From Source to Sea

Aquifer 560 Watershed
Natural Asset Management Project

Natural Assets Initiative
MAKING NATURE COUNT

TECHNICAL REPORT

March 2024

Natural Assets Initiative
MAKING NATURE COUNT

Invest in Nature

The Natural Assets Initiative (NAI) is a Canadian not-for-profit that is changing the way local governments deliver everyday services — increasing the quality and resilience of infrastructure at lower costs and reduced risk. The NAI team provides scientific, economic and municipal expertise to support and guide local governments in identifying, valuing and accounting for natural assets in their financial planning and asset management programs, and developing leading-edge, sustainable and climate-resilient infrastructure.

The Town of Gibsons acknowledges that it is situated on the unceded traditional territory of the Skwxwú7mesh Úxwumixw (Squamish Nation). This is the ancestral territory of the Skwx̱wú7mesh speaking peoples and has been stewarded by them since time immemorial.

The Aquifer 560 Watershed is on territory that was never ceded or given up to the Crown by the Skwxwú7mesh peoples. The term unceded acknowledges the dispossession of the land and the inherent rights that the Skwxwú7mesh hold to the territory. The term serves as a reminder that the Skwxwú7mesh have never left their territory and will always retain their jurisdiction and relationships with the territory.

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Acronyms

BC British Columbia
CAD Canadian Dollars
CAO Chief Administrative Officer
CC Climate Change
CES Cultural Ecosystem Services
CICES Common International Classification of Ecosystem Services
CRO Chief Resiliency Officer
CT Coastal Toolbox
DPA Development Permit Area
DSF David Suzuki Foundation
FCM Federation of Canadian Municipalities
GVWD Greater Vancouver Water District
ha hectare
HRVA Hazard Risk and Vulnerability Analysis
IAPP Invasive Alien Plant Program
IPBES Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC Intergovernmental Panel on Climate Change
ISMP Integrated Stormwater Management Plan
km kilometer
LID Low Impact Development
LOS Levels of Service
MEA Millennium Ecosystem Assessment
MNAI Municipal Natural Assets Initiative
NAI Natural Assets Initiative
NAM Natural Asset Management
NbS Nature-based Solutions
OCP Official Community Plan
PCSWMM Personnel Computer Storm Water Management Model
RUD Recreational Use Days
SCRD Sunshine Coast Regional District
SEI Sensitive Ecosystem Inventory
S2S Source to Sea and Methodology Integration Project
SWM Stormwater Management
tC Tonnes of Carbon
tCO2e Tonnes (t) of carbon dioxide (CO2) equivalent (e)
TEEB The Economics of Ecosystems and Biodiversity
ToG Town of Gibsons
VFR Vancouver Forest Region
WTP Willingness-to-Pay
yr year

1 Introduction

This section introduces the context for natural asset management (NAM) including: the rationale for watershed-scale NAM, the project goals and objectives and the project limitations.

Canadian local governments, Indigenous and Métis Nations, watershed agencies and other entities face infrastructure and asset management challenges. Many services these organizations provide, including water and wastewater, waste removal, transportation, flood attenuation, erosion control, and environmental services, depend on ageing engineered infrastructure assets that are in need of renewal. Meanwhile, climate change places increasing pressure on the existing infrastructure stock.

The term '*natural assets*' refer to the stock of natural resources or ecosystems that a municipality, regional district, or other watershed rightsholders or stakeholders could rely on or manage for the sustainable provision of one or more services.[1] Effective stewardship of natural assets helps these entities to deliver more resilient services in a changing climate, reduce associated costs, and provides an alternative to "building their way out" of infrastructure challenges. Natural assets can provide both critical infrastructure services and numerous co-benefits that add to community quality of life. This practice has become known as a Natural Asset Management (NAM), a subset of the broader field of nature-based solutions (NbS). NAM enables nature to be conceptualized, accounted for, restored, protected, and managed as a vital asset to ensure its long-term viability. NAM is based on standard asset management methods that Canadian public sector entities are increasingly required to adopt, methods which the Natural Assets Initiative (NAI) has adapted for the unique considerations of nature. NAM has evolved from a single isolated initiative in 2017 to action being taken by over 120 local governments across multiple provinces in 2023. The urgency to accelerate NAM is particularly acute in urban and peri urban areas; approximately 80% of Canadians live in the interface between natural and urban areas where nature is extremely important, but also highly vulnerable.[2]

NAM is an important tool for addressing climate change. A 2021 report from the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC) notes "only by considering climate and biodiversity as parts of the same complex problem… can solutions be developed that avoid maladaptation … ignoring the inseparable nature of climate, biodiversity, and human quality of life will result in non-optimal solutions to either crisis."[3] The IPCC Sixth Assessment Report includes a headline statement that stresses the fundamental importance of safeguarding biodiversity and ecosystems in the development of climate

1 MNAI (2018).

2 Brown et al. (2021).

3 Pörtner et al. (2021).

resilience[4]. It advises that "maladaptation can be avoided by flexible, multi-sectoral, inclusive and long-term planning and implementation of adaptation actions with benefits to many sectors and systems".[5] NbS are recognized as both a promising adaptation action that can help reduce some physical and socioeconomic impacts from climate change, and as potential mitigation actions to store and sequester carbon. NbS — of which NAM is one — may also play a role in reducing liability risks.

A key consideration for NAM is that ecosystems and natural assets rarely align with singular political boundaries and jurisdictions. Many entities rely on natural assets that are under the ownership and/or jurisdiction of others. Therefore, collaboration amongst many entities, and action at the watershed scale, is ultimately required for effective NAM. There are numerous and inherent challenges to watershed-scale efforts as documented in, for example, *Natural Asset Infrastructure in British Columbia*[6]. *The Source to Sea Project* (hereafter the S2S Project), the subject of this report, describes the efforts of the Town of Gibsons, British Columbia, to consider and tackle some of these barriers.

The Town of Gibsons, which deemed nature its most valuable asset back in 2014, has been an innovator of NAM.[7] The Town continues to be a 'living lab' for NAM and their efforts have inspired many others as well as shape the practice as it is today. Within this context, the Town of Gibson chose to work with the Natural Assets Initiative (NAI), a Canadian non-governmental organization, to expand the spatial scale of their earlier efforts — which focused on either land-based[8] *or* coastal and marine issues[9] — to consider the entire Aquifer 560 Watershed (hereafter the Watershed). The Watershed begins at the top of Mount Elphinstone and extends to the sea (see Figure 1). The Watershed covers multiple jurisdictions and landcover types, as illustrated in Figure 2.

4 IPCC AR6 WG II. (2022).

5 IPCC AR6 WG II (2022, p. 35).

6 MNAI. (2023).

7 Town of Gibsons. (2017).

8 Sahl et al. (2016).

9 MNAI. (2023).

Figure 1: *The Aquifer 560 Watershed*

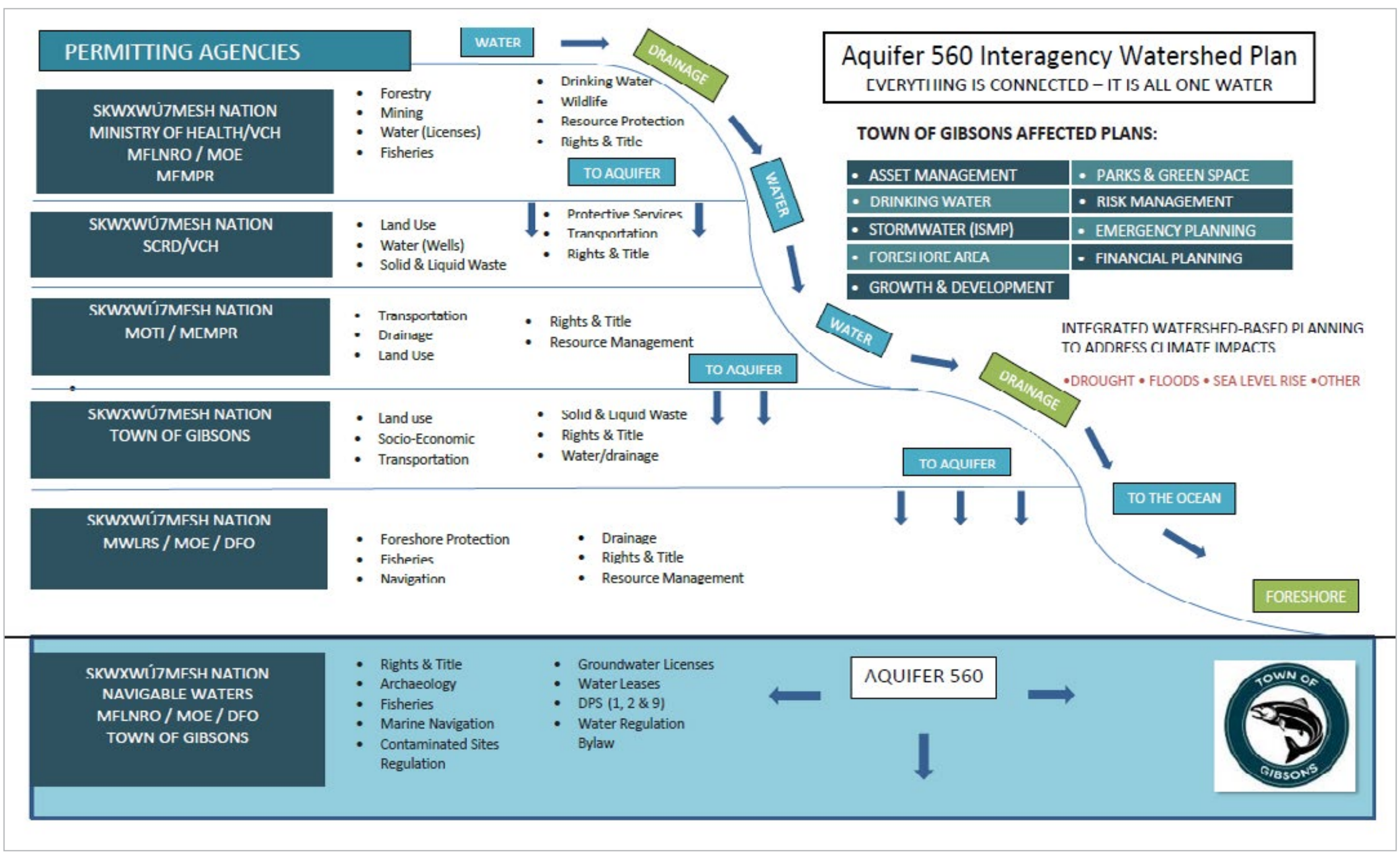

Figure 2: *Key stakeholders with jurisdiction within the Aquifer 560 Watershed*
Source: *Town of Gibsons, 2023*

Theirs is not the first effort to consider NAM at a watershed-scale; the 2022 Grindstone Creek project provides another recent example.[10] However, the S2S Project also explores surface water – marine interactions in the context of NAM, an area of research which had been unexplored. Results to date are highly relevant to many other communities in Canada and potentially beyond, given that almost 40% of the world's population lives within 100 km of a coast.[11] Furthermore, the S2S Project undertook an iterative approach in which new findings and results were, in some cases, implemented as the project progressed. This report provides S2S Project results to date.

The S2S project builds on previous work by NAI, Urban Systems, and Gibsons that evaluated flood protection benefits provided by the pond system at Whitetower Park[12], as well work by DSF, NAI, ESSA, and CBCL to evaluate flood and erosion protection benefits from coastal natural assets.[13]

1.1 S2S Project Goal & Objectives

The project goal is to ensure that the natural assets within the Watershed are understood, measured, valued, and ultimately managed to protect their integrity, and to safeguard the reliable flow of core infrastructure services and diverse co-benefits. Four objectives support this goal:[14]

1/ Understand the current roles of natural assets in the project area in providing stormwater management and flood mitigation services to the residents of Gibsons;

2/ Understand possible future roles of natural assets in the project area in providing stormwater management and flood mitigation services to the Town of Gibsons;

3/ Quantify the value of natural assets in the project area in terms of service provision, including determining costs and benefits relative to engineered alternatives; and

4/ Develop strategies for effective management of natural assets based on this understanding, including identifying potential synergies with other Town projects.

These goals and objectives were laid out in a Memorandum of Understanding between NAI and the Town of Gibsons (hereafter the Project Partners).

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10 Details on the Grindstone Creek project are available at mnai.ca/grindstone-creek-watershed-natural-assets-management-project/

11 See UNEP's Coastal zone management topic at unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/coastal-zone-management

12 Sahl et al. (2006).

13 MNAI (2021b).

14 Project objectives were changed from a focus from the provision of safe, reliable drinking water supplies for residents through aquifer recharge to stormwater management and flood mitigation. This change was made to align with modelling capabilities.

The methodology for the S2S Project is based on standard asset management practices that Canadian local governments are increasingly required to adopt, and which are articulated by organizations such as Asset Management BC, based on global norms (see Figure 3). NAI has adapted these methodologies to ensure that natural assets — which are complex in their role in service delivery, are context-specific, and present novel considerations — can be effectively integrated and considered in asset management.

***Figure 3:** Natural Asset Management wheel*
***Source:** NAI, 2017; Adapted from Asset BC, 2014*

WHY USE AN ASSET MANAGEMENT-BASED METHODOLOGY TO UNDERSTAND THE RELATIONSHIP BETWEEN LOCAL GOVERNMENTS AND NATURE?

- Asset management is becoming ubiquitous among Canadian local governments, offering scope to make NAM a broadly based, scalable and comparable practice.
- Asset management provides a useful and practical approach for conceptualizing nature not simply in narrow aesthetic terms, but as something upon which communities rely for a multiplicity of important services.
- Asset management is proving to be a mechanism that helps integrate nature-related considerations into core local government decision-making, thus broadening its relevance beyond departments that focus on environmental matters.

1.2 Limitations & Assumptions

The S2S Project contains several limitations and assumptions. Specific assessment limitations are listed in *section 3.8*.

INCOMPLETE INFORMATION

As noted, asset management is an *adaptive* management cycle, not a finite process. While this report is current at the time of its writing, many elements will evolve in response to data, feedback loops, actions taken by Project Partners, and continuous improvement.

VALUATION

NAI estimated the value of some of the services from nature relevant to the beneficiaries in this project, including local governments and communities more generally. Together, these service values provide a composite figure that can be considered as a *minimum service value*.[15] This composite figure can support and inform decision-making; however, it is only part of a broader understanding of what is meant by nature's "value". Furthermore, only a portion of the many services provided by the ecosystems of the Watershed are valued in the S2S Project.

15 It is also important to recognize these findings in terms of minimum service value because, unlike engineered assets that depreciate and decay, natural assets are often adaptable, providing services that become more valuable over time within a changing climate.

MODELLING

NAI undertakes detailed hydrologic modelling to assess the Levels of Service (LOS) that natural assets provide, and the value of those services, to allow for service-based comparisons with engineered assets. However, all environmental modelling simplifies systems and is limited by the assumptions required for generalization.

For this project specifically, the following modelling limitations are noted:[16]

- Modelling focused on surface water only, except for Gibson Creek which has groundwater inflows that were considered.
- The Personnel Computer Storm Water Management Model (PCSWMM), the model used in the project, is limited in its ability to simulate non-urban systems, which is an important limitation in the context of natural assets for stormwater management as those assets typically include full watersheds extending beyond urban boundaries.
- It was not possible to use PCSWMM and the Coastal Toolbox for integrated modelling between terrestrial and coastal systems. Guidance is provided to integrate the systems during future modelling efforts (*see section 5* for further details).

INDIGENOUS PEOPLES

The project has several limitations with respect to Indigenous peoples. Indigenous traditional knowledge and practices are based in a holistic and inherent understanding of nature, the benefits it provides, and the connections between all living things. All NAM initiatives, including the S2S Project, will achieve better outcomes when it includes Indigenous worldviews, knowledge, and perspectives.

This requires sustained, meaningful collaboration with Indigenous Nations. The S2S Project provides an opportunity to learn from those who have lived in the region for millennia, and determine ways in which their knowledge and perspectives can inform and be included in all resultant project programming. The Squamish Nation was engaged in the S2S Project kick-off and provided input on the relevance of the watershed to their Nation (*see section on non-quantified values*), but capacity restrictions limited engagement in other project components.

There is little published literature specific to the uptake of NAM by Indigenous Nations, including First Nations.[17] Therefore, an understanding of how best to engage, and of specific barriers they may face, is similarly limited, due to factors including lack of research and reporting with Indigenous Nations, and differences in definition, approaches to managing assets, and cultural relationships with nature.[18]

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16 Assessment limitations are explained in further detail in section 4.4.

17 Reed et al. (2022).

18 NAI recognizes that not all asset management terminology and approaches may align with First Nations, Inuit and Métis worldviews and perspectives. These factors must be considered in future Project stages.

2 Local Context

This section introduces the local context for the S2S project including: the people of the area, its geography, land uses, risks to natural assets, risk management regime, and local readiness for NAM.

2.1 Indigenous Peoples

The Watershed is located on the unceded territory of the Skwxwú7mesh Úxwumixw (Squamish Nation); the S2S Project and related work respects their Rights and Title. The Town of Gibsons is committed to ensuring alignment between Town priorities and the Squamish Nation's values.

2.2 Geography

The term "watershed" refers to the land that water flows across on its way to a common stream, river, or lake. A watershed can be very large if the receiving body of water of interest is also large, such as a lake or a major river; or small, if the receiving body of water is small, such as a pond or stream. Watersheds may nest within other watersheds; those that nest within larger watersheds are often referred to as sub-catchments or catchments. Watersheds are a useful scale at which to consider NAM as the health and performance of individual natural assets are connected and interdependent.

Gibsons is situated along the perimeter of the Salish Sea at the entrance to Átl'ka7tsem/ Howe Sound (Figure 1). As of the 2021 Census of Population (Statistics Canada), the town was home to 4,758 residents. The project area selected is the same as for the Town of Gibsons 2013 aquifer study;[19] the northern project boundary is the top of Mt. Elphinstone.

The project area spans 2,269 ha (22.7 km^2) and encompasses the Town of Gibsons, portions of the Sunshine Coast Regional District (SCRD), and the four catchments that contribute flows to Chaster Creek, Gibson Creek, Charman Creek, and Soames Creek. The area receives approximately 1400 mm of rainfall a year, predominantly of low intensity and long duration.[20] Stormwater runoff discharges into the four creeks as well as several smaller coastal outfalls, including Goosebird Creek, which was included in the Town of Gibsons' Integrated Stormwater Management Plan (ISMP), and the 2018 update to the ISMP,[21] but is not considered in the present project. The discharge is generally rainfall-driven (as opposed to snowmelt-driven), which makes the creeks relatively flashy (quick to respond, within hours of the onset of a storm event). The quick response time can make it challenging to capture field measurements of peak discharge.

Figure 1 shows the project area as well as the catchment boundaries and stream paths from the BC Freshwater Atlas.

19 Town of Gibsons, (2013).

20 AECOM. (2010).

21 Urban Systems. (2019).

2.3 Land Use

As depicted in Figure 2, the project area services and is stewarded by multiple jurisdictions and right holders. This means that collaboration among stakeholders, multiple levels of government, and First Nations is essential to long-term success.

The Watershed is predominantly rural, comprised of mostly forested lands. Large areas of undeveloped land on Mt. Elphinstone, unceded by the Skwxwú7mesh Úxwumixw (Squamish Nation) and claimed by the Crown and the Sunshine Coast Regional District (SCRD), flow into Gibson Creek, Chaster Creek, and Soames Creek. Land-use ranges from:

- Forestry
- Mining
- Agricultural
- Residential
- Commercial
- Industrial

2.4 Risk Context

Climate change is shifting the overall risk context in the Watershed; predictions indicate an increase in the frequency and intensity of storms, altered precipitation patterns, a shift in the timing and volume of snowmelt during the spring freshet, and a decrease in summer stream flows.[22]

Based on this, the S2S Project prioritized and focused on three interconnected risks that relate to stormwater management: flooding and erosion, sea level rise and storm surge, and aging infrastructure.

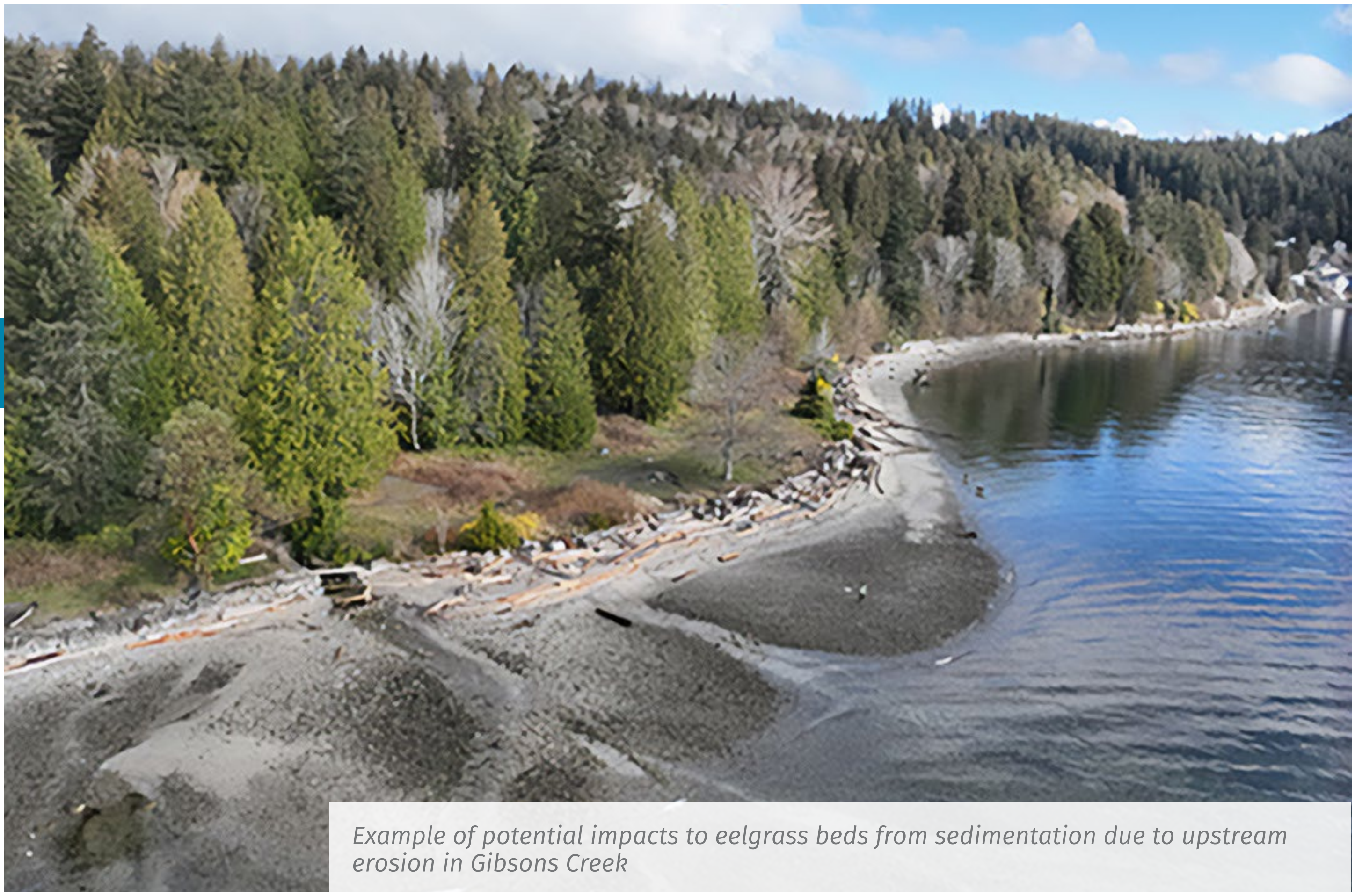
FLOODING AND EROSION

In Canada, flooding accounts for the largest portion of annual disaster recovery costs. Water damage is a key driver of increases in property and casualty insurance costs.[23] Atmospheric rivers hit southwestern British Columbia in November 2021, causing widespread damage which forced the SCRD to take emergency measures including evacuation orders, road closures, and boil water advisories. Service interruptions to water treatment plants were also experienced. In Gibsons, both fluvial (river) and coastal flooding contribute to flood risk.[24]

22 Ibid.

23 Moudrak et al. (2018).

24 Bartlett, K. (2021).



Example of potential impacts to eelgrass beds from sedimentation due to upstream erosion in Gibsons Creek

The ravines of Charman and Gibson Creeks have significant hazard areas with high estimated probabilities of erosion occurrence. Hazards include significant soil landslides, and related stream-flood and debris-flood hazards. Erosion also presents risks to aquatic ecosystems and biodiversity through excessive sedimentation. In terms of risks to the foreshore, the Town of Gibsons' Official Community Plan notes future erosion risk associated with sea-level rise, particularly along the shoreline in the inner harbour. This could leave the sewer line submerged and vulnerable to impacts of erosion. Along the beachfront, wave erosion may impact the safety of residents living on or near the bottom of steep slopes.

