COMMISSION FOR ENVIRONMENTAL COOPERATION

Nature-based Solutions to Address Flood Risks in Coastal Communities

Co-Benefits

Report Series:

Monitoring Efficacy: Proposed Methodology and Indicators

Monitoring Efficacy

Retrofitting Existing Infrastructure

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Abstract

Flood-risk management is a major concern for coastal urban and peri-urban areas, particularly when considering sea-level rise caused by climate change. Nature-based solutions (NBS) have the potential to meet many flood-risk management objectives while also providing social, environmental, and economic co-benefits. However, the uptake and implementation of NBS are limited by barriers related to understanding, valuing, and realizing potential co-benefits.

This document supports the uptake of NBS in coastal communities across Canada, Mexico and the United States, by providing decision makers with practical information and guidance related to NBS co-benefits. Potential co-benefits are summarized for ease of reference, though different conditions in the three countries may impact the type or magnitude of co-benefits provided by NBS. An assessment framework for valuating co-benefits is defined. Potential methods for valuing co-benefits are also summarized. In addition, challenges to realizing co-benefits and potential opportunities to alleviate these challenges are outlined for decision makers. Case studies are included throughout the report to provide real-world context and emphasize key concepts.

Executive Summary

Coastal areas in North America offer numerous benefits to their inhabitants, including recreational activities, access to nature and marine resources, and economic opportunities. However, many of these coastal areas are exposed to significant coastal flood hazards, which are expected to intensify due to increasing population growth, aging protective infrastructure (e.g., dikes) near the coastline, and climate change.

Conventional gray approaches (i.e., hard infrastructure) to coastal Flood-risk management (FrM) often result in unintended socio-economic impacts, regularly leading to the degradation or loss of natural ecosystems and even experiencing catastrophic failure. In contrast, Nature-based solutions (NBS) serve to mitigate flood risks through the informed use of natural systems and natural processes, while simultaneously providing environmental, social, and economic co-benefits. Co-benefits serve as a major driver for the usage of NBS for FrM in coastal communities and may serve to stimulate the uptake of NBS for FrM instead of more conventional, gray infrastructure. There are numerous outcomes and activities that benefit from assessing and valuing NBS co-benefits, including:

- Holistic comparison of FrM options (e.g., multi-criteria analysis);
- Anticipation of trade-offs and set priorities;
- Improving engagement and public buy-in;
- Increasing funding opportunities;
- Assessing unintended impacts;
- Informing adaptive management;
- Complying with project requirements (e.g., funding requirements); and
- Knowledge-sharing (e.g., research and guidance development).

Despite the numerous benefits, the uptake and implementation of NBS are limited by data gaps and barriers related to effectively identifying, valuing, and leveraging co-benefits. Barriers may be broadly broken into four categories:

- Social/attitudinal (e.g., perception that benefits are unrealistic or will not be realized);
- Technical (e.g., lack of technical guidance for co-benefit valuation);

- Environmental (e.g., seasonal or long-term variability of natural systems); and
- Institutional (e.g., lack of funding and lack of government awareness).

This document is intended to support the uptake of NBS in coastal communities by providing decision makers and FrM professionals with practical information and guidance related to NBS co-benefits and by addressing several previously identified data gaps and barriers. It does not provide in-depth technical guidance, nor is it intended to provide an exhaustive review of the rapidly growing body of literature on NBS.

Types of Co-Benefits

Co-benefits are the additional, yet valuable, secondary benefits—other than the primary benefits of FrM—that are provided by a project. Co-benefits broadly fit into three categories: (1) environmental, (2) social, and (3) economic. All three categories of co-benefits, as well as direct FrM benefits, are interconnected and have significant overlap. A comprehensive list of potential FrM benefits, and environmental, social, and economic co-benefits is provided in Section 2 of the report. Potential benefits may include, for example:

- **FrM:** Reduced flooding, reduced wave effects, improved erosion protection
- **Environmental:** Improved water quality, improved soil health, carbon sequestration, improved biodiversity
- **Social:** Poverty reduction, food security, inclusion and equity, improved well-being
- **Economic:** Reduced capital costs, eco-tourism, improved fisheries, increased tax revenue

Co-Benefit Assessment Framework

A co-benefits assessment framework was developed to support valuation and comparison of co-benefits within and between projects. The framework is divided into three iterative stages:

- **Stage 1. Identification**
  The Identification stage involves understanding the 'big picture' of an NBS project. During this stage, the project team should identify timelines, define an engagement strategy, and identify local issues and challenges to inform brainstorming of potential co-benefits. It is critically important to engage community members, Indigenous Peoples, historically marginalized groups, and other local stakeholders when identifying project-specific co-benefits. The Identification stage will result in the development of a broad list of potential co-benefits and strategies for implementation (e.g., design features or actions).
- **Stage 2. Valuation**
  Valuation is the process of determining the potential value of a given co-benefit. When valuing co-benefits, there is often a focus on the economic value of outcomes, which may inadvertently devalue less quantifiable (i.e., intangible) social and environmental co-benefits. This report recognizes the importance of adopting a more holistic approach to valuation, moving away from the idea that value is synonymous with money. Instead, valuation is defined as the process of quantifying the importance, worth, usefulness and/or monetary value of a given co-benefit. During this stage, the project team should identify resource and schedule limitations, select valuation methods, select performance indicators, set baselines, and undertake valuations for each co-benefit. Valuation methods will vary depending on resource limitations, the project impact or risk, and the project phase (e.g., scoping phase versus design phase).
- **Stage 3. Comparison**
  The Comparison stage involves assessing trade-offs and prioritizing certain co-benefits to support decision making and design. Co-benefits associated with different design options may also be compared to support selecting a preferred alternative (e.g., to support comparison of NBS and gray infrastructure). An approach using multi-criteria analysis is recommended for

comparing co-benefits, and help facilitate the comparison of non-quantifiable and intangible co-benefits. A template-rating framework is provided in the Appendix.

A key takeaway from this report is the importance of stakeholder involvement, multi-disciplinary expert involvement, and thorough consideration of resource limitations, all of which have significant impacts on the co-benefits assessment process.

Measuring and Monitoring FrM Benefits and Co-Benefits

Valuation methodologies should be selected considering the type of benefit being assessed, so that they provide a level of confidence commensurate with the potential level of impact or risk associated with the project. Choice of methodology will also be influenced by the availability of project resources, which may be broadly divided into three categories: time, budget, and expertise.

Low effort valuation methods include review of precedence (case studies) and solicitation of expert opinions, for example. These techniques are associated with low resource requirements and high levels of uncertainty; therefore, they may be appropriate for low impact/low-risk projects or for early in the project cycle, during the planning or scoping phases. High effort valuation methods may include field surveys (including subsequent data analysis), numerical modeling, and cost-benefit analyses, amongst others. These techniques are associated with high resource requirements and lower levels of uncertainty; therefore, they may be appropriate for high-impact projects or for later phases of the project's life cycle. Valuation approaches should be chosen based on project-specific needs. A range of potential valuation methods specific to environmental, social, and economic co-benefits are provided within Section 3.4.2 of the report.

The associated guidance document *Monitoring Efficacy: Proposed Methodology and Indicators* provides additional details on potential monitoring methodologies and proposed FrM performance indicators.

Co-Benefits and Adaptive Management

Adaptive management involves following an iterative process of learning and decision-making, which helps to reduce uncertainty and improve long-term project outcomes. It allows for project flexibility during all phases of the project (including design, implementation, construction, and operation) to manage uncontrollable and changing conditions, including climate change. As applied to co-benefits, adaptive management ensures that actions are taken throughout the project's life cycle to optimize co-benefits associated with the project and the co-benefits monitoring plan. Adaptive management of co-benefits also helps to reduce potential unintended impacts and create public accountability. Regular, long-term monitoring forms the foundation for effective adaptive management of co-benefits.

Opportunities and Future Initiatives

To help alleviate known data gaps and barriers, potential opportunities and future initiatives that may be implemented by decision makers are outlined within the report. Key opportunities are briefly summarized below:

- Develop public informational sessions and accessible materials related to co-benefits of NBS.
- Encourage diverse stakeholder engagement and involvement (e.g., through community science) throughout NBS projects and the co-benefits assessment process.
- Build technical capacity to understand and valuate co-benefits through training programs or coursework within existing academic programs/degrees.
- Develop a community of practice to encourage knowledge-sharing.
- Work to make historical, existing, and future co-benefits assessment data and case studies publicly available in a centralized location.
- Establish and disseminate additional technical guidance on co-benefit valuation for use by practitioners.

- Emphasize (or mandate) co-benefits assessments, adaptive management for co-benefits, and public data distribution within guidelines, funding requirements, permits, applications, and Requests for Proposals.
- Create additional funding streams for projects that demonstrate significant co-benefits for local communities and the environment.
- Create additional funding streams for projects involving long-term monitoring, valuation, data dissemination, and adaptive management related to co-benefits.
- Continue ongoing initiatives to value natural capital assets.

Preface

The Commission for Environmental Cooperation (CEC) is a trilateral organization that facilitates cooperation between Canada, Mexico and the United States to conserve, protect and enhance the North American environment. In 2021, the CEC initiated a project to help guide the broader implementation of nature-based solutions (NBS) for coastal flood-risk management (FrM) in North American communities. The initiative may be broadly partitioned into three phases, as follows:

1. **An intersectoral workshop series** to lay the foundation for a North American community of practice, convene practitioners to scope needs and opportunities, and identify barriers to implementation of NBS.
2. **A set of guidance documents** to address knowledge gaps and further develop opportunities identified during the workshop series, and guide best practices related to implementing NBS.
3. **Webinars** to improve the uptake and usage of the guidance documents.

As part of the first phase of the project, DHI Water and Environment Inc. (DHI) was engaged to develop and host the workshop series. The workshop series consisted of seven sessions held over a five-week period in May and June 2022. The sessions were focused on the following topics:

- 1A and 1B: Nature-based Solutions Co-Benefits
- 2A and 2B: Retrofitting Existing Infrastructure Using Nature-based Solutions
- 3A and 3B: Monitoring Efficacy of Nature-based Solutions
- 4: Summary Workshop

The workshop series saw the participation of 95 experts, spanning a range of academia, private industry, government, and nongovernmental organizations (NGOs) from across North America. Group activities were included in the workshop series to build community, develop ideas, solicit feedback, and identify gaps and opportunities. Group activities included discussions of six different case studies, four sets of collaborative online activities, and two interactive question series. The participation and idea development from participants with diverse backgrounds and experiences provided a strong foundation for building both a community of practice and guidance documents on NBS in North America.

The second phase of the project involved addressing knowledge gaps identified in the workshop series through the development and publication of a comprehensive set of guidance documents on NBS within an urban and peri-urban North American context. This document forms part of a series of guidance documents that are intended to be referenced as a whole. The guidance documents include:

- Co-Benefits (this document)
- Retrofitting Existing Infrastructure
- Monitoring Efficacy
- Monitoring Efficacy: Proposed Methodology and Indicators

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1 Introduction

Coastal areas offer numerous benefits to their inhabitants, including recreational activities, a moderated climate, access to nature and marine resources, and economic opportunities, amongst others. It is therefore unsurprising that one third of North Americans reside in coastal areas, with a high concentration in urban centers (Manson, 2005; NOAA, 2013; Sevilla et al., 2019). However, many of these coastal areas are exposed to significant coastal flood hazards, which are associated with immense social, environmental, and economic costs. As a recent example, Hurricane Ida made landfall in the United States on 29 August 2021, displacing thousands, resulting in the death of 87 people, and causing nearly US$80 billion in damages in the United States (Beven et al., 2022). The hurricane resulted in the release of toxic oils and chemicals into the natural environment, but the full ecological consequences of this single event are not yet well understood. More recently, on 24 September 2022, Hurricane Fiona made landfall in Atlantic Canada, causing over CA$800 million in insured damages and further immeasurable damage to the coastlines (Insurance Bureau of Canada, 2023). On 28 September 2022, Hurricane Ian also made landfall in Florida, becoming one of the most consequential storms in recent United States history, with approximately 134 casualties to date and 2.5 million Floridians evacuated (The Free Press, 2022; Livingston, 2022). Hurricane Ian caused an estimated US$1.2 billion to US$1.9 billion in total losses to agriculture production and infrastructure (Florida Department of Agriculture and Consumer Services, 2022). These catastrophic storm events, and their impacts, are expected to increase in both frequency and intensity as the climate continues to change (IPCC, 2022).

Coastal flood-risk management (FrM) is clearly a necessity for highly populated coastal regions. Conventional coastal FrM systems have relied upon gray engineering techniques, which typically involve building hardened structures with artificial material (i.e., concrete, steel, etc.) and frequently overlook or undervalue environmental, social, and economic needs and values (Bridges et al., 2021). These gray techniques often result in unintended socio-economic impacts, may experience catastrophic failure, and regularly lead to the degradation or loss of natural ecosystems. In contrast, Nature-based Solutions (NBS) serve to mitigate flood risks through the informed use of natural systems and natural processes, while explicitly valuing environmental, social, and economic co-benefits (Bridges et al., 2021; Shiao et al., 2020).

Inclusion of co-benefits into project planning recognizes that all projects result in impacts that extend beyond the primary goal of FrM and places explicit value on these impacts. The potential co-benefits provided by NBS serve as a major driver for their adoption for FrM in coastal communities. However, the uptake and implementation of NBS are limited by data gaps and barriers related to effectively valuating, realizing, and leveraging co-benefits.

This document aims to support the uptake of NBS in coastal communities by providing decision makers with practical information and tools related to NBS co-benefits and by addressing several previously identified data gaps and barriers. This document forms part of a series developed by DHI Water and Environment Inc. (DHI) on behalf of the Commission for Environmental Cooperation (CEC), which are intended to be referenced as a whole. The guidance documents include:

- Co-Benefits (this document)
- Retrofitting Existing Infrastructure
- Monitoring Efficacy
- Monitoring Efficacy: Proposed Methodology and Indicators

1.1 Objectives and Scope

An intersectoral workshop series was hosted by DHI in spring 2022 as part of an ongoing project by the CEC to support the broader implementation of NBS for coastal flood-risk management in North American communities (DHI, 2022). The workshop series consisted of seven sessions, with 95 attendees from Canada, Mexico, and the United States. Two of the sessions focused specifically on NBS co-benefits. During these sessions, attendees participated in idea generation and identification of data gaps, barriers, and opportunities related to co-benefits.

This document addresses knowledge gaps and barriers identified in the workshop series, synthesizes existing information, and provides practical tools to identify, assess, and realize co-benefits associated with NBS used to address flood risks in coastal communities. It is part of a comprehensive set of guidance documents, which are intended to support decision makers in implementing NBS for coastal flood-risk management across North America.

More specifically, this document aims to:

- Provide a comprehensive summary of potential social, environmental, and economic co-benefits within the North American context;
- Provide a resource outlining the benefits of NBS projects to disseminate to different stakeholders;
- Provide tools to identify, valuate, and compare co-benefits to support decision-making;
- Provide tangible examples of co-benefits and their quantification through case studies; and
- Where possible, address gaps and barriers identified during the previous intersectoral workshop series.

This document is intended to provide evidence and tools to support decision makers in the broader implementation of NBS to address coastal flood risks in coastal communities. The guidance herein is intended to assist decision makers in all stages of the project process, from conceptualization through design and operation. The document does not provide in-depth technical guidance, nor does it provide an exhaustive review of the rapidly growing body of literature on NBS.

For further reading material and key documents on NBS co-benefits, the reader is referred to Section 1.4.

1.2 The Value of Analyzing Co-Benefits

Co-benefits are the additional secondary benefits – other than the primary FrM benefit – that are provided by a project. Decision-making around conventional FrM solutions has generally relied almost entirely upon the analysis of direct project costs and FrM performance indicators. However, assessment of co-benefits may significantly enhance project outcomes and support decision making. Box 1 summarizes activities that may benefit from analyzing NBS co-benefits.

