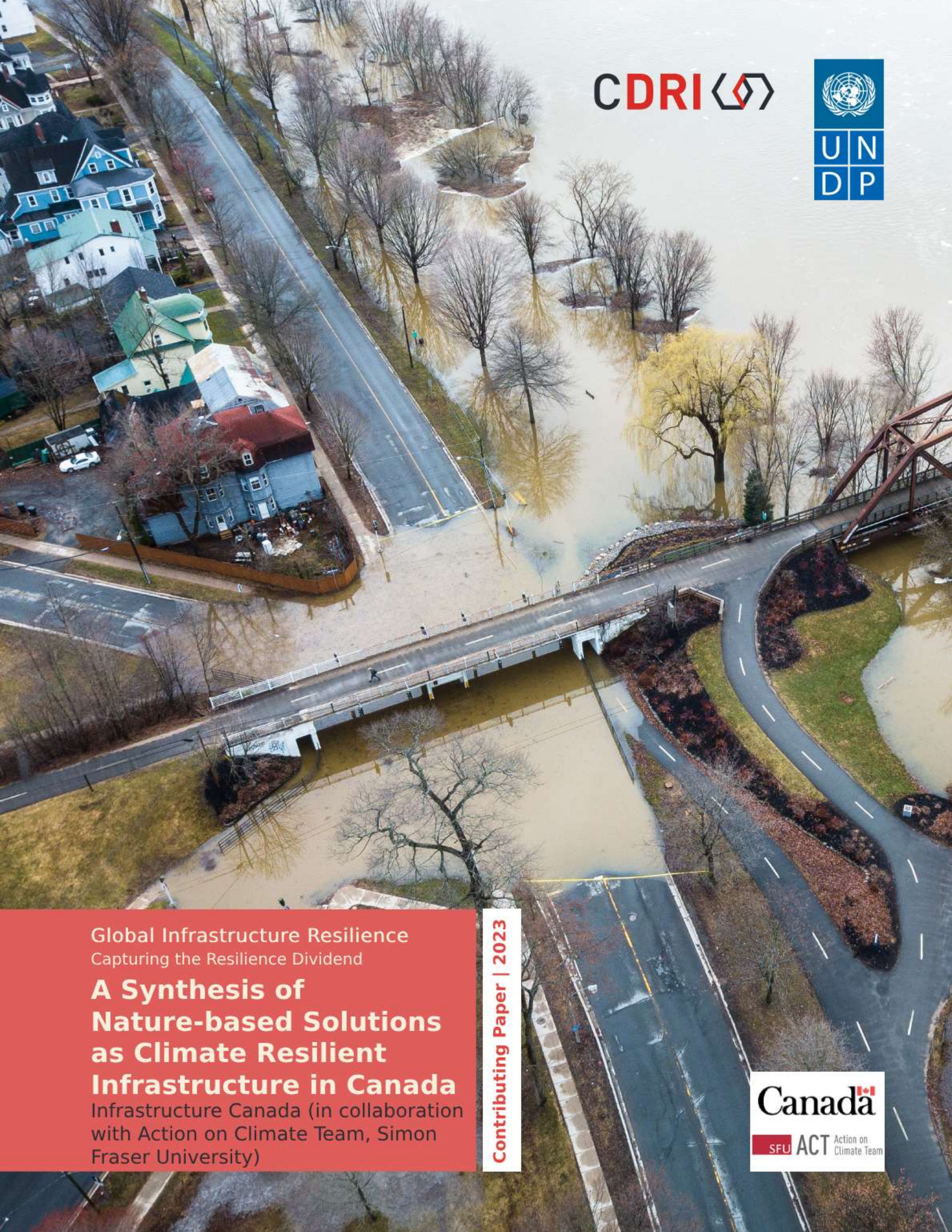

Global Infrastructure Resilience

Capturing the Resilience Dividend

A Synthesis of Nature-based Solutions as Climate Resilient Infrastructure in Canada

Infrastructure Canada (in collaboration with Action on Climate Team, Simon Fraser University)

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A Synthesis of Nature-based Solutions as Climate Resilient Infrastructure in Canada

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Table of Contents

EXECUTIVE SUMMARY 3
1. INTRODUCTION 5
1.1. NATURE-BASED SOLUTIONS: AN OVERVIEW 6
1.2. NATURE-BASED SOLUTIONS FOR DISASTER-RESILIENT INFRASTRUCTURE 9
1.3. RESEARCH METHODS 10
2. NATURE-BASED SOLUTIONS FOR FIVE KEY NATURAL DISASTER AREAS IN CANADA 10
2.1. URBAN HEAT ISLAND AND URBAN FLOODING 11
2.2. COASTAL FLOODING AND EROSION 18
2.3. RIVERINE FLOODING 24
2.4. WATER STRESS 28
2.5. LANDSLIDE AND UNSTABLE SLOPES 31
3. MONITORING AND EVALUATION 34
4. CONCLUDING REMARKS 38
APPENDIX 1. IUCN'S BEST PRACTICE CRITERIA 41
REFERENCES 43

EXECUTIVE SUMMARY

Nature-based Solutions (NbS) are gaining international attention due to their capacity to increase the resilience of built infrastructure to natural hazards and climate change by "protecting, sustainably using, managing and restoring natural or modified ecosystems."[1] Although NbS are rapidly emerging as viable, cost-effective, multifunctional strategies with benefits for both biodiversity and human well-being by public and private practitioners,[2] their implementation to date has been slow.

Currently, the Coalition for Disaster Resilient Infrastructure (CDRI) is taking stock, identifying key NbS approaches that can be mainstreamed at the global, national, and sub-national levels,[3] and is developing a Global Flagship Report to support this goal. The CDRI Report has five pillars, with *Pillar 3: Nature-based Solutions for Climate and Disaster-Resilient Infrastructure – A Case for Mainstreaming Nature-based Solutions in Infrastructure Development and Reconstruction,* dedicated to NbS acceleration. This report, prepared by the Action on Climate Team (ACT) at Simon Fraser University with Infrastructure Canada, is an annex to Pillar 3, and provides Canadian case studies for NbS in five key hazard areas: 1) urban heat island and urban flooding, 2) coastal flooding and erosion, 3) riverine flooding, 4) water stress, and 5) landslides and unstable slopes.

Public and private sector actors are moving quickly to consider NbS applications across hazard areas related to 'urban heat and flooding' and 'coastal flooding and erosion'. However, research shows that barriers to effective implementation include siloing among organizational departments and skill sets, not being large enough in scale to have optimal impact, and not being adequately funded nor effectively integrated into policy.[4] In Canada, a growing number of local governments are turning to NbS to provide municipal services more cost-effectively, such as water conveyance and storm water management, however their use remains siloed, resulting in a tendency to underestimate broader systems benefits, and hindering large-scale utilization.[5] The most widely discussed barriers to NbS uptake include inadequate funding, unfamiliar decision-making processes, fragmented governance, insufficient regulatory and political support, and uncertainties around planning and implementation.[6]

The ten Canadian case studies in this report provide examples of projects that have overcome these types of barriers. The Town of Gibsons, BC highlights ways a small municipality can recognize, assess, manage, and incorporate natural assets into municipal planning and accounting **(Innovative Funding)**. The City of Vancouver, BC demonstrates that municipalities can organize diverse urban greening efforts around specific stormwater management targets, streamline the planning and implementation process, and prioritize actions to achieve NbS goals **(Coordinated Approach)**. The City of Montréal, QC shows how a metropolitan city, highly developed with limited green space, can utilize a wide range of NbS interventions, from funding to capacity building and regulation, to enhance built infrastructure **(Financial and Regulatory Support)**. The Green Shores Program shows how a local non-profit organization can adopt an innovative initiative, utilize diverse funding sources, and support the contextual application of NbS **(Technical Support)**. Chapel Island, NS's erosion protection project outlines the role of collaborative community engagement in NbS adoption **(Inclusive Governance)**. The Town of

Truro, NS demonstrates how a comprehensive flood study can facilitate NbS decision-making in a socio-ecologically complex region **(Decision-Making Support).** The Toronto and Region Conservation Authority example illustrates that systematic ecosystem and conservation planning at the watershed scale can be more effective for organizing upstream and downstream NbS **(Integrated Eco-Regional Governance)**. The Town of High River, AB avoids projected recurring flood damages through a managed retreat strategy **(Policy Support)**. The Pelly's Lake Backflood Project in Manitoba takes a managed wetland approach to support the Lake Winnipeg Region's water security, agriculture, ecosystem health, and energy availability **(Decision Making Support)**. The District of North Vancouver, BC presents ways to integrate NbS that protect against natural hazards using municipal planning and regulations (**Regulatory and Political Support**).

ACT developed this report by performing a literature review across the five key hazard areas, delivering a survey that resulted in fifteen notable Canadian researcher and practitioner respondents, and interviewing eight Canadian NbS specialists. One hundred Canadian case studies were identified and analyzed using eight criteria from the International Union for the Conservation of Nature (IUCN)'s Global Standard for NbS.[7] Of note, the emphasis of Canadian NbS is heavily weighted toward urban heat and flooding, with many cases for coastal flooding and erosion emerging as well. Cases related to riverine flooding, water stress, and landslides and unstable slopes were less available. The case studies offer significant lessons learned about opportunities to advance and accelerate effective NbS in Canada.

1. Introduction

Built infrastructure in Canada is facing imminent environmental risks intensified by climate change, such as flooding, drought, and heat events. Canadian communities are seeing an ever-increasing need for the establishment of more resilient infrastructure to proactively buffer against disasters and remain adaptive to projected climate changes, while also reducing or avoiding emissions. Nature-based solutions (NbS) are being planned and implemented worldwide as a strategic low carbon resilience approach that can supplement core community services such as water and stormwater management while aligning with other objectives such as protecting and enhancing conditions for biodiversity, advancing equity and reconciliation, and ensuring community resilience under rapidly changing climate conditions. Diverse actors from across sectors are working to accelerate the implementation of NbS as a strategic low carbon resilience approach, reducing climate risk, emissions, and enhancing biodiversity, equity, health, and other sustainability objectives.

This review focuses on best practices and notable Canadian case studies that use nature-based solutions as a form of community infrastructure, providing services across five key hazard areas: 1) urban heat island and urban flooding, 2) coastal flooding and erosion, 3) riverine flooding, 4) water stress, and 5) landslides and unstable slopes. The findings and results were developed from a review of scholarly and grey literature across the five key hazard areas, responses from a survey of ten notable Canadian researcher and practitioner organizations, and interviews with eight Canadian municipalities/organizations working in NbS. One hundred Canadian case studies were identified and analyzed using the International Union for the Conservation of Nature (IUCN)'s Global Standard for NbS. The eight IUCN criteria for best practice (see Figure 1) were used to identify ten best practice case studies across the five key hazard areas.[8] It is important to note that Canadian NbS projects emphasize municipal service delivery, and community resilience toward urban heat and flooding, with noteworthy NbS cases in coastal flooding and erosion. There were fewer cases related to riverine flooding, water stress, and landslides and unstable slopes. Overall, the selected case studies below demonstrate how NbS practice can satisfy each criterion and provide lessons learned (see Table 1 below).

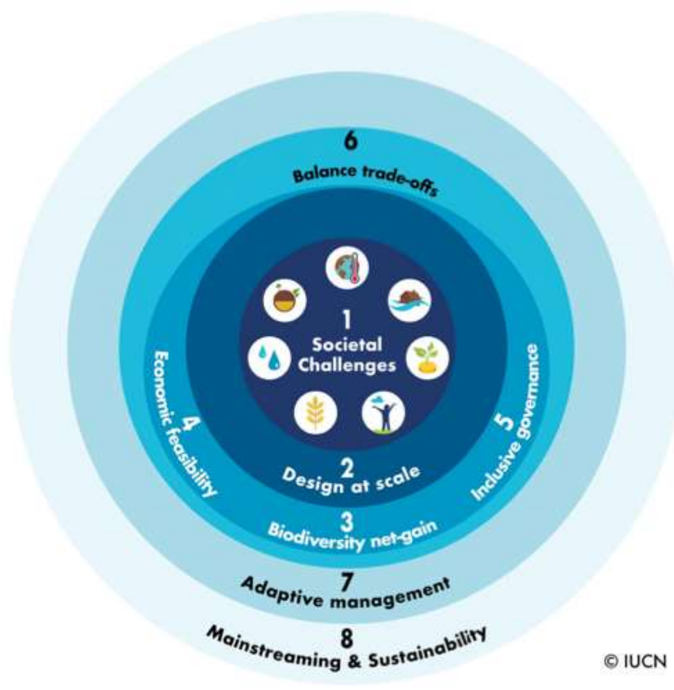

Figure 1: Eight Criteria of IUCN Global Standard for NbS

NBS are increasingly being evaluated for their capacity to complement built infrastructure using natural infrastructure - both the protection, restoration, and expansion of natural assets as well as the promotion of hybrid/green infrastructure - to deliver services. The goal of this review is to support Infrastructure Canada's efforts to better understand the application of, demand for, and criteria needed for investment in NbS in Canada. This review is also Canada's contribution to the Coalition for Disaster Resilient Infrastructure (CDRI) Global Flagship Report, featuring findings from a consortium of organizations interested in advancing NbS across local and global scales, to be released in 2023.

