylaws, regulations and other government policies or programs (e.g., building standards, land-use and zoning bylaws, hunting quotas).
- **Transitional risk avoidance:** Risk assessment findings can help an organization stay ahead of policy or regulatory changes. For example, transitional risks are related to changes in government policy, legal requirements, technological advancements and market shifts that occur in order to mitigate climate change risks (Chartered Professional Accountants Canada 2019).

2.7 Approaches to Climate Change Risk Assessment

A variety of approaches can be used to undertake a climate change risk assessment. Each approach has unique advantages or disadvantages, and there are frameworks and toolkits that can support this work (as outlined in Table 1 below). A number of approaches may be used in a single risk assessment process, depending on the objective.

2.7.1 Top-down Versus Bottom-up

Top-down

A top-down approach is typically carried out by an individual or small group of individuals internal to an organization (or externally via a third-party partner or consultant). The top-down approach can be carried out as a desktop study, where information is gathered from various datasets and sources of literature, and this research can be combined with engagement and first-person research with knowledge holders. The individuals leading this type of approach often have a background in climate change and a strong understanding of climate change science and technical considerations related to data and risk management. The steps involved in this approach are data gathering; identifying gaps; carrying out additional research; quantitative and qualitative assessment of impacts, vulnerabilities and risks; reporting on findings; and quality screening. Top-down approaches still include stakeholder engagement or consultation, though they typically take the form of information sharing rather than the generation of data inputs or new knowledge.

Commonly, the result is an inventory of known climate-related issues (e.g., impacts, risks, vulnerabilities or any opportunities resulting from a changing climate).

A top-down approach is typically faster to complete, due to limited external engagement, and is less complex in terms of execution as it can be carried out via desktop research.

Bottom-up

A bottom-up (or co-production or co-development) approach recognizes the skills and experiences of partners or stakeholders to an organization and uses them to develop the climate change risk assessment. This type of approach is led by one or more individuals from a given organization, and the early stages of this work typically involve the identification of stakeholders or partners to be engaged in the co-production of the assessment.

Often, the assessment of impacts, vulnerabilities or risks is undertaken by sector (e.g., industry, agriculture, communities, financial services) and regional stakeholders or partners, who can provide a holistic understanding of geographic issues and perspectives. A bottom-up approach requires frequent engagement with stakeholders and partners (either in-person or virtual) to allow for the co-production of assessment results.

The bottom-up approach can take more time and patience as it rests on the principle of trust and requires building that trust. However, this approach can help build momentum for later stages of adaptation planning by including stakeholders in all stages of the process (most notably risk assessment).

2.7.2 Quantitative Versus Qualitative

Quantitative

Undertaking a quantitative approach to climate change risk assessment requires the use of scientific climate data (e.g., historical climate and weather data, modelled climate projections and downscaled projections). Quantitative approaches also require the numerical scoring of vulnerabilities and risks using a framework that also supports the ranking of adaptive capacity, sensitivity, likelihood and/or consequence. These approaches involve subject-matter experts (from a given sector or geographic location), as participants need to have a thorough and comprehensive understanding of the subject matter so that they can be confident in assigning numerical values.

A quantitative assessment is often perceived as more rigorous or evidence-based and the results can be easily defended. However, it requires subject-matter experts as it can be difficult to assign numerical values to consequences and likelihoods given the uncertainty associated with climate change.

Qualitative

A qualitative approach can refer to the use of non-scientific data (e.g., Indigenous Knowledge, anecdotal data, local knowledge and socio-economic factors) to inform the identification of climate change impacts, vulnerabilities and risks, in addition to any scientific data that is used. This includes how a region may experience social consequences, such as higher inequality or vulnerability, which are directly amplified by climate change. It can also include the use of empirical evidence—rather than theoretical paradigms or traditional scientific data—to inform the historical and future understandings of climate and changing weather patterns and the associated risks. In a qualitative approach, numerical assessments of impacts, vulnerabilities and risk are not typically involved, as the assessment favours narrative and thematic assessments leveraged from perceptions and lived experience.

It can be easier to manage uncertainty in a qualitative assessment, as it is not limited to the confines of numerical allocations of risk. Therefore, it can be easier for a variety of partners and stakeholders to participate, as the assessment includes the lived experience of individuals in the descriptions of historical and current climate as well as changes to systems and practices. However, it can be challenging to compare results and prioritize risks, and they can be perceived as not being evidence-based.

2.7.3 Comprehensive Versus Tightly Scoped

Comprehensive

A comprehensive approach involves the widest scope. This could include looking at multiple climatic parameters (e.g., changes in precipitation, temperature or sea level) or looking across multiple thematic or service areas (e.g., engineered assets, health systems or natural environments). A comprehensive assessment generally takes a systems perspective, whereby an organization would look across built, natural and social systems to understand climate change risks in a given area, as well as the intersecting risks across systems. The greater the number of climatic parameters or thematic areas included, the more comprehensive the risk assessment process.

The comprehensive approach offers a wide view of climate change risks affecting a given jurisdiction as it looks across the broadest set of themes or climate parameters. However, it can often require teams to carry out additional risk assessments (at the asset class or individual asset level) based on the findings of the high-level assessment.

Tightly Scoped

In a tightly scoped approach, an organization would use a given thematic or focus area as the lens through which to carry out the assessment. This scope can be as specific as a given asset (e.g., a specific bridge, hospital or housing development), asset class or service area (e.g., highways and roads, food distribution network or tourism industry), or as broad as an entire system (e.g., natural ecosystems, social institutions and assets or economic systems). Additionally, as outlined earlier, scope can refer to the number of climatic parameters that are included as part of the assessment. A tightly scoped approach can still include all relevant climatic parameters, as it need not be scoped in terms of both focus area and climate parameters.

A tightly scoped assessment is generally faster to complete as it limits the number of climate parameters that need to be included, as well as the number of individuals who need to be involved. By its nature as a deep dive into one focus area, this type of assessment provides the most detailed and refined information to support later adaptation action. However, users may discover that the focus area included in the initial scope is not at risk (e.g., if carrying out an assessment of bridges, they may discover that the risk is relatively low), resulting in a perceived waste of time or resources.

2.7.4 Mixed-method Approach

In a mixed-method approach, any of the parameters outlined above are combined to create a customized approach to climate change risk assessment. When choosing a mixed-method approach, it is important to consider that some parameters are more challenging to bring together. For example, using a top-down approach (with its reliance on subject-matter expertise and third-party support) does not lend itself to highly qualitative data and inputs that are based on perceptions or lived experience. One should be transparent in justifying the use of a given method or framework and clearly lay out the decisions made as to the use of an approach and why it is the preferred option.

Note: The jurisdictional or geographic scale at which the climate change risk assessment is being carried out is also important to acknowledge. The scale could be considered at any jurisdictional order (federal, provincial, territorial or local), but an individual department or ministry should also consider their own assets and service delivery.

Table 1. Advantages and disadvantages of approaches to climate change risk assessment

	Advantages	**Disadvantages**	**Supportive risk assessment frameworks**
Top-down	• Faster, typically requires less time for completion due to limited external engagement • Less complex in terms of execution as can be carried out via desktop research • Typically carried out by a third-party consultant and can lean on the results as being delivered by experts	• Can be costly as requires extensive subject-matter expertise in one individual or group • May be a challenging approach for smaller communities lacking internal capacity and expertise or funds required to hire externally • Can be difficult to get buy-in for future adaptation efforts as partners/stakeholders were not directly involved throughout the entire risk management process	ISO 31000:2018 Ontario Climate Change and Health Toolkit PIEVC Engineering Protocol (note: this approach does require the involvement of a wide range of partners/stakeholders)
Bottom-up	• A more robust assessment involving a diversity of perspectives and expertise • Builds momentum for later stages of adaptation planning by including stakeholders in all stages of the process • Builds trust among partners/stakeholders and thus can lead to long-term successes in reducing risk	• Can be resource-intensive as extensive consultation and inclusion of diverse perspectives is required • Takes more time and patience as it rests on the principle of building trust • Can be perceived as being based on opinion and perception rather than being evidence-based or scientific	BARC Milestone 2 Climate Change Planning Tools for First Nations
Quantitative	• Easy analysis of risk assessment results • Often perceived as more rigorous or evidence-based and the results can be easily defended • Climate data are widely available (though this may be more challenging at very fine spatial scales) • Future projections of climate can be readily acquired through a variety of online portals and websites	• Requires subject-matter experts • Can be difficult for users to assign numerical values to consequences and/or likelihoods given the uncertainty associated with climate change • Does not include the lived experience or traditional and local knowledge of Indigenous Peoples or other groups	PIEVC Engineering Protocol BARC Milestone 2