SEA LEVEL RISK AND STORM SURGE

Rising sea levels threaten coastal zones through a range of coastal hazards, including: (i) the permanent submergence of land by higher mean sea levels or mean high tides; (ii) more frequent or intense coastal flooding; (iii) enhanced coastal erosion; (iv) loss and change of coastal ecosystems; (v) salinization of soils, ground and surface water; and (vi) impeded drainage. Over the next century, without adaptation, the vast majority of low-lying coastal communities face substantial risk from these coastal hazards.[25] In Gibsons, two areas of

25 Oppenheimer et al. (2019).

focus for storm surge and erosion included the "South Side" and "Marina Side" (Figure 4). The South Side beaches (including Atlee Beach, Pebbles Beach and Georgia Beach) are exposed to large storm waves and tidal forces from the Salish Sea to the south. They are somewhat protected at low tide by the large shallow reaches of the Gibsons Shoals but have experienced coastal erosion. Concrete blocks have been installed along Atlee and Pebbles Beach for protection. The Marina Side includes the inner harbour, Armours Beach (North and South) and the Bluff. This area is protected from southern storms by the peninsula, Keats Island and two large jetties. However, the area's exposure to Átl'ka7tsem/Howe Sound and storms from the northeast means it is still vulnerable to coastal flooding and sea level rise. Riprap has been placed in some areas to protect against coastal erosion.

AGING INFRASTRUCTURE

Existing engineered stormwater infrastructure was not designed to cope with increased water volume and flow rate associated with storm events, and often requires upgrades to meet current standards and/or measures that limit demands on it, both in the Watershed and beyond. The latter could involve natural asset interventions to extend the life of aging infrastructure stock, an attractive approach given that neither climate risks nor population levels are likely to decline.

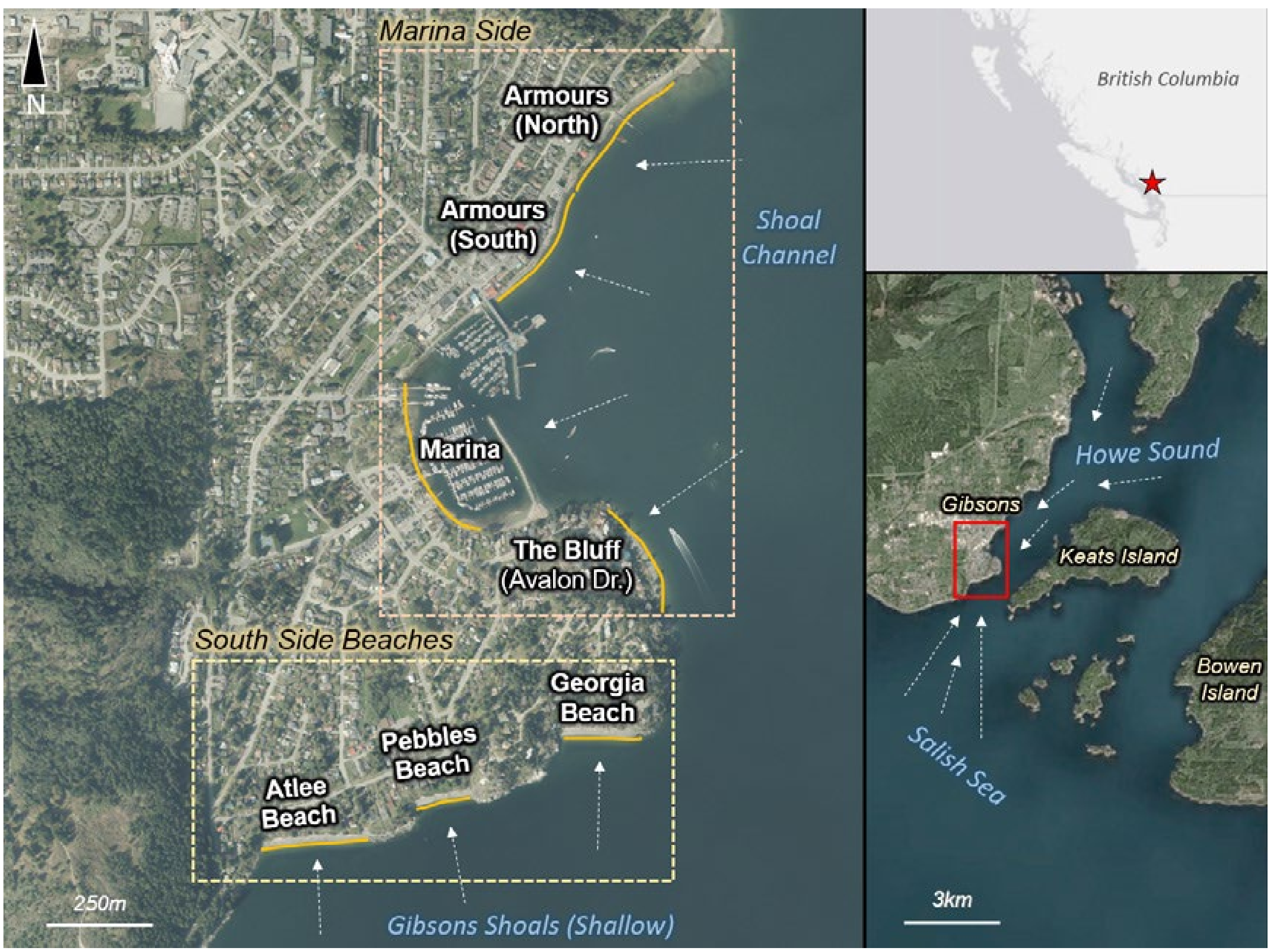


Figure 4: Coastal resilience project areas

2.5 Risk Management

Numerous risk management efforts have been taken over the last decade to mitigate risks from flooding, storm surge, and erosion challenges, for example:

- Development of education and awareness messaging to residents of the negative impacts of illegal dumping of green waste and refuse, particularly in the riparian areas and the foreshore.
- English ivy, Himalayan blackberry, horsetail, scotch broom and knotweed are a particular concern in the riparian areas and foreshore, as they choke out native vegetation and destroy habitat. In terms of invasive plant species management, the Town of Gibsons developed a knotweed management plan in 2019. Data on specific locations of knotweed and other invasive plant species is available through the BC government's Invasive Alien Plant Program (IAPP) Database, which the Town updates as new sites are discovered.
- All natural assets in Gibsons are at a high risk from development pressure.[26] Pollution, loss of native vegetation, increase demand on water supply, and sediment loading of creeks and the marine environment are all stressors associated with development. Risk management currently includes a Tree Preservation Bylaw, Development Permit Areas (DPA) Guidelines for environmentally sensitive and geotechnical hazard areas, in addition to the Town of Gibsons' Aquifer DPA to protect Aquifer 560 from land use and development activities that could compromise water supply and quality.

2.6 Governance, Policy and Structures

The Town of Gibsons' NAM approach, and therefore much of its success, historically has been confined to its jurisdictional boundary. This is because, as in most areas, ecosystem realities are misaligned with local, regional, and provincial governance and structures. Examples of how this impacts the Town's efforts include:

- Governance structures that exist at the scale of the watershed are fragmented and overlapping; different entities in the region are at different stages in terms of planning, monitoring, and implementation that affect natural assets; and there are few institutional or governance mechanisms that require or even facilitate dialogue across jurisdictional boundaries.
- There is no overarching strategy, imperative, or plan to ensure stewardship and protection of the ecological area in which Gibsons is located, notwithstanding the increased urgency created by climate change.
- There are no mechanisms that enable the Town of Gibsons to access relevant watershed scale data for areas beyond its jurisdiction.

26 Personal communications with Gibsons staff, October 2021.

These challenges have practical implications. For example, the recharge area of Aquifer 560, which is the Town's sole source of drinking water supply, extends beyond Town boundaries and its stability may be affected by actions elsewhere, including on private property and unceded land claimed by the Crown.[27] For example, there is industrial, commercial, and residential development occurring outside the Town's boundaries but within the Aquifer's recharge area.[28] Notwithstanding how essential the aquifer recharge area is to aquifer stability, it is challenging for the Town to monitor, much less act on, land outside its jurisdictional boundaries without the explicit collaboration of others. There is also no senior level of government with holistic responsibilities; the Province of BC has several Ministries with responsibilities to the aquifer recharge area (see Figure 2), but each has a separate mandate.

Another implication of these challenges is at play in the coastal areas of Gibsons. Due to its coastal vulnerability, the Town is actively pursuing a climate adaptation approach to help mitigate future damages from forecasted sea level rise and increased storm severity. However, Canadian coastal management for flood and erosion mitigation overlaps with multiple marine / coastal jurisdictions, making holistic action difficult. In addition to Gibsons, which sets and enforces regulations related to coastal development, provincial and federal governments set relevant regulations and laws (e.g., B.C. Environmental Land Use Act, Canadian Environmental Assessment Act). Importantly, jurisdictional overlaps may differ for natural versus hard/grey infrastructure assets, and management mechanisms available in one jurisdiction may influence natural assets in another. For example, septic systems that exist along coastlines may cause microbial or nutrient pollution in nearshore areas, which may subsequently affect nearshore seagrass beds. While subtidal seagrass beds may not fall within municipal jurisdiction, bylaws related to coastal septic systems can influence their condition.

On the positive side, there are multiple entities that can contribute important resources, data and expertise to support NAM to the extent that these entities can be mobilized around a common, coherent vision (see *Recommendations #3*, *#7* and *#11* in *Section 7.2*).

2.7 Coastal Resilience Project

The Town of Gibsons has already completed some coastal NAM activities through the *Managing Natural Assets to Increase Coastal Resilience* (Coastal Resilience) project in 2021. The project developed and tested a Coastal Toolbox (CT) model to determine how enhancing coastal natural assets like subtidal eelgrass, coastal vegetation or beach sediments could reduce flood and erosion impacts to the foreshore, especially if used alongside conventional grey infrastructure. Overall, the project demonstrated that:

27 MNAI 2023.

28 Personal communications with Gibsons staff, 2021.

- The CT is a rapid and easy-to-use tool that is sufficient for high-level initial screening and for quantifying the benefits associated with coastal natural assets.
- Natural assets provide protection against wave energy and water run-up, but not against storm surges and high tides.
- There are challenges associated with applying a generic tool to different types of coastlines. Gibsons' beaches are comprised of larger pebbles; at its current stage of development, the CT will be most applicable to areas with sandy shores.
- There's a need for a whole systems approach including exploring the role of watersheds in flood management.[29]

Through the Coastal Resilience project, it was also determined that climate change and extreme storms pose a future coastal flood risk for the Town of Gibsons, especially for buildings south and west of the marina (see Figure 5), but flood protection benefits provided by coastal natural asset alternatives are expected to be negligible. This does not preclude implementation of coastal natural assets, costs permitting, since these options would still provide multiple co-benefits of value to the community. It does make more relevant the question of whether terrestrial nature-based options in the watershed, like forest management and pond restoration, could provide the needed flood protection at equivalent (or lower) costs to grey infrastructure options (e.g., increased storm drain diameters, detention ponds, bypass pipes). If both types of storms do occur together (i.e., coastal storms and heavy rainfall events) their independent effects may result in cumulative flood and erosion damages in a single location over time and ultimately, backwater effects may be observed at the mouth of streams if tides and storm surge increase sea level elevation, thereby "backing up" the stream and possibly causing additional flooding.

The S2S Project built on these findings. It considered the role of watersheds in flood management and explored the extent to which terrestrial NAM contributes to both river and coastal flood mitigation, which would emphasize the need for a systems approach from source to sea in defining the role of natural assets in flood mitigation.[30]

2.8 Asset Management Readiness

In 2021, as part of the S2S Project, Gibsons, the SRCD and the District of Sechelt conducted an Asset Management Readiness Assessment adapted by NAI from a Federation of Canadian Municipalities (FCM) tool. The objective was to consider NAM maturity in relation to progress in asset management for engineered infrastructure. Four competency areas were explored: 1) Policy and Governance, 2) People and Leadership, 3) Data and Information, and 4) Planning and Decision-Making.

29 The *Coastal Resilience Guidance Document* addresses how to identify coastal jurisdiction considerations and recommends an approach to incorporating them into a project (see section 3.1, MNAI (2021b)).

30 See section 5 for recommendations on model integration.

Overall, the District of Sechelt and SCRD were at an early stage of formalizing asset management for both engineered and natural assets. The results below provide insights into the Town of Gibsons' maturity in asset management at the time the assessment was undertaken; they do not account for progress that may have been made since the assessment was undertaken.

COMPETENCY 1: POLICY AND GOVERNANCE

Gibsons has made significant progress in formalizing asset management and integrating natural asset considerations. The Town has an asset management policy that guides its asset management practices, and natural assets are recognized as part of its core infrastructure supporting service delivery. Gibsons had also created an asset management strategy and roadmap in 2017 (updated in 2019) using Asset Smart 2.0 and Asset Management BC's Roadmap template. The strategy was to be implemented over a three- to five-year timeframe. Gibsons was developing performance measures for asset management, working towards alignment of policies with its overall service delivery objectives and was beginning to develop formalized asset management plans. Performance measures existed for Aquifer 560 and were being developed for drainage and coastal assets.

COMPETENCY 2: PEOPLE AND LEADERSHIP

Gibsons is advanced in this competency area. Since 2012, Gibsons' Council has identified asset management as a key priority, and NAM-related activities are now included in operations and maintenance budgets. The Town now has a Natural Asset Technician responsible for incorporating NAM into municipal operations. Town policies contain well-defined roles and responsibilities for NAM, including a well-coordinated cross-departmental group committed to asset and natural asset management. The group includes the Chief Administrative Officer (CAO)/Chief Resiliency Officer (CRO), the Natural Asset Technician and representation from the Finance, Infrastructure Services, and Planning departments.

COMPETENCY 3: DATA AND INFORMATION

At the time of the assessment, the Town of Gibsons had inventoried all horizontal engineered assets and were in the process of completing inventories of other assets, such as parks and buildings. They had lifecycle data for critical water and sewer assets and were developing LOS. Asset management and financial information was not yet linked. They had begun work developing a basic inventory for natural assets, including the urban forest, and already had data related to water and drainage systems. The Town had in place a 10+-year monitoring program for the Aquifer 560 for both water quality and quantity. Data collected is used to inform strategy and by-laws. The Town also supports the Nicholas Sonntag Marine Education Centre (NSMEC) through the Healthy Harbour Project, which, among a multitude of initiatives, monitors eelgrass beds to inform protection. At the time of this report, the Town and was in the process of creating a budget for monitoring of urban forests and creeks, which lacked performance measures. In terms of financial data, the Town was at an early stage of documenting capital and operating expenditure data for engineered assets, which had been done for water and sewer assets. It had completed an economic valuation of the aquifer based on replacement costs.

COMPETENCY 4: PLANNING AND DECISION-MAKING

The Town has made progress in developing a structured approach to asset management to fully integrate natural assets (e.g., the approach for the Whitetower Park constructed wetlands and the foreshore area); staff were in the process of working on a water service NAM plan at the time of the assessment. All budgeting uses an asset management lens and the Town bases decisions on a long-term asset management financial model. Level of service work and risk assessments for engineered assets were under development and natural assets are being incorporated into asset management plans by service area. The Aquifer Mapping Study is an excellent example of a risk-based approach to decision-making undertaken by the Town.[31]

31 Gibsons' Aquifer Mapping Study is available at *gibsons.ca/sustainability/the-gibsons-aquifer/aquifer-mapping/*

3 Current State of Natural Assets

This section describes the results of the NAM assessment phase for natural assets in the Watershed, their condition, the risks they face, their service value, and options to continue enhancing understanding.

The NAM assessment phase[32] provides a baseline understanding of the current services that natural assets provide, and some corresponding values. Below are the results, including:

- The approach to identify and inventory natural assets in the Watershed.
- The current condition of natural assets in the Watershed.
- The value of a range of different services provided by the natural assets.
- The current risks to natural assets in the Watershed.

3.1 Identification of Natural Assets

As depicted in Figure 3, a natural asset inventory is a first component of the NAM assessment phase and was an early deliverable of the S2S Project. Natural asset inventories provide details on the types of natural assets upon which a local government relies, their condition, and the risks they face. Mapping the natural features of the Watershed involved:

1/ **Defining the natural assets**. This required combining information from existing data sets based on a hierarchy that prioritized best available data.

2/ **Splitting assets by sub-catchment boundaries**. Some natural asset areas cross sub-catchment boundaries within the Aquifer 560 Watershed. To link the assets to their respective sub-catchment, individual assets were split according to these boundaries.

3/ **Adding attributes to describe natural assets**. Once the base asset inventory was established, additional attributes beyond boundaries were added to define whether the assets are associated with:

  a/ Land use zoning

  a/ Official Community Plan land use

Table 1 shows the asset composition of each sub-catchment, as well as for the non-sub catchment area, for the selected natural asset types (forests, riparian areas, wetlands) that contribute to stormwater management. Appendix A provides the dataset used and their sources.

32 See Figure 3

SUB-CATCHMENT	TOTAL AREA (HA)	FORESTS (HA)	RIPARIAN AREAS (HA)	WETLANDS (HA)
Charman	125.2	75.6 (60%)	12.4 (10%)	0.7 (0.6%)
Chaster	986.3	758.6 (77%)	116.8 (12%)	13.9 (1%)
Gibson	278.4	228.3 (82%)	36.0 (13%)	0.0 (0%)
Soames	176.4	122.7 (70%)	116.8 (66%)	0.0 (0%)
Area outside catchments	702.8	220.0 (31%)	10.8 (1.5%)	4.8 (0.6%)

Table 1: Natural assets composition of the four catchment and the non-catchment areas in the project area

The S2S Project inventory is available for viewing in a web-based dashboard.[33]

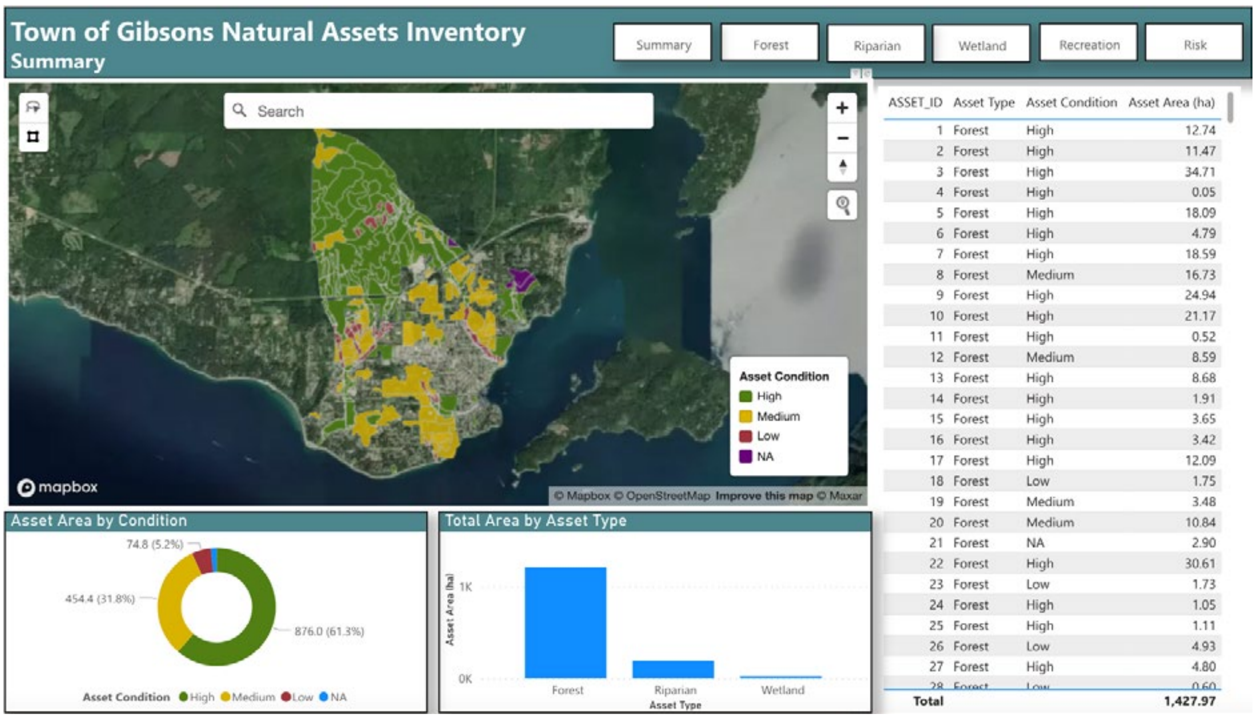


Figure 5: Screenshot of the Aquifer 560 Watershed's natural asset inventory online dashboard

3.2 Condition

Natural asset conditions influence their ability to provide services and resiliency to stressors and risk, among other things. A condition assessment provides valuable information on how well natural assets function relative to their ability to provide specific services. Baseline condition assessment data, expressed in an inventory, can be used to assess changes in the level of service provision that result from impacts or interventions that either improves or degrades asset conditions.

33 This interactive tool permits users to explore geographic differences at the sub-catchment scale and across jurisdictional boundaries, and to examine components that contribute to condition and risk ratings. Visit the *dashboard*

Condition assessments can be done using desktop reviews, reviews of past studies, field observations, and combinations thereof. In the case of the S2S Project, the condition assessment is based on a GIS desktop assessment.

The over-arching framework utilized by NAI was developed by NatureServe, and applied to the project area through the identification of indicators by ESSA. It used a three-level approach to provide a standard process to assess ecosystem health by considering its component vegetation, soil, and hydrology, as well as its size and interactions with the surrounding landscape.

The methodology utilized for ranking high, medium, low is based on parameters of size, condition, and land-use. Four condition metrics were incorporated into the S2S Project condition assessment:

1/ **Canopy closure**: Forest area health is based on the assumption that larger forest assets with larger canopy cover mean better forest condition. Forested assets were rated as:
   - **Low** – assets with closure of less than 50%
   - **Medium** – assets with closure of 50-70%
   - **High** – assets with canopy closure greater than 70%

2/ **Linear road density**: High road density implies more fragmentation and higher hydrologic impairment of water flows, which can cause changes to the quantity, quality, velocity and temperature of water flows in creeks. This was measured as km of road per square kilometers of area with the following condition ratings assigned according to the density of roads:
   - **Low** – asset with road density greater than 2km per km2
   - **Medium** – assets with road density between 1km and 2km per km2
   - **High** – assets with road density less than 1km per km2

3/ **Tree height**: In addition to canopy closure, forest area health is based on the assumption that a larger average tree height represents a more well-established forest area. Forest assets (which are primarily coniferous) were rated as:
   - **Low** – average tree height less than 7m
   - **Medium** – average tree height between 7 and 9m
   - **High** – average tree height greater than 9m

4/ **Riparian area**: The percentage of the sub-catchment that is riparian area, defined as areas within 30m of streams, lakes, and wetlands that link water to land.[34]

Figure 6 shows the percentage area of natural assets within the Watershed by condition rating. The majority (approximately 60%) of assets are rated in high condition.

