Ontario's Province-Wide Climate Change Impact Assessment

Decision-Making Supports

January 2023

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1.0 Job Aid Road Map

1.1 Overview

Between 2020 and 2022, the Province of Ontario undertook a comprehensive, multi-sectoral Provincial Climate Change Impact Assessment (PCCIA) of potential climate change-related impacts, including risks and opportunities, to help provide an understanding of how and where climate change may affect Ontario's economy, infrastructure, communities, public health, safety, and the natural environment.

In the PCCIA, more than 3,400 risk scenarios were developed and analyzed across six regions of the province (Far North, Northeast, Northwest, Eastern, Central and Southwest) and five Areas of Focus: Business and Economy, Infrastructure, People and Communities, Food and Agriculture, and Natural Environment.

1.2 Advancing Adaptation Work

The PCCIA helps to build knowledge and awareness of the impacts that are occurring now and how those risks will continue to develop into the future. The PCCIA also provides information to advance high-level strategies that address risk through the use of adaptation and resilience best practices. Priority risks are those that pose the most severe possible outcome that can be expected to occur based on a specific interaction between a climate variable and a Level 1 or Level 2 category. Areas of Focus for the PCCIA are organized into Level 1 and Level 2 categories that demonstrate steps of granularity. The number of Level 1 and Level 2 categories vary between each Area of Focus and they represent the diversity of systems affected by climate change.

Outputs from the PCCIA help establish a baseline level of climate risk against which continued and new risks can be assessed and compared. This PCCIA is the first for Ontario and presents a foundation for further application of methods and good rationale for implementation of climate change adaptation.

The intent of the PCCIA is to provide foundational province-wide information to help inform future work. There are numerous ways to interpret results in order to mainstream climate resilience into policies, programs, and operations and to motivate or catalyze adaptation initiatives. Additional work is needed to translate new risk information identified using the

PCCIA methodology into concrete adaptation plans and projects, put the systems and resources in place to monitor what works, track adaptation progress, and repeat the cycle to ensure that adaptation keeps pace with our rapidly changing climate.

This document, and the resources it contains, aim to support practitioners translate PCCIA methods and results into detailed impact assessment on themes relevant to their own contexts to ultimately inform practical adaptation planning.

1.3 Applying Decision-Making Supports: Step-by-Step Job Aids for Practitioners

Decisions often take place within complex contexts. Decision-making supports (DMS) can help structure decision-making, organize, and analyze information, and build consensus around options for action (Moss et al., 2014). A job aid is one type of decision-making support meant to help practitioners to mainstream considerations of climate resilience into their everyday responsibilities.

These PCCIA Job Aids provide quick-reference, step-by-step guidance for implementation to help practitioners carry out each step of the PCCIA's methodology in their own context, whether that might be within a specific institution, community, industry, or sector across a range of scales. These Aids profile the approach taken by the PCCIA, but also highlight different methods, tools, datasets, and best practices that could be useful for implementing each step in other contexts.

In each Job Aid you will find:

- Tables highlighting the use of Job Aids in the PCCIA across Areas of Focus with specific examples
- A case study illustrating the different ways in which principles may be put into practice across different settings and scales in the real world
- References to other Job Aids, sections of the PCCIA Technical Report, and other supporting documents
- A set of key takeaways based on lessons learned from the PCCIA development
- Key references for further reading

1.4 The Climate Change Risk Assessment Process

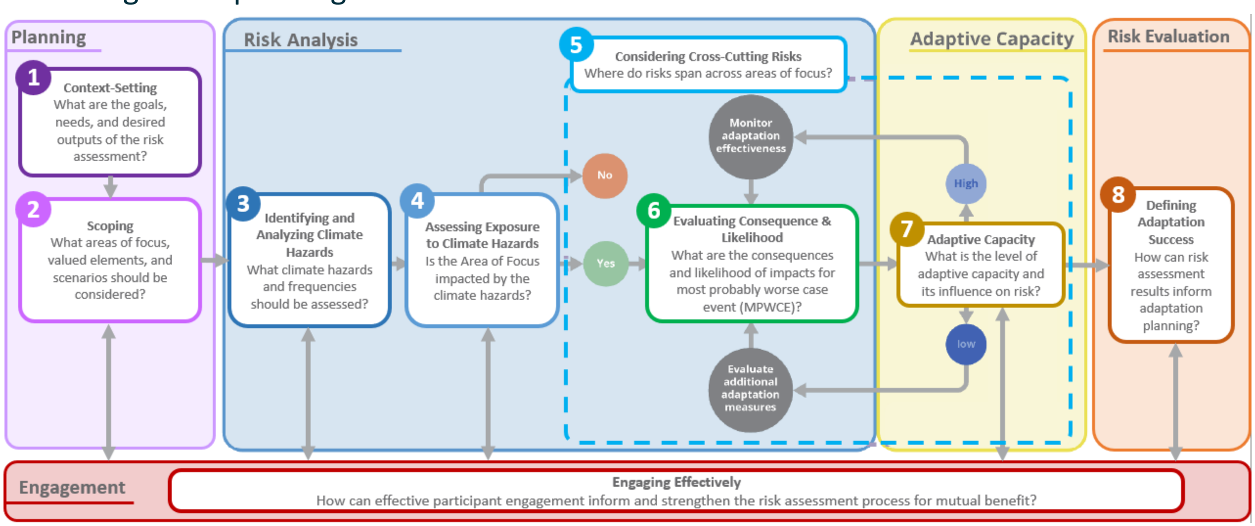
Climate change risk assessment typically follows one of two broad methodologies that frame risk through either (1) the considerations of vulnerabilities, exposure, and climate variables; or (2) the consideration of likelihood and consequences. These terms are defined in greater detail in the glossary at the end of this roadmap. The methodological framework used for the

PCCIA focused on the second option because it is most aligned with the standard definition of risk, which is a function of the frequency of exposure to a climate variable, the consequence (magnitude of the impact on a given valued element), and the likelihood (or the probability that the impact will occur).

This methodology also aligns with the Intergovernmental Panel on Climate Change (IPCC)'s transition from vulnerability towards risk-based approaches to adaptation to align with the practices of related disciplines like disaster risk reduction and enable more targeted approaches to adaptation focused on priority risks, in terms of their likelihood and consequences (Connelly et al., 2018). The final methodology framework used in the PCCIA, detailed in **Figure 1-1**, was developed in conjunction with best known practice for climate change impact assessment, including reference to international standards (specifically International Organization for Standardization (ISO) 14090)), other comparable climate change assessments, and professional experience from the consulting team. ISO 14090 outlines principles, requirements, and guidelines for adaptation to climate change (2019).

Each step in the process helps to answer a set of key questions (**Figure 1-1**, **Table 1-1**) and bring practitioners closer to the goal of targeted adaptation planning that makes the best use of limited resources.

Figure 1-1: A schematic showing the broader impact assessment process followed in the PCCIA (modified from the PCCIA Methodology Framework) with numbers indicating corresponding Job Aids described in **Table 1-1**.



The steps of this impact assessment process may also be implemented in iterative cycles across a continuum of scale and complexity, ranging from a scanning cycle (which aims to identify and engage the right participants, broadly scope impacts from climate change and interacting factors, and identify priority areas for more detailed assessment), to a portfolio cycle (which explores a priority area of focus to identify, prioritize, and act on important strategic risks and opportunities), and ultimately a project cycle (which targets a specific adaptation initiative or project) (Stafford-Smith et al., 2022). The PCCIA would be considered a scanning level impact assessment, with some elements of a portfolio approach. It is intended to characterize climate change risks at a broad scale across five thematic Areas of Focus and six geographic regions of Ontario to inform high-level adaptation planning and establish a baseline against which future impact/risk assessments can be compared. This impact assessment process was informed by quantitative and qualitative information sourced from literature reviews, professional judgement, and engagement with more than 200 decision-makers, experts, organizations, and Indigenous groups from across the province.

The outputs from the PCCIA can inform the future implementation of smaller portfolio-scale assessments of climate change impacts and adaptive capacity in smaller regions, watersheds, communities, sectors, or specific supply chains or organizations. Indeed, the PCCIA provides a methodology for future studies in Ontario.

Table 1-1: Summary of Job Aids in this series and the key questions they provide

Job Aid	Key Questions and Topics Addressed	Assessment Step
Road Map	Providing an overview of the risk assessment process and decision-making supports.	All
2.0 Engaging Effectively	• Why is engagement important? • Who is participating in the process? • How to keep stakeholders / Rights Holders engaged throughout? • How to ensure engagement mobilizes action on adaptation? • How to ensure the risk assessment process fosters climate justice?	Engagement

Job Aid	Key Questions and Topics Addressed	Assessment Step
Road Map	Providing an overview of the risk assessment process and decision-making supports.	All
3.0 Context-Setting	• Why assess climate change impacts? • What are the organizational requirements (if any), constraints and capacities? • Will it be data-driven or largely informed by stakeholder knowledge? • What are the desired outputs of the risk assessment?	Planning
4.0 Scoping	• Who should be involved in decision-making about scope? • How to decide on areas of focus and valued elements? • How to decide on timeframe and spatial scale? • How to decide on climate and socioeconomic scenarios? • How will risk assessment results be aggregated?	Planning
5.0 Identifying & Analyzing Climate Variables	• What types of climate information are needed? • How to select climate variables, including event-based and slow onset variables? • How to determine the frequency of climate variables?	Risk Analysis
6.0 Assessing Exposure to Climate Variables	• What types of data, information and knowledge sources will be used? • How can climate thresholds be used to characterize exposure scenarios? • How to represent interacting climate variables?	Risk Analysis
7.0 Considering Cascading and Cross-Cutting Impacts & Risks	• How to identify cascading and cross-cutting impacts and risks? • How to identify promising levers for adaptation solutions/decision-making at a systems level?	Risk Analysis

Job Aid	Key Questions and Topics Addressed	Assessment Step
Road Map	Providing an overview of the risk assessment process and decision-making supports.	All
8.0 Evaluating Consequences & Likelihood of Impact	• How to determine and apply consequence criteria? • How to determine and apply likelihood criteria? • How to include non-climate stressors in the risk calculation? • How to account for tipping points and cascading impacts?	Risk Analysis
9.0 Assessing Adaptive Capacity & its Influence on Risk	• How to define and characterize adaptive capacity? • How to evaluate adaptive capacity across varied values and Areas of Focus? • How do combinations of risk and adaptive capacity assessment guide action?	Adaptive Capacity Analysis
10.0 Defining Adaptation Success	• How can results inform a vision for adaptation? • How can results help identify shared adaptation goals and objectives? • How can results inform actions to take now, medium, and long term? • How to apply a greenhouse gas mitigation lens to risk assessment results? What about other lenses (e.g., “one health”)?	Risk Evaluation

1.5 References

International Organization for Standardization. (2020). ISO/DIS 14091 Adaptation to climate change —Guidelines on vulnerability, impacts and risk assessment. Geneva.

International Organization for Standardization. (2019). ISO/DIS 14090 Adaptation to climate change — Principles, requirements and guidelines. Geneva.

Moss, R., Scarlett, P. L., Kenney, M. A., Kunreuther, H., Lempert, R., Manning, J., ... & Patton, L. (2014). Decision support: Connecting science, risk perception, and decisions. Climate change impacts in the United States: The third national climate assessment, 620, 647.

Stafford-Smith, M., Rissik, D., Street, R., Lin, B., Doerr, V., Webb, R., Andrew, L. and Wise, R.M. (2022). Climate change adaptation guidance: Clarifying three modes of planning and implementation. Climate Risk Management, 35, p.100392.

1.1 Glossary

Adaptation: Process of adjustment to actual or expected changes in climate and their effects.

Adaptive Capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Area of Focus: The five main thematic areas that comprise the PCCIA. Areas of Focus are defined by the Ontario Ministry of the Environment, Conservation and Parks and include: Food and Agriculture; Infrastructure; Natural Environment; People and Communities and Business and Economy.

Climate Change: Refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or human activity.

Climate Variable: Changes in climate (events or stressors) that have the potential to cause harm or bring benefits.

Consequences: Negative impact that arises when a climate variable interacts with a system of interest, often expressed as the magnitude of impact.

Delta Approach: A method used to derive downscaled and bias-corrected climate change projections of future climate.

Exposure: An interaction, either actual or expected between the climate variable and the presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic activity.

Frequency: The number of occurrences of a repeating climate variables per unit of time.

Impact: Effect (of climate change) on natural and human systems. Impacts can be **direct**, caused directly by climate variables. Impacts can also be **indirect**, including cascading and compounding effects.

Interaction: The pairing of an asset/ service/operation with a climate variable that has the potential to impact the asset/service/operation.

Cascading impacts are indirect or knock-on consequences of direct impacts, due to interdependencies across systems, or that cascade through the system. **Compound** effects occur, for example, when more than one climate variable results in the same impact chain occurring simultaneously, thus amplifying the overall impact (e.g., the same climate drivers that cause high and extreme high temperatures can also cause drought and wildfire).

Most Probable Worst-Case Event: The Most Probable Worst-Case Event (MPWCE), otherwise references as 'risk scenario' considers the most severe possible outcome that can reasonably be expected to occur based on a specific interaction between the climate variable and a Level 1 or Level 2 Category. The MPWCE is a conservative risk estimate in order to provide latitude for adaptation planning purposes to reduce risk.

Likelihood: Chance of something happening. Often measured in qualitative terms such as **low, medium, or high.**

Level 1 is a category is defined as an overall "Sector."

Level 2 is a 'sub-sector' of Level 1

Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol: A risk assessment framework to assist practitioners in factoring climate change impacts into plans for design, operation, and maintenance of public infrastructure.

Representative Concentration Pathways (RCP): A greenhouse gas (GHG) concentration trajectory used by the IPCC. They are scenarios that include emissions and concentrations time series of GHGs, aerosols, and chemically active gases, as well as land use and land cover. The RCPs presented in the IPCC Assessment Report 5 (AR5) from 2013 range from significant GHG reductions in the near future (RCP2.6) to a "worst case" future with little reductions in emissions (RCP 8.5). Current global emissions are more in line with RCP8.5 (PCCIA Technical Report).

Resilience: The ability of social, economic and environment systems to withstand climate change-related situations including hazardous and catastrophic events or shifting trends in ways that these systems can maintain their essential functions or structures as well as the capacity to respond to future changes.

Risk Appetite: The amount and type of risk the organization is willing to accept.

Risk: The product of likelihood and consequence.

Vulnerability: The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.

2.0 Job Aid: Engaging Effectively

2.1 Job Aid in Brief

The Problem: Risk assessments relying exclusively on the work of subject matter experts may lead to results that are not relevant to the local context of the communities, sectors, regions, and ultimately the decisions that the assessment is meant to inform.

The Solution: Developing a dedicated Project Engagement Plan that includes early, ongoing, and tailored engagement across a diverse range of participants can help to draw on local experiences and ensure that the assessment will be relevant for decision-making.

The Way Forward: Effective engagement involves first deciding on the degree of engagement, then identifying a representative set of participants, developing an engagement strategy and tactics tailored to different types of participants and anticipate potential issues, and then documenting and effectively communicating results. It is important to recognize that special considerations must be taken to engage effectively with Indigenous Communities. Proper budget and time allocations are necessary to ensure inclusion of Indigenous People and respectful use of Indigenous Knowledge.

The Benefits: Meaningful engagement supports a holistic approach to risk assessment grounded in the local context and experience, results in more effective decision-making that is aligned with local needs, practices, and capacity, and increases the likelihood of successful implementation of adaptation options.

The Steps:

Step 1 – Engagement Scoping

Step 2 – Participant Analysis and Recruitment

Step 3 – Participant Engagement Tactics

Step 4 – Engagement Risk Assessment, Mitigation, and Evaluation

Step 5 – Documenting and Communicating Engagement Outcomes

2.2 Overview

Public engagement and participation are essential to the climate change risk assessment process based on the belief that adaptation is a shared responsibility and that those who are affected by climate change impacts and decisions have a right to be involved in understanding the problem, identifying, and implementing solutions (IAP2 2018). Participant engagement plays an important role throughout the risk assessment process by helping to (1) define the scope of the assessment (e.g., which sectors, components, and risks to consider), (2) ensure relevance of the assessment within local socio-ecological perspective, (3) share knowledge, experience, and other types of evidence to inform the assessment, (4) review and contextualize findings, and (5) act as champions to amplify the communication and application of outputs (Haddaway et al., 2017).

The level of engagement in any decision varies across a spectrum of public participation that ranges from simply informing participants to placing participants at the heart of decision- making (**Figure 2-1**). Regardless of the level of engagement, additional considerations are needed to ensure the process is transparent, fair, and inclusive in ways that reduce different dimensions of participant bias and facilitate equitable contributions from Indigenous Communities and other marginalized groups that are often the most vulnerable to climate impacts (USDN, 2017; Haddaway et al., 2017; POH, 2021). Such considerations may include assessment of participant readiness and capacity for engagement, providing financial or technical support to facilitate engagement, using non-traditional engagement techniques based in community practice, and developing strategies for capturing and incorporate different types of knowledge into the assessment (USDN, 2017; Haddaway et al., 2017; CCME, 2021). See the case study 'Climate Change Adaptation Planning with the Georgina Island First Nation' in this Job Aid for an example of successful and meaningful engagement.

Figure 2-1: The spectrum of public participation decision-making

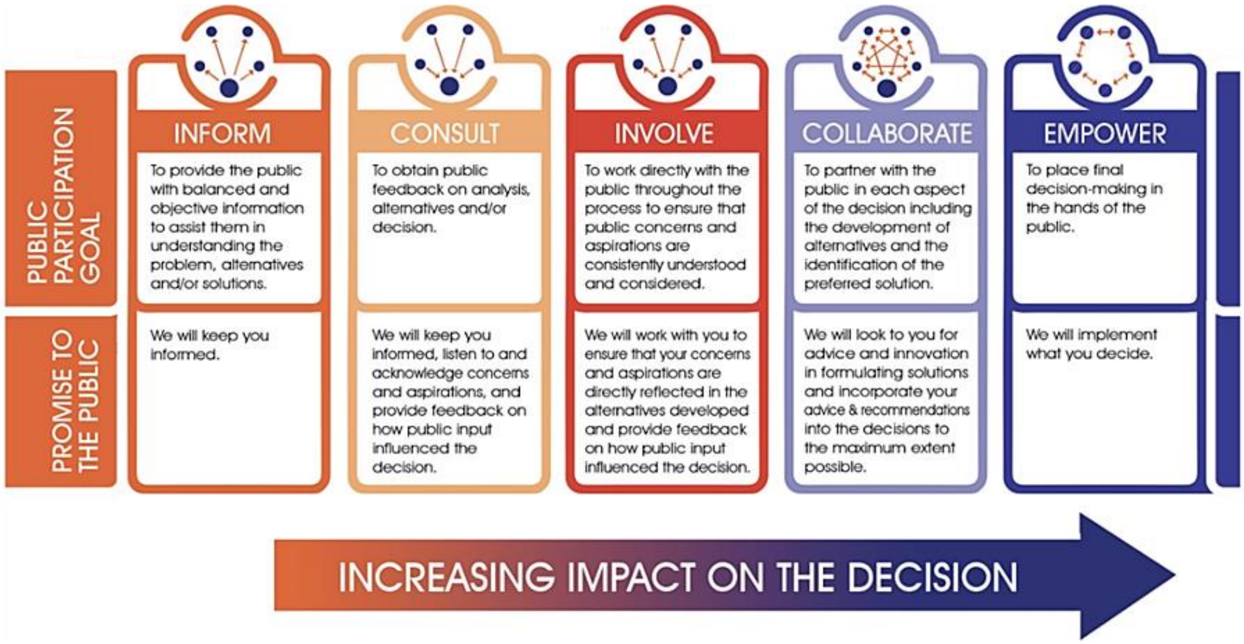


Figure Source: IAP2 2018

Ultimately, meaningful participant engagement supports a holistic approach to risk assessment that is grounded in the local context and experience, results in more effective decision-making that is aligned with local needs, practices, and capacity. It also reduces risks resulting from decisions that do not consider the interests of communities that will be affected, and increases the likelihood of successful implementation of adaptation options (Haddaway et al., 2017; Lieu et al., 2018; GIZ, 2022).

2.3 Key Questions

- Why is engagement important?
- Who is participating in the process?
- How to keep stakeholders and Rights Holders engaged throughout the risk assessment process?
- How to ensure engagement mobilizes action on adaptation (e.g., champions, finance)?
- How to ensure the risk assessment process fosters climate justice (at least “does no harm)?”
- How to assess if engagement was successful?

2.4 Guidance for Implementation

Risk assessment leads should undertake an engagement planning process at project initiation that progresses through the steps outlined below, ultimately leading to the development of a

Project Engagement Plan, similar to the one developed for the PCCIA that will guide engagement activities moving forward. For more information see the PCCIA Technical Report Appendix 3: PCCIA Engagement (PCCIA Technical Report Appendices).

Step 1 – Engagement Scoping:

It is important to decide on the most appropriate degree of participant involvement along the spectrum of participation early in the risk assessment process given project objectives, resources, and timelines. Most engagement processes have historically focused on informing or consulting participants, whereas more transformational approaches to effective climate change adaptation may require moving beyond this status quo. This would include moving towards deeper levels of engagement with the diverse communities and organizations who must act and interact to become catalysts for implementing effective solutions (Deubelli and Mechler, 2021). This is especially true of engagement with Indigenous Communities, which often requires a unique approach grounded in the unique principles, values, and protocols of each participating community, developing a shared understanding of worldviews, and building mutual respect, trust, and relationships over time to uphold the principles of Reconciliation (Charles-Norris, 2020; Fox, 2022). Although increasing levels of engagement require investment of additional time and resources, this investment is expected to yield greater participant buy-in, uptake, and implementation of the project outputs for more equitable and just adaptation outcomes (Haddaway et al., 2017; Yuen et al., 2017). There may also be a desire to form a peer review panel as part of an engagement strategy, as was done in the PCCIA, to provide an additional level of technical review and insights into the salience of draft products for decision-making, as well as increase the transparency and credibility of the risk assessment process.

Step 2 – Participant Analysis and Recruitment:

Participant or stakeholder analysis is the process of identifying, classifying, and understanding key actors in a system (**Figure 2-1**). This type of analysis is helpful for ensuring balance and equitable representation across participants, guiding prioritization among potential participants when resources are limited, identifying, and preparing for conflicts among participants, and tailoring engagement methods to specific types of participants. Importantly, including participants from enabling organizations such as community groups, governments, and funding organizations can help to bridge the transition from risk assessment outputs to adaptation planning and implementation.

Where the actors in a system are already well-known, this step may occur implicitly through direct selection, while in other cases it may unfold more deliberately using methods such as interest-influence matrices, social network or knowledge mapping, key informant interviews, or snowball sampling. Including several participants from each organizations is recommended to ensure continuity of participation in the event of staff turnover (Haddaway et al., 2017), so long as knowledge sharing occurs among these participants. It is important to clearly state expectations for the degree of engagement (including anticipated level of effort and engagement), objectives of engagement (including types of inputs sought), and expected outcomes of the engagement (importance, reciprocal benefits, and which aspects of the risk assessment participant input will influence) as early as possible in communications with potential participants (Haddaway et al., 2017). Regardless of the context, engagement should include a dedicated step, and plain-language reference materials, to ensure that participants understand the methodology being applied to the risk assessment before input is sought.

Step 3 – Participant Engagement Tactics:

The process of engagement itself may take place through many different modalities ranging from more unidirectional modes such as written communications, surveys, and websites to bidirectional modes such as interviews, focus groups, workshops, participatory field work, or trainings (**Figure 2-2**, **Table 2-1**). Engaging with participants at different times and through multiple modes of interaction can help to mitigate timing, technological, and language or literacy barriers to participation (Haddaway et al., 2017). Project leads should also consider the trade-offs between virtual engagements, which can lower travel barriers to participation but increase technological barriers to participation, and in-person engagements, which may require more resources for participation but result in more effective relationship-building and knowledge exchange. Even where virtual engagement is necessary, following best practices can help to make these meetings more welcoming, inclusive, and effective for everyone, including Indigenous participants (e.g., the Virtual Community Engagement Guide, by Sheedy 2022).