Qualitative	• Easier to manage uncertainty as not limited to the confines of numerical allocations of risk • Can be easier for a variety of partners and stakeholders to participate • Includes the lived experience of individuals in the description of historical and current climate and changes to systems and practices	• Sometimes perceived as not being evidence-based • Can be challenging to compare risk results and to prioritize risk rankings • More time-intensive as it requires a variety of methods to gather and coalesce inputs into one risk assessment	Climate Change Planning Tools for First Nations
Comprehensive	• Offers a wide view of climate change risks affecting a given jurisdiction as it looks across the broadest set of themes or climate parameters • Does not presuppose what the most important focus area might be; uses the risk assessment results to determine focus areas to investigate further	• Is often high-level due to challenges (time, resources, capacities) to undertaking an in-depth analysis of a given parameter or sector • May require additional risk assessments (at the asset class and/or individual asset level) based on the findings of the high-level assessment	BARC Milestone 2 Climate Change Planning Tools for First Nations
Tightly scoped	• Provides the most detailed and refined information to support later adaptation action, through a deep dive into one focus area • Is generally faster to complete as it limits the number of climate parameters that need to be included, as well as the number of individuals who need to be involved	• May discover that the focus area included in the initial scoping is not at risk, resulting in a perceived waste of time or resources (e.g., if carrying out an assessment of bridges, may discover that the risk is relatively low) • Requires more specific and subject-matter expertise into the focus area, which can be difficult and/or costly to obtain	Ontario Climate Change and Health Toolkit PIEVC Engineering Protocol
Mixed-method	• Can be customized to meet specific needs and requirements • Can draw from the benefits of various approaches (e.g., speed to complete, perspectives included, detailed and refined)	• Requires a more detailed understanding of each of the approaches (and associated frameworks) and how they can best work together (e.g., it could be challenging to bring together a top-down, qualitative, tightly scoped assessment)	District of North Vancouver case study in Section 4.0 offers an example of the mixed-method approach

3.0 SIX QUESTIONS TO CONSIDER BEFORE STARTING A CLIMATE CHANGE RISK ASSESSMENT

Risk assessment approaches are often complicated by the temporal and spatial uncertainties of climate change and through the interaction of multiple risk factors (e.g., existing stressors such as aging infrastructure and population growth). Additionally, the uncertainty related to the severity of climate change impacts and the socio-economic circumstances of future time periods adds further layers of complexity. A variety of good practices are available to undertake a climate change risk assessment. In order to find a framework that suits a user's needs, it is important to define and scope any risk assessment based upon goals, parameters and available resources before beginning data collection and analysis. While there may not be a single, ideal framework for assessing climate change risk, the following questions may help a user identify a framework based upon their needs, objectives and capacities related to understanding climate risks.

1. What is the goal of the risk assessment?

There may be one or several reasons for pursuing a climate change risk assessment. Knowing what drivers are motivating the risk assessment, or what information is being sought, can help organizations determine a path forward. See section 2.6 on Using Risk Assessment to Inform Decision-Making.

2. What are the organizational capacities and constraints?

All organizations have constraints in conducting a climate change risk assessment. The most common include budget, personnel, expertise, timeline, scheduling and data accessibility. Knowing these constraints in advance will help staff scope the assessment. Keep in mind that while certain constraints will have an impact on the robustness of an assessment, planning for them beforehand will help ensure the best quality of work. Conversely, it is important to identify what drivers or capacities are available to undertake an assessment. For example, having access to robust data, such as climate change projections, flood mapping, etc., will reduce the time and resources needed. These constraints and capacities will help inform the answers to question 3.

3. What are the scale and focus area of the risk assessment?

It is important to recognize that the scale and level of detail of climate change risk assessments will be different between organizations and may depend on available resources. Determining the scale of a climate change risk assessment will help in selecting an appropriate methodology. For example, is an assessment intended to analyze a single piece of infrastructure or all infrastructure assets? Scale can also refer to the geographic scale of assessment, e.g., does it intend to assess risks across a city, a region, or a province or territory?

Moreover, knowing the system or sector focus of the assessment will assist an organization in determining the appropriate methodology. For example, a health ministry may be interested in undertaking a risk assessment that looks solely at climate change and its impacts on human health. However, it may also be interested in undertaking a climate change risk assessment on one of more of its physical assets (e.g., a hospital or office building). Depending on the system or sector they are interested in assessing, the methodology and process they will follow will vary significantly. See Section 2.7 for more information on approaches to climate change risk assessment.

4. What types of data will be used to inform the climate change risk assessment?

A variety of data and information can be used and applied in the risk assessment. Most risk assessment processes are flexible and allow for a combination of qualitative data, such as stakeholders' lived experiences and Indigenous Knowledge, as well as quantitative data, including climate projections and hazard mapping. However, combining quantitative and qualitative evidence poses challenges to climate change risk assessments, particularly with regard to the weighing of evidence. For example, is a quantitative assessment of future impacts on sector X more informative or reliable than a qualitative process of using expert judgement and partner or stakeholder feedback to identify future impacts on sector X? It is important to consider these challenges when determining the types of data that will be included, and how to account for different data sources. Things to consider include:

- Will Indigenous Knowledge be included as a knowledge system throughout the entire risk assessment process?
- What groups will be engaged for data (e.g., local First Nations communities, regional organizations or municipal governments)?
- How will partners be engaged, and will it be in their language of choice (e.g., through in-person workshops, online surveys or social media)?
- When will first-person data be collected (e.g., throughout the entire risk assessment process or only at one specific point)?

Section 2.7.2 on quantitative versus qualitative approaches helps to distinguish the types of data that can be used for climate change risk assessments.

5. How participatory and inclusive does the risk assessment need to be?

Some approaches to risk assessment are more collaborative than others. While almost all climate change risk assessment methodologies recommend partner and stakeholder engagement to a certain degree, they may differ in the scope of that engagement, the types of partners or stakeholders being engaged and the degree to which they are engaged. Engagement can range from solely information sharing and disseminating outputs, to collaborative or co-developed climate change risk assessment processes. The number of individuals or organizations involved is also subject to a variety of constraints, such as time and financial resources. As such, it is not always possible to engage everyone desired in an assessment. However, it is important to note that failure to consult appropriate stakeholders or organizations in the adaptation planning and risk assessment processes could lead to challenges in later stages of climate change planning (Tonmoy *et al.* 2019).

6. How will we measure and track climate change risks over time?

Climate change is not a linear process, and risks will evolve and change over time. Risk assessments provide a snapshot of risk(s) in time. In order to be meaningful in the long term, risk assessments need to be repeated following an iterative process. For example, an organization's first climate change risk assessment will inform a range of actions to reduce high-priority risks. Organizations will then need to conduct another risk assessment within a defined time frame to see if the cumulative total of those actions influenced or changed the level of risk to their assets and operations. This time frame should be far enough into the future (approximately five to seven years) that a sufficient number of actions will have been implemented, and enough time will have elapsed to measure changes in the level of risk. The future risk assessment may also uncover possible new actions to undertake that were not apparent when the first risk assessment was conducted. When carrying out an initial risk assessment, users should be aware of transparency in decision-making and should clearly document the processes that were used to allow for replication in future iterations. While scope can change somewhat (e.g., number of impacts or inclusion of perceptions), it is important that on the whole the same risk assessment approach is used, making it easier to compare risks over time while still allowing for alterations based on lessons learned and refinements in risk assessment processes.

4.0 GOOD PRACTICES IN CLIMATE CHANGE RISK ASSESSMENT

The following section presents six frameworks that demonstrate good practice in climate change risk assessment, with supporting case studies to show how they have been applied. These six frameworks were identified through a comprehensive literature review and interviews with subject-matter experts and individuals who have applied these frameworks. This process helped distinguish these frameworks as adhering most strongly to the Guiding Principles in Climate Change Risk Assessment outlined in Section 2.5.

> Note to readers:
> The individual frameworks presented below use variations of climate-related vocabulary and terminology in very specific ways. As such, these definitions cannot be entirely uniform across all six frameworks. For example, the *Ontario Climate Change and Health Toolkit* (see Section 4.1) defines terms like exposure, sensitivity, and adaptive capacity using a health-focused lens.
>
> When selecting and applying a framework, be conscious of how these terms are used in the framework and agree upon a set of terms early in the process.