34 See Riparian Areas Protection Regulation (RAPR, 2019

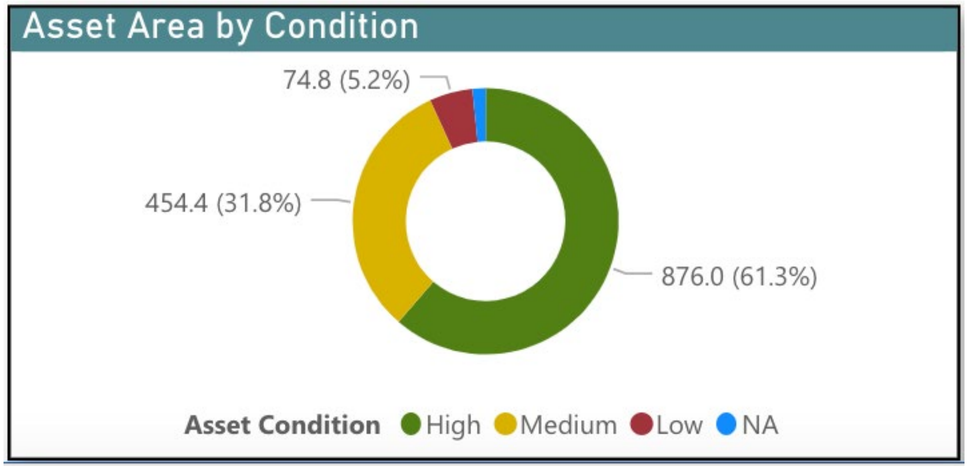


Figure 6: *Percentage of asset area by condition*

3.3 Value of Natural Asset Services

NAM is about far more than assigning a financial value to their services. Nevertheless, valuations can be helpful tools to build awareness and inform decision-making when they are situated within a broader understanding of the importance of nature. Table 2 summarizes the co-benefits considered for the project, which demonstrates the breadth services provided by nature in addition to stormwater regulation priorities.

CO-BENEFIT	RELEVANCE TO THE TOWN OF GIBSONS	FORESTS	WETLANDS
Air quality regulation	Forests play a role in removing toxins from the air	x	
Aesthetic appeal	Forests and wetlands contribute to the area's natural beauty, which attracts migrants and visitors	x	x
Climate change mitigation	Forests play a role in carbon storage and sequestration, which contributes to global climate change mitigation	x	x
Culture maintenance	Forests and wetlands contribute to the ability of Indigenous people to maintain a connection to their culture and heritage	x	x
Erosion prevention	Forest root networks help hold the soil around trees, which reduces the risk of landslides and stream sedimentation	x	
Food production (fish)	Salmon spawning in the watershed contribute to commercial, recreational, and subsistence fishing. Forests contribute to salmon habitat by providing shade and woody debris	x	
Food production (mushrooms)	Forests provide habitat for mushrooms, which are sold commercially or used for subsistence (wild mushroom harvest)	x	
Habitat provision (supporting services)	Forests and wetlands provide habitat for plants and animals that then supply other co-benefits (this is a supporting ecosystem service and should not be double counted during valuation)	x	x

CO-BENEFIT	RELEVANCE TO THE TOWN OF GIBSONS	FORESTS	WETLANDS
Health improvement	Forests and wetlands provide opportunities for exercise and time in nature, which, lowers rates of illness, decreases stress, and improves cognitive development	x	x
Pollination (supporting services)	Forests and wetlands can provide pollinator habitat. Pollinators then contribute to agricultural food production (this is a supporting ecosystem service and should not be double counted during valuation)	x	x
Recreation & tourism opportunities	Forests and wetlands provide opportunities for recreational activities enjoyed by residents and visitors (e.g., hiking, walking, mountain biking, camping, birdwatching)	x	x
Science & education opportunities	Forests and wetlands provide opportunities to do scientific research and for public education (e.g., school tours)	x	x
Soil formation (supporting services)	Forests deposit dead organic matter, which decays and becomes part of the soil, contributing to other co-benefits like timber production (this is a supporting ecosystem service and should not be double counted during valuation)	x	
Timber production	Logging occurs in the Chaster Creek catchment	x	
Water supply	Forests play a role in the capture of water and its infiltration into the groundwater supply	x	
Water quality regulation	Forests and wetlands help filter pollutants from the water supply (e.g., nonpoint source pollution from agriculture, roads)	x	x

***Table 2:** Range of co-benefits associated with forests and wetlands*

STORMWATER REGULATION SERVICES

- **Scenario 1:** reflects baseline conditions (i.e., the location and extent of existing natural assets) of the Watershed to manage a 12hr 100yr storm, which has a 1% chance of occurring in any given year)
- **Scenario 2:** assumes natural assets are removed and replaced with a "single-family residential" land-use type in Charman Creek and a "forestry practices" land-use type in Chaster, Gibson, and Soames Creek sub-catchments. The same rainfall event as Scenario 1 is modelled to demonstrate the peak flow and infiltration changes without the natural assets.

After modelling, a valuation of the role of natural assets in SWM was undertaken to quantify benefits by analyzing the capital replacement cost of natural assets with built stormwater infrastructure. The analysis did not include operating, maintenance, and renewal costs; good asset management planning requires an understanding of infrastructure lifecycle costs. Although this costing was unable to be completed within the Project timeframe, the Town was provided with a template of common costs that could be used to develop estimates for annual budgets. Table 3 below provides valuation results for baseline stormwater management services.

Based on the modelling and valuation, the conceptual cost of replicating natural assets' hydrologic functions using conventional SWM and low-impact development (LID) solutions (e.g., bio-retention areas, infiltration trenches, permeable pavements) was estimated at a rate of $65.11/m² for forest (riparian and non-riparian), and $268.84/m² for wetlands.

The total value of natural assets for one service — stormwater management — is thus estimated at more than $40 million ($40,924,000) for the forests and wetlands of the Aquifer 560 Watershed.

CATCHMENT	AREA (HA)	BASELINE NATURAL ASSET VALUE (2022 CAD $ '000)
Charman Creek	**156.5**	
Forests	72.8	$826
Riparian Areas	13.7	$158
Wetlands	0.7	$1,041
Total		**$2,025**
Chaster Creek	**695.4**	
Forests	590.9	$22,189
Riparian Areas	104.5	$4,170
Wetlands	0	n/a
Total		**$26,359**
Gibson Creek		
Forests	257.0	$6,024
Riparian Areas	33.8	$1,362
Wetlands	0	n/a
Total		**$7,386**
Soames Creek	**176.4**	
Forests	116.3	$4,981
Riparian Areas	8.0	$173
Wetlands	0	n/a
Total		**$5,154**
All Areas		
Forests	1,036.1	$34,020
Riparian Areas	160.0	$5,863
Wetlands	0.7 ha	$1,041
Grand total		**$40,924**

Table 3: Valuation results for stormwater management per sub-catchment under each natural asset class

***Note:** All values are rounded up to the nearest thousand ('000). Blank cells are not relevant to the scenario.*

3.4 Value of co-benefits

The S2S Project also explored the non-infrastructure services, or co-benefits, listed in Table 2; those chosen and measured for the project are described in more detail in Table 4.

SERVICE	DESCRIPTION	OUTCOME MEASURED
Recreation	Non-market value derived from engaging in recreation activities within the Gibsons' watershed (e.g., biking, boating, motoring, fishing, etc.)	Value people place on recreation opportunities
Water quality regulation	Estimates the value of water quality regulation by forests & wetlands using a replacement cost approach based on the cost of treatment for drinking water	Value people place on clean drinking water
Climate mitigation (e.g., carbon storage & sequestration)	Addresses the non-market values associated with the regulation of climate, including regulating albedo (ability of a surface to reflect light), some aspects of greenhouse gas emissions, & carbon sequestration.	Value of carbon sequestered by natural areas
Habitat provision	Addresses the non-market values associated with the refuge & reproductive habitat that ecosystems provide to wild plants and animals.	Value people place on preservation of biodiversity & habitat
Science and education opportunities	Assesses the social value of publications in social & natural science academic journals arising from research activities.	Value people place on research publications
Maintenance of culture	Addresses the role of natural resources in Indigenous well-being. This can include maintenance of culture, food, ceremony, sites of importance, etc.	Addressed qualitatively

Table 4: Summary of Services Explored, their Descriptions, and the Outcome Measured

Except carbon sequestration, average values per unit area (per ha) of different land cover types were extracted from primary studies that had ecological and socio-economic similarities. To the extent possible, results were adjusted to the local context, converted to current 2022 CAD $, and applied to the land cover classification from the inventory. For carbon sequestration, average rates of carbon sequestration by land cover type were extracted from relevant literature (see Table 7) and applied to the inventory area. Value was then calculated using the price of carbon. Details were provided to Project Partners and are summarized here.

Not every priority co-benefit can be assigned a dollar value with current economic methods because they are difficult or impossible to quantify (e.g., maintenance of culture). For co-benefits that cannot be monetized, there is a qualitative description. Further, when adding economic value across multiple co-benefits, one must be careful not to double count. For example, habitat provision is a supporting ecosystem service that is foundational to the provision of other services, so its value should not be added to that of other co-benefits unless those it supports are excluded from the calculus.

RECREATION

The Watershed provides many recreational opportunities that are of tangible benefit to the communities.

Existing BC-based research[35] was employed to estimate forest-based recreational use for forests in British Columbia's Vancouver Forest Region on a per-hectare basis and adjusted to the study area. No BC-based wetland recreation studies were identified, so a Portland, Oregon study[36] which applied hedonic pricing to estimate a recreation value of wetlands was used. Table 5 below provides the summary of recreational values by asset class.

ASSET CLASS	RECREATION VALUE	AREA OF NATURAL ASSETS	ANNUAL RECREATION / TOURISM BENEFITS
Non-riparian Forests	$157.67 ha/yr	1234.9	$195,000 / yr
Riparian Forest	$157.67 ha/yr	170.2	$27,000 / yr
Wetland	$470.52 ha	18.7	$9,000
		Total annual benefits	**$222,000/yr**
		Total one-time benefits ("in the bank")	**$9,000**

***Table 5**: Summary of recreational values by asset class*

***Note:** Annual benefits were rounded to the nearest $1,000 to emphasize that these values should be considered order of magnitude estimates only.*

35 Morton et al. (2021); Knowler and Dust (2008).

36 Mahan et al. (2000).

WATER QUALITY REGULATION

Residents are justifiably grateful for the high-quality water the Town enjoys, nearly 100% of which is drawn from Aquifer 560.[37] Natural assets support water quality regulation; for example, forests and wetlands intercept precipitation and impact the volume and timing of runoff and storage in surface and groundwater sources.[38] During these processes, natural assets moderate stream temperatures, sediment loads, nutrient loads, biological contaminants, and concentrations of chemical pollutants,[39] thus reducing costs of drinking water treatment from surface and groundwater sources.

To estimate the value of water quality regulation by forests and wetlands we utilized a study by Wilson (2010) that found the cost of treatment for drinking water increases by 20% for each 10% decrease in forest cover.[40] For wetlands, a study by Anielski and Wilson (2005) was used that based values on a review of 89 wetland studies globally. Table 6 below provides a summary of water quality regulation benefits from forests and wetlands in the project area.

ASSET	WATER QUALITY REGULATION VALUE ($/HA/YR)	AREA OF NATURAL ASSETS (HA)	ANNUAL WATER QUALITY REGULATION BENEFITS ($/YR)
Non-riparian Forest	$2,691	1234.9	$3,323,000
Riparian Forest	$2,691	170.2	$458,000
Wetland	$540	18.7	$10,000
		Total annual benefits	**$3,791,000**

Table 6*: Water quality regulation benefits from forests and wetlands in the Aquifer 560 Watershed*

Note: *Annual benefits are rounded to the nearest $1,000.*

CLIMATE CHANGE MITIGATION

BC residents face multiple challenges related to climate change such as increased frequencies of flooding, wildfires, and drought.[41] Forests can help mitigate climate change by storing and sequestering carbon. Valuing forest-based carbon benefits typically requires estimating the volume of carbon stored and sequestered, then multiplying that amount by a per unit monetary value. Valuation options include using a) the market-based cost of recapturing carbon; b) the cost of mitigating carbon emissions; and c) prices from actual carbon markets (e.g., cap and trade).[42]

37 Gibsons won "World's Best Water" at the Berkeley Springs International Water Tasting Contest in 2005

38 Calder et al. (2008); Dudley and Stolton (2003).

39 Ayenew and Tesfay (2015); Dudley and Stolton (2003); Duffy et al. (2020)

40 Ernst et al. (2007).

41 BC Auditor General. (2018)

42 Kulshreshtha et al. (2000).

Since the S2S Project is interested in the current baseline value of carbon storage provided by forests in the Watershed, both a carbon storage value and a sequestration value are provided. Note that carbon storage values are not annual values as the volume of carbon stored in the Watershed's forests will increase annually by the sequestration rate as trees grow. The results for carbon storage should be interpreted as one-time benefits "in the bank". Sequestration is reported separately and represents an annual value. Table 7 provides a summary of carbon storage benefits from forests in the project area.

ASSET	**TOTAL BIOMASS** (M^3)	**STORED CARBON** (TC)	**STORAGE VALUE** ($/TC)	**VALUE OF STORAGE BENEFITS** ($ Value of storage benefits ($))
Non-riparian Forest	28,524	14,262	$12.27-15.68	$175,000 – 224,000
Riparian Forest	4,350	2,175	$12.27-15.68	$27,000 - $34,000
			Total one-time benefits ("in the bank")	**$202,000 – 258,000**

***Table 7:** Carbon storage benefits from forests in the Aquifer 560 Watershed*

***Note:** Annual benefits were rounded to the nearest $1,000 to emphasize that these values should be considered order of magnitude estimates only.*

An estimated annual value of carbon sequestration relied on an assumed sequestration rate from Green Analytics (2020). The annual carbon sequestration benefits are shown in Table 8.

ASSET	**SEQUESTRATION VALUE** ($/HA/YR)	**AREA OF NATURAL ASSETS**	**ANNUAL SEQUESTRATION BENEFITS** ($/YR)
Non-riparian Forest	$272	1234.9	$336,000
Riparian Forest	$272	170.2	$46,000
Wetland	$434	18.7	$8,000
		Total annual benefits	**$390,000**

***Table 8:** Carbon Sequestration Benefits from Forests and Wetlands in the Aquifer 560 Watershed*

***Note:** Annual enefits were rounded to the nearest $1,000 to emphasize that these values should be considered order of magnitude estimates only.*

HABITAT PROVISION

Forest and wetland natural assets within the Watershed provide important habitat for plants and animals. Gibson Creek, which forms the boundary between the Town of Gibsons, the SCRD, and Ch'k̲w'elhp (Squamish Nation Reserve Land), is classified as an ecologically sensitive watercourse that supports cutthroat trout and is a spawning stream for pink and chum salmon.[43] Charman Creek supports fish in its lower drainage and is considered "a sensitive

43 AECOM (2010).

watershed, both environmentally and geotechnically".[44] Less information is available for Chaster and Soames creeks since they fall outside the Town's jurisdiction and were not included in its ISMPs, but the SCRD's 2009 ISMP does indicate that Soames Creek is fish bearing.[45] The riparian area around Soames Creek is considered a wildlife corridor by the West Howe Sound OCP. The Elphinstone OCP also indicates that Chaster Creek supports chum and coho salmon.[46]

Under the Millennium Ecosystem Service Assessment (MEA) classification scheme, habitat provision falls under the "supporting services" category, which has proven problematic for valuation purposes due to overlaps with other categories resulting in double counting.[47] As such, habitat provisions are not considered to be a terminal ecosystem service like other co-benefits included in this report, so valuation results for this service should not be added to results for other co-benefits.

Habitat services provided by forest and riparian areas were estimated using two studies to represent the range of possible values. They are a 2003 study by Knowler et al. that used coho salmon as an indicator species and developed a production function to estimate the value of forested habitat loss, and a 1997 study by Kulshreshtha and Loewen that assessed the value of habitat provision by using willingness-to-pay (WTP) surveys in Saskatchewan. Table 9 below provides a summary of habitat provision benefits from forests and wetlands.

ASSET	**HABITAT PROVISION VALUE** ($/HA)	**AREA OF NATURAL ASSETS** (HA)	**TOTAL HABITAT PROVISION BENEFITS** ($)
Non-riparian Forest	$8.82 – 168.22	1234.9	$11,000 – 208,000
Riparian Forest	$8.82 – 168.22	170.2	$2,000 – 29,000
Wetland	$371.37	18.7	$7,000
		Total annual benefits	**$20,000 – 244,000**

Table 9: Habitat provision benefits from forests and wetlands in the Aquifer 560 Watershed

SCIENCE AND EDUCATIONAL OPPORTUNITIES

The potential for research on forests in the Watershed is high given the relatively large number of nearby research institutions that host forestry and/or natural resource management departments, including Capilano University, University of British Columbia, Simon Fraser University, University of Victoria, British Columbia Institute of Technology, Royal Roads University, and Vancouver Island University.

44 ibid

45 SCRD (2011).

46 SCRD (2008).

47 Böhnke-Henrichs et al. (2013).

To estimate the value of science and educational opportunities, a study by Morton et. al. (2001) that assessed the social value of publications in social and natural science academic journals arising from research activities was used. Table 10 below provides a summary of the estimated value of science and educational benefits.

ASSET	**HABITAT PROVISION VALUE** ($/HA)	**AREA OF NATURAL ASSETS** (HA)	**TOTAL HABITAT PROVISION BENEFITS** ($)
Non-riparian Forest	0.07783	1234.9	$96
Riparian Forest	0.07783	170.2	$13
Wetland	0.07783	18.7	$1
		Total annual benefits	**$119**

Table 10*: Science and education benefits from Forests and wetlands in the Aquifer 560 Watershed*

Note: *Annual benefits were rounded to the nearest $1 to emphasize that these values should be considered order of magnitude estimates only.*

3.5 Non-quantified Values

In consultation with the S2S Project Partners, NAI identified and qualitatively addressed an additional benefit: Maintenance of culture. The importance of this benefit is widely acknowledged but few studies quantify it, and no appropriate studies were identified for transferring to the project area.

MAINTENANCE OF CULTURE / INDIGENOUS VALUES

Maintenance of culture is a non-material benefit derived from ecosystems that contributes to human wellbeing,[48] and provides a sense of place, a desire to engage in stewardship initiatives, and spiritual value.[49] This benefit includes the importance of the Watershed in cultural traditions and folklore, and the appreciation a community has for local ecosystems. It is meant to represent the cultural heritage and identity of all peoples in a project area but can be used to refer only to that of Indigenous peoples, which is how it is applied here. In commonly used ecosystem service classification systems (e.g., CICES, TEEB), this co-benefit excludes aesthetic and formal religious experiences, which are usually treated separately.

As a co-benefit, maintenance of culture is a subset of the broader category "cultural ecosystem services" (CES). While CES is treated as a discrete category, it is acknowledged that CES can be understood as the lens through which most other ecosystem services derive meaning.[50]

48 MEA 2003; Martin et al. (2016).

49 Chan et al., 2012; Klain and Chan. (2012).

50 Chan and Satterfield, 2015; Chan et al. (2011); Church et al. (2011); Poe et al. (2011); de Groot at al. (2005).

CES are often the co-benefits most valued by community members,[51] but they are frequently overlooked because their intangible nature makes them challenging to identify and evaluate. Economic valuation studies that include CES considerations tend to focus on recreation, tourism, and scenic beauty, as these types of CES are easier to quantitatively assess.[52] Few studies have attempted to quantitatively evaluate other aspects of CES such as cultural identity, and sense of place.[53]

The S2S Project area is integral to the culture, history and heritage of the Squamish Nation.

The following information was provided by Ta na wa Ns7éyx̱nitm ta Snew̓íyelh of the Skwxwú7mesh Úxwumixw (Squamish Nation).

The area called Ch'ḵw'elhp and Scheń̓ḵ (Gibsons) is the site of an early Sḵwx̱wú7mesh village. It was both a permanent village and a seasonal camp, used by Sḵwx̱wú7mesh people who travelled from the Squamish area to Gibsons and back. It was a shared place, as with all villages, between permanent villagers and seasonal visitors. There are two place names associated with the general area extending from Gibson Creek to Gibsons Harbour: Scheń (leaning or steadying rear against something) and Ch'ḵw'elhp (spruce). Part of the land in this area is still recognized as reserve lands belonging to ta Sḵwx̱wú7mesh Úxwumixw (the Squamish Nation). Many Sḵwx̱wú7mesh people are descendants of the inhabitants of this place and still have ties to Ch'ḵw'elhp and Scheńḵ.

This area is known as one of the origin places of the Sḵwx̱wú7mesh people and is included in the Nation's plans for future land use. The Sḵwx̱wú7mesh people have occupied the present-day Sunshine Coast since the beginning of time. Our place names, lineage, and legends establish a long and continuous history.

According to the 1876 census, there was a large longhouse, a burial ground, a potato patch, and a hunting and fishing station in the Gibsons area. It was also a plant gathering area, where medicinal plants were grown. Ancestral remains still exist in this region.

Ch'ḵw'elhp and Scheńḵ are important ḵwex̱nís (sea lion) hunting grounds as well as cháchu7 (saltwater hunting) grounds for the Sḵwx̱wú7mesh people and were rich/abundant with other marine life, including sts'úḵwi7 (salmon), x̱íxwa (sea urchin), asxw (seal), sheykw (clam), skeḿts (littleneck clam), yéw̓yews (orca), and ḵwenís (whale).

The Gibsons area also includes archeological sites and middens.

51 Rodrigues et al. (2017).

52 Rees et al. 2010, Guerry et al. (2012), Wiehl and Manns. (2014).

53 Rodrigues et al. (2018).

Tables 11-13 summarizes co-benefit valuation results for forest and wetland natural assets in the Aquifer 560 Watershed.

SERVICE	NON-RIPARIAN FOREST	RIPARIAN FOREST	WETLAND	COMBINED VALUE
Recreation	$195,000	$27,000		$222,000
Water quality regulation*	$3,323,000	$458,000	$10,000	$3,791,000
Carbon sequestration	$336,000	$46,000	$8,000	$390,000
Science and educational opportunities	$96	$13	$1	$110
Total	**$3,854,096**	**$531,013**	**$18,001**	**$4,403,110**

***Table 11**: Summary of annual co-benefit values from forests and wetlands in the Aquifer 560 Watershed (2022 CAD)*

** Results are based on value transfer from surface water studies, not groundwater studies. The Town of Gibsons relies primarily on groundwater.*

SERVICE	NON-RIPARIAN FOREST	RIPARIAN FOREST	WETLAND	COMBINED VALUE
Recreation			$9,000*	$9,000
Carbon storage†	$175–000 - 224,000	$27–000 - 34,000		$202–000 - 258,000
Total	**$175–000 - 224,000**	**$27–000 - 34,000**	**$9,000**	**$211–000 - 267,000**

***Table 12**: Summary of 'One-Time' co-benefit values from forests and wetlands in the Aquifer 560 Watershed (2022 CAD)*

** Not possible to annualize due to hedonic pricing method used by value transfer source.*

*† Storage is the current base value and is not an annualized amount like sequestration, which occurs over time. **Note:** Low-end values are used here to err conservatively.*

SERVICE	NON-RIPARIAN FOREST	RIPARIAN FOREST	WETLAND	COMBINED VALUE
Habitat provision‡	$11,000 – 208,000	$2,000 – 29,000	$7,000	**$20,000 – 244,000**

***Table 13**: Summary of 'One-Time' Co-Benefit Values from Forests and Wetlands in the Aquifer 560 Watershed (2022 CAD)*

‡ Habitat provision intentionally separate to avoid double counting.

3.6 Risk Identification Results

This sub-section provides an overview of the risk identification completed for the project. It is a starting point for understanding risks to natural assets and their associated services, rather than a full risk assessment, which is a detailed process that includes risk identification, analysis of probability and consequence, development of risk mitigation strategies, and control and documentation. Risks relevant to NAM typically include:

- **Service risk:** the risk of an asset failure that directly affects service delivery.
- **Strategic risk:** the risk of an event occurring that impacts the ability to achieve organizational goals.
- **Operations and maintenance risk:** risks related to poor asset controls and oversight, which can lead to poor record-keeping, poor management, and poor monitoring of assets.
- **Financial risk:** risks related to financial capacity to maintain local government services.
- **Political risk:** risks related to the nature of municipal politics; specifically, the values and priorities of decision-makers or the community that may not align with NAM.

