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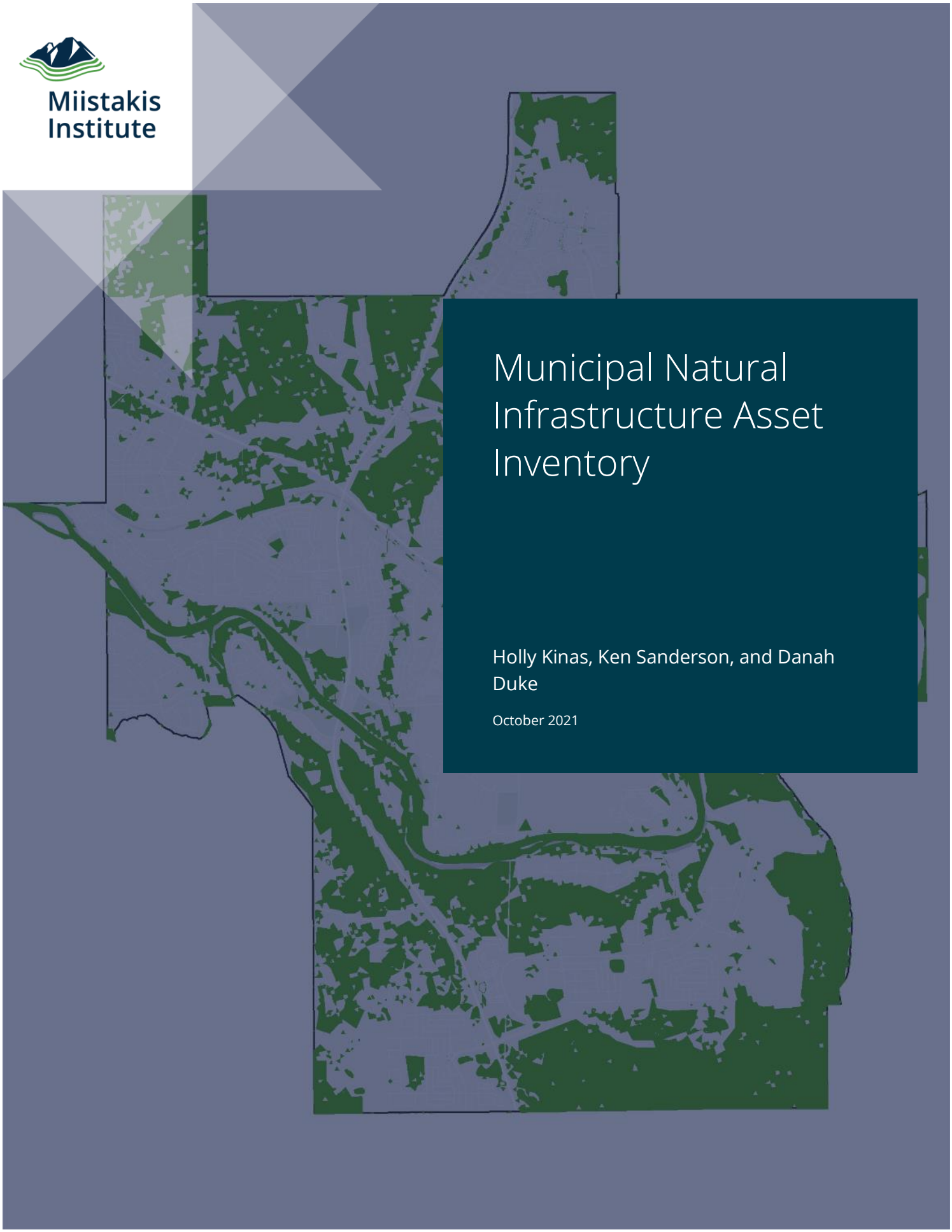

Municipal Natural Infrastructure Asset Inventory

Holly Kinas, Ken Sanderson, and Danah Duke

October 2021

Innovative research. Engaged communities. Healthy landscapes.

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October 2021

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Introduction

If you're reading this, you probably already understand that nature has value and provides ecosystem goods and services that benefit humans and ecosystems. You've probably heard terms used such as natural (or green) infrastructure, natural assets and wondered how these are related and how they apply to municipalities.