For each framework outlined below, the following information is presented:

- **Framework description:** Broad overview of assessment framework.
- **Target framework users:** User(s) or audience best suited to use the assessment to make decisions.
- **Context of assessment the framework is best suited for:** Scale and/or jurisdiction the assessment can be best applied to.
- **Decisions or processes the framework is best suited to support or inform:** Could include decisions, organizational processes, and initiatives such as adaptation strategy and/or plan development, education and information provision, capital investments, outreach and engagement, policy and program development, and transitional risk avoidance (see Section 2.6 for more information on using risk assessments to inform decision-making).
- **Stakeholders, partners and organizations best suited to be involved:** Could include relevant departments and staff, community members, organizations, Indigenous groups, external partners and subject-matter experts.

- **Degree of collaboration:** Includes information on how participatory or integrative the framework is.
- **Degree of contextualization and/or localization:** Includes information on how the framework supports and allows for the assessment to be localized and applied to various contexts, goals or study regions (specifically on how data and information is gathered, used and applied).
- **Aspects of the framework that assist with replicability:** Includes information that better helps its replication (e.g., checklists, templates, regional climate change data, case studies).
- **Other promising practices with the framework** (if applicable): Any other aspects of the framework that assist in its replicability, transferability and scalability.

4.1 *Ontario Climate Change and Health Toolkit*: Technical Document, Workbook and Report

Framework description: The *Ontario Climate Change and Health Toolkit* ("Toolkit") was developed in 2016 to support an adaptive and resilient public health system that anticipates, addresses and mitigates the emerging risks and impacts of climate change. It provides guidance to public health units on how to conduct a vulnerability assessment. The Toolkit includes a technical document, workbook and modelling study, and provides information on climate-related health risks in Ontario and options to manage those risks.

Target framework users: Public health officials (health units or providers) and consultants.

Context of assessment the framework is best suited for: The framework is best suited to guide a health-focused climate change vulnerability assessment. The method by which the Toolkit analyzes health risks and vulnerability to them is inherently scalable and can be applied to various regions (i.e., local, regional, provincial or territorial), with both the technical document and workbook aiding in capacity building and process implementation.

Decisions or processes the framework is best suited to support of inform: Adaptation strategy and/or plan development, education and information provision, outreach and engagement, policy and program development, and transitional risk avoidance.

Stakeholders and participants best suited to be involved: Local health units or health authority representatives, health service providers, representatives and/or staff from relevant ministries or departments (e.g., ministries responsible for the environment, natural resources, health, public works or planning), conservation authorities, utility providers, First Nations and Indigenous Peoples, non-governmental organizations (NGOs) and other community groups that work with or represent particularly vulnerable groups.

Degree of collaboration: The framework is highly collaborative, as it requires interdisciplinary decision-making involving varied stakeholders within a project team. In using a public health lens to conduct a climate change vulnerability assessment, the framework is highly inclusive and integrative by nature, with methods to identify risks to and plan for vulnerable populations (i.e., older adults, young children, newcomers to Canada, and those who are physically impaired or socially disadvantaged). Moreover, the identified health impacts of concern cover a variety of disciplines, ranging from epidemiology to emergency management.

Degree of contextualization and localization: The framework places a strong emphasis on the use of first-hand professional knowledge, local weather and climate data, expert interviews, provincial and community reports, peer-reviewed literature, census data and department documents. Use of anecdotal or cultural knowledge can supplement the assessment when there is inadequate professional knowledge, especially when characterizing the sensitivity and ability of vulnerable populations to cope and adapt (i.e., through interviews with those who work with these groups).

Aspects of the framework that assist with replicability: The Toolkit includes a technical document, workbook and modelling study. The technical document is a succinct overview of the assessment process, providing the rationale for each step and a simplified checklist at the end to ensure all steps are performed. The workbook provides in-depth instructions for each step, including templates (for information sources, data collection, planning, etc.), guiding questions to aid decision-making, useful links, examples of health hazards, current and future vulnerability indicators, monitoring indicators and other information to support assessment design and completion. The modelling study also summarizes climate change and health projection scenarios for the 2050s and 2080s for each of the 36 public health unit areas in Ontario and provides graphical representation to showcase the spatial distribution of potential health risks.

Other promising practices with the framework: Special attention was paid to ensuring the Toolkit is clear and easy to use. It is written in accessible language and uses appropriate explanatory text for more technical concepts. The framework also recognizes that an iterative process for managing and monitoring health risks is necessary. It encourages setting a time frame in which the vulnerability assessment will be repeated in order to identify if new risks have arisen or if there are any changes to existing risks.

How to access the *Ontario Climate Change and Health Toolkit*:
http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit/climate_change_toolkit.pdf

4.1.1 Case Study: Assessing Health Impacts and Vulnerabilities to Climate Change Within Simcoe Muskoka

Project Background

The Simcoe Muskoka District Health Unit (SMDHU) is responsible for the health of 540,249 people within the County of Simcoe, the District of Muskoka, and the four local First Nations communities.

When SMDHU identified climate change as a key concern for public health in 2015, they initiated planning for their Climate Change Action Plan. As part of this process, they conducted a vulnerability assessment to assess potential climate-related health outcomes and the populations vulnerable to those outcomes, as well as policies and actions that could improve the adaptive capacity of the health sector to address climate change-related health impacts (SMDHU 2017b).

Context of Assessment

SMDHU was identified as one of two health units to pilot the Toolkit in the development of their Climate Change Action Plan. Simcoe Muskoka is expected to see increases in temperature, precipitation and extreme weather events (e.g., flooding, thunderstorms, drought) from climate change—likely resulting in risks such as food insecurity, air pollution, reduced access to potable water and injuries from extreme weather events. SMDHU found that the resulting impacts and risks to the population within the study region will be varied, with greater effects on those already experiencing health inequities associated with income, health status, age and gender (SMDHU 2017a).

Project Planning and Implementation

A core Climate Change Steering Committee and a smaller internal workgroup comprising staff across different levels and all departments at the Health Unit led the planning process. To support their efforts, an external review panel with representatives from local, provincial and federal entities was established to support consultation and to review the results. This panel included individuals from Health Canada, Public Health Ontario, the Public Health Agency of Canada, Environment and Climate Change Canada, the City of Barrie, the District of Muskoka, the Muskoka Watershed Council and the Nottawasaga Valley Conservation Authority (SMDHU 2017a).

SMDHU defined the scope of the assessment to include the northern, southern and central regions of the County of Simcoe and the northern region of the District of Muskoka. This scope illustrates the differing geographical regions within the area, while utilizing the downscaled projection model data that was available to support the assessment. The workgroup then selected appropriate timeframes and tailored their assessment by identifying six climate-related health outcomes of greatest concern: temperature extremes, extreme weather events and natural hazards, air quality, contamination of food and water, infectious disease transmission by insects and ticks, and exposure to ultraviolet radiation. Next, multiple inputs were used to determine projected climatic changes in the region (SMDHU 2017a).

Climate-related health outcomes were examined across exposure, sensitivity and adaptive capacity[1] to determine projected climate change impacts. The Toolkit supported information gathering and helped determine the current and future state of the identified climate-related health outcomes. For example, some vulnerability indicators used to examine the exposure and sensitivity to extreme temperatures included the number of current and projected extreme heat days, the number of heat-related hospital visits and/or mortalities, the impact on socially and economically disadvantaged populations, the proportion of the population without air conditioning, access to cooling centers, and many more (SMDHU 2017a).

[1] See report glossary for definitions of these terms.

When assessing the adaptive capacity of each climate-related health outcome, the SMDHU identified current actions being taken by the Health Unit and potential actions that could be implemented to support adaptive capacity across four areas of responsibility: Population Assessment, Surveillance, Health Promotion (policy development, advocacy and public education), and Health Protection (disease and injury prevention) (SMDHU 2017a). In doing so, they identified their existing policies and programs and what they could do to build upon these actions.

In addition, 15 interviews were conducted with key stakeholders from various organizations (e.g., conservation authorities, education, health care, government ministries, local municipalities and non-profits) to gather input on priority health risks and key vulnerabilities that they felt were of relevance for the study region (SMDHU 2017a).

Key Replication Factors

SMDHU identified their climate-related health outcomes of concern (e.g., air quality) based on information from Health Canada and other vulnerability assessments completed in Ontario. Although these outcomes can vary throughout geographic areas in Canada, vulnerability indicators across these health outcomes are relatively similar, and thus can be used at any scale (i.e., municipal, federal, provincial, territorial) to assess exposure, sensitivity and adaptive capacity.