Box 1. Activities which benefit from or require the analysis of NBS co-benefits

- **Holistic Comparison of FrM Options** (e.g., multi-criteria analysis)
- **Anticipate Trade-Offs & Set Priorities**
- **Improve Engagement & Public Buy-In**
- **Increase Funding Opportunities**
- **Assess Unintended Impacts & Improve Accountability**
- **Inform Adaptive Management**
- **Comply with Project Requirements** (e.g., funding requirements)
- **Knowledge-sharing** (e.g., research and guidance development)

Early in the scoping and planning phases of a project, assessing co-benefits allows for a holistic comparison of benefits provided by numerous FrM options, helping to maximize project outcomes and meet the needs of community members and stakeholders. Assessment of co-benefits also allows the project team to anticipate trade-offs between potential benefits and set priorities. The co-benefits assessment process is described further in Section 3.

Importantly, analyzing co-benefits provides the project team with evidence-based projections of the potential benefits. This helps to improve public buy-in and provides leverage by which to obtain funding for the project.

Analyzing potential co-benefits early in the project also helps to plan future performance evaluations and provides a baseline for which measured co-benefits can be compared against. As such, the assessment of co-benefits throughout the project life also helps to ensure that the project is meeting goals (i.e., ensure compliance and improve accountability) and informs adaptive management activities. Adaptive management of co-benefits is discussed in Section 5.

Co-benefit measurement and knowledge-sharing may lead to new insights into NBS function and benefits, supporting new technical guidance for NBS. In addition, knowledge-sharing may enable evidence-based policy changes and improve the overall uptake of NBS.

Practically, there is a need to tie the scope and scale of co-benefit assessment activities to the overall project needs, risks, and funding limitations. Consequently, the value of analyzing co-benefits is dependent on the specific project details and the type of NBS. Methods for valuing co-benefits are discussed in Section 4.

1.3 Identified Barriers to Realizing Co-Benefits

Box 2 provides a summary and expansion of barriers identified during the CEC's workshop series on NBS (DHI, 2022) related to realizing (i.e., achieving and becoming aware of) co-benefits.

A significant barrier to assessing co-benefits is the need to involve qualified professionals that span multiple disciplines, which poses logistical and budgetary difficulties, particularly during the early phases of a project. There appears to be ambiguity about who needs to be involved, at what stage, and for which activities.

Box 2. Barriers to realizing NBS co-benefits

Type of Barrier	Focus (this report)
Social/Attitudinal	
• Siloed or lack of knowledge of potential co-benefits for the public	✓
• Insufficient incorporation of traditional, Indigenous, and local knowledge	✓
• Lack of acknowledgement for trade-offs (unrealistic promises)	✓
• Uncertainty or perceived risk that benefits will not be realized	○
• Lack of accountability for unintended consequences	✓
• Uncertainty or risk that co-benefits will not be realized for long-term projects which require continued investment	✓
Technical	
• Lack of guidance for project planning (with application to a broad range of project locations, sizes, and budgets)	✓
• Lack of comprehensive technical guidance for co-benefit valuation (quantitative and qualitative)	✓
• Lack of definitive framework valuating, prioritizing, and tracking co-benefits	✓
• Lack of definitive guidance for monitoring or tracking co-benefits	✓
• Lack of up-to-date and useable case studies and inventories (demonstrating both successful and unsuccessful outcomes)	✓
• Uncertainty of predictive tools related to long-term behavior	○
• Lack of trained and qualified professionals	○
• Need for expert involvement across disciplines (e.g., social science experts)	○
Environmental	
• Seasonal and long-term variability of natural systems	○
• Near- and long-term impacts of climate change on natural systems	○
• Variable levels of resilience to the impacts of climate change	○
Institutional	
• Lack of government awareness on NBS co-benefits	✓
• Lack of consideration for co-benefit valuation in regulatory approvals	○
• Lack of funding for all project phases, including tax incentives (from planning, design, operations, to monitoring and adaptive management)	○
• Focus on traditional (i.e., gray) flood protection methods for funding and regulatory approvals	○
• Focus on short-term horizons for realization of benefits	○

Source: Adapted from barriers identified as part of the intersectoral workshop series on NBS, hosted by DHI on behalf of the CEC in spring 2022

There also appears to be a perceived lack of technical guidance related to co-benefit valuation, particularly with application to a broad range of project locations, sizes, and budgets (Brill et al. 2021). Experts suggest that a lack of valuation frameworks, monitoring guidance, and up-to-date case studies pose significant barriers to assessing and realizing co-benefits.

In addition, experts have recognized a lack of standardized methods to facilitate the identification, measurement, and valuation of co-benefits, which includes analysis of historical data and valuation of intangibles (i.e., non-economic or qualitative co-benefits). Without a level of standardization for how co-benefits should be identified, measured, and valuated, both the analysis of available options and the comparison of co-benefits between projects are challenging and can introduce high levels of uncertainty. Though many methods for identification and valuation exist, there is no "one size fits all" approach and it is important to remember that the value of nature and natural assets varies across cultures and regions, making it difficult to produce a definitive, globally applicable, valuation of nature (IPBES, 2022). The magnitude of potential outcomes and resources required to realize co-benefits are best understood when there is ample historical data and case studies to review and assess.

Experts have also indicated that institutional barriers pose a significant challenge to incorporating the assessment of co-benefits into projects. Institutional barriers included a lack of understanding or of consideration within regulations, a focus on short-term benefits, and a general proclivity for conventional (i.e., gray), structural FrM approaches. These barriers are further amplified by a lack of funding to support co-benefits assessment throughout the project's life cycle. Many decision makers and funders are unaware of the potential benefits of NBS or do not put significant value on social and environmental benefits, and are consequently hesitant to fund these projects (Brill et al., 2021).

This report aims to alleviate several of these data gaps and barriers, where possible (as identified in Box 2), or, where not possible, to identify methods for addressing them through further initiatives (see Section 6). Barriers that are a focus of this report include social/attitudinal, technical, and institutional barriers, which may be alleviated (in part) through making available additional data, knowledge, or guidance. Barriers that require additional actions to be taken by decision makers (such as the establishment of funding sources and other policy instruments) have not been addressed.

Additional data gaps and barriers related to retrofitting existing infrastructure, using NBS and monitoring the efficacy of NBS, are outlined in the associated reports: *Retrofitting Existing Infrastructure* and *Monitoring Efficacy.*

1.4 Further Reading

Numerous publications were reviewed and referenced to prepare this report. These documents—as well as the CEC's workshop series on NBS—served as the foundation to develop the guidance, processes, and considerations outlined in this report. Key reference materials are listed below and may provide the reader with further information and technical guidance.

- *Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience,* United States Army Corps of Engineers (USACE) (Bridges et al., 2015)
- *A Guide to Assessing Infrastructure Costs and Benefits for Flood Reduction,* National Oceanic and Atmospheric Administration (NOAA) (Eastern Research Group, 2015)
- *A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas* (Raymond et al., 2017)
- *A Framework for Assessing Benefits of Implemented Nature-Based Solutions* (Watkin et al., 2019)
- *Incorporating Multiple Benefits into Water Projects: A Guide for Water Managers*, Pacific Institute (Diringer et al., 2020)
- *Benefit Accounting of Nature-Based Solutions for Watersheds: Guide,* United Nations CEO Water Mandate and Pacific Institute (Brill et al., 2021)
- *International Guidelines on Natural and Nature-Based Features for Flood Risk Management,* USACE (Bridges et al., 2021)
- *Quantifying co-benefits and disbenefits of Nature-based Solutions targeting Disaster Risk Reduction* (Ommer et al., 2022)
- *Managing Natural Assets to Increase Coastal Resilience, Guidance Document for Municipalities* (MNAI, 2021a)

2 Types of Co-Benefits

This section describes the broad categories of possible FrM benefits and co-benefits provided by NBS projects, and provides examples of these potential benefits.

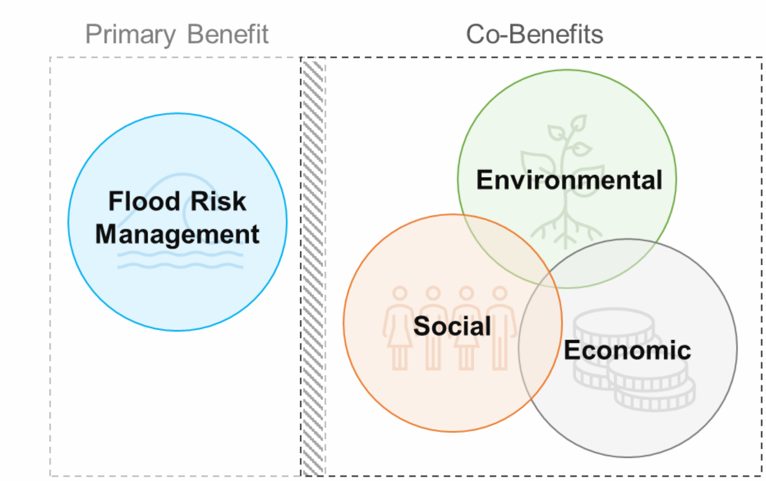
2.1 Overview

The benefits provided by NBS include both primary FrM benefits and secondary co-benefits. Broadly speaking, benefits may be split into four interconnected categories (Bridges et al., 2021; Shiao et al., 2020), as listed below and shown in Figure 1:

- Flood-risk management;
- Environmental;
- Social; and
- Economic.

These four categories are dynamic and interconnected. There is significant overlap between FrM benefits and co-benefits within all categories. In practice, strategic implementation of certain co-benefits may introduce additional (potentially unintended) changes and impacts to a system, leading either to synergies or to trade-offs between co-benefits (see Section 3.5). As such, it is important to recognize and consider the interconnectivity of co-benefits when undertaking design and implementation activities.

Figure 1. Primary FrM benefits and secondary environmental, social, and economic co-benefits



The following sub-sections provide a summary of potential co-benefits that may be achieved through a NBS project. These co-benefits are intended to support the overall identification of potential co-benefits of a given project (see Section 3.3) and the process of communicating them to stakeholders and the project team. Because the benefits of NBS often span multiple categories (to varying degrees), the category and magnitude of each benefit are also indicated.

The lists of potential co-benefits should be considered as indicative and not exclusive. Identification of co-benefits and their value should be done on a project-specific basis, with consideration for project goals, community needs, site conditions and with the involvement of relevant stakeholders.

Projects may identify and prioritize only some of the listed potential co-benefits, or achieve them to varying degrees, while other projects may include co-benefits additional to those listed. Identification, valuation, and comparison of co-benefits are discussed in detail within Section 3. A comprehensive example of the primary FrM benefits and secondary environmental, social, and economic co-benefits provided by a mangrove restoration project in San Crisanto, Mexico, is highlighted in Case Study 1.

2.2 Flood Risk Management

The primary goal of all FrM projects is to reduce or mitigate flood-related risks. Potential direct benefits provided by a FrM project are provided in Table 1.

Although FrM benefits are not the primary focus of this report, they are outlined here due to their relevance and inter-relation to co-benefits. FrM benefits and co-benefits have significant overlap and interdependency. For example, by reducing maximum still water levels during flood events, numerous environmental (e.g., surface water quality), social (e.g., well-being through increased security), and economic (e.g., increased property values) co-benefits may be realized.

Table 1. Examples of flood-risk management benefits

Category				
FrM	**Enviro.**	**Social**	**Econ.**	**Potential FrM Benefits**
●	◔	◕	◕	Reduced maximum still water flood levels
●	○	◕	◕	Reduced wave effects (i.e., overtopping)
●	◔	◕	◕	Reduced or diverted flood velocities
●	◕	◕	◕	Shorter flood duration
●	○	◔	◕	Residual performance following flood events
●	○	◔	◕	Resilience or contingencies for failure
●	◕	◕	◕	Erosion protection
●	◕	◔	◔	Improved sediment supply or retention

● Greatest benefit ◕ Some benefit ◔ Minor benefit ○ No benefit

Source: Adapted from Brill et al., 2021, 20

Case Study 1. San Crisanto Mangrove Restoration

San Crisanto Mangrove Restoration:
Incorporating co-benefits from the start

San Crisanto, Yucatán, Mexico

The community of San Crisanto is located on communal land (ejido) collectively managed by 150 local families, in the Sinanché municipality of Yucatán, 50 km east of Progreso. In 1995, hurricanes Opal and Roxanne struck the Yucatán region and caused damage to the mangrove forests, which led to extensive flooding in San Crisanto.

In 2001, the ejido, in partnership with the San Crisanto Foundation, created a sustainable development program with the primary aim of restoring the mangroves, increasing biodiversity, and reducing flood risk (UNDP, 2012). The program was intended to tackle flood risk while prioritizing environmental co-benefits simultaneously.

As a result of this program, the area is now officially registered as a 'wildlife conservation management unit' and 60% of the mangroves lost during Hurricane Isidore in 2002 have been restored (UNDP, 2012; NBSI, 2022). The mangrove restoration resulted in improved water quality, increased freshwater fish, prawns, crocodiles and migratory and endemic bird populations, as well as improved drainage and flood protection from future storms (UNDP, 2012).

The project has also generated significant social-economic benefits. Tourism has benefitted from the restored waterways and cenotes, with flat-bottomed rowboat tours now available through the mangroves. Youth have been actively involved in conservation efforts and 60 jobs have been created. In 2001, 90% of the population in San Crisanto was living below the national poverty line and by 2010, 100% of the population had incomes twice the national average (NBSI, 2022). Recently, the additional co-benefit of carbon sequestration in the restored mangroves has allowed San Crisanto to trade Mexico's first carbon credits on the international market (Godoy, 2022).

Additional information may be found at: <https://sgp.undp.org/resources-155/award-winning-projects/393-san-crisanto-foundati0n/file.html>

Figure 2. Transect monitoring of restored mangroves in San Crisanto

Source: San Crisanto Foundation, Nature4Climate, 2022

2.3 Environmental

Several potential environmental co-benefits for FrM projects are provided in Table 2. The list is not exhaustive, and additional environmental co-benefits should be identified on a project-specific basis (see Section 3.3).

As with all co-benefits, there may exist positive interactions, or synergies, between environmental co-benefits (for instance, habitat connectivity may also benefit the abundance and diversity of native plant species). Most of the environmental co-benefits listed below also provide ecosystem services for people (i.e., social or economic co-benefits). For example, increased terrestrial habitat availability through green spaces can have positive effects on human health and well-being, property values and tourism (Ommer et al., 2022). Some environmental co-benefits may also result in negative impacts or trade-offs between other co-benefits. For example, increased numbers of local pollinators, which support agricultural production, may be seen as a nuisance to local communities (Ommer et al., 2022).

It is commonly argued that the natural environment also has intrinsic value, regardless of the services provided to people. For certain projects, where stewardship and restoration are foundational values to the project stakeholders, it may be appropriate to consider additional environmental co-benefits that have intrinsic value (IPBES, 2022).

Table 2. Examples of environmental co-benefits

Category				
FrM	**Enviro.**	**Social**	**Econ.**	**Potential Environmental Co-Benefits**
○	●	◕	◕	Surface water quality
◕	●	◔	◕	Surface water storage
○	●	◕	◕	Groundwater quality
◔	●	◔	◕	Groundwater recharge and storage
◔	●	◔	○	Soil health
◔	●	◕	○	Terrestrial habitat availability and quality
◔	●	◕	○	Aquatic habitat availability and quality
○	●	○	○	Habitat connectivity
◔	●	◔	○	Abundance and diversity of native plant species
○	●	◔	◕	Abundance and diversity of native animal species
○	●	○	◕	Support for local pollinators
○	●	◔	◔	Natural pest control
◔	●	○	◔	Production of raw (natural) materials
○	●	◕	○	Reduced pollution (improved air quality)
◔	●	◕	◕	Reduced carbon emissions
◔	●	◕	◕	Carbon sequestration

● Greatest benefit ◕ Some benefit ◔ Minor benefit ○ No benefit

Sources: Adapted from co-benefits identified as part of the intersectoral workshop series on NBS hosted by DHI on behalf of the CEC in spring 2022, an internal workshop with experts from DHI in fall 2022, Brill et al., 2021, 20, and Ommer et al., 2022, 2

2.4 Social

Several potential social co-benefits are provided in Table 3. The list is not exhaustive, and additional social co-benefits should be identified on a project-specific basis (see Section 3.3). It is important to engage community members, Indigenous Peoples, historically marginalized groups, and other local stakeholders when identifying project-specific co-benefits, particularly in relation to social co-benefits that directly impact the quality of life and overall well-being of community members.