Natural infrastructure mitigates climate risks by activating natural ecosystem processes such as accessing and enhancing the absorption capacity of floodplains, modifying stormwater conveyance, increasing water storage capacity and reducing runoff (Horizon Advisors, 2019; ICF, 2018). Natural infrastructure is a key component of effective municipal climate adaptation strategies, specifically by addressing flood and drought threats. There is a growing body of evidence that supports the ability of natural infrastructure to mitigate risks and damage related to climate change, which is especially important in light of the forecast increased frequency and severity of extreme weather events (Environment and Climate Change Canada, 2017). By mitigating flood and drought risk, natural infrastructure (and nature in general) has the ability to enhance watershed resiliency—the core objective of the Government of Alberta's Watershed Resiliency and Restoration Program and the focus of this project, the *Municipal Natural Infrastructure Asset Inventory.*

One of the most common and powerful ways for municipalities to conceptualize the value of nature is to categorize 'nature' into specific assets—natural assets—and incorporate them into asset management inventories. Emerging evidence shows that identifying, measuring and managing natural assets as part of an overall municipal asset management strategy can save capital and operating costs and reduce risk (Municipal Natural Assets Initiative (MNAI), 2017). Additionally, municipalities are finding that natural assets are resilient and adaptable to climate change. With effective identification, monitoring, maintenance and rehabilitation now, natural assets can provide service and add value for decades in ways that much grey infrastructure (dams, storm drains) cannot (Municipal Natural Assets Initiative (MNAI), 2017). For example, many natural assets serve multiple purposes; consider urban forests that reduce flooding risk as well as provide valued recreational opportunities.

Creation of a comprehensive inventory of municipal natural assets is one of the first steps in management and valuation of these assets and the services they provide. The idea behind the *Municipal Natural Infrastructure Asset Inventory* is to create a spatial resource and database using best available data, and then allow users to self-identify the 'infrastructure' functions and services in which they are most interested and the natural assets that support them. This guidebook is freely available online, and generic so that each municipality can tailor it to create their own municipal natural infrastructure asset inventory.

The Municipal Natural Assets Initiative (MNAI) is a leader in the field of natural infrastructure for Canadian municipalities. The *Municipal Natural Infrastructure Asset Inventory* builds on both their experiences with inventory projects across Canada (Municipal Natural Assets Initiative (MNAI), 2021a) and their Primer on Natural Asset Management. These align with Step 2 in their municipal asset management planning process: "identify key natural assets and the services they provide" (Municipal Natural Assets Initiative (MNAI), 2017).

The goal of the *Municipal Natural Infrastructure Asset Inventory* is to support Alberta municipalities in identifying their own natural infrastructure assets and evaluating the flood and drought-related ecosystem services they provide. A tool in this process is to map these assets to aid in the municipal planning process. Increasing the understanding and visibility of natural assets will lead to support for their protection and enhancement—citizens can't protect natural assets that they don't know exist!

Importance of Natural Infrastructure for Municipalities

A spatial inventory is a tool that municipalities can use to provide the information necessary to value and conserve natural infrastructure; it answers the questions what natural infrastructure do we have and where is it found? The creation of a natural asset inventory lends itself to the same asset management processes already being used by municipalities and improves understanding of the vital services that nature provides compared to those provided by grey infrastructure (Municipal Natural Assets Initiative (MNAI), 2017). Answering the questions of what and where natural infrastructure is, places it in an appropriate spatial context in the municipal landscape. Both resource management and land use planning are heavily dependent on spatial data. Decision-making systems (both technical and conceptual) will depend on having natural infrastructure mapped at relatable spatial scales.

Understanding the ecosystem services provided by natural infrastructure allows managers to prioritize either particular assets or ecosystem services (or both), based on the needs of the municipality. For example, if there were a desire to increase water storage for drought preparation, wetland conservation could be prioritized over forest conservation as wetlands contribute more to water storage than forest or grassland natural assets.

Fiscal valuation of natural infrastructure provides an additional financial value to natural assets, supplementing qualitative knowledge of the value assigned to them and informing decisions relevant for service delivery, planning, engineering, operations and management (Brown et al., 2019). We did not include a fiscal valuation in our estimate of the financial contribution of natural assets. However, it may benefit a municipality to calculate fiscal valuations to further enhance the business case for the conservation and restoration of natural infrastructure.

Consideration of natural assets in policies and processes such as Municipal Development Plans, Area Structure Plans, Climate Resiliency Strategies and Biodiversity Policies is becoming more common in practice. An example of this can be seen in the City of Calgary, where natural infrastructure has been included within the Municipal Development Plan (Part 2 'City-wide Policies' in section '2.6 Greening the City'; City of Calgary, 2021). The section on 'Natural Infrastructure' (NI; Section 2.6.1) speaks directly to its importance and the services it provides, as well as the city's policies to support protection and restoration of natural assets. It speaks to establishing an integrated approach to natural asset management and decision making as part of The City's ongoing planning, investment and asset management processes (City of Calgary, 2021). However, without natural asset maps the implementation of NI to address floods and droughts through municipal planning will remain limited and ineffective.

Recognizing natural assets' inherent link to climate change resiliency via the ecosystem services they provide, on top of those offered by grey infrastructure, opens doors to new funding opportunities to maintain or rehabilitate natural assets. As part of asset management, infrastructure is assigned a lifespan. As grey infrastructure ages, there are opportunities to pursue hybrid approaches (enhanced or engineered natural assets) as well as complete replacement of grey infrastructure with natural assets. Alternative funding sources may also be available through development cost charges in some municipalities (Municipal Natural Assets Initiative (MNAI), 2017).