Additional interviews conducted with key stakeholders are a proven method to ensure the integration of a wide range of perspectives on vulnerability. Both the questions and format of this engagement (e.g., focus groups, one-on-one interviews) can be easily tailored to suit different assessment needs.

Challenges and Lessons Learned

Given the substantial number of First Nations communities in the study region, more opportunities for engagement with these communities would have been beneficial for gathering input on priority health risks and verifying whether the results of the assessment were representative.

Another challenge common to many climate change risk assessments is the availability of rigorous climate data sets to map out current trends and future projections. For example, this assessment had missing and/or incomplete historical and future data, posing issues around the uncertainty of threshold-based climate indices such as heavy precipitation days (≥ 10mm) or the number of tropical nights (daily minimum is > 20°C). Although assessments like this one use the best information available at the time, uncertainty can be minimized by repeating these assessments (i.e., every three, five or 10 years) to close data gaps or integrate new, more rigorous data sets when they become available.

Success Factors and Positive Outcomes

Garnering input from a broad and diverse group of stakeholders, spanning multiple orders of government as well as local expertise from those who work with or represent vulnerable groups, allowed for a highly contextual and localized vulnerability assessment.

The results of the assessment are intended to inform Phase II of SMDHU's Climate Change Action Plan, which includes the development of a stakeholder engagement plan, internal staff education plan and a knowledge translation plan to support communities and health units in conducting climate change vulnerability assessments in their own regions (SMDHU 2017a).

4.2 ISO 31000:2018 Risk Management—Guidelines (Including ISO/IEC 31010:2019)

Framework description: ISO 31000:2018 (the "standard") is a standard created by the ISO that provides a common approach to managing risk faced by organizations that is not industry- or sector-specific and can be customized to any organization and its context (ISO 2018). The standard can be used throughout the life of the organization and can be applied to any activity, including decision-making at all levels.

The standard contains high-level guidance on risk assessment methodology, defining the scope, context and criteria of the assessment, as well as identifying what to keep in mind when conducting risk identification, analysis, evaluation and treatment. The standard is usually accompanied by ISO/IEC 31010 (Risk Management—Risk assessment techniques), which elaborates on the process in ISO 31000:2018 and provides more detailed instructions on the selection and application of a range of techniques for assessing risk in a wide range of situations (ISO 2018).

Further to this, ISO 14090:2019 ("Adaptation to Climate Change—Principles, requirements and guidelines") and the accompanying ISO/DIS 14091:2019 (Draft International Standard; "Adaptation to climate change—Guidelines on vulnerability, impacts and risk assessment," pending finalization) were developed as specialized expansions to the risk assessment portion of ISO 31000, and can serve as valuable companion documents (ISO 2019a, ISO2019b). While ISO 31000 provides guidance on risk assessment methodology that can be used to manage all types of risks (including climate-related risks), ISO 14090:2019 specifically considers climate-related risks and measures to plan for adaptation (ISO 2019a). Given that it is not a manual on how to conduct a vulnerability or risk assessment and is not a demonstration of a specific assessment, it was not included as a case study. However, it provides a detailed checklist outlining elements that need to be achieved in order to receive the ISO standard, which could be valuable to support any climate change risk assessment work. Key sections include identifying objectives, assessing climate change impacts, determining impact assessment methods and assessing adaptive capacity. There is also a section on adaptation planning, implementation, monitoring and evaluation. Methods involve qualitative approaches and consider all types of risks and vulnerabilities. This standard is applicable to any organization or sector (ISO 2019b).

Target framework users: Staff from all orders of government, NGOs and non-profits, professional bodies (i.e., planners, engineers and public health officials), consultants, businesses and more.

Context of assessment the framework is best suited for: The standard provides a broad set of guidelines intended to provide structure to and streamline risk management across all industries, niches, organization types and orders of government.

Decisions or processes the framework is best suited to support or inform: Capital investments, education and information provision, outreach and engagement, policy and program development, transitional risk avoidance, and adaptation strategy and/or plan development.

Stakeholders and participants best suited to be involved: From a climate change assessment perspective, this could be staff from across all orders of government and their public and private sector partners (e.g., local industries, utilities, health authorities), Indigenous Peoples, community members from across various groups (i.e., environmental organizations, vulnerable populations, religious and cultural groups) and more.

Degree of collaboration, contextualization and localization: The standard is meant to be tailored and adapted to suit each climate change assessment's specific context and needs, and as such, it requires participation from across the organization in question, various sectors and/or industries, and the community. In addition, a core tenet of this framework is communication and consultation, emphasizing the importance of promoting awareness and understanding of risk as well as obtaining feedback and localized information to support the assessment. IEC 31010:2019 aids in the implementation of techniques to assist with decision-making and knowledge collection where there is uncertainty.

Aspects of the framework that assist with replicability: The standard takes users through the core concepts and principles of risk management (i.e., risk identification, analysis and treatment). To supplement this standard, IEC 31010:2019 provides users with a range of examples and techniques (i.e., activities and methods of analysis) to support this process, including techniques around eliciting views from stakeholders and experts; identifying risk; determining the sources, causes, and drivers of risk; understanding consequences and likelihood; providing a measure of risk; evaluating the significance of risk; and recording and reporting.

How to access the ISO and IEC documents: ISO 31000:2018 (https://www.iso.org/iso-31000-risk-management.html) and IEC 31010:2019 (https://www.iso.org/standard/72140.html)

4.2.1 Case Study: Preliminary Strategic Climate Risk Assessment for British Columbia

Project Background

As one of the most populous provinces in Canada and with differing geographical regions and climates, it was important for BC to better understand the climate change risks posed to its social, environmental, economic and built systems. In 2019, the BC Climate Action Secretariat (CAS), Ministry of Environment and Climate Change Strategy, developed a climate change assessment framework and conducted a preliminary assessment of climate-related risks at the provincial level (BC Ministry of Environment and Climate Change Strategy 2019a). This represents the first time a province-wide climate change risk assessment was conducted in Canada.

Context and Objectives of Assessment

Upon the recommendation of the BC Office of the Auditor General to undertake a province-wide climate change risk assessment, BC developed their own risk assessment framework using the ISO 31000 standard (BC Ministry of Environment and Climate Change Strategy 2019b).

This framework was developed to ensure that it was compatible with existing methodologies used by the Province to assess other types of risk, namely the Risk Management Guideline for the BC Public Sector. Utilizing a standardized approach ensures that the assessment outputs can be easily integrated into the BC Risk Register—which is used to inform senior-level decision-making in the Province—in a format that is consistent and comparable to other non-climatic risks (BC Ministry of Environment and Climate Change Strategy 2019b).

Project Planning and Implementation

The project was managed by the CAS, with planning led by ICF, an external consulting firm, and supported by over 70 experts and a Project Advisory Committee composed of 20 representatives from eight BC ministries (BC Ministry of Environment and Climate Change Strategy 2019a). The project team created a framework that was consistent, replicable and scalable so it could be customized to analyze climate-related risks in small communities or the entire province. To achieve this, they established four high-level steps:

1. understand the context (scope, objectives and audience)
2. identify risk events
3. analyze the likelihood and consequence of risks
4. evaluate risks (assigning a risk rating and evaluating the adequacy of existing risk mitigation measures) (BC Ministry of Environment and Climate Change Strategy 2019b).

Opting for a scenario-based approach, the project team and advisory committee identified 15 provincially significant climate-related risk events (e.g., severe riverine flooding) and specific scenarios for each (e.g., a 500-year flood on the Fraser River). This method was selected to illustrate the types of risks that would be faced by the provincial government that could have significant consequences across sectors and ministry responsibilities. The 15 risk events were a severe wildfire season, a seasonal water shortage, a heat wave, ocean acidification, glacier mass loss, a long-term water shortage, a reduction in ecosystem connectivity, saltwater intrusion, a loss of forest resources, an increase in invasive species, moderate flooding, severe riverine flooding, a severe coastal storm surge, extreme precipitation and a landslide, and an increased incidence of vector-borne disease (Lyme disease) (BC Ministry of Environment and Climate Change Strategy 2019a).