Whenever possible, co-creating the engagement strategy with participants will help to identify the most effective engagement strategies for different groups, particularly Indigenous Communities and other marginalized groups, to improve participation, knowledge sharing, and outcomes (Yuen et al., 2017). In some cases, this may require non-standard approaches to engagement including storytelling, games, the use of illustrated worksheets (see examples in the case study in this Job Aid as well as engagement tools developed by Up North on Climate), and participatory risk mapping exercises (Bitsura-Meszaros et al., 2019; Albagli and Iwama, 2022). Where the risk assessment intends to source local data to inform qualitative or quantitative assessment of risks, additional engagement may be needed to reduce barriers to data sharing, for example, through brokering of data-sharing agreements (David-Chavez and Gavin, 2018; Alexander et al., 2020). Emerging resources like the Indigenous Data Toolkit can help to provide useful guidelines for navigating this process.

Figure 2-2: Primary types of participants and the tactics that may be used to engage them in a risk assessment process (Adapted from: GIZ, 2022).

Also consider how best to structure engagements in relation to the scope and objectives of the assessment. For example, in the PCCIA, engagement sessions organized around Areas of Focus helped to develop a more comprehensive view of thematic risks across a broader region. While sessions organized around specific geographies may be better suited to understanding local contexts and identifying cross-cutting risks within specific organizations, communities, or regional supply chains necessary to inform practical adaptation planning. The frequency of engagement should be aligned with the complexity and length of the process as well as participant capacity for engagement. Long gaps between engagements can lead to significant dropout of participants, however, intermittent, or phased engagement can avoid overburdening resource-limited participants (Haddaway et al., 2017).

Table 2-1: Engagement used in the PCCIA and the broad outcome of the process.

Engagement in Action in the PCCIA	
Engaging Effectively in the PCCIA	The specific elements or tactics of engagement used in the PCCIA were chosen and designed to capture meaningful information that would support the assessment in the most efficient manner. The engagement tactics varied depending on the purpose and intent and included webinars, surveys, virtual workshops, virtual meetings, and ongoing communication.
Engaging Effectively Outcome	Engagement was a crucial component of the PCCIA as it helped reveal data and information, but also people's perceptions of impacts, risk tolerances and perspectives on priority areas that might otherwise be missed through a literature review. The engagement process for the PCCIA yielded some important observations and lessons that can be noted for subsequent iterations of an Ontario-wide climate change impact assessment. These can be found in the PCCIA Technical Report Appendices.

The PCCIA engagement process included an introductory webinar, a survey, and virtual workshops organized around Areas of Focus with Ontario government representatives, sector experts, Indigenous Organizations, and other external participants (**Table 2-1**). In total, more than 250 organizations were engaged over the course of the PCCIA. The PCCIA sought to engage meaningfully with Indigenous Communities however, due to project time constraint and methodology, higher input was obtained from Indigenous Organizations who worked closely with or represented membership of Indigenous Communities. The engagement process was used to confirm and validate impacts and risks and supplement the knowledge base for the assessment. While Indigenous Communities in Ontario contribute least to climate change, the effects of it are being felt disproportionately by these communities. The uptake of key outcomes of the future climate change assessments will be influenced by the extent to which Indigenous Communities see their input reflected in the work. Proper funding and time allocation will be required to significantly engage with Indigenous communities and bring forth equitable adaptation strategies.

PCCIA Application: The PCCIA process developed a participant tracking database that could provide a starting point for identifying potential participating individuals or organizations with relevant expertise to engage in a risk assessment process ,where their previous experience with the risk assessment process could be valuable.

Step 4 – Engagement Risk Assessment, Mitigation, and Evaluation:

As with any project, engagement may not always unfold according to plan. Once the scope, objectives, participants, and tactics of the engagement process have been determined, it is important to carry out a risk assessment on the engagement plan itself and identify mitigation strategies to ensure continued success. Risks related to the engagement process may include misalignment of expectations about the engagement process, lack of participation, lack of representation from marginalized groups, conflict, or unanticipated delays in the engagement and implications for the project timeline (PCCIA Engagement Plan; Haddaway et al., 2017). Strategies for mitigating these risks are captured in the best practices outlined in prior steps.

Project leads should develop a strategy for defining and evaluating the ongoing success of the engagement process, which might include measures such as levels of participation, the volume and quality of inputs received over time, and direct participant feedback through surveys (Haddaway et al., 2017). Evaluation can help to identify issues as they emerge and catalyze the proactive implementation of risk mitigation measures to enable course corrections.

Step 5 – Documenting and Communicating Engagement Outcomes:

At the conclusion of the risk assessment, participant engagement activities, contributions, and impacts should be tracked, documented, and acknowledged as part of project reporting. This step fulfills the commitment to transparency and accountability with participants, demonstrated how inputs shaped project outcomes, and provide a record of lessons learned to inform related engagement processes in the future (Haddaway et al., 2017).

However, engagement does not end when the assessment is completed, and further measures are necessary and urgent to disclose identified risks to affected communities, organizations, and sectors in a timely manner and improve the ongoing visibility, accessibility, and use of the assessment outputs to inform decision-making at multiple scales. Such measures might include the development of non-technical summaries and case studies tailored to different audiences (as is the case in this series of Job Aids), visual communication tools such as videos and infographics, interactive websites that allow users to explore information from different angles (e.g., by sector, by risk, by affected component, or by geographic areas), and follow-up workshops (SWM, 2020). A review of best practices from around the world provides more detailed recommendations and examples on how to improve engagement with risk assessment outputs to ensure their continued uptake and use in decision-making (SWM, 2020). When the time comes for adaptation planning, further stakeholder engagement is also essential for identifying critical pathways and methods of intervention, surfacing intervention risks, and selecting options for implementation that are endorsed by the community (van Vliet et al., 2020).

2.5 Risk Assessment in Action

Case Study 1: Climate Change Adaptation Planning with the Georgina Island First Nation

Year: 2015 **Focus:** People and Communities

Link: Climate Change Adaptation Planning with the Georgina Island First Nation

Context:

With funding from Crown Indigenous Relations and Northern Affairs Canada (CIRNAC), Georgina Island First Nation partnered with the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR), to develop a climate change adaptation plan for their community. The approach combined aspects of Traditional Ecological Knowledge (TEK) and Community Knowledge, and climate vulnerability and risk assessment methods, to support the Chippewas of Georgina Island First Nation assess both current and future climate-related risks and impacts. Robust and meaningful engagement with the Community was critical to the success of this project. Engagement activities were planned to ensure the project was guided by the Georgina Island First Nation values and experiences. An Advisory Committee comprised of Community members was established at the project onset to provide advice and help guide the process.

Approach to Risk Assessment and Use of Data:

The Project Team developed an adaptation planning framework and workbook which outlined how climate risk assessment methods and TEK would be used to inform the identification and evaluation of climate risks. The bottom-up framework outlines a seven-step process, incorporating the assessment of vulnerabilities, estimation of risk, and identification of existing adaptive capacity to prioritize climate risks and impacts felt by the Community.

Engagement activities including Community workshops and meetings were held to inform, update, and seek feedback from Community members. In addition, a Community Adaptation Liaison (CAL) was hired and actively engaged the Community through the collection of Traditional Ecological Knowledge, supported in information sessions, and provided regular project updates to community members.

The engagement tactics employed were tailored to the community and cultural context. For example, the project team hosted engagements in the format of existing events (community bingo nights and dinner with the Elders) to encourage attendance (see **Figure 2-3**). The Indigenous medicine wheel was used to frame the risk assessment (CIER, 2006; see also other applications process and structure knowledge integration in Marshall et al., 2020; Schaefer et al., 2021; POH, 2021). Keeping the community informed and ensuring timely and consistent communications with community members throughout the entire project duration was a fundamental component of engagement.

How Results Influenced Decision Making

Over the project duration, several Georgina Island Band policies and plans were reviewed and analyzed to identify the associated impact on enabling or impeding adaptation efforts. Existing policies and plans where adaptation considerations could be included in the future were identified for consideration in future updates. This exercise was completed to help support the mainstreaming of climate adaptation into community planning and decision-making processes.

Impact or Outcomes of Implementation

With guidance from an Advisory Committee, a series of adaptation recommendations were identified to respond to the identified climate risks. While emphasis was placed on the highest priority risks, adaptation measures addressed both high and lower priority risks. A supporting implementation plan was also developed to support the community with advancing the identified responses into actionable items. Several recommendations have been implemented by the Community, along with monitoring efforts to identify additional actions needed to build capacity under changing climate conditions.

Figure 2-3: Interactive risk assessment workshop with Georgina Island First Nation community members.

Image Source: Photo courtesy of Kerry Ann Charles.

Key Lessons from this Case Study

Key components that resulted in a successful adaptation plan for the community included, the multi-faceted engagement approach throughout each phase of the project, utilizing existing community events for engaging members on the project and adopting a bottom-up approach where community engagement guided the climate risk assessment process. This approach resulted in meaningful and applicable products for the Chippewas of Georgina Island First Nation to utilize in advancing their community's adaptation efforts.

2.6 Key Takeaways

- Determine the appropriate level of engagement for the risk assessment and identify internal collaborators and external partners and participants and clearly define expectations for their roles and contributions prior to beginning work.
- Consider forming an advisory committee or group to guide or review draft information.
- Based on the methods and approach to the risk assessment being followed, identify when and how stakeholders and partners will be engaged through the development of an engagement plan.
- In general, seek to engage upfront in visioning and scoping process, in characterizing system information to feed a risk assessment, in reviewing draft risk assessment results, and in mobilizing risk assessment information and in building momentum for buy-in or implementation.
- Ensure that timely, clear, and simple communication is provided to participants and partners throughout a risk assessment to keep them engaged. When engaging non-technical stakeholders and rights holders, invest in the development of interactive websites, infographic summaries, and other forms of visually oriented communication to facilitate knowledge translation and engagement for specific audiences.
- The more complex the risk assessment process and methodology, the more important it becomes to provide participants with engagement opportunities and resources to build understanding of the methodology and confidence in providing inputs as well as interpreting and implementing outputs.
- When done right, the engagement process should unfold within an open and supportive environment that helps to build participant trust in the process and its outcomes. In the absence of sufficient engagement among participants, obtaining buy-in and building momentum for implementing risk assessment outputs can be challenging.

2.7 References and Resources

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3.0 Job Aid: Context-Setting

3.1 Job Aid in Brief

The Problem: As climate change continues to alter our environment, the need to manage risks is increasingly apparent. Organizations can use climate change risk assessments to inform adaptation plans. There is no right way to undertake a climate change risk assessment; context is everything. Unless the “why” and “what” of the assessment is clear from the onset, results of the process can be disappointing.

The Solution: Compiling information on past and current climate-related events is a good place to start in establishing the context for a climate change risk assessment, as is clarifying who is responsible for adaptation measures and how climate change could affect the organization's ability to deliver on its mandate or mission.

The Way Forward: Getting clarity on the context for a climate change risk assessment involves identifying the goals and audiences, determining the organizational requirements, constraints, and capacities, identifying the type of assessment and data needed, and determining the desired outputs.

The Benefits: Understanding the context for a climate change risk assessment is critical for ensuring the assessment meets the needs of the region, communities, and organizing bodies responsible for the assessment.

The Steps:

Step 1 – Identify Goals

Step 2 – Determine Organizational Requirements, Constraints, and Capacities

Step 3 – Determine the Type of Assessment and Data

Step 4 – Identify Desired Outputs

Step 5 – Establishing Governance

3.2 Overview

Climate warming in Canada is occurring at twice the rate of the global average, and the resulting impacts are already being felt in the form of more frequent and intense extreme events like heavy rains, heatwaves, droughts, as well as reduced snow cover, longer growing seasons, and more (Bush and Lemmen, 2019). In Ontario, annual mean temperature has risen by 1.3˚C between 1948 and 2016 and is projected to increase by 2.3˚C between 2031 and 2050 under a high emissions scenario (RCP8.5) (Cohen et al., 2019). As these trends and events become more frequent and greater in magnitude, duration, and climate impact severity (UNDRR, 2022), the need to prepare for the associated risks is critical.

Climate change risk assessment is a part of risk management that considers the vulnerabilities, exposure and climate variables, likelihoods, and consequences of a warming climate (CCME, 2021). The purpose of conducting a climate change risk assessment is to understand the likelihood of climate variables and potential impacts such that climate adaptation and resilience can be prioritized (C40 Cities, 2018). The results of climate change risks assessments inform the selection of adaptation strategies and measures, and support securing investments in climate resilience (CCME, 2021). It is becoming increasingly common for cities to require some form of climate risk management plan with emphasis on sectors aligning with the five Areas of Focus identified through the PCCIA (PCCIA Technical Report, C40 Cities, 2018). Risk management requirements are also emerging for the private sector (OSFI, 2022).

This Job Aid presents the process of identifying and understanding the context for undertaking a climate change risk assessment. It does so by asking key questions such as why a risk assessment might be prudent, what requirements, constraints, and capacity considerations should be made, what sources of information can or should be leveraged, and what types of outputs could be useful.

3.3 Key Questions

- Why assess climate change risk?
- What are the organizational requirements (if any), constraints and capacities?
- Will it be data-driven or largely informed by stakeholder and Rights Holder knowledge?
- What are the desired outputs of the risk assessment?

3.4 Guidance for Implementation

Step 1 – Identify Goals:

Goals for developing a climate change risk assessment are context specific and should be clear to all involved. Examples of goals within the Infrastructure Area of Focus may be to reduce the number of service disruptions or increase the useful life of assets (**Figure 3-1**). Broadly, risk assessment supports a systematic approach to decision making under uncertainty, which is accomplished through identifying, understanding, and communicating the involved risks (PCCIA Technical Report; CCME, 2021). Risk assessments also support the development of adaptation strategies, educational campaigns, allocation of capital investments/funding for resilient infrastructure, outreach and engagement, policy development, and to help organizations keep on top of regulatory changes that may occur in response to climate risks (CCME, 2021).

Figure 3-1: Context-Setting used in the PCCIA and an example Level 1 outcome within the Infrastructure Area of Focus. For more information, see section 5.0 Infrastructure of the PCCIA Technical Report

Context Setting Level	Context Details
Context - Setting in the PCCIA	Given the complexity of the PCCIA, a clear list of goals at the onset was crucial. By identifying, understanding, and communicating the existing and potential future climate impacts across Ontario, the Provincial Government, municipalities, Indigenous Communities, and other local decision-makers will be further supported in making informed and timely choices that can help keep communities and people healthy and safe.
Context Setting in the Infrastructure Area of Focus	Infrastructure has many interdependencies and numerous indirect and cascading impacts that can occur between and within infrastructure systems affecting its organizational constraints and capacity. Beyond the direct physical impacts, it was recognized that impacted infrastructure is felt by individuals, communities and businesses who rely on that infrastructure, making the risk widespread.
Context Setting Outcome in Infrastructure	The assessment of Infrastructure Area of Focus included 690 unique scenarios across several climate variables and associated consequences for direct physical impacts. Indirect impacts were noted and reported on qualitatively throughout the PCCIA.

An example from context-setting in the Infrastructure Area of Focus for the PCCIA is:

> Two key climate variables were identified as driving risk profiles for Pipeline Transportation infrastructure (Level 1 category): extreme precipitation event (shorter term), and accumulated precipitation (longer term). Both variables have the potential to trigger geotechnical hazards such as landslides and river scouring, which may result in slope instability causing pipeline dislodgement and rupture.

The PCCIA was developed to foster resilience to climate change by providing a comprehensive and repeatable process for understanding how and where climate change could affect Ontario's economy, community wellbeing, health and safety, and natural systems (PCCIA Technical Report). As such, it serves as an excellent resource for contextualizing the application of a climate change risk and impact assessment. It highlights the need to understand current and future climate change impacts, and the risks associated with a changing environment.

Climate change risk assessments can range in complexity and scope from small, rapid assessments meant to outline the potential magnitude of one risk, to very comprehensive, large assessments that are accomplished over many years, and with many stakeholders involved (CCME, 2021). It is important to understand who the target audience for the results of the risk assessment will be (see the Lake Huron Case Study in this Job Aid). The inability to recognize the need to adapt is a barrier towards undertaking a climate change risk assessment, especially in the context of other limits like resources, and a lack of clarity of roles and responsibilities (Burbidge, 2016). If these conditions exist, compiling empirical information on the effects to the organization from past climate-related events and presenting them to leaders in the organization may be a better place to start. Questions to consider when deciding on whether a risk assessment is pertinent for your organization include: How vulnerable is the area (economic, social, environmental)? What is the adaptive capacity of the area? (C40 Cities, 2018). How will the climate change in your area, and how has it changed already (Burbidge, 2016)? Who is responsible for adaptation measures in your organization (Burbidge, 2016)? Could climate change affect your organization's ability to deliver on its mandate, or meet performance requirements?

PCCIA Application: The PCCIA Technical Report's introductory sections (Sections 1.0 and 2.0) present the context for the assessment. Primarily, it establishes the importance of resilience in the face of climate change, and its application within decision-making frameworks. It clearly articulates how assessing the impacts, risks, and opportunities climate change precipitates can help develop a more strategic approach to adaptation planning.

Step 2 – Determine Organizational Requirements, Constraints, and Capacities:
It is common to encounter constraints when conducting climate change risk assessments. These can include limitations to budget, personnel, expertise, time, and data accessibility (CCME, 2021). Although it is unlikely that all capacity and resource constrains can be avoided, understanding your limitations can help you plan accordingly such that the quality of the work is not undermined (CCME, 2021). For this reason, it is recommended that any past institutional or organizational plans be reviewed for their effectiveness in adapting to or reducing risk (UNDRR, 2022). It is, however, important to recognize that past practices

regarding climate change may need further consideration to be more consistent with current scenarios, and to ensure that "systems thinking", or a more holistic approach, is undertaken. Similarly, knowing what resources are available ahead of developing the risk assessment can help streamline the implementation process (CCME, 2021). Resources can include risk assessment frameworks and guidance that may be useful in other contexts. Stafford-Smith et al. (2022) reviewed 39 risk-based adaptation guides, providing a useful overview of tools available and their uses.

It is important to recognize the additional limitations faced by Indigenous Communities throughout the province. There is significant research to indicate that Indigenous Populations are more vulnerable to climate change impacts due to socio-economic disparities, social gradients in health, close relationships to sometimes rapidly changing environments, remoteness of reserves, lack of adequate infrastructure and other systemic barriers, and capacity issues as a result of colonial legacies (Centre for Indigenous Environmental Resources, 2006).

Step 3 – Determine the Type of Assessment and Data:

Climate change risk assessments can take multiple forms. They can be top-down, bottom-up, quantitative, qualitative, comprehensive, tightly scoped, or a mix of all (CCME, 2021). Goals and objectives as well as human and financial resources shape the method to adopt (C40 Cities, 2018). Furthermore, risk assessments can be developed in such a way that they leverage already-existing objectives, goals, policies, and frameworks (UNDRR, 2022). Based on the type of assessment you want to do, you might consider different types of data. Data can include stakeholder and Indigenous lived experiences and knowledge, climate projections, hazard maps, weather station data, studies on climate impacts and risk, studies on disaster risks, expert elicitation, data on population, land use, and assets, existing strategies, and existing planning tools (disaster planning, land use planning, etc.), to name a few (CCME, 2021; UNDRR, 2022). Ontario GeoHub and Ontario Open Data are resources that can help in locating relevant data that can support assessments.

A few questions to consider when deciding what kinds of data to include: Will Indigenous Knowledge be included throughout the risk assessment process? What groups of people will be included? How will partners be engaged, and language barriers be accounted for? (CCME, 2021)(See also Job Aid on "Engaging Effectively").

Step 4 – Identify Desired Outputs:

Ideally, a climate change risk assessment should provide decision-makers with information to develop a list of actions to prioritize to address the most impactful risks (CCME, 2021). The PCCIA methodology for instance, has been developed in a manner that is scalable to local contexts and needs. Risk and adaptive capacity scores can be assessed and employed at various scales. Subsequent local climate change risk assessments could leverage this information to dive into further depth and/or explore further indirect impact, consequences, and identify priority areas. These priority areas can then be addressed through the development of adaptation strategies and measures that align with needs of the community (PCCIA Technical Report). Examples of outputs generated through risk assessment should also be clearly and transparently documented, such that the process can be replicated (CCME 2021). The PCCIA process included technical reports, risk registers, adaptation "best practices" guidance, decision-making supports, summary reports and a data package (PCCIA Technical Report).

Step 5 – Establishing Governance

Governance of the assessment, outputs, and actions is critical to success. As such, early on there should be opportunities to identify organizations, government and / or communities that could play a role as a governance entity. Users may want to consider Integrated Governance that places sustainability at the heart of governance and corporate boards' strategic planning / goals. With an Integrated Governance model, companies are directed and controlled in a way in which sustainability issues are integrated ensuring value creation for the company and beneficial results for all stakeholders in the long term (UNEP, 2014).

3.5 Risk Assessment in Action

Case Study 2: Lake Huron Climate Change Risk Assessment (CCRA): Climate Change Information Products for Indigenous Communities in Grey, Bruce, and Huron Counties

Year: 2015 **Focus:** People and Communities

Link: Lake Huron Climate Change Risk Assessment (CCRA): Climate Change Information Products for Indigenous Communities in Grey, Bruce and Huron Counties

Context: Over the course of two years, Bruce Power, in partnership with the Council of the Great Lakes Region and the Climate Risk Institute, engaged with Indigenous and Métis communities in Grey, Bruce, and Huron counties to produce knowledge and information products that address opportunities and risks related to climate change and specific environmental, cultural, and socioeconomic values and activities in the counties that host or surround Bruce Power facilities.

Climate change vulnerabilities, risks and opportunities were assessed and risk scenarios were developed to capture current and projected risks to key habitats and ecosystems of importance to Indigenous and Métis Communities.

Approach to Risk Assessment and Use of Data: Consultations with Saugeen Ojibway Nation (Chippewas of Nawash Unceded First Nation and Saugeen First Nation), Historic Saugeen Métis, and Métis Nation of Ontario were carried out early in the process to establish a common understanding of the status of CCRA needs in Indigenous and Métis Communities in the region and assess constraints, capacities and the degree of involvement of each of the Communities. Community engagement was critical in establishing the context for the risk assessment, defining the approach and objectives of the work, and developing a common understanding of related needs and interests.

Figure 3-2: At the water's edge of Lake Huron, Ontario

Image Source: LisArt, used under Flickr creative commons licence

Furthermore, it helped build relationships with the Communities and gain acceptance and support for the climate change work.

Climate change risk assessment frameworks and examples of several climate information products were presented and led to a habitat-based approach to integrate Traditional Ecological Knowledge (TEK) and western scientific knowledge to determine the vulnerability of beings/species to climate change. Follow-up discussions with Community members helped to identify key habitats and species of particular interest for the assessment as well as the types of risk information products that would be of greatest potential interest and use to the Communities, such as ArcGIS-based story maps.

Engagement sessions were held with the community to collaborate on and gain insights about integrating TEK into the risk assessment framework as directed by community leads.

TEK and community information were collected through reviewing shared documents and records, meetings with community contacts, and any additional community resources shared with the Project Team (e.g., historical fish harvest numbers). By applying a holistic approach and using a combination of Indigenous and western scientific knowledge to identify key climate impacts and related risks, the information products developed during the risk assessment were tailored to the needs of each community.

Scientific evidence was collected through a comprehensive review of the literature, guided by key focus areas (i.e., habitats/ecosystems) revealed during initial engagement sessions. Climate variables and associated indices were identified for each habitat-type (Coniferous and Mixed Forests, Great Lakes, Alvars and Cliffs), calculated using the most recent climate projections and analyzed to identify the likelihood of each risk scenario. For instances where specific thresholds and associated climate indices could not be identified, qualitative risk statements were developed, in replacement of quantitative risk scores. Social, cultural, and economic consequences associated with each risk scenario were assessed using a qualitative approach and presented as co-developed narrative statements, capturing community insights and considerations.

How Results Influenced Decision Making: Developing climate information products tailored to community needs provided them with knowledge and tools to strengthen climate resiliency and flagged the importance of dedicated staff to support this work on a continuous basis.