Background

In 2018, the Miistakis Institute began exploring the use of natural infrastructure to help municipalities prepare and respond to flood and drought events. The first resource produced was the *Municipal Flood and Drought Action Planning Primer*. This Primer uses a question-and-answer template as a starting point for municipal staff and elected officials to initiate flood and drought mitigation planning.

The *Municipal EcoToolkit*, is a resource created by Miistakis that provides information on tools used by municipalities to maintain natural systems and infrastructure.

Finally, the *Working With Nature Toolkit* is a free online resource created for local governments wanting to understand, conserve, and plan to leverage their natural infrastructure. The toolkit process was piloted with the Town of Cochrane, Alberta, and laid the foundation for the *Municipal Natural Infrastructure Asset Inventory* project.

Our Process

The process undertaken for the Municipal NI Inventory project completes the recommended Step 3 of *Working With Nature*—creating an inventory of existing natural infrastructure assets in a municipality. We have created a list of general assets that apply to municipalities in Alberta (and beyond) as a guide to help municipalities tailor an inventory to their own municipality. By completing it, a municipality can create a map of natural infrastructure and help build a case for its value, protection, and enhancement.

The *Municipal Natural Infrastructure Asset Inventory* began with a literature review to set the context for the work. We found that some Canadian municipalities had already completed a natural infrastructure asset inventory (Appendix A). From this, we created a list of the natural assets and the ecosystem services they provide and evaluated the assets' contributions to floods and drought mitigation.

Next, we developed a natural asset framework that outlines a step-by-step process for creating an NI asset spatial inventory. We worked with Planning Services and Geomatic Services within the Town of Cochrane as an extension of the pilot project *Working With Nature*. With their assistance, we created a five-step methodology that could be followed by other municipalities interested in creating a spatial inventory. Examples from the Town of Cochrane are included throughout this document. If you would like more information on the final spatial inventory for the Town of Cochrane, please contact the Town of Cochrane's Planning and/or Geomatic Services departments.

Finally, this guidebook was created to step municipalities through the process of creating their own spatial inventory. The methods described include specific instructions on what data are available to Alberta municipalities and recommendations on how to use this to create a natural infrastructure asset spatial layer. Included is the process of evaluating each asset's contribution to flood and drought ecosystem services as well as a broad assessment of the current condition of each asset. If your municipality is interested in creating a natural infrastructure asset inventory and you have questions related to this methodology, please reach out to us at the Miistakis Institute.

Municipal Natural Assets

Defining Natural Infrastructure

All flood and drought-related assets can be categorized as either green or grey infrastructure. Grey infrastructure refers to traditional (or traditionally constructed) infrastructure, such as wastewater treatment plants, seawalls, pipes, and levees (ICF, 2018).

Natural infrastructure is defined as "*existing, restored or enhanced combinations of vegetation and associated biology, land and water, and naturally occurring ecological processes that generate infrastructure outcomes, such as preventing and mitigating floods*" (ICF, 2018). A variation on this definition is "*a strategically planned and managed network of natural lands, such as forests, wetlands and other open spaces, which conserves or enhances ecosystem values and functions and provides associated benefits to human populations*" (Gartner et al., 2013). The term natural infrastructure is sometimes used interchangeably with green infrastructure; however, an important distinction between the two is that NI should be considered a subset of the broader category of green infrastructure, with NI being restricted to intact, naturally existing ecosystem elements (Horizon Advisors, 2019). Importantly, because NI is "fully natural", once it is established, it requires no human intervention or management, unlike other types of green infrastructure.

For the purposes of this project, we have broken down green infrastructure into three categories of natural assets: fully natural, enhanced natural and engineered natural (Figure 1). We have excluded other types of green infrastructure such as solar panels, water meters, for example, as we are specifically focused on green infrastructure that is fully natural or enhanced. Under each category in Figure 1 we list the associated natural assets, which are defined as the stock of natural resources and ecosystems that yield a flow of benefits to people (Municipal Natural Assets Initiative (MNAI), 2017).