The project team then examined the potential likelihood and consequences of the 15 climate-related risk events. These were evaluated across nine consequence categories that captured physical and mental health, social, environmental, infrastructural and economic consequences. In terms of likelihood, the risk events were evaluated across two distinct time frames, present day (2000–2019) and the 2050s (2040–2059), to see how the likelihood changed over time. Scores were then plotted on a risk matrix and overall risk ratings were calculated for each risk event. The consequence and likelihood categories developed for this assessment were unique to the needs of the CAS (BC Ministry of Environment and Climate Change Strategy 2019a). More information on how these categories were developed and the caveats considered while evaluating the risk events and the assessment findings is included in the accompanying document to the report, *Strategic Climate Risk Assessment Framework for British Columbia* (BC Ministry of Environment and Climate Change Strategy 2019b).

The BC climate risk assessment involved extensive stakeholder engagement throughout the process. As the audience for the assessment was the provincial government, several workshops were held with representatives from across all provincial ministries and key external stakeholder groups to review and test the framework, select provincially significant risk events, and vet the draft risk assessment ratings. To support their input, one-on-one interviews with experts who specialized in different risk events and consequences were also conducted. In total, over 100 individuals contributed to the assessment (BC Ministry of Environment and Climate Change Strategy 2019a).

Key Replication Factors

A transparent and evidence-based approach was a core objective of BC's climate change risk assessment. Detailed explanations for all likelihood and consequence ratings are provided in the Appendix of the report so its users (e.g., those working to mitigate these risks or regional and municipal governments wanting to conduct their own assessment) can understand the risk ratings and how to interpret the results (Bhat and Asam, personal communication, 2020).

Other orders of government and organizations can use the climate change risk assessment framework as a template to develop their own risk assessments. However, risks that are significant at that organization's particular scale or context should be identified, and consequence categories should be tailored to suit their needs (e.g., morbidity and mortality would look different in other jurisdictions based on the number of cases of illness on record).

Challenges and Lessons Learned

Given that this was the first time BC had completed a provincial-level climate change risk assessment, some challenges were to be expected. Because the province used a standardized approach, it was difficult to appropriately include Indigenous perspectives of climate risk in the assessment. Incorporating the traditional values and belief systems of all First Nations residing in BC can be especially challenging when using an approach that encourages the categorization of risk, when these elements are often interconnected. To remedy this, a second phase of work was planned to address how to better integrate Indigenous perspectives.

Another challenge within the assessment was examining how climate change risks are connected to one another, often causing compounding and cascading impacts. The report highlights one example of how long-term water shortages and resulting drought-like conditions can cause a severe wildfire to burn a much larger area. It further indicates how risks can be compounded, demonstrating that heavy precipitation events that follow fire events can create ideal conditions for landslides. In the assessment, risk events were considered independently of one another, and although compounding risk events are discussed conceptually in the report, it would be helpful to explore them in more depth to paint a more accurate picture of the likelihood and consequences of these risks over the long term.

Success Factors and Positive Outcomes

The development of a climate change risk assessment framework that produced results that were comparable to both climate risks and to other non-climate risks allowed for a greater understanding of risk tolerance and action prioritization by the provincial government.

The results of the assessment serve as an important informational tool to support BC's ultimate goal of developing a provincial climate change and adaptation strategy, as indicated in the CleanBC Plan (BC Ministry of Environment and Climate Change Strategy 2019a). In addition to this work, the Province is identifying how their assessment framework can be made more applicable to suit different scales and contexts (e.g., individual ministries, regional districts and public sector organizations) (Bhat and Asam, personal communication, 2020).

4.3 Building Adaptive and Resilient Communities Milestone 2—Vulnerability and Risk Assessment (2011)

Framework description: The Building Adaptive and Resilient Communities (BARC) framework is a five-milestone planning framework for local governments to develop and implement a localized climate change adaptation plan. Originally called the Adaptation Initiative, the BARC framework was developed in 2011 by ICLEI Canada and has been applied in over 70 municipalities across Canada (ICLEI Canada 2020).

Centred on multi-stakeholder collaboration, the program builds internal capacity for municipalities to research and identify localized climate trends and impacts, run a collaborative risk and vulnerability assessment process, and identify adaptation actions that address priority risks. The program also includes a robust methodology for implementing these actions as well as monitoring and reviewing them. The intent of the framework is to support municipalities to develop an adaptation plan that is highly tailored to local circumstances, vulnerabilities and risks. More specifically, Milestone 2 of this framework guides users through conducting a climate change vulnerability and risk assessment.

Target framework users: The framework is intended for municipal or regional staff, regardless of department or area of expertise. Departments responsible for leading adaptation planning efforts include Sustainability or Climate Change departments, Public Works, Community Services, Economic Development, and Tourism and Communications.

Context of assessment the framework is best suited for: The BARC framework was created for local and/or regional governments of any size, budget or location. The framework can be applied to corporate assets and services or expanded to include community assets and stakeholders. However, with some general modifications to vocabulary and a broader taxonomy, it could be easily applied at different jurisdictional scales (e.g., provincial or territorial).

Decisions or processes the framework is best suited to support or inform: Adaptation strategy and/or plan development, education and information provision, outreach and engagement, and policy and program development.

Stakeholders and participants best suited to be involved: Municipal staff and their external public and private sector partners (e.g., local industries, utilities and health units), as well as various key stakeholder groups in the community, such as religious, social, youth, community, cultural and environmental groups.

Degree of collaboration: BARC is a highly participative process that encourages the development of a multi-disciplinary adaptation team to guide assessment and planning processes. The foundation of BARC is built on municipal service input to the adaptation process.

Degree of contextualization and/or localization: The process for completing each of BARC's milestones is based on local conditions and contexts. For example, Milestone 2, "Research," begins with users identifying localized climate change projections for the study region. After this, a multi-stakeholder engagement process is conducted to identify how the community will be impacted by climate hazards and impacts from the present until the end of the century. In order to conduct the risk and vulnerability assessment, the project team must have an acute awareness of local conditions and historical knowledge of the area, in addition to professional expertise in their various fields. This helps them contextualize and evaluate how and to what degree of severity a specific climate change impact will affect the community.

Aspects of the framework that assist with replicability: Alongside its guide to the methodological process of adaptation planning, the BARC framework includes a workbook that provides worksheets and activities to help users complete each step. The framework was designed to be open-source and used by municipalities independently of ICLEI Canada or a consultant if desired. It is intended to be used and replicated across multiple municipal contexts and tailored to local interests and requirements.

How to access the BARC Milestone 2 framework: www.icleicanada.org/barc or https://icleicanada.org/project/changing-climate-changing-communities-guide-and-workbook-for-municipal-climate-adaptation/

4.3.1 Case Study: City of Edmonton Climate Change Vulnerability and Risk Assessment

Project Background

As Alberta's second-largest city and Canada's fifth most populous municipality, the City of Edmonton is home to approximately 972,223 people. In 2016, the City initiated a process of developing the *Climate Resilient Edmonton Adaptation Strategy and Action Plan* to address the potential impacts of climate change on its natural and built systems, businesses, institutions and community. A core part of this process was an Edmonton-specific climate change vulnerability and risk assessment that was used to determine the possible vulnerabilities, risks and opportunities of climate change (City of Edmonton 2018).

Context and Objectives of Assessment

Climate projections indicate that Edmonton is warming at a faster rate than the global average (City of Edmonton 2018). As a result, Edmonton is likely to experience an overall warmer and drier climate, with drier summers and more extreme precipitation events. The City Council acknowledged the need to examine the risks posed from these climate change impacts in more depth and established the Initiative on Energy Transition and Climate Resilience to direct its efforts (City of Edmonton 2018).

To guide their vulnerability and risk assessment process, the City followed Milestones 1 and 2 of the BARC framework. This entailed a multi-stakeholder-driven approach in identifying relevant climate change impacts across broader theme areas such as People, Food, Water, Infrastructure, Places and Economy (City of Edmonton 2018). Impacts under these areas were examined for their sensitivity and adaptive capacity, and then assessed for their potential likelihood and consequences over the long term (City of Edmonton 2018).

Project Planning and Implementation

To determine current and future climatic variables and impacts, the City used a combination of stakeholder input as well as historical weather and climate data. Following the BARC framework, municipalities are required to assess climate change impacts across different systems, specifically the built, social, economic and natural systems. The City of Edmonton chose to tailor these criteria and capture impacts on Health and Safety, Economy, Social Well-being and Natural Environment (City of Edmonton 2018).

The vulnerability and risk of these climate change impacts were assessed to prioritize impacts to which the community is most vulnerable or that pose the highest level of risk. The likelihood and consequences of each climate impact were assessed across 12 consequence criteria within social, environmental and economic themes.