RISK METHODOLOGY

In October 2021, Town of Gibsons staff participated in an NAI-led risk management workshop to identify risks to natural assets and their associated services. This exercise led staff to identify a total of 13 stressors,[54] including:

1/ Development Pressure
2/ Erosion
3/ Green waste dumping
4/ Invasive plant species
5/ Drought (current and future)
6/ Deforestation
7/ Flooding (current and future)
8/ Forest Fire
9/ Pollutant loading from urban, agricultural or industrial sources (e.g., road salts)
10/ Storm events (rainfall)
11/ Storm surge
12/ Sea level rise
13/ Ocean temperature rise

Natural asset classes considered:

- Foreshore
- Creeks
- Forest
- Urban Forest
- Wetlands and Ponds
- Riparian Areas
- Eelgrass
- Aquifer

54 Stressors' become 'risks' when they have been identified as high probability and high consequence.

SUMMARY OF RISK RATINGS AND RISK MANAGEMENT

Table 14 below summarizes the natural asset risk ratings.

RISKS	FORESHORE	CREEKS	FOREST	URBAN FOREST	WETLANDS & PONDS	RIPARIAN AREAS	EELGRASS	AQUIFER	H COUNT
Green waste dumping	H	H	M	H	M	H	L	L	**4**
Flooding (current & future)	M	H	L	L	L	M	L	L	**1**
Forest fire	L	L	M	L	L	M	L	L	**0**
Invasive species	L	H	H	H	M	H	M	L	**4**
Development pressure	M	H	H	H	H	H	M	H	**6**
Pollutant loading	L	M	L	M	H	L	M	L	**1**
Storm events (rainfall)	M	H	L	L	M	H	M	L	**2**
Drought (current & future)	L	L	H	H	L	M	L	H	**3**
Erosion	H	H	L	L	L	H	L	L	**3**
Storm surge	H	L	L	L	L	L	H	L	**2**
Sea level rise	H	L	L	L	L	L	H	M	**2**
Ocean temperature rise	L	L	L	L	L	L	H	L	**1**
Deforestation	L	H	H	M	M	H	M	H	**4**

***Table 14**: Final ranking of natural asset risks*

***Note:** Top risk categories are highlighted in orange.*

The natural asset types that faced the highest number of risks were creeks (7 high risks) and riparian areas (6 high risks), followed by the foreshore (4 high risks) and the urban forest (4 high risks). Priority risks and their associated risk management in the Town of Gibsons are discussed below. Note that the management strategies identified during the workshop are broad, Town-wide strategies.[55]

GREEN WASTE DUMPING

The foreshore, creeks, the urban forest, and riparian areas were identified at high risk from green waste dumping. The 2014 Foreshore Condition Assessment Report noted that on the southern beaches on Franklin Road, properties were experiencing erosion and land accretion due to coastal storm surges and an abundance of groundwater seepage. Green waste dumping may have exacerbated these issues.

55 Recommended actions from this study are specific to the project area and found in *Section 7*.

Management Strategy: Measures currently being taken by the Town to mitigate this risk include the development of education and awareness messaging to residents to curb dumping, particularly in the riparian areas and the foreshore.

INVASIVE PLANT SPECIES

Creeks, forests, the urban forest, and riparian areas were identified at high risk from invasive plant species, with knotweed, blackberry, English ivy, and Scotch Broom noted as species of concern. Past creek assessments undertaken by the Town noted knotweed as a particular concern as it chokes out native vegetation and destroys native habitat.

Management Strategy: To manage invasive plant species, the Town of Gibsons developed a knotweed management plan in 2019. Data around specific locations of knotweed may be available through the BC government's Invasive Alien Plant Program (IAPP) Database. In 2020, staff proposed an invasive plant species bylaw which aimed to require control of invasive plant species by private property owners within 30 days of notification and provide authority to the Town to control or remove in the event of non-compliance. The bylaw was not approved by Council due to the lack of treatment facilities in the area to properly dispose of the invasive plants.

DEVELOPMENT PRESSURE

All natural assets are at a medium-to-high risk from development pressure, particularly creeks, forests, the urban forest, wetlands and ponds, riparian areas and the aquifer. Development is also a concern to the marine environment through potential for pollution. Less than 5% of mature dryland forest remains undisturbed on the Sunshine Coast due to extreme development pressure.[56]

Most of the current and future development pressure is occurring in upper Gibsons. Development Permit Areas (DPA) have been identified where there are risks to natural assets, but there are currently no bylaws with regulatory authority to sufficiently protect natural assets in these areas; the Town is currently working to address gaps in existing bylaws.

In terms of the impact of development pressure on creeks, runoff is expected to increase from 48% of annual precipitation to 68%, which reflects the increase in impermeable surfaces. The projections for increased runoff based on current land use projections range from 19% increase in Gibson Creek, to 76% increase in runoff in Goosebird Creek.[57] Infiltration estimates are projected to decrease from 37% to 28% at full development.[58]

Management Strategy: Staff noted the need for an update to the Subdivision and Development Servicing and Stormwater Management Bylaw to avoid water diversion that undermines the health of trees.

56 From Town of Gibsons Official Community Plan Reconnaissance Study of Geotechnical Hazards and Biophysical Environment (p. 101), Thurber, 1991.

57 Goosebird Creek runoff levels were included in the Town of Gibsons' ISMP and the 2018 update to the ISMP but are not considered in the present study.

58 AECOM (2020).

With respect to wetlands and ponds, Gibsons' Official Community Plan (OCP) states that development should be directed away from wetland areas and areas necessary to maintain wildlife connectivity between habitat areas. It states that "no buildings, structures, or uses permitted on the land shall be sited within the following areas:

- areas with grades steeper than 25 percent to protect soil cover and drainage patterns
- the area within 100 m of the eagle nest shown on Schedule D
- the natural clearings shown on Schedule D

The Town established an Environmentally Sensitive DPA for the "Riparian Assessment Areas" in alignment with the Province's Riparian Area Protection Regulation.

The Aquifer Mapping Study recommends that development planning should be considered in conjunction with watershed(s) and aquifer management planning to ensure a proper balance (p. 110). The study suggests that establishing DPAs within the Town of Gibsons and the SCRD may be needed to control development activities that may affect the sustainability and protection of Aquifer 560. The study also notes that policies developed by the Town/SCRD should be "integrated with upcoming Provincial Regulations regarding groundwater licensing and use" (2013, p. 117).

Note that Gibsons' OCP does include Section 16.10 *Gibsons Aquifer Development Permit Area (DPA) No. 9*. The objectives of this DPA are to protect Aquifer 560 from land use and development activities that could pollute the water supply and to promote the efficient use of water to ensure a sustainable hydrologic system in the Watershed and a sustainable source of potable water.

With respect to the foreshore, Gibsons' OCP supports an appropriate setback/leave strip along the shore to protect these areas from potential adverse effects of development. The primary objective of the setback/leave strip is the conservation and protection of the environmental values of the marine environment, including adjacent backshore upland vegetation.

DROUGHT

Forests, the urban forest, and the aquifer were identified at high risk due to drought (current and future), however, wildfires associated with drought are becoming another significant concern.

The 2005 Hazard Risk and Vulnerability Analysis (HRVA) notes that drought risk to streams and wetland habitats in the SCRD is moderate-to-high, depending on the degree of adjacent development and the land use restrictions in place to protect these habitats. Increasing development around wetland areas (i.e., increasing total impervious area, or paved surfaces) can lead to drying of these areas, much like the effect of droughts on streams. Development pressure coupled with drought can therefore create cascading impacts on the health of wetlands and streams.

Management Strategy: The Gibsons Water Supply Strategy Update includes Section 3.4 - *Climate Variability and Water Conservation*, which recommends that the Town continue to monitor groundwater levels to ensure long term stability of the aquifer and adjust water-use patterns in response to changing climate conditions and other unplanned events. It recommends the use of water restrictions to curb excess demands for outdoor water use.

The Town is currently studying the hydraulic connections between surface water from creeks and groundwater, which could enhance understanding of the potential impact of drought on the health of both the creeks and the aquifer; drought combined with deforestation upstream could also impact water quantity of Aquifer 560. As of 2023, both the SCRD and the Town of Gibsons have water licences to withdraw water from Aquifer 560 for beneficial water use. In early 2022, the Aquifer Mapping Study update was completed; one of several recommendations was to work more closely with the SCRD and other stakeholders to protect the watershed areas which recharge Aquifer 560. In light of this, the Town has identified the need to develop a Regional Watershed Agreement with the SCRD.

At the time of this report, the Town and the SCRD have jointly drafted an "Aquifer 560 Watershed Agreement", with the following intentions included:

> *The ToG [Town of Gibsons] and the SCRD share a mutual interest in joint planning, management and monitoring the common aquifer and watersheds of their respective wellfields and water supply systems within Aquifer 560; and*
>
> *The ToG and the SCRD wish to enter into this Agreement to govern the terms and conditions to support the joint provision of sustainable water supply and to monitor and protect the environment, for the immediate and long term.*

Finally, the Town is continuing to work toward a Water Sustainability Plan designation with the Squamish Nation and the Province to advance protection of the Watershed.

EROSION

The Gibsons' foreshore, creeks and riparian areas were identified as high risk from erosion, particularly in Charman Creek, Gibson Creek and Pebbles Beach. Gibsons' OCP notes that the ravines of Charman and Gibson Creeks have significant areas with high estimated probabilities of occurrence of erosion, which could result in significant soil landslide and related stream-flood and debris-flood hazards.

The HRVA notes that particular attention should be paid to the effects of erosion on critical infrastructure, specifically road or bridge washouts (2005). It also notes that slow erosion and soil creep are preventable through hazard abatement programs, so the risk to critical infrastructure is identified as low, provided that land use planning initiatives are proactive.

Erosion also presents risks to aquatic ecosystems and biodiversity. Excessive sedimentation can bury nests of salmon eggs, cut off the oxygen supply to invertebrates that live in stream substrates, and kill small aquatic plants and microorganisms that many other stream dwellers depend on for food. High quantities of sediments suspended in the water column can also aggravate the gill and respiratory tissues of local fish populations, stressing the animals and increasing their risk of mortality. The risk is considered moderate provided hazard abatement actions are taken.

Management Strategy: Gibsons' OCP notes that erosion risk could increase in the future because of climate impacts associated with increased precipitation, especially rain, which can increase runoff, decrease local soil nutrients, and diminish slope stability.

In terms of risks to the foreshore, the OCP notes future erosion risk associated with sea-level rise, particularly along the shoreline in the inner harbour. This could leave the sewer line submerged and vulnerable to impacts of erosion. Along the beachfront, wave erosion may impact the safety of residents living on or near the bottom of steep slopes. Policies to mitigate risks could include monitoring the impacts of sedimentation, erosion, and nutrient / pollutant load on the Harbour Area, and developing strategies to ensure the harbour remains at depths suitable for vessels and that ecological conditions are maintained.

DEFORESTATION[59]

Development pressure is the primary cause of deforestation in the urban forest of the Town of Gibsons. At present, the forested areas of the foreshore and the riparian areas are protected through Environmentally Sensitive and Geotechnically Hazardous DPAs, and the Tree Preservation Bylaw.

Outside of the Town's boundaries but within the Watershed, deforestation occurs from forestry practices such as logging and associated access road building. These activities may also present a risk to the natural assets such as creeks, Aquifer 560 and the marine foreshore. For example, BC Timber Sales' 2021-2026 operating plan includes cut-blocks within the Aquifer 560 recharge area, which could lead to increased sedimentation and siltation of creeks, and potential pollution to surface water, groundwater, and the marine environment.

MAPPING OF TOP RISKS

To the extent possible, the top risk categories are spatially represented in the Natural Asset Dashboard. The Town provided GIS shapefiles representing the spatial coverage of the following risks: development, invasive plant species, erosion, green waste dumping, and deforestation. Drought risk is considered to affect the full project area. Data limitations did not allow the representation of deforestation through urban tree canopy reduction. The final risk map is presented in Figure 7.

59 For the purpose of this report, deforestation is defined as the removal of forest or stand trees from land that is converted to non-forest use, leading to deterioration of service provision. In the Town of Gibsons this occurs at a size of 0.5 ha, thus limiting the representation of urban forest canopy loss.

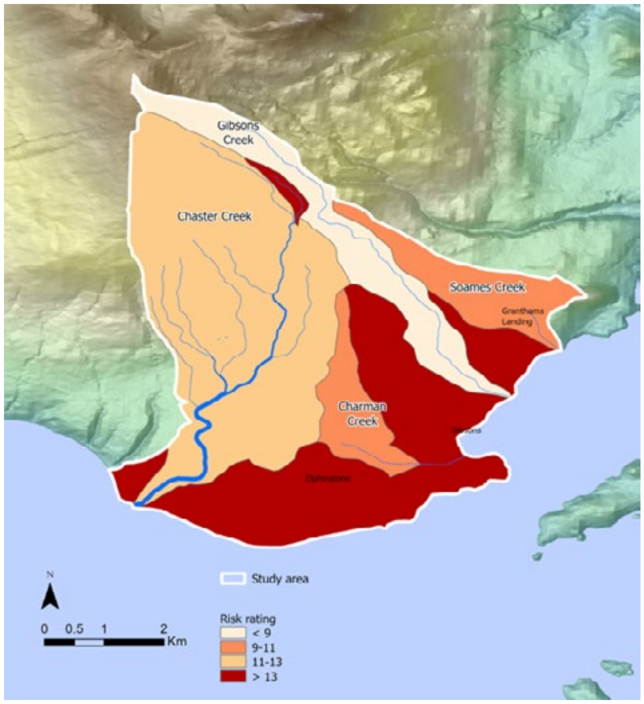


Figure 7: Cumulative risk ratings for each sub-catchment in the S2S Project Area [60]

3.7 Monitoring Programs

The Town of Gibsons has extensive monitoring programs to track the condition of lands and waters in which they operate or have jurisdiction as follows.

- Regular drinking water testing based on the Drinking Water Quality Program, with a goal to supply and deliver safe, top quality drinking water to customers within the Town boundaries.
- Annual Groundwater Monitoring Program which includes groundwater sampling and water level/data logger download for all monitoring and water supply wells, compiling and reviewing water chemistry data and water level data from all wells, reviewing pumping volumes and assessing well conditions.
- In 2023, the Town will expand its groundwater monitoring network with the installation of additional monitoring wells in Lower Gibsons to help characterize the competency of the confining unit (the aquitard which confines the artesian pressure of the aquifer), in addition to studying the hydraulic connection between surface and groundwater. Drilling of the wells will also provide a collection of sediment samples to help understand infiltration rates.
- An environmental classification system for the management of watercourses assists in streamlining the regulatory approval process for instream works or activities required as part of ongoing municipal operations, land use planning and development, and emergency response within Gibsons.

60 Appendix C provides a summary of the process followed to map the top risk categories.

- The S2S Project necessitated the need for flow monitoring of Chaster, Charman and Gibson creeks. Hydrometric stations were installed in 2021 and continually log water level and temperature. Routine flow measurements were performed by Town staff with the assistance of the Sunshine Coast Streamkeepers to develop a rating curve for the stormwater modelling component of this Project.
- A limitation of the S2S Project was access to hourly precipitation data in the Watershed. This data gap prompted the Town to install six climate stations (precipitation and temperature) in the spring of 2023 that will support water management and initiate a sustainable monitoring network for future studies. Multiple stations were installed to better represent the complex distribution of precipitation expected in the region. The data will provide information to assess precipitation-to-infiltration-to-aquifer recharge.
- Partnership with the NSMEC through the Healthy Harbour Project to undertake eelgrass bed monitoring to inform protection.

3.8 Assessment Phase Limitations and Gaps

NAI's assessment of the current state of natural assets contains limitations and knowledge gaps related to inventory, condition data, valuation data, water quality modelling and co-benefit valuation.

The natural asset inventory and condition assessment does not include information on soils, groundwater or aquifer recharge as data limitations did not allow for their inclusion in this project. Specifically:

- PCSWMM estimates soil erosion using the Modified Universal Soil Loss Equation (MUSLE). Average soil loss during a flood event is a function of flood volume, peak discharge, slope, soil erodibility, vegetation cover, and erosion control practices. This limitation results in the ability to forecast direction of change rather than absolute values.
- Elevation of the groundwater table and of bedrock were not considered and a high groundwater table may reduce the infiltration.
- Low Impact Development (LID) options were modelled through an approach in which precipitation in the watershed is captured by LIDs of uniform size and efficiency. In practice, the size, shape and function of LIDs to service a large catchment area may vary due to factors such as topography, drainage conditions, soil conditions, and groundwater.
- Conduits used in the model are simplified and may require refinement to accurately define sinuosity, slope, and length of the creek.

The valuation of primary services contains the following limitation:

- The valuation of primary services approximates the cost per square metre to install engineered stormwater strategies if the natural assets were removed. This is not an exact representation of what would actually occur.

For the co-benefits valuation, effort was made to transfer primary studies from sites with similar ecological and socio-demographic characteristics. However:

- Every ecosystem is unique and per-hectare values derived from another location may not be relevant to the ecosystems to which they are applied.
- Valuations are static analyses that provide values at a point in time and need to be updated regularly.
- Values can only be regarded as a minimum, as primary studies may not be available to monetize all services, and/or the valuation of some services may not be possible or desirable.
- Primary research to obtain the contribution of groundwater in water regulation would be useful for refining the value of water quality regulation.
- Primary research to better understand Indigenous values would contribute to the understanding of Indigenous values associated with the Aquifer 560 Watershed.

3.9 Next Steps for Continuous Improvements in Assessment Phase

As part of adaptive asset management and continuous improvement, next steps could include:

- Improving the inventory with the addition of soils, groundwater recharge zones, and age data. The first two items are relatively straightforward; age data for natural assets, by contrast, can be more difficult to assess. While some natural asset ages can be determined (e.g., trees), others are difficult or impossible (e.g., streams). It is recommended to start with tree age or ages of recently restored assets and factor in other assets as guidance becomes available.
- Ensuring monitoring data is integrated into the inventory in the long term. The inventory could be structured to provide integration with the monitoring stations, resulting in real time updates to the inventory and condition assessment.
- Continued collaboration with the Squamish Nation to further Watershed stewardship and protection.
- Implementing bylaws to sufficiently protect natural assets in upper Gibsons from development, as well as the steeply sloped dryland forest areas; update the Subdivision and Development Servicing and Stormwater Management Bylaw to avoid water diversion that undermines the health of trees.
- Develop a regional watershed agreement with the SCRD and continue to work toward a Water Sustainability Plan designation with the Squamish Nation and the Province to advance protection of the Watershed.

4 Integrating Coastal and Land-Based Approaches

This section describes efforts to integrate land based and coastal modelling systems. Due to data limitations, the simulation of biophysical feedbacks between coastal and terrestrial systems was not possible. However, guidance for appropriate modelling considerations and model selection are provided here for future work.

4.1 Rationale for Model Integration

While both land-based (terrestrial) and coastal systems can contribute to flooding and erosion, sometimes simultaneously, modelling — and often resulting management approaches — for each system are typically evaluated separately. This siloed approach may overlook feedbacks between each system, making it difficult to identify a comprehensive package of NAM actions that address the full range of a coastal community's flood and erosion mitigation needs. To address this, the S2S Project considers how NAM for flood and erosion mitigation can be evaluated quantitatively by integrating terrestrial freshwater with coastal systems.

As mentioned, the S2S Project found integration between coastal and terrestrial systems was **not possible** using PCSWMM and Coastal Toolbox. Recognizing this, guidance on future integration between coastal and terrestrial systems has been developed and a summary of it provided here. A full model integration report was provided to Project Partners. It is hoped that this approach will aid the Town of Gibsons and others achieve more holistic approaches that better align with ecological boundaries.

STARTING POINT FOR MODELLING INTEGRATION

Integration of tools for quantitative assessment can occur along a continuum from "consider together, model separately" to "full model coupling" (see Figure 8). Full model coupling can be an efficient solution when clear feedbacks exist between modelled systems, such that outputs from one model are automated as inputs to another. Software packages designed to model hydrologic processes regularly use such coupling. For example, to simulate terrestrial freshwater systems, separate sub-models for precipitation, evapotranspiration, and runoff processes may be integrated into a single hydrological modelling software.

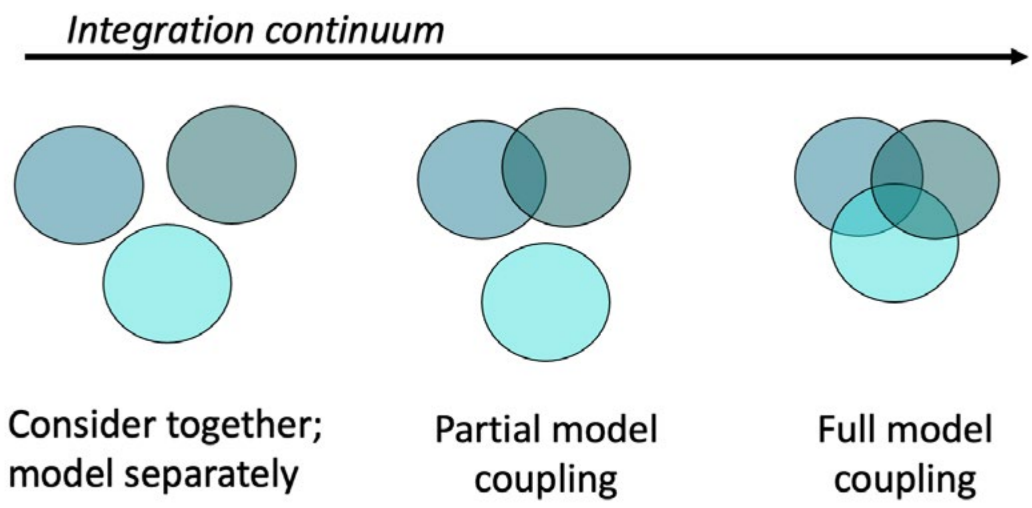


***Figure 8**: Integration continuum. Source: ESSA (2022)*

Whether feedbacks between systems are relevant depends on the question being asked and the ecosystem services of interest. Users should be cautious when interpreting outputs from such integrated solutions. Overconfidence can arise when users assume capturing more system linkages will result in a better overall simulation but increasing model complexity usually introduces new challenges for validation, calibration, and uncertainty. As Sang notes "it is hard to factor out all the sources of error in multiple models chained together" (2020, p. 222).

The S2S Project asked '*is there a modelling approach that could capture the flood and erosion processes from both events occurring simultaneously,*[61] *or the cumulative effects of both processes over time?*' The answer is *yes*, but with different modelling tools and research questions than the ones mentioned above.

Integration efforts required consideration of two main modelling exercises:

- The Coastal Toolbox (CT) requires wind, wave, and tide input data and provides high-level outputs for flood depth and extent as well as potential land loss from erosion for compatible beach types. These data are generated along multiple 1D profiles and then interpolated to produce a semi-2D map of flood extent and depth. Since the model is intended as a coarse first-pass assessment of natural asset options, no dynamic 2D hydrologic modelling occurs — the model assumes water levels behave like a bathtub, raising and lowering evenly across the landscape.

61 Note that estimating the joint probability of such events is an entire sub-topic. One relatively simple design would be to select the scenario that results in the highest combined total water level from two simulations: 1) a heavy rainfall event that has a short return interval (e.g., 2yrs) and a storm event with a longer return interval (e.g., 50-100yrs), and 2) a heavy rainfall event that has a longer return interval (e.g., 50-100yrs) and a storm even with a short return interval (e.g., 2yrs).

- The PCSWMM model developed with Gibsons during the S2S Project is designed to estimate how alterations to existing natural asset features (forests, wetlands, riparian areas) will affect municipal SWM during heavy precipitation events, particularly with climate change scenarios. The model requires precipitation and streamflow input data and provides outputs for changes in flow volume at selected points along a stream network. Neither the inputs nor the outputs from the CT or this 1D version of PCSWMM are relevant to the questions being answered by the other model.

4.2 General Considerations for Integrated Modelling Approaches

Outputs from the CT could be used as inputs to a 2D version of the PCSWMM model to capture backwater effects. Coastal storms and heavy rainfall events do not always correspond, although their independent effects may result in cumulative flood and erosion damages at the same location over time. However, if both types of storms do occur together, backwater effects (see Figure 9) may be observed at the mouth of streams if tides and storm surge increase the sea level elevation, thereby "backing up" the stream and possibly causing additional flooding. Water level outputs from the CT could be used as a sea level boundary condition for outflow from streams in a hydrodynamic (2D) PCSWMM model. Using PCSWMM in this way would require acquiring creek cross sections, which we recommend doing during a future phase of work.