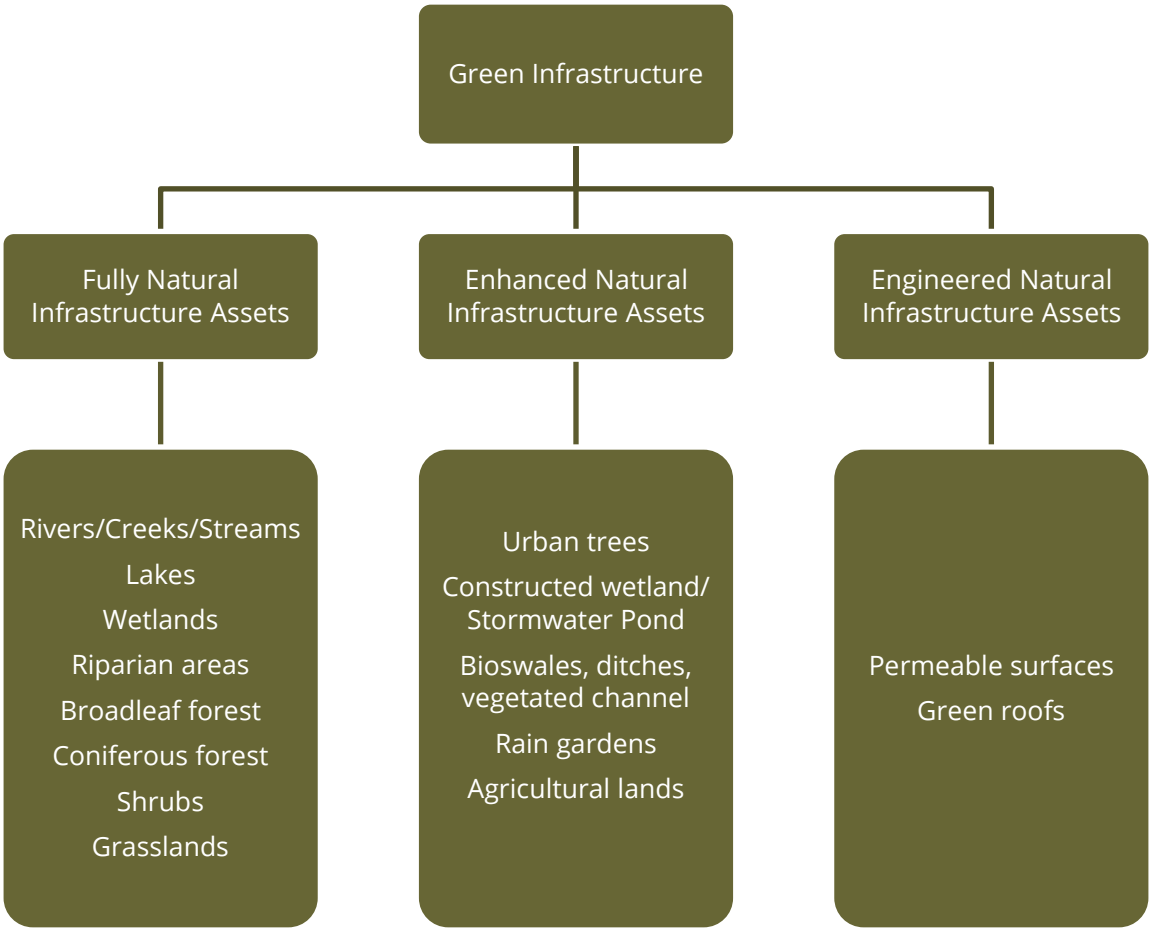

Figure 1: Green infrastructure components and associated natural infrastructure assets.

Ecosystem Services

Natural assets cannot be considered without also considering the vital ecosystem services they provide. This includes those that grey infrastructure could never provide given that it is designed for a singular purpose (Horizon Advisors, 2019). Our inventory allows municipalities to select a service of interest and view the natural assets that contribute to that service. From a planning perspective, this functionality is critical to building the business case for conservation, restoration or enhancement of a natural asset that contributes to a desired municipal service.

There is a great degree of agreement for categorizing ecosystem services into provisioning, regulating, supporting and cultural services (City of Saskatoon, 2020; Fiera Biological Consulting Ltd., 2020; Ivanic et al., 2020; Millennium Ecosystem Assessment, 2005a; Municipal Natural Assets Initiative (MNAI), 2017; Truchy et al., 2015); however, there is some variation among those services. We used the services outlined in Ivanic et al. (2020) and the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005b) as a starting point and reviewed a variety of other ecosystem service lists (City of Saskatoon, 2020; Fiera Biological Consulting Ltd., 2020; Ivanic et al., 2020; Millennium Ecosystem Assessment, 2005a; Municipal Natural Assets Initiative (MNAI), 2017; Truchy et al., 2015), to

create a functional list for this guidebook. We specifically identified the ecosystem services that focus on flood and drought services that natural assets provide, while still highlighting the many other services that natural assets provide (Table 1). These additional services (those not related to flood and drought), are what make natural infrastructure unique and more beneficial than grey infrastructure, which only serves a stormwater management purpose.

From our list of ecosystem services provided by natural infrastructure, we identified seven associated with flood and drought risk and mitigation (highlighted in Table 1). The majority of these services are focused on water flow and storage with the remaining focused on temperature (urban heat island regulation) and erosion control.

Table 1: Ecosystem services provided by natural assets. Bolded services marked with an asterisk highlight ecosystem services that relate to flood and drought management.