The City determined a likelihood level for each climate variable or impact. To do so, they used a combination of climate models, research, statistical analysis and subject-matter expert input. The City gathered publicly available information to support the quantification of physical damages and service losses to the specific asset and service areas. The types of data gathered included published damage curves and quantitative vulnerability indices. Experts for each thematic area were engaged to help inform likelihood and consequence ratings.

Another way the City tailored their approach was by pursuing an in-depth economic analysis of climate change impacts on their communities. The City received funding to conduct an external study that explored city-wide economic losses and estimated social costs and economic opportunities associated with inaction in response to climate change. Serving as a business case, this study supported City Council buy-in for climate change planning (City of Edmonton 2018).

The method of combining quantitative research with subject-matter expertise builds upon the BARC framework, which typically focuses on community stakeholder input and is supplemented by climate change projections to estimate likelihood and consequences (City of Edmonton 2018). This approach maintained the collaborative co-production ethos of the BARC framework, which relies heavily on input from staff and community experts across systems, and layered in technical analysis to quantify risks and potential losses. This strategy bolstered the City's goal of an evidence-based approach to adaptation planning.

Key Replication Factors

The BARC framework was originally designed for local government staff to assess climate change vulnerabilities and risks across multiple systems within their community. With small edits to nomenclature, the process itself can be applied by any order of government, including regional, provincial or territorial, or even Canada-wide.

The framework provides a platform for engaging relevant staff and community partners to improve awareness of climate change impacts and to gather input on how climate change may affect community services and functionality in the future. The BARC framework also provides the flexibility to integrate additional technical research into the vulnerability and risk assessment process, seen through Edmonton's economic analysis and additional research into quantitative damages and losses.

Challenges and Lessons Learned

The City found that staff and community stakeholders who were less familiar with climate change thought the vulnerability and risk assessments were complex and hard to understand. However, those who were familiar with climate change or had experience with asset management or similar disciplines were more comfortable with the process (City of Edmonton 2018).

An ongoing challenge with many climate change assessments is the availability of appropriate climate data sets to include in the assessment process. Interviews with staff from the City highlighted that this proved to be particularly challenging when trying to quantify threshold events to define the consequence evaluation criteria. In such instances, the City had to downscale global climate data from various sources and create its own quantitative data sets to inform the consequence criteria. As a lesson learned, the City began collecting some of these data at the local level to better plan for future interventions.

Success Factors and Positive Outcomes

After completing the vulnerability and risk assessment process as part of Resilient Edmonton, the City created a formal mechanism for both city administration and council members to integrate climate science and evidence into all decision-making processes, requiring cross-organizational integration and leadership (City of Edmonton 2018). In addition to this, the City began hazard mapping at the neighbourhood level across four climate variables: flooding, wildfire, extreme heat and ecosystem sensitivity (Tomaras, personal communication, 2020).

4.4 Climate Change Planning Tools for First Nations

Framework description: Community planning is a principal component of adapting to climate change in Indigenous communities. The Climate Change Planning Tools for First Nations framework was developed in 2006. It is a knowledge- and capacity-building resource that walks through the climate change planning process using six key steps, with a guidebook for each. Guidebooks 1, 2 and 3 cover initiating the planning process all the way to completing a vulnerability assessment.

Target framework users: Government staff, consultants and Indigenous community members.

Context of assessment the framework is best suited for: The framework is best suited to guide a holistic, community-based climate change vulnerability assessment in a First Nations community. It is not detailed enough to be applied at the provincial or territorial level but can be used in conjunction with other methodologies.

Decisions or processes the framework is best suited to support or inform: Education and information provision, outreach and engagement, policy and program development, and adaptation strategy and/or plan development.

Stakeholders and participants best suited to be involved: Government staff or members from the administration, councillors, external consultants, representatives from local organizations/groups (e.g., fishers, hunters or trappers associations, and health units), Elders (e.g., Elders' committees), youth (e.g., classrooms and youth committees) and community members.

Degree of collaboration: The framework builds capacity among its stakeholders through step-by-step instruction and is inherently collaborative; it recommends that the working group or project team involved be a diverse and inclusive mix of members, with representation from staff, council and the community. In addition, extensive stakeholder consultation and engagement from various population segments are a core tenet of this framework.

Degree of contextualization and/or localization: The framework heavily emphasizes the requirement of Indigenous knowledge (i.e., anecdotal and cultural) from the community throughout the process. It also advocates for the use of first-hand local knowledge, such as input from planning or public works professionals, and local information and data, such as local geographic information system (GIS) mapping and localized climate change data.

Aspects of the framework that assist with replicability: The framework itself includes six guidebooks developed for and by First Nations to build capacity and a knowledge base to carry out a climate change vulnerability assessment. It provides clear steps and instructions from project initiation to the completion of the assessment. It is interspersed with templates for data collection, sample communications strategies and text that can be used (e.g., pamphlets, posters, newsletters and activities), templates to gather information during the vulnerability assessment (e.g., climate change impact identification), call-out boxes detailing examples of successful planning initiatives that have been implemented by other First Nations communities (e.g., communication and engagement strategies, and vulnerability assessment outcomes), and guiding questions to ask yourself when implementing a similar approach.

How to access Climate Change Planning Tools for First Nations:
http://www.yourcier.org/climate-change-planning-tools-for-first-nations-guidebooks-2006.html

4.4.1 Case Study: Georgina Island First Nation Climate Change Vulnerability and Risk Assessment

Community Background

The Chippewas of Georgina Island First Nation is located on and off the east shore of Lake Simcoe, within the Township of Georgina. The First Nation Reserve No. 33 consists of three separate islands (Georgina, Snake and Fox Islands) and two mainland access points, with the population of the reserve residing on Georgina Island—home to around 80 households and 225 cottages (Ontario Centre for Climate Impacts and Adaptation Resources [OCCIAR] and Chippewas of Georgina Island 2015).

Project Context and Objectives

The decline of ice quality and shortening of ice freeze-up and ice season have resulted in significant social and economic challenges around winter fishing and transporting of people and goods across the ice in Georgina Island. Climate change projections depict an increase in shoreline erosion and extreme weather, supporting observations made by Elders and community members that indicate a noticeable change to the environment and wildlife in the area (OCCIAR 2015).

In an effort to address these challenges, a climate change vulnerability and risk assessment was conducted as part of an overall three-year climate change adaptation project. With support from Aboriginal Affairs and Northern Development Canada, this initiative was a joint partnership between the Chippewas of Georgina Island First Nation and the OCCIAR (OCCIAR and Chippewas of Georgina Island 2015). The planning framework used for the assessment was adapted from the Climate Change Planning Tools for First Nations framework (developed by the Centre for Indigenous Environmental Resources [CIER]) as well as other methodologies, emphasizing the interaction of western science and Traditional Ecological and Community Knowledge.

Project Planning and Implementation

Alongside a core Project Team and Community Adaptation Liaison, many stakeholders and participants (e.g., Community Advisory Committee [CAC]) contributed to the planning and execution of the assessment. Throughout the process, various meetings and workshops were held to inform the community of the project, collect Traditional Ecological Knowledge (TEK), and ground-truth results and findings. For example, one of these workshops took the format of an "Information Session/Bingo Night," which built on an existing event to attract more attendees. Community engagement was always supported by a suite of visual communication strategies such as posters, presentations, maps and informational packages to help illustrate the project's objectives and results.

The Project Team used the concept of the medicine wheel from the Climate Change Planning Tools for First Nations to gather historical data and understand community sustainability from an environmental, cultural, social and economic perspective (OCCIAR and Chippewas of Georgina Island 2015). The Project Team used this tool and the results of the TEK survey to conduct a vulnerability assessment "Impact Trees" activity adapted from CIER's "Influence Diagrams" activity. This activity assessed five climate-related hazards: extreme precipitation, winter, wind, summer and drought. "Impact Trees" were then prioritized by the CAC with a focus on impacts related to the two areas voted as most vulnerable (Chippewas of Georgina Island 2014).

The Project Team went on to prioritize the future risks of climate change through evaluating the potential likelihood and consequence of the top two priority areas. Finally, the historical and projected climate data were compared to historical weather and climate observations from the TEK survey results and the risks prioritized by the CAC. This side-by-side analysis highlighted areas of concurrence between western science and TEK, underscoring areas of risk within the community. The results of the assessment were then ground-truthed through additional meetings and workshops with the community (Chippewas of Georgina Island 2014).

Key Replication Factors

The TEK survey was a highly effective method of collecting feedback and input. It provided important insight into experiences felt by the community (i.e., to natural systems, built systems, social systems) and how they may have changed over the years. This survey can be adapted and used for similar planning efforts in different contexts.