Social co-benefits are highly linked to other co-benefits, resulting in both synergies and trade-offs. For example, poverty reduction provides both social well-being and economic benefits to a community. Increasing tourism may also result in the production of new businesses and jobs but result in over-crowding and increased property prices, thereby negatively impacting new homebuyers and increasing property taxes (Ommer et al., 2022).

Table 3. Examples of social co-benefits

Category				
FrM	Enviro.	Social	Econ.	Potential Social Co-Benefits
○	○	●	○	Well-being through improved security and peace of mind
○	○	●	○	Well-being through connectivity to green-space and natural systems
○	○	●	◔	Broader recreation and gathering spaces
○	○	●	○	Inclusion and equity
○	○	●	◕	Poverty reduction
○	○	●	◕	Improved esthetics
○	◕	●	◔	Low-impact transportation networks
○	◕	●	○	Noise abatement
○	○	●	○	Cultural, religious, and spiritual settings
○	◔	●	○	Indigenous participation and stewardship
○	◔	●	◔	Foraging, gathering, and traditional usages
○	○	●	◕	Food security
◔	◕	●	◔	Opportunities for education/scientific study
◔	◕	●	◕	Climate adaptation and mitigation

● Greatest benefit ◕ Some benefit ◔ Minor benefit ○ No benefit

Sources: Adapted from co-benefits identified as part of the intersectoral workshop series on NBS hosted by DHI on behalf of the CEC in spring 2022, an internal workshop with experts from DHI in fall 2022, Brill et al., 2021, 20, and Ommer et al., 2022, 2.

2.5 Economic

Several potential economic co-benefits are provided in Table 4. The list is not exhaustive, and additional economic co-benefits should be identified on a project-specific basis (see Section 3.3).

Notably, all the identified economic co-benefits also provide social co-benefits, but rarely provide significant environmental co-benefits (although environmental co-benefits often provide secondary economic co-benefits). Consequently, prioritizing economic co-benefits of NBS may result in poor outcomes (i.e., trade-offs) for the environment.

Table 4. Examples of economic co-benefits

Category				
FrM	**Enviro.**	**Social**	**Econ.**	**Potential Economic Co-Benefits**
◔	○	◔	●	Reduced capital costs
◔	○	◔	●	Reduced maintenance costs (improved resilience)
◔	○	◔	●	Reduced costs to adjacent infrastructure (avoided flood losses)
○	◔	◕	●	Eco-tourism opportunities
○	◔	◕	●	Fisheries
○	◔	◕	●	Agricultural output
○	○	◕	●	Job opportunities
○	○	◕	●	Support artisanal livelihoods
○	○	◕	●	Increased land/property value
◔	◔	◔	●	Increased tax revenue
● Greatest benefit ◕ Some benefit ◔ Minor benefit ○ No benefit				

Sources: Adapted from co-benefits identified as part of the intersectoral workshop series on NBS hosted by DHI on behalf of the CEC in spring 2022, an internal workshop with experts from DHI in fall 2022, Brill et al., 2021, 20, and Ommer et al., 2022, 2.

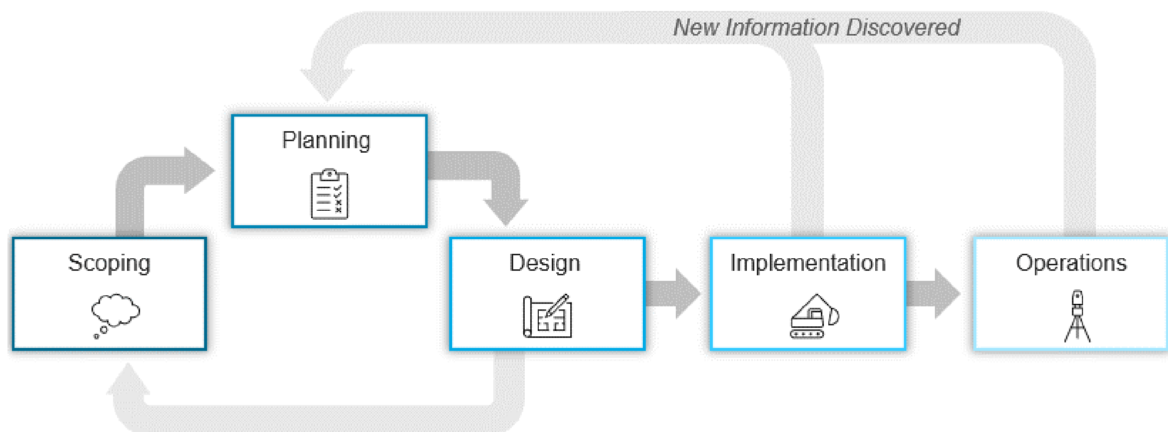
3 Co-Benefits Assessment and Decision Support Tools

This section provides an overview of the overall implementation process for NBS, details the co-benefits assessment process, and provides frameworks to support decision makers through each portion of the process. Case studies are included in this section to emphasize key concepts and ideas.

3.1 Project Phases for Implementing NBS

A typical framework for the development of a NBS project encompasses five main phases: scoping, planning, design, implementation, and operations (Figure 3) (Bridges et al., 2021, 209). In conventional (i.e., gray) FrM projects, co-benefits are often identified in the later stages of the project, if at all, and are frequently considered an afterthought or a beneficial by-product of the main objective. In contrast, co-benefits are an essential component of NBS and should be considered during all phases of the project.

Figure 3. Framework for development of a NBS project



Source: Adapted from Bridges et al. 2021, 209

During the Scoping Phase of the project, a broad range of FrM goals and co-benefits should be identified. Identification of co-benefits at this stage should involve a diverse assembly of interested individuals and groups, including stakeholders, public and private groups, and decision makers (Bridges et al., 2021, 62) (described in Section 3.3). Relying on a single organization or small group of individuals may unintentionally promote specific project objectives while ignoring other important potential project goals. Stakeholders may also be able to provide support or funding during future phases of the project.

During the Planning and Design Phases of the project, potential co-benefits should be frequently re-evaluated to reflect changes in planning or design (as will be described below in Section 3.4). Co-benefits should be compared to understand project trade-offs in relation to the overall project objectives (will be described in Section 3.5).

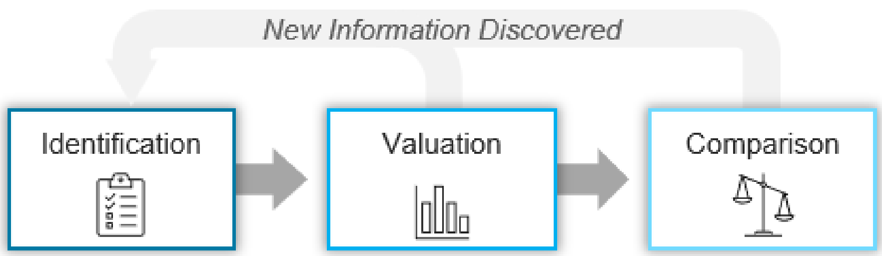
During the Implementation Phase, the project should be constructed such that FrM benefits and co-benefits are realized. Post-construction monitoring may provide early confirmation that co-benefits are being realized, as described in the associated guidance document: *Monitoring Efficacy: Proposed Methodology and Indicators.*

During the Operations Phase, co-benefits should be monitored and assessed. If the project is not achieving the required FrM benefits and co-benefits, adaptive management should be undertaken as described in *Monitoring Efficacy: Proposed Methodology and Indicators.*

3.2 Co-Benefits Assessment Process

The typical co-benefits assessment process follows three iterative stages: (1) identification, (2) valuation, and (3) comparison (Figure 4). It should begin during the early phases of a NBS project and be reassessed at various phases of the project life cycle, as was discussed above in Section 3.1.

Figure 4. Conceptual framework for co-benefit assessment



Identification of co-benefits involves understanding the ‘big picture’ of a NBS project and the adjacent environmental, social and economic context in which the project exists. Identification involves engaging with stakeholders, government agencies, Indigenous Peoples, identifying key experts, and thinking broadly about the challenges and opportunities that may exist both locally and more regionally. The process for identifying co-benefits is described further in Section 3.3.

Valuation is the process of determining the potential value of a given co-benefit. The term ‘value’ is sometimes used synonymously with ‘economic benefit,’ which may be the case when examining economic co-benefits; however, value may also be provided through non-economic means, via other services provided to society or the environment (see Case Study 2). Valuation methods will vary depending on resource limitations (including funding, schedule, and expertise constraints), and may involve both qualitative and quantitative techniques. The process for valuing co-benefits is described further in Section 3.4.

Comparison involves assessing trade-offs and prioritizing certain co-benefits to support decision-making and design. Co-benefits associated with different design options may also be compared to support selection of a preferred alternative. The process for comparing co-benefits is described further in Section 3.5.

Case Study 2. San Francisco Bay Sea Level Rise Adaptation Framework

San Francisco Bay Sea Level Rise Adaptation Framework: Identifying and valuing co-benefits of NBS projects

San Francisco, California
United States

Point Blue Conservation Science (PBCS), the San Francisco Estuary Institute, and the County of Marin collaboratively produced the *Sea Level Rise Adaptation Framework* in 2019. The goal of the Adaptation Framework was to "enable planners and other coastal decision makers to identify, evaluate, and prioritize adaptation strategies" to manage coastal flood and erosion risk in the San Francisco Bay area "in a way that transparently considers multiple benefits" (PBCS et al., 2019).

Extensive consultation and engagement were carried out with key stakeholders to identify benefits, trade-offs and NBS options. The framework was then used to assess a suite of NBS options across the San Francisco Bay area. The assessment was carried out on an Operational Landscape Unit scale and considered the value of a range of co-benefits associated with the different NBS options (PBCS et al., 2019).

These included:

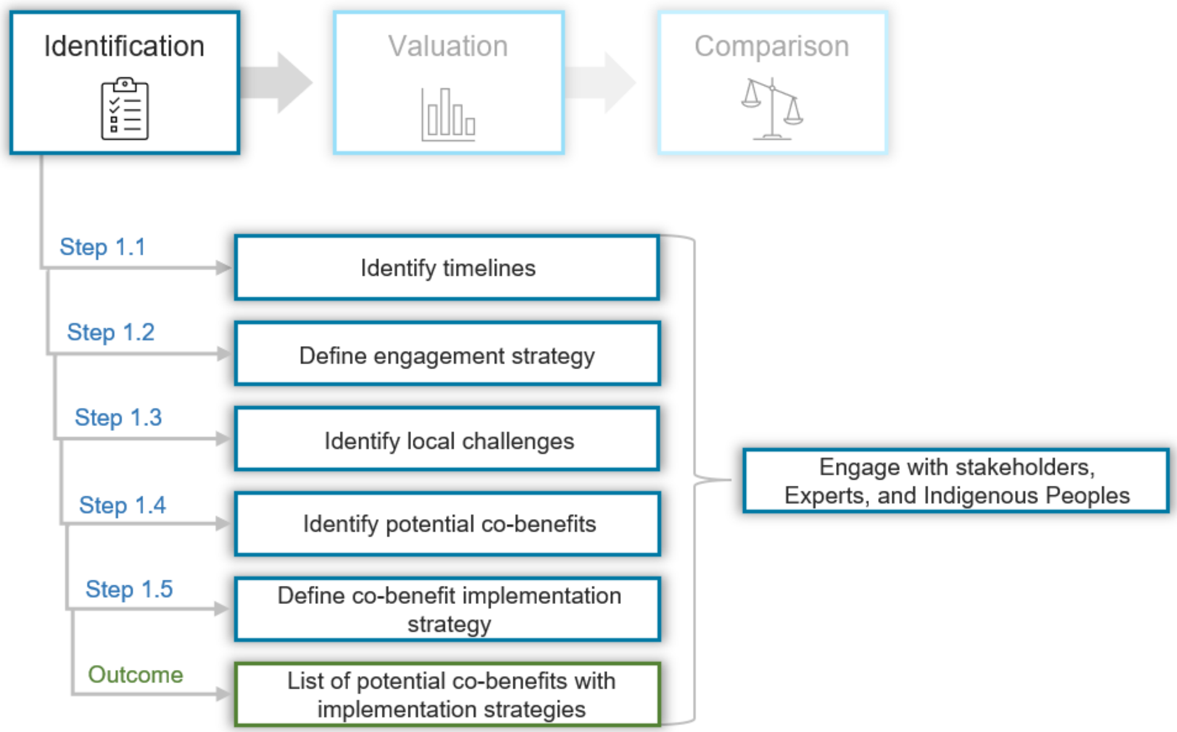
Regulating services: reduction in erosion, storm surge, flooding, carbon sequestration, water filtration and pest and disease regulation;
Supporting services: biodiversity support and nutrient cycling;
Cultural and social services: recreation and tourism, education, aesthetics, spiritual and religious, cultural heritage and services to disadvantaged communities; and
Provisioning services: food and raw materials (PBCS et al., 2019).

When the co-benefits of different NBS options are evaluated, a dollar value was not always assigned. Instead, benefits from each NBS option being considered were assessed based on the scale of the benefit. For example, the length of a new trail network associated with each NBS option was compared, rather than a value for the increased recreational capacity from the trail network. The increase in restored marsh area was also used as a metric, rather than attempting to quantify the value of the marsh (PBCS et al., 2019).

3.3 Identification of Co-Benefits

Identifying potential co-benefits allows the project team to fully understand the project's potential impacts and establish the ability for more applicable solutions that can address multiple needs (Bridges et al., 2021, 108). Impact refers to 'having a strong effect,' which includes positive (i.e., benefits or synergies) and negative outcomes (i.e., costs or trade-offs). As part of the identification process, it is critically important to cast a wide net to avoid restricting potential co-benefits at an early stage (which may cause unintended limits on the potential for incorporating other co-benefits as the project progresses). It is also important to acknowledge that even though this report has categorized co-benefits as environmental, social or economic (as per Section 2), co-benefits are often intra- and interconnected, and the systems they impact are dynamic and ever-changing. Involving a broad range of stakeholders, Indigenous Peoples and experts in the identification process helps to ensure that these requirements are met. Figure 5 outlines an approach for identifying co-benefits that incorporates these concepts; however, it is important to recognize that every NBS is unique and varies greatly, depending on location, local climate projections, temporal and spatial variability, resources, NBS project type, project scale, and site-specific needs. The assessment process should therefore be used as a guideline and modifications to the process may be made to meet overall project objectives (PBCS, 2019, 32).

Figure 5. Conceptual framework for co-benefit identification



3.3.1 Step 1.1: Identify Timelines

The overall project timeline should be well understood before assessing co-benefits and engaging stakeholders. A well thought-out timeline for the project (including individual phases) may allocate the appropriate amount of time and effort for assessing co-benefits. Understanding the overall project timeline will support later phases of the co-benefits assessment process (see Section 3.4). In addition, ensuring the project timeline aligns with local policy and regulation requirements, as well as funding agreements, will help prevent overall delays.

3.3.2 Step 1.2: Define Engagement Strategy

An engagement strategy should be developed early in the Identification stage. It is vital that the strategy consider which stakeholders should be engaged, when, with what frequency and how engagement should be implemented. Engagement should be accessible, inclusive, equitable and meaningful to achieve optimal results (IDB and Acclimatise, 2020). Stakeholder engagement should also continue throughout the Valuation and Comparison stages of the co-benefits assessment process, helping to assess and reassess the needs of the community, environment and economy (Shiao et al., 2020, 38). Engagement strategies are discussed in detail in Chapter 3 of the *International Guidelines on Natural and Nature-based Features for Flood Risk Management,* USACE (Dillard et al., 2021).

To successfully identify all potential co-benefits and define how they may best be achieved, it is important to engage a diverse group of stakeholders. Stakeholder motivations for engaging in the project may vary based on their geographic location, historical context, economic sector, and environmental, social and economic priorities and challenges (Shiao et al., 2020, 14). A broad group of stakeholders will therefore bring different goals, interests and viewpoints to the project (Bridges et al., 2021, 715). Considerations for who should be included in the engagement process is discussed further in Section 3.3.6. Below are some useful questions to ask potential stakeholders to help understand their needs, goals and intentions (Brill et al., 2021).