Table 1: Ten Canadian NbS best practice case studies across five challenge areas

Hazard Area	Case Study Title	Key IUCN Criteria
1. Urban Heat Island and Urban Flooding	1.1 Town of Gibsons, British Columbia *Enhancing Natural Assets for Stormwater Management and Flood Mitigation*	Economic Feasibility, Mainstreaming and Stability
	1.2 City of Vancouver, British Columbia *Orchestrating Urban Greening Strategies Around Urban Stormwater Management*	Societal Challenge Addressed, Mainstreaming and Stability
	1.3 City of Montréal, Québec *Supporting and Enforcing Urban Greening to Mitigate Heat Island Effects*	Inclusive Governance, Mainstreaming and Stability
2. Coastal Flooding and Erosion	2.1 Stewardship Centre for BC, Green Shores Program *Building capacity and mobilizing knowledge to adopt NbS*	Mainstreaming and Stability
	2.2 Chapel Island, Nova Scotia *Enhancing holistic NbS value through community engagement*	Inclusive Governance
	2.3 Town of Truro, Nova Scotia *Restoring natural assets to mitigate coastal flooding in the Bay of Fundy*	Scale of Design
3. Riverine Flooding	3.1 Toronto and Region Conservation Authority, Ontario *Overcoming fragmented governance at watershed scale*	Inclusive Governance, Adaptive Management
	3.2 The Town of High River, Alberta *Strategically returning the land to nature*	Economic Feasibility
4. Water Stress	4.1 Pelly's Lake, Manitoba *Improving water storage capacity and water quality through an engineered wetland system*	Economic Feasibility, Balanced Trade-Offs
5.Landslides and Unstable Slopes	5.1 District of North Vancouver, British Columbia *Incorporating NbS strategies in the community plan to improve landslide resilience*	Inclusive Governance, Mainstreaming and Stability

1.1. Nature-based Solutions: An Overview

Over the past two decades, the International Union for Conservation of Nature (IUCN), an international leader on NbS, has developed resources and tools providing guidance on how to leverage nature and the power of healthy ecosystems to protect people, optimize infrastructure, and safeguard a stable and biodiverse future.[9] The IUCN defines NbS as "actions to protect, sustainably use, manage and restore natural or modified ecosystems, which address societal challenges, effectively and adaptively, providing human well-being and biodiversity benefits."[10] An increasing number of scholars and practitioners are identifying and evaluating NbS for their ability to address societal challenges through the protection, sustainable management, and restoration of ecosystems, benefiting biodiversity, community services, climate mitigation and resilience, and human well-being. The World Economic Forum has called NbS research and practice a US $10 trillion opportunity.[11] Institutions, including the United Nations Environment Programme, the World Bank, national and local governments, and civil society groups are increasingly literate about the opportunity cost of losing irreplaceable natural systems and services, and the need to value and account for the critical values and services provided.[12]

This rise in interest has contributed to a myriad of NbS terms and approaches, and, as a result, a proliferation of siloed objectives. For instance, synonyms ranging from natural assets, natural capital, natural infrastructure, and natural systems to green/blue/ecological infrastructure, green planning, and low impact development are being applied across engineering, biology and conservation, and planning disciplines. The Natural Solutions Initiative (NSI) (2021-2025), a research-to-practice initiative from the authors of this report at ACT - the Action on Climate Team at Simon Fraser University, aims to overcome this siloing by valuing and optimizing the multiple objectives that NbS can be used to address. NSI will develop more systemic framing and metrics that articulate NbS as a multi-solving strategy across climate change, biodiversity, equity, and sustainable service delivery objectives.

For our purposes here, the Canadian Council of Ministers of the Environment (CCME) distinguishes natural infrastructure (NI) from green infrastructure (GI), asserting that the former, is entirely made of components found in natural ecosystems (such as water, native species of vegetation, sand, and stone, etc.), while GI is made of hybrid or enhanced elements of nature.[13] This aligns with ACT's Natural Solutions Initiative, in which a more systemic framing of the multifunctionality of NbS is encouraged and is aimed at developing a more coherent understanding of the interdependence of NbS across scales. Doing so, ensures that the foundational goal of NbS is to protect and enhance both the ecological processes for the health and integrity of ecosystems (e.g., form, flow, function, thresholds, habitat, etc.), and for cultural health and well-being (e.g., indigenous harvesting, ceremony, etc.), while also providing key services for the sustainable functioning of regional and local socio-economic systems (e.g., water conveyance, stormwater management, flood and heat protection, etc.).

In this framing, bioregionalism or eco-regions such as watersheds become the central focus, whereby NbS – natural infrastructure/assets and green infrastructure are both used to support and enhance broader ecological processes in a coherent manner. This shifts NbS application from short-term, discrete projects to coordinated management challenges at the regional/landscape scale. Projected climate impacts occur at this scale. Ensuring that NbS investments made now account for changing climate conditions is crucial for identifying cost-effective and resilient NbS approaches and investments over the longer term. Better understanding of projected impacts and risks for ecosystems, services and populations, and core infrastructure will support the advancement of effective, resilient NbS into the future. This will require coordinated management across scales, jurisdictions, and uses for sustainable ecosystem management and service delivery.

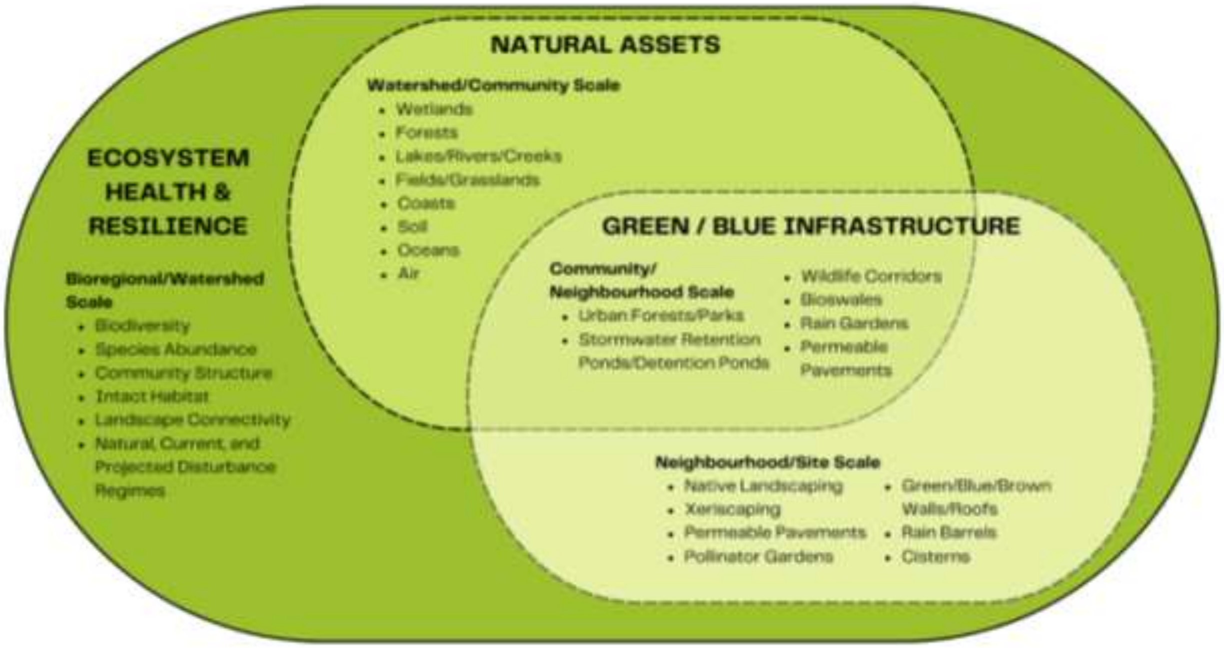

Figure 1-1: Scale and Application of NbS for Ecosystem Health and Resilience

Figure 1-1 illustrates how ACT's NSI's framing of NbS can be used to enhance ecosystem processes and services (upstream), using a combination of natural asset (midstream) and green infrastructure (downstream) strategies that are viewed within an interdependent system. In this context, NbS actions can be used to enhance overall ecosystem health and resilience at the regional scale by:

1. **Protecting, restoring, and enhancing natural infrastructure/assets** (e.g., forests, wetlands, foreshores, etc.) and their ecological functions and services; and
2. **Promoting green-blue infrastructure**, designing and engineering solutions that enhance ecological functions and services (e.g., rain gardens, green roofs, permeable surfaces, etc.).

Multiple values and benefits arise from NbS applications that enhance ecological processes and create coherence for the sustainable delivery of ecosystem services across scales. Some of these values include reducing flood and heat risks, sequestering carbon, saving taxpayer dollars on expanded infrastructure, improving air and water quality, enhancing green connectivity and biodiversity, saving costs on heating and cooling, increasing recreation, health and mental well-being, and enhancing property values, to name a few. It is important that all direct and indirect benefits and values are considered, quantitatively where possible and qualitatively where not, to coordinate interdependent NbS that optimize both the value of, and valuations for NbS.

NbS Applications	NbS applications are structural measures that build the health and resilience of ecosystem processes and services at a systems level, including protection, restoration, and expansion of natural assets as well as use of engineered green-blue infrastructure.
NbS Practices	NbS practices refer to actions or processes related to NbS planning, design, implementation, operation & maintenance, and monitoring & evaluation (e.g., decision-making processes for projects, standards and manuals, best practice criteria, cost-benefit analysis tools, triple-bottom line assessment, post-construction monitoring and reporting, etc.).
NbS Strategies	NbS strategies are interventions and instruments (i.e., non-structural measures) that advance and accelerate NbS in practice (e.g., urban forest management strategies, tree planting initiatives, rain barrel programs, community garden initiatives, Low Impact Development (LID), Best Management Practices (BMP), watershed management, etc.).

Table 1-1: Categorized NbS Terms in This Report

1.2. Nature-Based Solutions for Disaster-Resilient Infrastructure

Climate change intensifies hazards, damages and disaster risks. For instance, changes in temperature and precipitation patterns drive hazards such as heatwaves, flooding, and drought, which can trigger large-scale disasters such as wildfires and landslides.[14] The slow encroachment of sea level rise is projected to result in more frequent and intensified coastal flooding, storm surge, and saltwater intrusion to groundwater.[15] Rapid development increases the exposure of infrastructure, assets, and populations, amplifying the risks associated with climate change-exacerbated hazards. Infrastructure is resilient when it is able to recover from disasters brought by natural hazards (e.g., earthquakes, tsunamis, hurricanes, cyclones, tornados, floodings, and droughts) and anthropogenic hazards (e.g., human errors, malevolent attacks).[16]

In addition to protecting biodiversity and sequestering carbon, NbS are emerging as a critical strategy to minimize the projected impacts of climate change, increasing resilience to extremes in heat, drought, and flood events, and reducing reliance on emissions-intensive, costly grey infrastructure that may have negative land use impacts. Working with nature to enhance the valuable processes and services it provides for free is increasingly viewed as a cost-effective climate action strategy that simultaneously reduces climate risk and emissions, while advancing other co-benefits such as improved air and water quality, enhanced biodiversity and human well-being, and sustainable economic opportunities.

In 2020, the Government of Canada announced it was dedicated to investing in NbS to help achieve 2030 and 2050 climate change objectives and launched several funding programs, including the Natural Climate Solutions Fund, that provide CA$4 billion for NbS projects.[17] In 2021, Infrastructure Canada also announced a CA$200 million Natural Infrastructure Fund to support natural or hybrid projects that contribute to natural environmental protection, community resilience, and economic growth and job creation.[18] The emerging, and increasingly shared, understanding is that the value provided by Canada's ecosystems and associated services (historically assessed at CA$0) must be measured, valued, and monitored as crucial adaptive, resilience-building strategies under rapidly changing climate conditions.[19]

This report aims to enhance awareness about where and how NbS are being applied in Canada. Part 1 provides an overview of NbS terms and approaches and lays out the rationale and methods for development of this report. Part 2 identifies and details best practice cases studies across five climate hazard areas: 1) urban heat island and urban flooding, 2) coastal flooding and erosion, 3) riverine flooding, 4) water stress, and 5) landslides and unstable slopes. Part 3 discusses findings on key success factors and opportunities that can help advance NbS in Canada, and Part 4 provides concluding remarks.

1.3. Research Methods

If designed and implemented effectively, NbS can help to address multiple societal challenges, from minimizing environmental disaster and climate risks to advancing socioeconomic and sustainability goals.[20] There have been several efforts to establish standards for NbS. In 2020, the IUCN established a global standard for NbS best practice with eight criteria, ranging from framing and design to feasibility and governance to monitoring and trade-offs.[21] Twenty-eight indicators are included to support the advancement of inclusive governance and environmental, economic, and social development outcomes[22] (see Appendix 1).

These criteria provide a basis for thinking systemically about NbS planning to implementation and were used to guide best practice case study selection for this report. Data collection methods included a literature review of NbS in Canada, a survey with ten organizational participants, and eight interviews with NbS specialists, which led to identification of 100 case studies, primarily related to urban heat and flood risks, with coastal flooding and erosion as the second most represented case context. Ten notable case studies were identified across the five hazard areas. These were selected based on an analysis using the IUCN's eight best practice criteria, the high-level findings of which are presented in Section 2 below.

2. Nature-based Solutions for Five Key Natural Disaster Areas in Canada

Since 1948, Canada's annual average temperature has increased by 1.7°C, and this warming trend is expected to continue upwards.[23] Anthropogenically-driven climate change has intensified drought and heatwaves, which in turn trigger wildfires; permafrost melt and sea-level rise, that result in flooding and saltwater intrusion; and severe weather events such as extreme rainfall, storms, and heat domes. In 2021, Canada suffered CA$2.1 billion in insured damages due to climate change-related weather, storms, floods, and wildfires.[24] Actual direct and indirect economic and social costs are estimated to be closer to CA$10.6-17.1 billion,[25] and annual damage costs are expected to rise substantially within a decade.[26] Responding to the impacts of these climate risks imposes significant burdens on Canadian communities with limited financial resources.[27]

In light of these projected increases in climate-related disasters, NbS are being viewed as cost-effective avoidance, adaptation, and resilience-building strategies. NbS are not a one-size-fits-all approach, but tend to provide multi-solving benefits across environmental, social, and economic areas. As an example, the Province of Nova Scotia recently estimated that the continued loss of wetlands to development is estimated to be equal to $2 billion annually in lost services, such as water purification, groundwater recharge, and erosion protection in local governments.[28] Accounting for indirect benefits such as biodiversity enhancement and carbon storage only increases this value.