Provisioning Services	Regulating Services	Supporting Services	Cultural Services
• **Water*** • Food • Wood and fibre • Soil • Medicinal resources • Ornamental resources • Genetic resources	• **Water storage*** • **Groundwater recharge*** • **Water flow regulation (conveyance)*** • **Moisture retention*** • **Urban heat regulation*** • **Erosion control*** • Climate regulation (carbon sequestration and storage) • Air purification • Water purification • Soil purification • Pollination • Pest and disease regulation	• Biodiversity maintenance and protection • Ecosystem process maintenance	• Recreation and tourism • Aesthetic values • Education and research • Spiritual and religious values • cultural and historical values • mental well-being and health

Definitions of Terms used in Flood and Drought Ecosystem Services

Water Provision: fresh water provided by the ecosystem *(Millennium Ecosystem Assessment, 2005b)*. Examples of natural assets that provide this service: glacier, rivers, lakes.

Water storage: stores of excess fresh water in flood events, and stores of water in periods of drought. Examples of natural assets that provide this service: lake, wetland.

Groundwater recharge: provides egress for rain/surface water to pass into underground aquifers/reservoirs. Examples of natural assets that provide this service are wetlands, urban parks, grasslands, and forests.

Water flow regulation (conveyance): management of both the volume and speed of stormwater flows between two points (Fiera Biological Consulting Ltd., 2020). Examples of natural assets that provide this service: wetlands, coniferous forest, bioswales.

Moisture retention: resistance of general drying trends to ensure vegetation stays moist even as ambient temperatures rise. Maintenance of soil moisture during times of high temperature or water scarcity, reducing fire risk and maintaining vegetation. Examples of natural assets that provide this service: wetlands, riparian areas.

Urban heat island regulation: temperature reduction at a local scale, most applicable to urban settings where infrastructure such as pavement increases the local temperature. Examples of natural assets that provide this service: urban trees, green roofs, broadleaf forests.

Erosion control: vegetative cover plays an important role in soil retention and the prevention of landslides *(Millennium Ecosystem Assessment, 2005b)*. Examples of natural assets that provide this service: broadleaf forest, coniferous forest, grasslands.

Framework for Creating an NI Asset Inventory

We outline an approach for creating an NI asset inventory, specifically identifying NI assets and determining where they occur on the landscape within a municipality. We further assess how each NI asset contributes to flood and drought mitigation. This approach includes five steps that result in a spatial layer of NI assets which can be used to support municipal planning, service delivery, operations, and management. We use the Town of Cochrane as a case study for the application of the proposed framework. Municipalities in Alberta have varying degrees of in-house GIS capacity and data, so their capacity and spatial resources will need to be assessed prior to creating an NI asset inventory.

It is important to note that the scale of the data used to create the NI asset inventory is appropriate for regional planning (i.e., Town of Cochrane) but not appropriate for fine scale neighborhood planning. A more detailed land cover dataset would allow for finer scale applications.

Step 1: Identify NI assets

It is important to identify the NI assets to be included in the inventory. For the purposes of this inventory, we were interested in focusing on the many NI assets that provide flood and drought mitigation services: water provisioning, water storage, ground water recharge, water flow regulation (conveyance), moisture retention, urban heat island regulation and erosion control. For inventories that address other ecosystem services, a suite of additional/alterative NI assets could be identified.

The NI assets that are the focus of this inventory and their contributions to flood and drought mitigation are listed in Table 2.

Table 2: Natural assets included in inventory and their contributions to flood and drought mitigation.

Natural Asset	Natural Infrastructure Type	Type of Ecosystem Service (Flood and Drought specific)						
		Provisioning	Regulating					
		Water	Water storage	Groundwater recharge	Water flow regulation (conveyanc	Moisture retention	Urban heat regulation	Erosion control
Rivers, Creeks and Streams	Natural	•					•	
Lakes	Natural	•	•	•	•		•	
Wetlands	Natural	•	•	•	•	•	•	
Riparian areas	Natural		•	•		•	•	
Broadleaf forest	Natural		•	•	•	•	•	•
Coniferous forest	Natural		•	•	•	•	•	•
Urban trees	Enhanced				•		•	•
Shrubs	Natural		•	•	•	•	•	•
Grasslands	Natural		•	•	•	•	•	•
Constructed wetland/ Stormwater Pond	Enhanced		•	•	•		•	
Green roofs	Engineered				•		•	
Bioswales, ditches, vegetated channel	Enhanced				•		•	•
Rain gardens	Enhanced				•		•	•
Agricultural lands	Enhanced				•		•	•

For this inventory we focused on fully natural and enhanced NI assets where data were available. Currently, there is insufficient spatial data for the Town of Cochrane on soils, green roofs (none found in Cochrane to date), bioswales, ditches, vegetated channels, and rain gardens. Because these enhanced and engineered natural infrastructure assets

contribute to flood and drought mitigation, if these natural assets are added in the future, that should be incorporated into the data layer retroactively.

Step 2: Acquire spatial datasets

The second step is to acquire spatial data for all of the identified NI assets in Step 1. The biophysical data required to create the NI inventory are described in Table 3.

Table 3: Biophysical data required to create a natural infrastructure inventory.