Impact or Outcomes of Implementation: Results of the risk assessment provide opportunities for improved observation and monitoring and can support land-use planning, resource management and climate adaptation planning in the communities. Additionally, story maps and risk narratives were used for educating community members on climate change risks and adaptation, and support existing community initiatives.

Furthermore, results of the risk assessment could serve as a valuable consultation tool for streamlining responses to climate change related inquiries, such as municipal requests for climate change adaptation planning.

Key Lessons from this Case Study: Deep and meaningful engagement of Indigenous communities was critical to both determining what information products could be useful and confirming that results match the vision and unique needs of the community. Continuous involvement of community partners ensured the outcomes of the assessment were readily applicable and useful for communities' needs and could be supported beyond the timeframe of the risk assessment project itself.

3.6 Key Takeaways

- Simplify and disseminate background information related to climate change and potential impacts prior to and throughout the kickoff of the risk assessment process.
- Identify goals of the entire process upfront, such as creating resilience-oriented policies, prioritizing actions, or better understanding risks.
- Align your risk assessment process with the outcomes you are hoping to achieve. Avoid finishing a risk assessment only to inquire how the information will be mainstreamed, applied, or used.
- At the onset, identify decision-makers, partners and stakeholders and rights holders that need to be influenced, made aware of climate change risk assessment outputs, or those who will play a role in its delivery.

3.7 References and Resources

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4.0 Job Aid: Scoping

4.1 Job Aid in Brief

The Problem: Launching into a climate change risk assessment without clarity on the intended outcomes and outputs of the process make it difficult to generate results that matter for decision making, wasting time, and eroding relationships.

The Solution: Identifying the scope, or the goals, objectives, components to focus on, time and spatial scales, as well as the target audiences and people involved, is a step in undertaking a risk assessment that is realistic and relevant.

The Way Forward: Scoping for a climate risk assessment begins by building a diverse team. Once a team has been assembled, deciding on the Areas of Focus, and time and spatial scales are next steps to ensure efforts are specific, directed, and aligned with decision-making needs. Finally, deciding on climate and socioeconomic scenarios and aggregating risk results will ensure the most relevant data is used.

The Benefits: Beginning with the end in mind, through effective scoping, is critical to developing a risk assessment that most directly meets the needs of the individuals, groups, communities, and regions that benefit from such an assessment.

The Steps:

Step 1 – Building a Team

Step 2 – Deciding on Areas of Focus

Step 3 – Choosing Spatial and Time Scales

Step 4 – Deciding on Climate and Socioeconomic Scenarios

Step 5 – Aggregating Risk Assessment Results

4.2 Overview

After understanding the context for a climate change risk assessment, including its overall goals and target audiences, scoping is a critical step to ensure that the subsequent work is relevant and effective. Climate change risk assessments can be comprehensive and involve many stakeholders and Rights Holders working over many years bringing together multiple datasets, or it can be a quick assessment of a single risk (CCME, 2021), based on desk-based research. To adequately scope a climate change risk assessment, it is important to determine the coverage of the assessment: what elements or components to focus on, spatial and timescales, and representation of future conditions. Well thought-out scoping helps align efforts with policy making and mandates (Waldick et al., 2015). Top-down and bottom-up scoping approaches exist and understanding which approach to use will help develop a robust risk assessment that appropriately captures the complexities inherent in the geographic scale or time horizon of the work (Waldick et al., 2015).

This Job Aid walks through the steps involved in scoping for a climate change risk assessment, namely building a team, selecting Areas of Focus, deciding on spatial and time scales, how to characterize the future, and how to aggregate results.

4.3 Key Questions

- Who should be involved in decision-making about scope?
- How to decide on Areas of Focus and valued elements?
- How to decide on timeframe and spatial scale?
- How to decide on climate and socioeconomic scenarios?
- How will risk assessment results be aggregated?

4.4 Guidance for Implementation

Step 1 – Building a Team:

Scoping decisions regarding climate change risk assessments should aim to be as participatory and inclusive as possible (CCME, 2021; Smith et al., 2022; UNDRR, 2022). Often, there is a lack of quantitative data about climate change risks, so, in addition to providing insights on the focus on the assessment, experts, stakeholders and Rights Holders can be critical sources of knowledge of climate change risk (van Vliet et al., 2020). Furthermore, because climate change affects everyone, teams are often comprised of a wide range of collaborators, including scientists and subject matter experts, governments, Indigenous organizations, local residents, and more (ISO, 2018; CCME, 2021), although their roles in the assessment process can differ. A diverse group of individuals on the team may also help develop outputs that are relevant for many different groups (**Table 4-1**).

The organization undertaking the risk assessment is responsible for appointing a project team. The first step is to identify interested parties that are versed in the context of the system, the objectives, and climate change and its impacts (ISO, 2020). Decision-makers can be an invaluable part of the team, as they can provide value judgements, and can foster ownership of the results (ISO, 2020).

PCCIA Application: The PCCIA process developed a participant tracking database that could provide a starting point for identifying potential participating individuals or organizations with relevant expertise to engage in a new risk assessment process where their previous experience with the risk assessment process could be valuable.

The level of engagement of stakeholders and rights holders can change from one risk assessment to another, and especially in light of schedule and financial constraints (CCME, 2021; van Vliet et al., 2020). Nevertheless, it is important to ensure effort is made to consult and engage stakeholders and Rights Holders in the process to mitigate challenges down the road (CCME, 2021; Tonmoy et al., 2019) (see Job Aid on "Engaging Effectively"). It is similarly important to consider and understand how the various stakeholders and rights holders involved will understand and perceive climate change impacts, likelihoods, and consequences (CCME, 2021).

The knowledge and stories shared by Indigenous Peoples are invaluable in understanding the observed impacts of climate change, as it represents generations of place-based experiences (CCME, 2021). Therefore, the risk assessment process should create space for meaningful engagement and collaboration with Indigenous Peoples and their knowledge and ways of knowing, being respectful of cultural research ethics and engagement protocols (MNO 2008, Indigenous Innovation Initiative 2021).

Overall, including a variety of stakeholders and rights holders in scoping the risk assessment allows them to express their perspectives and priorities; increasing the legitimacy and uptake of the assessment process and its results (van Vliet et al. 2020).

Table 4-1: Scoping used in the PCCIA and an example Level 1 outcome within the People and Communities Area of Focus. For more information, see Section 8.0 People and Communities of the PCCIA Technical Report.

Scoping Level	Scoping Details
Scoping in the PCCIA	A climate change impact assessment requires holistic knowledge of risk perceptions and risk tolerances from key stakeholders and impacted communities to determine the scope and assessment of action. The main audiences for PCCIA engagement included the Impact Assessment Inter-Ministerial Committee (IAIC), Indigenous Organizations and other external participants (non-governmental organizations, industry and trade associations, and other Area of Focus specific organizations).

Scoping Level	Scoping Details
Scoping in the People and Communities Area of Focus	The Level 1 categories were intended to capture direct impacts to the health and well-being of, and key services to, people and communities in Ontario. This includes considering multiple levels at which climate risks interplay, and existing capacity to adapt to a changing climate (both acute and chronic climate events and changes).
Scoping Outcome in People and Communities	A total of four unique Level 1 categories were identified for the People and Communities Area of Focus. Climate variables identified that impacts within Level 1/Level 2 categories include both acute and chronic temperature and precipitation events, as well as wildfire.

A scoping example in the People and Communities Area of Focus from the PCCIA is:

> The PCCIA found that there are direct impacts to Indigenous Communities (Level 1 category) as a result of climate change including extreme heat and cold events, flooding, and wildfire risks. These climate variables exacerbate existing health and socio-economic inequalities, physical and mental health impacts, increased injuries and deaths from extreme weather-related accidents, and evacuation or displacement from traditional territories (National Collaborating Centre for Indigenous Health, 2022).

Step 2 – Deciding on Areas of Focus:

Climate change risk assessments can be large and comprehensive, or smaller in scope and rapid (CCME, 2021). The methodology used in a climate change risk assessment will depend on the focal areas of interest or “systems” of interest. In turn, the choice of focal areas depends on the goals of the risk assessment, input from stakeholders, and Indigenous Communities. Focal areas should represent the ecological, social, and system diversity within the geographic scale and time horizon of greatest interest (PCCIA Technical Report). Drawing on an example from the CCME report on Guidance on Good Practices in Climate Change Risk Assessments (2021), the area of focus could be a single infrastructure asset, or it could seek to analyze all infrastructure within a geographic area of interest. As with many other steps of the risk assessment process, relying on stakeholder feedback during the identification of the priority focus areas is important to mobilize risk assessment results. Further, be sure to think critically about utilizing the same method as past research. Climate conditions are continuously changing and assessment approaches that have worked in the past may be insufficient in this new environment.

PCCIA Application: The PCCIA methodology divided Areas of Focus into levels such that broader themes could be considered as well as more discrete components of the themes (e.g., a Level 1 category could be Transportation, and a level 2 category could be Rail) (PCCIA Technical Report). An inter-ministerial advisory group defined the initial thematic scope of the PCCIA, which was then refined to best suit the assessment scale and scope within each Area of Focus (PCCIA Technical Report).

Step 3 – Choosing Spatial and Time Scales:

The spatial scale at which a climate change risk assessment is undertaken varies between projects and depends on goals and the availability of information and resources (CCME, 2021; UNDRR, 2022). The PCCIA used six geographic regions consistent with border derived from Census Canada Division boundaries. This consistency enabled use of existing data without further parsing of geospatial census attributes to different spatial bounds (PCCIA Methodology Framework). The six geographic regions also had some consistency with the boundaries of Ontario's ecozones. Ultimately, the geographic scale of the assessment should be relevant for the specific system(s) and populations at risk and of interest and should consider the availability of data for different spatial scales (ISO, 2020).

Because climate change is non-linear and risks change over time, some risks will be rapid-onset (e.g., landslides), and others will be slow-onset (e.g., changing annual average temperatures) (UNDRR, 2022). When deciding on appropriate time horizons, organizations should consider the lifespan of the system, the timescales over which the impacts of climate change will reach critical thresholds, lead time for adaptation measures, the availability of data, long-term uncertainty of climate change impacts, and potential interactions between impacts over different timescales (Waldick et al., 2015; ISO, 2020).

Typically, climate change information included in assessments operate within 30-year time periods for current (e.g., baseline), near future (e.g., 2050s) and far future periods (e.g., 2080s) (UNDRR, 2022). Generally speaking, for an assessment it is pertinent to consider time horizons that reflect the time it takes for the focus area to show observable changes; the time horizon needed to iteratively assess risk should match the expected lifespan of the consequence of the climate change adaptation decision being made in response to the risk (ISO, 2019). For example, a time horizon of five years may be suitable for agriculture, but a time horizon of 100 years may be ideal for forestry (ISO, 2019; UNDRR, 2022).

Step 4 – Deciding on Climate and Socioeconomic Scenarios:

Uncertainty in long-term climate change is typically accounted for and considered by using alternative emissions pathways or "Representative Concentration Pathways" (RCPs) and a range of outputs from Global Circulation Models (GCMs). RCP8.5 currently represents the “worst case” scenario (among climate change scenarios), and current global emission are trending along this pathway (PCCIA Technical Report). Aside from reflecting future emissions and climate conditions, risk assessments can also account for changes to population, economic growth, and land use, for example, using socio-economic projections. Socio-economic scenarios are a useful tool in considering plausible changes to non-climate factors that provide a “backdrop” against which impacts from climate change can be understood (PCCIA Technical Report).

PCCIA Application: The PCCIA methodology utilizes approximately 40 Global Climate Models, used to calculate potential future climate conditions (PCCIA Technical Report). Using multiple estimates is important to account for the full range of plausible futures and inherent uncertainty in the trajectory of emissions. The PCCIA employed the Delta Approach which is a method used to derive downscaled and bias-corrected climate change projections of future climate. The PCCIA also considered a single, “middle-of-the-road” future socio-economic scenario to help characterize how populations, demographics, assets and other factors might change in the future. The scenario is based on the Shared Socio-economic Pathway (SSP) 2 from the IPCC (PCCIA Technical Report). Socio-economic projections informed adjustments to the scores assigned to the consequence of climate change impact. For example, if more people are exposed to climate variables of increasing frequency and / or severity into the future (e.g. extreme temperatures), the consequences in terms of number of people affected would also increase (For more information see PCCIA Technical Report).

Step 5 – Aggregating Risk Assessment Results:

Climate change risk assessments can produce a significant number of broad-reaching results that can be overwhelming or confusing to work with, especially for inexperienced users (Stafford-Smith et al., 2022). Aggregation, or the summarization of data from different sources can lead to complex cross-sectoral assessments, but should not compromise the use of individual results (ISO, 2020). For climate change risk assessments that have made substantial use of quantitative or semi-quantitative data to develop indicators, decisions about how indicator values are normalized, aggregated, and weighted are needed (UNDRR, 2022). There are several methods that can be used to aggregate indicators, if that is what the organization decides is pertinent and feasible. They can be aggregated to produce a single assessment for each climate change impact or can be further aggregated into more discrete units of the system at risk (e.g., by sector) (ISO, 2020).

One method of summarizing results from multiple sources can be to implement a stepped rating scale such that summaries for each climate impact or indicator can be developed. For more quantitative results, normalization (usually a standard range between 0 and 1) of the indicators and combining them with critical risk thresholds can be useful (ISO, 2020). Risks can each be aggregated into single overarching risk values for the sector or region, but it is important to remember that these highly aggregated results do not illustrate the influence of the indicators (ISO, 2020). Aggregated results can be depicted through charts or maps with narrative descriptions (ISO, 2020).

4.5 Risk Assessment in Action

Case Study 3: Mainstreaming Climate Change – Integrated Landscape Assessment, Decision-Support Process and Tool Kit

Year: 2015 **Focus:** Food and Agriculture

Link: Mainstreaming Climate Change: Integrated Landscape Assessment, Decision-Support Process & Tool Kit

Context: A place-based decision-making framework was developed that considers regional and global sectoral drivers and ensures that all necessary adaptation actions, policies, and measures are effectively mainstreamed into planning strategies for Eastern Ontario. The work focused on characterizing changes and measuring, evaluating, and mapping climate change impacts in the context of quantitative data on the agricultural sector.

Using available socio-economic and biophysical information from regional authorities, alternative future scenarios were developed to describe the range of socio-economic futures and their vulnerabilities to climate change. Integration of diverse sets of available data, rather than narrowly focused sectoral assessments, helped identify shared common objectives such as maximizing the long-term environmental, economic, and social well-being within the region. Exploring the future scenarios highlighted shared regional priorities and helped identify adaptation priorities requiring more integrated regional planning.

Approach to Risk Assessment and Use of Data: The spatial focus of the assessment followed the political boundaries of Eastern Ontario as defined by Statistics Canada corresponding to recognized municipal and regional jurisdictions. Advantages of this approach include a more uniform regulatory environment, easier data collection as well as direct connection to jurisdiction-wide policies.

The time horizon for a project is crucial in making the results of a study relevant for stakeholders. Data reporting intervals (e.g., census data) and data availability were considered when defining the time frame for the assessment. Choosing a time span of 25 years allowed some distance from current trends and challenges and enabled forward thinking that facilitated discussions regarding sensitive issues. This period was divided into short-term horizons of one year that recognized the timing for adaptations and needed policies to be implemented. The suite of stakeholders included responsible authorities from a variety of sectors and scales. Multidisciplinary discussions allowed different scenarios to be defined and helped identify quantitative measures that were used to compare scenarios and explore the utility of different policy and management adaptation options.

Figure 4-1: Central Experimental Farm in urban Ottawa

Image Source: Jamie McCaffrey, used under Flickr creative commons license

Four alternative scenarios were explicitly developed to quantitatively represent different trajectories of plausible future conditions and land use, as well as providing a basis to allow specific adaptation options to be explored. The scenarios were set up to allow stakeholders to consider development of the region in general and agricultural practices in particular.

The assessment of scenario simulations was made by using quantitative, computer-based approaches that combine existing data, reporting metrics, and scientific models. The research team focused on making use of data and information that were publicly available and would, therefore, create a base set of criteria for future project groups, including those with limited resources to purchase spatial data sets.

How Results Influenced Decision-Making

The use of different scenarios provided a range of potential future conditions or states for discussing adaptation needs and priorities both in general (e.g., where will conditions change?) as well as specific terms (e.g., what sector or land-use activities present the greatest benefits, or risks, to priorities for the region in the future?).

In the more immediate term, a computer-based model could be used as a tool by farmers and other regional decision-makers to consider how their operations might be affected by future conditions and look at some alternative options based on a range of factors outside what they are generally able to consider.

Impact or Outcomes of Implementation

The assessment of alternate scenarios provided guidance for mainstreaming adaptation as well as insights into the types of policies and responses that would need to be developed. The use of scenarios showed that adaptation is a cross-cutting effort and demonstrated the way in which the activities of various regional sectors interact, highlighting the need for an integrated approach that includes farm-level actions, business development and information needs and tools for regional and local decision-makers.

Key Lessons from this Case Study

The inclusion of regional organizations with mandates to manage or provide relevant information for scoping purposes was critical; not only to ensure that the most relevant priorities were included, but also because they played an important role in producing and disseminating information about the region. Establishing an understanding of regional policy and programs was used to scope the work and ensure mechanisms (existing or needing to be established) by which actions could be implemented were in place within the region.

4.6 Key Takeaways

- Begin with the end in mind: anticipate project scope and define system components to align with policy making and mandates, where appropriate.
- Discuss the elements or components of the system needing assessment. Optimize scope based on time and resources available, the extent to which climate may cause impacts, and the importance of capturing interdependencies or cascading risks between system components (e.g., avoid assessing only one facility to characterize supply chain disruptions associated with external influences and transportation corridors).

- Decide on a top-down versus a bottom-up approach based on the scale and scope of your assessment. The larger the geographic scope, the more likely a top-down approach could produce insights and information across systems or sectors providing strong breadth.
- Select a time frame that aligns with the systems or sectors being assessed, and the implications of climate-informed decisions (e.g., infrastructure lifespans, planning and policy horizons can be used as a reference point in collaboration with climate and sector experts to decide on appropriate timeframes).
- Confirm the specific target audiences for each product to minimize re-iterations and to ensure plain language communication is used where needed.

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5.0 Job Aid: Identifying and Analyzing Climate Variables

5.1 Job Aid in Brief

The Problem: Climate variables are the main drivers of risk in climate change risk assessments. Not all climate variables are relevant in all cases. Focusing on the irrelevant climate variables can lead to inefficiencies and poor characterization of risk.

The Solution: Climate variables should be considered from a range of sources and chosen based on significance and prominence to your geographic context. Consider what climate variables could cause impacts and include as many as possible to robustly characterize risks. The variables can then be incorporated into the climate change risk assessment as the likelihood component through calculations of climate change variable frequency.

The Way Forward: Identifying priority climate variables can be done in collaboration with stakeholders and Rights Holders who are most knowledgeable about local changes in climate. Data and information can stem from historical climate datasets, Traditional Ecological Knowledge (TEK), case studies, and climate models. The variables are analyzed for long term trends or frequency and integrated into a risk assessment. In some cases, variables can be mathematically combined to create indices that drive impacts.

The Benefits: Investing time upfront to identify and analyze variables that are most relevant to the assessment context will ensure that the assessment is capturing the main drivers of impacts and that there is robust knowledge of how climate is changing and is projected to change. This will focus adaptation planning and implementation.

The Steps:

Step 1 – Identifying Climate Variables

Step 2 – Determining the Types of Information Needed to Analyze Climate Variables

Step 3 – Integrating Climate Variable Information into the Risk Assessment

5.2 Overview

As climate change continues to progress, the need to assess and manage climate-related risks also grows in importance (Smith et al., 2022). Identifying and analyzing climate variables is one key component of climate-related risk. In the context of climate change, a variable usually refers to physical events or their physical impacts, with the potential for harm (ISO, 2019). Climate variables include changes in average and extreme temperatures, precipitation amount and type, and climate extremes such as droughts and wildfires. Climate change risk assessments, including this PCCIA, often tailor definitions of climate variables to correspond to the goals of the initiative. For example, the PCCIA defined climate variables as changes in climate events or stressors that have the potential to cause harm or bring benefits (PCCIA Methodology Framework). This definition recognizes that climate variables may also lead to "upside risks" or opportunities, such as enhanced crop yields in a lengthened growing season. Climate variables are the main sources or drivers of climate change risk to a population, place, ecosystem, asset, or service that is sensitive to climate variation. Therefore, identifying climate variables for the risk assessment and characterizing them in terms of, for example, frequency of occurrence, geographic and temporal variation, allows for examination of the resulting impacts and consequences (PCCIA Methodology Framework).

This Job Aid (1) helps users understand the process of identifying climate variables that are most relevant for their risk assessment efforts, and (2) describes how climate variables can be analyzed to inform the risk assessment.

5.3 Key Questions

- What types of climate information are needed?
- How to select climate variables, including event-based and slow onset variables?
- How to determine the frequency of climate variables?

5.4 Guidance for Implementation

Step 1 – Identifying Climate Variables:

Climate variables should provide adequate representation of the impacts to vulnerable people, ecosystems, places, assets, or services within the risk assessment's focus areas (PCCIA Methodology Framework, US Climate Resilience Toolkit). Climate variables should be relevant to the jurisdiction or system being assessed, and ideally applicable across many sectors or systems (OCAAF, 2017). A good place to start is to review literature and records on current climate system and conditions and consider the types of climate and weather-related events that have happened in the past, and events and gradual changes that are projected to occur in the future (US Climate Resilience Toolkit, Ouranos 2016). Information to support this step includes historical climate data, climate change projections, climate event data, scientific papers, factsheets and case studies, and local and Traditional Knowledge (WorldFish 2013, Livingston 2022). Be mindful of how older studies have generated and treated climate variables and seek most recent data and other sources of information. Also give consideration to climate variables within a larger system and how climate variables may interact with one another to create unique events and impacts. Comparing climate records with local stories and experiences of significant events can help to identify a robust set of climate variables to include in the assessment (WorldFish 2013).

Identifying climate variables will usually require input from many stakeholders, Rights Holders, or team members who can offer different perspectives across the risk assessment's Areas of Focus. Workshops are commonly used as a means of generating information about potential variables and allow for many different perspectives and experiences (WorldFish 2013). Broader community visioning events that seek input on areas of expansion or growth can also solicit the potential impacts of climate change and thus identify climate variables that are most relevant to growth (WorldFish 2013).

For the PCCIA, selecting climate variables involved iterative engagement of an internal project technical team and an inter-ministerial advisory committee. Climate variables were chosen based on their 1) representativeness of as many impacts across the risk assessment's Areas of Focus; 2) potential for greatest impacts (positive or negative) on the Areas of Focus; 3) expected changes from current, to short (2050s), or long (2080s) timeframes; and 4) level of certainty associated with future projections. The 15 climate variables chosen for the PCCIA were represented across eight climate variable groups: High Temperatures, Temperature, Precipitation, Winter Precipitation, Extreme Precipitation, Low Temperature, Drought, and Wildfire.

PCCIA Application: The list of the PCCIA's 15 climate variables and their relevance to each Area of Focus included in the risk assessment can serve as a starting point for organizations and communities setting out to undertake a climate change risk assessment. This information is available in Section 2.0 of the PCCIA Technical Report. The section also provides context for the identification of the climate variables, which hinges mainly on their relevance for the scale and scope of the PCCIA, and iterative engagement with many different stakeholders.

Step 2 – Determining the Types of Information Needed to Analyze Climate Variables:

Broadly, climate information can include sources like fact sheets, briefing notes, case studies, and reports (Livingston 2022). Climate data may refer to more specific quantitative sources such as observed historical data, simulated historical data, and projected data in both tabular and spatial (i.e., values on maps) formats (Livingston 2022). Climate data is typically collected via weather stations, or available as outputs of climate modelling efforts. A large amount of climate information and data is available online through web portals. The online resources often contain datasets, training resources, tailored products, maps, worksheets, and links to subsequent resources that give additional context for interpretation and application (Clunas 2022). Some notable Canadian data portals include ClimateData.ca, the Ontario Climate Data Portal, The Canadian Centre for Climate Services, and the Climate Atlas (Zhu et al. 2020, Livingston 2022). See Section 3.0 of the PCCIA Technical Report for more information on the climate variables and climate data used in the assessment.