- What type of NBS are most applicable to you/your business and at what geographic scale?
- How do your goals and skills align with the proposed project?
- What challenges do you see in the community (economic, social, environmental)?
- What type of NBS would benefit you/your business most?
- Are there other synergistic opportunities?
- What amount of time can you commit to the project?
- Are you interested in contributing to the funding of the project?

3.3.3 Step 1.3: Identify Local Challenges

Informed by the engagement process, the project team should identify the environmental, social and economic challenges that exist for the specific project location. Challenges may vary drastically depending on geography, environmental conditions, social needs, government structure and legislation, and other pre-existing issues. Table 5 provides examples (non-exclusive) of challenges that may be identified for the project locality.

Table 5. Examples of flood risk, environmental, social, and economic challenges

Flood Risk	Environmental	Social	Economic
Erosion or sedimentation	Water quality/ supply/storage	Lack of public education	Poverty and lack of affordable housing
Natural disasters	Air quality	Noise pollution	High taxes
Sea-level rise	Soil fertility/health	Light pollution	High energy costs
	Climate change	Human physical health	Low property value
	Carbon sequestration	Human mental health	Low tourism
	Habitat health/loss	Lack of outdoor space	High unemployment
	Biodiversity loss/density	Lack of recreational space	Low agriculture production
	Environmental regulations	Lack of sustainable urbanization	Minimal urban development

3.3.4 Step 1.4: Identify Potential Co-Benefits

During this step, the project team should develop an extensive list of potential co-benefits that could be included in the NBS project. At this stage, the list of potential co-benefits should be broad, and the project team should not seek to narrow the potential co-benefits by imposing project limitations. This list of theoretically possible co-benefits should be informed by feedback obtained through the engagement process and the location-specific challenges. Identified co-benefits should aim to mitigate known challenges and reflect the needs of the community. It may also be helpful to categorize each identified co-benefit as environmental, social, or economic to ensure that all challenges and needs are considered.

3.3.5 Step 1.5: Define Co-Benefits Implementation Strategy

As a last step in the Identification stage of the co-benefits assessment, the project team should identify a project implementation strategy to achieve the identified co-benefits. The implementation strategy should define key actions or features necessary to realize each co-benefit. Questions to consider during this process are listed below.

- What type of solution is being considered?
- What design features or actions could be included to achieve each co-benefit?
- Will any of the design features or actions negatively impact another co-benefit (i.e., cause trade-offs)?
- What are the schedule, funding, and resource limitations related to the design feature or action?
- Given the limitations, is it feasible to include the necessary design features or actions to achieve the co-benefit?
- Given the project goals and stakeholder needs, is it important to include the co-benefit?

During the scoping and planning phases of the project (as defined in Figure 3), the implementation strategy will be highly conceptual in nature. At this stage, each identified co-benefit should be associated with a design feature or action. The design team may narrow down the broad list of potential co-benefits to include only those which are reasonable to achieve or of significant importance considering the project goals and stakeholder needs, thereby allowing the project to remain on schedule and within budget. Co-benefits that are of little value and/or are not feasible to be achieved through the project should be removed. This is a critical step in determining the prioritization of project-specific co-benefits, which is covered in detail in Step 3.2 (see Section 3.5.2.). During the early phases of a project, the project team may be reviewing more than one FrM option; in this case, a co-benefit implementation strategy should be developed for each option under review, and the assessment process should be followed through to the last step of the Comparison stage (see Section 3.5.3).

As the project advances and the NBS design and overall implementation strategy is better defined, the co-benefit identification process should be revisited to ensure that all potential co-benefits have been identified. The design feature(s) or action(s) required to achieve each co-benefit should also become better defined, with less uncertainty. An example of how a co-benefit identification and implementation strategy can evolve as new information is made available is provided in Figure 6.

Figure 6. Hypothetical example of a co-benefit implementation strategy evolution as project phases progress from early (scoping and planning) to late (design and implementation) stage

Challenge	Target / Potential Co-Benefits	Design Features or Actions
Little public space near the shoreline	Increased public green-space Improved access to the foreshore	Commit to purchasing land to develop park space Incorporate pathways and seating into design Plant native vegetation for greenery Incorporate mild slopes that facilitate shoreline access

Early Stage
(Scoping and Planning)

Late Stage
(Design and Implementation)

Challenge	Target / Potential Co-Benefits	Design Features or Actions
Little public space near the shoreline	Increased public green-space ~~Improved access to the foreshore~~ Terrestrial habitat availability Abundance and diversity of native plant species	**2.0 Ha** of land purchased and dedicated to park space **2 km** of multi-use pathways **30% area** to be populated with a mix of native vegetation **Habitat area to be delineated** with fencing and signage to be provided

Description:
In this example, two potential co-benefits were identified in the early (scoping and planning) stages of the project. Four different, high-level design features were considered.
As the project progressed into later (design and implementation) stages, one of the potential co-benefits was de-listed since it was not deemed to be feasible given project constraints and stakeholder needs. However, two additional co-benefits were identified. Design features associated with all three remaining co-benefits were better defined.

3.3.6 Considerations for Who Should be Involved

Every NBS initiative is expected to require a project-specific group of individuals and organizations to inform the overall project direction. Important stakeholders and organizations to include in the co-benefits assessment process may include affected landowners/community members, Indigenous leaders, local community groups, non-profits, government representatives, the academic community, and industry members. Several notable organizations, professionals, and stakeholders to involve are discussed in this section.

Indigenous knowledge provides a highly valuable perspective, not only for NBS and co-benefit identification, but also for identifying potential FrM solutions (Ibrahim, 2016). Indigenous wisdom and knowledge have been built up and passed down for generations by people who have lived in close contact with the land and understand these dynamic systems in a holistic way (Government of Canada, 2020). Indigenous knowledge provides important information related to social, cultural, economic, health, and biophysical issues. It also helps to inform an understanding of governance, traditional laws, values, customs, and traditional uses of local resources (see Case Study 3).

National and local government and public agencies are examples of policy stakeholders. It is imperative to follow local, regional, and national requirements (e.g., permits and approvals) for a given project, and failure to do so may lead to unnecessary complications and delays, or potentially to project termination (IDB and Acclimatise, 2020). The policy and program stakeholders are often tasked with making decisions for multiple projects simultaneously and may be able to help align the project with similar ones to minimize costs and maximize potential co-benefits (e.g., biodiversity initiatives, urban regeneration, etc.). Notably, changes in government administration or policies may impact the feasibility, cost, and schedule of the NBS. The timeline of the NBS project should therefore be considered in relation to elections (IDB and Acclimatise, 2020).

Community-level stakeholders may include community members, landowners, NGOs, and local business. These groups include individuals that may be directly impacted by the NBS project. Involving the community, either through public workshops/education or by direct involvement in the project implementation, can create a sense of teamwork, ownership, and public buy-in.

Academics, scientists and technical experts are an additional group of valuable individuals who can provide input on data and methodologies and offer guidance and advice for identifying co-benefits (Bridges et al., 2021, 725). Finding experts for a project (who may span a broad range of fields of practice) can often prove difficult. Universities, research institutions, or professional communities of practice are often a good place to begin the search for experts, either locally, nationally or internationally.

Case Study 3. Portage Park beach nourishment, British Columbia, Canada

Portage Park beach nourishment: Partnership between municipal government, provincial government, and First Nations.

View Royal, British Columbia, Canada

Portage Park is a public park located in the municipality of View Royal, west of Victoria on Vancouver Island in British Columbia. Following storms in 2006 and 2007, Portage Park suffered coastal erosion and damage. The shell midden in the park, which is culturally and archaeologically important to the local First Nations, was also damaged during the storms (Eyquem, 2021).

Recognizing that coastal hazards and damage to the park and midden would increase with sea-level rise, the municipality of View Royal partnered with the Province of British Columbia and with the Esquimalt and Songhees First Nations, to find a solution to protect the park from coastal hazards (Province of British Columbia, 2007).

Desirable outcomes were established between stakeholders, which identified co-benefits of the coastal defense project. The outcomes identified included: protecting the culturally sensitive shell midden, protecting and improving the intertidal habitat, maintaining public access, and maintaining supply of material to the beach, all while considering maintenance needs and aesthetics (Eyquem, 2021).

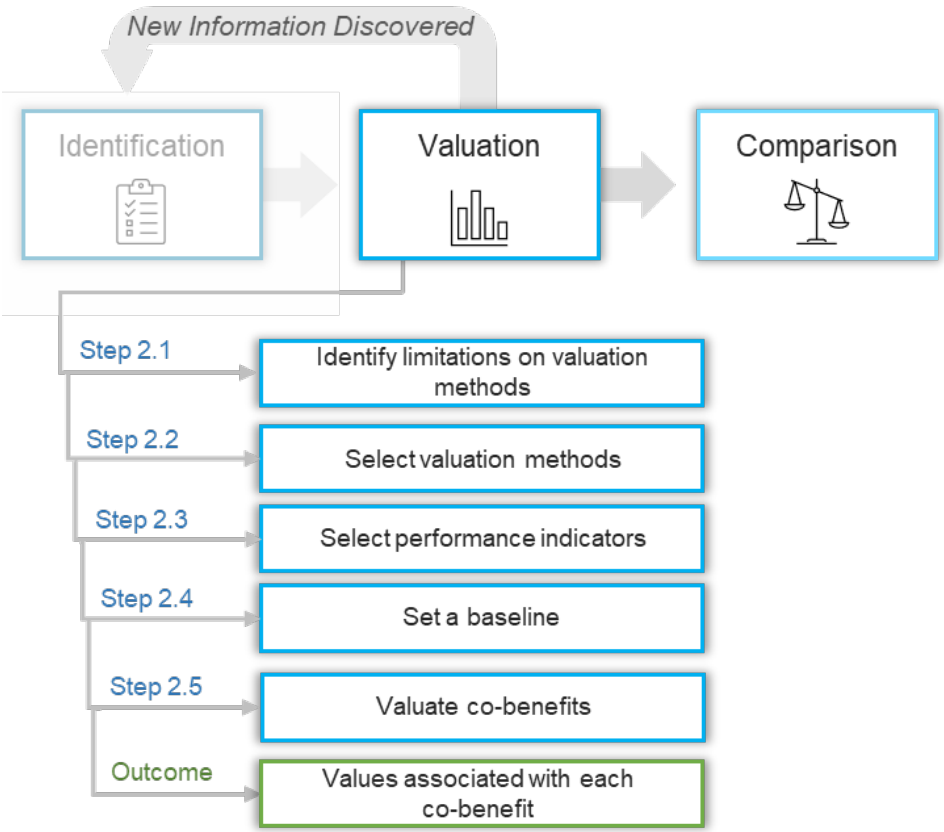
Options including a log crib wall, seawall, rip rap and beach nourishment were considered and ranked based on the desirable outcomes (Eyquem, 2021). Beach nourishment was chosen as the option to be implemented, as it was the highest ranked in the desirable outcomes analysis and the least expensive option (Eyquem, 2021). Since the beach nourishment project was completed, there has been no erosion observed. The midden, access to the beach and intertidal habitat have all been protected and maintained, meeting the needs of both the local municipality and the First Nations.

3.4 Valuation of Co-Benefits

The second stage of the assessment framework involves valuating—or assigning value to—the co-benefits identified in the first stage. The term ‘value’ is often associated with a monetary measure; however, in this report, valuation refers to the process of quantifying the importance, worth, usefulness and/or monetary value of a given co-benefit, which may be assessed using either qualitative or quantitative metrics.

Figure 7 outlines a generalized approach for valuating the potential co-benefits provided by the NBS project. As with the Identification stage, the valuation process will be project-specific and may vary, depending on specific project needs.

Figure 7. Conceptual framework for co-benefit valuation



3.4.1 Step 2.1: Identify Limitations on Valuation Methods

The first step in the Valuation process involves identifying limitations that will constrain the type of valuation methods that may be used. Limitations generally fall into four resource categories:

- Information/data;
- Funding;
- Schedule/time; and
- Expertise/knowledge/methods.

These four items are the foundational resources needed to undertake co-benefit valuation. Limitations on these resources will help inform which methodologies are possible. These four foundational elements are discussed further below.

Data availability will indeed limit the types of valuation methods that can be completed. Particularly during early project phases, the project may be only vaguely defined and data availability is typically limited. As such, it is generally applicable during these early phases to rely on historical and readily available data and existing case studies to inform the potential value/impact of co-benefits. At later stages, data collection and monitoring campaigns can be planned and undertaken to obtain information on key performance indicators, as described in the associated guidance document *Monitoring Efficacy: Proposed Methodology and Indicators.*

Funding limitations will impose constraints on both the valuation methodologies used and the implementation strategies aimed at realizing co-benefits. It is important to develop a funding strategy at an early stage, and to allocate budget for co-benefit valuation and related monitoring initiatives to collect necessary data. During these early stages of project implementation, it is generally applicable to rely upon simple qualitative methods that may be completed quickly, with little expertise and minimal budget, such that the project team can establish a first, rough estimate of the potential magnitude and types of co-benefits provided by the NBS. Besides funding a project through grants, stakeholders and businesses may be motivated to contribute funds if they know they will maximize their investments through provision of co-benefits (Brill et al., 2021). This first, rough valuation of co-benefits therefore provides critical information to help establish funding sources and begin other project activities. When additional funding is available at a later stage, alternative and more rigorous valuation methods may be considered, as described in Step 2.2 (see Section 3.4.2).

Schedule/time limitations impose significant constraints for both the collection of data and its assessment to inform the valuation. Having a robust understanding of the project timeline, hazard rate, time requirements for different valuation methods, as well as the time necessary to successfully implement and monitor co-benefit performance, will allow for appropriate resource allocation. Notably, the overall project schedule and time allowance for co-benefit valuation will be heavily influenced by the nature of the flood risk hazard. For example, emergency projects will require that the initial project phases be implemented quickly, leaving little time for data collection and assessment of co-benefits. In this case, an initial, quick assessment may be completed, with more rigorous data collection and analysis reserved for the operational phase of the project. Understanding schedule limitations and time requirements for different valuation methods (i.e., field survey compared to observational analysis) is vital to choosing an appropriate valuation method. Further, environmental, economic and social systems will evolve and adapt at different rates to hazards and other events. Monitoring and adaptive management plans should therefore be developed to accommodate the assessment of both short-term and long-term co-benefit outcomes. In the long-term, for instance, the value and outcomes of co-benefits may be impacted by shifting baselines in the environment as a result of climate change. Incorporating predictions of future conditions under different scenarios (e.g., varying sea-level rise projections) into the valuation of co-benefits may provide a way to capture the long-term value of various project options more accurately. Considerations related to the temporal scale of monitoring activities are summarized in the associated guidance document *Monitoring Efficacy.*

The level of expertise and knowledge available is another important limiting factor in the choice of valuation methodology for co-benefits. Co-benefits are diverse and cover a broad range of topics (e.g., flood levels, property values, tourism) spanning environmental, social, and economic fields of practice. It can be difficult to find local, available experts knowledgeable on all identified co-benefits, particularly within the given schedule/budgetary constraints. Due to logistical constraints, experts are often integrated into the project team only after the initial scoping phase of the project is complete. It is therefore generally necessary to undertake valuations during the early project phases where there will be significant expertise limitations in several areas. This allows the project team to establish a first, rough estimate of the potential magnitude and types of co-benefits provided by the NBS. In later phases, robust knowledge related to each co-benefit is highly valuable and expert advisors should be utilized to their fullest potential. The goal of including experts in the project is to create an effective group, which can provide a suitable level of knowledge and guidance, given project-specific needs.