Data Type	Data Use & Description	Data Availability/Source
BIOPHYSICAL DATA		
Hydrology	Identifying Rivers, streams, and lakes on the landscape to add to the land cover • Alberta Base Features — Hydrology	Freely available from Altalis
Elevation	Digital Elevation Model used to calculate slope and stream order used to calculate the width of linear hydrological features • Alberta Provincial Digital Elevation Model (DEM)	Freely available from Altalis
Wetlands	Identifying wetlands on the landscape to include as natural infrastructure. An ABMI dataset was used for most of the province and AMWI was used for the provincial white zone. • Alberta Biodiversity Monitoring Institute (ABMI) Wetlands Inventory • Alberta Merged Wetlands Inventory (AMWI)	Both datasets are freely available from the ABMI website and Alberta Government, respectively.
Riparian	Identifying riparian areas on the landscape to include as natural infrastructure. • Alberta Government Lotic Riparian Polygons Digital Elevation Model (DEM) Derived • Alberta Government Lotic Riparian Polygons Strahler Order Derived	Both datasets are freely available from the Alberta Government.
Land cover	Identifying main landscape features to include as natural infrastructure. • Agriculture and Agri-Food Canada (AAFC) Annual Crop Inventory	Freely available from the Government of Canada Open Data Portal
Urban trees	Identifying urban trees in the Town of Cochrane to include as natural infrastructure • Cochrane Urban Tree Database	Available from the Town of Cochrane
ANTHROPOGENIC DATA		
Human footprint	Used to calculate the impact of human disturbance on natural infrastructure • Alberta Biodiversity Monitoring Institute (ABMI) Wall-to-Wall Human Footprint	Freely available through ABMI website.
Storm water ponds	Used to identify storm water ponds in the Town of Cochrane to include as natural infrastructure • Cochrane Storm Water Database	Available from the Town of Cochrane

Step 3: Identify land cover base layer, and extract natural assets

As a first step in the development of the natural infrastructure spatial layer, we selected a land cover to act as a base layer. To determine the most appropriate data source to use we assessed four different land cover datasets:

- AAFC Annual Crop Inventory,
- ABMI Wall-to-Wall Land Cover,
- AB Ground Vegetation Inventory, and
- Alberta Satellite Land Cover.

All datasets were compared against each other and with underlying imagery for the Town of Cochrane to determine the best fit (Figure 2).

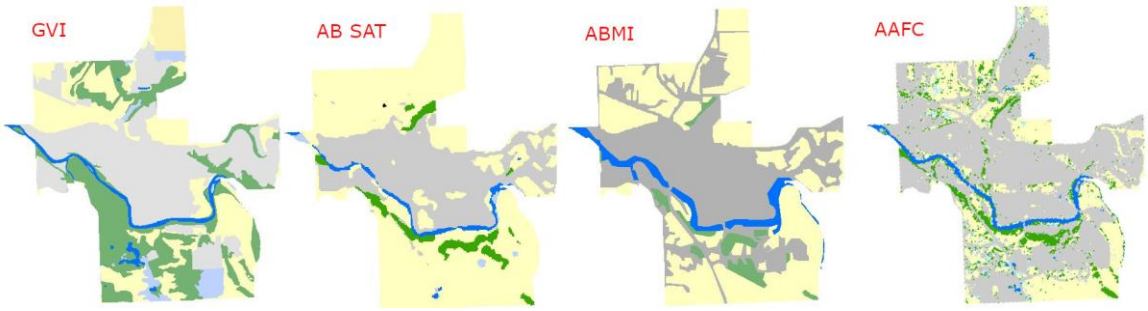

Figure 2: A comparison of available land cover datasets for consideration of a base layer.

We selected the AAFC Annual Crop Inventory as the base layer because it was up to date and represented the finest data resolution. The ABMI Land Cover was comparable but 10 years older and is not being updated. The AAFC Annual Crop Inventory spatial resolution (25m grid size) limits its use to regional level planning. We extracted land cover classes data from the AAFC Annual Crop Inventory that best represent natural assets, excluding classes better represented in other datasets. We retained shrubland, grassland, agriculture (all different agriculture types combined into a class), forest (undifferentiated), coniferous, broadleaf and mixedwood.

Step 4: Build additional NI asset layers

We identified a number of additional NI assets from other datasets to integrate into the NI spatial layer. These included riparian areas, wetlands, urban trees and water bodies including large rivers, small rivers and streams and lakes.

Build Riparian Asset Layer

We developed a riparian spatial layer by merging and dissolving two key GOA datasets:

- Alberta Government Lotic Riparian Polygons DEM Derived, and
- Alberta Government Lotic Riparian Polygons Strahler Order Derived

The merged riparian dataset approximates all riparian areas within the province. As the datasets are largely derived from DEMs this approach is not reliable in heavily modified urban areas where the landscape has been changed.

Build Wetland Asset Layer

To generate a wetland layer, we used the ABMI Wetlands Inventory as a base layer because it is the most recent and accurate wetland layer for Alberta. However, it does not include the provincial white zone. To address missing wetlands, we added wetland data from the Alberta Merged Wetlands Inventory for these areas.