The types, formats, and level of detail of climate information to characterize climate variables should match the scope of the risk assessment and resources available. Cautions and guiding principles to consider when beginning to collect and work with climate information are as follows (Ouranos 2016):

- Basic climate information can be just as useful as detailed information, in the case of qualitative or semi-quantitative risk assessments.
- Fine-scale resolution is not always better than coarse-scale resolution.
- Always consider a range of results in model outputs (not just the mean or median results).
- Use outputs from an ensemble of multiple models.
- Understanding sources of uncertainty in data and information.
- For each climate variable, clarify the temporal and spatial resolution required, the climate variables of interest and the climate statistics of most relevance.

Step 3 – Integrating Climate Variable Information into the Risk Assessment:

Although human-caused climate change is unequivocal, levels of certainty vary for future change including the occurrence of extreme weather events. A way to express this uncertainty and account for it in risk assessments is by using a measure of climate variable frequency. Climate variables can be either discrete events of a particular frequency or magnitude (e.g., amount of rainfall in one day) or they can be continuous events with an associated impact threshold pertaining to exposed people, places, assets, or services over a period of time (e.g., average seasonal precipitation) (PCCIA Methodology Framework).

One way of characterizing the frequency of a variable is to apply a score that represents the number of occurrences of a climate variable per unit of time. The PCCIA methodology assigns a score from 1 to 16, with a baseline score of 4, for each climate variable based on whether that variable is increasing or decreasing in frequency (number of days, degrees, millimeters, etc.) relative to baseline conditions (such as a historic 30-year average) (PCCIA Methodology Framework). A threshold for a frequency score may change depending on the system exposed to the climate variable (see Job Aid 4 on "Assessing Exposure to Climate Variables"), with related decisions informed by expert feedback, and literature review; this is important because a variable in one area of focus may be more or less impactful than the same variable in a different area of focus (PCCIA Methodology Framework). **Table 5-1** below provides a visual representation of this scoring method.

Table 5-1: Visual representation on the scoring criteria to characterize the frequency of climate variables in the PCCIA (Source: PCCIA Technical Report).

Frequency / Probability Score	Category	Definition
16	**Significant Negative**	+2.5 standard deviations
8	**Slight Negative**	+1.5 standard deviation
4	**Baseline**	Baseline
2	**Slight Positive**	
1	**Significant Positive**	

Other ways to integrate climate variable occurrence into risk and vulnerability assessment include using a specific climate variable scenario as the basis for risk assessment (PEI, 2021) and integrating climate information into indices and models that link climate variable occurrence to impact (see the Case Study in this Job Aid).

The depth and rigor of the assessment, as well as the objectives at hand, will determine whether the climate change risk assessment requires deeper analysis of the climate variable's association to impact (using thresholds) or whether a more qualitative approach will suffice (Smith et al. 2022). Certainty that is well characterized can be adequately represented in a single probability distribution and linked to a narrow definition of risk. However, increased uncertainty arises when decision-makers do not know or cannot agree upon how actions relate to consequences, probability distributions to use in models, or which consequences to consider as well as their importance (Smith et al. 2022). Therefore, understanding whether uncertainties are well-characterized or deep can influence the utilized risk assessment process (Smith et al. 2022). For example, risks may be well-characterized for a particular, sector, timescale, region, or organization, resulting in less uncertainty. Conversely, risk assessments that consider vast interactions between many sectors and systems are likely associated with greater uncertainty (Smith et al. 2022).

5.5 Risk Assessment in Action

Case Study 4: Climate Change Vulnerability Assessment for Aquatic Ecosystems in the Mississippi and Rideau Conservation Authority Watersheds

Year: 2014 **Focus**: Natural Environment

Link: Climate Change Vulnerability Assessment for Aquatic Ecosystems in the Mississippi and Rideau Conservation Authority Watersheds

Context: This case study represents a collaborative effort between several agencies including the Mississippi Valley and Rideau Valley Conservation Authorities (MVCA, RVCA), the Ontario Ministry of Natural Resources (OMNR) and other organizations and individuals concerned with the effects of climate change on the natural assets of eastern Ontario. The objectives of this study were to utilize indicators to assess the vulnerability of aquatic ecosystems to inform the development of a climate change adaptation strategy for the Mississippi-Rideau region. The study also made recommendations on new approaches and existing programs that could be used to address uncertainties and knowledge gaps and how to integrate these into new and future climate change initiatives.

Approach to Risk Assessment and Use of Data

Consultations with project partners (OMNR, MVCA and RVCA) led to the identification of four ecological indicators: 1) wetland vulnerability, 2) habitat availability for wetland-dependent bird species, 3) stream temperatures and change in temperatures throughout the region, and 4) maximum lake surface temperatures.

These indicators reflect the state of aquatic ecosystems within the Mississippi-Rideau watersheds and build on previous climate change assessments in the region. The indicators represent measures that can be used to quantify the sensitivity of each system to climate change, inform adaptation actions and strategies for each ecosystem component and point to possible improvements to regional monitoring and planning programs. Existing empirical models (Neff et al., 2005; Mortsch et al., 2006; Sharma et al., 2007; Moore et al., 2013) were adapted to relate the ecosystem indicators to climate. Seamless coverages of mean annual, maximum annual, and mean July air temperature as well as total precipitation in the growing season (McKenney et al. 2006; Lalonde et al. 2012) were used calculate and assess indicator baseline change (1970 to 2000) and projections of future change in two time periods (2050s and 2080s).

Figure 5-1: Aquatic Habitat.

Image Source: Photo by Ross Dunn, used under Flickr creative commons license

Wetland vulnerability, defined as degraded quality or loss due to drying, was assessed using projected mean air temperature and total precipitation during the growing season (April to September) and groundwater discharge potential. These variables were selected because changes in any one affect the water budget of the wetland systems.

Hydrological Vulnerability Index (HVI) was used to assess present and future habitat availability for wetland-dependent bird species using characteristics such as marsh dependency, nesting habitat, nest location and foraging habitat (Mortsch et al., 2006). The American Coot (Fulica americana), which is sensitive to changes in wetland habitats, and is widely distributed throughout the study region was included as a representative species in these analyses.

To predict temperatures in streams, maximum air temperature, groundwater discharge, elevation range and stream order of different segments of the tributaries were used in an empirical model of Maximum Weekly Average Stream Temperature (MWAT) (adapted from Moore et al., 2013). Selection was based on the fact that MWAT is linked to fish species distributions and can quantify the hottest and potentially biologically limiting conditions in streams (Wehrly et al. 2009; Moore et al. 2013).

Maximum surface lake temperatures were used as an indicator of the potential impacts of climate change on lake ecosystems. Current and future mean July and mean annual air temperatures were calculated for each lake, with maximum surface temperatures in lakes predicted using an existing model developed by Sharma et al. (2007) for Canadian lakes. Parameters including maximum surface temperature, mean July temperature, mean annual air temperature, day of the year, longitude (the location the lake centroid), and a coefficient describing the interannual variability were used in calculations. Monitoring data from the study area were used to validate the predictions.

How Results Influenced Decision-Making

Results of the assessment helped identify areas of vulnerability in waterbodies within the study area watersheds, prioritize adaptation needs, and develop monitoring programs to measure adaptation success and determine changes in existing vulnerabilities.

Recommendations were proposed to address and manage uncertainties and knowledge gaps and integrate the results into future climate change initiatives. Since many of the aquatic ecosystems within the region are already under stress due to anthropogenic activities, initiating proposed responses as soon as possible was strongly encouraged. A cumulative effects approach that allows researchers and practitioners to assess the impacts of both climatic and non-climatic stressors on aquatic resources was also proposed.

Key Lessons from this Case Study

Climate and other biological indicators can be combined to advance an understanding of changing vulnerabilities and impacts to aquatic systems. Evidence-based assessment and planning provides a methodical approach to arrive at adaptive measures to improve watershed resilience. Supportive adaptation considerations should be integrated into policy and processes at all levels, from provincial to municipal, and in all associated sectors and inform future climate change assessments within the watershed.

5.6 Key Takeaways

- Invest time upfront identifying priority variable(s) that may inform the types of climate information needed. Based on assessment scope and budget, identify climate variables to adequately characterize impacts and understand levels of certainty.
- Select climate variables that are relevant to the jurisdiction or system being assessed. In a multi-sectoral assessment, consider climate variables that are applicable across several sectors or systems in addition to those that are critical for certain sectors.
- Use international standards (e.g., Intergovernmental Panel on Climate Change, International Organization for Standardization) and frameworks (e.g., PIEVC), and consult among experts to determine the best approach in determining climate variable frequency and conducting climate change analysis. Depending on the scope and system being

assessed, detailed and quantitative frequency analysis may be necessary in order to fully understand risks from extremes or in systems or sectors where impacts can be severe.

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6.0 Job Aid: Assessing Exposure to Climate Variables

Job Aid in Brief

The Problem: Although human-caused climate change is unequivocal, accurately projecting the timing and location of specific climate change events and impacts is challenging and carries uncertainty.

The Solution: Exposure analysis is a systematic approach to clarify the significance of each climate variable relative to populations, ecosystems, assets, and services to people.

The Way Forward: Exposure analysis is accomplished by cross-referencing each valued element with a climate variable, characterizing how climate variables could lead to impacts, assessing, monitoring and re-evaluating the results over time. Literature review, data overlays and discussion with key experts, stakeholders, and rights holders inform this exercise.

The Benefits: By assessing exposure to climate variables, you can understand what populations, ecosystems, assets, or services within your system of interest could be most susceptible to climate change impacts and why, orienting adaptation efforts.

The Steps:

Step 1 – Assessing Exposure to Each Climate Variable

Step 2 – Characterizing Exposure Scenarios

Step 3 – Evaluation, Monitoring and Reassessment

6.1 Overview

Exposure is the degree to which a climate variable will affect the valued components or elements within a system of interest and is common to risk assessment approaches. Exposure has strong spatial and temporal dimensions, which vary by location based on climate projections or other climate patterns. This aspect of risk assessment helps to understand who or what may be facing the most likely and consequential impacts of climate change and assists with prioritizing risk management and adaptation interventions that are tailored to local conditions.

To conduct an exposure assessment, we need to identify and analyze the interaction between climate variables and populations, places, ecosystems, assets, or services of interest that may be sensitive to climate variation (**Figure 6-1**). Considering the effects of cascading and interacting climate variables and impacts is also important. Both quantitative and qualitative research are relevant for this analysis.

Figure 6-1: Elements influencing exposure to climate variables.

Image Source: UNDRR, 2022

This Job Aid helps users understand which climate variables present the greatest degree of impact to the components or focal elements of the climate change risk assessment.

6.2 Key Questions

- What types of data, information and knowledge sources will be used?
- How can climate thresholds be used to characterize exposure scenarios?
- How to represent interacting climate variables?

6.3 Guidance for Implementation

Step 1 – Assessing Exposure to Each Climate Variable:

Once relevant climate variables are established, research is required to determine the degree to which the valued elements are exposed to each variable. It is essential to recognize that the severity of the impact will vary depending on the valued element and the focal theme. For instance, compared to manufacturing, industries such as forestry, fishing, and hunting, have a higher degree of exposure due to their reliance on natural resources which are highly exposed to climate change, ultimately making them more susceptible to risks from climate change (PCCIA Technical Report).

Accurate estimation of exposure requires a combination of quantitative and qualitative data. Quantitative data to support exposure analysis is primarily obtained through climate models. However, there will also be quantitative data on the distribution and density of assets and activities related to different focal themes in spatial datasets (e.g., distribution of hunting lodges, hospitals, agricultural lands, etc.) that will overlap with climate models. These datasets are obtained from international, national, provincial, local, and organizational data repositories (e.g., Statistics Canada, Government of Ontario open data portal, regulatory authorities, Conservation Authorities and climate services). For example, the buildings sector module of Climate Data provides easy access to building-relevant climate datasets, information, guidance, and case studies demonstrating the use of climate data in adaptation efforts for the Canadian building sector. Open access sources provide a leg up in identifying foundational data required to conduct a risk assessment. Therefore, data sharing and transparency in data use are valuable practices in climate change risk assessment. Where data is not available, related proxy indicators may sometimes be used (UNDRR 2022).

Another way to obtain semi-quantitative or qualitative data on exposure is through elicitation of subject matter experts and public participatory exercises. For example, participatory GIS exercises can be used to both ground truth spatial datasets and expand the understanding of where the activities and assets in each focal theme are occurring relative to climate variables and qualitative assessments of how exposure might vary by location (Bitsura-Meszaros et al. 2019). Additional qualitative data can be obtained from stakeholder input via surveys, group discussions, expert experience, and literature review (PCCIA Methodology Framework). When planning to collect information through participatory methods, it is critical to explicitly consider how best to engage with different communities to capture and incorporate Indigenous and local knowledge through the risk assessment process. Some of this knowledge is publicly accessible through web portals (e.g., the Indigenous Knowledge section of the Climate Atlas of Canada) or collaborative research publications (e.g., Golden et al. 2014, Menzies et al. 2022), but must be complemented through a community engagement process specific to the context of a given risk assessment and at the discretion of the Indigenous group or Community.

When researching exposure to a climate variable, you can consider which assets, demographics, livelihoods, and services are most exposed to climate events and projections (US Climate Resilience Toolkit 2022). The PCCIA Methodology uses a matrix to document overlap between climate variables and valued elements pertaining to infrastructure, food and agriculture, the natural environment, business and economy, and people and communities. It is common to list the climate variables along the top of the matrix and list the thematic focus (broken down into constituent categories or valued elements) down the side of the matrix as a first iteration, even if it does not fully capture the nuances present within each geographic region (PCCIA Methodology Framework).

It is crucial to consider how populations, activities, assets and services might be impacted by a climate variable (ISO, 2019) and how interacting climate variables affect each other leading to cascading impacts, and also how exposure to climate variables might change over time. According to ISO 14090, both slow-onset and sudden impacts need to be included for this sub-step of the assessment, each of which may have direct and indirect effects on the organization (2019). For instance, certain climate variables indirectly affect within-organization activities like employee health and safety, assets and business disruption, and cause infrastructure damage (ISO, 2019). In addition, exposure is considered a highly dynamic risk factor and can change over time as, for example, populations grow and migrate, community development expands into floodplains, and disasters linked to natural hazards reshape the landscape. One example of exposure analysis is contained in the climate risk matrices for electricity transmission and distribution and commercial real estate sectors developed by the Intact Centre to integrate climate change risk into financial valuation (Feltmate et al. 2020).

Step 2 – Characterizing Exposure Scenarios:

The next step is to conduct a threshold analysis to characterize different exposure scenarios. According to ISO 14090, a threshold analysis begins by describing the system, defining the problem, identifying the objectives and constraints, and setting the system boundaries (2019). Once established, research is required to determine the potential climate variables affecting the system (or valued element), projected outcomes, and the associated uncertainty. The relevant thresholds are then determined to understand at which point the system can no longer be effective because of the climate variable. In this way, thresholds are associated with tipping points that may significantly increase the likelihood of severe consequences and can lead to cascading impacts (UNDRR 2022; Simpson et al. 2021) (see Job Aid 5 on "Considering Cascading and Cross-Cutting Impacts" for more information). For a detailed description of a threshold analysis, see ISO 14090.

PCCIA Application: The PCCIA used the concept of "Most Probable Worse-Case Events (MPWCE)" to specify scenarios where the interaction between a climate variable and a Level 1 or 2 category could lead to consequential impacts (**Table 6-1**). A key step in specifying these MPWCEs was to identify in the literature and document climate thresholds pertaining a range of different elements (e.g., species, assets, economic activity, human populations) and involving one of the 15 climate variables that the PCCIA focused on. The PCCIA Technical Report summarizes these risk scenarios for practitioners to examine and isolate cases relevant to their study.

Step 3 – Evaluation, Monitoring and Reassessment:

Exposure analysis needs to be documented and reassessed over time to maintain an accurate understanding of the potential vulnerability of the focal theme. Reassessments can reflect changes within an organization or community, changing environmental or other external influences, and evolving climate change knowledge and information (ISO, 2019). Updates to our understanding of exposure can lead to changes in adaptation priorities.

Table 6-1: Assessing Exposure to Climate Variables used in the PCCIA and an example Level 1 outcome within Food and Agriculture Area of Focus. For more information see Section 5.0 Food and Agriculture of the PCCIA Technical Report.

Exposure to Climate	Exposure to Climate Variable Level Details
Assessing Exposure to Climate Variables in the PCCIA	In the PCCIA Most Probable Worst-Case Event otherwise references as 'risk scenario' considers the most severe possible outcome that can reasonably be expected to occur based on a specific interaction between the climate variable and a Level 1 or Level 2 category. The MPWCE is a conservative risk estimate in order to provide latitude for adaptation planning purposes to reduce risk.
Assessing Exposure to Climate Variables in the Food and Agriculture Area of Focus	The Food and Agriculture Area of Focus was divided into three Level 1 and sixteen Level 2 categories to capture major primary agricultural production systems in Ontario. All commodities across each region are expected to experience some level of increased risk from current levels to the end-of-century, exacerbated or influenced by projected changes in climate variables, socio-economic projections, regional considerations, and production values/exposed losses. The most prominent climate variables driving risks in this Area of Focus include Extreme Hot Days, Degree Days <0°C and Moisture Deficit/Drought.
Assessing Exposure to Climate Variables Outcome in Food and Agriculture	There were 924 unique climate risk scenarios that were identified and subjected to quantitative assessment in this Area of Focus. Direct variables interact with field crop, fruit, vegetable, and livestock production resulting in damage to plants, yield loss and compromised animal development and reproduction among other impacts. Indirect impacts stem from climate variables interacting with pests and diseases, soil and water resources as well as infrastructure critical for crop and livestock production.

An example of assessing exposure to climate variables within the PCCIA Food and Agriculture Area of Focus is:

> This assessment identified extreme temperatures, drought conditions and low temperatures as the main drivers of direct risks to livestock production (Level 1 category), with regional differences contributing consequential impacts. Livestock are also affected by the changing climate indirectly, through impacts on pasture, forages, and water supply as well as farm infrastructure. Indirect impacts associated with climate conditions were reported on qualitatively.

6.4 Risk Assessment in Action

Case Study 5: Climate Change Vulnerability Assessment of Ontario's Electrical Transmission Sector

Year: 2015 **Focus:** Infrastructure

Link: Climate Change Vulnerability Assessment of Ontario's Electrical Transmission Sector

Context: Since 2009, Ontario Indigenous communities, stakeholders, academics and experts had identified the need to understand the reliability of the province's electrical supply and recommended a climate change risk assessment be conducted. Developed based upon these recommendations, this case study was completed between 2013 and 2015, overseen by staff of the Ontario Power Authority, since amalgamated with Ontario's Independent Electricity System Operator (IESO). The main study components were: (1) a screening-level climate change and engineering vulnerability assessment of a major electrical transmission station in southern Ontario, including high voltage electrical transmission components within the station and major high-voltage circuits into and out of the station; and, (2) an evaluation of the types of adaptation measures that could be used to help manage severe weather and climate change-related risks across a broader set of transmission system segments. Technical work was completed by Nodelcorp Consulting, Risk Sciences International and staff at the Toronto and Region Conservation Authority (TRCA).

Figure 6-2: Storm damage to electrical transmission lines.

Image Source: Photo by Caddie Brain used under creative commons license

Approach to Risk Assessment and Use of Data:

The Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol was used to scope the risk assessment, which involved five main components (illustrated below).

Using this approach, infrastructure components were identified to assess the extent of exposure to climate variables. As an example, components included: 500kV and 230kV transmission towers, conductors, insulators, tower arms, breakers, drainage elements, among others. Climate parameters were then developed based upon relevant infrastructure thresholds within scope of the case study and based on available climate model data. Ice storms of varying magnitudes/thresholds (25 mm, 29 mm, 50 mm); EF2+ tornados, extreme temperatures of various thresholds, high intensity winds, and short-duration rainfall events (>100 mm) were included.

Expert deliberation informed by targeted forensic investigation (of past relevant electrical system failures) and reviews of relevant engineering climatology- and climate design-related literature allowed for the pairing of infrastructure components with relevant climate variables and performance thresholds. Current and projected likelihood of occurrence for each climate performance thresholds. Current and projected likelihood of occurrence for each climate parameter was estimated. Likelihood and consequences were ranked to estimate risks, using the PIEVC process.

Steps in application of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol:

Case study selection

- Development of criteria for identifying the priority segments of Ontario's transmission system for a climate risk and vulnerability assessment.
- Application of criteria through weighted decision analysis to select case study.

Case study definition

- Refining the system elements to be included, the range of climate-related hazards for consideration.
- Confirming the spatial and temporal scales proposed for the assessment.

Climate information

- Consolidating and, as necessary and possible, deriving new climate data and impact information tailored to the requirements of the assessment.
- Developing relevant electricity infrastructure response threshold values.

Assessment and adaptation options

- Characterization and ranking of climate change risks to the case study transmission systems.
- Multi-criteria analysis of adaptation options through PIEVC Triple Bottom Line Module to determine suitability of potential risk management measures to other comparable segments of the Ontario grid.

How Results Influenced Decision-Making

A total of 667 infrastructure component-climate variable interactions were assessed, with results indicating four high risks, 397 medium risks, 266 low risks and 85 special cases. The assessed segment of the Ontario electrical system was determined to have considerable built-in redundancy, including twinned circuits, and alternative circuits feeding common switching stations. Considering these design elements, and existing maintenance and operational procedures, it was determined that in most cases (notably excluding the special cases), severe climate events could cause inconvenience and increased maintenance requirements but would not be likely to significantly affect the delivery of service.

Risk assessment results were used to develop recommendations for consideration by staff involved in policy, engineering, and operational development of Ontario's electricity grid. Main recommendations included:

1. Monitoring the frequency and impact of high wind events and ice storm events
2. Surveying transmission system-transportation system crossings
3. Conducting additional forensic analysis of certain infrastructure components such as four-wire bundles

Key Lessons from this Case Study: Several lessons learned are identified based on the completion of this case study. The knowledge of industry experts regarding physical characteristics and operation practices of infrastructure may not be reflected in literature or documentation and it is, therefore, paramount to consult with them to better understand and assess climate vulnerabilities. Lack of long-term historical climate information within the immediate vicinity of electrical infrastructure was a limitation to assessing exposure. Expanded monitoring that includes climate conditions directly relevant to transmission infrastructure, particularly “small scale, high impact”, and cascading impacts could benefit adaptation options. Forensic analyses and information (e.g., "breaking thresholds" identified through analysis of in-field infrastructure performance) could be built on in future climate change risk assessments on infrastructure.

6.5 Key Takeaways

- Begin by creating a longer (ideal) list of data – both quantitative and qualitative – to inform the assessment. For example, will modeled floodplain mapping be important to identify exposure to infrastructure elements?
- Undertake literature review and engagement with experts to identify how climate variables could lead to impacts on the systems, and rationale for whether a system or element is exposed to climate variables.
- Evaluate the extent to which thresholds are available and known for the system being assessed. Consider sources such as: professional judgment, codes and standards, oral history, engagement among knowledge holders, etc. Other sources include risk registers from projects such as the PCCIA, which includes hundreds of exposure scenarios that practitioners can examine for relevance.
- Develop criteria that are relevant to the system or sector to inform the extent to which it may be exposed (e.g., low lying areas, proximity to sources of contamination, etc.) or undertake modeling such as flood modeling, heat island mapping via satellite imagery, etc.

6.6 References and Resources

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7.0 Job Aid: Considering Cascading and Cross-Cutting Impacts & Risks

7.1 Job Aid in Brief

The Problem: The far-reaching nature of many climate variables and their complex interactions with natural and human systems mean that risks and impacts can ripple across interconnected sectors in ways not always accounted for in adaptation planning.

The Solution: Explicitly identifying and considering the consequences of cross-cutting risks can help to "stress-test" a multi-sectoral system of interest and identify weak links or points of likely failure to strengthen through adaptation measures.

The Way Forward: Cross-cutting risks can be addressed by first defining the cross-sectoral system of interest, mapping interactions among climate variables and components of the system, quantifying the level of risk and impacts across the system, and focusing on key vulnerabilities for adaptation planning for collaborative risk reduction.