As research and practice continue to demonstrate the viability and benefits of NbS, a growing number of Canadian communities are seeking robust ways to successfully plan and implement them. Canadian communities can benefit from natural assets such as forests and wetlands if they are valued and managed strategically.[29] This section features best practice NbS cases across five main hazard areas: 1) urban flooding and urban heat island, 2) coastal flooding and erosion, 3) riverine flooding, 4) water stress, and 5) landslide and unstable slopes. The IUCN's Global Standard criteria is used to identify best practice cases and aims to illustrate ways the best practice criteria can be applied to diverse NbS strategies within each disaster area. The cases also provide insights into aspects of the NbS strategies that might be enhanced to facilitate more optimal outcomes. [30]

2.1. Urban Heat Island and Urban Flooding

As of 2021, 82% of Canada's total population lives in urban areas,[31] and this number will continue to grow.[32] Intensifying urbanization places additional pressures on urban areas and communities already struggling with aging infrastructure and limited financial resources. Urban development increases impervious surface area, disrupting the hydrological cycle, generating urban stormwater runoff, impairing water quality, increasing surface flooding, and contributing to the urban heat island effect.[33] Climate change is exacerbating these risks in urban areas, and Canadian cities are projected to experience more frequent and intensified flooding and heat island effects.[34] Damages from urban flooding and casualties and fatalities caused by extreme heat are contributing to exponential claims in loss and damage and are expected to continually increase, with disproportionate impacts on the already exposed and vulnerable.[35]

2.1.1. NbS Best Practices

Cities are investigating the opportunities of NbS as cost-effective strategies to address current and projected urban heat island effect and flooding issues. Both research and practice demonstrate that NbS can be cost- and time-effective as a substitute or complement to conventional gray infrastructure approaches in municipal service delivery.[36] For instance, protection and expansion of urban forests and the daylighting of streams and riparian areas are now being viewed as critical applications that provide a variety of urban heat and flood mitigation services.[37]

A growing number of cities are undertaking a range of NbS strategies, from enhancing natural infrastructure/assets (e.g., urban forest management) to retrofitting the built environment using green infrastructure (e.g., rain garden projects, tree planting initiatives, and de-pavement programs). Urban NbS strategies that aim to address heat and flood risk include:

- <u>Urban forestry and urban forest management</u>: The Canadian Urban Forest Strategy defines urban forestry as "the sustained planning, planting, protection, maintenance, management and care of trees, forests, greenspace along with related resources in and around cities as well as communities for economic, environmental, social, and public health benefits for people."[38] Urban forestry is a viable option for regulating heat and flooding. Urban vegetation and forestry systems can reduce surface and air temperature through shading and evaporative cooling.[39,a] Some studies found that shading and evapotranspiration can lower peak temperatures by 1-5°C in summer.[40] Urban forests can also mitigate flooding by intercepting rainwater and infiltrating stormwater.[41] In Canada, a growing number of municipalities have developed urban forest management plans to increase tree canopy cover, improve tree conditions (e.g., diversity and size), and minimize risks (e.g., disease and removal).[42] The Halifax Regional Municipality is one example, discussing stormwater management and urban heat island effects in its municipal long-term urban forest management plan.[43]

- Urban stream restoration: Daylighting projects that restore and rehabilitate part or all of water bodies that were culverted or otherwise undergrounded during urban development can help prevent flooding and mitigate urban heat island effects.[44] The City of Vancouver and neighboring municipalities have been uncovering lost streams and restoring them to their natural conditions to support stormwater and heat management.[45]
- Tree planting: Urban trees provide shading and can be used to moderate urban temperatures across the community and to reduce building energy costs for cooling and heating.[46] Many cities have launched tree planting initiatives, including the Brampton One Million Trees Program,[47] One Million Trees Mississauga,[48] and the Winnipeg Million Tree Challenge.[49] *i-Tree* is a useful management tool that enables inventorying and condition assessments of tree data and estimation of the value of various benefits on an annual basis (e.g., energy saving, emissions reduction, air quality improvement, and stormwater management).[50] The Government of Canada plans to fund tree planting activities up to $3.2 billion over 10 years.[51] A strategic management approach should be followed to make a planting program successful, especially under changing climate conditions.[52]
- Green infrastructure: Many municipalities install rain gardens, bioswales and bioretention systems to manage urban stormwater runoff. One of the most well-known strategies is Green Streets (i.e., Complete Streets), which implement green infrastructure, such as bioswales or bioretention systems, on rights-of-way. Toronto's Green Streets Technical Guidelines provide standard specifications, performance parameters, prioritization methods, and monitoring recommendations for planning and implementing various green infrastructure measures on streets.[53]
- Community gardens: Urban agriculture is not only a critical topic for food security and circular economy, but is also being advanced as an opportunity to reduce heat and stormwater. For example, a study found that New York City's community gardens have the potential to manage 12 million gallons of stormwater annually.[54] Some applications connect community garden projects with community development for all the additional benefits provided such as revitalizing underutilized lands, enhancing community cohesion, and providing ecological and food security education to urban communities.[55]

[a] Evaporative cooling uses "the sunlight to evaporate water and thus remove heat and lower the air temperature of the air to be used for cooling." https://doi.org/10.1016/B978-0-12-819723-3.00008-1

For instance, Winnipeg's Youth for EcoAction Program uses urban agriculture for youth community education and neighborhood revitalization.[56]

- De-pavement: De-pavement (i.e., de-sealing) removes impervious surfaces and converts areas into permeable (e.g., cobblestone, gravel, etc.) or green spaces. Depave Paradise is a Canadian non-profit organization that collaborates with community organizations and volunteers to convert pavement to green space and has achieved over 16,000 square miles of conversion in 32 Canadian cities.[57]

2.1.2. NbS Best Practice Case Studies

Some Canadian municipalities are showing impressive leadership on urban NbS strategies. The Town of Gibsons, BC, the City of Vancouver, BC, and the City of Montreal, QC each provide unique yet replicable cases that protect and expand natural assets and GI solutions to retain and absorb rainfall and stormwater and minimize the urban heat island effect. This section provides high level summaries of how each address the eight IUCN criteria.

Case Study 1. Town of Gibsons, British Columbia *Enhancing Natural Assets for Stormwater Management and Flood Mitigation* Highlighted IUCN Criteria: Economic Feasibility, Mainstreaming and Stability
The Town of Gibsons highlights how a small municipality can recognize, assess, manage, and incorporate its natural assets into municipal planning and accounting. This innovative case shows how a small municipality of less than 5,000 people protected and expanded existing natural assets and applied green infrastructure to deliver water and stormwater management solutions, saving taxpayers money and contributing to other co-benefits. **Societal challenge addressed:** An untreated intact aquifer motivated the Town to think differently about natural assets and ecosystem services, resulting in the integration of natural assets into municipal accounting structures.[58] **Scale of design:** In 2014, the Town deemed nature to be its most valuable asset. Gibsons saved money by protecting stormwater ponds, that could retain and absorb greater water volume than the grey infrastructure alternative, while decreasing the projected burden on existing stormwater infrastructure. **Biodiversity and ecosystem integrity:** The Town's White Tower Park stormwater pond project restores the infilled wetland and protects Charman Creek's natural habitats.[59] **Economic feasibility:** The projected cost of Gibson's stormwater upgrade was CA$4.5 million in grey infrastructure expansion. Choosing NbS, restoring and expanding existing stormwater ponds, reduced costs to under CA$1 million, spent primarily on land purchase and the development of a new amenity, White Tower Park. This asset is expected to appreciate not depreciate with time, and requires 75% less spending on O&M annually, saving taxpayers money now and into the future.[60] **Inclusive governance:** Town staff engaged with the Sḵwx̱wú7mesh Úxwumixw (Squamish Nation) to advance an Indigenous Guardians program to support shared management of the assets. The Town continues to engage with the Sunshine Coast Regional District (SCRD), and other orders of government on the protection of shared aquifer recharge areas.

Balanced trade-offs: The expansion of White Tower Park led to negotiations with owners/developers of the high-value asset lands. The ponds were identified as significant public assets; developers were provided more flexible permitting in exchange.
Adaptive management: The Town continues to monitor the ecosystem services being provided to the community, while also sharing the results of the current aquifer monitoring and watershed management opportunities with the Province of BC's Ministry of Forests, Lands, and Natural Resources (FLNR) to continue to advance natural asset protection and watershed management opportunities.
Mainstreaming and stability: The Town created two new positions: 1. The Chief Administrative Officer is now also the Chief Resiliency Officer, positioning resilience as a central mandate for the municipality, and 2. a Natural Assets Technician, the first in Canada, was hired to continue to monitor natural assets to keep accounting updated, and to plan for further NbS development and management. Staff are developing a corporate resiliency dashboard to identify climate-forward and nature-based strategies and actions. The corporate strategy is now based around agile teams that can more comprehensively and collaboratively address four key areas: risk, resilience, planning & development, and resource management.

Case Study 2. City of Vancouver, British Columbia
Orchestrating Urban Greening Strategies Around Urban Stormwater Management
Highlighted IUCN Criteria: Societal Challenge Addressed, Mainstreaming and Stability

The City of Vancouver aims to transform a problem into a resource through NbS strategies. This case demonstrates how municipalities can organize diverse urban greening efforts around specific stormwater management targets, streamlining the planning and implementation process, and prioritizing actions to achieve NbS goals.

Societal challenge addressed: To mitigate stormwater runoff issues, the City of Vancouver coordinates various NbS strategies, including the Rain City Strategy and Urban Forest Strategy. These strategies are well-connected with the City's other NbS strategies, such as Biodiversity Strategy (2016) and Bird Strategy (2020). Urban stormwater runoff and Combined Sewer Overflow (CSO) are also primary sources of water pollution when capacity is exceeded; the NbS approach is designed to reduce this.[61]
Scale of design: In 2017, the City adopted a Citywide Integrated Rainwater Management Plan (IRMP).[62] In 2019, the Rain City Strategy established citywide NbS goals, including a long-term, aspirational target to capture and clean a minimum of 90% of Vancouver's rainfall, and an intermediate target to "[m]anage urban rainwater runoff from 40% of impervious areas in the City by 2050."[63] The design standard is set to manage at least 44mm of precipitation per day.[64] An updated Urban Forest Strategy (2018) emphasizes the role of trees in urban heat alleviation, with four measurable targets.[65]
Biodiversity and ecosystem integrity: The IRMP specifies locations that can enhance biodiversity by rainwater management area,[66] and an Urban Forest Strategy applies Biodiversity and Bird Strategies to identify biodiversity hot spots.[67]
Economic feasibility: Vancouver's Green Rainwater Infrastructure (GRI) approach can be up to three to six times more economically effective than traditional grey infrastructure.[68] The

estimated annual co-benefits by acre of vegetated GRI are estimated to be CA$8,000 in energy saving, CA$160 in CO_2 emissions reduction, CA$1,000 in air quality improvement, and CA$4,725 in property values increase.[69] The city currently imposes stormwater rates to properties to finance GRI.

Inclusive governance: City departments, expert panels, and public and industry representatives were involved in the development of the Rain City Strategy.[70] The City also intends to prioritize vulnerable and underserved populations to ensure they receive benefit from the implementation of GRI.[71]

Balanced trade-offs: The Rain City Strategy emphasizes the responsibilities of property owners, imposing rates in wastewater and rainwater management. [72] The City is mandating GRI in new development and imposing rates for stormwater and surface water management to emphasize and share the financing responsibilities with property owners.[73]

Adaptive management: The IRMP recommends evaluating the implementation progress every five years. The report card assesses progress in public, private and park lands, and the City is using it to track progress, update planning documents, and adjust its long-term goals. For instance, in 2020, the City planted its 150,000th tree, one of the Urban Forest Strategy goals, and adjusted its canopy cover target from 23% to 30% by 2050.[74]

Mainstreaming and stability: Vancouver's NbS strategies align with other citywide initiatives, including its Greenest City Action Plan and Climate Change Adaptation Strategy. The City is undertaking amendments to zoning bylaws and development permit processes to mandate GRI.

Case Study 3. City of Montréal, Québec

Supporting and Enforcing Urban Greening to Mitigate Heat Island

Highlighted IUCN Criteria: Inclusive Governance, Mainstreaming and Stability

The City of Montréal illustrates how a metropolitan city, highly developed with limited green space, can utilize a wide range of NbS to enhance built infrastructure, primarily to minimize heat impacts, and to promote funding, capacity building, and regulation that ensures NbS is adaptive to climate changes over time. This case study includes two NbS strategies: 1) a long-lasting funding program that helps convert underutilized properties to green spaces and 2) the first Canadian zoning bylaw that mandates green infrastructure installation.

Societal challenge addressed: After the extreme heat in summer 2010 caused 106 related deaths, the Borough of Rosemont- La Petite-Patrie became the first city in Canada to develop a comprehensive white and green roof regulation to reduce the impact from extreme heat.[75] This mobilized significant NbS neighborhood- and project-based approaches.