Build Lake Asset Layer

We used Alberta Base Features hydrology polygons to capture larger hydrological features. Wetlands and icefields were removed from the dataset.

Build Large River and Small River/Stream Layers

We used the Alberta Base Features hydrology polylines and Alberta Provincial DEM to generate stream orders. From these we approximated the widths of rivers and buffered lines based on guidelines developed by Alberta Conservation Association and the Alberta Research Council (Scrimgeour et al., 2003) (Table 4).

We used the Alberta Provincial DEM to calculate flow direction, flow accumulation, and stream order that was then applied to Alberta base features types. We also applied the appropriate width buffer to each feature type based on stream type and order (Table 4).

The resulting dataset was partitioned into two water NI asset types: large rivers and small rivers and streams.

Table 4: Hydrology network buffer widths.

Feature Type	Strahler Stream Order	Width buffer (m)
STR-RECUR	1	0.5
STR-RECUR	>1	1
All other STR-* and RIV-MAJ-*	1	1
All other STR-* and RIV-MAJ-*	2	2
All other STR-* and RIV-MAJ-*	3	4
All other STR-*	>3	5
All RIV-MAJ-*	≤ 3	6
All RIV-MAJ-*	4	7
All RIV-MAJ-*	5	8
All RIV-MAJ-*	6	9
All RIV-MAJ-*	7	10
All RIV-MAJ-*	>7	13

Urban Tree Layer

The Town of Cochrane provided their plant database that documents point locations of trees and other plants throughout the town. Trees were extracted from this dataset to create an urban tree layer. These points were compared to satellite images to determine their approximate width and found to be 1–4 meters. The tree points were therefore buffered by 1 meter, to give a median width of 2 meters. As trees age, the buffer distance can be revisited to include growth.

Stormwater Pond Layer

The Town of Cochrane provided their storm water database that includes a pond dataset.

Step 5: Integrate asset layers to create an NI asset inventory

The different NI asset layers were combined to create the NI asset inventory. To integrate the NI asset layers we followed the following process:

I. Each type of NI in the land cover base layer was assigned a unique code (Table 5). This layer forms the basis of the NI asset inventory to which other NI asset layers were merged in sequence:
II. The riparian asset overlaps with wetland assets, so we compared the two layers and removed riparian data where they overlapped with the wetlands layer. We kept the wetlands because they were more accurate and already included a riparian component. We then merged these two NI layers.
III. Riparian and wetland assets overlap with the NI inventory asset layer. We therefore created additional sub-categories within the NI inventory asset layer. For example, the grassland NI asset type was subdivided into grassland and riparian grassland, and wetland grassland types. We did this with a union of the riparian/wetland layer with the NI inventory layer.
IV. The NI asset inventory layer (now including riparian and wetland assets) was merged with the hydrology layers (streams and lakes), and where there was overlap the water layers were prioritized and replaced the previous asset type.
V. The NI asset inventory layer (now including riparian, wetlands, lakes, major rivers, small rivers and streams) was merged with the stormwater ponds layer. Where there was overlap, the stormwater ponds were prioritized and replaced the previous asset type.
VI. The NI asset inventory layer (now including riparian, wetlands, lakes, major rivers, small rivers and streams and stormwater ponds) was merged with the urban tree layer.
VII. The NI asset inventory layer was clipped to the Town of Cochrane boundary and visually spot-cleaned. All riparian areas that did not overlap with other land cover types were removed as the riparian datasets are largely derived from DEM's and, as described above, are considered unreliable in modified urban areas. Some streams

were removed as they no longer exist and wetlands/ponds were added or removed to match the underlying satellite imagery.

Table 5 lists the NI asset inventory and corresponding codes for the Town of Cochrane.

Table 5: Natural asset inventory and codes for the Town of Cochrane specific to flood and drought ecosystem service provision.

Code	NI Asset Type
5	Riparian Area
8	Wetland
50	Shrubland
55	Riparian Shrubland
58	Wetland Shrubland
110	Grassland
115	Riparian Grassland
118	Wetland Grassland
120	Agriculture
125	Riparian Agriculture
128	Wetland Agriculture
200	Forest (undifferentiated)
205	Riparian Forest
208	Wetland Forest
210	Coniferous
215	Riparian Coniferous
218	Wetland Coniferous
220	Broadleaf
225	Riparian Broadleaf
228	Wetland Broadleaf
230	Mixedwood
235	Riparian Mixedwood
238	Wetland Mixedwood
300	Streams and Small River
310	Large River
311	Lake
320	Cochrane Storm Pond
400	Cochrane Urban Tree

Natural Infrastructure Asset Inventory for the Town of Cochrane

The spatial representation of the Town of Cochrane's complete natural infrastructure asset inventory is displayed in Figure 3. With GIS expertise, the data can be displayed in a variety of ways including by asset type and/or ecosystem service. Appendix B describes the

geodatabase field attributes. If you would like more information on the final spatial inventory for the Town of Cochrane, please contact the Town of Cochrane's Planning and/or Geomatic Services departments.