The Benefits: By identifying and addressing key vulnerabilities in critical cross-sectoral systems like energy grids, food supply chains, or the health care system, decision-makers can increase the resilience of the overall system to reduce the risk of catastrophic and cascading failures.

The Steps:

Step 1 – Defining the System

Step 2 – Mapping Interaction Mechanisms

Step 3 – Quantifying Interactions

Step 4 – Identifying Key Vulnerabilities and Evaluating Adaptation Opportunities

7.2 Overview

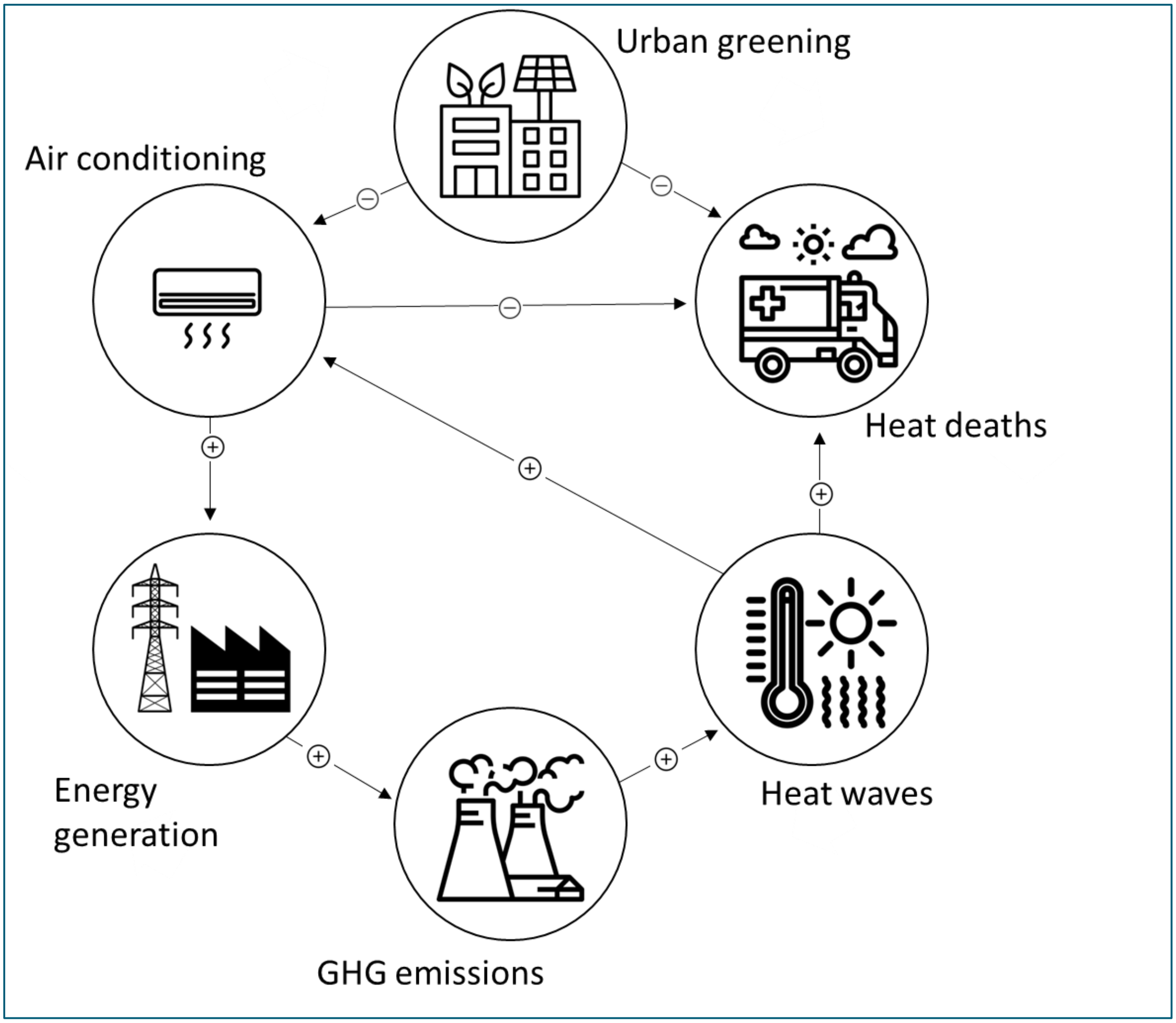
Climate change risk assessments typically focus on assessing risks of individual components within individual sectors or Areas of Focus, often leaving out risks related to interactions among components. This can lead to blind spots for strategies designed to improve climate resilience. The spectrum of climate and non-climate drivers of risk, their range of spatial and temporal scales, and their intersection with socio-ecological systems gives rise to complex risks that must be accounted for in risk assessments to develop more effective climate solutions (Dawson et al., 2015; Challinor et al., 2018; Simpson et al., 2021; ISO, 2020; PCCIA Methodology Framework Report). Through such complex risks spanning more than one sector or area of focus, climate change has the potential to disrupt complex systems by interrupting or altering existing interdependencies, or by creating new ones, in ways that modify the nature, consequence, and likelihood of climate risks relative to analyses where interactions are ignored. Six key dimensions of interdependencies merit consideration (e.g., Dawson et al. 2015, Simpson et al. 2021).

- **Functional**: where one system is connected to and relies on inputs or services from another to operate (e.g., permeability of vegetated watersheds shaping risk of stormwater management infrastructure).
- **Physical**: where systems interact through physical processes such as river flows or shared infrastructure with similar constraints (e.g., shared impacts from climate-related disruptions to infrastructure services).
- **Spatio-temporal**: where proximity or connectedness across space or time leads to similar responses across systems (e.g., risk resulting from exposure of assets and people to a large flood event).
- **Economic**: where shared markets, supply and demand for resources or services, and budgetary constraints of end users across regions or provinces create similar financial pressures (e.g., where supply-chain effects increasing the price of fuel have far-reaching impacts on the transportation sector and consumer behaviour).
- **Institutional**: where a shared regime, policy, or regulation applying to multiple systems, regions, or provinces creates similar constraints on system behaviour (e.g., requirements of publicly listed companies to disclose physical climate risks).
- **Social**: where interactions between members of a community that interact with multiple sectors act as a bridge across sectors to communicate and respond to risks. (e.g., social networks that spread good practice to manage climate risks).

These interactions may create both cascading impacts, where the risks of a single climate variable on one component of the system triggers other risks or impacts across multiple levels and components of a system in a ‘domino effect’, as well as cumulative risks, where the risks of multiple cascading climate variables converge on a single component of the system and interact in complex ways which may amplify overall risk (Mora et al. 2018, Simpson et al. 2021). In addition to assessing risks caused by climate change itself, interconnected risks arising from measures to adapt to climate change and reduce greenhouse gas emissions should also be considered as part of adaptation planning (**Figure 7-1**) (Van Vliet et al. 2020, Simpson et al. 2021, Sillmann et al. 2022).

This Job Aid provides guidance on how to identify and assess cross-cutting risks and use the results of this analysis to guide adaptation planning.

Figure 7-1: An example of how cross-cutting and cascading impacts apply to climate change adaptation interventions for extreme heat.



Adapted from: Simpson et al., 2021

7.3 Key Questions

- How to identify cascading and cross-cutting impacts and risks?
- How to identify promising levers for adaptation solutions/decision-making at the systems level?

7.4 Guidance for Implementation

Step 1 – Defining the System:

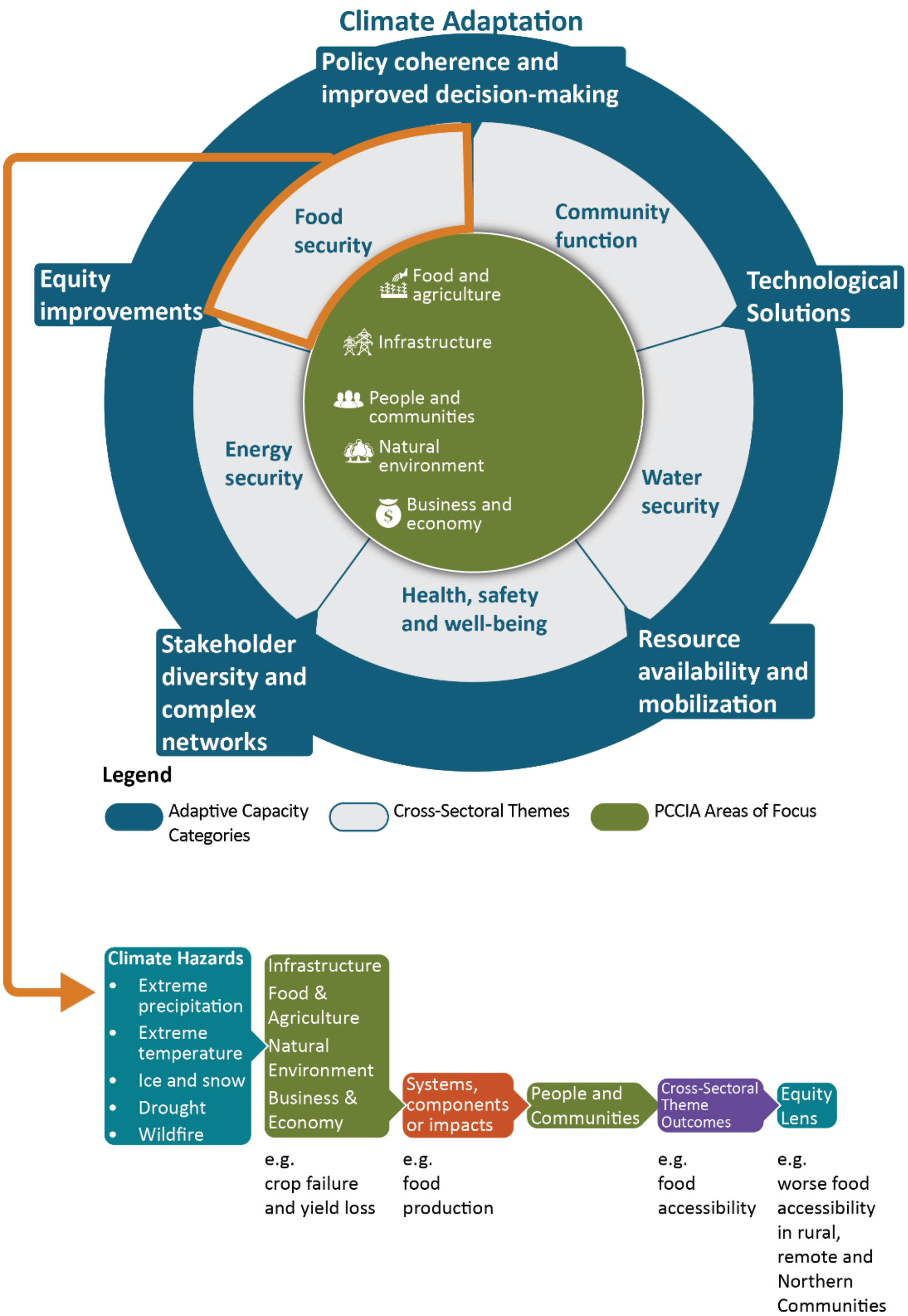
Consideration of cross-cutting risks begins with identifying one or more defined systems including components or processes spanning multiple Areas of Focus (**Table 7-1**), as well as the appropriate spatial or temporal scale of analysis to bound this element of the risk assessment. In the PCCIA process, examination of cross-sectoral impacts focused on the analysis of five cross-sectoral system themes (**Figure 7-2**), some of which were identified at the beginning of the risk assessment process and some of which emerged through risk assessment work on individual Areas of Focus. It is also important to define what types of interactions will be considered.

PCCIA Application: The PCCIA approach to cross-cutting impacts considered cascading impacts of climate variables from one Area of Focus to another as well as indirect connections between system components within Ontario and constrained the analysis of cross-cutting impacts to those that directly affect People and Communities (PCCIA Technical Report).

It is also possible to conduct a more complex analysis that explicitly considers interactions among determinants of risk (climate and non-climate) as well as between multiple risks at multiple spatial and temporal scales (Simpson et al. 2021), including external risks from interprovincial and global social and market forces such as changes in tourism, migration, supply and demand, and commodity prices (Surminski et al. 2018).

In addition to the broader climate variable and socioeconomic scenarios identified in an earlier step of the risk assessment process (see Job Aid 2 on "Scoping"), it may be useful to define more detailed scenarios or "storylines" specific to the cross-cutting context. Scenario and storyline approaches can be particularly useful when uncertainty is high, as is often the case for complex climate change risks likely to involve data gaps, unknown interactions and tipping points across the system examined (Simpson et al. 2021). In these cases, context-specific storylines can help managers to explore the consequences of more unlikely but plausible outcomes to "stress-test" the cross-cutting system of interest given a specific set of assumptions and surface potential weak links or points of likely failure to inform adaptation planning (Simpson et al. 2021, Sillmann et al. 2022). For example, a potential storyline providing the context for assessing cross-cutting risks to a municipal water supply might involve a backdrop of record population growth, an exceptional drought year, prior litigation that has limited the city's ability to develop additional water storage options, and time pressure from water-intensive industries planning to leave the area unless conditions improve (C40 Cities 2017). Exploration of these storyline scenarios can take the form of "serious games", where managers from different sectors are provided with a scenario and are asked to work together to identify systemic risks and solutions under pressure in response to a series of unexpected climate variable events to understand how these scenarios might drive system responses beyond traditional management expectations (Undorf et al 2020, Sillmann et al. 2022).

Figure 7-2: A conceptual framework outlining the interconnectedness between each Area of Focus and cross-sectoral themes (at left, including Water Security, Health Safety and Well-Being, Energy Security, Food Security, and Community Function), and an example of a climate influence or impact diagram for one of those cross-sectoral themes focused on health, safety, and well being (Source: PCCIA Technical Report – refer to the full report for larger, high-resolution risk map figures for this and other cross-sectoral themes).



Step 2 – Mapping Interaction Mechanisms:

Once the system has been defined, interactions among components must be identified and mapped or visualized. This is typically accomplished through the development of a conceptual model (a structured flowchart, also known as an impact diagram or chain, as used in the PCCIA) (**Figure 7-2**) or alternatively an interaction matrix (a structured table), based on cause-effect linkages that include all major factors and processes contributing to climate risk within a specific context. Several interactive tools are available for building and visualizing these conceptual models, including Gephi and Kumu.

The construction of the models is typically informed by literature review, expert elicitation, and participatory engagement to allow for knowledge integration and to create a shared understanding of root causes and relationships (Simpson et al. 2021, Zebisch et al. 2022). This step can help to refine the scope of the exercise by retaining only those components and interactions within the broader system that are most relevant to the objectives of decision-makers using the risk assessment. In addition to their utility in the risk assessment process, impact chain diagrams serve as a useful tool for the communication of complex cause-effect relationships (Zebisch et al. 2022) and for identifying adaptation measures with the potential for broad-based applications.

Table 7-1: Considering Cascading and Cross-cutting Impacts and Risks and an example Level 1 outcome. For more information see Section 10.0 Cross Sectoral Considerations of the PCCIA Technical Report.

Cascading and Cross-cutting Impacts and Risks	Cascading and Cross-cutting Impacts and Risk Details
Considering Cascading and Cross-cutting Impacts and Risks in the PCCIA	The assessment of climate change impacts within each Areas of Focus led to the identification of themes that encompass more than one Area of Focus. There are interdependencies among the five Areas of Focus and therefore several impact pathways. Indirect and cascading impacts identified within each Area of Focus informed the components of the cross-sectoral analysis. Each theme conveys climate impacts relevant to Ontario.
Considering Cascading and Cross-cutting Impacts and Risks in Cross-Sectoral Considerations	A people-centric approach was applied to the analysis of each cross-sectoral theme, with impacts cascading through each Area of Focus, into the People and Communities Area of Focus. This approach illustrates how impacts under each cross-sectoral theme may ultimately pose risks to Ontario's people and communities.

Cascading and Cross-cutting Impacts and Risks	Cascading and Cross-cutting Impacts and Risk Details
Considering Cascading and Cross-cutting Impacts and Risks Outcome	Taking a people-centric approach enables a consistent framing of the cascading impacts across every Area of Focus, and was an important theme reflected in PCCIA results.

An example of the cascading and cross-cutting impacts and risks to water transmission under the Water Security Cross-Sectoral Theme, is:

> Direct and indirect impacts of climate change on water resources pose risks to water use and ultimately compromise water security for human health, livelihoods, and economic development in Ontario. Water transmission covers the delivery of clean water to businesses and communities and safe transport of sewer and stormwater to treatment facilities through water transmission pipelines. Disruptions to water transmission have direct implications for water security, especially water availability and quality.

Step 3 – Quantifying Interactions:

In some risk assessments, it may be desirable to quantify the magnitude of interactions and risks within the system using either qualitative (e.g., network properties like number of interaction inputs and outputs per node, or expert scoring of the magnitude of impact) or quantitative (e.g., indicator data, models) information, as well as the uncertainty in these assessments, depending on the level of data availability for different pathways (Zebisch et al. 2022). Using analytical techniques such as Bayesian Belief Networks through tools like OpenMarkov, it is also possible to assign a level of risk to each node in the network and trace how risk propagates through the system to evaluate the level of overall risk at the end of each chain of cascading impacts (WSP 2020).

In the business sector, standards indicate that quantifying risk encompasses the anticipated impacts of both climate variables and climate resilience expenditures on operations as well as financial valuation, share price performance, and credit ratings (DICO 2018, Feltmate et al. 2020). Guidance is now available for incorporating different types of climate-specific information on financial performance (e.g., trends in earnings or debt/equity ratio following an extreme weather event or the implementation of adaptation measures) into common existing valuation methods that can inform risk disclosure (Feltmate et al. 2020). Carrying out this exercise across organizations related to a cross-sectoral theme can help businesses to better understand how cross-cutting and cascading climate impacts may translate to compounding financial risks across supply chains and portfolios.

Quantifying interactions can be a data-intensive process and can be challenging for cross-sectoral risk assessments where some communities or sectors are willing to share data while others are not (e.g., in the interest of privacy, trade secrets, Indigenous data sovereignty, and other considerations), leading to an incomplete picture of cross-cutting risks (C40 Cities 2017). Data-sharing agreements can help to overcome these barriers by specifying which qualitative and quantitative data can be shared and how it can be used for mutual benefit (David-Chavez and Gavin 2018, Alexander et al. 2020), and emerging resources like the Indigenous Data Toolkit can help to provide useful guidelines for navigating this process.

Step 4 – Identifying Key Vulnerabilities and Evaluating Adaptation Opportunities:

Climate impact conceptual models can inform systems analysis and structured discussion to identify pathways, nodes, or specific assets and areas encompassed by these nodes that might represent critical sources of systemic risk to be addressed through adaptation interventions (Zebisch et al. 2022, Sillmann et al. 2022). In addition, quantitative information on the relative level of risk across different nodes can provide additional information to identify the most vulnerable parts of the system where risks overlap (e.g., which nodes are impacted by the largest number of upstream risks, which nodes have the highest number of downstream impacts, and which pathways represent the greatest overall level of risk?) (WSP 2020). This information can in turn help decision-makers prioritize among potential impact pathways measures to target the most vulnerable parts of the system, weigh the relative benefits of different adaptation measures by considering their performance across the full range of cascading impacts, and support proactive interventions to reduce the impact of future system shocks (Dawson et al. 2015, Zebisch et al. 2022, Sillmann et al. 2022).

7.5 Risk Assessment in Action

Case Study 6: Resilient Food Systems, Resilient Cities: A High-Level Vulnerability Assessment of Toronto’s Food System

Year: 2018 **Focus:** People and Communities; Food and Agriculture

Link: Resilient Food Systems, Resilient Cities: A High-Level Vulnerability Assessment of Toronto’s Food System (2018)

Context: In 2018, Toronto Public Health commissioned a vulnerability assessment of Toronto’s Food System. The purpose of this study was to identify the most significant risks climate change would pose to food distribution and access within Toronto and make recommendations that would increase the resilience of the City's food system (Zeuli et al.

2018). The assessment identified interactions among system components and cascading impacts that could affect Toronto's food system, including failures across several sectors such as energy, transportation and telecommunication services and networks. The report highlights the importance of cross-sectoral assessment and collaboration to effectively build climate resilience and minimize the risk of future disruptions. Approach to Risk Assessment and Use of Data.

Figure 7-3: Transportation networks in the city of Toronto.

Source: Photo from Zeuli et al. 2018

A cross-sectoral assessment approach was applied to capture how impacts of extreme weather could influence risks to the food system (see **Table 7-2** for system components). The most critical interdependencies identified in the assessment included failure or disruption of public transportation, road networks, the electrical power system, telecommunications, and fuel supply transportation, storage and distribution infrastructure. The study examined food supply, food access and public health impacts by analyzing the potential risks to various components of the food system, including the identified interdependencies and cascading impacts.

Table 7-2a: Food system components assessed in the study.

Food System Sectors	Food System Sector Description
Regional and local food production	All agricultural production including farms, vertical farms and community gardens within a 160km radius of downtown Toronto
Food processing	All food cleaning, packaging, processing and manufacturing facilities

Food System Sectors	Food System Sector Description
Food distribution	Primary warehouse suppliers and secondary suppliers that move food from processing facilities to food retail stores and other food access points (e.g., restaurants, food banks etc.). This includes the Ontario Food Terminal.
Food retail	Supermarkets, grocery stores, convenience stores and farmers markets.
Restaurants	Chain and independent restaurants.
Food assistance network	Food banks, food pantries, meal delivery programs, soup kitchens, and mobile soup kitchens that collect and distribute food to communities or individuals.
Home meal preparation	Home food storage and meal preparation. This includes high-rise apartment units.

Table 7-2b: Interdependent infrastructure assessed in the study.

Food System Interdependent Infrastructure	Food System Interdependent Infrastructure Description
Public transportation	Trains, subways, buses and streetcars that allow Toronto residents to access food and workers in the food sector to commute to work.
Road network	Trans-Canada or National highways, major highways, secondary highways, collector roads, local roads, bridges and culverts in the GTA used to distribute food to retails stores in Toronto and allow residents to access food.
Electrical power system	The system of transmission terminal stations, municipal substations, switches, transformers and overhead and underground wires used to provide electrical power to residential, commercial and industrial customers.
Telecommunications	The network of land, mobile phones and internet service over which communications are transmitted.
Fuel supply transportation, storage and distribution	All infrastructure required to process, transport, store and distribute liquid fuels. Liquid fuels relevant to the food system include gasoline, diesel, propane and natural gas.

How Results Influenced Decision-Making

The assessment identified six key vulnerabilities to extreme weather events for Toronto's food system. These included urban flooding, risks to critical infrastructure, vulnerability of the Ontario Food Terminal, vulnerable neighbourhoods, food insecurity and related systemic vulnerability and coordination of action among agencies and stakeholders. To address these cross-cutting risks and strengthen the resilience of the food system, it was identified that the City of Toronto must work and engage with several public and private organizations, to support coordinated systems-level adaptation planning. Specifically, communication and coordination across government agencies and the private sector was identified as a key area for effective resilience planning moving forward.

Impact or Outcomes of Implementation

One of the key risks revealed through this assessment was the vulnerability of the Ontario Food Terminal during an extended power disruption, resulting in limitation to food access and availability within Toronto and more broadly across Canada. It is important to note that this study did not assess impacts to food security explicitly.

In response, coordinated action to increase energy and flood resilience including emergency response planning and preparedness measures were identified, requiring involvement from several sectors, agencies and organizations.

Key Lessons from this Case Study

This case study highlights the significance of interdependencies and cascading impacts when assessing climate risks to food systems. Many key lessons were realized. Cascading impacts and interactions related to climate change can cause significant risks across different systems and should not be overlooked in climate change risk assessments. This assessment provides a robust foundation for informing systems-level adaptation planning and future assessments on complex climate risks across food systems and related sectors.

7.6 Key Takeaways

- Depending on the scale of assessment, develop a process or decision rules to identify "direct" or "within scope" impacts and risks, and distinguish those from cascading or cross-cutting impacts and risks. This may look substantially different depending on the scale, sector, and scope of assessment.
- For example, if an assessment is being undertaken for a portfolio of assets across Ontario, consider guidance from robust frameworks such as PIEVC. Identify and group "like" elements but then distinguish climate risks on those elements from risks that may be posed due to adjacent lands or broader connections to other industries (e.g., utilities).