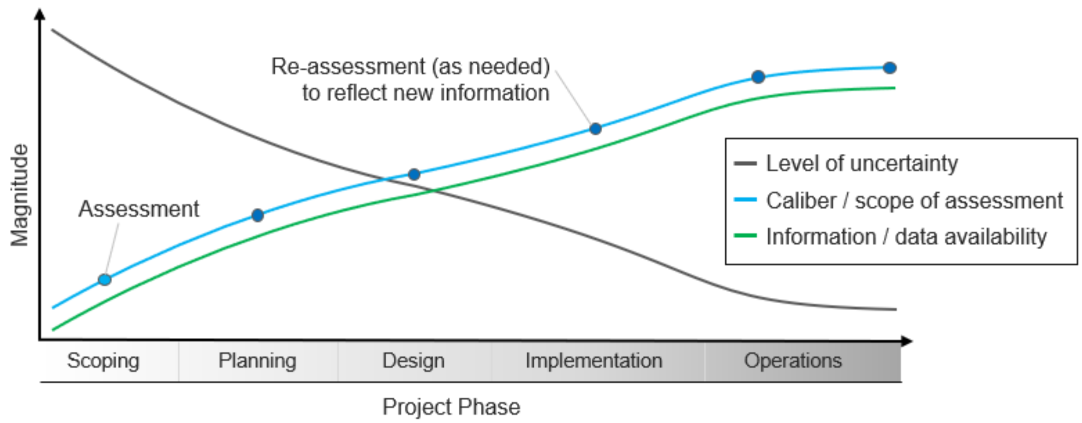
However, adding experts to the team may also add unnecessary expense or create management difficulties. When there is a gap in knowledge, additional time or funding may be needed in order to achieve optimal results. Alternatively, the project team may consider using alternative valuation methods (that require less expertise) and clearly defining the level of uncertainty involved in the analysis to account for the lack of knowledge.

3.4.2 Step 2.2: Select Valuation Methods

The second step in the process involves selecting appropriate valuation methods for each identified co-benefit. Numerous potential valuation methods exist for the same co-benefit, including qualitative and quantitative methods. However, different valuation methods may result in significantly different outputs and levels of uncertainty and require significantly different resources to implement (Raymond et al., 2017). Quantitative valuation methods (e.g., numerical modeling, economic analysis, statistical analysis) are often preferred to qualitative methods (e.g., workshops, canvassing, case studies)—particularly for environmental and economic co-benefits—as they typically have well defined methodologies and result in clear outcomes with less uncertainty. Consideration should be given for valuation methods that may be used to valuate multiple co-benefits, to allow for reduced valuation costs and ease of co-benefit comparison and prioritization (see Section 3.5). However, if only one method is applied to all co-benefits (e.g., only cost-benefit analysis), it may result in de-valuing co-benefits with less tangible outcomes (e.g., intrinsic values). To compare different FrM options, special consideration should also be given to valuation methods and indicators that may be used for the same co-benefit on all FrM options being considered (i.e., are universal). Utilizing indicators and methods that can be replicated is vital for monitoring co-benefit evolution and for comparing outcomes of NBS projects (see the associated guidance document: *Monitoring Efficacy*). Types of valuation methods (i.e., measurement and monitoring methods) are summarized in Section 4.

Selection of valuation methods for each co-benefit should depend upon identified limitations (see Step 2.1, Section 3.4.1) as well as the overall project phase. Early in the project implementation (i.e., during scoping and planning stages), the NBS will be poorly defined and numerous limitations will exist such as data availability, schedule, budget and expertise. As such, it is generally applicable during these early phases to rely upon simple qualitative methods that may be undertaken quickly, with little expertise, and minimal budget. The caliber/scope of the valuation methods may be increased as additional information and other resources become available at later stages of the project (see Figure 8). Federal funding or other funding may promote the use of cost-benefit analysis. If so, consideration should be given for valuation methods that can inform this type of later analysis. Increasing the caliber of the valuation methods as the project evolves helps to optimize resources throughout the project life cycle while also reducing uncertainty as the project progresses.

Figure 8. Conceptual model showing the iterative assessment process



Note: The caliber and scope of the co-benefits assessment should be expected to increase as the project progresses and new information is obtained.

3.4.3 Step 2.3: Select Performance Indicators

As a next step, it is necessary to select performance indicator(s) for each co-benefit. Performance indicators are a unit of measurement by which benefits and trade-offs can be estimated. Selection of appropriate performance indicators should consider the type of co-benefit, the valuation method, data availability, resource limitations, and the spatial and temporal scale of the project (Brill et al., 2021). Examples of potential performance indicators and valuation methods for co-benefits are provided in Figure 9. Additional information on performance indicators can be found in the associated guidance document: *Monitoring Efficacy: Proposed Methodology and Indicators.*

Figure 9. Hypothetical example of co-benefits, potential indicators, potential valuation methods, and baseline conditions

Co-Benefits	Indicator	Valuation Method (Early Stage)	Valuation Method (Late Stage)	Baseline
Increased public green-space	Area (ha) of publicly accessible space within natural setting	Desktop design (estimate)	Technical analysis using satellite imagery	Existing area within project footprint
Terrestrial habitat availability	Area (ha) populated with terrestrial vegetation, with no public access	Desktop design (estimate)	Field survey using remote sensing technologies	Existing area within project footprint
Increased land/property value	Annual property assessment ($)	Case study assessment	Review of publicly available data	Existing average property assessment value within floodplain

Description:
In this example, three potential co-benefits and performance indicators are identified. In the early (scoping and planning) stages of the project the proposed valuation methods are low-effort desktop estimates and case study assessments. As the project progresses into later (design and implementation) stages, more sophisticated valuation methods are required, which will provide a greater degree of certainty, but require additional effort to complete.

3.4.4 Step 2.4: Set a Baseline

Establishing baseline conditions is an important step in understanding the magnitude of change caused by a project, helping to facilitate options analysis, design changes, or adaptive management. By establishing baseline conditions, the relative impacts for each co-benefit may be assessed, whether they are negative or positive compared to the baseline. Case Study 4 provides an example of establishing baseline conditions before the project begins, which informs adaptive management and allows for co-benefits to be realized.

Baseline conditions are generally set at two major milestones (Bridges et al., 2021):

- Prior to construction (existing/historical baseline): To understand how performance indicators have changed in response to project implementation, and thereby the magnitude of co-benefits provided.
- Following construction (modified baseline): To inform adaptive management and ensure performance metrics are met.

Baseline data should be established for each indicator, such that the relative magnitude of each co-benefit is captured over time (as indicated in Figure 9). It is worth noting that in the long term, baseline environmental conditions may shift as a result of climate change. Maintaining awareness of long-term changes to baseline conditions (for example, sea-level rise) as they are predicted and as they occur is important to informing a long-term adaptive approach to the management and monitoring of the project, as well as to how co-benefits are measured, monitored, and understood. Administration of baseline data, such as where they are archived, and who owns them (and is responsible for them), is discussed in the associated guidance document *Monitoring Efficacy.*

Case Study 4. New Brighton Park restoration

New Brighton Park Shoreline Habitat Restoration Project:
Setting a baseline

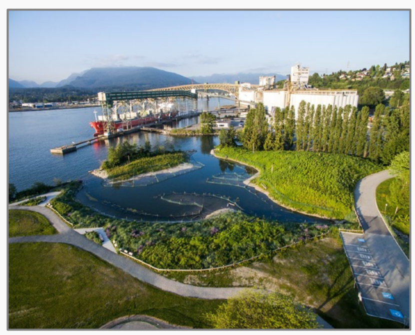
Vancouver,
British Columbia, Canada

New Brighton Park is a coastal public park in Vancouver, British Columbia. In 2017, the Vancouver Fraser Port Authority, Vancouver Board of Parks and Recreation, and the Musqueam, Squamish and Tsleil-Waututh Nations (Port of Vancouver, 2018) completed a tidal marsh wetland and island restoration project at the park. The wetland restoration was intended to improve habitat for juvenile salmon, increase public access to nature (Port of Vancouver, 2018), and address issues, both of coastal flooding and of flooding from storm water overflow, in order to reduce coastal erosion (Eyquem, 2021). The project received Green Shores Gold Certification through the Stewardship Centre of British Columbia (SCBC, 2020).

In 2015, before the project was constructed, a comprehensive assessment was completed at the site, to establish a baseline of the existing habitat and the ecology of the site (Davis et al., 2015). This involved a range of site surveys, including backshore, intertidal, subtidal and terrestrial vegetation surveys. Other sources of information were also used to complement the field surveys and establish the biophysical conditions at the site, including a desk study of habitat and species inventories, and aerial photographs provided by the Port of Vancouver (Davis et al., 2015). The marsh restoration was completed in 2017 and an annual monitoring program was begun in 2018.

Establishing a baseline and a regular monitoring program has helped identify the co-benefits that were realized from the project, such as increased biodiversity, the presence of juvenile salmon, and improved wetland habitat (Port of Vancouver, 2018). Monitoring has also informed adaptive management of the site, identifying the need for supplemental planting and irrigation in certain areas and fencing to prevent Canada Geese from grazing on the salt marsh plantings (Eyquem, 2021).

Figure 10. Restored salt marsh wetland at New Brighton Park



Source: Port of Vancouver, 2018

3.4.5 Step 2.5: Valuate Co-Benefits

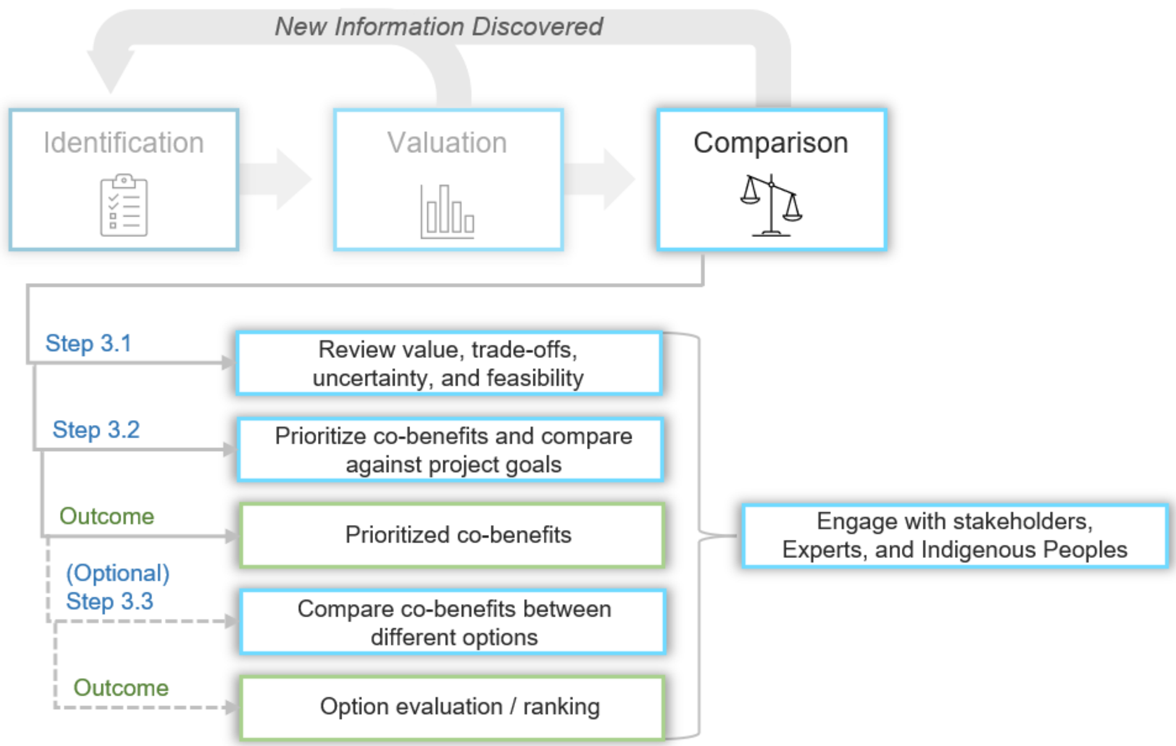
The last step involves applying the identified methodology (from Step 2.2, Section 3.4.2) and valuing each co-benefit. An important part of this process is collecting necessary data to inform the valuation. Depending on the type of valuation method, data may be compiled from various sources (e.g., from historical surveys) or collected directly for the assessment (e.g., through surveying initiatives).

The outcome of the Valuation stage should be a refined list of potential and feasible co-benefits with associated value. Notably, this process may result in negative valuations (i.e., costs), which are equally important to determine as positive valuations (i.e., benefits). Negative valuations may be addressed through design modifications or adaptive management practices. Refer to the associated *Monitoring Efficacy* guidance document for information on adaptive management.

3.5 Comparison of Co-Benefits to Support Decision-Making

The final step in the assessment framework is Comparison of co-benefits. At this stage, the potential co-benefits are prioritized based on the project goals, stakeholder goals, feasibility, uncertainty, benefits and trade-offs, budget, schedule, and expertise limitations. Figure 11 provides an approach for comparing and prioritizing potential co-benefits provided by the NBS project.

Figure 11. Conceptual framework for co-benefit comparison



3.5.1 Step 3.1: Review Value, Trade-Offs, Uncertainty, and Feasibility

As a first step in the process, the value (or benefits), trade-offs and potential compromises associated with planning, designing for, and realizing specific co-benefits need to be determined and discussed with the project team, including all stakeholders. When comparing and prioritizing co-benefits, it is important to recognize where trade-offs exist and compromises are possible. Trade-offs are negative environmental, social or economic effects that result when two benefits cannot be achieved or optimized within the same design (for example, the trade-off between tourism revenue and environmental protection, see Case study 5) (Diringer et al., 2020). If the same co-benefit is being favored regularly (when setting priorities in Step 3.2, Section 3.5.2), it can create sub-optimal levels for the neglected co-benefits (Brill et al., 2021, 49). Trade-off preferences can also lead to issues if specific stakeholders or marginalized groups are regularly excluded from receiving the benefits of NBS or co-benefits (Brill et al., 2021, 50). Trade-offs and benefits can then be managed successfully once their outcomes are properly assessed, fully divulged, and agreed upon by project stakeholders, experts, and Indigenous Peoples (Brill et al., 2021, 50).

While analyzing the benefits and trade-offs, uncertainty should also be considered. Uncertainty is the result of imperfect information and knowledge gaps; and in the context of FrM, it is generally related to natural system variability and limitations in knowledge (Bridges et al., 2021, 26). The future impacts of climate change on coastal environments, including sea-level rise and changes to the frequency and severity of storm events will also introduce uncertainty. Many aspects of future environmental, social and economic conditions are not controllable and developing uncertainty scenarios informed by predictions of future changes can provide insight into potential outcomes (Diringer et al., 2020, 28). Additional research and monitoring can also reduce the level of uncertainty, although it cannot be eliminated completely (Cado van der Lely et al., 2021, 11). A monitoring and adaptive management plan should be in place to help with the level of uncertainty that can arise during implementation, post-construction, and during operation of the NBS (Diringer et al., 2020, 28; Cado van der Lely et al., 2021, 12). Monitoring methodology is discussed in detail in the associated guidance document *Monitoring Efficacy: Proposed Methodology and Indicators.*

The level of uncertainty and various project constraints (including design and funding limitations) will help determine the feasibility of proposed co-benefits. Ideally, the potential impact provided by a co-benefit would be commensurate with the level of resources required to realize the co-benefit. If the number of resources required to achieve a specific co-benefit or the level of uncertainty around achieving the co-benefit are too high, it may be determined that the co-benefit is not feasible. For example, land use and permitting requirements often impose significant constraints on projects such that achieving co-benefits on a large scale is not feasible.

Case Study 5. Mayakoba coastal development

Mayakoba coastal development:
Balancing the benefits of NBS against the benefits of development

Playa del Carmen, Quintana Roo, Mexico

The Mexican Caribbean coast has the most hotels in Mexico, being the prime coastal tourist destination of the country. As a result of hotel development, the Mexican Caribbean has also suffered the most considerable degree of coastal squeeze in Mexico (Lithgow et al., 2019), which in turn has a negative impact on the main attraction to the area: its pristine beaches.

In response to the environmental degradation in the area, the Mayakoba resort was planned as an alternative to the standard tourism development of the area, with a trade-off between tourism revenue from conventional high-density development and environmental protection. The resort, comprised of 13 hotels, a golf course, recreational areas, beach clubs, and real estate development, was planned around the conservation and recovery of its mangroves, dunes, and tropical forest to promote sustainability, preserve the beaches, and increase resilience to coastal hazards.