Scale of design: To combat the urban heat island effect, the Borough added four regulatory measures to its zoning bylaws, including installing green, white or reflective roofs in retrofit and new building developments, greening parking lots, a minimum solar reflectance index for road surface materials in parking lots, and a minimum vegetation requirement for new building lots.[76] Since implementation, approximately 2,000 roofs have been retrofitted, accounting for roughly 10 percent of flat roofs in the borough of Rosemont- La Petite-Patrie.[77] In addition, as of 2020, Montréal's Green Alley Program has supported 479 green alley projects across Montréal.[78]

Biodiversity and ecosystem integrity: One of the greatest benefits of green alleys is biodiversity improvement.[79] Green alleys can help habitat creation and increase connectivity between natural habitats for birds and insects.[80]
Economic feasibility: These strategies are generally cost-effective as they focus on converting undervalued areas between buildings to urban green amenities that provide benefits.[81] Although there are cost variations in types, sizes and locations, a nationwide study found that rate of investment in green roofs has increased by 220%.[82]
Inclusive governance: The Regroupement des écoquartiers (REQ), a municipal organization, oversees the Program, but each project is initiated and led by local communities with support from their boroughs and eco-districts.[83] All five local organizations of the Alliance worked closely with residents on the design through conceptualization and management of the project via a series of workshops.
Balanced trade-offs: Green alleys can be developed on private land as well as public alleys.[84] For instance, Alliance Ruelles bleues-vertes experimented with a shared governance structure between the public and private domains.[85]
Adaptive management: The Program encourages alley committees, composed of residents surrounding the alley, to develop a long-term plan to keep the alley alive and develop subsequent phases.[86]
Mainstreaming and stability: Maintenance of the projects has been a challenge due to lack of sustained funding and evaluation mechanisms, and the difficulty of maintaining resident involvement over time.[87] Though it is difficult to assess the influence of the bylaw on reducing the urban heat island effect, roof permits and greening land cover can be used as proxies that influence the albedo effect on a neighbourhood basis.

2.1.3. Challenges and Opportunities

The case studies in the previous section provide some insights into NbS strategies in urban contexts. The findings highlight the economic feasibility, scale, inclusive governance, and mainstreaming criteria. Strategically assessing and managing natural assets can help deliver municipal services, such as stormwater management and flood mitigation, in a more economical and sustainable way (i.e., economic feasibility). Measurable goals, prioritized actions, and design standards can help organize and optimize various urban NbS strategies (i.e., scale and interaction). A funding program that combines various government and non-profit funding sources can support resident-initiated NbS projects (i.e., inclusive governance). A regulatory approach, such as zoning bylaw, can help incorporate green infrastructure into urban development process (i.e., mainstreaming and stability).

The case studies also reveal both challenges and opportunities in urban NbS uptake. For instance, biodiversity is often not explicitly addressed in urban NbS strategies. One of the many co-benefits of Montréal's green alleys is that they can improve biodiversity by increasing the connectivity between green spaces through the creation of green corridors.[88] The case of Vancouver shows how biodiversity strategies can be integrated with stormwater management and urban forest strategies.

The challenges found in the case studies echo those identified elsewhere in NbS literature. For instance, barriers to the uptake of NbS in urban areas which can be classified into three categories: financial, administrative and political, and technical issues.[89] Key barriers that posed delays for implementation include lack of standards and regulations, complex socioeconomic conditions, financial issues, and acceptance challenges.[90]

The most referenced barrier to green infrastructure adoption is funding.[91] Many municipalities are using general funds to finance their green infrastructure projects.[92] Other funding sources include fees, stormwater utility, federal or state grants, municipal bonds, loans, and public-private partnerships.[93] A more direct way to finance such projects is the imposition of a Pigouvian tax (i.e., stormwater utility or development impact fee) that makes owners of impervious surface properties pay for the stormwater runoff management. As of 2021, 62 Canadian local governments have stormwater utilities with an average household fee of CA$15.75; the most popular type is the flat fee.[94] This approach requires a complementary financing program to avoid burdening lower-income households.[95]

The greatest area of impervious surfaces in municipalities is on private property. It is therefore important to include private property owners in NbS planning and implementation.[96] Strategies that encourage private property owners to adopt NbS applications include stormwater fee discounts, development incentives, grants, rebate/installation financing, and awards/recognition.[97]

Although there are some criticisms on economic-driven approaches, cost-benefit analysis is considered an effective tool showcasing benefits and return on investment. There are numerous tools that can be used to estimate the cost and benefits of constructing, maintaining, and operating urban NbS applications, including:

- Sustainable Technologies Evaluation Program (STEP) Life Cycle Costing Tool https://sustainabletechnologies.ca/lid-lcct/
- Great Lakes Commission: Green Infrastructure Optimization Tool https://www.glc.org/work/greater-lakes/tool
- Center for Neighborhood Technology (CNT): Green Values Calculator https://cnt.org/tools/green-values-calculator
- United States Environmental Protection Agency: Green Infrastructure Cost-Benefit Resources https://www.epa.gov/green-infrastructure/green-infrastructure-cost-benefit-resources
- Water Research Foundation: Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC) https://clasic.erams.com
- CIRIA: Benefits Estimation Tool (B£ST) https://www.susdrain.org/resources/best.html

Lastly, a significant percentage of NbS research argues for the importance of equitable planning and implementation.[98] Some governments acknowledge potential negative impacts of urban greening, such as green gentrification,[99] and suggest options to avoid unintended consequences, including affordable housing policy and inclusionary zoning.[100] Some municipalities and institutions are focusing on installation of green infrastructure in low-income housing projects. For example, the Montreal Urban Ecology Centre and the Office municipal d'habitation de Montréal led a project in the suburb of Longueil, Quebec called "Vert chez nous" from 2013-2015 to design green and user-friendly developments around low-income housing in collaboration with residents in order to minimize heat, reduce costs for cooling (and heating), thereby increasing livability.[101] These types of approaches promote equity considerations, an important aspect of low carbon resilience planning.[102]

2.2. Coastal Flooding and Erosion

Coastal flooding and erosion are caused by various factors exacerbated by climate change including sea level rise, storm surges combined with high tides and strong waves, and subsidence.[103] Canada has the world's longest coastline at 247,000 km, and over 4.7 million people live within 10 km of the coast, with over 6.2 million residing within 100 km of the coast.[104] Due to increasing populations and development in coastal cities, the exposure to risk and projected damages from flooding and erosion is growing. The annual cost for climate change-induced coastal flooding is estimated to increase by CA$8.1 billion (in 2008 CA$) by 2050 under a high climate change-rapid growth scenario (though this number is expected to have dramatically increased).[105] Coastal erosion has already resulted in significant shoreline recession, land and water quality degradation, and displacement and increased flooding risks.[106] Increased development in coastal areas increases exposure and risk to assets and people over time.

2.2.1. NbS Best Practices

Coastal NbS are being investigated in Canada as cost-effective and resilient ways to address rapid changes in storm surge and cumulative impacts of sea level rise. Coastal NbS applications include coral/shellfish-built reefs, marsh, seagrass beds, floating gardens, barrier islands, intertidal/mud flats, coastal wetlands, beaches, dunes, waterfront parks, maritime forests, and upland shrubs.[107] These applications attenuate wave energy and contribute to the reduction of coastal climate risks by mitigating coastal flooding and storm surge and preventing coastal erosion by trapping and stabilizing coastal sediments.[108] Coastal NbS can also be used to improve biodiversity, restoring and enhancing terrestrial and aquatic habitats, while also providing recreational and tourism amenities to coastal communities.[109]

Coastal adaptation practices can be broadly categorized into four actions: protect (e.g., dune building and beach nourishment), accommodate (e.g., flood proofing, flood storage, etc.), avoid (e.g., restrictions through zoning, land development regulation), and retreat (e.g., land acquisition, easement, wetland restoration).[110] Representative NbS strategies include:

- <u>Habitat protection, restoration, and enhancement</u>: Natural habitat protection and/or engineered assets that mimic natural processes in intertidal areas help reduce coastal risks and contribute to biodiversity improvement.[111] Popular practices include reef, dune, and wetland protection and/or restorations with salt-resilient native species. The Town of Souris, PEI found that its newly constructed inter-tidal reefs performed as expected, including wave attenuation, beach and dunes condition improvement, and tourism attraction.[112]

- Coastal wetland and maritime forest conservation: Coastal natural assets, such as salt marsh and upland shrubs, are recognized as ecologically valuable and effective coastal risk mitigation measures.[113] Protecting existing natural assets is far more cost-effective than planting (e.g., afforestation) and restoration. Urban and agricultural development has contributed to the destruction and loss of wetlands.[114] In southern Canada alone, nearly 70 percent of wetlands have been lost.[115] Nova Scotia estimates this loss as equivalent to CA$2B annually in services provided to communities. Land acquisition is a permanent but costly way to protect wetlands. Many provincial governments, including Ontario and Nova Scotia, take a conservation easement approach.[116] Conservation action plans provide data and strategies needed to protect these important assets, for instance in the Great Lakes Wetlands Conservation Action Plan and the Network Action Plan in the Northern Shelf Bioregion.[117]
- Living shorelines: The promotion of living shorelines, also known as re-naturalization, shoreline greening, or realignment, is a comprehensive approach that includes practices to stabilize soil (e.g., slope grade reduction, biomass addition, vegetation cover establishment, etc.), restore natural hydrologic flows, and create and enhance habitats (e.g., marsh and salmon).[118] The Green Shores projects, delivered by the Stewardship Centre for British Columbia, provides a framework to understand the broader value of NbS, using a triple-bottom-line analysis.[119]
- Strategic retreat: Strategic retreat, also known as managed or planned retreat strategy, is a sustainable, longer-term, cost-effective approach that restricts development and/or slowly removes assets and people from high-risk coastal areas. When future costs of flood and erosion damages are estimated over time,[120] managed retreat becomes a cost-effective option. Estimates show the cost as only 3-4% of projected lifecycle damage, losses, and costs over time.[121] This strategy is proactive. For instance, the Hamlet of Tuktoyaktuk, NT has already implemented planned retreat strategies to avoid damages and costs from projected coastal erosion over time.[122] Although this approach may be desirable, there are political, social, cultural, psychological challenges in implementing the strategy.[123] Building consensus and establishing transparent, community-led mechanisms are essential to overcome such barriers.[124] In addition to the socio-economic benefits for communities, the retreat strategy can also be used to contribute to biodiversity improvement (e.g., restoration).[125]
- Beach nourishment: Beach nourishment includes sand and stone replenishment activities in buffer zones to prevent and reduce coastal flooding and erosion.[126] This strategy has often been referred to as the most cost-effective practice,[127] and can also help revitalize beach areas and attract tourism.[128]

2.2.2. NbS Best Practice Case Studies

Largely due to the geographical scales and governance complexity, coastal NbS projects often involve diverse actors, including different orders of government, professionals, and various groups of communities that have different interests and level of NbS knowledge. This section provides high level summaries of three coastal NbS best practice cases.

Case Study 4. Stewardship Centre for BC, Green Shores Program
Building capacity and mobilizing knowledge to adopt NbS
Highlighted IUCN Criteria: Mainstreaming and Stability

The case of the Green Shores Program illustrates how a local non-profit organization can adopt an innovative initiative, utilize diverse funding sources, and support the contextual application of NbS through training and education for local government staff, developers, community members and other relevant stakeholders. In 2005, the Stewardship Centre for BC (SCBC) adopted the Green Shores Program and mobilized and refined it to accelerate ecological restoration approaches.

Societal challenge addressed: NbS strategies are used to adapt shorelines to the projected sudden (e.g., extreme weather, storm surge) and cumulative impacts (e.g., sea level rise) of climate change, while also protecting and enhancing coastal and shoreline ecosystems in the face of continual development pressures.[129]
Scale of design: The Green Shores Program provides technical NbS guidance at three scales: local government, shoreline development, and homes.[130] For local governments, the program builds awareness and capacity through the delivery of workshops, one-on-one coaching, and milestone-based certification. The Green Shores Credits and Rating Guide helps homeowners, builders, and developers identify benefits of NbS and key opportunities, providing a rating system that rewards participants.[131]
Biodiversity and ecosystem integrity: The Green Shores approach supports the health of aquatic and terrestrial species. In 2021, the program selected three sites of the Resilient Coast for Salmon (RC4S) project along the east coast of Vancouver Island to encourage coastline NbS protecting riparian areas, waterways, and habitat to ensure the resilience of wild salmon species.[132]
Economic feasibility: This innovative initiative uses diverse funding sources including grants from a variety of sponsors ranging from individuals, real estate groups, foundations, and the Federal Government. The Green Shores Program is delivered through a non-profit entity, the SCBC, to showcase the cost-effective benefits of protecting, restoring, and enhancing NbS along coastlines.[133]
Inclusive governance: The program facilitates an inclusive process that brings developers, community members, local governments, and First Nations together into planning and design. One of the RC4S project sites, Dyke Road Park in Comox, BC on K'omoks First Nation territory, facilitates collaborative NbS design activities and the sharing of local and traditional knowledge.[134] This collaborative project includes several stakeholders from K'ómoks First Nation, Project Watershed, Northwest Hydraulic Consultants, Hapa Collaborative, Paul de Greef Landscape Architect, Pacific Salmon Foundation and SCBC.
Balanced trade-offs: The program provides technical support to help assess trade-offs between options and realize the social, economic, and environmental benefits. The report, *Green Shores 2020: Impact, Value and Lessons Learned*, shows the social impacts and extended cost-benefits of the projects in BC.[135]
Adaptive management: Green Shores training, delivered through partner academic institutions, provides understanding of the importance of monitoring over time, encouraging indicator development and adaptive management. *The Green Shores for Shoreline*

Development Credits and Rating Guide emphasizes the importance of pre- and post-monitoring for coastal NbS projects.[136]

Mainstreaming and stability: The SCBC continues to expand its programs in British Columbia and Atlantic Canada,[137] yet it remains unclear as to whether this is the best delivery model. SCBC and the Green Shores Program rely on soft money, creating uncertainty for the future of the program, which is currently funded by grants from a variety of sponsors ranging across individuals, foundations, and federal funding bodies.