The Project Team adapted various methodologies to best combine holistic, community-based planning and western science to develop their own seven-step planning framework. This framework can influence vulnerability and risk assessments at the sector level (e.g., municipal infrastructure, tourism or agriculture) or at various geographical scales (e.g., a single watershed, at the regional level or at the territorial level). In addition, project reports and findings detail how the communication and engagement strategies were employed and why they were successful.

Challenges and Lessons Learned

To assist other users around decision-making during the vulnerability assessment, it would have been more beneficial to see specific breakdowns of how the climate change impacts were assessed across specific criteria, such as adaptive capacity, sensitivity, or magnitude and duration of impact. Instead, the Project Team took a more discussion-based approach where impacts were ranked on a scale of one to three. Furthermore, there was no discussion pertaining to how risk would be measured or tracked over time, or more specifically, if and/or how this assessment would be repeated (e.g., every three, five or ten years).

Success Factors and Positive Outcomes

The process for conducting these assessments was representative, contextual and participatory by design. The partnership between OCCIAR and the community aided in capacity building and ensured the process was tailored to be culturally and locally specific. The climate change vulnerabilities were identified by community members, with risks prioritized by a CAC comprised of Elders, youth and band office officials. Building off CIER's framework and conducting a side-by-side analysis of TEK and western science was also a unique way to underline areas of risk in the community.

Results of the vulnerability and risk assessments were essential in identifying specific adaptive strategies and forming an adaptation plan. Outcomes of the assessments have been incorporated into a sub-watershed plan for the Island, carried out in partnership with the Lake Simcoe Region Conservation Authority (Chippewas of Georgina Island 2014), and have also informed drainage improvements in a wetland area.

4.5 Public Infrastructure Engineering Vulnerability Committee Engineering Protocol

Framework Description: The Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol (the "Protocol") is a five-step process to assess infrastructure vulnerability to climate change in relation to the nature, severity and probability of future climate hazards. It outlines a five-step methodology for assessing risks and conducting an engineering analysis on specific built physical and natural assets (Engineers Canada 2016):

1. Project Definition
2. Data Gathering and Sufficiency
3. Risk Assessment
4. Engineering Analysis
5. Recommendations and Conclusions.

Ultimately, the Protocol is intended to support decision-making for infrastructure operation, maintenance, planning and development under climate change conditions (Engineers Canada 2016).

The third step, focused on the risk assessment, involves an evaluation of the interactions between infrastructure components, the climate and other factors that could lead to vulnerability (e.g., geography or age) (Engineers Canada 2016).

Target framework users: Engineers, planners, asset management departments, infrastructure managers, operations and maintenance personnel, and landscape architects.

Context of assessment the framework is best suited for: The Protocol was originally developed to be applied to Canadian public sector infrastructure but can also be used to assess privately owned infrastructure. The assessment is intended to be applied to specific built physical and natural assets (e.g., a stormwater treatment plan or park), or to a class of built assets (e.g., road networks).

Decisions or processes the framework is best suited to support or inform: The Protocol is best suited to support infrastructure maintenance and operations plans, as well to prioritize infrastructure and to inform future decision-making and planning. Asset Management professionals may be particularly interested in the outputs of the assessment. The assessment could also inform due diligence requirements for insurance and liability purposes.

Stakeholders and participants best suited to be involved: Engineers, risk management officials, climatologists and/or meteorologists with knowledge of climate change science, models and projections, infrastructure operations and maintenance personnel, infrastructure managers, and asset management teams or departments.

Degree of collaboration: The Protocol recommends building a multi-disciplinary team to conduct the assessment. Specifically, the Protocol recommends a diverse set of qualified professionals who have an understanding of risk and risk assessment methodologies, relevant engineering knowledge of the infrastructure type, climatological or meteorological experience with climate change projections and modelling, hands-on operational and management knowledge of the infrastructure type, and local and historical knowledge regarding recent climatic events and their impact in the region (Engineers Canada 2016).

Degree of contextualization and/or localization: The Protocol is highly localized—it is specific to a single asset type (or class) and considers localized climate hazards and projections in its assessment. Moreover, the Protocol emphasizes that local knowledge, filtered through the overall expertise of the assessment team, can help compensate for data gaps and provide a basis for professional assessment infrastructure vulnerability (Engineers Canada 2016).

Aspects of the framework that assist with replicability: The PIEVC website showcases many examples of the Protocol being applied across a variety of assets (such as buildings, roads, electrical systems, airports, parks, and water, wastewater and stormwater systems) in over 45 projects in Canada and two international projects. The Protocol also provides guidance on how facilitators should conduct various vulnerability and risk assessment workshops with practitioners.

How to access PIEVC documents: https://pievc.ca/ or https://pievc.ca/protocol

4.5.1 Case Study: City of Miramichi Climate Vulnerability Assessment of Highway Infrastructure

Background and Project Description

In May 2012, the Province of New Brunswick (NB), through the Environmental Trust Fund, awarded funding to the City of Miramichi to carry out a climate change vulnerability assessment of highway infrastructure using the Protocol. The project focused on two major roads within Miramichi: portions of the King George Highway and of Highway 117.

Context and Objectives of Assessment

Due to its location within a tidal estuary, Miramichi was experiencing extreme flooding on a regular basis during major storm events, which had negative repercussions. The principal objective of the assessment was to identify components of highway infrastructure in Miramichi that were at risk of failure, damage and/or deterioration from extreme climatic events or significant changes to baseline climate design values. The arterial highway included in the assessment is approximately 20 km long and represents major transportation linkages for the region. The City used the assessment as part of a broader Climate Change Adaptation Strategy (Riley Environment Limited 2013).

Project Planning and Implementation

The Protocol is completed in five steps:

1. Project Definition
2. Data Gathering and Sufficiency
3. Risk Assessment
4. Engineering Analysis
5. Recommendations and Conclusions.

The Data Gathering step was largely informed through a workshop with 14 community stakeholders, including representatives from Miramichi, NB Department of Transportation and Infrastructure, NB Climate Change Secretariat, Miramichi Region Planning Commission, Miramichi River Environmental Action Committee and engineering consultants. This workshop helped identify 300 interactions between climate change events and infrastructure components.

The Protocol defines the risk of an infrastructure component as a function of probability of one of the 14 climate-related factors multiplied by the severity of the consequences and effects on the infrastructure (PIEVC 2013).

As a recognized risk assessment methodology, the Protocol enables the identification of key vulnerabilities and risks in a form that enables engineers to exercise their professional judgment in assessing infrastructure design, operations and maintenance. It establishes the probabilities of climate events affecting the functionality of the infrastructure. Concretely, this means identifying which infrastructure components require adaptation and how to adapt them.

The assessment concluded that there was no significant risk for Miramichi's highway infrastructure either in 2012 (the year of the assessment) or 2055 (the projection year). Out of the 300 climate-related factors and component interactions assessed, 87 interactions were deemed as medium risk for 2012, with an increase to 116 medium-risk interactions in 2055 (Riley Environment Limited 2013). The greatest infrastructure concern was the capacity of the culverts under the highway to handle increases in precipitation. Overall, the highway infrastructure was determined to be fairly resilient to the effects that may result from climate change, provided highways are properly maintained.

Key Replication Factors

The case study provides a detailed presentation of results from the assessment, as well as a walk-through of the planning process. It could provide guidance to other communities or stakeholders that wish to apply the Protocol to similar infrastructure types (i.e., highways or road networks). However, due to the highly localized nature of the assessment, specific recommendations from the Miramichi highway case study are not applicable to other assessments. Results depend on specific, localized climate change hazards and projections of the study area, as well as on the design, conditions and location of the infrastructure asset.

Challenges and Lessons Learned

Some challenges were presented when determining climate change projections for various climate parameters. While parameters related to temperature have higher confidence, those for precipitation are lower, and those for extreme weather events are even more difficult to quantify. To address these limitations, the team consulted literature on extreme weather events for the area. If projections and literature were not available, professional judgement was used to estimate trends. This decision resulted in less confidence for certain climate-related hazards, such as hurricanes, tornadoes, ice storms and other severe storms.

Another lesson learned from the study was the desire from workshop participants to factor community- or social-related impacts into the assessment. For example, groups were concerned about whether people would be stranded or isolated if infrastructure components were to fail, or whether community members would be able to get to work. Accounting for these impacts more directly in the results may result in a more complete assessment of risk.