- Allow for time to consider cross-cutting and cascading impacts while undertaking risk assessments on separate Areas of Focus rather than leaving this task until the end to maximize the ability to detect and capture these types of interactions.
- In identifying adaptation options across systems, consider the highest risks but also risks that may manifest similarly in different contexts or locations. Systems-level adaptation opportunities such as policy.
- Operating procedures, endorsed frameworks for resilient investment, bolstered monitoring and inspection, or protection for high function elements are examples of adaptation levers that could reduce systems-level impacts to different climate variables.
- Prioritize the need for adaptation in areas where risks overlap (e.g., across Areas of Focus, sectors, or regions) or become amplified.

7.7 References and Resources

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8.0 Job Aid: Evaluating Consequence and Likelihood of Impact

8.1 Job Aid in Brief

The Problem: Although gaining a general understanding of the impacts of climate change in your area or sector is straightforward, information on the consequence and likelihood of impact to a system or valued element is often unavailable in useful formats. This lack of understanding can lead to ineffective and inefficient climate change adaptation planning.

The Solution: Several international and national standards and frameworks exist to define consequence and likelihood of climate change impact and estimate risk. Practitioners can avoid re-inventing the wheel and creating new methods or criteria where others could be tailored to specific assessment needs.

The Way Forward: Evaluating consequence and likelihood of impact can be done by defining risk scenarios, developing indicators and an associated scoring system, assigning scores, and identifying tipping points for each risk scenario, and calculating the final risk score by considering climate variable frequencies.

The Benefits: By evaluating the consequence and likelihood of a climate change impact on ecological, built and human systems of value, practitioners can turn insights on numerous and varied exposed values into risk information to inform strategic choices. This can better inform resource allocation and lead to more effective decisions related to climate change adaptation planning.

The Steps:

Step 1 – Defining Risk Scenarios

Step 2 – Establishing Indicator and Scoring System

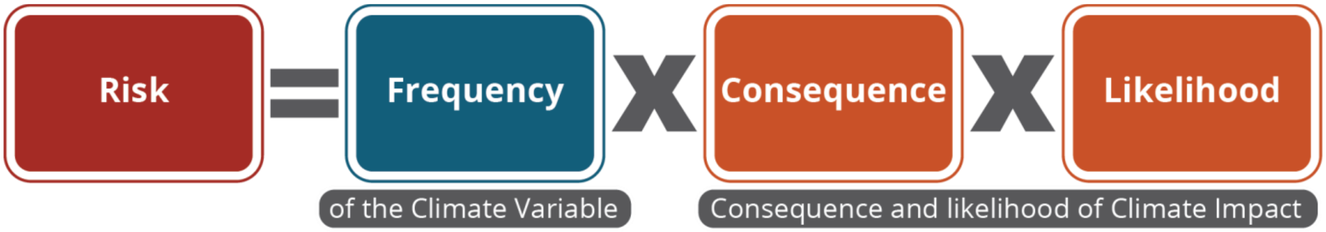
Step 3 – Assigning Scores

Step 4 – Calculating Final Risk Score

8.2 Overview

Effectively analyzing the consequence and likelihood of a climate variable on an exposed ecological, built or human value is critical for robust adaptation planning. International Organization for Standardization (ISO) 14090 outlines principles, requirements, and guidelines for adaptation to climate change. ISO 14090 suggests two distinct strategies to assess risk: 1) the consideration of vulnerabilities, exposure, and climate change variables, or 2) the consideration of likelihoods and consequences (2019). The PCCIA employed the second of these strategies, which is based on assigning scores to a climate variable's frequency and the likelihood, and consequence of impact, and multiplying these scores together to obtain a final risk score. Job Aid 3 on Identifying and Analyzing Climate Variables describes hazard frequency scoring.

Figure 8-1: PCCIA risk formula (PCCIA Methodology Framework)



The consequence is the degree to which a climate variable will cause damage to various categories within a given focal area – that is, the consequence of the climate change impact (described as the Most Probable Worse Case Event in Job Aid 5 on Assessing Exposure to Climate Variables). Categories or valued elements or components could include species and/or ecosystem health, infrastructure, business operations, social stability, and others. Consequence is determined through a range of methods from literature reviews to impact modelling; it is good practice to have a workshop with stakeholders to build out the consequence rating scale (ICF 2021). A scale of this kind primarily adopts qualitative indicators that are associated with minor to catastrophic consequences. Each indicator is associated with a numerical score that will fit into the risk analysis (PCCIA Methodology Framework; ICF 2021). Likelihood is distinct from consequence. As used in the PCCIA process, likelihood represents the probability that the climate change impact will occur.

Risk is measured by assigning a score to the likelihood and consequence of a climate change impact on a specific focal area or category within it, multiplying these scores together (PCCIA Methodology Framework) and by the frequency of the climate variable. The resulting score is the final risk score for that combination of climate variable and focal area (or category within it). While there is not a standard scoring methodology, the approach described below will present a foundation for evaluating the likelihood and consequence of climate variable impacts on exposed values.

This Job Aid: 1) helps users score climate change risk scenarios based on their unique perspectives and 2) describes how to apply consequence and likelihood criteria within the risk formula. These results clarify the relative severity of different risks and help to prioritize opportunities for adaptation. When worked on in a group setting, these results also help to gain perspective on how people feel or react to events and situations, which is valuable information to develop adaptation strategies.

8.3 Key Questions

- How to determine and apply consequence criteria?
- How to determine and apply likelihood criteria?
- How to include non-climate stressors in the risk calculation?
- How to account for tipping points and cascading impacts?

8.4 Guidance for Implementation

Step 1 – Defining Risk Scenarios:

The first step is to conduct qualitative research to understand the potential impacts of a climate variable. The variable exposure scenarios described in Job Aid 4 (on Assessing Exposure to Climate Variables) and cascading and cross-cutting impacts described in Job Aid 5 (on Considering Cascading and Cross-Cutting Impacts & Risks) are inputs to develop risk scenarios or potential climate change impacts. These potential impacts can be translated into a qualitative indicator with an associated numerical score. The PCCIA used a five-point scale with five qualitative indicators of increasing severity (consequence) or probability (likelihood). Each qualitative indicator is associated with a numerical score where each increment is 100% higher than the previous one, resulting in a numerical scoring system of 1, 2, 4, 8, and 16 (PCCIA Methodology Framework). These scores help to identify which combination of climate variable and exposure of valued elements present the most significant risk to the organization, region, or sector (**Table 8-1**).

Step 2 – Establishing Indicator and Scoring System:

Several parameters must be established before undertaking risk analysis. First, consider the perspectives under which to assess the consequences of impacts from climate variables (for instance, the PCCIA used human health and safety, environmental damage, disruption of services, and financial loss). Second, establish qualitative indicators and their associated numerical scores. The PCCIA used Very Low, Low, Medium, High, and Very High consequence ratings corresponding to a numerical score of 1, 2, 4, 8, and 16, respectively. The PCCIA categorized the likelihood of a consequence as Improbable, Remote, Occasional, Probable, and Frequent, again using the same numerical scoring scheme of 1, 2, 4, 8, and 16, respectively. Assigning a qualitative indicator to a particular risk scenario is done at the discretion of those conducting the risk assessment and should be based on expert research and stakeholder and knowledge of rights holders.

Step 3 – Assigning Scores:

There are a few factors to consider when assigning likelihood and consequence scores for a risk scenario. These include 1) whether or not a system has known tipping points, 2) how future climate variable will manifest, 3) their anticipated intensity, frequency, and timescale, 4) the impacted sectors, 5) the impact on vulnerable people, and 6) the compounding of multiple interacting climate variables (C40 Cities, 2018). These impacts should be quantified whenever possible to understand the societal and economic costs of not adapting to climate change (C40 Cities, 2018). It is also important to capture gaps in current understanding to identify future research priorities and understand where to make improvements to the adaptability of a system over time (C40 Cities, 2018; ISO, 2018). Understanding the dynamic nature of systems is also important as climate variables and system vulnerabilities are constantly changing over time (Viner et al. 2020). To reconcile this, the projected change over a given time period should be considered in addition to the static state at any point in time (Viner et al. 2020).

Tipping points and cascading impacts could alter one or both of the consequence or likelihood rating scores and are critical to consider as part of the risk assessment. Tipping points are associated with a threshold for which we can assess the likelihood of exceedance. If the likelihood of exceedance is high, consequences can escalate rapidly. Furthermore, when efforts are not taken to mitigate risk, interacting variables can result in cascading impacts and will exacerbate the likelihood and consequences of extreme events (UNDRR 2022; Simpson et al. 2021) (see Job Aid 5 on Considering Cascading and Cross-Cutting Impacts and Risks for more information). Tipping points should also be investigated for socioeconomic systems (van Ginkel et al. 2020; Kopp et al. 2016). These are often more influenced by the rate of change rather than the magnitude and are best assessed on smaller scales (community level vs. national level) (van Ginkel et al. 2020). Socioeconomic tipping points can be difficult to predict, but it is recommended that stakeholder perceptions and Indigenous perceptions, values and priorities are considered in the process to help define them (van Ginkel et al. 2020). Some questions to consider to ensure that tipping points are considered in a risk assessment are as follows (UK Environment Agency 2021):

- Critical thresholds (where a 'tipping point' is reached, for example a specific temperature where site processes cannot operate safely)
- Changes to averages (for example an entire summer of higher than expected rainfall that causes waterlogging)
- Where variables may combine to cause more impacts

Step 4 – Calculating Final Risk Score

1. Establish the qualitative and quantitative scores for each climate risk scenario under each different perspective;
2. Input the scores into the risk analysis formula in combination with climate variable frequency scores.

This will produce an overall risk score and allow for the comparison of multiple risk scenarios. Once these scores are established, we can then evaluate the adaptive capacity of the area of interest, categories or components within it.

Table 8-1: Evaluating Consequences and Likelihood of Impact in the PCCIA and an example Level 1 outcome. For more information, see Section 9.0 Business and Economy of the PCCIA Technical Report.

Evaluating Consequences and Likelihood of Impact	Evaluating Consequences and Likelihood of Impact Details
Evaluating Consequences and Likelihood of Impact in the PCCIA	In addition to the process outlined in Step 1: Defining Risk Scenarios, risks were evaluated in all Level 1 and Level 2 categories for each Area of Focus. The evaluation included 15 climate variables. Consequences were identified and scored under current, mid-century (2050s) and end of century (2080s) time periods. As a result, risk scores were produced for each unique interaction (e.g., one climate variable and its associated MPWCE on a particular Level 2 category in one region of Ontario). Every risk score was then compared, evaluated, normalized and "rolled up" to produce a representative risk profile for a Level 2 category, then a Level 1 category, then an entire Area of Focus, and finally across an entire geographic region.

Evaluating Consequences and Likelihood of Impact	Evaluating Consequences and Likelihood of Impact Details
Evaluating Consequences and Likelihood of Impact in Business and Economy Area of Focus	Consequences were evaluated based on two criteria: 1) financial business loss, and 2) operational and service disruptions. Financial consequences were assessed on the basis of the amount of business loss that a single firm might be expected to experience in relation to a single MPWCE (assessed as a % of annual company revenue). Operational and service disruption consequences were assessed on the basis of the degree to which an asset or service would no longer function at normal levels due to a MPWCE (assessed as a % of loss of function of asset or service).
Evaluating Consequences and Likelihood of Impact Outcome in Business and Economy	The PCCIA identified eleven Level 1 categories, of these, a total of 350 unique climate risk scenarios were deemed significant and subjected to assessment. The types of consequences evaluated for Businesses and Economy Level 1 Industries were: operational/service disruption, asset and infrastructure loss and damage, change in availability and quality of inputs, costs, legal liability and non-compliance, risk to worker and customer safety and well-being, and supply chain and distribution network interruption.

An example of evaluating consequences and likelihood of impact in the Business and Economy Area of Focus, Manufacturing Level 1 Category is:

> Extreme temperature events (e.g., Extreme Hot Days) combined with humidity/moisture could affect the storage and shelf life of material inputs (e.g., resins, epoxies), semi-manufactured and finished products (plastic packaging) leading to a supply chain and distribution network interruption.

8.5 Risk Assessment in Action

Case Study 7: Assessing Climate Change Risks at the Kam Kotia Mine Site

Year: 2021 **Focus:** Infrastructure, Business and the Economy
Link: Assessing Climate Change Risks at the Kam Kotia Mine Site

Context: In 2020, a Climate Change Risk Assessment for the Kam Kotia abandoned mine site located near Timmins, Ontario was conducted to determine i) how climate impacts such as extreme weather events and precipitation variability may impact the Kam Kotia site, ii) to inform future remediation work on the site, and to iii) pilot a risk assessment framework for use in the screening-level assessment of climate risks related to abandoned or orphaned mine sites.

Approach to Risk Assessment and Use of Data

The assessment sought to identify and analyze the impacts of climate change and subsequent risks to the Kam Kotia site and to inform future remediation and adaptation efforts. The assessment process was adapted from the Mining Association of Canada (MAC) framework and National Orphaned / Abandoned Mines Initiative guidance and included 6 steps: project scoping, information gathering, vulnerability identification, risk ranking system, risk assessment, and adaptation and implementation.

Vulnerability scenarios were developed for different climate variables based on how they might interact with the mine site. Once vulnerability scenarios were developed, likelihood, risk, and potential consequences were derived for each scenario. A likelihood rating (i.e., rare, unlikely, possible, likely, or almost certain) for each climate variable and parameter was determined for historical conditions, and change into the 2050s, and 2080s was assigned. Consequence categories and criteria were developed to assess the magnitude of impact for each vulnerability scenario. A consequence rating (i.e., very low, low, moderate, high, very high) was assigned to each scenario based on its impact to financial/socioeconomic activity, physical damage, public health, and the environment (see **Table 8-2**).

Table 8-2: A Framework for defining Categories of Consequence and their Severity.

Category	Very Low	Low	Moderate	High	Very High
	1	2	3	4	5
Financial/ Socioeconomic	Little or no impact on site budget, minimal interruption of socioeconomic activity	Able to accommodate within site budget, temporary interruption of socioeconomic activity	Able to accommodate within broader Ministry funds. Short term, on-site loss of socioeconomic activity	Able to accommodate within broader Ministry funds but only with cuts or reserve funds. Short term, on-site and off-site loss of socioeconomic activity	Unable to accommodate within reserve funds. Permanent loss in socioeconomic activity.

Physical Damage to Property	Minor, isolated, and/or cosmetic damage to property	Moderate, or limited loss of physical property	Significant, localized loss of property or moderate damage or loss on a wider scale.	Significant loss of property on a wide scale.	Widespread severe damage or loss of key assets, leading to cascading impacts.
Public Health	Minor incident (cuts and scrapes). Little or no impact on injured person's ability to carry on regular activities.	Medical aid required. Disruption to injured party's daily activities/quality of life.	Permanent disability. Isolated lengthy lost time injury. Significant disruption to injured party's daily activities/quality of life.	Fatality; permanent disability for several individuals. Significant disruption to multiple injured parties' daily activities/quality of life.	Multiple fatalities; permanent disability for numerous individuals. Catastrophic impact on quality of life.
Environment	Impact not likely measurable within ecosystem.	Negligible impact on local environment. Exceeds natural variability.	Localized or reversible environmental damage.	Widespread or irreversible environmental damage.	Widespread and irreversible environmental damage.

How Results Influenced Decision-Making

The risk assessment combined the likelihood and consequence ratings to produce a climate risk matrix. From the climate risk matrix, four classes of risk were established:

- **Class I risk** – risk is well below risk acceptance-intervention threshold, no intervention required at time of analysis
- **Class II risk** – risk is close to or on risk acceptance-intervention threshold, active monitoring and/or further evaluation is required
- **Class III risk** – risk exceeds risk acceptance-intervention threshold, active intervention is required
- **Class IV risk** – risk significantly exceeds risk acceptance-intervention threshold, urgent intervention is required

The risk assessment led to six scenarios that were Class IV risks (requiring urgent intervention) for current conditions, ten Class IV risks predicted for 2050, and 12 were Class IV risks predicted for 2080. The assessment identified opportunities for adaptation including knowledge and information sharing, bolstering remediation actions, and building management capacity. Results were used in 2022 to inform procurement of certain services for the Kam Kotia site.

Key Lessons from this Case Study

Mine sites are unique in the context of how climate change vulnerabilities and risks can occur. Two lessons from the Kam Kotia assessment include: 1) Information availability can be a significant limitation when characterizing and assessing likelihood and consequence in sufficient detail. It was identified that improved information and knowledge of onsite characteristics would enable a more rigorous assessment of likelihood and consequences under this assessment. 2) Bolstering remedial action planning (e.g., installing backup generators, deepening fill to avoid impacts) and building management capacity were identified as key outcomes of this assessment.

Case Study 8: Portfolio Climate Change Risk Management by the Ontario Teachers' Pension Plan (OTTP)

Year: 2021 **Focus:** People and Communities, Business and Economy
Link: Portfolio Climate Change Risk Management by the Ontario Teachers' Pension Plan (OTTP)

Context: Against the backdrop of recommendations released by the Task Force on Climate-related Financial Disclosures (TCFD), the Ontario Teachers' Pension Plan created and rolled out a Low Carbon Economy (LCE) Transition Framework and released a Climate Change Risk Management Report in 2018. Its purpose, generally, is to guide a more systematic approach to help understand the potential impacts of climate change and make more informed decisions on individual public and private investments and the portfolio as a whole.

Approach to Risk Assessment and Use of Data

The approach to climate change involved the creation of three future scenarios to a low carbon economy, as a function of five catalysts: policy, technology, consumer preferences, capital, and physical impacts. These scenarios are not meant to be predictions or forecasts, rather possible future developments to plan and account for. Each of these scenarios are assessed qualitatively and within relevant future timeframes: short, medium, and long term in the context of risks and opportunities. Consequences (or implications) for companies and for the Ontario Teachers' Pension Plan as a whole are described for each time horizon. For both, physical risks due to increasing frequency of extreme events, water constraints or shortages, infrastructure damage or loss, and disruption to supply chains or markets are identified.

As part of this process risk management process and report, the Ontario Teachers' Pension Plan also established quantitative metrics in line with international frameworks and initiatives, such as the Global Real Estate Sustainability Benchmark (GRESB) and International Centre for Pension Management (ICPM). These metrics focus on assessing companies through examining existing practices and analyzing corporate operational datasets. Within these frameworks, climate-related metrics are based on materiality, sector, or subsector, and generally include measures like absolute and relative emissions; energy, water, and waste management; physical resiliency; supply chain management; and the proportion of operations in climate-sensitive locations. Similarly, metrics that can be applied to portfolios across diversified geographies and asset classes (e.g., infrastructure, real estate, equities) are being developed. A subset of measures of exposure to climate risk under development are illustrated in **Table 8-3**.

Table 8-3: Risk Metric Framework

Risk Metric or Area of Exposure	What it Attempts to Answer	Limitations
Physical Exposure	What proportion of assets is exposed to acute climate change impacts? What proportion of assets is exposed to chronic climate change impacts?	Very difficult to get data on locations of all public company operations. Difficult to get specific details; many vendors provide physical risk information at city level or higher. Many tools provide comparative or score based measures as opposed to direct risk measures that could be input into valuation models.
Legal Exposure	What companies in the portfolio could face legal and litigation risk based upon climate change impact or poor disclosure?	Difficult to assess without legal precedence. No vendors have been identified who provide this data.

Risk Metric or Area of Exposure	What it Attempts to Answer	Limitations
Ratio of low-carbon to high-carbon linked revenues	How much of the portfolio is invested in a low-carbon economy vs. a high-carbon economy? What is the portfolio's level of preparedness or consistency with the current climate scenario pathway?	Challenging to get good data on companies' different revenue streams. Coverage limited to sectors that can be delineated by green/brown.
Value at risk	How much can the portfolio lose under different climate change scenarios?	Modelling challenges. Limited transparency on underlying assumptions makes it difficult to evaluate the quality of the model.

How Results Influenced Decision-Making

The Ontario Teachers' Pension Plan is currently in the process of evaluating data and working with industry partners to develop a measurement framework, including the identification of targets to track progress in relation to their climate change risk management report. As this work is ongoing, OTTP has described existing processes in place that consider climate change on their investments, including: Climate change considerations across the investment cycle (e.g., assessment and decision-making processes before acquiring an asset.

- Strengthened engagement among companies and financial institutions to adopt similar frameworks and undertake assessment and reporting, based on TCFD.
- Promoting standardized and climate data on company-level climate-related risks.
- Refinement of understanding the interconnectedness of physical and transition risks to climate change.
- Improving datasets and tools in support of assessment and decision-making.

Key Lessons from this Case Study

Two key lessons were gleaned from the OTPP process:

1) data availability constrained the ability to establish risk baselines and thus resilience targets
2) non-climate data related to (eg.) revenue streams, other location-specific information, were also lacking and were not granular enough to inform a fulsome assessment of climate risk. For example, in some cases, only city-level data were available.

8.6 Key Takeaways

- Undertake literature review from a variety of sources to identify what consequence and likelihood criteria has been used for similar assessments.
- Leverage international and national standards and frameworks for consequence and likelihood criteria and scoring. Avoid re-inventing the wheel and creating new methods or criteria where others could be adapted/tailored to specific assessment needs.
- Involve climate experts and other relevant professionals in the development of consequence and likelihood rating criteria.
- Explicitly consider if or at what point in the methodology cascading impacts will be evaluated or quantified. For example, these can be evaluated as part of risk or considered qualitatively as part of analysis and reporting if data are unavailable. In some cases, tipping points or cascading impacts are important to quantify, therefore other experts should be engaged to determine preferred approaches suitable for the scale and scope of the assessment.

8.7 References and Resources

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9.0 Job Aid: Adaptive Capacity

9.1 Job Aid in Brief

The Problem: Adaptive Capacity is often excluded from climate change risk assessments and can lead to suboptimal decisions about where and how to allocate resources for adaptation.

The Solution: Explicitly characterizing and comparing these results with risk information can help identify opportunities for building or maintaining climate resilience through measures that focus on adaptability.

The Way Forward: Adaptive Capacity can be explicitly integrated as part of climate change risk assessment processes by first understanding key determinants of adaptive capacity, gathering data and information to populate indicators for each determinant, evaluating levels of adaptive capacity across components of systems being assessed, and focusing on key opportunities to enhance adaptive capacity via components that present a combination of high climate change risk and low adaptive capacity.

The Benefits: By analyzing adaptive capacity explicitly, the robustness of risk assessment results increases, and decision-makers can spot opportunities to support greater adaptability of the overall system and of specific populations, places, sectors or assets presenting unique constraints.

The Steps:

Step 1 – Gathering Information to Characterize Adaptive Capacity

Step 2 – Evaluate Adaptive Capacity

Step 3 – Using Adaptive Capacity Assessments to Identify Opportunities to Inform Decision-Making

9.2 Overview

Adaptive capacity is the ability of systems, institutions, humans, and other organisms to cope with or adjust to potential damage from climate change, to take advantage of opportunities, or to respond to consequences. The higher the adaptive capacity, the better. Adaptive capacity assessments help practitioners evaluate natural and human systems' ability to manage climate change impacts and identify priorities for strengthening this capacity under future conditions (Brooks & Adger, 2005; CCME 2021). These assessments help identify gaps between "business as usual" and where an organization needs to be to deal with anticipated climate change impacts (ISO, 2019). Adaptive capacity can be measured alongside risk and utilize a similar scoring system to facilitate comparisons between the two metrics (PCCIA Methodology Framework). Ultimately, the combination of high risk and low adaptive capacity indicates opportunities for targeted adaptation and resilience measures.

This Job Aid describes a practical approach to 1) characterize and evaluate adaptive capacity, and 2) use the results of adaptive capacity assessments for adaptation decision-making.

9.3 Key Questions

- How to define and characterize adaptive capacity?
- How to evaluate adaptive capacity across varied values and Areas of Focus?
- How do combinations of risk and adaptive capacity assessment guide action?