Case Study 5. Chapel Island, Nova Scotia

Enhancing the holistic NbS value through community engagement and joint fact-finding

Highlighted IUCN Criteria: Inclusive Governance

Chapel Island's erosion protection project demonstrates an example of collaborative community engagement in an NbS initiative. The case shows how practitioners may set up a community consultation process that helps integrate local knowledge and the value of natural assets, and provide options for hybrid NbS applications to mitigate erosion.

Societal challenge addressed: Chapel Island in Cape Breton, NS is an important cultural and biological site for the Mi'kmaq people and lies near Potlotek First Nation.[138] The island is at high risk of erosion due to strengthened wind, increased precipitation, and wave energy from storms and sea level rise.[139] Almost all of the southern half of the island, where the cultural and social sites are located, is exposed to severe erosion hazards.[140]

Scale of design: The primary objective of this coastal adaptation project is to protect the natural assets and sustain the inherent character of the island, including 10 hectares of shoreline stabilization involving 13 Mi'kmaq bands, and a 350-hectare shoreline restoration project involving a dozen families working as "community waterkeepers."

Biodiversity and ecosystem integrity: The EcoAction Community Funding Program[141] educated community members about the watershed and healthy ecosystems. The favored option was restoration of habitat, including salt marsh, seagrass, and oyster reefs to enhance ecosystem integration.[142] Potlotek First Nation provided local knowledge, including identification of ecologically important areas for oysters and how oyster reefs may be integrated into the coastal adaptation measure.[143]

Economic feasibility: A living shoreline, a hybrid approach of hard infrastructure and natural assets (e.g., salt marsh, seagrass habitat, and oyster beds), was identified as the most cost-effective option that would also serve community needs.[144]

Inclusive governance: The project featured a wide range of participants, including local community leaders, senior citizens, Potlotek First Nation representatives, 13 Mi'kmaq bands, families working as 'community waterkeepers', and Indigenous Services Canada before the design process began.[145] The design process included regular meetings to support collaboration, identify specific and contextual issues, incorporate local and traditional knowledge, and ultimately inform the project directions and decision-making.

Balanced trade-offs: Project funders have still expressed a lack of confidence in the long-term effectiveness of these types of strategies for erosion protection.[146] This puts pressure on stakeholders and emerging governance to monitor and evaluate effectiveness over time.

Adaptive management: This case shows that the NbS solutions can be socially robust when the process remains committed to participatory design that builds upon traditional and local knowledge.[147] "The waterkeepers" contributed to design and now share in the responsibility for implementation and support in monitoring NbS over time.
Mainstreaming and stability: Funding support for the management of the project is uncertain due to existing preference for more conventional, hard infrastructure approaches for shoreline management. Data is being collected on effectiveness over time to build evidence of the viability of soft approaches.

Case Study 6. Town of Truro, Nova Scotia
Restoring natural assets to mitigate coastal flooding in the Bay of Fundy
Highlighted IUCN Criteria: Scale of Design

The Town of Truro is located within the floodplain of the Salmon River, also named Plamui-sipu or Punamu'kwatik by Mi'kmaq people, that feeds the Bay of Fundy in Nova Scotia, with the world's most frequent and highest tides.[148] Marsh restoration and dike relocation and realignment were used as a solution to reduce coastal flooding impacts. The scope and scale of this case, combined with the hybridized technology and degree of stakeholder engagement, showcase the considerable creativity and flexibility needed to turn such a complex challenge into an innovative management opportunity.[149]

Societal challenge addressed: Truro is prone to seasonal flooding due to its proximity to the Salmon River, and extreme tides and ice jams along the Bay of Fundy,[150] making it one of the most frequently flooded developed areas of Atlantic Canada.[151]
Scale of design: Dikes were relocated and realigned to allow for salt marshes to be re-established, restoring up to 700 metres of floodplain[152] in three phases over time: transition, establishment, and equilibrium.[153] The region's socioecological complexity required innovative computing technology to provide reliable models and technical problem-solving.[154] The jurisdictional scale of the project added to the complexity, as wetland management is shared by many federal, provincial, and municipal departments.[155] Innovative governance arrangements and reconfigurations contributed to the success of this project.[156]
Biodiversity and ecosystem integrity: Projected benefits of the project include improved habitat for fish and other marshland species, and increased awareness of the Salmon River, which is currently obscured by dike construction and industrial development.[157]
Economic feasibility: The marsh restoration and dike relocation were a cost-effective alternative to raising dikes, creating berms, and building a tidal dam that would cordon off the Bay of Fundy.[158] Diverse social, environmental, and economic co-benefits were identified as adding multifunctional values, such as carbon capture and storage, habitat improvements, stormwater management, supporting environmental education awareness, nature-based adaptation training, and passive recreation.[159]
Inclusive governance: Convening multiple stakeholders (e.g., scientists, government, public representatives, and First Nations leaders) was identified as a key success factor to achieving marsh naturalization and dike realignment in Truro.[160] For example, early discussions with stakeholders helped local landowners understand the goals, making them more receptive to selling their land.[161] Continuous coordination with the Millbrook First Nation and regular

public open houses to build awareness and gather concerns and priorities were crucial parts of project success.
Balanced trade-offs: Budgetary limitations for conventional measures contributed to partnership formation.[162] This catalyzed new governance and regulatory arrangements whereby the Department of Agriculture relinquished responsibility for maintaining the dikes, negotiating new roles and resources with the Department of Transportation and Infrastructure (renamed Department of Public Works).[163]
Adaptive management: A post-restoration monitoring program funded by Public Works was designed to assess the outcomes over a five-year period,[164] including changes in hydrology, vegetation, water quality, soils, and overall marsh health, as well as changes in tidal wetlands and potential benefits such as carbon dioxide capture and storage.[165]
Mainstreaming and stability: Innovative governance arrangements contribute to the mainstreaming of this project. There is also a recognized need for a continued multi-pronged approach, that educates decision-makers and community on the influences of land-use planning and regulation that is needed for ongoing support for NbS into the future.[166]

2.2.3. Challenges and Opportunities

These case studies confirm challenges and uncover opportunities in coastal NbS. Despite evidence for cost-effectiveness and co-benefits, the uptake of coastal NbS has been slow. Previous studies showed that one of the biggest obstacles is lack of capacity to adopt NbS.[167] The Green Shores Program provides lessons on how civil society organizations can play a crucial role in brokering NbS knowledge for implementation. The SCBC developed a technical assistance program, consisting of both training and certification, to mobilize NbS approaches among leaders and practitioners to help to prepare for climate impacts.[168] Fragmented governance and the absence of specific regulations and policies also hinder uptake.[169] The Truro case provides some critical insights into overcoming jurisdictional complexity in coastal NbS adaptation. Echoing the findings from the Chapel Island case, results from the assessment of six coastal adaptation projects in Nova Scotia indicate that institutional and knowledge barriers are the dominant challenges in NbS adoption.[170] Each of these cases builds knowledge and overcomes barriers, illustrating new pathways forward.[171] Some widely mentioned barriers to planning and implementing NbS in coastal areas, and reference to opportunities to overcome these barriers, include:

- Comprehensive funding: Lack of funding is a universally cited challenge, and many opportunities are limited to shovel-ready projects. To build planning capacity that initiates first steps, there is a need for funding intended to assess, plan, and design coastal NbS.
- Lack of capacity for planning and implementation: Coastal NbS practice is relatively new to practitioners. There are some guidelines and user-friendly toolboxes that help initiate coastal NbS practice.[172]
- Centralized, organized, and standardized data sharing: Similar to NbS in other regions, coastal NbS often require a site-specific approach and are not directly replicable.[173] Although design of NbS is usually project-specific, universally applicable elements exist such as streamlined planning and implementation processes, technical guidelines, and

monitoring and evaluation methods. Standardized performance monitoring would help future decision-making and establish confidence for investors.[174]

- Integrated governance: Integrated, multi-level governance is required to avoid piecemeal and ad-hoc projects. More coordinated approaches are likely to optimize the benefits and limit the trade-offs of NbS .[175]
- Complementary policy and regulation: Prohibiting development in high-risk areas using land-use policy and regulation and incentives to deter development (e.g., development cost charges (DCC), insurance premiums, etc.) in vulnerable coastal areas would support strategic retreat and conservation strategies.

2.3. Riverine Flooding

Canada has 25 major watersheds, 100 sub-watersheds, and more than 8,500 rivers.[176] Riverine flooding in Canada is largely caused by a combination of hydrometeorological factors (e.g., prolonged and/or intensified rainfall, rapid snowmelt, and debris flow and ice-break barriers), generating high water levels.[177] More frequent and severe rainfall events caused by climate change, combined with decreases in permeable areas due to land cover changes caused by deforestation, wildfires and urbanization increases risks of fluvial flooding.[178] Removal of land cover and root systems increases flood risks, especially at peak flow periods.[179] In Canada, flooding is the most common and costly environmental hazard.[180]

Riverine NbS applications, such as the restoration and enhancement of inland wetlands and riparian areas, can help mitigate flood risk by absorbing excess water, improving infiltration capacity, delaying peak flow and recharging groundwater. Riverine NbS can also improve water quality and provide fish and wildlife habitat as well as recreational amenities.[181]

2.3.1. NbS Best Practices

Integrated Water Resource Management (IWRM) is included in United Nations Sustainable Development Goal 6.5.1., which encourages "the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[182] Long-standing, comprehensive approaches in river basin management and IWRM are well-established,[183] yet urban planning and other land-uses are increasing the exposure of assets and people to climate impacts and hazards, including projected increases flood risk. Applying NbS as a proactive response to fluvial flooding, aims to enhance and restore natural systems and assets while providing multiple other benefits and values. NbS strategies that help to manage riverine flooding include:

- <u>Wetland conservation and restoration</u>: Wetlands are viable flood control mechanisms that reduce peak flows, enhance infiltration, and improve storage and retention capacity,[184] but have been vulnerable to loss by urban and agricultural development due to poor zoning and permitting practices. Governments often use land acquisition or easement to protect wetlands. For more information, refer to conservation and restoration strategy in Section 2.2. Coastal Flooding and Erosion.
- <u>Naturalizing channels, riverbanks, and riparian areas</u>: Protecting and enhancing riparian areas is important to retain and absorb water volume, naturalizing the functions of

creek and river channels. The addition of flood-attenuating features (e.g., woody deflectors/debris, shrubs, and grass)[185] or constructed wetlands that mimic natural processes, including conveyance or retention capacity, are key living shoreline and dike strategies being applied to minimize risk.[186]

- Watershed management: At the watershed scale, flood can be managed in a holistic and strategic way by managing a variety of key factors such as monitoring and forecasting, protection and enhancement of ecologically important areas, and strategic, lower-risk development outside of floodplain areas.[187] The TRCA has adopted and updated plans that provide comprehensive watershed conditions, scenarios with climate and development projects, and strategies to improve watershed health.[188]
- Strategic retreat/setback: Municipalities can preserve and restore floodplain functions by strategically relocating properties in flood-prone areas. For more information, refer to strategic retreat strategy in Section 3.2. Coastal Flooding and Erosion.

2.3.2. NbS Best Practice Case Studies

The following case studies are selected to highlight the opportunities in NbS adoption specific to the socio-ecological characteristics of riverine flooding. The first underlines the importance of a holistic approach at an eco-regional scale (i.e., watershed). The second case emphasizes the role of provincial and local governments and the importance of inclusive governance in an NbS strategy that is sustainable but often controversial for responding to chronic riverine flooding (i.e., managed retreat).

Case Study 7. Toronto and Region Conservation Authority (TRCA), Ontario *Overcoming fragmented governance at watershed scale and re-naturalizing brownfield for flood protection* Highlighted IUCN Criteria: Inclusive Governance, Adaptive Management
The TRCA case study demonstrates that systematic ecosystem and conservation planning at a watershed scale is the most effective scale for organizing both upstream and downstream NbS for riverine flooding. **Societal challenge addressed:** With a rapidly growing population surrounding Toronto, Canada's largest city, Carruthers Creek watershed has lost much of its natural cover, largely due to urbanization. The TRCA protects and improves the welfare of communities through assessment and optimization of ecosystem services, particularly water sustainability, and flooding and erosion hazard reduction at the watershed scale.[189] Analysis of natural assets, climate hazards, and development stressors (natural cover, growth) raised concerns for flooding, impaired water flows and water quality, erosion, heatwaves, and extreme weather threatening communities, ecosystems, and agriculture in the region. **Scale of design:** The TRCA has jurisdiction over nine watersheds surrounding the Greater Toronto Area (GTA), including the waterfront shorelines of Lake Ontario. The TRCA developed the Carruthers Creek Watershed Plan (CCWSP) to preserve the "long-term ecological and hydrologic functions of the features and areas" in the watershed.[190] Completed in 2021, the CCWSP spans over 3,700 hectares in the Region of Durham, northeast of Toronto, identifying

and addressing key climate impacts and risks across the watershed relating to the water resource system, the natural heritage system,[b] water quality targets, and natural hazards.

Biodiversity and ecosystem integrity: The CCWSP identifies biodiversity support and habitat creation as co-benefits of watershed management. It also includes the monitoring program that assesses the water resource system (e.g., fish community) and natural heritage system (e.g., forest birds).

Economic feasibility: The CCWSP makes recommendations on actions for both the natural heritage system and green infrastructure and identifies roles and responsible for implementation. However, there is little emphasis on the political and/or funding levers required to move the plan to implementation.

Inclusive governance: Between 2017-2019, the TRCA worked directly with several project partners in plan development including the Region of Durham, Town of Ajax, City of Pickering, and other stakeholders (e.g., watershed residents, landowners, farmers, developers, golf course operators, and environmental non-government organizations), and the public. The Mississauga's of Scugog Island First Nation also engaged in the planning process.[c]

Balanced trade-offs: The CCWSP's management framework aims to balance trade-offs through prioritization of likely climate impacts on the watershed's natural hazard areas and/or water resource systems and plans to address the consequences for infrastructure and/or land use decisions. Interestingly, the plan refers to "ecosystem compensation"[191] where impacts are unavoidable.