Hotels and large infrastructure were not permitted within 600 m of the beach (Zárate-Lomelí et al., 2013), to mitigate coastal squeeze and promote the preservation of coastal dunes. The project also included the construction of artificial channels to restore the degraded mangrove ecosystem. The golf course is irrigated by treated wastewater, which drains into these channels, along with fertilizer runoff, which is absorbed and regulated by the mangrove system.

An environmental monitoring program has been implemented to assess the impacts of the development, providing a measure of success of the project. There has been a significant recovery of biodiversity and species populations observed since the development was completed (Cruz et al., 2020). The development now acts as a natural reserve and habitat for over 300 vertebrate species. The project contributes to sustainable economic growth with a business model based on sustainability and empowering local communities and producers. As a result, it has received several awards for sustainable development (UNWTO, 2018). Although the density of the tourist development is lower than conventional developments in the area, one night at a Mayakoba resort is significantly more expensive than at a conventional hotel development.

3.5.2 Step 3.2: Prioritize Co-Benefits and Compare Against Project Goals

Co-benefits should be listed and prioritized in consideration of their ability to meet project goals and community needs, the magnitude of their impacts (i.e., positive and negative), trade-offs, feasibility, and uncertainty. Co-benefits, which can be achieved feasibly and legally through the design and implementation process, should be prioritized. Several different sets of prioritizations should be considered to determine which prioritization is most suitable for the project. Prioritizations should be compared against overall project objectives and stakeholder needs. If any stakeholder or project goals are not expected to be met, the team should evaluate if a different set of prioritizations would better meet project needs, and—if they cannot be met due to project constraints—this should be communicated with the project team, including all stakeholders.

It is important to emphasize that numerous potential and valid prioritizations could result from this stage, depending on the project and stakeholder goals. As such, it is very important to continue to engage with the project team and stakeholders and communicate how the prioritizations fit within the overall project objectives and big-picture goals. Effective communication with all stakeholder groups will ensure that the anticipated outcomes are achieved (Bridges et al., 2021, 274).

This step will result in a prioritized list of co-benefits with the value/magnitude of impact. This information will help to advise which portions of the design are fundamental and where trade-offs can be made to accommodate other project constraints. Co-benefit prioritizations may be made public to help communicate project intent and benefits. In addition, co-benefit prioritizations provide critical information for adaptive management activities, creating clear prioritizations for interventions (if required).

3.5.3 Step 3.3: Compare Co-Benefits between Different Options (Optional)

During the early (i.e., scoping and planning) phases of a project, the project team may review more than one FrM option, including gray infrastructure or a 'do nothing' option. Co-benefits may be compared using a multi-criteria analysis (MCA) between various FrM strategies to inform selection of a preferred option. A good example of MCA is provided in Ruangpan et al. 2021. It is particularly important to include co-benefits in options analyzed when comparing conventional (i.e., gray) solutions to NBS, instead of relying on monetary costing alone. Case Study 6 provides an example of the comparison of conventional (i.e., gray) intervention and a 'do nothing' approach.

When comparing options, the same list of potential co-benefits should be valuated for all options, ideally using the same valuation methodologies. This helps to avoid introducing errors and uncertainty into the valuation through different methodologies.

Prior to comparing co-benefits, a framework for assignment ratings and weight should be assigned for each co-benefit. The weight associated with each co-benefit should be larger for high priority co-benefits that best meet project goals and stakeholder needs (not necessarily the same prioritizations as in Step 3.2, Section 3.5.2). Key aspects of the rating assignment strategy include:

- Normalizing ratings to a common scale (5- or 10-point scale, for example); and
- Providing rating guidance, such that it is clearly understood how to assign ratings.

For quantitative performance indicators, ratings may be scaled directly based on the magnitude of the benefit, or a scaling function may be applied. For semi-qualitative or qualitative performance indicators, it is often appropriate to assign a rating based on qualitative descriptors of the magnitude of the benefit. **It is often useful and even necessary to engage stakeholders or experts to provide input on both weightings and rating allocation.** This may be easily achieved through surveys or polling. An example of a potential comparison framework is provided in Figure 12, showing a rating assignment strategy and weighting scheme. A template-rating framework to facilitate comparison of co-benefits for multiple FrM options (similar to Figure 12) is provided in the Appendix for ease of use. Bridges et al., (2015) and Watkin et al., (2019) also outline methodologies for executing similar frameworks to assess and compare co-benefits of NBS.

It should be noted that capital costs, maintenance costs, and/or life cycle costs may be incorporated in the comparison as economic co-benefits. For projects where budgetary constraints are high, implementation strategies (i.e., designs) that fit within the budgetary constraints should be considered and a high weight should be placed on these co-benefits.

Figure 12. Hypothetical example of a rating assignment strategy and weighting scheme for co-benefits

Co-Benefits	Indicator	Rating	Rating guidance	Weight
Increased public green-space	Area (ha) of publicly accessible space within natural setting	5	≥10 ha, relative to baseline	20 %
		0 - 5	Scale linearly between 0 - 10 ha, relative to baseline	
		0	0 ha, relative to baseline	
Reduced life-cycle costs (100 years)	Estimated life cycle cost ($)	5	Lowest Cost	50 %
		0 - 5	Scale linearly between highest and lowest cost	
		0	Highest Cost	
Improved inclusion and equity	Feedback/sentiment of stakeholders (including marginalized groups)	5	Fair and inclusive opportunities are integrated into the design and implementation, based on local challenges and needs	30 %
		0 - 5	Scale based on feedback	
		0	Fair and inclusive opportunities are not considered in the design and implementation	
				100 %

Description:
In this example, a multi-criteria analysis is being set-up for three potential co-benefits. Performance indicators are identified for each co-benefit. Rating scales and rating guidance are established for each performance indicator. Weightings are assigned for each co-benefit.

Case Study 6. Qualicum Beach waterfront evaluation frameworks

Qualicum Beach waterfront evaluation frameworks:
Evaluating co-benefits, comparing options, and improving designs

Qualicum Beach, British Columbia, Canada

In 2016, the Town of Qualicum Beach published a *Waterfront Master Plan* (Town of Qualicum Beach, 2016). It aimed to guide future development along the waterfront in a sustainable manner, while responding to climate change related effects and aligning with community values and goals.

As part of the *Waterfront Master Plan,* two evaluation frameworks (which use MCA) were developed to help assess proposed waterfront developments in a systematic and transparent matter, and inform decision making related to their approval (Town of Qualicum Beach, 2016, 4):

- Engineering and Environmental Framework
- Community Values Framework

The Engineering and Environmental Framework included 11 criteria, which aimed to assess compatibility with coastal processes, foreshore ecological services, and technical feasibility/longevity (SNC Lavalin, 2016, 3). The Community Values Framework included seven (7) criteria, which were informed by extensive community engagement (Town of Qualicum Beach, 2016, 39). Each criterion was scored between +2 and -2, with weightings ranging between 1–12 percent (SNC Lavalin, 2016; Town of Qualicum Beach, 2016). Extensive guidance was also provided for each criterion to help instruct valuations.

Wilson et al., (2018) describe an application of the Engineering and Environmental Framework to a proposed shoreline protection project. In this example, the proposed solution (an armour rock revetment) was evaluated and compared against a 'do nothing' approach. The assessment resulted in a negative valuation for the proposed solution in comparison to the 'do nothing' approach (Figure 13). As a consequence, the design was amended (resulting in a beach nourishment) such that the project provided additional co-benefits which better aligned with the Town's priorities.

Figure 13. Example valuation for a proposed rock armour revetment against a 'do nothing' approach, which resulted in a negative evaluation

No.	Criteria Name	Score		Weighted Score	
		Armour Rock Revetment	'Do Nothing'	Armour Rock Revetment	'Do Nothing'
1a	Compatibility with Expected Sea Level Rise	-2	-2	-20	-20
1b	Flood Adaptation Effectiveness	-2	-2	-24	-24
1c	Compatibility with Coastal Processes	-1	+2	-12	+24
			Sub-Total	-36	-20
2a	Effect on Marine Riparian Vegetation	-1	0	-8	0
2b	Foreshore Habitat Supply	-1	0	-8	0
2c	Foreshore Habitat Diversity	-1	0	-8	0
2d	Marine Pollutants	0	0	0	0
2e	Cumulative Effects to the Foreshore Environment	-1	0	-5	0
			Sub-Total	-29	0
3a	Compatibility with Existing Infrastructure and Adjacent Properties	+1	-1	+11	-11
3b	Stability and Maintenance	+1	-1	+10	-10
3c	Technical Feasibility and Innovation	-1	0	-11	0
			Sub-Total	+10	-21
			Total	**-55**	**-41**

Source: Wilson et al., 2018

4 Methods for Valuating Co-Benefits

Co-benefit valuation is fundamental for the effective implementation of NBS and realization of co-benefits. Valuing co-benefits (qualitatively or quantitatively) allows for an understanding of potential benefits, the effectiveness of specific interventions, reduces uncertainty related to incomplete knowledge and unpredictable/dynamic systems, increases comparability across different NBS, informs adaptive management activities, and provides information for future learning and NBS uptake (Cado van der Lely et al., 2021, 21; Raymond et al., 2017; Schmalzbauer 2018, 15).

Co-benefit valuation relies heavily on data collection and monitoring. Planning of a data collection and monitoring program should start at the scoping stages of the project and be adapted throughout the project. The program design must be thorough and rigorous, but flexible enough to allow for adaptation throughout its lifetime and as the climate changes. It is also important for the monitoring program to be practical and economical, so that it does not become onerous to fund and/or conduct over the years (Palinkas et al., 2022). The project scale, complexity, funding opportunities, and other project particulars will therefore impact the level of effort invested in monitoring.

Data collection and monitoring activities should be incorporated throughout the entire NBS project cycle, either as a continuous process or triggered by specific events or needs (e.g., post-construction survey or data collected before and after a storm). The associated *Monitoring Efficacy* guidance document outlines four broad monitoring stages:

1. **Historical monitoring** – helps to inform scoping and project planning and may involve reliance on monitoring work completed by others prior to project conceptualization.
2. **Baseline monitoring** – establishes existing conditions, acts as a reference to monitor performance, and informs the design.
3. **Compliance monitoring** (including construction monitoring and as-built surveys) – feeds into adaptive management during construction, informs modifications to the construction process, and extends post-construction to ensure compliance and establish a starting point for performance evaluation.
4. **Operational (long-term) monitoring** – used to evaluate performance over time and inform adaptive management, evaluate project benefits and impacts, and inform future projects.

Explicitly defining baseline environmental, social and economic conditions for the project site and adjacent sites is particularly important for effective valuation of co-benefits (Diringer et al., 2020, 29). Specific performance indicators and metrics need to be defined prior to project implementation and then regularly evaluated through the entire NBS project cycle (Raymond et al., 2017). For more details on monitoring methodology and performance indicators, refer to the associated guidance document, *Monitoring Efficacy: Proposed Methodology and Indicators.*

Chosen valuation methodologies may differ greatly depending on the type of co-benefit being assessed, and should provide a level of confidence commensurate with the potential level of impact or risk associated with the project (see Figures 15, 16 and 17). Choice of methodology will also be influenced by data availability, whether a qualitative or quantitative assessment is required, schedule, budgetary limitations, expertise limitations, project scale, and overall project needs.

Potential methods and resources required to measure and monitor FrM benefits, and environmental, social, and economic co-benefits are summarized in the following sub-sections.

4.1 Flood-risk management Benefits

Although FrM benefits (and their measurement) are not the primary focus of this report, they are discussed briefly here due to their relevance and inter-relation to co-benefits.

In order to support the scoping, planning, design, implementation, or long-term management of all FrM projects, including NBS, it is necessary to estimate or assess the magnitude of FrM benefits. Techniques to value FrM benefits will depend on the type of benefit, the potential impact or risk associated with the project, and the level of resources available to support FrM benefit measurement, monitoring, and valuation. Examples of FrM benefits are summarized in Table 1 (see Section 2.2).

Resources required to undertake valuations may be broadly divided into three categories: time (or schedule), budget (or money), and expertise (or expert availability). Projects with large potential impacts (or risks) to the surrounding communities and ecosystems will generally have more stringent project requirements and require a higher level of certainty, thereby necessitating the use of more sophisticated approaches that generally have larger resource needs. In contrast, a flood protection project for a single property may not pose significant risks or provide significant benefits to nearby communities or ecosystems. It may therefore be appropriate to utilize techniques to measure FrM benefits that require minimal resources and have a higher level of uncertainty than would be appropriate for a city-wide flood protection program with high potential impacts, for example.

Data collection or monitoring methods may be either direct or indirect and allow for qualitative or quantitative valuation. Low-effort techniques to estimate FrM benefits include review of precedence (case studies) and solicitation of expert opinions, for example. These techniques are associated with low resource requirements, high levels of uncertainty, and may be appropriate for low-impact/low-risk projects or for early in the project cycle, during the planning or scoping phases (as shown in Figure 8). High-effort techniques may include field surveys (including subsequent analysis of data), numerical modeling, and passive measurements (including subsequent analysis of data), among others. These techniques are associated with high resource requirements, lower levels of uncertainty, and may be appropriate for high-impact projects or for later phases of the project life cycle. For example, early in the project development process, a literature review may be sufficient to estimate potential wave dissipation and inform the feasibility of providing flood protection via oyster reef construction. Later in the project, a wave buoy may be installed to establish baseline conditions, confirm wave dissipation performance after construction, and inform long-term adaptive management. Case Study 7 describes the use of several techniques (numerical modeling, terrestrial LiDAR scanning, and technical analysis of orthophotos) to assess FrM performance.

The associated guidance document *Monitoring Efficacy: Proposed Methodology and Indicators* details potential monitoring methodologies and proposed FrM performance indicators. Ommer et al., (2022) and Raymond et al., (2017) also provide useful information on potential indicators, baseline data, and monitoring methods (see Section 1.4).

Case Study 7. Humboldt coastal dune climate ready project

Humboldt coastal dune climate ready project: Monitoring flood risk management efficacy and biodiversity

Humboldt County, California, United States

The Humboldt dune system encompasses a 50 km stretch of dunes and beaches along the California coast, west of Eureka. The dunes provide a defense against coastal hazards for human communities and critical infrastructure, including a water pipeline and wastewater treatment plant. With the aim to increase the coastal protection provided by the dunes from sea-level rise and increasing coastal hazards, the US Fish and Wildlife Service and the Humboldt Bay National Wildlife Refuge have been monitoring the dunes' response to different restoration and stabilization approaches (Friends of the Dunes, 2020), mainly through native vegetation planting and invasive species removal (Judge et al., 2017).

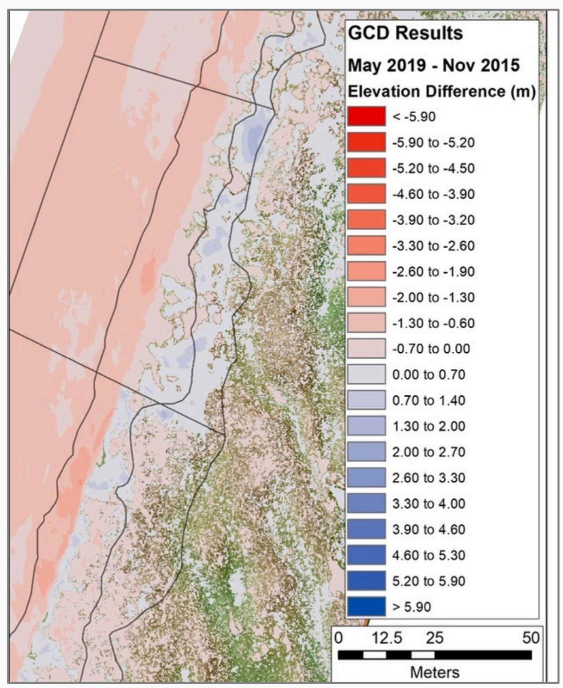
The monitoring program has assessed how flood-risk management, dune habitat and biodiversity have responded since the restoration strategies were implemented in 2008 (Judge et al., 2017).

The project measured (Judge et al., 2017):

Sediment budgets under different vegetation treatments using terrestrial LiDAR remote sensing and aerial photograph analysis to assess shoreline change;
Foredune building and dune elevation were monitored using topographic data measured in the field; and
Biodiversity and vegetation cover were measured by field teams along transects.