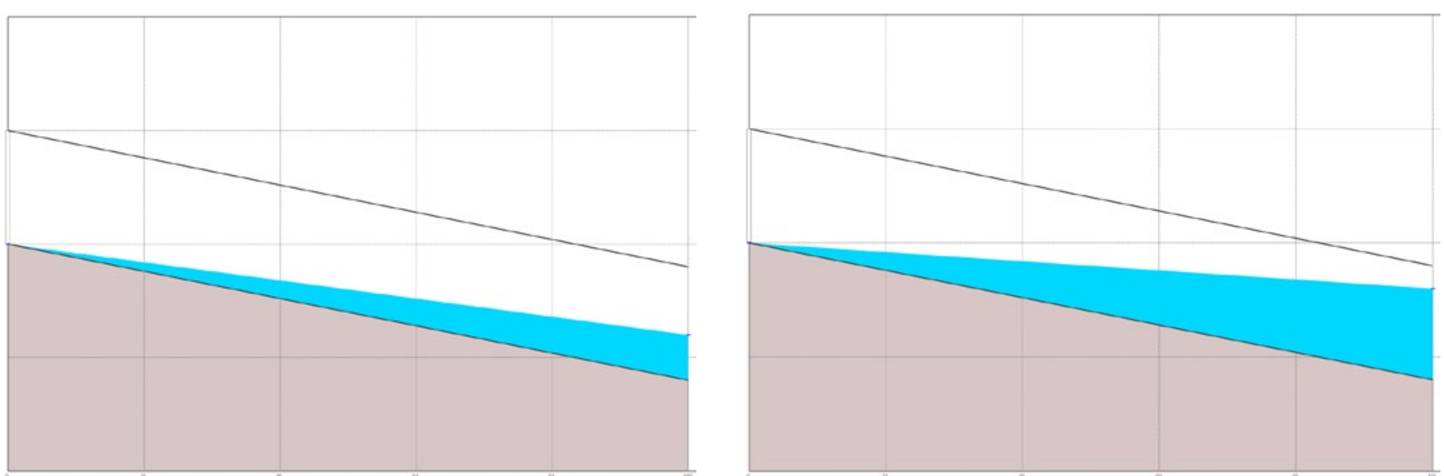


Figure 9: *Example of backwater effect. Source: ESSA (2022)*

In Figure 9, both panels show the water depth in a creek during the same storm, but the water level of the ocean in the right pane is significantly higher than in the left pane (e.g., due to storm surge). The sea level causes the creek to "back up", potentially causing upstream flooding.

4.3 Model Selection

Selecting a model from the wide range of available tools can be confusing as most tools focus on simulating physical processes disconnected from the natural asset policy context, based on the information available.[62] Prematurely selecting modelling tools may result in the inability to answer key questions. For example, if a community is interested in understanding both the water quality regulation and flood mitigation services of a forested ecosystem, different models may be required to address these two ecosystem services. Where multiple models are needed, additional schematization is likely required to make the models "talk" to one another. Data limitations may also influence model selection. Some tools can simulate multiple ecosystem services in one package, but input data requirements may preclude using that tool for one or more services. Another model may have less stringent data needs and can be used instead to simulate that service. If no alternative is available, primary data collection may be the only option. Table 15 shows which models can address different water-based municipal services.

One caution is that while modelling software can simulate a physical process, it does not mean it is the most appropriate choice or that a community will be able to access the full capabilities of the tool. Local data availability may limit what can be done, or the underlying mathematical models may only be relevant to specific coastal or terrestrial ecosystem types (e.g., sandy beaches versus rocky coastlines). While this rapid review can serve as a first pass guide, model selection should always be done after conducting a preliminary feasibility assessment that includes additional selection criteria such as cost, data availability, quality of documentation and support, transferability to the local ecosystem, and appropriate temporal and spatial resolution. Importantly, **model selection should be driven by Big Questions**, not by the software most commonly in-use by practitioners (although this can be one of the selection criteria). While tools in common use may seem convenient, it is preferable to use the right tool for the questions, accompanied by a user guide and staff training (e.g., PCSWMM is commonly used and well-suited to modelling urban stormwater systems, but it is not well-suited to an integrated Source to Sea approach that extends outside the urban environment).

62 Sang (2021)

CANDIDATE SIMULATION MODELLING SOFTWARE PACKAGES	TERRESTRIAL						
	Flood Mitigation	Erosion Prevention	Water Quality Regulation	Drinking Water Storage (surface)	Drinking Water Storage (groundwater)	Flood Mitigation	Erosion Prevention
PCSWMM	X		X	X			
Raven	X		X	X			
MIKE-URBAN	X		X	X			
MIKE-FLOOD			X				
MIKE-SHE	X		X	X	X		
TUFLOW	X	X	X			X	X
TELEMAC-2D						X	X
X-Beach 2D						X	X
MIKE21-2D	X	X	X				
Delft3D-FLOW	X		X				
HEC-RAS	X	X	X				
WEAP	X		X	X			

Table 15: Crosswalk table showing which candidate simulation models can support evaluation of each municipal focal ecosystem service

4.4 Results of Model Integration

The model integration component of this project was completed to identify a comprehensive package of NAM options that address the full range of a coastal community's flood and erosion mitigation needs. While the current models being used (PCSWMM in terrestrial areas and CT in coastal areas) could not be integrated to address the research questions posed by the Town of Gibsons and ultimately required a 2D or 3D modelling software, results showed that outputs from the CT could be used as inputs to a 2D version of the PCSWMM model to capture backwater effects. If this is of interest, the Town would need to acquire creek cross sections.

4.5 Recommendations for Future Integration

The PCSWMM tool was limited for use in a Source to Sea context because it is designed for urban settings and cannot capture key processes in non-urban parts of the Watershed. However, the hydrologic modelling PCSWMM facilitated was a necessary step toward full Source to Sea integration that can be used as inputs to a future phase of work. The ability to simulate changes in 2D flood extents from terrestrial and coastal storms under different NAM combinations is ultimately needed. This requirement means 2D hydrologic modelling is the obvious next step. Once 2D maps from both terrestrial and coastal storm processes are generated, they can be overlain and merged to assess overall risk to infrastructure under different design storms.

5 Planning Phase of Natural Asset Management

The NAM planning phase (the yellow part of the circle depicted in Figure 1) sets Levels of Service for natural assets and allows scenarios to be explored through modelling once baseline conditions are established in the assessment phase. These scenarios can inform decisions based on changes in services and values from different simulated climatic conditions or land use decisions. This section describes planning phase results.

5.1 Developing Natural-Asset Related Levels of Service for Stormwater Services

Levels of Service (LOS), including strategic, corporate, customer (also referred to as community), and finally, technical LOS, are shown in Figure 10 below. They represent the service delivery commitment of a local government. LOS inform asset management and financial plans and help local governments to prioritize capital and operational spending decisions.

The Town of Gibsons, like most local governments of its size and maturity in asset management, is at an early stage of developing LOS. The Town has already drafted some LOS for some assets, but they have not yet been finalized or approved by Council. While it is staff's role to develop LOS, to communicate to Council the costs required and the risks of failing to achieve them, it is Council's role to approve LOS, to monitor the local government's performance on them, and to use them to guide budget decisions.

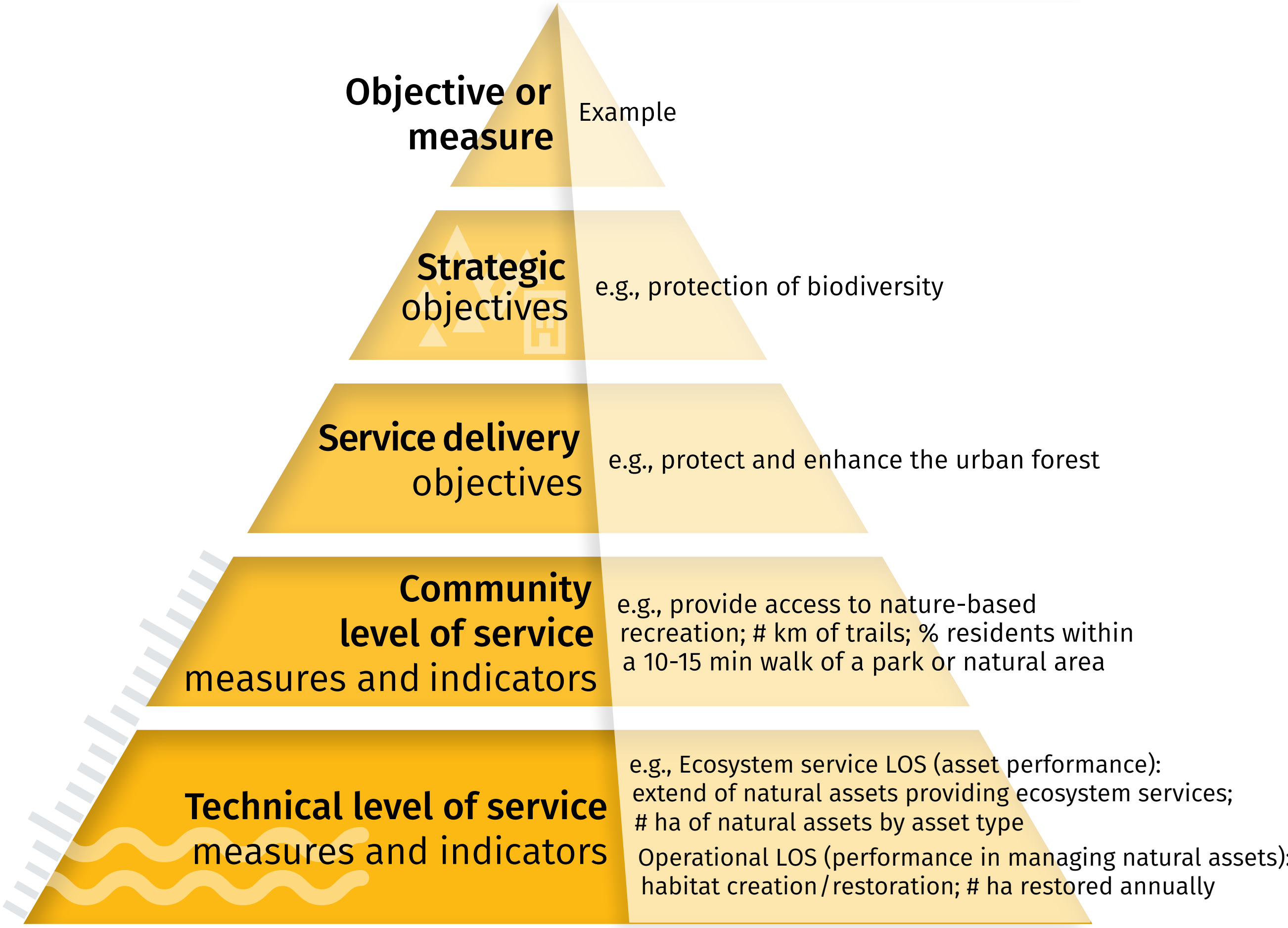


***Figure 10:** Illustrating levels of service*

The Town of Gibsons' asset management policy defines LOS as the service level delivered to the public by the Town. This can take the form of the selection of services that are provided (e.g., bike lanes, doggie bags, or a new pool), the standard of infrastructure in place (e.g., concrete sidewalks versus gravel paths), or the standard to which an asset is maintained (e.g., the frequency of scheduled curb sweeping). The desire of Council or the public for a particular LOS will directly affect utility fees or taxation.

As part of the S2S Project, staff participated in an LOS workshop to build capacity in developing LOS for natural assets and to explore potential natural asset-related LOS for stormwater services. This section outlines the key outputs from the workshop and offers guidance to support the establishment of natural asset-related LOS.

5.2 Alignment of Natural Asset LOS with the Town's Strategic Priorities

LOS for natural assets should aligned with the Town's strategic priorities. The Town of Gibsons is a leader in NAM and already formally recognizes natural assets as part of its core infrastructure system. As such, the Town has several policies and service delivery objectives in place, shown in Table 16 below, that natural asset-related LOS should align with.

DOCUMENT	NATURAL ASSET-RELATED OBJECTIVE OR POLICY
Eco Assets Strategy	To leverage natural assets to prevent flooding, provide drinking water and manage rainwater (compare costs with engineered assets, save money).
Eco Assets Strategy	To maintain a healthy ecosystem (maintain the condition of natural assets).
OCP	Protect the quality of the natural environment, including the presence of valued wildlife and green space in the Town's wooded and natural areas.
OCP	Protect the Gibsons Aquifer, as a source of high-quality drinking water for the Town.
OCP	Maintain and improve the natural features of the Town of Gibsons, by both identifying and preserving the natural amenities which play a significant role in the definition of the Town's "sense of place". A related policy is to grow environmental assets, reclaim habitat, green streets.
OCP	Ensure future development is compatible with the physical characteristics of the site and surrounding area and the overall carrying capacity of the Town.
OCP	Minimize risks to life and property from natural hazards and disasters such as floods, erosion and slides.
OCP	Improve the local air and water quality.
OCP	Maintain public access to natural areas, the shoreline, and the characteristic viewscapes of the Town.

Table 16: Town of gibsons natural asset-related objective & policies

***Note:** The above table is not necessarily an exhaustive list; it is recommended that, as the Town proceeds with developing LOS for natural assets, staff review all strategic documents to ensure alignment, including master plans, climate action or resilience plans and strategies. In particular, the Town has just finalized its 2023-2027 Council Strategic Plan and LOS should incorporate any natural asset or infrastructure related objectives included in the plan.*

5.3 Stakeholder and Rightsholder Needs and Interests in Natural Asset Services

LOS need to be defined based on an understanding of the service expectations of the community and their willingness to pay for services. Staff identified the stakeholders and rightsholders in Table 17, for which needs and interests should be considered when defining LOS for natural assets (with emphasis on stormwater/drainage services). While the Town may have some information about their interests from sources such as previous planning exercises, community engagement, committees, surveys, or customer service complaints, they may also need to base LOS on some assumptions about their interests that can be validated or updated as part of continuous improvement efforts. The Town will need to ensure their LOS is aligned with all relevant provincial and federal regulations and local by-laws and regulations.

STAKEHOLDER CATEGORY	STAKEHOLDERS/RIGHTSHOLDERS
Recipients of the service	Private landowners, local businesses, residents, tourists, cyclists, swimmers, children, seniors, youth, adults, nature lovers, fishing community, fish, wildlife, insects (flora and fauna), Ministry of Transportation and Infrastructure (jurisdiction over roads outside of town, which have ditches and flooding issues)
Rightsholders	Squamish Nation (also a neighbouring community)
Regulatory Agencies	Provincial government (multiple ministries), Federal government (multiple ministries), Vancouver Coastal Health Authority, Ministry of Transportation and Infrastructure
Wider Community	Real Estate developers, BC Timber Sales (did an analysis of runoff impacts, their actions are causing runoff into the creeks), local businesses
Neighbouring Municipalities	Sunshine Coast Regional District, District of Sechelt
Other Service Providers	Gibsons Landing Harbour Authority (GLHA), Gibsons Marina, Hyak Marine, Smitty's Marina and Kayak Adventures, transportation operators, Ministry of Transportation and Infrastructure

***Table 17**: Stakeholders and rightsholders in the S2S project watershed*

5.4 Potential Corporate Stormwater Service Objectives

Corporate LOS objectives should flow from strategic objectives. They represent high-level performance objectives used to measure progress on service delivery, and they guide the development of more specific customer and technical LOS linked to that objective. Corporate LOS are typically written as qualitative descriptions of services the local government aims to provide to the community.[63] They may or may not include targets.

There are four key corporate stormwater service objectives that flow naturally from the Town's strategic objectives, shown in Table 18, that can be used as a proposed starting point for defining customer and technical LOS.

POTENTIAL CORPORATE LOS FOR STORMWATER	SOURCE DOCUMENT
Provide integrated stormwater management services at the lowest possible lifecycle management cost.	**Asset Management Policy** seeks to provide services at lowest possible lifecycle cost. **Drainage Asset Management Plan (Draft):** includes customer LOS statement: understand natural asset value and capacity.
Leverage green infrastructure to manage stormwater services.	**Eco assets strategy:** Leverage natural assets to prevent flooding, provide drinking water and manage rainwater (compare costs with engineered assets, save money). **Drainage Asset Management Plan (Draft):** includes related customer LOS: Prioritize open channel conveyance of rainwater where possible; natural environment is enhanced. **OCP policy 6.3.6:** Consider daylighting the culverted sections of Charman and Goosebird Creeks in the Gibsons Landing area & other enclosed watercourses, wherever possible.
Minimize risks to life and property from natural hazards and disasters such as floods, erosion and slides.	**OCP:** Minimize risks to life and property from natural hazards and disasters such as floods, erosion and slides. **Source to Sea co-benefits assessment (this project):** Manage risk of landslides and stream sedimentation from erosion; forest root networks help hold the soil around trees.
Support safe, high-quality multi-functional use of natural stormwater infrastructure to provide residents with access to nature for cultural, recreational, and economic activities.	**Source to Sea co-benefits assessment (this project):** outlines recreation, culture and the local economy as important co-benefits of natural assets recognized by the Town.

Table 18: Potential corporate LOS for stormwater management

63 Corporate LOS are sometimes used interchangeably as customer LOS statements.

5.5 Data and Information Needed to Define Customer and Technical Stormwater LOS

Customer LOS are performance measures that describe the service the community should expect to receive in terms the public can understand. They can be expressed as qualitative statements (e.g., minimize property damage from flooding) or quantitative measures (e.g., number properties flooded). They should be accompanied by a set of measurable indicators to measure and track performance on service delivery over time.

Technical LOS are performance measures that describe the expected performance of the asset and the operational requirements to manage them to deliver the desired level of service. In the case of natural assets, technical LOS should include:

1/ Relevant measures of the ecological performance of natural assets related to the service (e.g., water storage capacity of a wetland; canopy interception).

2/ The Town's operational performance on the lifecycle management of natural assets (e.g., monitoring requirements for flow monitoring, such as number of monitoring stations, frequency of monitoring, monitoring parameters.

Technical LOS can be expressed qualitatively as operational requirements (e.g., outfalls are to be inspected twice a year and checked for debris after all major rainfall events), but like customer LOS, should be accompanied by a set of measurable indicators that will be used to measure and track performance on service delivery over time (e.g., % of outfalls inspected twice a year, target = 100%).

To determine the technical LOS for stormwater management provided by natural assets, the following data and information needs to be collected and tracked on an ongoing basis (some of which is already being collected by the Town):

- Spatial data capturing natural areas, impervious/pervious surfaces, watercourse features, building footprints, digital elevation, and extent of stormwater management facilities;
- Neighbourhood boundaries, if there is a desire to assess metrics by neighbourhood;
- Inventory of installed green infrastructure, detailing type (e.g., rain gardens, permeable surfaces, stormwater ponds, and natural areas, etc.);
- Assessment of water storage capacity for wetlands and other types of relevant green infrastructure;
- Stormwater modelling outputs to estimate influence of natural areas and other green infrastructure on peak flows or avoided runoff;
- Floodplain flood control data needs: channel geometry, flow data, digital elevation model (DEM), flow and water level monitoring;
- Creek flood control data needs (water levels, groundwater, precipitation, and velocity);

- Surface water level monitoring (water level logger);
- Groundwater monitoring (drive point piezometer (to be installed in proximity to the surface water level monitoring stations));
- Precipitation data: rain gauge; for scenario analysis (Climate Change) — Intensity-Duration-Frequency curves;
- Wetland flood control data needs: surface and groundwater levels (piezometers);
- Water quality data needs: water quality testing and monitoring; and
- Detailed condition assessments evaluate the physical condition the natural asset and its ability to enable related ecosystem services (can support prioritization of restoration projects where natural assets are delivering stormwater services).

Some next steps the Town of Gibsons can take to develop technical LOS for stormwater include:

1/ Determining the scope of stormwater-related natural asset data and information the Town is collecting or plans to collect.

2/ Documenting how data will be stored and shared (note that other jurisdictions are interested in sharing and accessing data).

3/ Documenting the frequency of monitoring and updates (in some cases data may be updated automatically and presented in a dashboard, such as the hydrometric data, in other cases staff will be required to update the data).

4/ Formalizing technical LOS, track indicators and report on progress.

Through this and previous studies, there is a solid foundation of data and information about stormwater services being provided by natural assets in the Aquifer 560 Watershed to develop stormwater LOS. Asset management is a process of continuous improvement, and data gaps can be filled as part of continuous improvement efforts. LOS measures will evolve over time.

EXAMPLES OF NATURAL ASSET STORMWATER CUSTOMER AND TECHNICAL LOS

The number of customer and technical LOS the Town decides to track should be manageable based on resources available and staff capacity, and should consider the universal values of service delivery, shown in Table 19.

SERVICE VALUE	EXPECTATION
Safety	The service is delivered safely and risks are managed
Regulatory	The service meets all regulatory requirements
Reliability	The service is reliable
Accessibility	The service is accessible
Quality	The service is satisfactory to those who use it or benefit from it
Sustainability	The service is sustainable (socially, environmentally, and financially)
Cost/affordability	The service is affordable
Customer service	The Town is responsive to questions or concerns about the service

Table 19: *Universal values of service delivery*

Below are some examples of customer and technical LOS that could be tracked for each of the four corporate service objectives for stormwater in Table 18.

Corporate service objective: Provide integrated (natural & built) stormwater management services at the lowest possible lifecycle management cost			
Customer LOS Objective	**Service Value**	**LOS indicator** (performance measure)	**Customer or technical indicator**
Stormwater services are responsive to community needs	Cost/Affordability	# complaints related to stormwater services	Customer
	Customer service	Response time to manage stormwater-related inquiries	Customer
Stormwater costs are affordable	Cost/Affordability	Total O & M costs/km² catchment area	Technical
	Cost/Affordability	Total O & M costs/km² buried conveyance infrastructure	Technical
	Cost/Affordability	Total O & M costs constructed wetlands/storm ponds	Technical
	Cost/Affordability	Total O & M costs natural wetlands	Technical
	Cost/Affordability	Stormwater value of natural assets, disaggregated by natural asset type	Technical
	Cost/Affordability	% stormwater services paid for through stormwater utility	Technical
Corporate Service Objective: Minimize risks to life and property from natural hazards and disasters such as floods, erosion, and landslides			
Customer LOS Objective	**Service Value**	**LOS indicator** (performance measure)	**Customer or technical indicator**
Protect the community and property from damages caused by flooding and erosion	Reliability	# properties impacted by flooding	Customer
	Safety	# injuries reported caused by flooding, # deaths	Customer
Protect and restore trees and vegetation in priority areas to support infiltration and water storage, where risks of landslides and stream sedimentation from erosion are high	Sustainability	% riparian areas located in high-risk areas in good condition	Technical
	Sustainability	% of watercourse length and wetlands with at least 30m (or other appropriate buffer) of natural riparian cover on all sides of the watercourse	Technical
	Sustainability	% invasive plant species by natural asset type and location	Technical
	Sustainability	Volume of green waste attributed to dumping	Technical
	Safety	# landslides reported	Technical
	Safety	Change in extent of erosion	Technical
	Sustainability	# sites assessed each year for erosion and sedimentation with established monitoring protocols	Technical

Corporate Service Objective: Leverage green infrastructure to manage stormwater services			
Customer LOS Objective	**Service Value**	**LOS indicator** (performance measure)	**Customer or technical indicator**
Prioritize open channel conveyance of rainwater where possible	Sustainability	Ratio of buried conveyance infrastructure to open channel	Technical
Account for and manage natural assets as part of the stormwater system	Reliability (capacity)	% of stormwater system capacity (m^3 of storage or reduced runoff) by green infrastructure type	Technical
	Reliability (capacity)	Total wetland storage capacity (m^3)	Technical
	Sustainability	% wetland gain or loss	Technical
	Reliability (capacity)	Estimated reduction in stormwater runoff (e.g., m^3 of peak flow rainfall controlled by wetlands)	Technical
	Sustainability	# of wetlands assessed each year based on established monitoring protocols	Technical
	Reliability (capacity)	% stormwater runoff managed through canopy interception	Technical
	Sustainability	Total canopy coverage by catchment area	Technical
Minimize impervious surfaces; manage more rain where it falls	Quality	Area of impervious surface	Technical
	Quality	% of impervious cover by neighbourhood	Technical
Corporate Service Objective: Support safe, high-quality multi-functional use of natural stormwater infrastructure to provide residents with access to nature for cultural, recreational, and economic activities			
Customer LOS Objective	**Service Value**	**LOS indicator** (performance measure)	**Customer or technical indicator**
Residents and visitors have safe and reliable access to natural areas for recreation or cultural activities	Accessibility	% stormwater facilities accessible to the public for recreation, social or cultural activities	Technical
	Quality	% of residents satisfied with the quality of natural areas accessible to the public	Customer
	Quality	# complaints about access to or quality of natural areas	Technical
	Safety	# injuries reported in natural areas	Technical
	Reliability	# times stormwater facilities closed to the public unexpectedly	Technical
	Quality	% stormwater facilities that meet park design standards	Technical

***Table 20:** Examples of customer and technical LOS*

Next, the Town should finalize LOS measures to track, note whether data currently exists and whether information is known about the current LOS being delivered. Once current LOS has been identified, the Town will be able to work towards defining its desired LOS. Desired LOS can be expressed as a desired trend (e.g., increase % of riparian areas in good condition) or as a target (e.g., 80% of riparian areas in good condition).