Positive Outcomes

One key positive outcome and recommendation of the study was for the City of Miramichi to develop an Operations and Maintenance (O & M) Procedures Manual for the highway infrastructure. The O & M Manual would consider the climatic events that were identified as most severe and include special procedures to address them, where required. Other recommendations included developing an O & M plan for culverts, to ensure their functionality during extreme weather events, and including a vegetation management plan to minimize the risk of blockages.

The PIEVC Assessment of Miramichi's road infrastructure also informed the development of the City's Climate Change Adaptation Plan, which was completed in 2019.

4.6 Mixed-method Approach to Climate Change Risk Assessment

Another method by which climate change risk assessments can be conducted is through a hybrid, or mixed-method, approach. This is the term for when users combine components from different vulnerability or risk assessment frameworks to create a customized approach. Results from these types of assessments can sometimes offer greater validity and reliability for staff and decision-makers, as the approach used for risk assessment was developed to meet specific and localized goals or objectives. This customizability can help offset the inherent challenges of using any one approach by itself.

When proceeding with a mixed-method approach, users should be certain to:

1. Be cautious of terminology used within the assessment (e.g., ensuring that definitions and concepts are used in the same contexts and new terms are added and defined where necessary).
2. Ensure that the chosen methodologies can be replicated in future iterations of the assessment (e.g., making sure the same types of information or data can be collected in the same way at later intervals).
3. Transparently document defensible reasons to select a mixed-method approach (e.g., if a more granular level of economic analysis or understanding is needed to increase buy-in or to inform capital investments).

The case study below is an example of how a mixed-method approach was selected and applied to the District of North Vancouver's corporate-focused climate change vulnerability and risk assessment.

4.6.1 Case Study: District of North Vancouver Climate Change Vulnerability and Risk Assessment

Project Background

The District of North Vancouver is a district municipality in BC with a population of approximately 85,300 people. The District is one of three municipalities that make up the "North Shore" of Metro Vancouver. The District staff began developing their Climate Change Adaptation Strategy in 2015 to build on their existing initiatives and to address the anticipated social, economic and environmental impacts of climate change. As part of this process, they undertook a comprehensive vulnerability and risk assessment to determine the District's sensitivity and adaptive capacity to potential climate change impacts, as well as the likelihood and consequences of those impacts (District of North Vancouver 2017a).

Context and Objectives of Assessment

In years prior to the risk assessment, the District of North Vancouver experienced extreme precipitation and flooding events, reduced water levels, water restrictions, droughts, record-setting summer temperatures, and increased numbers of forest fires and subsequent impacts to air quality (District of North Vancouver 2017b).

With future climate change intensifying these events and placing a strain on the District's assets and operations, community members and surrounding ecosystems, the District chose to develop a corporate-focused risk assessment and adaptation strategy. To guide their risk assessment process, they used a mixed-methods approach, applying Milestones 1 and 2 of the BARC framework as well as the ISO 31000 methodology.

Project Planning and Implementation

The process began with the formation of a core Climate Change Adaptation Team to lead planning and provide strategic direction. Composed of District staff members from various departments, the team was intentionally multidisciplinary and reflective of a wide range of perspectives within the administration. Next, historical climate data for the District was collected and modelled to identify trends and projected climate impacts using the information from the Pacific Climate Impacts Consortium.

Using the climate change science as well as their local knowledge and field expertise, the Adaptation Team followed the BARC framework to identify climate change impacts across different drivers and systems (capturing built, social, economic and natural systems). The District defined these drivers to be municipal services, infrastructure and systems, parks and environment, and health and safety, and addressed four key climate variables of concern: temperature, precipitation, extreme weather and sea-level rise. The vulnerability of these potential impacts was assessed using a function of sensitivity and adaptive capacity criteria. The climate change impacts were then further evaluated through a two-pronged risk assessment approach.

The District chose to adapt their climate change risk assessment approach so the assessment results aligned with existing corporate assessments and processes. Since ISO 31000:2009 was already used in the District's Asset Management Plan to assess infrastructure risks, the District chose to mirror this approach and apply the framework to all built environment–related impacts (Murphy, personal communication, 2015). The remaining non-infrastructure-related impacts were assessed using BARC's risk assessment methodology.

The methodology was adjusted for both likelihood and consequence evaluations. Instead of assessing the likelihood of each impact statement as a whole, the District chose to determine both the likelihood of the climatic event (e.g., drought), as well as its consequence (e.g., reduced potable water). Consequences for infrastructure-related impacts were measured against the following criteria: injury, service interruption, environment, finance and reputation. These consequences were also weighted differently, while BARC consequence criteria were weighted equally across various categories. For the remaining impacts, consequences were assessed using the BARC framework, which included five criteria: public health and safety, local economy and growth, community and lifestyle, environment and sustainability, and public administration and governance (District of North Vancouver 2017a). Results from both assessments helped prioritize the climate change impacts to which the District was most vulnerable and/or that posed the highest level of risk.

The District's adaptation strategy acknowledged that the best way to measure how climate change risk evolves is through the repetition of a comprehensive risk assessment. The District committed to repeating this assessment every five years to accommodate the most recent climate science and to modify climate impacts to capture observed or recently projected changes (District of North Vancouver 2017a).

Key Replication Factors

Although BARC was originally created for cities and towns, the framework broadly assesses impacts across systems by using a variety of data collection methods and by engaging a diverse group of stakeholders. With adjustments and small edits to nomenclature, the methodological framework can be readily applied at any scale. In this case, the District chose to adapt BARC to suit their corporate-focused planning needs.

By using ISO 31000:2009 to support their analysis of risks to infrastructure, the District highlighted how to include a more granular level of analysis if needed and how including elements of a more standardized approach helped meet the goals of the assessment.

Challenges and Lessons Learned

Challenges arose in the initial application of the BARC Risk Assessment methodology, as municipal staff were not familiar with it and had not applied it in previous work. Through continued discussion with District staff, the team decided to use ISO 31000:2009 based on the National Asset Management System Risk Registers framework, as it was a methodology that staff were comfortable using and Finance staff were willing to create a template to merge the methodology with the District's existing climate change impact statements. One potential lesson from this challenge would be to present the risk assessment methodology before undertaking the assessment, to ensure buy-in and to account for desired changes from key staff and stakeholders.

Although the District's climate planning efforts were corporate-focused, greater emphasis could have been put on gathering and integrating input from the community and other stakeholders. More specifically, the results of the vulnerability and risk assessments could have been validated with the key external stakeholders (e.g., health units, local environmental groups and organizations, and academic institutions) and other staff members in the Corporation (i.e., through engagement strategies such as a survey or a pop-up event).

Success Factors and Positive Outcomes

Using a mixed-method approach in the District's risk assessment process helped to ensure that the Climate Change Adaptation Strategy would be successful in the District's local context. Since many of the District's existing policies and programs already used the Asset Management risk assessment methodology, utilizing a similar framework in its Adaptation Strategy would assist with mainstreaming new actions. Moreover, the mixed-method approach assisted with obtaining strong buy-in from the Finance department, which created and used the asset management risk assessment methodology (Murphy, personal communication, 2015).

Results of the assessments fed into the rest of the planning process, helping to inform actions and the Adaptation Strategy. For example, part of the Strategy suggested that climate change could be integrated into several District programs and policies, such as the Official Community Plan, Parks and Open Space Strategic Plan, Transportation Plan, Integrated Stormwater Management Plan, and Natural Hazards Management Program (District of North Vancouver 2017a).

5.0 CONCLUSION

As outlined within this guidance document, climate change risk assessments are an integral part of any adaptation effort as they can help to reduce some of the inherent uncertainties associated with climate change (e.g., future climate projections, conflicting values and outcome attribution) through the identification, analysis and evaluation of climate risks.

Climate change risk assessment offers a framework to help teams identify, understand and prioritize climate change risks to ultimately support the selection of adaptation responses to reduce them. Risk assessment, as part of a broader risk management process, offers a practicable and credible approach for prioritizing complex risk issues and for ultimately selecting the most suitable risk reduction strategies in order to achieve societally acceptable levels of risk. It also provides a means to balance a range of considerations and to use predictive information.

While there may not be a single ideal framework for assessing climate change risk, the questions presented in Section 3.0 of this document have been developed to help a user identify a given framework based on their needs, objectives and capacities related to understanding climate risks. A variety of good practices are available to support users undertaking a climate change risk assessment. In order for users to find a framework that suits their needs, it is important to define and scope any risk assessment based upon goals, parameters and available resources before beginning data collection and analysis.

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