Using these data and a sea-level rise model, a vulnerability assessment of cultural, ecological and infrastructure assets to coastal hazards will be carried out. This will aid in identifying areas of the dunes that may need further restoration work to increase flood protection. More information about the project can be found at Friends of the Dunes (2020) <https://www.friendsofthedunes.org/hcrp>.

Figure 14. Dune elevation difference measured between 2015 and 2019, red is erosion, blue is accumulation



Source: Friends of the Dunes, 2020

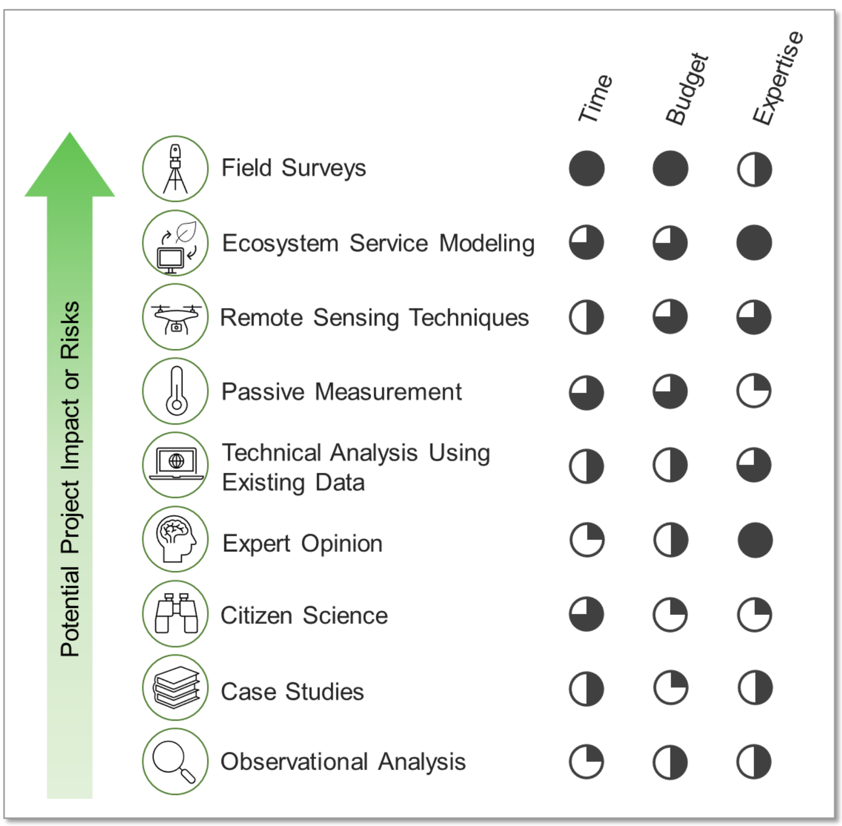
4.2 Environmental Co-Benefits

An environmental co-benefit may be valued by estimating the monetary value of provided services (see Section 4.4 for discussion of economic valuations); however, the intrinsic value of environmental co-benefits is not always appropriately captured through this type of analysis. Instead, environmental co-benefit performance indicators are often better characterized through other measurement and monitoring methods. There are numerous techniques that exist to estimate, measure, or monitor environmental co-benefits. Figure 15 provides a list of potential methodologies related to environmental co-benefits and summarizes the level of resources that may be required to undertake each method. The arrow and color gradient indicate the level of potential project impact or risk. The higher levels of potential impact or risk are shown in conjunction with potential valuation methods, which require higher levels of resources but achieve a higher degree of certainty.

The list of potential methods is not exhaustive and methods are not mutually exclusive. Instead, the list is provided to establish that a broad range of methods may be considered. Depending on project-specific limitations, some methods may not be applicable or there may be specialized methods that would provide more optimal outcomes.

As discussed in Section 4.1, resources required to undertake valuation initiatives may be broadly divided into three categories: time, budget, and expertise. Projects with large potential impacts (or risks) may necessitate the use for more resource-intensive techniques. See the associated *Monitoring Efficacy: Proposed Methodology and Indicators* guidance document for more details on NBS monitoring methodology and indicators.

Figure 15. Potential methods to valuate environmental co-benefits, based on level of project impact and resource availability



Field surveys (i.e., employing personnel and equipment to collect discrete data) and passive measurements (i.e., employing instrumentation or tools to collect long-term data) provide a means of obtaining empirical, quantitative and qualitative data from a project site. Field surveys and passive measurements require significant resources, but may be tailored to meet the project needs, schedule, budget, and expertise. Field surveys are often employed before, during and after construction to assess project compliance and reduce uncertainty. Passive measurements (e.g., weather monitoring stations, erosion pins) provide a useful alternative when site access is limited, or when experts are not readily and locally available.

Ecosystem service modeling involves the measuring and monitoring of ecosystem health, resilience and biodiversity while simultaneously assessing what benefits the ecosystems provide to humans (Liquete et al., 2015; Maes et al., 2012; Raymond et al., 2017). This method provides a value for a variety of environmental co-benefits (e.g., soil health, habitat connectivity), which can be quantitatively estimated through ecosystem service and network modeling.

Remote sensing techniques (e.g., topographic surveys using LiDAR or drone-based photogrammetry) are effective means for rapidly gathering direct, qualitative and quantitative data across a large area, particularly in sensitive areas or where site access may be limited. Remote sensing techniques often require specialists to undertake the survey, and budgetary requirements vary significantly, depending on the technique.

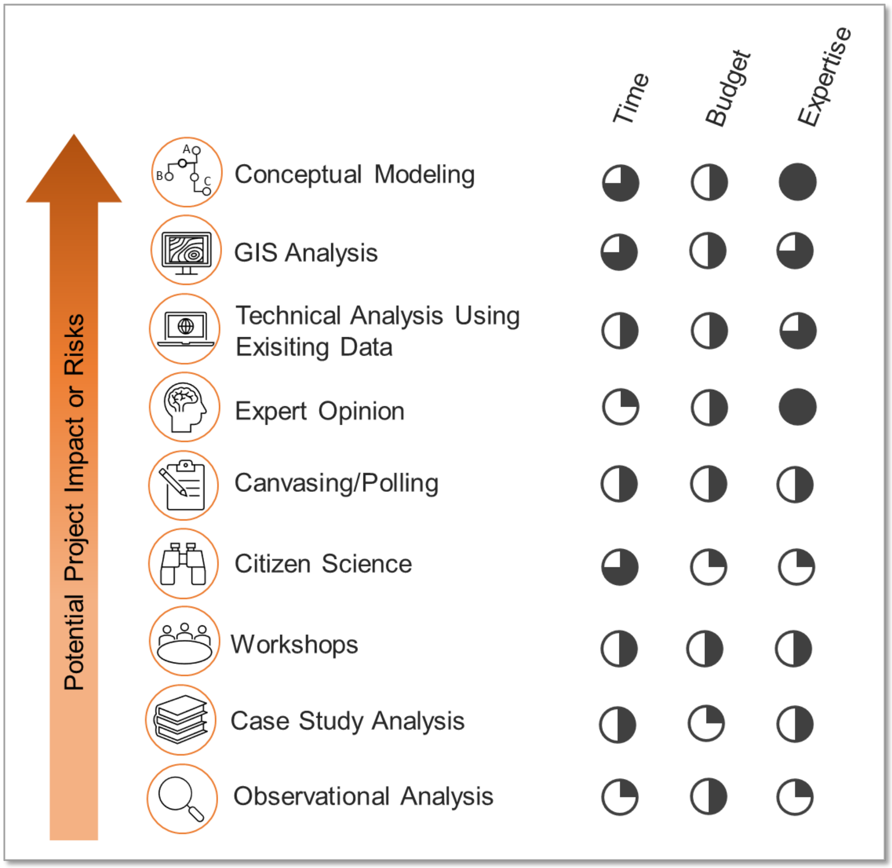
Technical analysis involves assessment with data/information, using secondary or pre-existing data. Multiple types of methodologies fall into the category of technical analysis. For example, multi-spectral aerial images collected from satellites (e.g., Sentinel, Landsat) can be used for vegetation biomass analysis or Normalized Difference Vegetation Index (NDVI) both of which quantify vegetation and may provide insight into a variety of environmental challenges, including air quality, carbon sequestration, vegetation health and noise attenuation (Ommer et al., 2022). Notably, numerous programs already exist across North America to collect and distribute remote sensing data (e.g., aerial imagery, LiDAR data, bathymetry data), which provide an excellent source for data required for technical analyses.

Less resource-intensive techniques include solicitation of expert opinions, community science, review of case studies, and observational analysis (i.e., analysis based solely on what can be observed) (Shiao et al., 2020; Brill et al., 2021). Notably, obtaining expert opinions may provide significant benefits during early phases of a project when budget and available data are limited. Expert opinion can be highly effective as these individuals can create inferences and make informed decisions based on the limited information at hand, while drawing on extensive knowledge and practice within a specific field.

4.3 Social Co-Benefits

Social co-benefits may also be valued by estimating the monetary value of provided services (see Section 4.4 for discussion of economic valuations); however, if an economic valuation is adopted, intangible social co-benefits (e.g., equity and inclusion) are generally disregarded. Social co-benefits are often better characterized through several alternative techniques. Figure 16 provides a broad list of potential methodologies related to social co-benefit valuations and summarizes the level of resources that may be required to undertake each method. Depending on project-specific limitations, some methods may not be applicable or there may be specialized methods that would provide more optimal outcomes. See the associated guidance document, *Monitoring Efficacy: Proposed Methodology and Indicators,* for more details on NBS monitoring methodology and indicators.

Figure 16. Potential methods to valuate social co-benefits based on level of project impact and resource availability



Conceptual modeling involves developing a graphical representation of a dynamic system, which illustrates positive and negative relationships, connections, and feedbacks (Gray et al., 2015; Raymond et al., 2017). The objective is to gather a group of diverse experts and brainstorm elements important to the system being analyzed, followed by creating links between elements with varying levels of influence (both positive and negative) as determined by the experts. Gray et al., (2015) highlight a case study that utilizes Fuzzy Conceptual Modeling (FCM) and resilience analysis to describe changes in community well-being and wildlife versus increased immigration.

Numerous social co-benefits relating to recreation and tourism may be assessed through GIS analysis techniques (e.g., land-use change analysis using air photos collected for the project). GIS analyses that rely on secondary or pre-existing data may require less resources, except where ground-truthing is required.

Community involvement and communication are a vital part of measuring social co-benefits. Effective ways to achieve this are through community science, workshopping, and canvassing/polling. Workshopping and canvassing/polling, in particular, create an open dialog between decision makers and the community, both of which can support social, co-benefit valuation and help to build public buy-in. Revealed preference surveys, for example, are often used to establish an economic value related to some social co-benefits. Case Study 8 provides an example of using community engagement and canvassing to support a socio-economic study.

Similarly to environmental and economic co-benefit methods, social co-benefits may also be valuated via case study analysis, observational analysis, and solicitation of expert opinions. All three of these methods require relatively few resources and may be appropriate for projects in early developmental stages, or projects with low potential impacts or risks.

Case Study 8. Monitoring Socio-economic Impact of NBS sites in New York State

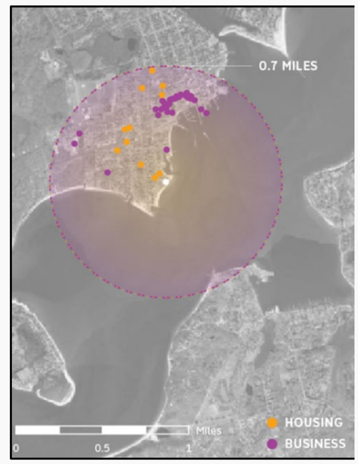
Widow's Hole Preserve: Monitoring Socio-economic Impact of NBS using the Statewide Framework

New York, United States

New York State has developed the Statewide Shoreline Monitoring Framework, a standardized monitoring framework for use in assessing the various NBS sites throughout the state (Science + Resilience Institute, 2020). The Framework is intended to measure the hazard mitigation efficacy, ecological impact and socio-economic impacts of NBS. The associated guidance document, *Monitoring Efficacy: Proposed Methodology and Indicators,* provides more detail on this initiative.

The Widow's Hole Preserve's living shoreline project was assessed through desk and field study as part of a pilot project to test the Framework and inform its future development (Science + Resilience Institute, 2020). An observational shoreline social assessment was conducted by a field team within a "Social Zone" around the site, established prior to the field visit. In addition, a household survey of randomly pre-selected households within a radius (1.08 km) of the 30 nearest businesses was carried out. The field team recommended shrinking this radius for future visits in order to save time and ensure that the household closer to the shoreline feature was being monitored.

Figure 17. Socio-economic survey area



Source: Science + Resilience Institute, 2020

The table below lists some of the parameters and indicators from the Statewide Shoreline Monitoring Framework included in the socio-economic study (Science + Resilience Institute, 2020). Additional information on indicators (and other project details) may be found through the Department of State website for the Statewide Shoreline Monitoring Framework: <https://dos.ny.gov/statewide-shoreline-monitoring-framework>.

Table 6. Parameters and indicators included in the socio-economic study

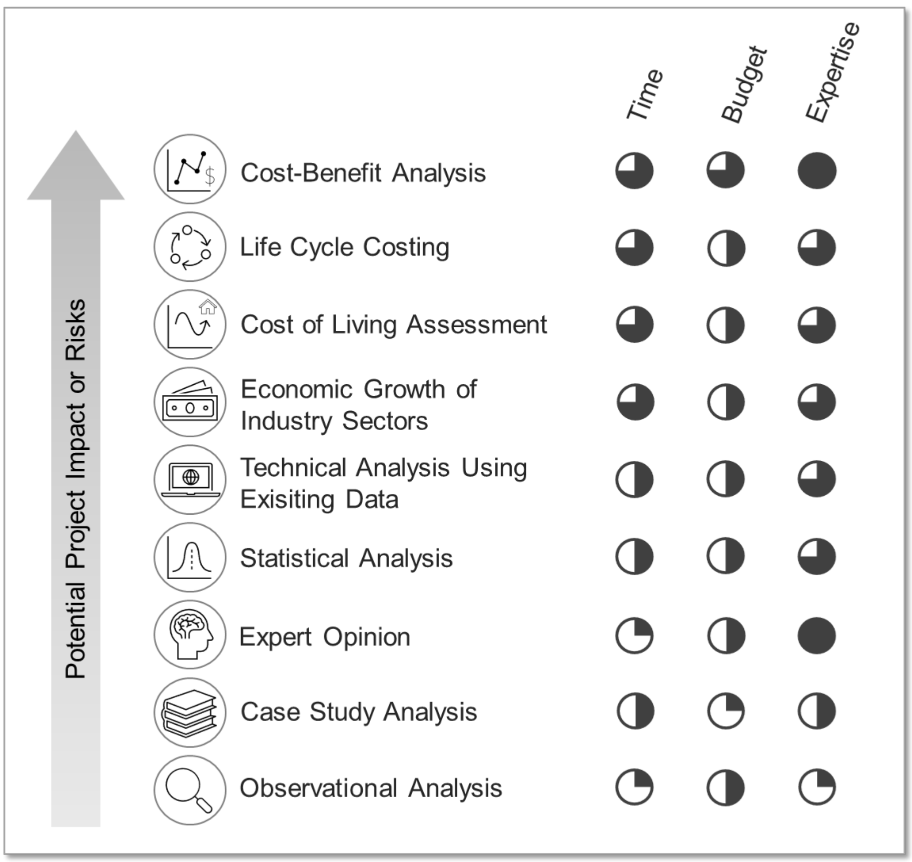
Parameter	Indicator
Quality of Life	Community perception of risk Neighborhood satisfaction
Civic Engagement	Number of people participating in shoreline stewardship
Recreation and Cultural Use	Observational survey
Economic Development	Change in real estate value Business activity index Infrastructure/facilities exposed to flood hazards
Environmental Justice	Environmental Justice Index

Source: Adapted from Science + Resilience Institute, 2020

4.4 Economic Co-Benefits

Many economic co-benefits can be assessed directly via quantitative methods, since indicators for these co-benefits are often expressed in monetary units. However, qualitative methodologies may still be applicable when resources or data are limited. Figure 18 provides a broad list of potential methodologies related to economic co-benefits and summarizes the level of resources that may be required to undertake each method. Depending on project-specific limitations, some methods may not be applicable or there may be specialized methods that would provide more optimal outcomes. The associated guidance document *Monitoring Efficacy: Proposed Methodology and Indicators* offers more details on NBS monitoring methodology and indicators.