Table 21 below provides an example of how the Town can track and report on progress in achieving its desired LOS.

SERVICE VALUE	LOS MEASURE	UNIT OF MEASURE	TYPE OF MEASURE	CURRENT PERFORMANCE	CURRENT PERFORMANCE DATA SOURCE	CURRENT COST ($)	TARGET PERFORMANCE (OR TREND)
Sustainability	% riparian areas in high-risk areas in good condition	%	Technical	e.g. 60%	Desktop condition assessment or field assessment	e.g., $/year investment in restoration	e.g. Increase % Or 80% in good condition

Table 21: *Example of progress tracking and reporting*

6 Exploring Future Scenarios

6.1 Scenario Modelling

In addition to the baseline valuation, the S2S Project assessed five candidate management alternatives that either increase or decrease the extent or quality of natural assets in the project area. This section reports on the additional benefits or costs relative to current conditions (i.e., with natural assets) from implementing these alternatives.

Outputs from the model quantify SWM services provided by the watershed's natural assets (forests, riparian areas and wetlands) —these were assigned a dollar value based on their cost of replacement with a built alternative (in this case, stormwater retention ponds). The scenario analysis extends this baseline valuation to determine if changes in the management of natural assets would result in significant improvement or diminishment in the value of service provision.

ENHANCE/RESTORE FORESTS

This management option envisions implementing forest restoration (e.g., tree planting) to enhance 0.9 ha of existing forest in the Goosebird Creek watershed (Figure 11), thereby increasing canopy cover and interception. Simulating Goosebird Creek stormflows was not part of the original project, so to represent this scenario, benefit transfer from other parts of the project was applied. Assuming that restoration is desired, the current forest is not 100% functional and is therefore capturing less precipitation by canopy interception than expected in a fully functional forest. The benefit transfer approach assumes Charman Creek's Forest is fully intact and transfers its per-hectare replacement value for forests ($10,532/ha). However, since Goosebird Creek's forest canopy interception service is degraded to an unknown percent, results for different levels of degradation are provided. If the service is 50% degraded, restoring the forest to a fully functional state would generate $4.7 thousand in SWM benefit (50% of $10,532/ha x 0.9 ha) in addition to baseline values for the catchment; the equivalent values for assumed degradation of 20%, 10% and 5% are $1.90 thousand, $0.95 thousand, and $0.47 thousand respectively. These values are low, but they are only for SWM and do not consider potential benefits from forest enhancement such as recreation opportunities, air quality regulation, habitat, and shade during heat waves.

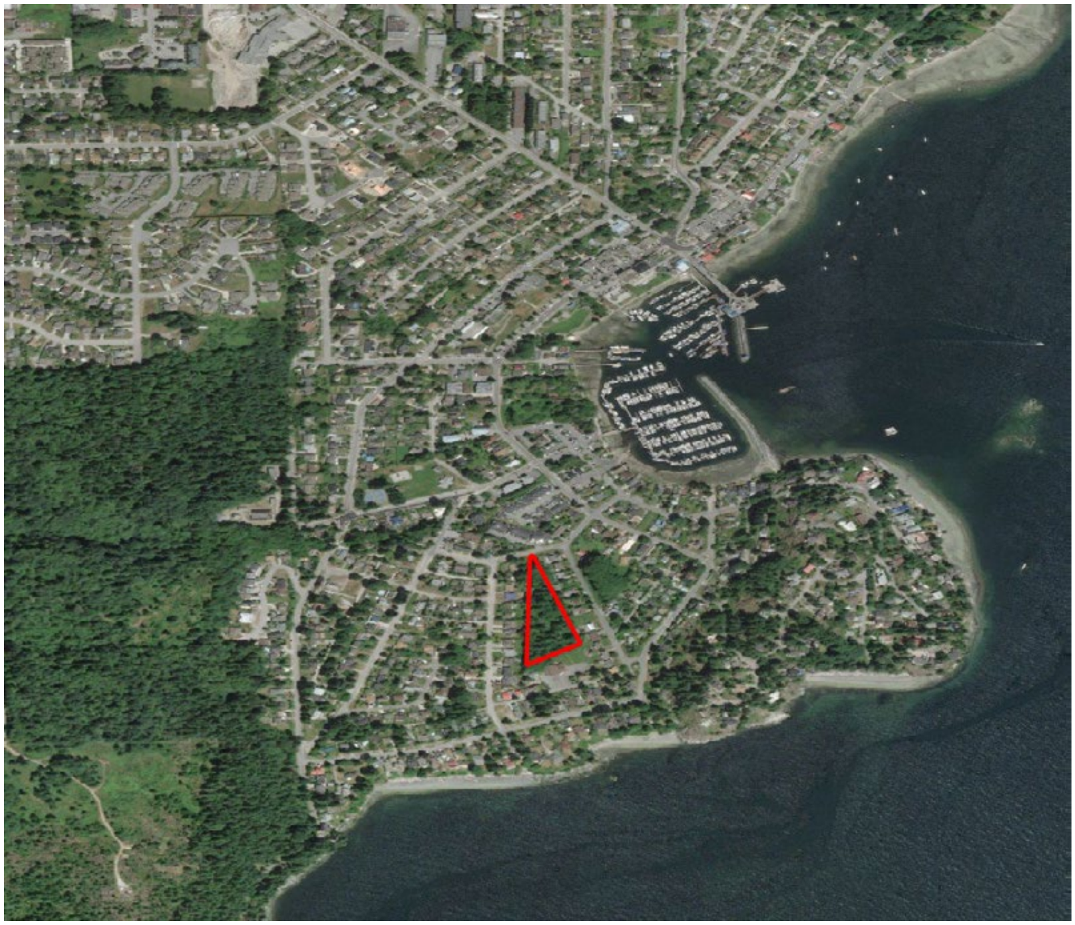


Figure 11: *Location of the "Enhance/Restore Forest" management option*

DECREASE FOREST

This management option envisions forest removal due to urban development in four areas. The Shaw Rd South/Gospel Rock area shown at the bottom of Figure 12 is 68.7 ha, with 30.2 ha (44%) occurring within the Charman Creek watershed, known locally as Charman Lands. Approximately 1,287 m^3 of detention pond storage is required to replace the stormwater LOS lost with the removal of the 30.2 ha Charman Lands Forest, at the cost of about $0.35 million (see Appendix A for detailed breakdown). For the remaining 38.7ha in the area, the average forest replacement value per hectare for the Charman Creek watershed ($10,532/ha) was used to get a value of $0.41 million ($10,532/ha x 38.7 ha). Adding these values together yields a $0.75 million replacement value ($346,534 + $407,588) for SWM that would be lost if the forest in this area were removed.

The potential development at Park Rd West (top left of Figure 12) is 5.6 ha, of which 4.8 ha (85%) is classified as forested. Potential future development would require an estimated 102 m^3 of storage to replace the level of SWM service provided by the forested area, worth an estimated $0.027 million (102 m^3 x $268.84/$m^3$). The neighbouring Park Rd East potential development covers an area of 16.6 ha, 13.9 ha (84%) of which is forested. 2,478 m^3 of storage is required to restore SWM service to pre-development levels, at an estimated cost of $0.666 million (2,478 m^3 x $268.84/$m^3$).

The Whitetower/Shaw Rd location is only 1.5 ha and contains 0.94 ha (63%) of forest. It would require an estimated 345 m^3 of storage to restore the SWM service lost due to potential development, worth an estimated \$0.093 million (345 m^3 x \$268.84/m^3). The total SWM value that would be lost if forests were removed in all four potential development areas is \$1.54 million (\$0.754 + \$0.027 + \$0.666 + \$0.093).

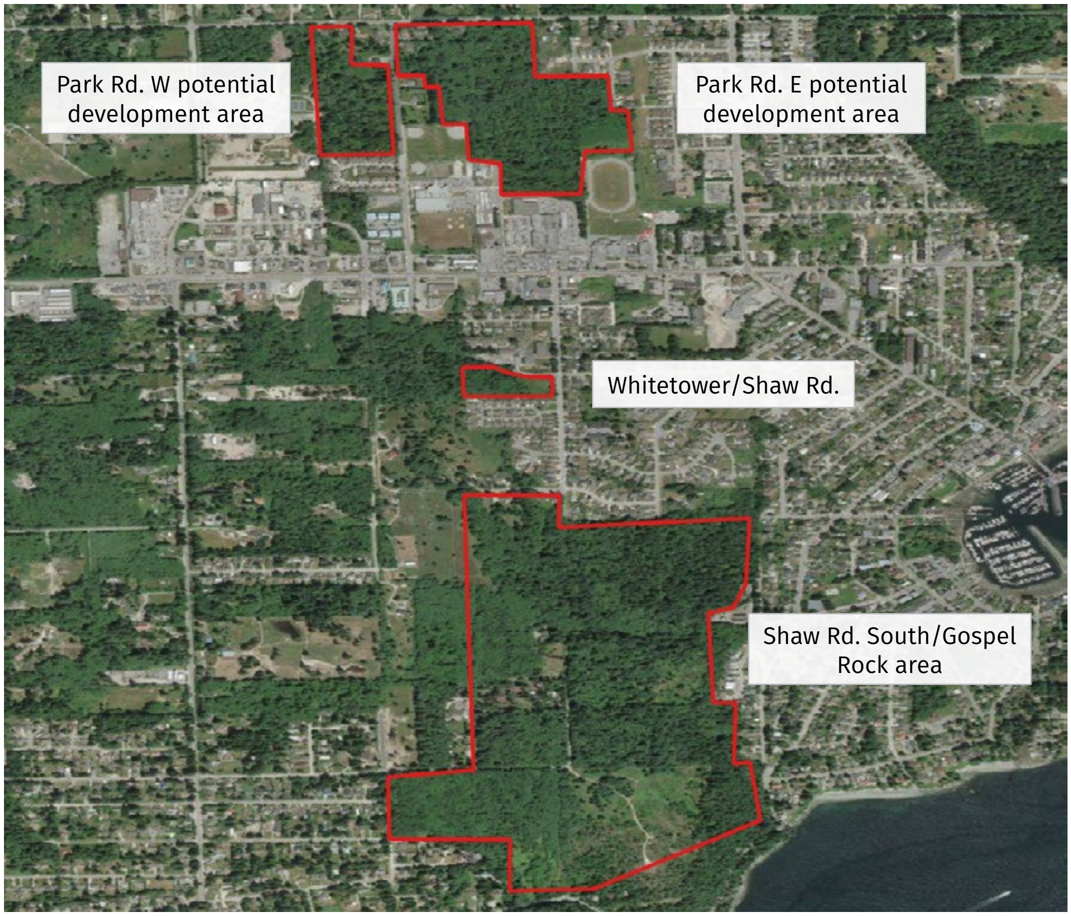


***Figure 12**: Location of the "Decrease Forest" management option*

INCREASE WETLAND AREA

This management option envisions an increase in wetland area at four locations (Figure 13). Due to a lack of depth estimates with which to calculate the volume of these candidate areas (required for modelling in PCSWMM), the benefit transfer approach was applied using the average replacement value per hectare of modeled wetlands in the Charman Creek watershed (\$1,379,533/ha). The Reed Road candidate area (largest area in Figure 13) is more than three times the area of the existing Whitetower Park ponds and represents nearly 90% of the total value for this management option. In total, if the increase in all four wetlands were completed, the added SWM value would be nearly \$3 million (the SWM value of the existing Whitetower Park ponds is \$0.87 million — see baseline results for Charman Creek).

WETLAND NAME	INCREASED AREA (M²)	ESTIMATED STORMWATER MANAGEMENT VALUE (CAD 2022)
Reed Road	19,300	$2,662,499
Davis Road	1,104	$152,300
Henry Rd East	476	$65,666
Henry Rd West	717	$98,913
Total	21,597	$2,979,377

Table 22: *Increase wetland area valuation results*

Figure 13: *Location of the "Increase Wetland Area" management option*

NEW WETLAND

This management option involves creating 1,290 m2 of new wetland near Payne Road (Figure 14). Like the "Increase wetland area" management option, there are no depth estimates with which to calculate the volume of this candidate area, so the benefit transfer approach was again applied using the average replacement value per hectare of modeled wetlands in the Charman Creek watershed ($1,379,533/ha). If this wetland were added, it would provide an estimated SWM value of $177,960 (0.129 ha x $1,379,533/ha). The new wetland is 29% larger than an existing wetland at Shaw Rd (Shaw Pond) (1000 m2), which is valued at a replacement cost of $98,933 (see detailed results for Charman

Creek in Appendix A). Its potential upstream catchment would also be 35.0 ha compared to 1.8 ha for Shaw Pond, which could potentially provide a larger benefit. However, that would require further modelling and an area-storage curve to confirm.

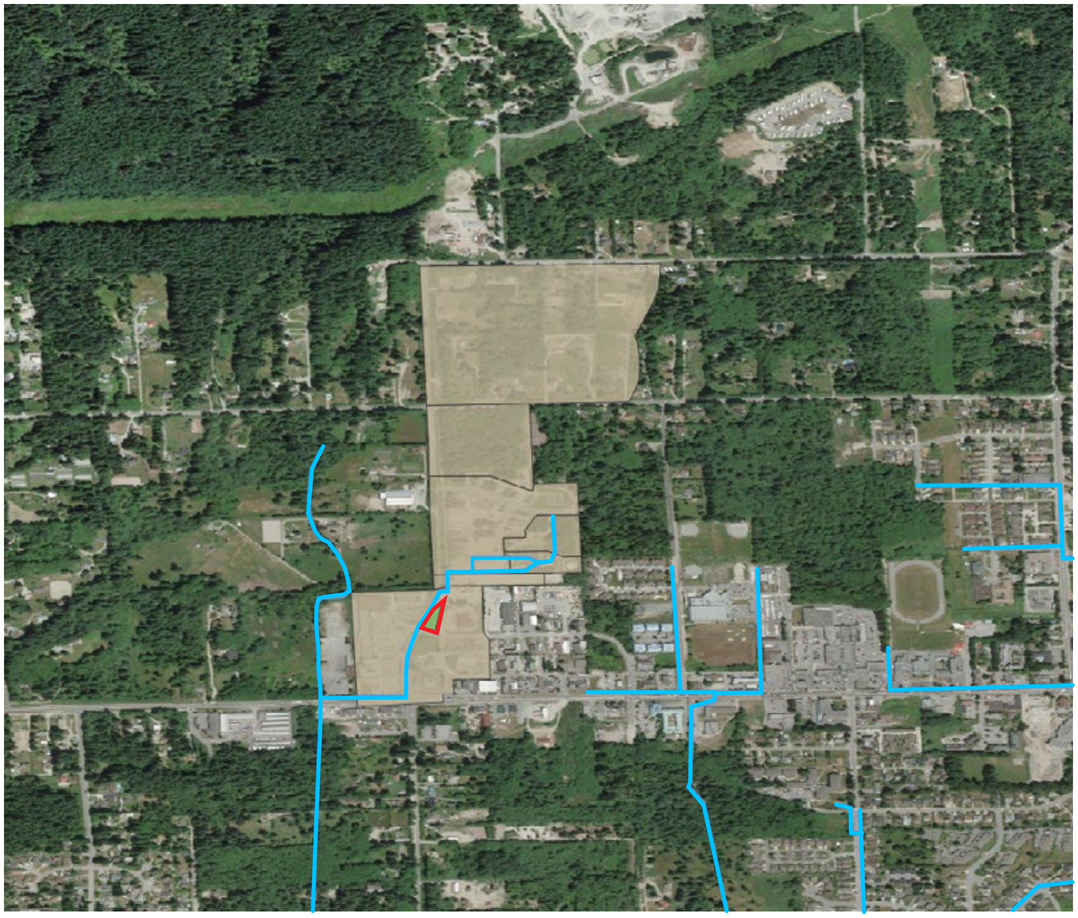


Figure 14*: Location of the "New Wetland Area" management option.*

The green area shows the location of the wetland, the light brown areas are the potential catchment area and the blue lines are streams.

INCREASE RIPARIAN AREA

Similar to the "enhance/restore forest" management option (see above), this management option envisions implementing forest restoration (e.g., tree planting) to enhance the canopy interception service provided by riparian forest in two locations: 1) along Charman Creek and, 2) along Goosebird Creek (Figure 15). The Charman Creek riparian area is 0.5 ha, and the Goosebird Creek area is 0.1 ha. The Charman Creek area was evaluated during the baseline study, so the resulting average riparian value can be applied ($10,716/ha). Like the "enhance/restore forest" management option, it is assumed the riparian area is degraded to an unknown degree, so results are for a range of degradation assumption. If the canopy retention service is 50% degraded, restoring it to full functionality would result in a SWM value of $2,679 (50% of $10,716/ha x 0.5 ha) in avoided replacement costs. The equivalent values for 20%, 10% and 5% degradation are $1,072, $536, and $268, respectively. The proposed new riparian area at the mouth of Goosebird Creek (locally known as Labonte Park) has an estimated value $1,072 (0.1 ha x $10,716/ha).

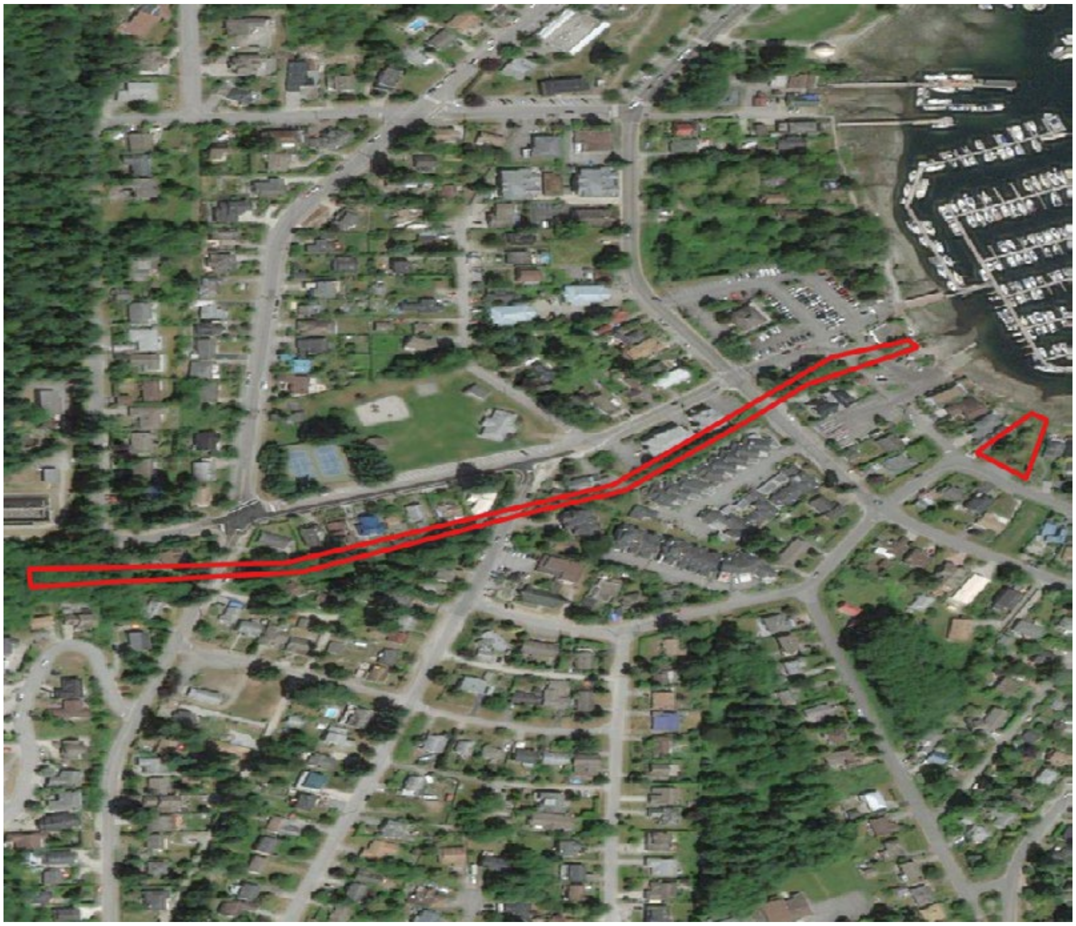


***Figure 15**: Location of the increase riparian area scenario.*

The red outlines show locations of the riparian areas. The northernmost area is Charman Creek and the area south of it is the candidate Goosebird Creek area.

6.2 Summary of Results

Results for baseline valuation, climate change, and the five management options are summarized in Table 23. These results are for a 12hr 100yr storm (i.e., 1% chance of occurring in any given year).

CATCHMENT	Baseline Natural Asset Value (2021 CAD $ '000s)	DIFFERENCE FROM BASELINE (2021 CAD $ '000S) Climate Change	Enhance / restore Forest	Decrease Forest	Increase Riparian Area	Increase Wetland Area	New Wetland
Charman Creek (156.5 ha)							
Forests (72.8 ha)	$767	$99		($415)			
Riparian Areas (13.7 ha)	$147	$63			$3		
Wetlands (0.7 ha)	$966	$315				$152	
Total	**$1,880**	**$477**					
Chaster Creek (590.9 ha)							
Forests (590.9 ha)	$20,597	$240		($405)			
Riparian Areas (104.5 ha)	$3,871						
Wetlands (0 ha)						$165	$178
Total	**$24,468**	**$240**					
Gibson Creek (387.3 ha)							
Forests (257.0 ha)	$5,592	$249					
Riparian Areas (33.8 ha)	$1,264	$108					
Wetlands (0 ha)						$2,662	
Total	**$6,856**	**$356**					
Soames Creek (176.4 ha)							
Forests (116.3 ha)	$4,624	$633					
Riparian Areas (8.0 ha)	$161	$27					
Wetlands (0 ha)							
Total	**$4,785**	**$660**					
Residual Areas							
Forests			$5				
Riparian Areas					$1		
Wetlands							
All Areas							
Forests (1,036.1 ha)	$31,580	$1,221	$5	($820)			
Riparian Areas (160.0 ha)	$5,443	$197			$4		
Wetlands (0.7 ha)	$966	$315				$2,979	$178
Grand Total	**$37,988**	**$1,733**	**$5**	**($820)**	**$4**	**$2,979**	**$178**

Table 23: *Valuation results for stormwater management under each NAM scenario*

Note: *All values except for baseline are relative to baseline and are rounded up to the nearest '000. Blank cells are not relevant to the scenario. Number in parentheses for each natural asset type is area under current conditions. The total area of each watershed is listed in parentheses after the name of the creek.*


7
6

7 Conclusions and Recommendations

Results from the S2S Project are summarized here along with management actions for consideration.