Adaptive management: The CCWSP used best available climate projections, developing three climate scenarios to 2100 to build upon the 2003 plan modernizing a plan to address responsible growth and the long-term resilience of the watershed ecosystem under rapidly changing conditions. Indicators to be monitored and evaluated over time include the water resource system (i.e., aquatic ecosystems), natural heritage system (i.e., terrestrial ecosystem), surface water quality and quantity, and groundwater quantity.[192]

Mainstreaming and stability: The TRCA is a unique body that applies a systemic lens to water ecosystem and service protection within a bioregion. Within Canada, conservation authorities only exist in Ontario but fulfill an increasingly important area – watershed management under rapidly changing development and climate conditions. Their mandate allows for the management of cross-boundary issues related to stormwater management, carbon sequestration, drinking water, and biodiversity support across local and regional jurisdictions.

Case Study 8. The Town of High River, Alberta

Strategically returning the land to nature

Highlighted IUCN Criteria: Economic Feasibility

[b] Natural heritage system "[c]onsists of natural features and areas, including wetlands, forests, meadows and valleylands, that are needed to maintain biodiversity and healthy ecosystems (CCWSP, p.5)."

[c] In many regions of Canada, First Nations territorial claims are still in dispute. Though still controversial and underexplored, NbS, at the territorial, bio-regional, and watershed scales may present a fruitful opportunity to learn from and work alongside First Nations, their traditional ecological knowledge, and territorial sovereignty/co-management opportunities.

The Town of High River, Alberta's managed retreat strategy is an example of post-disaster adaptation. With high risk of recurring flood, residents living in the floodplain were provided a buyout option for their properties. This case highlights an effective community-based managed retreat strategy, in which a floodplain buyout program was initiated by the town's council, with provincial funding, supporting a program to incentivize the removal of exposed assets and people from high-risk areas, with the goal of transitioning towards a naturalized floodplain.

Societal challenge addressed: After a devastating flood, the High River Council initiated a managed retreat strategy for the neighbourhood of Wallaceville,[193] and asked the province to initiate a Floodway Relocation Program (FRP)[194] - a voluntary property buyout program to motivate residents to relocate.[195] The province reconstructed the area as a floodplain.[196]
Scale of design: The program was eligible for the residents in the floodplain, approximately 250 people.[197]
Biodiversity and ecosystem integrity: Similar to other floodplain buyout programs,[198] the FRP did not include any ecological restoration projects. The demolition of human-made structures can provide space for nature to re-thrive, yet restoration could expedite improvements for biodiversity.[199]
Economic feasibility: The FRP used funds from the Disaster Recovery Program (DRP) to purchase properties from 102 homeowners at the assessed value (i.e., pre-flood property tax assessment),[200] which were remediated and demolished at the province's expense. With the projected likelihood of flood recurrence, repositioning infrastructure, assets, and people out of harm's way rather than rebuilding was viewed as the most cost-effective strategy over the longer term.
Inclusive governance: Critiques were made regarding the buyout program. It was voluntary, and limited one-way communication[201] did not create shared responsibility for collective action.[202]
Balanced trade-offs: The Province owns the reclaimed land, and the Town recommended to transform the area into an ecological park.[203] Some homeowners chose to rebuild despite being disqualified for disaster relief assistance in the event of another flood.[204] Poorly executed knowledge-sharing and communication about the risks and consequences were viewed as part of the reason some people chose to stay.
Adaptive management: There are measurements in place to monitor the flow of the river and flood risk,[205] and early warning systems are in place to inform residents of flood hazard risks during peak season.[206]
Mainstreaming and stability: As of 2015, the Wallaceville neighborhood was returned to an "undeveloped" state.[207] The Town of High River integrated the buyout area into a parks master plan.[208]

2.3.3. Challenges and Opportunities

The case studies above illuminate challenges and opportunities for NbS for riverine flooding. Environmental governance is particularly challenging in riverine NbS, which require collective and coordinated actions at an eco-regional scale (e.g., watershed or river basin). The case of

TRCA outlines the advantages and trade-offs of watershed governance, and how more holistic conservation planning can be used to better understand water systems, protect natural assets and advance green infrastructure in future development. The case provides practical scenario planning methodologies and monitoring indicators essential for watershed scale NbS planning and implementation that are useful for legislators, policymakers, planners, and municipal asset managers.

Proactive actions that prevent damages are ideal, but post-disaster recovery is also critical to innovative NbS strategies, and natural disasters often create a window of opportunity for critical decision-making. After Hurricane Hazel, Canada's deadliest storm to date, the province of Ontario made amendments to the Conservation Authorities Act, allowing them to purchase and regulate lands for conservation and public safety.[209] Similarly, the destructive flooding in 2013 forced the Town of High River to initiate a managed retreat strategy program.

Riverine flooding requires collaborative, coordinated actions to address interconnected factors such as development in upstream areas, and flood control capacity and water quality impairment in downstream areas. Even if wetlands are restored and enhanced in downstream areas, flooding will continue if unregulated development continues upstream, where perception of downstream risk may be lacking. In addition to these potential conflicts, inter-municipal issues around flood risk management may arise due to disproportionate costs and other burdens.[210] River basins or watersheds are therefore an effective scale for consideration of flood management to help balance conflicting interests and foster cooperation for riverine NbS, as are regional-scale partnerships. In Ontario, the Conservation Authorities Act provides a legal basis for watershed management planning; a US example is the Chesapeake Bay Commission, a partnership of six watershed states, the District of Columbia, and the United State Environmental Protection Agency.[211] This multi-jurisdictional partnership makes joint decisions, including setting goals and tracking progress to make all partners accountable for their work to improve water quality and prevent flooding in the Chesapeake Bay Watershed.[212]

Currently, innovative watershed governance is being explored in the Province of BC, as an opportunity for Indigenous management or co-management opportunities. The bioregion of a watershed transcends jurisdictional boundaries, aligns with more holistic thinking and systemic solutions-building, and creates complex, interdependencies that require cross-cutting collaboration, shared responsibility, and collective implementation, monitoring, and management. These unique areas provide a window of opportunity to include Indigenous worldview, knowledge, and management.

2.4. Water Stress

Over the past half-century, significant droughts have occurred in several Canadian regions.[213] Drought has wide-ranging consequences, including negative impacts on the natural environment, economy, and society,[214] as well as increased wildfire and landslide risks.[215] More severe, frequent, and prolonged droughts negatively impact biodiversity, especially species susceptible to water stress.[216] Between 2001 and 2010, Canada experienced severe droughts that caused high aspen tree mortality, influencing biodiversity in these areas.[217] Drought also creates tremendous uncertainties around agriculture and food security with ripple impacts on the economy.[218] For instance, recent drought and extreme events negatively affected the agricultural industry, leading to poorer quality crops and lower productivity.[219]

2.4.1. NbS Best Practices

Natural assets can help to mitigate drought, and they can also be at risk from climate change and its impacts. As such, it is important that NbS be designed both to prepare for and to avoid drought. Protecting and enhancing ecosystems, conserving water, and planning for resilience are increasingly crucial objectives. Current strategies that build toward these objectives include:

- Natural asset protection, restoration, and enhancement: Natural assets such as forests and wetlands can reduce drought impacts by retaining water and streamflow.[220] In one example, Transition Salt Spring is undergoing a watershed-level forest restoration initiative to mitigate both flooding and drought and enhance ecological integrity.[221] Forests play a crucial role in drought prevention. Forest management approaches that reduce water stress include drought-resilient species selection, alien species removal, and multiseriate development.[222] Managed wetlands act as water retaining areas and can also reduce drought risk.[223]
- Water conservation: Agriculture and other industries, including the residential sector, are changing water management practices to include NbS, for instance, by replacing water-intensive plants with drought-tolerant varieties. The Town of Okotoks, AB is utilizing a variety of water conservation strategies, including residential xeriscaping and rain barrel rebate programs.[224] The Water Conservation Guide for BC, developed by the BC government, POLIS, and the Okanagan Basin Water Board, provides a step-by-step water conservation planning process with checklists for each step (Belzile et al., 2013).[225] The guide includes NbS options in water governance such as wetlands and bioswales.
- Drought management and drought response planning: NbS are being incorporated into drought management and response planning. The City of Calgary, AB is developing a Drought Resilience Plan that includes strategies such as water use monitoring, outdoor water restrictions, tree management, and opportunity assessment for fish habitat, water quality, and natural assets protection.[226] Some municipalities also consider downspout disconnection as NbS to manage stormwater runoff and recharge groundwater by avoiding draining rainwater into sewers and infiltrating it to the ground.[227]

2.4.2. NbS Best Practice Case Studies

Drought has far-reaching impacts on the environment and economy and involves diverse actors. The Pelly's Lake case shows how an NbS strategy can provide solutions to diverse stakeholders (e.g., water security for farmers, flood control for downstream communities, pollutant reduction for upstream communities, habitat protection for conservation authorities, etc.).

Case Study 9. Pelly's Lake, Manitoba
Improving water storage capacity and water quality through an engineered wetland system

Highlighted IUCN Criteria: Economic Feasibility, Balanced Trade-Offs
The Pelly's Lake Backflood Project took an engineered wetland approach to support the water security for agriculture industry, flood control for downstream, and ecosystem health of the Boyne River watershed.[228] **Societal challenge addressed:** Pelly's Lake located in the headwaters of the Boyne River Watershed has complex environmental and economic challenges, including water quality issues in upstream (e.g., increased nutrient loading), high flood risks downstream, and water security issues for agriculture in the region.[229] The Lake was enhanced with an engineered wetland system that stores water in the spring freshet to mitigate flood risks, reduce pollutant loading, and retain irrigation water for agriculture irrigation during end-of-season drought periods.[230] **Scale of design:** The project covers 627 acres of wetland system in south-central Manitoba that effects upstream water quality, downstream water flow, and the region's agriculture industry.[231] **Biodiversity and ecosystem integrity:** The engineered wetland with increased water retention capacity improves habitat conditions for wetland species.[232] **Economic feasibility:** The water retention benefits of the wetland services far outweighed the capital cost (approximately CA$551,000).[233] The cumulative discounted value of the ecosystem services provided by the project to 2050 (i.e., cattail harvesting, nutrient removal, carbon sequestration, and flood protection) was estimated at CA$60 million.[234] **Inclusive governance:** The design of this project includes systemic framing and features benefits for local stakeholders and agricultural landowners.[235] La Salle Redboine Conservation District (LSRBCD) and the International Institute for Sustainable Development (IISD) collaborated with local landowners, including farmers and a nearby Oakridge Hutterite colony.[236] The project also included diverse actors, including the Rural Municipality of Victoria, Manitoba Habitat Heritage Corporation, Lake Winnipeg Basin Stewardship Fund, Lake Winnipeg Foundation, and Manitoba Conservation and Water Stewardship.[237] **Balanced trade-offs:** The project required private landowners' involvement to support temporary water storage on their lands and to protect priority habitats within and surrounding the wetland. Six landowners agreed to conservation easements with Manitoba Habitat Heritage Corporation to achieve both water retention and protection goals.[238] **Adaptive management:** The project includes ongoing data collection on the system performance, water flows, and nutrients loading.[239] This will inform the stakeholders on the health of the site while contributing to wider understanding and insight into managed wetlands, and their use in NbS at a large scale (e.g., watershed).[240] **Mainstreaming and stability:** This project supports the region's watershed management goals, such as reducing surface runoff to mitigate flooding, enhancing watershed health, supporting fish and wildlife habitats, improving water security throughout the growing season, and increasing awareness of watershed health conditions among residents.[241] Some local governments in the same watershed, including the Rural Municipality of Dufferin, launched a Watershed Tax Credit Program to incentivize landowners to participate in water retention projects by maintaining and restoring wetlands.[242]

2.4.3. Challenges and Opportunities

The Pelly's Lake case study highlights the fact that NbS strategies for drought risk reduction benefit from a regional approach (e.g., watershed scale) grounded in understanding of interconnected complex factors, including environmental conditions (e.g., warmer, drier climate and algal blooms) and economic activities (e.g., agriculture). The case also confirms that cost-benefit analysis can help build consensus around the risks and costs of drought and the benefits of NbS in both the short- and long-term, important for a regional approach that often involves conflicting water interests (e.g., water demands, productivity in the agricultural industry, reduction of upstream algal blooms, etc.). Cost-benefit analyses also helped to inform stakeholders about the benefits of both drought prevention and NbS approaches.

The causes of water stress are diverse, and the negative impacts of drought are far-reaching.[243] As such, a wide range of actors across industries and sectors impacted by drought are also responsible for implementing drought management solutions. Public and private incentives are already used in areas of forest offsets and conservation.[244] Drought management at a regional scale could be advanced by similar types of incentives.

Monitoring and evaluation approaches for drought conditions have been standardized (e.g., Canadian Drought Monitor), and some tools, such as the Canadian Water Sustainability Index (CWSI), help communities evaluate their hydrological well-being using indices, incorporating water-related data into benchmarks and showing a comprehensive profile of water issues.[245] However, these drought data tools rarely integrate NbS options, such as forest and wetland conservation, and therefore often act simply as warning signals that are not connected with nor result in drought resilience planning. For example, drought management plans often discuss the importance of natural assets, but do not identify actions that should be taken to protect and enhance them. Integration of NbS approaches with provincial or local planning such as hazard mitigation planning may help establish a more robust platform to plan and design NbS as well as leverage funding sources.[246] Finally, quantification of NbS performance in drought reduction is important but notoriously difficult,[247] reemphasizing the importance of research into development of monitoring and evaluation that can be used to support NbS updates.