9.4 Guidance for Implementation

Step 1: Gathering Information to Characterize Adaptive Capacity

The first step in an adaptive capacity assessment is to thoroughly review the literature and obtain expert knowledge to understand the current and future adaptability to climate change in the specific thematic and geographic context being evaluated within the climate change risk assessment (PCCIA Methodology Framework). **Table 9-1** below and case studies in this Job Aid provide examples of adaptive capacity assessment and include data considerations and how to characterize adaptive capacity. Commonly, characterizations of adaptive capacity start by defining the determinants or assets that are known to contribute to (Williamson & Isaac, 2013) or influence (C40 Cities, 2018) adaptive capacity.

Table 9-1: Examples of determinants of adaptive capacity from a range of systems or sectors.

Water sector governance (Allen et al., 2021)	Local governments & communities (Fuchs et al., 2019)	Forest sector (Diao, 2016)	Agriculture sector (Williges et al., 2017)	Conservation of species and populations (Thurman et al., 2020)
• Regime (rules, policies, laws, regulations, property rights) • Knowledge • Networks	• Asset base • Institutions and entitlements • Knowledge and information • Innovation • Flexible and forward-looking decision making and governance	• Economic resources • Technology • Knowledge capital • Infrastructure • Institutions • Social capital • Human capital • Cultural capital • Natural capital • Political capital • Risk management	• Human capacity • Social capacity • Natural capital • Physical capacity • Financial capacity	• Demography • Distribution • Movement • Evolutionary potential • Ecological role • Abiotic niche • Life history

Determinants of adaptive capacity are diverse, depending on the systems of interest and exposure to climate variables (Keskitalo et al., 2011). For example, factors that shape whether farmers can adapt to drought will likely differ from factors that shape waterfront property owners' capacity to adapt to variable lake levels and enhanced erosion, although shared determinants are possible (e.g., access to information) (Brooks & Adger, 2005). Scale is important as characterizing adaptive capacity at, for example, a household-level is different than doing so for a community, a watershed, or an industry sector. Multi-sectoral assessments and those with broad geographic coverage will tend to use more generalized determinants of adaptive capacity, compared to highly localized assessments. Technology, equity, resource availability, governance, and complexity were the broad-based determinants selected for Ontario's PCCIA, but these should be determined on a case-by-case basis (**Table 9-2**).

Each determinant reflects various dimensions of adaptive capacity, which practitioners can characterize using indicators and narratives. National census data and other datasets available regionally (e.g., public health units) can serve to populate high-level indicators. Aside from relevance, data availability at the scale and scope needed is a dominant influence on the selection of adaptive capacity indicators (Lanford et al., 2014). In some cases, primary data collection may be necessary. Interviews, participatory planning exercises, and ethnographic approaches (Whitney et al., 2017) can provide quantitative and qualitative data to characterize adaptive capacity, tailored to the assessment context. Engaging experts, stakeholders, and Rights Holders in refining the selection of adaptive capacity determinants and related indicators enhances the robustness of the assessment and provides opportunities to uncover data sources (Diao, 2016) (see Job Aid on "Engaging Effectively").

Although the assessment of adaptive capacity has historically focused on human systems, there is increasing recognition of the importance of assessing and understanding the adaptive capacity of natural systems, which are associated with a different range of characteristics, including different types of ecological diversity, connectivity, and plasticity, among others (Whitney et al., 2017, Brown et al., 2018). Understanding the adaptive capacity of both human and natural systems can help to develop a more holistic understanding of climate change risks as well as inform more effective adaptation policies and programs (Adger et al., 2018).

Step 2: Evaluate Adaptive Capacity

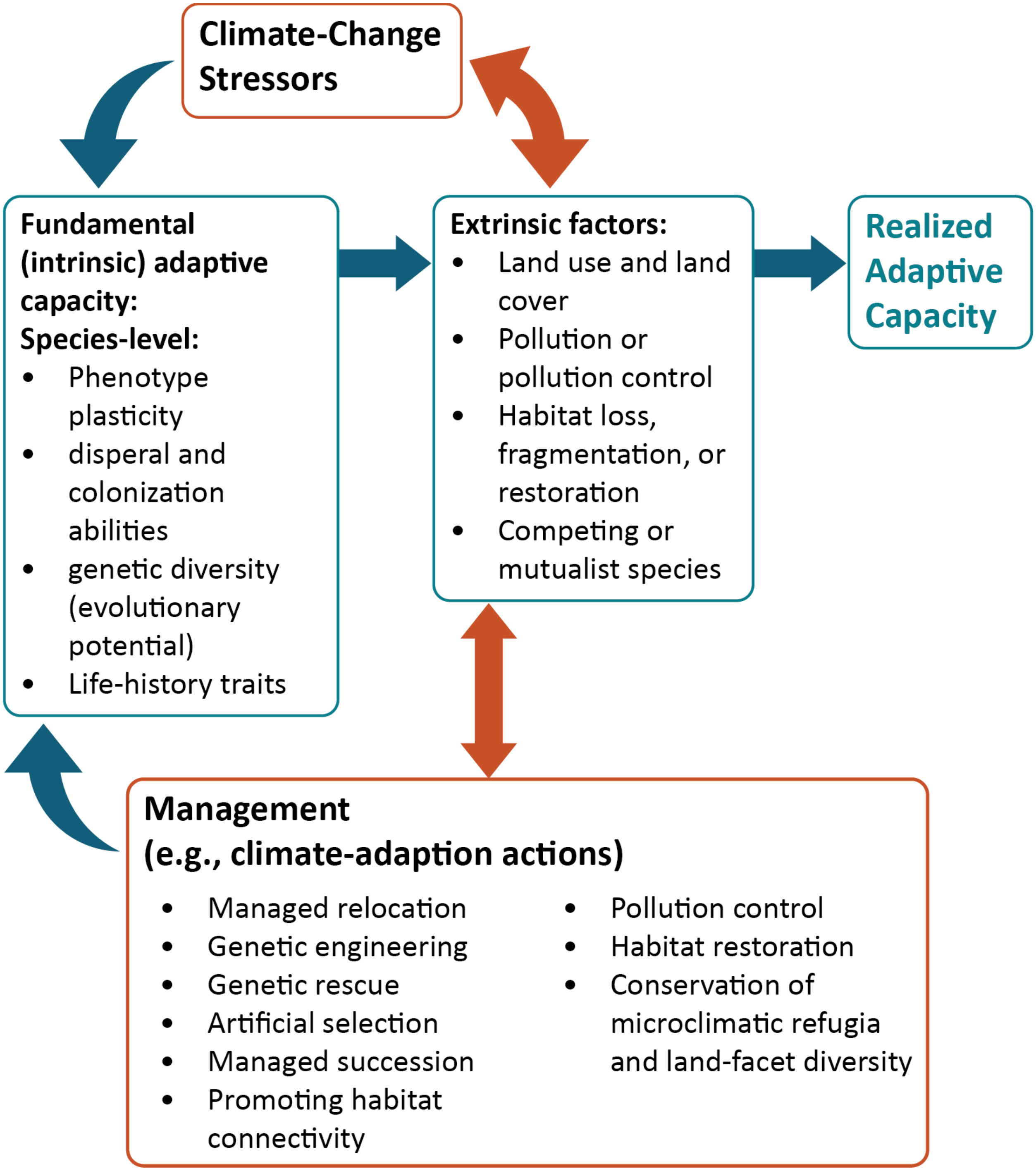
Once key elements of adaptive capacity have been defined and characterized, the next step is to confirm and deploy an approach to evaluate adaptive capacity. Evaluation of adaptive capacity levels can involve scoring, rating, ranking, developing compound indices, with and without weights on individual determinants (see case studies in this Job Aid). The PCCIA scored each determinant of adaptive capacity (technology, equity, resource availability, governance, and complexity) either as low (1), medium (4), or high (16), adopting a similar scoring system as the climate change risk assessment to facilitate comparison of results (**Table 9-2**). Because of the wide-ranging scope of the PCCIA, adaptive capacity assessment was relatively high level and at broad geographic scales.

Table 9-2: Adaptive Capacity in the PCCIA.

Adaptive Capacity	Adaptive Capacity Details
Adaptive Capacity in the PCCIA	In the PCCIA, Adaptive Capacity was qualitatively characterized at the Level 1 level based on literature review and expert experience. The indicators were scored on a 3-point scale from Low to High (1, 4, 16). Two Adaptive Capacity Scores were generated: • Level 1 Category Adaptive Capacity • Regional Adaptive Capacity

Adaptive Capacity Components	Adaptive Capacity was analyzed with consideration of one or more of the following key indicators: • Technology – The ability of technological resources that can build resilience into the systems being assessed • Resource Availability – Availability of human and financial resources • Equity – The presence of equally distributed opportunities such as access to healthcare, employment opportunities, distribution of income, or social cohesion • Governance – How a sector is prepared to respond to climate change hazards and prevent shocks • Sector Complexity – The number of players, stakeholders, and decision-makers present. This component assumes that the higher the complexity, the lower the capacity to adapt
Calculating Adaptive Capacity	The Regional Adaptive Capacity Level 1 ranking was derived by multiplying the Regional Adaptive Capacity Score and Level 1 Category Adaptive Capacity Score. The Area of Focus Total Adaptive Capacity was derived by summing and normalization the Level 1 rankings.

Figure 9-1: Conceptual model illustrating how climate adaptation strategies can close the gap between species' inherent adaptive capacity and the adaptive capacity that has actually afforded them ("realized" adaptive capacity) due to pressures from human activities. Reproduced from Beever et al. 2016.



Step 3: Using Adaptive Capacity Assessments to Identify Opportunities to Inform Decision-Making

With evaluations of adaptive capacity in hand, practitioners are poised to understand facets that can enable climate resilience as compared to levels of climate change risk at different time scales. It's important to note that assessment of adaptive capacity correlates to current conditions and future climate change risks can best be managed by building capacity among those areas of adaptive capacity. This comparison helps identify priorities for building climate resilience (by region, sector, social group, species, or ecosystem) of high risk and low adaptive capacity systems, and aspects of adaptive capacity that should be maintained to address future climate threats. Supporting broad-based improvements in adaptive capacity is one strategy to adapt to climate change, which is especially powerful when management action to reduce exposure to climate variables or to decrease sensitivity to climate variables are not feasible or take longer to implement and show their effect. The more local the scale or domain-specific the scope of the assessment, the more tangible and specific adaptive capacity opportunities can be, such as **Figure 9-1** illustrates.

PCCIA Application: The PCCIA Technical Report identified priorities and opportunities to build climate resilience for each of the five Areas of Focus. These tables in the Technical Report highlight Area of Focus -specific components at high risk of climate change and with lower to medium levels of adaptive capacity, which implies the need for focused adaptation and improvement to adaptive capacity.

It is worth noting that implementing adaptation strategies, regardless of the focus, can require significant financial, social, human, or natural resources and require strong "buy in" and willingness to adapt (Brooks & Adger, 2005). For this reason, a climate change adaptation plan can be developed that encompasses policies and strategies to better align with adaptive capacity goals (ISO, 2019). Job Aid 8 on "Defining Adaptation Success" includes further guidance to take the results from the climate change risk assessment and begin to develop a risk-informed adaptation plan.

9.5 Risk Assessment in Action

Case Study 9: Climate Change and Health Vulnerability Assessment - for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph

Year: 2022 **Focus:** People and Communities

Link: Climate Change and Health Vulnerability Assessment - for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph (2022)

Context: In partnership with ICELI Canada, the Region of Waterloo Public Health (ROWPH) and Wellington-Dufferin-Guelph Public Health (WDGPH) undertook a Climate Change and Health Vulnerability Assessment (CCHVA). The purpose of this vulnerability assessment was to evaluate the climate-related health risks to residents in the jurisdictions of WDGPH and ROWPH. The Assessment focuses primarily on identifying vulnerable populations, understanding patterns of climate-related vulnerability, providing baseline health information, and defining existing adaptive capacity.

Figure 9-2: Black-legged tick, a potential vector for Lyme disease and threat to public health

Source: Photo from Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph, 2022

Approach to Risk Assessment and Use of Data

This assessment examined baseline climate-related health concerns, identified future impacts based on projected climate change, and documented population-level vulnerabilities based on exposures, sensitivity, and adaptive capacity

The project included a comprehensive literature review to identify key elements of adaptive capacity in relation to climate-related outcomes, as well as stakeholder engagement and statistical analyses of sociodemographic and health data. The Ontario Climate Change and Health Toolkit and Health Canada's Climate Change and Health Vulnerability and Adaptation Assessment were used to guide the characterization and assessment of vulnerability, including elements of adaptive capacity, among population groups. See **Table 9-3** for an example of the population characteristics analyzed in relation to extreme heat and adaptive capacity in the jurisdiction.

Vulnerability was assessed for several climate-related health impacts, including extreme temperatures, ultraviolet radiation extreme weather, air quality, vector-borne and zoonotic diseases, and food- and water-borne illnesses and mental health.

Table 9-3: Population statistics for adaptive capacity to extreme heat for Wellington-Dufferin-Guelph and Waterloo Region, 2016.

Population Characteristics	Wellington-Dufferin- Guelph % of total population	Waterloo Region % of total population	Ontario % of total population
Prevalence of low income after-tax	9.9%	12.1%	14.4%
No high school certificate, degree or diploma	11.1%	18.7%	10.4%
% of owner households spending 30% or more of income on shelter costs	17.2%	14.6%	19.8%
Dwellings requiring major repairs	5.1%	5.0%	6.1%

Housing unsuitability (crowding)	3.4%	4.5%	6.0%
Apartment in a building that has five or more storeys	5.7%	10.8%	17.2%
Speaking neither English nor French	0.9%	1.8%	2.5%
Immigrants	16.4%	22.6%	29.1%
Recent immigrants - 2011 to 2016	9.7%	11.8%	12.3%
Visible minority population	11.6%	19.0%	29.3%
Identified as Indigenous	1.6%	1.7%	2.8%

Table Source: Climate Change and Health Vulnerability Assessment – for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph, 2022. Data from Statistics Canada 2016 Census of the Canadian Population; Canadian Community Health Survey 2015/2016.

How Results Influenced Decision-Making

One of the main objectives of this assessment was to support the identification of opportunities for building adaptive capacity by strengthening existing measures and recommending additional actions to better respond to climate-related health risks. This report provides a robust framework and assessment of vulnerability, including the many facets of adaptive capacity. It is anticipated that the findings and recommendations of this assessment will be used to support a variety of public health, government, and community-led adaptation interventions in the future.

Impact or Outcomes of Implementation

The outcomes of this assessment describe community vulnerabilities and establish baselines for climate-related health impacts, to better understand changes over time. The assessment focuses primarily on identifying climate-related health impacts, analyzing baseline health information, identifying vulnerable populations of concern, and outlining existing levels of adaptive capacity (i.e., individual, population and system characteristics).

Key programs, policies and related actions to build adaptive capacity were identified for health outcomes associated with the changing climate. The assessment highlights both existing and recommended adaptive actions to address climate-related health outcomes, including public health, individual, and community driven actions.

Key Lessons from this Case Study

This assessment identifies key characteristics found to exacerbate exposure and sensitivity or limit levels of adaptive capacity to climate-related health impacts. It assesses several facets of adaptive capacity including spatial distribution and sociodemographic variables. The assessment notes lessons including a) the importance of identifying factors that influence a person's capacity to adapt, b) and how stratifying health-related outcomes by socio-economic data can advance understanding of vulnerability and distribution across population groups and health determinants in the jurisdiction.

Case Study 10: Climate Change Vulnerability Assessment Tool for Drinking Water Source Quality

Year: 2022 **Focus:** People and Communities
Link: Climate Change Vulnerability Assessment Tool for Drinking Water Source Quality

Context: One of the first of its kind in Ontario, the Climate Change Vulnerability Assessment Tool provides a practical and consistent approach to assess local climate change impacts, determine vulnerability of drinking water systems to climate change, and highlight areas where actions may be needed to further protect source water quality. The semi-quantitative tool uses widely established vulnerability assessment methods to assess climate change exposure, sensitivity, adaptive capacity of a drinking water system's source water quality.

Approach to Risk Assessment and Use of Data

The assessment tool is multi-disciplinary in nature, relying on various subject matter experts for its application. This follows best practices of established climate change vulnerability assessment methods, as well as the multi-stakeholder source protection planning process in Ontario. The assessment tool is Microsoft Excel-based and contains a series of linked worksheets:

- **A.** Assess climate change exposure at the area scale
- **B.** Evaluate climate change sensitivity at the area and intake/well scales
- **C.** Review the climate change impact scores for the area and intake/wellscales
- **D.** Determine the adaptive capacity and climate change vulnerability of the area and intake/well scales
- **E.** Incorporate the climate change vulnerability rating into existing drinking water quality threat risk assessment
- **F.** View a summary of the assessment results

The tool seeks information from the user to describe attributes relevant to adaptive capacity of the study area and intake or well. In the assessment tool, the analysis of adaptive capacity is based on information about the study area and intake or well, as well as additional input provided by the user to consider factors including:

- Financial constraints to addressing climate change impacts
- Presence or absence of a backup supply of drinking water
- Existing policies and/or management procedures in place to address climate change impacts on water quality
- Infrastructure that helps reduce climate change impacts

- Capacity for property owners to prevent, protect against, mitigate, respond to, and recover from flooding

Figure 9-3: Drinking water protection zone Source: Conservation Ontario

Based on this information, an adaptive capacity rating is calculated, using the equation presented below. This formula weighs attributes that are directly relevant to the drinking water system source water as twice the value of the attributes associated with the broader study area. This is because the attributes evaluated at the area scale encompass a broader area that may not have direct impacts to water quality, and so these attributes carry less weight than the system-level attributes.

How Results Influenced Decision-Making

Once the adaptive capacity scores are calculated, the assessment tool determines an overall climate change vulnerability score based on the climate change impact and adaptive capacity scores. The assessment tool has been piloted across several study areas and scales in Ontario. First Nation reserves were not included in the pilot study areas. The results of the assessment tool can be used to help inform discussions around protection, management and adaptation actions at both the municipal and watershed scales.

Figure 9-4: Adaptive capacity rating equation used in this case study. The final adaptive capacity score was given as a score out of 3 and demonstrated as a percentage with the associated rating of “high”, “medium”, or “low” adaptive capacity. For a percentage of 67% or higher, a “high” adaptive capacity rating was given; and for below 33%, a “low” rating was given. The higher the adaptive capacity, the greater the ability the drinking water system has to adjust to impacts from climate change. (Source: Milner et al., 2020).

$$\textit{Adaptive Capacity} = \frac{\left(\dfrac{\overbrace{\sum_{i=1}^{M}(a_1 + a_2 + a_3 + \cdots + a_m)}^{\text{Area Attributes}}}{M}\right) + \left(2 \times \dfrac{\overbrace{\sum_{i=1}^{N}(b_1 + b_2 + b_3 + \cdots + b_n)}^{\text{Drinking Water System Attributes}}}{N}\right)}{3}$$

Where: *a* is the score of a specific attribute within the area
b is the score of a specific attribute for the drinking water system
M is the total number of attributes for the area
N is the total number of attributes for the drinking water system.

Impact or Outcomes of Implementation

The results of this assessment tool may serve to further encourage climate change risk management of drinking water system infrastructure in Ontario and support local climate change strategies or plans. Given that the effects of climate change are currently being observed in the province, the assessment tool is crucial to build resilience and protect Ontario’s drinking water sources as we move into an increasingly uncertain and variable future.

Key Lessons from this Case Study

Throughout the development of the assessment tool, several iterations were developed and refined. The following lessons are identified for this case study: 1) Diverse information and local context-appropriate data inputs are needed to inform the assessment; 2) Involvement of various subject matter experts and other local expertise will ensure results are accurate and representative; 3) The multi-disciplinary nature of the process of the assessment tool is key to ensuring meaningful inputs, and useful outputs.

9.6 Key Takeaways

- Undertake literature review of both peer reviewed and grey literature to identify how much is known about adaptive capacity for similar assessment type, and methods used to characterize adaptive capacity for the systems of interest.
- Confirm, based on international and national standards and guidance, how adaptive capacity will be evaluated - and if quantitatively scored and factored into risk ratings.
- Following climate change risk and adaptive capacity assessments, identify opportunities to increase adaptive capacity of elements or areas where reducing the exposure or susceptibility to climate variables may take longer or be particularly significant. Finer spatial scaled assessments present more opportunity for specific adaptive capacity improvements.
- Pay specific attention to elements or areas of highest risk and lowest adaptive capacity to target adaptation and resilience action.

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10.0 Job Aid: Defining Adaptation Success

10.1 Job Aid in Brief

The Problem: Climate change risk assessments do not take place in a vacuum. Organizations use various decision processes that account for various drivers of risk. Climate change is one such driver with the assessment process being the means to the resilience end, through adaptation action.

The Solution: Defining adaptation success prior to embarking on climate change risk assessment and making sense of risk analysis results in the context of broader organizational goals and norms is an opportunity to create a shared understanding of the problem and an informed evaluation of what to do about it.

The Way Forward: Evaluating climate change risk information and deciding on additional action involves (1) reaching agreement on climate change risks, (2) clarifying your risk appetite, (3) deciding to mitigate, transfer, accept or avoid each risk in line with the vision for adaptation, and (4) communicating the results of the process.

The Benefits: By connecting a vision of successful adaptation with a set of priorities stemming from risk evaluation informed by organizational goals and norms, practitioners can pave the way for a coherent, risk-informed adaptation plan with specific objectives, actions, as well as indicators and metrics to report on progress.

The Steps:

Step 1 – Reaching Agreement on Climate Change Risks

Step 2 – Clarifying Your Risk Appetite

Step 3 – Deciding on a Course Toward Successful Adaptation

Step 4 – Communicating the Results of Risk Evaluation

10.2 Overview

Results of climate change risk assessment inform adaptation planning, mainstreaming and implementation of adaptation strategies and measures (ISO, 2019). But these results are just one source of information for risk-based decision-making. Organizations and communities have strategies covering different policy issues, and implement or are subject to numerous decision-making frameworks and commitments. Climate change impacts can make the goals and objectives in these strategies, policies, and frameworks harder or easier to achieve. With climate change risk assessment results in hand, decision-makers are well-positioned to clarify or refine what successful adaptation looks like in line with these broader goals and objectives. Defining adaptation success can be useful for reasons, including (Resilience Metrics, n.d.):

- **Improved communications and public engagement:** positive visions of adapting to a changing climate, rooted in shared values, and informed by clear evidence of challenges ahead, can motivate collective action and sustain political will to act.
- **Aligned planning and decision-making:** a shared vision for adaptation success within an organization helps match resources to desired outcomes and fosters coherence in approaches across units and teams.
- **Strengthened case for adaptation spending:** with a clear vision of adaptation success along with the indicators and metrics to track performance toward desired outcomes practitioners are better equipped to explain how to allocate spending, to what effect and the relative advantages of different investments.
- **Improved accountability:** articulating a vision for adaptation success that is responsive to identified climate change risks contributes to due diligence and, when backed by concrete actions and reporting, can satisfy emerging demands for businesses and local governments, among others, to demonstrate their climate preparedness.
- **Continuous learning and improvement:** adapting to climate change is never-ending; it is not a "one and done". A vision for adaptation success applies to a long-term horizon, guiding action to take now, but allowing for learning and course corrections as climate change unfolds and enhanced knowledge of what works.

A clear definition of adaptation success helps translate the results of climate change risk analysis into adaptation decisions, a normative process that distinguishes between what is and what ought to be. Questions such as "what are acceptable risks?" and, "what and how much to do to safeguard or protect people, assets, or ecosystems?" are inherently value laden. Making sense of climate change risk information is an opportunity to create a shared understanding of the problem and an informed evaluation of what to do about it (McDermott et al., 2018). This Job Aid focuses on a final step in conventional risk assessments:

risk evaluation (ISO, 2018). This step is a bridge between generating information on climate change risks and deciding on actions to manage identified risks.

10.3 Key Questions

- How can risk assessment results inform a vision for adaptation?
- How can risk assessment results help identify shared adaptation goals and objectives?
- How can risk assessment results inform adaptation actions to take now, in the medium and long term?
- How to apply a greenhouse gas mitigation lens to risk assessment results? What about other lenses (e.g., "one health")?