7.1 Conclusion

Effective stewardship of natural assets helps local government to be more resilient, deliver affordable services in a changing climate, reduce costs, and provide an alternative to “building their way out” of infrastructure challenges. Natural assets can provide both critical infrastructure services and co-benefits that add to community quality of life. This practice has become known as a Natural Asset Management (NAM), a subset of the broader field of nature-based solutions (NbS). NAM enables nature to be conceptualized, accounted for, restored, protected, and managed as a vital asset to ensure its viability for the long-term.

A key consideration for NAM is that ecosystems rarely align with political boundaries and jurisdictions. Many entities rely on natural assets that are under the ownership and/or jurisdiction of others. Therefore, collaboration amongst many entities, and action at a watershed scale, is ultimately required for effective NAM.

The Town of Gibsons, deemed nature its most valuable asset in 2014, has been an innovator of NAM.[64] They continue to be a ‘living lab’ for NAM and their efforts have inspired many others. The S2S Project considers NAM at a watershed-scale and also explores surface water – marine interactions in the context of NAM, an area of research which had not been undertaken. Results to date are highly relevant to many other communities in Canada and potentially beyond.

The S2S Project presented an opportunity to take a holistic, evidence-based, watershed-scale approach to:

- Maintain and enhance multiple services.
- Enhance and complement long-standing efforts to reduce flooding risks – both terrestrial and coastal.
- Prepare for and adapt to changing precipitation patterns in a changing climate described above, which will amplify existing risks.

Based on evidence, the S2S Project will contribute to substantially lower lifecycle costs than relying solely on engineered solutions. It will also provide co-benefits that correlate with health, protected and well-managed ecosystems.

64 Town of Gibsons. (2017).

7.2 Recommendations to Advance Natural Asset Management in the Aquifer 560 Watershed

Recommendations connect the results of the S2S Project with the regulatory/jurisdictional/policy context and are based on NAM priorities identified by Town of Gibsons staff. Recommendations are structured according to whether they could be undertaken over the short-term (1-2 years) or medium-term (3-5 years) or as part of continuous improvement efforts. Some recommendations build on activities already initiated by the Town following learnings from Phases 1 and 2 of this project and are noted below.

Recommendation #1: Use findings from this project to prioritize capital projects

Timeline: **Short-term**

Actions & Rationale: This project provided insight into the stormwater benefits of potential afforestation or restoration projects in different locations and assessed the co-benefits that natural assets provide. The Town already has a list of NAM projects in the pipeline for implementation (or currently being implemented). It is recommended that staff assess the list of priority projects considering new information gained from this project and if required, re-prioritize to manage costs and risks of stormwater services and other co-benefits.

A restoration project along Charman Creek is already underway. The stormwater value of restoration in this area was modelled in Scenario 5.

Another potential short-term capital project is based on Scenario 4, which modelled the stormwater value of a new wetland that could be constructed near Payne Road. This area of Town is currently being developed; however, the exact location of a potential new wetland needs to be identified.

Recommendation #2: Update land use policies and by-laws to mitigate high risks to natural assets from development pressure

Timeline: **Short-term**

Objective: Ensure that land use plans and policies consider the stormwater services and other co-benefits provided by natural assets in the Watershed and sub-catchments.

Actions & Rationale: The project has resulted in an improved understanding of the current state of natural assets in the Watershed and their important role in delivering stormwater services and other co-benefits to the community. Development pressure was identified as a high risk to all natural assets in the Watershed.

The scenarios modelled in this project considered how of a range of potential, mostly land use-related, changes would impact stormwater services (afforestation, wetland enhancement or construction, urban development and restoration). Scenario 2 considered the impact of urban development on stormwater services in three locations: the Shaw Rd South/Gospel Rock area, the Whitetower/Shaw Rd area and the Park Rd East and West area. **The total capital cost to replace stormwater services provided by the existing natural assets in these locations would be roughly $1.5M, which does not account for ongoing operating and maintenance costs of constructed stormwater ponds.** It is in the Town's interest to leverage natural assets, where possible, to manage the lifecycle costs of stormwater services in new and existing developments. It should also be noted that development pressure is the leading cause of deforestation, one of the high risks to natural assets.

In the short-term, the Town will be updating its DPAs – Geotechnical Hazards and the Environmentally Sensitive Areas; field assessments were done in 2023 in Charman, Goosebird and Gibson Creeks, the foreshore and areas of wetlands not previously mapped in the SEI. The Town may consider further updates to the OCP, which is an opportunity to ensure that aspects of the plan, such as zoning, sufficiently protect critical natural assets including the Town's tree canopy, in addition to the consideration of requirements around impervious coverage permitted on lots. Updates to set-back requirements from creeks or other requirements that support SWM objectives could also be explored. The Town should also review and if necessary, update other by-laws that affect drainage, such as its Stormwater Management Bylaw, its Development Cost Charges Bylaw, and its Water Regulation Bylaw.

The Town would also benefit from developing a Parks Master Plan aligned with its Urban Forest Strategy, currently in development, and ensure that any plans for naturalization or tree planting are designed with the results of this project and other urban forest objectives in mind. The Town should ensure that its existing Tree-Preservation By-Law is aligned with the Urban Forest Strategy and Parks Master Plan.

Overall, it will be important to ensure alignment between the new OCP and the results of this assessment to ensure that land use policies, bylaws and DPAs manage risks to natural assets effectively, and in accordance with best management practices.

Recommendation #3: Strengthen multi-jurisdictional collaboration and governance.

Timeline: **Short-term**

Objective: Ensure effective management of natural assets outside of the jurisdiction of the Town of Gibsons to protect critical stormwater services and other co-benefits they provide to the community.

Actions & Rationale: Chaster Creek, with the largest extent of intact forests and riparian areas, is the biggest contributor to stormwater services in the watershed and mostly lies outside of the jurisdiction of the Town. However, undersized culverts cause erosion and flooding downstream. Much of the Watershed in this catchment area is Crown land under provincial jurisdiction, where there is potential to consider and address a variety of impacts at a watershed-scale through setting Water Objectives. Nevertheless, Gibsons Town Council approved funding for a flow accretion study along Chaster Creek and is committed to ongoing flow monitoring in this part of the Watershed because of the understanding that the Town depends on natural asset services being provided within and outside their jurisdiction.

Gibsons' staff reached out to the Province to inform them of the new hydrometric stations it was installing for monitoring in the three creeks and the reason for monitoring. The Province is now taking the initiative to install additional monitoring stations and the Town and Province are sharing monitoring data. The SCRD has also requested access to the data to inform decision-making. The project has therefore led to increased understanding of the need for multi-jurisdictional collaboration and governance of the watershed to better manage water services. The Town has drafted an Aquifer 560 Watershed Agreement with the SCRD to help manage and protect the services provided to the community by natural assets.

Recommendation #4: Use findings from this project to inform the Urban Forest Strategy

Timeline: **Short-term**

Actions & Rationale: This project prompted the Town to collect LIDAR data in 2021 to document canopy cover in the Watershed. The canopy cover data can be used to inform the Urban Forest Strategy, which is currently being developed. The stormwater valuation and co-benefits assessment from this project can also be used to inform the strategy.

Recommendation #5: Advance development of a stormwater utility

Timeline: **Short to Medium-term**

Objective: Ensure sufficient funding for natural asset and engineered stormwater infrastructure assets to achieve desired stormwater LOS.

Actions & Rationale: The Town currently relies on general taxation and grant funding to cover the cost of stormwater services, which is insufficient to manage capital, operating and maintenance costs. It is a high priority for the Town to establish a stormwater utility to secure funding for NAM work and other stormwater service costs. The utility would collect revenue in the form of parcel taxes or user fees.

The Town would benefit from developing a long-term financial plan for its stormwater system to guide the fee structure for a new stormwater utility. The Town has already begun identifying the operations and maintenance costs for their drainage services; they should have a strong understanding of the time and resource requirements for different types of assets that support drainage. Costs studied to date include an assessment of the projected lifecycle management costs for the proposed additional stormwater pond in Whitetower park, which was compared with an engineered alternative.

It is important to note that a stormwater utility would operate only in the Town of Gibsons, and some interventions to manage stormwater services will be needed outside of its jurisdiction. The Town is addressing this issue in the short-term through development of an Aquifer 560 Watershed Agreement with the SCRD. The agreement will provide the space to collaborate on monitoring and restoration work outside of the Town’s jurisdiction (see *recommendations #7* and *#8*).

Recommendation #6: Ensure measures are in place to mitigate high risks related to green waste dumping and invasive plant species

Timeline: **Short to Medium-term**

Objective: Reduce prevalence of green waste dumping and invasive plant species to protect ecological health of the watershed.

Actions & Rationale: Green waste dumping is among the top risks to the foreshore, creeks, the urban forest, and riparian areas in the watershed. Mitigation measures currently being taken include the development of education and awareness messaging to residents to prevent dumping, particularly in the riparian areas and the foreshore. It is recommended that the Town track and report on extent of dumping and review whether additional enforcement measures are needed to reduce this risk.

Invasive plant species are also a high risk to natural assets in the Watershed. While the Town has made some progress in managing invasive plant species, one of the barriers to making further progress on removal is that there is no approved site for disposition of materials. It is recommended that the Town continue its efforts to find a suitable location and process for disposal to address this high risk to native species and ecological health. This is a pre-requisite to establishing an invasive plant species bylaw.

Recommendation #7: Communicate the results of this project and build awareness of the service delivery value of the Watershed

Timeline: **Short to medium-term**

Objective: Build public awareness and support for protection and management of natural assets in the Aquifer 560 Watershed.

Actions & Rationale: A unique characteristic of NAM is that good management practices need to be undertaken by both the private and public sectors to achieve service delivery objectives. It is critical that the public be aware of the value of services provided by natural assets in the Watershed, and that they understand the actions they can take to protect and manage those services.

It is recommended that the Town communicate the results of this project and continue its broad efforts to educate the community about the value of the Watershed and good NAM practices. Potential next steps for the Town could include developing or expanding education programs and partnerships with stewardship groups, community organizations, the SCRD and the Squamish Nation.

Recommendation #8: Address data and information gaps to improve knowledge about the role of the Watershed in stormwater service delivery

Timeline: **Continuous Improvement**

Actions: The modelling report recommended several actions the Town can take to address data and information gaps identified in the report. Table 24 below summarizes the gaps and recommended actions.

GAP	RECOMMENDED ACTION
Insufficient flow data	Collect supplementary flow data at more stream locations with permanent stream gauges. (Low-cost option: Measure flow during a storm, e.g., over 8hrs, to provide minimum necessary data after a single storm.) NOTE: As a result of this project, Town staff have purchased flow sensor equipment to measure flows during storms and to validate the existing rating curve.
No nearby weather stations	Measure rainfall during storm over full day to determine whether lag exists between storm peaks in Sechelt and Gibsons, obtain time series of precipitation intensities. Develop gridded precipitation data by interpolating b/w weather stations using LIDAR or radar data. NOTE: As a result of this project, the Town has installed 6 weather stations in the Aquifer 560 Watershed to improve reliability of precipitation data.
Canopy interception assumptions	Put rain gauges out in a forest for areas with/without canopy and compare the data to obtain a local % canopy interception.
Insufficient wetland storage data	Take field measurements [e.g., go out in a boat or gumboots to measure depth and area so a set of Sensitive Ecosystem Inventory (SEI) storage curves can be developed].
Soil infiltration assumptions	Take local soil infiltration measurements.
Stream channel assumptions	Measure cross-sections of stream channels.
Inability to simulate flood extent	Conduct 2D modelling to permit model coupling more easily between terrestrial and coastal flood dynamics to assess overall risk to infrastructure under different design storms.
Outdated or poor-quality data	Use land use classifications to estimate updated imperviousness values and improve the coverage of the SEI via ground-truthing with GPS.

Table 24: Gaps and recommended actions

Recommendation #9: Build understanding of the hydraulic connection between surface and groundwater to support aquifer protection

Timeline: **Continuous improvement**

Actions & Rationale: During Phase 2, the project team explored the modelling approach that would be taken to assess stormwater services provided by natural assets in the watershed. A key objective was to build an understanding of the hydraulic connection between the groundwater and surface water in the Watershed and the dynamics between stormwater, aquifer recharge and discharge on creek flows from the top of the mountain down to the sea. When the team began developing their approach to capturing flow data, they realized they did not have a way to determine the contribution of both groundwater and surface water to creek flows.

Early conversations with Town staff about this limitation spurred them to seek budget from Council for a flow accretion study in the Chaster watershed, which will take place in Summer 2023. The study considers areas of gains and losses in the creek flows and change of water temperature at various locations along Chaster Creek, which may be an indicator of recharge and/or discharge areas of the aquifer and help characterize the relationship between surface and groundwater on flows in the creek. The knowledge of which areas of the Creek are recharge areas for the aquifer is critical to ensure they are monitored and protected from contamination long-term. It is recommended that the Town build on this study and develop an ongoing monitoring program to track changes to and health of aquifer recharge areas, and to build its understanding of the hydraulic connection between surface and groundwater in other parts of the Aquifer 560 Watershed.

Recommendation #10: Validate condition of natural assets to support prioritization of natural assets restoration and management

Timeline: **Continuous improvement**

Actions & Rationale: The project prompted the Town to formally assess the condition of Charman Creek riparian areas, which had 27 known engineered structures in various locations and some badly eroded areas. The assessment helped build the case for restoration and led to the Town being awarded grant funding of $6M for creek restoration projects in Lower Gibsons.

Staff noted that the lower portion of the riparian area of Chaster Creek is quite degraded, with banks collapsing and heavy sedimentation. Desktop condition assessment is insufficient to inform the location and extent of restoration required to maintain ecological health and prevent erosion. The Town would benefit from validating the condition of natural assets in Chaster Creek and other parts of the watershed, including forests, riparian areas, and wetlands, to help prioritize future restoration projects and other lifecycle management needs. The Town is considering using drones to build stream profiles along the creeks.

The Town would also benefit from developing a plan for regular condition assessment and maintenance plan for stormwater ponds and ditches, which feed into the creek system.

Recommendation #11: Strengthen collaboration with the Squamish Nation

Timeline: **Continuous improvement**

Actions & Rationale: The Squamish Nation is aware of this project and have been involved in conversations related to the co-benefits assessment on cultural and other services the Watershed provides. As a result of this project, there are new opportunities to collaborate on NAM. For example, the Town offered to share flow monitoring data from Gibson Creek with the Squamish Nation in advance of a culvert replacement and channel restoration being undertaken on the Squamish Reserve Land just outside of the Town.

In addition, staff are undertaking a flow accretion study of Gibson Creek, which will include a location at the outfall in Squamish Nation's jurisdiction. Squamish Nation sent an Archaeological/Cultural/Environmental monitor to join the Town's consultant during the fieldwork portion of the project, as a learning opportunity. The Nation was eager to have the Town install a hydrometric station on their land in 2021 and the Town will share the resulting data through its data portal. These efforts are demonstrating the benefits to the Town and Squamish Nation of working together and may lead to new opportunities to combine western science with traditional ecological knowledge to support protection and management of natural assets.

Recommendation #12: Continue to build staff capacity in NAM

Timeline: **Continuous improvement**

Actions & Rationale: This project helped to facilitate the Town's overall progress in NAM. The Town benefits from having a full-time, dedicated Natural Asset Technician, which is both rare and innovative in the municipal sector. The Natural Asset Technician can connect knowledge from multiple natural asset-related studies, focus efforts on continuous improvement of data and information, seek funding for NAM activities, and build bridges between different functions in the local government, such as planning, administration, finance and infrastructure.

Cross-functional coordination and collaboration will be needed to support further integration of NAM in the Town's operations and decisions. It is recommended that the Town continue to support education and training internally and ensure appropriate resources are dedicated to continuous improvement of NAM. The Town may also benefit from conducting a NAM competency assessment to identify gaps in skills and knowledge to address.

Appendix A: Data Sources for Inventory and Model Development

Data	Source	Notes
Forest delineation	BC Vegetation Resource Inventory (VRI)	Defined "forested areas" as VRI stands where non-vegetated land comprises less than five percent of the stand area
Wetlands delineation	Sensitive Ecosystem Inventory (SEI)	
Riparian areas delineation	Sensitive Ecosystem Inventory (SEI)	
Stream network	Provided by the Town of Gibsons	
Imperviousness	Global Man-made Impervious Surface (GMIS) dataset	
Infiltration rates	The Agriculture and Agrifood Canada Detailed Soil Survey (DSS) compilation	Matched soil type polygons to infiltration rates by soil type in the 2018 ISMP update using closest matches
Precipitation	Weather stations at Sechelt and Port Mellon.	

Appendix B: Readiness Assessment Template

This Maturity Scale (based on FCM's Readiness Scale) measures the progress of local governments in asset management practices; NAI has adapted it for natural assets. The scale shows that creating and implementing an asset management system is an iterative process that takes time and resources. It structures the asset management journey and provide an objective means of evaluating progress.

WHY COMPLETE THE ASSESSMENT AS A FIRST STEP?

This assessment helps municipalities understand their stage of asset management in the four competency areas for both engineered and natural assets, which will enable them to understand how their work on NAM fits into the asset management process. It supports developing a roadmap for progress and ensure that NAM considerations are incorporated into municipal planning, operations, and service delivery.

How does it work?

FCM has developed a readiness scale with five main competencies that local governments can use to develop a well-functioning asset management system:

1/ Policy and governance: creating policies and objectives related to asset management, bringing those policies to life through a strategy and roadmap, and measuring progress and monitoring implementation over time.

2/ People and leadership: creating cross-functional teams with accountability and ensuring adequate resourcing and commitment from senior management and elected officials to advance asset management.

3/ Data and Information: collecting and using asset data, performance data and financial information to support effective asset management planning and decision-making.

4/ Planning and decision-making: documenting and standardizing how the organization sets asset management priorities, conducts capital and O&M planning, and decides on budgets.

5/ Contribution to asset management: supporting staff in asset management training, sharing knowledge internally to communicate benefits of asset management and participating in external knowledge sharing.

Communities can use the scale (*fcm.ca/en/resources/mamp/tool-asset-management-readiness-scale*) to assess maturity in asset management and progress in the competencies. The Canadian Network of Asset Managers has produced an "Introduction to AM for Communities" that explains the five asset management competencies aligned with FCM's Readiness Scale.[65]

65 FCM. Asset Management Readiness Scale; *fcm.ca/en/resources/mamp/tool-asset-management-readiness-scale*

Local governments may be performing well in one competency while working actively to improve performance in others. Every local government will have unique strengths and weaknesses and will need to create its own roadmap based on current status and priorities.

Tool: Competencies for building NAM into FCM's Asset Management Readiness Scale

NAI has adapted the FCM Asset Management Readiness Scale to include indicators that demonstrate how local governments can build NAM considerations into standard asset management practices. NAI has done this for four of the five competencies identified in the scale. The competency "Contribution to Asset Management" is less relevant and has been omitted for the purpose of this tool.

INSTRUCTIONS

1/ Bring a group of cross-functional staff together to conduct the self-assessment; this should not be done by one person in isolation.

2/ For each asset management competency, read through the descriptions and outcomes for each level.

3/ Discuss and evaluate your organization's current state. You may be at different levels for standard, engineered assets than for natural assets in each category or sub-category. Select a score based on your organization's level as a whole. You may be further advanced in some asset classes than others; the score should reflect the organization's overall maturity in asset management.

4/ Assign the level for which your organization has completed the corresponding outcomes.

5/ In the "Maturity Assessment Completion Form" below, describe briefly why you chose this level. You may note where you are further ahead (or behind) in certain areas.

Note: NAM outcomes are shown in blue, italics.

TIPS

- When self-assessing, choose the level that describes your achieved outcome. The exception would be Level 1, at which point you may be in the process of getting started. If you are still working on a level, assign yourself the previous level.
- Do not worry if you are at an early stage/level. This is not a test!
- You can progress through the five competencies in any order. The focus your efforts is up to you and will depend on local needs and priorities.
- Although the exercise is intended to be applicable to all infrastructure assets, please focus on water infrastructure assets (both engineered and natural) for the competencies: Data and Information and Planning and Decision-Making.

COMPETENCY: POLICY AND OBJECTIVES OUTCOME

This competency involves putting in place policies and objectives related to asset management, bringing those policies to life through a strategy and framework, then measuring and monitoring implementation over time.

POLICY AND OBJECTIVES OUTCOME

Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have set expectations for our AM program. We have the support we need to begin work on an AM policy.		We have drafted an AM policy and strategy and have developed a framework for our AM system.	We are using our AM policy to guide our actions. We have created a road map and have established performance measures.	We have a fully functional AM system. We are using performance measures to track progress and outcomes.	We are continually improving the AM system. Our AM objectives and road map are refined based on the evolving needs of our community.
	Senior management is committed to formalizing an AM program. *Senior management has recognized the role of natural assets in service delivery as part of its commitment to a formal AM program.*	We have drafted an AM policy. Senior management and council have endorsed the AM policy. *Our AM policy explicitly includes natural assets and ecological services they provide to support municipal service delivery.*	We are starting to use AM policy to guide our actions. *Our policy objectives around natural assets are starting to guide our actions.*	We are managing assets and services in accordance with AM policy and organizational objectives. *We are managing natural assets in accordance with AM policy and objectives.*	We are validating and refining corporate, service and AM objectives based on the evolving needs of our community.

SELF-ASSESSMENT

Level Engineered Assets	Level Natural Assets	Describe Current Actions and List Supporting Documents	Potential Actions for Improvements

STRATEGY AND ROAD MAP

Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
	We have identified the benefits that we want AM to deliver and the benefits support organizational objectives. *We have identified the benefits that we want natural assets to deliver and the benefits support organizational objectives.*	We have completed the strategy and road map for our AM system that outlines our approach for the next 1 to 3 years. *Our strategy and road map include objectives related to natural asset management and show how it will be integrated into core infrastructure management processes over the next 1 to 3 years.*	We have established a road map to guide the detailed actions surrounding our AM strategy deployment over the next 3 to 5 years. *Our road map includes ecosystem-based management activities over the next 3 to 5 years, such as identifying plans and procedures to assess the health of natural assets.*	We are achieving our AM policy objectives through a fully functional AM system. Necessary workflows, documents and reporting tools are in place. *We are updating our road map to address evolving needs.*	We are following our road map in continually improving the AM system and in documenting the improvements. *We are continually improving our natural asset management plan.*

SELF-ASSESSMENT

Level Engineered Assets	Level Natural Assets	Describe Current Actions and List Supporting Documents	Potential Actions for Improvements

MEASUREMENT AND MONITORING OUTCOME					
Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have identified short-term actions that will demonstrate early progress on AM. *We have identified short-terms actions that incorporate natural asset management into our AM system.*		We are collecting baseline data on our current AM practices. *We have identified relevant baseline data to measure our progress on natural asset management.*	We have established performance measures to monitor AM system progress and its outcomes and benefits to our community. *Our performance measures include measures that monitor our progress on natural asset management.*	We are using performance measures to monitor AM progress, outcomes and benefits. *We are using performance measures to monitor progress in incorporating natural asset management into our AM system.*	We are monitoring performance and using the feedback to prioritize and make ongoing refinement and improvements. *We are refining our monitoring and performance measures of natural asset management.*

SELF-ASSESSMENT: Level Engineered Assets	Level Natural Assets	Describe Current Actions and List Supporting Documents	Potential Actions for Improvements

COMPETENCY: PEOPLE AND LEADERSHIP

This competency involves setting up cross-functional groups with clear accountability and ensuring adequate resourcing and commitment from senior management and elected officials to advance asset management.