Figure 18. Potential methods to value economic co-benefits, based on the level of project impact and resource availability



An economic cost-benefit analysis entails comparing the sum of economic costs and the sum of economic benefits (present or future value) for a specific action (Groenendijk et al., 2020). Economic cost-benefit analyses allow for the valuation of numerous co-benefits, including, for example, costs saved due to volunteer hours, avoided flood losses and increased taxes. Notably, this type of analysis requires significant supporting information to be collected, measured, or modeled. For example, to estimate avoided flood losses, flood extents may need to be modeled with and without intervention and impacted assets valued. Eastern Research Group (2015) provides a thorough guide to undertaking cost-benefit analyses for NBS projects. Case Study 9 provides an example of utilizing cost-benefit analysis to valuate and compare various coastal hazard defense options.

Case Study 9. Anse du Sud cost-benefit analysis

Anse du Sud cost-benefit analysis:
Cost-benefit analysis including co-benefits

Percé, Quebec, Canada

Natural Resources Canada launched a program in 2016 to assess the economic viability of various coastal adaptation options (NRCan, 2022). As part of this project, a cost-benefit analysis was conducted to evaluate the economic benefits of both NBS and hard engineering coastal defense options, compared to non-intervention at 11 sites in Quebec and Atlantic Canada (Boyer-Villemaire et al., 2016).

The town of Percé suffered damage from storms in 2016 and 2017, resulting in the loss of the boardwalk at Anse du Sud (Alberti-Dufort et al., 2022). Anse du Sud was included as one of the 11 sites assessed in the cost-benefit analysis, which quantified the estimated costs associated with the construction of each coastal defense option and the benefit from increased flood protection. The analysis also quantified a dollar value for the co-benefits expected to be associated with each option, including:

- Tourism;
- Fish spawning grounds;
- Recreational use of the coastline;
- Quality of life; and
- Improved landscape (Boyer-Villemaire et al. 2016).

Beach nourishment was found to be the most beneficial coastal defense option for Anse du Sud, with a financial benefit of over C$770 million over 50 years, compared to non-intervention (Boyer-Villemaire et al., 2016), mainly due to the significant increase in tourism anticipated from the improved beach (Alberti-Dufort, 2022).

Life-cycle cost valuation is an engineering-economic analysis tool which may be used to assess the total cost required to implement, monitor, and repair a FrM project (including components aimed at maximizing co-benefits) over the long-term. It takes into consideration all initial and future costs from investments, purchase of materials, installation, operating, maintenance, financing and disposal over the lifetime of the project. This method is especially useful when comparing project alternatives that provide the same benefits (including FrM benefits, and environmental or social co-benefits) but differ with respect to capital and operational costs (Kubba, 2010).

Many economic valuation methods rely heavily on expert knowledge and use indicators involving large-scale and quantitative data. This often requires technical analysis to identify trends in market data, as well as statistical analysis, which involves collecting, exploring and discovering trends or patterns (e.g., Damage Cost Assessment, Replacement Cost Assessment, etc.). For example, a cost-of-living assessment uses locally available data related to the costs to cover basic expenses for day-to-day living (i.e., food, water, housing, taxes, healthcare) and compares it to local wages (Banton, 2021). This may help to assess the economic co-benefits of a project on a community.

Another valuation method involves reviewing how various sectors of the economy have evolved over time in response to co-benefits. For example, this method may be used to assess how agricultural sectors have been altered by quantifying fisheries yield, crop production, and livestock yield. Other sectors which can be valuated using economic growth include tourism, small businesses, and entertainment.

Similarly to environmental and social co-benefit methods, economic co-benefits may also be valuated via case study analysis (e.g., benefit transfer analysis), observational analysis, and solicitation of expert opinions. All three of these methods require relatively few resources and may be appropriate for projects in early developmental stages, in locations where little data are available, or for projects with low potential impacts or risks. Case Study 10, supported through the use of an existing toolbox, describes an initiative to evaluate the economic benefits provided by natural municipal assets (MNAI, 2021b).

Case Study 10. Municipal Nature Assets Initiative in British Columbia

Municipal Natural Assets Initiative:
Coastal resilience including economic co-benefits

Gibsons, British Columbia, Canada

Municipal natural assets refer to natural resources or ecosystems that a local government may rely upon to sustainably provide local services and manage risks. In addition to other co-benefits, natural assets may provide significant economic benefits to communities by reducing flood- and erosion-related costs and damages, and improving maintenance and operational costs (MNAI, 2021b).

The Municipal Natural Assets Initiative (MNAI) launched a Coastal Resilience project in 2020-2021 to address the impacts of climate change on vulnerable coastal infrastructure within the south side and marine side of Gibsons, British Columbia, Canada.

As part of this project, Gibsons assessed the potential for various adaptation measures to mitigate future erosion and flood impacts related to climate change, sea-level rise, and increased storm activity. The MNAI process for this project involved quantitatively assessing the avoided costs and damages (i.e., cost of beach loss, cost of flood damages) of four natural assets (including shoreline vegetation enhancement, beach nourishment, submerged eelgrass enhancement, and submerged structures) and developing a Coastal Toolbox modeling tool to compare the success of each natural asset (MNAI, 2021b).

The analysis results suggest that shoreline vegetation enhancement, beach nourishment, eelgrass enhancement, and improved sediment retention are expected to best mitigate erosion-related costs. The analysis also suggests that infrastructure along the south side of Gibsons (see Figure 19) is subject to minor flooding risks; however, there are also between 14 and 52 buildings on the marina side that are exposed to flood risks, particularly as sea-level rise. Coastal storm events could amount to between C$3.4 million and C$16.2 million in damages on the marina side (MNAI, 2021b).

Figure 19. Project area overview, Gibsons, British Columbia

Source: MNAI, 2021b

5 Co-Benefits and Adaptive Management

Adaptive management is an iterative and systematic decision-making process focused on identifying uncertainties and determining ways to reduce risk and uncertainty through monitoring (Bridges et al., 2021, 273; Rist et al., 2013). This management approach allows the project team to monitor, learn from, and manage the system in a flexible manner, thereby ensuring that outcomes (i.e., goals or metrics) are achieved for all performance indicators (Bridges et al., 2021, 274); Cado van der Lely et al., 2021).

Adaptive management is critical to ensuring that co-benefits are realized, during all phases of the project life cycle, but particularly during the operational phase of the project. Adaptive management ensures that actions are taken throughout the project life cycle to optimize co-benefits associated with the project and its co-benefits monitoring plan. Adaptive management of co-benefits will also help to reduce potential unintended impacts and create public accountability.

Monitoring provides essential data for both co-benefits valuation and adaptive management. Therefore, monitoring and adaptive management programs must be designed with careful consideration of identified co-benefits and planned co-benefit valuations. The selection of performance indicators and metrics should encompass enough information to inform planned valuations and reduce project uncertainties.

It is also important to understand the need for timely feedback between monitoring initiatives, valuations, and the adaptive management, which helps to facilitate action by decision makers, especially at critical stages, such as during construction or when interventions are required post-construction. In addition, the duration of monitoring and adaptive management to achieve co-benefits should extend well after construction or adaptive management interventions have been taken (Cado van der Lely et al., 2021).

For additional information on adaptive management, refer to the *International Guidelines on Natural and Nature-based Features for Flood Risk Management, Chapter 7: Adaptive Management* (de Looff et al., 2021).

6 Opportunities and Future Directions

Co-benefits strengthen NBS project outcomes through positive impacts to the environment, society, and economy. Broader, positive impacts may be achieved by aligning project goals with the goals of the local community, Indigenous Peoples, and stakeholders. Assessment of co-benefits has numerous advantages, including allowing for the holistic comparison of various options, improving public buy-in, and informing adaptive management. However, there are several challenges and knowledge gaps that exist, relating to assessing and realizing co-benefits which impede the overall uptake of NBS. Section 1.3 identifies several barriers to realizing environmental, social, and economic co-benefits. A summary of potential opportunities and initiatives that decision makers may take to alleviate these challenges and barriers is provided in Box 3.

Notably, improving communication and engagement with the local community, Indigenous Peoples, academics and stakeholders can often reduce social barriers related to co-benefits. Increasing communication helps to facilitate cooperation, understanding, development of communal goals, trust with decision makers, and knowledge-sharing. This can be achieved through hosting workshops or seminars related to co-benefits or through community science initiatives, for example.

Standardized methods and frameworks are vital to developing a technical understanding of co-benefit identification, valuation, comparison, and overall successful implementation. Standards are beneficial at both national and local scales, and help with assessing the suitability, scale, and the economic, environmental, and social feasibility of a given NBS. In addition, standardized methods and frameworks can assist with the consideration of co-benefit trade-offs, ensuring transparency, facilitating adaptive management, and allowing for the exploration of possible linkages with international goals and commitments. Developing industry-wide standards offers guidance for decision makers, reduces uncertainty, and improves the ability to compare co-benefits provided by multiple FrM projects. The associated guidance document, *Monitoring Efficacy: Proposed Methodology and Indicators,* proposes standard monitoring methodologies and indicators for NBS to help meet this need.

Knowledge-sharing is also essential to reducing barriers around co-benefit implementation. Creating a centralized, industry-wide database for co-benefit case studies, valuations, and monitoring results will provide additional information to support future project assessments. This may be accomplished through many different means, including cooperation among local, regional, and national governments, international organizations, or through established communities of practice (e.g., CEC NBS community of practice).

A large barrier to realizing co-benefits (and integrating them into adaptive management, for example) is the lack of funding available for assessment of co-benefits, long-term monitoring initiatives, and NBS, as a whole. While improving communication and engagement, developing case studies, and raising awareness of the benefits of NBS can help, a strategic, regional-level funding system may assist in alleviating these challenges. Increasing investments related to co-benefits will include long-term collaboration between stakeholders, government agencies, and private partners. Funding strategies should take into account regional-specific policies, mechanisms, and protocols (Brill et al., 2021). Governments may further support NBS and co-benefits by developing policies and legislation that can mandate the incorporation of co-benefits assessments, the dissemination of co-benefit related project data, and drive further investments in NBS.

Box 3. Opportunities and future directions related to co-benefits of NBS and the type of barrier that the opportunities address

	Opportunities and Future Directions	Type of Barrier Addressed: Social	Technical	Environ.	Institutional
1.	Host or fund sessions, workshops, and seminars on NBS co-benefits.	✓	✓	○	✓
2.	Encourage diverse stakeholder engagement (i.e., policymakers, Indigenous Peoples, social groups) during the entire project life cycle.	✓	✓	○	○
3.	Develop community science initiatives to further engage the local community and improve trust and buy-in.	✓	✓	○	○
4.	Develop a community of practice with experts spanning multiple disciplines across multiple regions.	✓	✓	○	○
5.	Develop short training programs (with easily accessible materials) for standard valuation methods for co-benefits.	○	✓	○	○
6.	Include training on co-benefit identification, valuation, and comparison, within academic programs/degrees.	○	✓	○	○
7.	Develop a centralized (industry-wide) database to host and disseminate co-benefit assessment data.	✓	✓	○	○
8.	Work to make existing, historical co-benefit data publicly available.	✓	✓	○	○
9.	Encourage and highlight case studies with co-benefit valuations (particularly those comparing NBS to gray infrastructure).	○	✓	○	✓
10.	Encourage and highlight case studies with long-term results.	○	✓	✓	✓
11.	Establish or identify industry-standard technical guidance for co-benefit valuation methods (for use by practitioners).	○	✓	○	○
12.	Amend regulatory approvals to require the comparison of co-benefits for multiple design options (including a 'do-nothing' approach).	○	○	○	✓
13.	Request (i.e., within Requests for Proposals) that proponents include co-benefit assessment.	○	○	○	✓
14.	Require that project teams commit to data distribution (including the results of co-benefits assessments).	✓	○	○	✓
15.	Develop regional-level funding streams for long-term monitoring and adaptive management of co-benefit performance indicators.	✓	○	○	✓
16.	Develop regional-level funding streams for projects that involve significant co-benefits for local communities and the environment.	✓	○	○	✓
17.	Distribute existing co-benefit guidance to government organizations.	○	○	○	✓
18.	Continue ongoing initiatives to value natural capital assets, to highlight co-benefits provided by NBS.	✓	○	○	✓

7 Conclusions

This document compiles information related to co-benefits within the context of FrM using NBS in Canada, Mexico, and the United States. Its focus is on guidance related to the identification, valuation, and comparison of co-benefits, and on potential opportunities to alleviate information gaps and barriers to co-benefit implementation.

Co-benefit valuation is necessary to compare effectively NBS to conventional (i.e., gray) FrM solutions and communicate fully the benefits that NBS can provide. Co-benefit valuation also supports design, adaptive management, future research and general uptake of NBS for FrM.

A co-benefit assessment framework was developed as part of this report to support the incorporation of co-benefits into the project development cycle. That framework is divided into three iterative stages: (1) Identification, (2) Valuation, and (3) Comparison.

The Identification stage involves understanding the 'big picture' of a NBS project, broad engagement and consultation, and identification of local issues and challenges. This stage will result in the development of a broad list of potential co-benefits and strategies for implementation (e.g., design features or actions). Many potential environmental, social, and economic co-benefits are described in Section 2.

Valuation is the process of determining the potential value of a given co-benefit. When valuing co-benefits, there is often a focus on the economic value of outcomes, which inadvertently devalues less quantifiable (i.e., intangible) social and environmental co-benefits. This report recognizes the importance of adopting a more holistic approach to valuation, which moves away from the idea that value is money, and vice versa. Instead, valuation is defined as the process of quantifying the importance, worth, usefulness and/or monetary value of a given co-benefit. Valuation methods will vary depending on various resource limitations (including funding, schedule, and expertise constraints), and may involve both qualitative and quantitative techniques. Potential valuation methods are summarized in Section 4.

The Comparison stage involves assessing trade-offs and prioritizing certain co-benefits to support decision making and design. Co-benefits associated with different design options may also be compared to support selection of a preferred alternative (e.g., to support comparison of NBS and gray infrastructure). In this report, it is recommended that an approach using multi-criteria analysis be adopted for comparing co-benefits, facilitating the comparison of non-quantifiable and intangible co-benefits.

Finally, there are numerous opportunities to advance NBS by removing barriers and data gaps related to valuating and realizing co-benefits. Expanding funding opportunities for projects involving co-benefit valuation, broadening training/knowledge on co-benefit valuation, and developing case studies or project databases for reference on future projects and by decision makers, are essential to removing barriers to realizing co-benefits.

Appendix: Template-rating Framework

A template-rating framework to facilitate comparison of co-benefits for multiple FrM options is provided below. The framework utilizes a multi-criteria analysis approach, which facilitates the rating and comparison of intangible (or qualitative) co-benefits. The framework may be completed on a project-specific basis and used to rate each FrM option under consideration. Stakeholders, experts and the project team should be engaged to contribute and provide guidance on weighting. Once ratings are completed, the total rating may be used to compare FrM options and select a preferred option.

Table 7. Template-rating framework

1. Indicator Selection & Description		**2. Define Rating Strategy**			**3. Assess Ratings**		
Indicator	**Associated Co-Benefit(s)**	**Rating**	**Rating Guidance**	**Weight (%)**	**Rating**	**Justification**	**Weighted Rating**
[Add description of indicator that has been measured/valuated]	*[List all co-benefits for*	5	*[Provide guidance for how*	*[Assign weighting between 0 - 100%]*	*[rating assigned by user, between 0 - 5]*	*[User to justify rating and refer to rating guidance]*	*[Weighted rating = Weight (%) x Rating]*
	which indicator applies]	4	*each rating should be*				
		3	*assigned by the user]*				
		2					
		1					
		0					
		5					
		4					
		3					
		2					
		1					
		0					
		5					
		4					
		3					
		2					
		1					
		0					
			Total:	**100%**	*Max = 5 pts*	**Total:**	

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