10.4 Guidance for Implementation

Evaluating climate change risk information and deciding on adaptation action takes place in the following four steps. Unless the objective of a climate change risk assessment is purely to build awareness of the implications of climate change impacts, all risk assessments should undertake these steps in some way.

Step 1 – Reaching Agreement on Climate Change Risks

Risk assessment (Job Aid #4, 5 and 6) results can come in many formats, including qualitative narratives, long lists of risk statements triaged by urgency or other qualifiers, risk registers, and consequence/likelihood matrices (so-called "heatmaps") showing risk scores, and conceptual models (example **Figure 7-2**) showing cascading and cross-cutting risks (see Job Aid 5 on "Considering Cascading and Cross-Cutting Impacts"). Whatever the format, before moving on to adaptation planning, decision-makers, stakeholders and Rights Holders should aim to arrive at consensus on the validity of the climate change risks presented (U.S. EPA, 2014). Bringing together those involved in risk analysis, decision-makers, and groups affected by climate change risks to collectively reflect on the risk information and making any needed adjustments to risk scores based on new evidence or local knowledge adds robustness and credibility to the risk analysis effort. The PCCIA was an expert- and literature-driven process and final risk scores did not always account for current and planned adaptation, opting instead to overlay high-level adaptive capacity scores to risk scores to provide a sense of residual risk.

With a finalized list, matrix or register of climate change risks organized by urgency, magnitude, or some other measure of importance, the process advances toward adaptation in light of the organization's goals and objectives (see Case Study 11 on the City of Thunder Bay in this Job Aid). No organization or community has the capacity and resources to implement all possible measures to reduce climate change risk and increase resilience

(Hallegatte et al. 2021). Compiling risk results in different ways (e.g., by ecosystem, policy domain, urban or rural settings) to map with organizational goals and objectives helps deepen understanding of where climate change risk may be concentrated, and the climate change risks worth paying attention to (U.S. EPA 2014). It also starts to clarify the risks your organization "owns" or can influence, as well as potential entry points for adaptation and risk reduction (UNDRR 2022). For example, the Council of Canadian Academies undertook a strategic and expert-driven assessment of climate change risk for Canada, overlaying federal government mandates, policy priorities and public concerns to the analysis to identify areas for federal intervention (CCA 2019).

PCCIA Application: The PCCIA Technical Report presents rated risks by Area of Focus (e.g., Infrastructure, Food and Agriculture, Business and Economy) in aggregate form and by each of the six regions within Ontario. There are other ways to roll up and organize results, including regionally and sectorally.

Step 2 – Clarifying Your Risk Appetite

Turning analysis of climate change risks into information for decision-making involves making value or normative judgements on the appropriate action to take (McDermott & Surminski 2018). Key to this is clarifying the amount and type of risk the organization is willing to accept (their risk appetite) and any variation in this (risk tolerance) (TBS n.d., IRM n.d.). Risk appetite varies among individuals within the organization so achieving alignment is important to foster consistent, risk-informed decision-making. To do this, first compile information on contextual issues (organizational norms, political, regulatory, cultural, financial) shaping the organization's response to climate change risk. Organizations with a risk culture will tend to have guidance on risk appetite and risk tolerance for evaluating enterprise-wide (see
Table 10-1) or project-specific risk. Requesting this guidance from risk specialists in your organization is a good place to start. Even where such guidance already exists, it is worth considering whether the organization's risk appetite needs adjusting given the unpredictable nature of climate change risk (compared to other risk drivers) (UK NAO 2021) and, by implication, the potential need for novel responses (Mechler & Schinko 2016).

Table 10-1: Sample Guidance on Risk Tolerance for an Organization.

Risk Level	Risk Tolerance and Escalation Guidelines
Very High	**Not Tolerable** – Immediate risk mitigation required. Risk to be monitored closely by leadership. Organizational leader to be briefed upon exposure. The organization should be prepared to respond to consequences.
High	**Not Tolerable** – Ongoing risk mitigation required. Risk to be monitored closely by leadership. Management to be briefed upon exposure. The organization should be prepared to respond to potential consequences.
Moderate	**Tolerable with Caution** – Risk absorbed within normal course of work. Management in affected domains are aware and monitor periodically.
Low	**Tolerable** – Risk managed by routine procedures. Management involved as needed.

The matrix below was developed with a focus group of community members, asked to indicate their acceptance of a consequence for different probabilities of occurrence. The risk results were determined by a small group, with risk defined as "not acceptable", "acceptable if it was also as low as reasonably possible (ALARP)", or "acceptable", based on two potential scenarios and levels of probability.

Table 10-2: Risk tolerance matrix for exceeding aquatic environmental thresholds (Source: adapted from Christoffersen et al. 2019).

Aquatic Environment Threshold Scenario	1 in 10,000,000	1 in 1,000,000	1 in 100,000	1 in 10,000	1 in 1,000
Site-specific **water quality objectives are exceeded** by 100% in Yellowknife Bay beyond the mixing zone for **2 months in a year**	• 5 "acceptable"	• 4 "acceptable" • 1 "acceptable if as low as possible"	• 2 "acceptable" • 3 "acceptable if as low as possible"	• 1 "acceptable" • 4 "not acceptable"	• 5 "not acceptable"

Aquatic Environment Threshold Scenario	1 in 10,000,000	1 in 1,000,000	1 in 100,000	1 in 10,000	1 in 1,000
Untreated effluent or mine water seepage released into Yellowknife Bay for **2 months in a year**	• 3 "acceptable" • 2 "acceptable if as low as possible"	• 1 "acceptable" • 3 "acceptable if as low as possible" • 1 "not acceptable"	• 4 "not acceptable" • 1 "acceptable if as low as possible"	• 5 "not acceptable"	• 5 "not acceptable"

External engagement using participatory approaches offers an opportunity to create a more complete picture of risk appetite, adding transparency to decision-making. This is particularly important in cases where organizational guidance is unavailable or not fit for purpose, where national or regional guidance exists but is difficult to translate to your context (e.g., the precautionary principle), or where misalignment between your organization's stance and the social appetite for risk is possible (McDermott & Surminski, 2018). Since climate change risk is unevenly distributed geographically and across human populations, engaging directly with individuals and communities with the potential to bear the brunt of the consequences of impacts is especially important.

Table 10-2 shows a risk tolerance matrix developed by eliciting risk attitudes from community members close to the site of a proposed mine reclamation project. A similar exercise could be completed to explore and document attitudes on climate change risk.

Step 3 – Deciding on a Course Toward Successful Adaptation:

With guidance criteria and clarity on the organization's risk appetite in hand, decision-makers can take a closer look at the list of climate change risks to decide, at a high level, how to approach the identified risks (**Table 10-2**). The objective of this process is to decide whether the organization will mitigate, transfer, accept or avoid each risk (U.S. EPA 2014).

Figure 10-1: Options for managing risks identified through a climate change risk assessment process (Sources: ISO, 2018; U.S. EPA, 2014)

Figure 10-1 expands on the courses of action for managing risks identified through a climate change risk assessment to include an option to undertake additional research on risks considered too uncertain and to avoid over-interpretation of results (McDermott & Surminski 2018). In theory, actions to reduce climate change risk (i.e., “risk mitigation” or adaptation) lower the consequence or likelihood of impact or both. Changing the occurrence of climate-related hazards is generally only possible through global cuts in greenhouse gas emissions, therefore, organizations can act to reduce exposure and susceptibility to impact.

Organizations can opt to maintain existing controls on risk, which can include relying on existing emergency management and business continuity plans. This is different from accepting the risk or doing nothing because maintaining existing risk controls requires sustaining resources allocated to that task. Accepting the risk means that the organization accepts that the consequence may occur, and typically involves monitoring to detect shifts in risk profiles. Transferring the risk entails handing over responsibility to address the risk to another party. Insurance is a common option for risk transfer. Avoiding the risk involves changing organizational goals, activities, or physical locations to prevent exposure to the risk. Because risk avoidance generally involves stopping channeling resources toward the goal, activity or location that would be affected, triggering biases in thought patterns such as loss aversion (The Decision Lab, n.d.), this option can be unpopular.

Experience implementing actions to manage climate change risks is growing; however, organizations may still be unfamiliar with the risk mitigation options available to them or their relative costs and benefits. Before deciding on an organization’s approach to manage each risk it is wise to build awareness of feasible and suitable options. Several resources on adaptation strategies and measures exist, including through Climate-ADAPT, EPA, ICLEI-Canada, U.S Climate Resilience Toolkit and the Adaptation Resource Pathways of Natural Resources Canada.

PCCIA Application: One of the outputs of the PCCIA process is a library of adaptation best practices for Ontario, outlining adaptation measures to build the resilience of businesses, communities, infrastructure, and natural systems. This compendium could inform the development of an initial list of adaptation strategies and actions to consider in response to both immediate and long-term climate change risks, such as the exercise undertaken by Metrolinx in Case Study 12 in this Job Aid.

Aside from filtering possible adaptation responses through conventional considerations such as potential costs/benefits and feasibility of implementation, other “lenses” to account for include the following:

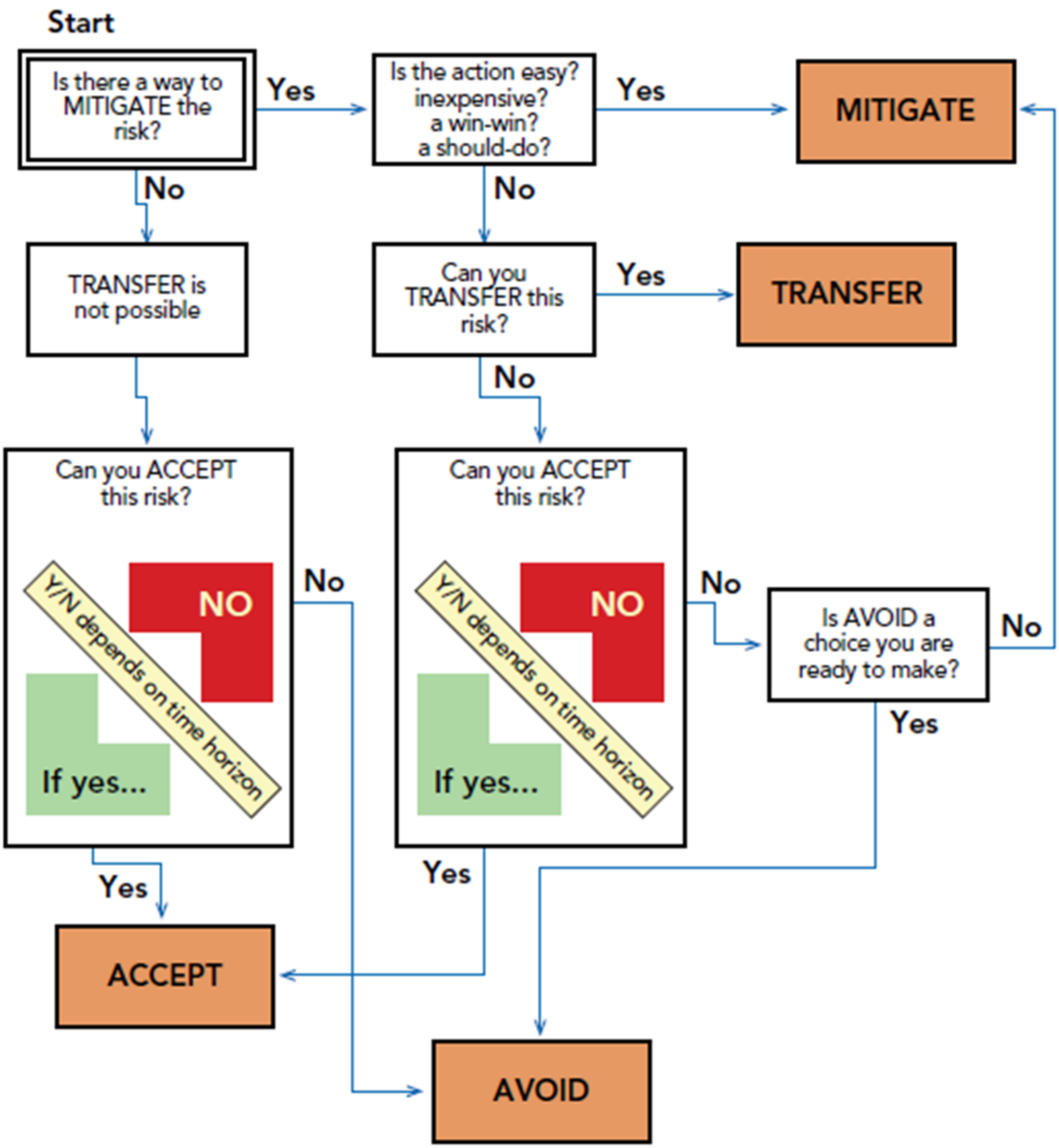
- Adaptation approaches that can address multiple risks.
- Adaptation approaches that could lead to maladaptation, either reducing other organization’s capacity to adapt or locking in the organization into a pathway ill-suited to evolving climate change risk.
- Adaptation approaches with co-benefits, such as the potential for greenhouse gas mitigation, human health benefits, biodiversity benefits, alignment with commitments to Indigenous Reconciliation, and improved social equity and justice.
- Trade-offs between different strategic or policy priorities.

With a more informed position on the “solution space”, cases where adaptation (risk mitigation) can lead to multiple benefits, and clarity on risks the organization needs to own or contribute to mitigating, risk evaluation then involves systematically deciding on what to do in response to each identified climate change risk. As you work through this process consider sequencing actions. Some climate change risks may be deemed urgent. The second UK Climate Change Risk Assessment assigned urgency to climate change risks based on evidence that risks were unlikely to be reduced to a low magnitude through spontaneous action alone and where net benefits to action were apparent (Brown et al. 2018). For interconnected risks, there can be an order to implementation, as action on one (no action) can reduce (or amplify) risk. In yet other cases, critical “windows of opportunity” to address climate change risk may exist and be beneficial to seize on (CCA 2019), such as cycles of capital stock renewal. **Figure 10-2** illustrates a logical sequence of considerations to help decide on an organization’s response to each risk. Tailoring this flow chart to the organization’s specific context is a worthwhile exercise if no similar or more detailed guidance already exists.

Connecting a vision of successful adaptation with a set of priorities stemming from risk evaluation paves the way for a coherent, risk-informed adaptation plan with specific objectives and actions to achieve them, as well as indicators and metrics to report on progress towards implementing actions and reducing risks.

The below flow chart starts with considering whether there are feasible ways for the organization (and partners) to reduce risk to a tolerable level. If not, the organization must accept or avoid it. If yes, mitigation could be the first choice depending on the nature of the risk. Risk transfer could be the next best option but if no other part can or wants to agree to the risk transfer, the organization could accept the risk, if it is low-impact or medium impact in the longer-term. Otherwise, if the organization is not prepared to avoid the risk, mitigation is the option to pursue (Source: U.S. EPA 2014).

Figure 10-2: Flow chart guiding decision-making on climate change risk when priorities must be identified and not every risk can be mitigation (Source: U.S. EPA 2014).



Step 4 – Communicating the Results of Risk Evaluation:

Documenting and communicating the results of risk evaluation is an important step in any risk assessment process (ISO, 2018). These efforts should be pursued at three levels. First, the outcomes of risk evaluation should be integrated into other pertinent strategy documents, such as the organization's enterprise risk management strategy (Government of Ontario, n.d.), and the implications of these inclusions analyzed. Second, informing staff on the selection of risk management measures fosters coherent action on shared goals across the organization, including building a common understanding of roles and responsibilities for climate change risk management (UNDRR, 2018). Third, disclosure of climate-related risks is increasingly expected by external stakeholders (OSFI, 2022) and gaining traction among organizations committed to climate action. Aside from responding to shifting market expectations on climate disclosure, for a public-sector organization communicating their approach to managing climate change risks raises awareness of the extent of protection from climate change impacts that households and firms can expect so private actors can then make the risk adaptation decisions, too (Hallegatte et al. 2020). In some cases, responsibilities for managing climate change risks and related liabilities are encoded in law or regulations.

Climate change risk assessments are only relevant for exploring the risks present at certain times or under certain conditions. Therefore, the process should be iterative over a longer period of time (CCME, 2021). For example, after an initial risk assessment, there should be a follow-up period of approximately five to seven years where subsequent assessments are undertaken to determine if the actions taken have sufficiently addressed the initial risks (CCME, 2021). This timeframe allows for several of the risk-reduction actions to have been implemented, and for any potential responses to be observable.

10.5 Risk Assessment in Action

Case Study 11: Climate-Ready City – City of Thunder Bay Climate Adaptation Strategy

Year: 2015 **Focus:** People and Communities; Infrastructure; Natural Environment

Link: Climate-Ready City – City of Thunder Bay Climate Adaptation Strategy

Context: In partnership with EarthCare, the City of Thunder Bay developed a Climate Adaptation Strategy to help the city prepare for, respond to, and recover from the potential impacts of climate change with an emphasis on increasing the resilience of infrastructure and the natural environment.

Approach to Risk Assessment and Use of Data: This Strategy has been widely recognized for its comprehensive assessment, planning and engagement approaches taken, in alignment with ICLEI Canada's Building Adaptive & Resilient Communities (BARC) Five Milestone Framework.

Figure 10-3: Banner for Thunder Bay's Climate Adaptation Strategy.

Image Source: Climate-Ready City – City of Thunder Bay Climate Adaptation Strategy, 2015

Figure 10-4: Strategic Themes to Focus Adaptation Efforts

Image Source: Climate-Ready City – City of Thunder Bay Climate Adaptation Strategy, 2015.

Results from the assessment work were used to prioritize a list of 46 potential climate change impacts, with medium to high-risk scores being carried forward to the planning-phase. A total of nine priority impacts associated with extreme weather events and rising temperatures were identified through the assessment process. From here, adaptation actions prioritized were analyzed from the lens of implementation to identify resources required to move forward and support the progression from the adaptation planning to implementation phase. Short-term actions (requiring less than two years to implement) were identified as 'quick wins' that could be easily implemented and help to gain support. Longer-term actions were identified as requiring ongoing and collaborative efforts over a number of years to achieve successful implementation.

The Project Team then applied a strategic approach by identifying how the priority impacts could affect the key pillars of the City's Corporate Strategic Plan. This approach helped to tie adaptation actions to existing strategic goals and direction. The city also developed an accompanying business case for adapting and managing the identified climate risks. Costs associated with property damage, infrastructure destruction, loss of production or services, loss of biodiversity and declining housing values were used to make the case for investment in adaptation.

How Results Influenced Decision-Making

The results of the completed vulnerability and risk assessment, along with a series of engagement activities, were used to inform the vision, goals and adaptation actions included in the Strategy. When identifying and prioritizing key adaptation actions to address high-ranking risks and vulnerability, several strategic themes emerged (see **Figure 10-4**) and were used to provide direction on implementation for City Staff and Council.

Impact or Outcomes of Implementation

The proposed actions were tailored for the City of Thunder Bay, based on priority risks and impacts identified and considering the City's existing adaptive capacity. The Strategy includes details relevant to the implementation of each action, including primary leads, potential partnerships, supporting plans and strategies, and estimated costs and timelines. In addition, the Strategy outlines an action register template for reporting on the progress of each action.

Key Lessons from this Case Study

Select lessons from the City of Thunder Bay's Climate Adaptation Strategy include the alignment of the adaptation strategy with the City's existing corporate strategic priorities, enabled the integration and mainstreaming of adaptation into existing plans, policies and goals, while promoting cross-departmental collaboration. This approach helped to enhance the City's overall capacity to address climate-related impacts and risks. As well as to continue advancing adaptation efforts, the City has prioritized continued collaboration, adequate resources and staffing, and robust governance systems, for future success.

Case Study 12: Metrolink Climate Adaptation Strategy

Year: 2018 **Focus:** Infrastructure

Link: Metrolinx Climate Adaptation Strategy

Context: Metrolink provides multimodal transportation services across the Greater Toronto and Hamilton Area (GTHA) and manages over $19.5 billion in transportation infrastructure. In 2016, Metrolinx conducted a vulnerability assessment using the PIEVC protocol (AECOM et al. 2016), and in 2017 they released a foundational resilience report, summarizing adaptation and resiliency best practices (Chiotti et al., 2017). Informed by this work and engagement with stakeholders and subject matter experts, the Metrolinx Climate Adaptation Strategy outlines key measures for improving resiliency of their infrastructure, facilities and protocols to climate-related risks.

Figure 10-5: GO Train.

Image Source: Metrolinx Climate Adaptation Strategy, 2018

Approach to Risk Assessment and Use of Data

To identify targeted adaptation actions, a preliminary vulnerability assessment was conducted.

Metrolinx applied the PIEVC Protocol to six of the agency's assets that were representative of all assets across the corporation, including two each of stations, facilities, and segments of rail corridors. The process was strictly evidence-based and resulted in ranking of climate change risks. Results were reported in an organization-wide climate Adaptation Strategy and included lessons from the assessment process.

How Results Influenced Decision-Making

Metrolinx is recognized as a leader in climate adaptation, with their 2018 Metrolinx Adaptation Strategy being one of the first of its kind for the transportation sector. One of reasons for its success is the foundational work completed ahead of the strategy development, along with detailed actions, roles, and responsibilities. The strategy includes elements of asset management, design practices, emergency response planning and preparedness, regional and strategic planning, along with engagement activities and education initiatives. Metrolinx uses the strategy to guide planning and decision-making processes and investments to manage and minimize current and future climate-related impacts and risks.

Impact or Outcomes of Implementation

The background vulnerability assessment revealed that several climate-related risks pose threats to infrastructure, operations, reputation, working conditions, and health and safety at Metrolinx. The results of the assessment were used to develop a list of 40 key adaptation actions to build climate resiliency across the organization, addressing both immediate and long-term risks.

Adaptation actions proposed in the Strategy are assigned across several business units in the enterprise. The strategy outlines requirements for implementation plans to be completed by each business unit, including a list of steps needed to complete the action, cost-benefit analysis, budget and resource availability and requirements, and a process for monitoring and reporting on progress. Metrolinx also highlights the importance of integrating climate resiliency into their governance systems to support the mainstreaming of actions into other corporate strategies and plans. This is critical for successful adaptation as it sets out clear roles and accountability for implementation across business units.

Key Lessons from this Case Study

Key lessons from this case study include:

- The approach applied by Metrolinx proved to be a valuable planning exercise and resulted in a robust adaptation strategy, with actionable and targeted actions.
- Linking and mainstreaming adaptation into corporate planning and decision-making processes and investments support implementation and helps manage and minimize current and future climate-related impacts and risks.

- Metrolinx identified the requirement for a system-wide climate vulnerability assessment to provide a more comprehensive baseline to inform adaptation and resiliency planning. The results of a system-wide assessment helped to better prioritize action and response towards the most critical climate-related risks to the Metrolinx's infrastructure, operations, health safety and services.

10.6 Key Takeaways

- If this was not done during context setting or scoping, consider undertaking a "visioning exercise" among stakeholders and those involved in scoping a risk assessment. For example, what does a resilient system look like and how could undertaking a risk assessment support resilience building.
- Once risk results are available, identify adaptation high-level actions that can address each one, or multiple risks, consider the appropriate scale of those actions based on mandate, risk appetite, resource availability and ambition.
- Apply other lenses to adaptation actions, such as identifying co-benefits or trade-offs with reducing greenhouse gas (GHG) emissions. Subsequent work can then occur to scope or apply actions where adaptation and GHG mitigation can be addressed together.
- Always propose roles and responsibilities (e.g., lead, support, collaborators) for adaptation actions that can help in future implementation.
- Consider how long adaptation actions may take to implement (e.g., short, medium, long term) and put bounds around timelines based on mandate or context (e.g., within a term of council at a municipality, or next fiscal year, etc.).
- Estimate the possible level of resources required to implement adaptation actions - even qualitatively or at a high level. As a next step, consider breaking adaptation actions into "tactics" or explicitly building them into work plans to ensure staff feel a sense of responsibility to address them.
- Use the outputs of risk evaluation to create an implementation and monitoring plan and explicitly commit to reporting on progress towards implementing actions and reducing risks, and in iterating as needed to undertake future risk assessments.

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