CROSS-FUNCTIONAL REPRESENTATION OUTCOME					
Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have council support to establish a cross-functional AM team to explore AM needs and develop a plan for improving our AM system.		We have a clear mandate for our AM team, and council has approved funding for priority improvements to our AM system.	Our AM team has clear responsibility for improving our AM system. Council champions AM as a core business function.	Our AM team is responsible for guiding and supporting AM on an ongoing basis. AM system roles and responsibilities are operationalized.	Our council's commitment drives continuous improvement of the AM system. Roles and responsibilities evolve to meet ongoing needs.
We have identified the representation we need on our cross-functional AM team. *The resources we have identified include staff from the key departments, such as engineering, public works, parks, engineering, planning, and finance to ensure a holistic and effective approach that can integrate natural asset management into the AM requirements.*		We have formed a cross-functional AM team to guide and oversee AM system planning and deployment. *Our cross-functional team includes a staff person responsible for incorporating natural asset management-related needs into our AM system.*	The AM team works within our organization to lead, communicate and support AM improvement and organizational changes. *A member of the AM team leads, communicates and supports improvements to natural asset management and champions its incorporation into core AM practices.*	Our AM team has been made permanent and tasked with guiding and supporting the AM function across the organization on an ongoing basis. *Our AM team has been tasked with guiding and supporting the integration of natural asset management in our AM system.*	The AM team guides and supports the ongoing improvement of the AM system within the organization. *The AM team is guiding and supporting the integration of natural asset management in our AM system.*

ACCOUNTABILITY OUTCOME					
Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have a champion who has been tasked with planning for our AM program. *The resources appointed to investigate our AM needs will include natural asset management-related needs in the terms of reference.*		Our AM team has been made accountable for guiding AM development, with a documented mandate, terms of reference, and a 1- to 3-year road map. Our AM team is accountable to senior management and council. *Our mandate and the terms of reference include a requirement to assess AM needs related to natural asset management.*	Our AM team has been made accountable for AM implementation and we have added AM system roles and responsibilities to staff job descriptions. *We have included natural asset management roles and responsibilities in staff job descriptions.*	We have operationalized AM roles and responsibilities across our organization. *We have operationalized natural asset management roles and responsibilities across our organization.*	We are documenting changes to AM roles and responsibilities as needed to support our evolving requirements. *The changes we are documenting include AM system roles and responsibilities needed to support evolving requirements related to natural asset management.*

RESOURCING AND COMMITMENT OUTCOME					
Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
Council is aware of the resourcing and funding dedicated to exploring AM system requirements and to proposing an AM road map. *Council is aware of the resourcing and funding needed to incorporate natural asset management into the AM system requirements and road map.*		Council demonstrates buy-in and support for AM and has approved funding for priority improvements. *Council has demonstrated buy-in for priority initiatives that will improve natural asset management and incorporate it into core asset management business practices.*	Council champions AM as a core business function and has approved funding to continue AM road map activities. *Council has approved funding to improve natural asset management and incorporate it into core AM business practices.*	Council has approved funding for ongoing AM system monitoring and enhancement. *Our ongoing AM system monitoring and enhancement includes monitoring and enhancement of natural assets.*	The AM team measures and monitors this progress. Council is committed to ongoing improvement of the AM system. *The AM team measures and monitors this progress related to natural asset management. Council is committed to improving this aspect of our AM system.*

COMPETENCY: DATA AND INFORMATION

This competency involves using asset data, performance data and financial data to support effective asset management planning and decision-making.

ASSET DATA					
Working on Level 1	Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have pooled inventory data, including approximate quantities of assets, within most asset groups. We have some anecdotal information on asset condition and age. *We have started to take an inventory of the natural assets in our jurisdiction that supports municipal service delivery.*		We have basic inventory data for most major assets, including information on general asset properties such as size, material, location and installation date. We are moving our data to a centralized location for use by the AM team. We have defined critical assets and have some condition information for them. *We have basic inventory data for some key natural assets, which includes the type, location and size of the asset.*	We have basic inventory data for all our assets, with some level of service information and standardized condition ratings. We have defined life-cycle investment requirements for critical assets. We have linked AM and financial information for our critical assets. *We have basic inventory data for all critical natural assets assumed to support municipal service delivery, which includes the type, location and size of the asset.*	We have expanded inventory data on some assets, including condition and performance information. We have evaluated the relative risks and life-cycle investment requirements associated with critical assets. We update data according to AM plans or strategy cycles. *We have expanded inventory data for some critical natural assets and have assessed the risks to them and evaluated operations and maintenance requirements to ensure they support the desired level of service.*	We have expanded inventory data and have evaluated the relative risks and life-cycle investment requirements associated with most assets. *We have expanded inventory data for most natural assets and have assessed the risks to them and evaluated operations and maintenance requirements to ensure they support the desired level of service.*

PERFORMANCE DATA OUTCOME

Working on Level 1 / Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have informal or anecdotal approaches for measuring asset condition or performance. *We are aware of common or emerging approaches for measuring the condition of our natural assets and their performance in supporting municipal service delivery.*	We have some information on asset condition and performance of critical assets collected from a variety of sources. *We have some information on the condition and performance of at least one critical natural asset, based on a combination of online data collection, field data collection and modelling (e.g., SWIMM for stormwater management performance).*	Some level-of-service measures have been defined and data have been captured. We have reviewed service levels and asset performance with council. *We have information on the condition and performance of the most critical natural assets and have defined the desired level of service for them and have reviewed this information with council.*	We have defined and measured levels of service for critical service areas. We communicate the results from our level-of-service measurement program to staff and council regularly. *We have defined the desired level of service for some critical natural assets and include results from our level-of-service management program to staff and council.*	We have defined and measured levels of service for most or all critical service areas. We continually improve how we collect data on level-of-service performance. *We have defined the desired level of service for most critical natural assets and we continually improve how we collect data on level-of-service performance and connect it to standard AM data.*

FINANCIAL DATA OUTCOME

Working on Level 1 / Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
We have financial data on our assets, supporting minimum PS-3150 reporting requirements. *We do not yet have financial data that puts a value on the national assets that support municipal service delivery.*	We have captured capital and operating expenditure data for some assets. We have developed a strategy to link AM and financial information. *We have captured capital and operating expenditure data for at least one critical natural asset, which will support the desired level of service required by the asset.* *We have completed an economic valuation of at least one critical natural asset, based on the replacement cost of grey infrastructure alternatives that could provide equivalent services.*	We have captured capital and operating expenditure data for most assets. We have linked AM and financial information for all critical assets. We can demonstrate the gaps between forecasted infrastructure needs and current spending levels. *We have captured capital and operating expenditure data for most critical natural assets that will support the desired level of service required by the asset.* *We have completed an economic valuation of most critical natural assets and have integrated this information into our AM system to support long-term financial planning.*	We have calculated the cost of service delivery for all critical assets. *We have incorporated the cost of managing some natural assets into financial planning and budgeting.*	We understand the trade-offs between investment and quality of the front line service we deliver, and we use this to refine our financial plans. *We have incorporated the cost of managing most critical natural assets into our long-term financial plans.* *We understand the trade-offs between investments in natural asset management and the quality of service they can deliver, and we use this to refine our financial plans.*

COMPETENCY: PLANNING AND DECISION-MAKING

This competency involves documenting and standardizing how the organization sets asset management priorities, conducts capital and operations and maintenance planning, and decides on budgets.

Working on Level 1 Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
Our asset investment plans address basic needs and respond to known problems. We evaluate priorities based on experience, council and management input and available information.	Our asset investment plans address observed short-term issues. We evaluate each need individually, and teams set priorities independently of each other, based on objectives and criteria representing the needs of their departments.	Our asset investment plans manage short-term risks and service impacts. We set priorities based on common organizational goals and objectives. We have drafted preliminary AM plans.	Our asset investment plans balance short-term service objectives (our desired level of service) with longer-term goals and risks. Planning is carried out using our AM system and kept up to date via normal business.	Our asset investment plans are integrated to address risks to service and business goals. We have detailed AM plans for all services. We are continually improving our approach.
DOCUMENTATION AND STANDARDIZATION OUTCOME				
Our approach to asset investment planning varies across the organization. *Our approach to asset investment planning does not yet include a documented approach to managing or protecting the natural assets that support municipal service delivery.*	Our departments follow a similar but informal asset investment planning approach. We evaluate investment needs and priorities based on a mix of structured and ad-hoc practises and criteria. *One department is responsible for conservation and protection of natural assets, which have not typically been included in asset investment planning or evaluated in relation to the municipal services they provide.*	We have deployed a structured asset investment planning approach, but application is inconsistent. We set priorities using similar criteria based on organizational goals and objectives. *We have begun to incorporate investment plans for natural assets into our asset investment planning, in coordination with related service areas and departments.*	We employ a consistent structured asset investment planning approach across each of our critical services. We set priorities using criteria which are fully aligned with our organizational goals and objectives. *We are incorporating investment plans for natural assets in our asset investment planning and setting priorities that ensure conservation and protection of natural assets.*	We employ our structured asset investment planning approach across all services. We adapt our planning approach and criteria to align with evolving organizational goals and objectives. *Natural assets have been formally incorporated into structured asset investment planning, and their conservation, protection and management is a key organizational goal.*

ASSET MANAGEMENT PLANS OUTCOME				
Working on Level 1 Completed Level 1	Completed Level 2	Completed Level 3	Completed Level 4	Completed Level 5
Our asset investment plans are typically reactive and focus on addressing basic needs (e.g., growth, regulations and known problems). Priorities are evaluated with available information, staff experience and input from council and management. *Asset investment plans focus on addressing needs related to grey infrastructure assets.* *Some commitments have been made to conserve and protect critical natural assets/areas, but these commitments have not yet translated into developing formal natural asset management plans.*	We have draft AM plans for some asset classes, with forecasted financial needs based on estimated data. *Natural assets are not yet incorporated into our asset investment plans in any formal way. Our approach to managing natural assets is short-term and reactive.*	Our asset management plans are based on short-term issues and priorities. We have drafted preliminary AM plans for critical services based on available information about service levels and risk management. *We have developed AM plans for some critical natural assets, which are based on available information about service levels and risk management. Plans are reviewed annually.*	Our asset management plans are based on short- and long-term issues and priorities. We have developed detailed AM plans for most services. They include basic-needs forecasting and risk management strategies for critical assets. *Our asset investment plans incorporate analysis from our risk-assessment and adaptive-management plans for key natural assets.*	We have integrated and optimized asset management plans. We have developed detailed AM plans for all services based on actual data. Our AM plans include needs forecasts and risk management strategies for most assets. Plans address risk to service and business goals. *Our asset investment plans are optimized and fully integrate management of natural assets to support sustainable service delivery.*

Appendix C: Risk Mapping Methodology

For each sub-catchment (i.e., Charman, Chaster, Gibson, Soames) and the area outside these watersheds within the project area, the proportion of each asset type overlapping the stressor shapefiles was calculated. This resulted in the percent-area of each stressor type within each asset type by sub-catchment. For each asset type, the percent-area of each stressor was multiplied by its risk rank (see table A1), and all results were added together to get a cumulative risk score for each asset type. Lastly, for each sub-catchment, scores were added together for all the three asset types represented in the Dashboard (i.e., forest, riparian areas, wetlands) to get an overall cumulative risk rank. This process is captured in Table A2 below.

	Likelihood	Severity	Overall Risk Score	Rank
Erosion	3.5	3.5	12.25	1
Development	4.5	4.5	20.25	6
Drought	4	4	16	4
Invasive Species	5	3	15	2
Green Waaste Dumping	5	3	15	2
Deforestation	4	4.5	18	5

Table A1: *Risk rating for top risk-asset categories*

STEP 1. Calculate the area of each stressor within each asset type

	NATURAL ASSETS (ha)			STRESSORS (ha): Development			Invasive species			Drought		
Sub-catchment	Forests	Riparian	Wetland	Forests	Riparian	Wetland	Forests	Riparian	Wetland	Forests	Riparian	Wetland
Area outside watersheds	219.99	10.79	4.80	58.73	0.74	0.00	0.10	0.00	0.00	219.99	10.79	4.80
Charman	75.59	12.45	0.00	10.69	0.12	0.00	0.00	0.00	0.00	75.59	12.45	0.00
Chaster	758.61	116.76	13.91	22.63	6.44	0.00	1.42	0.00	0.00	758.61	116.76	13.91
Gibsons	228.27	36.01	0.00	4.55	1.49	0.00	1.64	0.01	0.00	228.27	36.01	0.00
Soames	122.65	17.70	0.00	7.64	4.03	0.00	0.03	0.00	0.00	122.65	17.70	0.00
TOTAL	1405.12	193.71	18.71	104.24	12.82	0.00	3.21	0.01	0.00	1405.12	193.71	18.71

	STRESSORS (ha): Erosion			Green Dumping			Deforestation	
Sub-catchment	Forests	Riparian	Wetland	Forests	Riparian	Wetland	Forests	Riparian
Area outside watersheds	0.00	0.00	0.00	0.42	0.23	0.00	0.00	0.00
Charman	0.00	0.00	0.00	0.12	0.05	0.00	0.00	0.00
Chaster	0.63	0.47	0.00	0.00	0.00	0.00	26.22	0.00
Gibsons	0.00	0.00	0.00	4.10	4.02	0.00	0.00	0.00
Soames	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.63	0.47	0.00	4.64	4.30	0.00	26.22	0.00

STEP 2. Calculate the % area of each stressor within each asset type

	Development			Invasive species			Drought		
	Forests	Riparian	Wetland	Forests	Riparian	Wetland	Forests	Riparian	Wetland
Area outside watersheds	26.70%	6.86%	0.00%	0.05%	0.01%	0.00%	100.00%	100.00%	100.00%
Charman	14.14%	0.97%	0.00%	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%
Chaster	2.98%	5.51%	0.00%	0.19%	0.00%	0.00%	100.00%	100.00%	100.00%
Gibsons	1.99%	4.15%	0.00%	0.72%	0.02%	0.00%	100.00%	100.00%	100.00%
Soames	6.23%	22.74%	0.00%	0.03%	0.01%	0.00%	100.00%	100.00%	100.00%
Total	7.42%	6.62%	0.00%	0.23%	0.01%	0.00%	100.00%	100.00%	100.00%

	Erosion			Green Dumping		Deforestation	
	Forests	Riparian	Wetland	Forests	Riparian	Forests	Riparian
Area outside watersheds	0.00%	0.00%	0.00%	0.19%	2.17%	0.00%	0.00%
Charman	0.00%	0.00%	0.00%	0.16%	0.40%	0.00%	0.00%
Chaster	0.08%	0.40%	0.00%	0.00%	0.00%	3.46%	0.00%
Gibsons	0.00%	0.00%	0.00%	1.79%	11.16%	0.00%	0.00%
Soames	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.04%	0.24%	0.00%	0.33%	2.22%	1.87%	0.00%

STEP 3. Multiply each stressor % area by the appropriate risk rank* for that stressor, add all stressors together to get a cumulative risk rank per asset type

	Forests	Riparian	Wetland	Cumulative
Area outside watersheds	5.87	4.52	4.00	14.40
Charman	4.99	4.08	0.00	9.07
Chaster	4.42	4.39	4.00	12.81
Gibsons	4.19	4.51	0.00	8.70
Soames	4.44	5.59	0.00	10.03
Overall	4.64	4.51	4.00	13.15

***Risk Ranks from MNAI**

	Likelihood	Severity	Overall Risk !	Rank
Erosion	3.5	3.5	12.25	1
Development	4.5	4.5	20.25	7
Drought	4	4	16	4
Invasive Species	5	3	15	2
Green Waste Dumping	5	3	15	2
Deforestation	4	4.5	18	6
Urban Tree Canopy	4	4	16	4

Table A2: *Risk mapping sorkflow*

References

AECOM. (2010). *Integrated stormwater management plan*. Final report prepared for the Town of Gibsons. pp. 143.

Anielski, M. and S.J. Wilson. (2005). *Counting Canada's natural capital: assessing the real value of Canada's boreal ecosystems.* Canadian Boreal initiative, Pembina institute, Canada.

Ayenew, B. and Tesfay, Y., (2015). *Economic valuation of forest ecosystems service's role in maintaining and improving water quality.* Economics, 4(5), pp.71-80.

Bartlett, K. (Nov 25, 2021). How the CVRD responded to last week's emergency and how it's preparing for the next one. Coast Reporter: *www.coastreporter.net/local-news/how-the-scrd-responded-to-last-weeks-emergency-and-how-its-preparing-for-the-next-one-4796405*.

BC Auditor General. (2018). *Managing Climate Risks: An independent audit.* Available at: *www.bcauditor.com/sites/default/files/publications/reports/Climate_Change_FINAL.pdf*.

B.C. Ministry of Forests. (1991). *Outdoor recreation survey 1989-90: how British Columbians use and value their public forest lands for recreation*. Victoria, B.C.

Böhnke-Henrichs, A., Baulcomb, C., Koss, R., Hussain, S. S., & de Groot, R. S. (2013). *Typology and indicators of ecosystem services for marine spatial planning and management*. Journal of Environmental Management, 130(11), 135-145. *https://doi.org/10.1016/j.jenvman.2013.08.027* Brown, C., Jackson, E., Harford, D. and Bristow, D. (2021): *Cities and Towns;* Chapter 2 in Canada. In F.J. Warren and N. Lulham (Eds.), *A Changing Climate: National Issues Report*. Government of Canada, Ottawa, Ontario. *link*

Calder, I., Hofer, T., Vermont, S. and Warren, P., (2008). *Towards a new understanding of forests and water.* UNASYLVA-FAO-, 229. (pp.3).

Duffy, C., O'Donoghue, C., Ryan, M., Kilcline, K., Upton, V. and Spillane, C., (2020). *The impact of forestry as a land use on water quality outcomes: An integrated analysis*. Forest Policy and Economics, 116, p.102185.

Dudley, N. and Stolton, S. (2003). *Running Pure: The importance of forest protected areas to drinking water*. A research report for the World Bank / WWF Alliance for ForestConservation and Sustainable Use, United Kingdom.

Edmonds, D.A., Chadwick, A.J., Lamb, M.P., Lorenzo-Trueba, J., Murray, A.B., Nardin, W., Salter, G. and Shaw, J.B., (2021). *Morphodynamic modeling of river-dominated deltas: a review and future perspectives*.

Ernst, C., Gullick, R. and Nixon, K. (2007). "*Protecting the Source: Conserving forest to protect water.*" In The Economic Benefits of Land Conservation. The Trust for Public Land. www.tpl.org

IPCC. (2022): Summary for Policymaker [H.-O. Portner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegr.a, M. Criag, S. Langsdorf, S. L.schke, V. M.ller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergivernmental Panel on Climate Change [H. – O. P.rtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegr.a, M. Criag, S. Langsdorf, S. L.schke, V. M.ller, A. Okem (eds.)]. Cambridge University Press. In Press.

Knowler, D.J., MacGregor, B.W., Bradford, M.J., and Peterman, R.M. (2003). *Valuing freshwater salmon habitat on the west coast of Canada*. Journal of Environmental Management, 69(3), 261-273.

Kulshreshtha, S.N. and Loewen, K.G., (1997). *Value of wilderness protection in Saskatchewan: a case study of existence values*. Journal of Sustainable Forestry, 5(1-2), 207-216.

Kulshreshtha, S.N., Lac, S., Johnston, M., and Kinar, C. (2000). *Carbon Sequestration in Protected Areas of Canada: An Economic Valuation.* Prepared for Canadian Parks Council.

Moudrak, N., Feltmate, B., Venema, H., Osman, H. (2018). *Combating Canada's Rising Flood Costs: Natural infrastructure is an underutilized option. Prepared for Insurance Bureau of Canada*. Intact Centre on Climate Adaptation, University of Waterloo. *https://www.intactcentreclimateadaptation.ca/wp-content/uploads/2018/09/IBC_Wetlands-Report-2018_FINAL.pdf.*

Municipal Natural Assets Initiative. (2017). *Defining and Scoping Municipal Natural Assets.* MNAI.

Municipal Natural Assets Initiative (2021). *Managing Natural Assets to Increase Coastal Resilience, Gibsons Pilot Study, British Columbia, Pilot Study.* MNAI. *https://mnai.ca/media/2021/11/MNAI-Pilot-Coastal-Resilience-Gibsons-103.pdf*.

Municipal Natural Assets Initiative (2021b). *Managing Natural Assets to Increase Coastal Resilience, Guidance Document for Municipalities. mnai.ca/media/2021/11/MNAI-Coastal-Asset-Guidance-Doc-cover-101-combined.pdf*.

Municipal Natural Assets Initiative. (2022). *Grindstone Creek Watershed Natural Assets Management Project: Summary Report. MNAI.ca*.

Municipal Natural Assets Initiative. (2023) *Natural Asset Infrastructure in British Columbia: Barriers and Opportunities.* MNAI. *mnai.ca/barriers-and-opportunities*

Mohan, B.L., Polasky, S. and Adams, R.S. (2000). *Valuing Urban Wetlands: A Property Price Approach*. Land Economics 76(1): 100-113.

Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. P.rtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegr.a, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 321–445. *https://doi.org/10.1017/9781009157964.006*.

Pate, J. and Loomis, J. (1997). *The effect of distance on willingness to pay values: a case study of wetlands and salmon in California*. Ecological economics, 20(3), 199-207.

Pörtner et al. (2021). IPBES-IPCC co-sponsored workshop report on biodiversity and climate change: IPBES and IPCC. 2020. *www.ipcc.ch/site/assets/uploads/2021/07/IPBES_IPCC_WR_12_2020.pdf*.

Reed, G., Brunet, N. D., McGregor, D., Scurr, C., Sadik, T., Lavigne, J., & Longboat, S. (2022). *Toward Indigenous visions of nature-based solutions: an exploration into Canadian federal climate policy*. Climate Policy, 22(4), 514-533. *doi.org/10.1080/14693062.2022.2047585*.

Richardson, L. and Loomis, J. (1996). *The total economic value of threatened, endangered and rare species: An updated meta-analysis*. Ecological Economics 68(5): 1535-1548. DOI: *10.1016/j.ecolecon.2008.10.016*.

Rodrigues, J. G., Conides, A. J., Rivero Rodriguez, S., Raicevich, S., Pita, P., Kleisner, K. M., ... & Villasante, S. (2017). *Marine and coastal cultural ecosystem services: knowledge gaps and research priorities*. One Ecosystem 2 (2017).

Sahl, J., Hamel, P., Molnar, M., Thompson, M., Zawadzki, A., and Plummer, B. (2016). *Economic valuation of the stormwater management services provided by the Whitetower Park ponds, Gibsons, BC.* *mnai.ca/media/2018/01/TownofGibsons_CaseStudy.pdf*.

Sang, N., (2020). 6 C*oastal and Freshwater Flood Models: A Review in the Context of NbS*. In Modelling Nature-based Solutions: Integrating Computational and Participatory Scenario Modelling for Environmental Management and Planning (pp.210).

Sunshine Coast Regional District. (2008). Elphinstone Official Plan Document. Available at: *https://www.scrd.ca/ocp/elphinstone/#*.

Sunshine Coast Regional District. (2009). Integrated Stormwater Management Planning, Phase 2: Watershed Assessments. *gibsons.ca/wp-content/uploads/2021/11/2009-FEB-13-Delcan-Integrated-Stormwater-Management-Planning-Phase-2-Watershed-Assessments.pdf*.

Town of Gibsons. (2005). Hazard Risk and Vulnerability Analysis. *www.scrd.ca/wp-content/uploads/2022/11/HRVA-GIBSONS_FINAL.pdf*.

Town of Gibsons. (May 2013). Aquifer Mapping Study. *gibsons.ca/wp-content/uploads/2018/01/Aquifer-Mapping-Report-Final.pdf*.

Town of Gibsons. (December 2014). Foreshore Condition Assessment Final Report. *gibsons.civicweb.net/document/16795*.

Town of Gibsons. (March 2015). Smart Plan: Gibsons Official Community Plan. *gibsons.ca/wp-content/uploads/2019/01/Official-Community-Plan-Bylaw-No.-985-2015-current.pdf*.

Town of Gibsons. (2019). Integrated Stormwater Management Plan Update. *gibsons.civicweb.net/document/62665*.

Town of Gibsons. (July 2017). Water Supply Strategy Update. *gibsons.civicweb.net/document/19155*.

Town of Gibsons. (2017). Towards an Eco-Asset Strategy. *gibsons.ca/wp-content/uploads/2017/12/Eco-Asset-Strategy.pdf*.

Town of Gibsons. (2021) Tree Preservation Bylaw. *gibsons.ca/services/bylaw-enforcement/tree-preservation-bylaw/*.

Urban Systems. (2019). *Town of Gibsons 2018 Integrated Stormwater (Rainwater) Management Plan* — Final Update. *gibsons.civicweb.net/document/62665*

Wilson, S.J. (2008). *Ontario's wealth, Canada's future: Appreciating the value of the Greenbelt's eco-services*. (pp. 70). Prepared for the David Suzuki Foundation

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