2.5. Landslide and Unstable Slopes

Thousands of landslides occur every year in Canada, especially in the Canadian Rockies and along waterways,[248] with estimated damage costs between CA$200-400 million annually.[249] Landslide risk has dramatically increased in recent years;[250] one study forecasts three times more occurrences in Vancouver's North Shore Mountains by 2100.[251] Since 1771, over 780 people in Canada have lost their lives due to landslides, with casualties highest in BC (356) followed by Quebec (239).[252] In addition to fatalities, injuries, and damages to property and infrastructure, landslides disrupt ecosystems by destroying wildlife habitats and impairing soil and water quality.[253]

Landslides are often triggered by a combination of poorly planned development and economic activities on unstable or steep slopes and are projected to increase as climate change impacts such as extreme precipitation and severe drought, impair soil stability and amplify risk.[254] In addition, decreases in vegetation and root stability from clearing for economic development and wildfire burn areas also increases the risk of landslides.[255] Disaster events, such as hurricane, tsunami, earthquake, and volcanic eruption, trigger landslides.[256]

2.5.1. NbS Best Practices

Slope stabilization via protection, restoration, and enhancement of vegetation to enhance root structure is an important NbS.[257] Riprap and hard-armoring have been traditional measures used to reduce erosion and mitigate landslides, especially along shorelines, however these approaches also disturb ecosystems, impede natural functions, and interfere with riparian zone establishment.[258] NbS to reduce landslide risk include:

- Conserving and enhancing natural assets: reinforce landslide-prone areas, such as shorelines and riverbanks.[259]
- Reinstating vegetation on unstable slopes: assist with infiltration and reduce erosion risks.[260]
- Natural armoring measures: hydro-seeded grass, engineered logjams, and brush mattresses that prevent erosion and control excessive debris flow.[261]
- Removing invasive species and replanting native vegetation: stabilizes slopes and improve natural drainage.[262]
- Removing or replacing impervious grey infrastructure with green infrastructure: reduces landslide risks by assisting infiltration, reducing overland flows, and restoring the natural hydrological cycle.[263]
- Align landscaping with natural contours: avoid terracing.[264]

2.5.2. NbS Best Practice Case Studies

Flooding and erosion, and even drought may trigger landslides, thus the NbS strategies discussed previously can indirectly contribute to landslide hazard reduction. The case of the District of North Vancouver shows how NbS strategies against landslides and other indirect contributing hazards (e.g., flooding, erosion, and wildlife) can be incorporated into the official municipal planning process.

Case Study 10: District of North Vancouver, British Columbia *Incorporating NbS strategies in the community plan improve landslide resilience* Highlighted IUCN Criteria: Inclusive Governance, Mainstreaming and Stability
The District of North Vancouver incorporates landslide prevention strategies into its official community plan, connecting them with the municipality's overall development and environment management approaches. The case also highlights how a municipality can take an inclusive approach in the hazard prevention planning process. **Societal challenge addressed:** The District is prone to landslides due to its sloped topography and 2,400 mm of average annual rainfall, only projected to increase under climate change.[265] In 2005, the Berkley landslide destroyed two homes, seriously injured a man, killed a woman,[266] and elevated landslide risks due to the increased natural hazards (i.e., flooding,

erosion, and wildfire), spurring the District to implement a landslide management strategy in municipal planning.

Scale of design: The District's Official Community Plan (OCP), adopted in 2011 and updated in 2021, outlines landslide mitigation actions and promotes continuous maintenance and monitoring of unstable slopes.[267] The District also connects its landslide prevention policy with the Tree Protection Bylaw, Post-Wildfire Rehabilitation Plan, and Forest Resiliency Strategy.[268] NbS strategies that minimize landslide risks are a crucial part of the District's risk management such as setting slope hazard development permit areas to providing landowner guidelines for maintenance of vegetation in buffer zones, and protection of trees on unstable slopes, and landscaping that follows natural contour lines.

Biodiversity and ecosystem integrity: The OCP emphasizes biodiversity enhancements to which NbS for landslides indirectly contributes. The Tree Work in the District Corporate Policy 13-5280-1 was established to support an objective in the OCP that outlines "the expected proactive management of our natural areas to improve biodiversity and forest health."[269]

Economic feasibility: The District is reviewing options to finance its forest resilience strategy and flood and erosion reduction strategy, helping to reduce landslide risks and protect properties.[270]

Inclusive governance: One of the hallmarks of this case study is the District's community-based Natural Hazards Task Force, which established risk-tolerance criteria and deployed a wide range of data on natural hazards and risk reduction to inform community members and decision makers.[271]

Balanced trade-offs: Traditionally, OCPs focus on land use planning for infrastructure, housing, and transportation. The District demonstrates how a municipality can incorporate NbS strategies into its OCP to manage the built and natural environment and utilize a wide range of interventions from monitoring and setting landslide-prone areas,[272] to enforcing tree protection bylaws to protect slope stability and/or ecology of the subject area.[273]

Adaptive management: The Post-Wildfire Rehabilitation Plan includes monitoring of the impacts of wildfire on slope stability, such as increased risk of landslide and debris flow.[274] The Forest Resiliency Strategy that is currently under development includes recommendations on ecological monitoring that assesses forest ecosystem changes over time to prevent natural hazards and adapt to climate change.[275]

Mainstreaming and stability: The District's strategies to reduce landslides and other natural hazards by managing forests, creeks, and other natural assets are documented in its OCP, Climate Change Adaptation Strategy, Post-Wildfire Rehabilitation Plan, and Forest Resilience Strategy.

2.5.3. Challenges and Opportunities

This case highlights ways to mainstream priority NbS strategies into an official community plan. The District's natural hazard task force provides insights into public involvement in risk management, demonstrating the role of quantitative risk-tolerance criteria in helping community members understand the risks they are facing.[276]

NbS strategies to prevent or mitigate landslide risks (e.g., forest conservation) are fundamentally similar to those for other disaster types but are generally under-studied or under-emphasized in terms of their effectiveness, including slope stability control (e.g., root structure/system), vegetation management (e.g., restoration and rehabilitation), and drivers (e.g., deforestation and clearcut logging).[277] Loss or impairment of natural assets from climate change is a contributor to landslides.[278] Some useful tools are emerging that help to evaluate effectiveness of NbS for landside prevention:

- The Landslide Risk Mitigation Toolbox (LaRiMiT) was developed by the Norwegian Geotechnical Institute and provides 80 landslide risk reduction measures in 11 categories.[279] The first two are specifically relevant to NbS, and comprise 24 NbS measures including living approaches (e.g., hydroseeding, live transplanting, bush layering, etc.), hybrid living/non-living approaches (e.g., geotextiles, beach replenishment, etc.), and passive controls to dispersing landslide energy (e.g., afforestation).[280]
- Modelling software programs, such as FUNWAVE-TVD (Total Variation Diminishing) and BROOK90 enable the evaluation of effectiveness of NbS for landslide hazards.[281]

3. Monitoring and Evaluation

Monitoring and evaluation (M&E) is a fundamental aspect of adaptive management, and is needed to promote effective NbS practice. M&E provides evidence for the performance of actions, helps identify opportunities to iterate or update strategies,[282] and bridges gaps between science and policy to clearly communicate information,[283] while conveying the realities of performance, or lack thereof, by providing measurable and objective information.[284] Though NbS are rapidly being adopted in regions and communities internationally, systematic M&E for these projects is developing slowly.[285] In the absence of a universally standardized monitoring framework for NbS, this report uses IUCN's Global Standard to provide guidelines for NbS M&E, particularly adaptive management criteria (Table 3-1).

Table 3-1 IUCN's Global Standard: Monitoring and Evaluation Guidelines in Adaptive Management Criteria

#	Key Goals & Tasks	Description
7	Adaptive management	NbS are managed adaptively, based on evidence
7.1	Regular M&E	A NbS strategy is established and used as a basis for regular monitoring and evaluation of the intervention
7.2	Lifecycle M&E plan	A monitoring and evaluation plan is developed and implemented throughout the intervention lifecycle
7.3	Integrative learning	A framework for iterative learning that enables adaptive management is applied throughout the intervention lifecycle

Monitoring NbS projects over time is important to assess performance and changes from baseline conditions over time, including emerging areas of vulnerability. This data help to refine strategies and protocols for responding if NbS is not achieving objectives. This is particularly important under dynamic climate changes where adaptation (i.e., the capacity to adjust to changes), resilience (i.e., the capacity to recover quickly from stressors), and ecosystem health (e.g., watershed health index) are likely to be impacted over time. Identifying indicators and determining regular monitoring and reporting over time is a critical piece of the planning process, especially regarding decisions about technical suitability, financial feasibility, alternative methods of evaluation, and prioritization. Monitoring also incentivizes collection of data that can be used to evaluate performance of individual NbS applications (e.g., wetland, forest, bioswale, green roofs, etc.), progress of NbS strategies (e.g., wetland restoration, forest management, rain garden projects, etc.), and ultimately the benefits of NbS for ecosystem health and multiple aspects of resilience (see Figure 1-1).

Several M&E methods have evolved in parallel with the growing popularity of NbS and advancements in technology, such as remote sensing.[286] Although the IUCN Global Standard provides guidelines, and research communities continue to offer diverse M&E data and methods, practitioners need to identify appropriate indicators, monitoring processes, and evaluation metrics tailored to their specific contexts.[287] This section provides an overview of M&E guides and reports that can provide insights and tools for NbS practitioners.

- Performance M&E: M&E for post-construction monitoring is relatively well-established in the urban NbS area. Some municipalities provide a standardized manual or report to assess if implemented NbS performs as it is designed.
  - *The Toronto Green Streets Technical Guidelines (GSTG)* identifies monitoring objectives and parameters, including effectiveness in mitigating urban heat island effect, achieving pollutant reduction, flood mitigation, infiltration improvement, energy saving, greenhouse gas emissions reduction, and water quality enhancement.[288] GSTG also addresses costs related to monitoring (e.g., staff resources for salaries and training, equipment and supplies, data analysis, and reporting) and recommends budgeting for monitoring in NbS practice.
  - *The Vancouver Green Infrastructure Performance Monitoring Report* demonstrates how a local government can ensure its GI strategy is achieving both progress and the desired outcomes.[289] The report includes monitoring objectives, performance targets, results, and conclusions to inform further actions. If mandated, this type of monitoring report can be useful to track progress and assess performance, especially for publicly funded projects.
- Environmental M&E: Measuring actual environmental outcomes of NbS strategies, especially at a regional scale is notoriously difficult, but important.[290] Some manuals provide guidelines of NbS M&E at the watershed scale.
  - *The Low Impact Development Stormwater Management Planning and Design Guide* provides monitoring guidelines for various types of GI.[291] The document includes empirical data on the monitoring period, GI specification (e.g., substrate depth), and rate of runoff reduction. It introduces the integrated watershed monitoring programs that can help monitoring environmental effects of urban NbS strategies for stormwater management.

- *The Low Impact Development Stormwater Management Guidance Manual* highlights the importance of understanding the cumulative impact of the urban NbS strategies and provides guidelines to establish pre- and post-development condition monitoring at the project area and watershed scale.[292]

- Environmental, Social, and Economic Impact M&E: Some guides and reports provide a more holistic approach to M&E for effects of NbS. The triple bottom line approach is often used to emphasize and quantify co-benefits associated with NbS strategy; some guidelines and interactive tools assist with cost-benefit or co-benefit assessment.
  - *Green Shores 2020: Impact, Value and Lessons Learned* assesses the broader impacts of three coastal NbS projects in British Columbia through social impact analysis and triple bottom line evaluation.[293] The report shows how to quantify and monetize qualitative values and services that coastal NbS provides.
  - *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits* provides principles and methods to quantify co-benefits of various urban green infrastructure applications.[294] Quantification of co-benefits are especially well established in the urban flooding and heat management field. More tools in this field are introduced in Section 2.1.
  - *The Coral Reef Restoration Monitoring Guide* introduces a set of metrics designed to assess impacts on ecosystems.[295] The set consists of two groups of metrics: universal (ecological restoration and environment) and goal-based performance metrics (ecological restoration, socioeconomic, event-driven, climate change adaptation, and research metrics). The universal metrics include performance indicators that should be monitored and evaluated for any restoration project. The goal-based performance metrics include criteria tailored to specific interests, such as biodiversity abundance, coastal protection, disease recovery, and resilience improvement. This guide's monitoring approach helps NbS adopters select appropriate indicators and establish processes based on their specific goals and objectives for the coastal NbS practice.
  - *The Performance and Impact Monitoring of Nature-Based Solutions* presents NbS indicators that can be used in 13 areas: carbon emissions, temperature, flood vulnerability, drought vulnerability, water quality, green space management, biodiversity, air quality, urban regeneration, participatory planning and governance, social justice & social cohesion, health and well-being, and economic activity and green jobs.[296] This document expands the areas and issues that NbS can address and shows how to monitor and evaluate the impacts.
- Implementation M&E: NbS strategies often require long time frames for implementation, and thus require M&E on progress.
  - *The Municipal Natural Asset Management Monitoring Report* provides a monitoring framework that focuses on evaluating progress in natural asset management implementation.[297] The framework includes four sets of indicators: 1) awareness, capacity and education, 2) implementation, 3) ecosystem rehabilitation and restoration, and 4) service delivery. Each indicator is accompanied by benchmark(s) to assess degrees of implementation. This unique monitoring framework is especially useful for the municipal managers to

measure their progress in natural asset management and other NbS strategies that include diverse actions and interventions from regulation to investment and management.

Many of the case studies reviewed for this report did not include and/or document M&E processes. To assist uptake of M&E in NbS strategies, Table 3-2 organizes relevant indicators around the five disaster areas the report focuses on and summarizes them into two categories: 1) proxy indicators that measure progress and success of an NbS strategy, and 2) outcome indicators that assess project impacts on disaster risk reduction. As NbS M&E is an evolving field, this table is not an exhaustive list. The proxy and outcome indicators listed for each category are only related to some of the strategies, where relevant.

Disaster Area	NbS Strategy	NbS Proxy Indicator	Outcome Indicator
Urban Flooding and Urban Heat Island	• Green Streets project (bioretention, bioswale, street tree, permeable pavement) • Green roof incentive program • Green infrastructure zoning bylaw • Tree planting initiatives • De-pavement project	• Increased acreage, volume, inch/mm, percent of stormwater/rainwater managed by green infrastructure • Decreased impermeable surface area • Increased percent of tree canopy • Number of planted trees • Number of permits issued for green roof installation	• Reduced frequency of surface flooding and/or volume of stormwater runoff • Increased infiltration rates • Reduced peak flow • Reduced urban heat island effect (increased thermal comfort, decreased heating degree days)
Coastal Flooding and Erosion	• Beach nourishment • Coral reef restoration • Salt marsh habitat creation • Living shoreline strategy • Managed retreat	• Acreage or number of natural assets preserved, conserved, created, managed, enhanced or restored • Volume of storm storage • Number of properties removed from flood-prone area	• Reduced inundated area and frequency of inundation • Increased stormwater storage capacity • Reduced damages from storm surge events • Decreased wave energy • Decreased wave height • Reduced rate of erosion
Riverine Flooding	• Wetland conservation and restoration • Naturalizing channels, riverbanks, and riparian areas • Managed retreat	• Acreage or number of natural assets preserved, conserved, created, managed, enhanced or restored • Acreage or kilometer of riverine areas naturalized • Number of properties removed from flood-prone area	• Reduced inundated area and frequency of inundation • Reduced damages from extreme weather events • Reduced peak flow

Water Stress	• Forest, wetland, and stream management, conservation and reforestation • Water conservation through rain barrel or xeriscaping • Downspout disconnection for groundwater recharge	• Acreage of natural assets preserved, conserved, managed, enhanced, or restored to reserve water • Acreage of water-intensive crops or plants, or non-native species removed • Acreage converted to water-resilient crops or plants • Number and volume of rain barrels or other water conservation devices installed	• Increased (or back to normal) surface water flow • Increased (or back to normal) groundwater level • Increased soil moisture • Improved vegetation condition
Landslide and Unstable Slope	• Vegetation maintenance and reinstatement • Xeriscaping • Natural armoring for erosion prevention • Natural asset management to prevent flooding, erosion, and wildfire that triggers landslides • Green infrastructure projects to improve natural drainage system	• Acreage of area with improved root systems • Acreage of vegetated areas managed to prevent flooding and erosion • Acreage of forest areas protected from wildfire • Acreage of areas with improved natural drainage • Acreage of areas recovered from flooding, erosion, or wildfire	• Reduced frequency and likelihood of landslide events • Reduced flooding, erosion, and wildfire likelihood that contributes to landslide risks

Table 3-2 Indicators to Measure Progress and Success of NbS Strategies

4. Concluding Remarks

This report presents case studies and NbS best practice criteria relevant to five disaster areas that pose increasingly significant and costly risks to Canadians as climate change advances – urban flooding and heat, coastal flooding and erosion, riverine flooding, water stress, and landslides and unstable slopes. Assessing Canadian NbS cases using IUCN's Global Standard, this report is intended to provide useful resources for and insights into planning, implementing and monitoring NbS best practice, and uncover both opportunities and limitations in current approaches. These findings support Infrastructure Canada's efforts to better understand the application of, demand for, and criteria needed for investment in NbS in Canada, and the federal government's allocation of funding to support NbS development.

The results include a number of conclusions regarding outstanding needs to ensure NbS are effectively planned and implemented, including: development of comprehensive and standardized NbS M&E frameworks, tools and resources; strategic planning that acknowledges complexity in NbS and engages all stakeholders; tools and indicators to assess the benefits of NbS for biodiversity; greater transparency around funding needs and uses, and ways that NbS can be financed; meaningful efforts to work respectfully with Indigenous peoples to ensure both that there are appropriate conditions for engagement and that traditional knowledge is applied in NbS; use of standardized multi-criteria decision-making processes; integration with other planning processes; and development of both funding and programs dedicated to educating and training practitioners. As usage of NbS becomes more mainstream, addressing these factors will help to ensure that such solutions are viable investments in both the short and long term, with a wide range of benefits for people and biodiversity, including significant levels of avoided damages from extreme events. Further information on the research findings and conclusions can be found in Table 4.1.

Table 4.1 – Research findings and remarks

Criterion	**Research Finding and Remark**
Societal challenges addressed	Measure of success: All reviewed cases discussed overall challenges (e.g., flooding, erosion, heat) but often did not specify a measure of success for NbS practice (e.g., volumes of stormwater managed, rate of erosion reduced, volume of storm surge storage increased). While defining success for NbS practice is still an evolving area, there should be best possible clear and measurable goals and objectives to ensure and refine the practice process. Clearly stated interrelated challenges: Multifunctionality and co-benefits of NbS were emphasized but often remained descriptive and not fully investigated. Interconnected challenges and benefits of NbS should be clearly analyzed to inform responsible actors and impacted communities and encourage their participation in NbS practice.
Scale of design	Systems thinking: The case studies in this report shows how NbS practice works at different scales: a small municipal scale (e.g., Town of Gibsons, BC), a large municipal scale (e.g., City of Vancouver, BC), a riverine or coastal neighborhood scale with complex governance (e.g., Town of Truro, NS), and watershed scale (e.g., Toronto and Region Conservation Authority). All the case studies show the importance of systems thinking in NbS practice.
Biodiversity and ecosystem integrity	Standardized biodiversity assessment: The research found that NbS strategies, particularly coastal restoration projects, emphasize habitat creation and enhancement. However, they often did not include specific parameters to measure the impact on biodiversity nor monitoring frameworks to assess improvements in ecosystem integrity. Standardized monitoring data sets and protocols can help practitioners incorporate biodiversity into NbS practice.
Economic feasibility	Siloed knowledge: Information on funding for implementation was lacking details. Many cases reviewed included various funding agencies in the projects, but the description of funding was often limited to naming the funders. Funding for operations and maintenance was usually not eligible for public funding programs (e.g., federal or provincial grants); local governments or responsible organizations need innovative financing approaches to operate and maintain NbS. However, there is a lack of understanding about what options are available in what situation and which have been successful or not. Uncovering the details of funding mechanisms from key cases will be critical to encouraging more public and private investors.
Inclusive governance	Siloed knowledge: Participatory planning processes were not well documented, often limited to descriptions of who was involved. It is important to document how project participants were identified, and how discussions have evolved over time and concluded, to provide take-away lessons. Historically marginalized and underrepresented populations should be involved in the entire decision-making process to improve procedural as well as distributive equity. Particularly in Canada, engagement with First Nations is important in NbS practice, but the process is as yet not well established and should be advanced based on evidence-based knowledge sharing.
Balanced trade-off	Multi-criteria decision-making: Although NbS are multifunctional, they are not a cure-all solution, and conflicting interests can arise in NbS practice, especially around cost-effectiveness and co-benefits. For example, bioswales provide more benefits at a higher cost than porous pavement for the same stormwater management capacity. The research found some coastal projects included cost-benefit analysis to evaluate alternatives from grey-only to all-green approaches. This process often only included cost-relevant values, but it can be

	extended to non-market driven values. Standardized multi-criteria decision-making processes can help facilitate balanced trade-offs among conflicting interests.
Adaptive management	Standardization and requirement: Many cases reviewed did not have monitoring frameworks, including some public funding programs. This undermines the potential of NbS projects and reinforces perceived uncertainties around them. Standardized protocols are required to collect both quantitative and qualitative data. Authoritative agencies (e.g., federal, provincial, regional, local governments) and funders (e.g., public, private, non-profit) should mandate disclosure of data and provide standardized templates for NbS projects to gain optimal benefits from funding programs.
Mainstreaming and stability	Integration with regular planning and policy practice: While most urban NbS strategies were relatively well-connected with other city-wide plans, including official community plans and climate action plans, NbS strategies for other disaster areas were less well incorporated into capital programs or municipal plans. The District of North Vancouver shows the potential to integrate NbS into official municipal plans and climate action plans designed to address climate hazards. Federal, regional, or provincial leadership in integrating NbS strategies into environmental and climate policy is also critical to NbS uptake at the ecosystem scale. Education and training: Supporting NbS strategies in the long-term requires development of an active learning system and curriculum. The research found that some non-profit organizations are actively contributing to NbS education, e.g., the Stewardship Centre for BC’s Green Shores’ training and certification program. Federal funding could help establish a more robust NbS education system, e.g., Natural Resources Canada’s Building Regional Adaptation Capacity and Expertise Program (BRACE) provided funding to train and educate practitioners in adaptation strategies, including NbS. More NbS-focused funding to develop education and training program will contribute to mainstreaming and stability of NbS practice.

Appendix 1. IUCN's Best Practice Criteria

#	Key Goals & Tasks*	Description
1	Societal challenges	NbS effectively address societal challenges
1.1	Prioritized challenges	The most pressing societal challenge(s) for rights-holders and beneficiaries are prioritized
1.2	Clearly stated challenges	The societal challenge(s) addressed are clearly understood and documented (e.g., sustainable service delivery, climate adaptation, emissions reduction, biodiversity and/or equity advancements, reconciliation, etc.)
1.3	Outcome Identification	Environmental, social, and economic outcomes arising from the NbS are identified, benchmarked, and periodically assessed
2	Scale of design	Design of NbS is informed by scale
2.1	Triple-bottom line interactions	The design of the NbS responds to relevant interactions with ecosystems, society, and economy (e.g., biodiversity, cost savings, human safety and well-being)
2.2	Integration and synergy	The design of the NbS is integrated with other complementary interventions and seeks synergies across sectors (e.g., existing strategies, plans, etc.)
2.3	Risk consideration	The design of the NbS incorporates risk identification and risk management beyond the intervention site (e.g., projected climate impacts and hazards, incremental and sudden changes, etc.)
3	Biodiversity and ecosystem integrity	NbS result in a net gain to ecosystem integrity and biodiversity
3.1	Evidence-based response	NbS actions directly respond to evidence-based assessment of the current state of the ecosystem and prevailing and projected drivers of degradation and loss (e.g., flow and volumes, land-use changes, increasing frequency of flood events, etc.)
3.2	Measurable outcomes	Clear and measurable ecological and biodiversity outcomes are identified, benchmarked, and periodically assessed
3.3	Monitoring	Monitoring includes periodic assessments of unintended adverse consequences for natural systems arising from the NbS
3.4	Enhancement	Opportunities to enhance ecosystem integrity and connectivity are identified and incorporated into the NbS strategy
4	Economic feasibility	NbS are economically viable
4.1	Cost benefit	The direct and indirect benefits and costs of the NbS are identified and documented, i.e., who pays and who benefits, opportunity costs, replacement costs, co-benefits, etc.
4.2	Cost effectiveness	A cost-effectiveness study is provided to support the valuation and choice of NbS over time, including the likely impact of any existing or projected changes in conditions, regulations, and/or subsidies
4.3	Effectiveness justification	The effectiveness of the NbS design is justified against available alternative solutions, taking account of associated externalities
4.4	Resource portfolio	NbS design considers a portfolio of resourcing options such as market-based, public and/or private sector investment, voluntary commitments, and actions to support regulatory compliance
5	Inclusive governance	NbS are based on inclusive, transparent, and empowering governance processes

5.1	Pre-facto engagement	A defined and fully agreed-upon feedback and grievance resolution mechanism is available to all stakeholders before an NbS intervention is initiated
5.2	Comprehensive and inclusive planning	Participation in planning is based on mutual respect and equality, regardless of gender, age or social status, and upholds the right of Indigenous Peoples to Free, Prior and Informed Consent (FPIC)
5.3	Stakeholder identification	Relevant stakeholders who are directly and indirectly affected by the NbS are identified and involved in all NbS planning processes
5.4	Inclusive response	Decision-making processes document and respond to the rights and interests of all participating and affected stakeholders
5.5	Joint decision	Where the scale of the NbS extends beyond jurisdictional boundaries, mechanisms are established to enable joint decision-making of the stakeholders in the affected jurisdictions
6	Balanced trade-off	NbS equitably balance trade-offs between achievement of the primary goal(s) and continued provision of multiple benefits
6.1	Cost-benefit trade-off	The potential costs and benefits of associated trade-offs of the NbS intervention are explicitly acknowledged and inform safeguards and any appropriate corrective actions
6.2	Land ethic	The rights, usage of and access to land and resources, along with the responsibilities of different stakeholders, are acknowledged and respected
6.3	Safeguard	Established safeguards are periodically reviewed to ensure that mutually agreed-upon trade-off limits are respected and do not destabilize the NbS
7	Adaptive management	NbS are managed adaptively, based on evidence
7.1	Regular M&E	A NbS strategy is established and used as a basis for regular monitoring and evaluation of the intervention
7.2	Lifecycle M&E plan	A monitoring and evaluation plan is developed and implemented throughout the intervention lifecycle
7.3	Integrative learning	A framework for iterative learning that enables adaptive management is applied throughout the intervention lifecycle
8	Mainstreamed	NbS are sustainable and mainstreamed within an appropriate jurisdictional context
8.1	Information sharing	The NbS design, implementation and lessons learnt are shared to trigger transformative change
8.2	Policy and regulation support	The NbS informs and enhances policy and regulation frameworks to support its uptake and mainstreaming
8.3	Support national and global targets	Where relevant, the NbS contributes to national and global targets for human well-being, climate change, biodiversity and human rights, including the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)

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