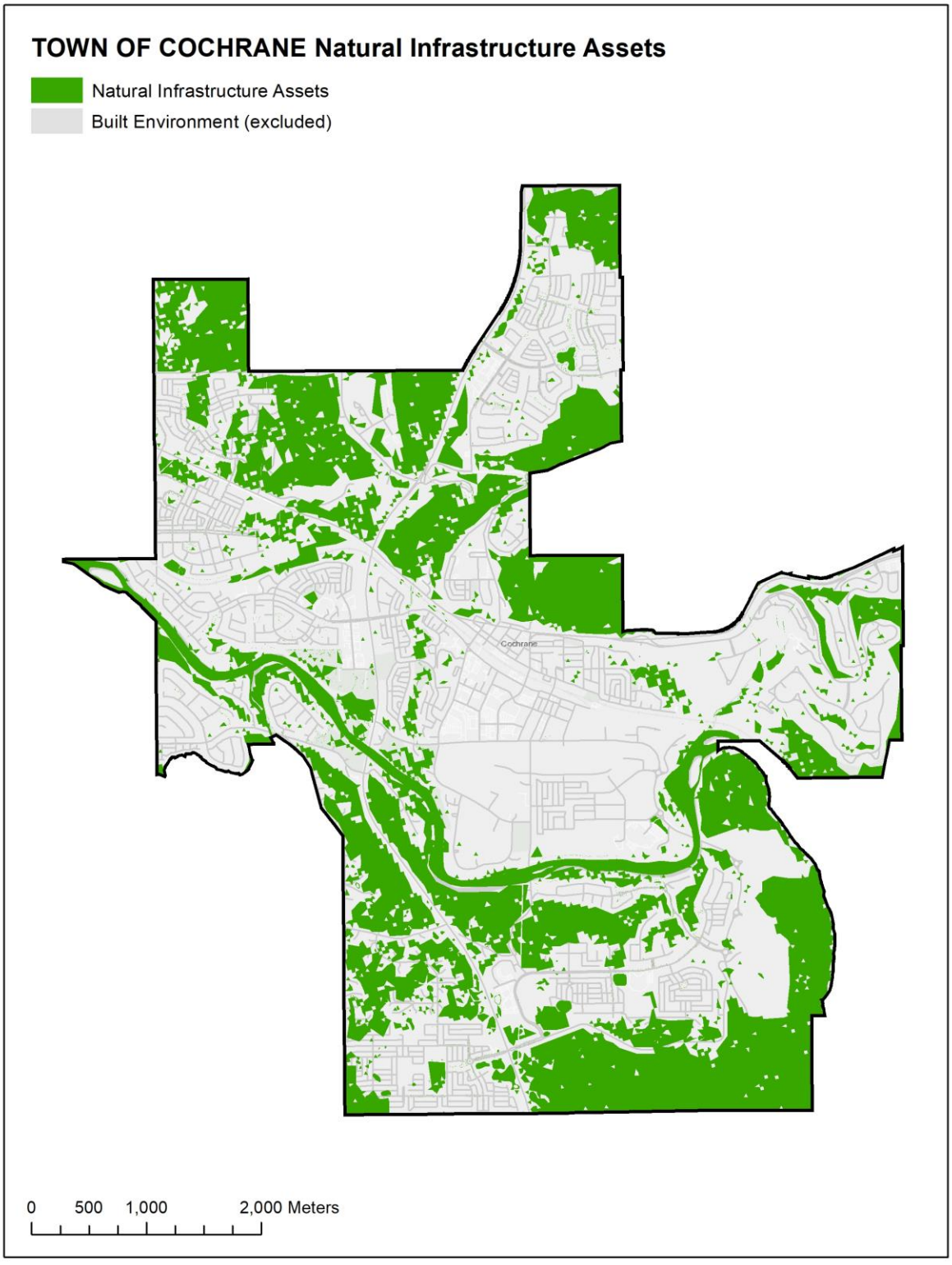

Figure 3: Town of Cochrane natural infrastructure assets.

Evaluating NI's Contribution to Flood and Drought Mitigation

To assess the contribution of NI assets to flood and drought across the study area, we assigned low, medium and high values to each NI asset for different ecosystem services. Values were assigned based on research review and expert knowledge. These values could later be modified based on emerging research or other new information. The values were 1 (low) – 3 (high) and when a specific ecosystem service did not apply to an asset, it was given a value of 0 for not applicable.

Water Provisioning

Water Provisioning is the fresh water provided by the ecosystem *(Millennium Ecosystem Assessment, 2005b)*. The Town of Cochrane's drinking water comes from the Bow River, which was assigned a high value while remaining assets were assigned a zero value being non-applicable to water provisioning (Figure 4).

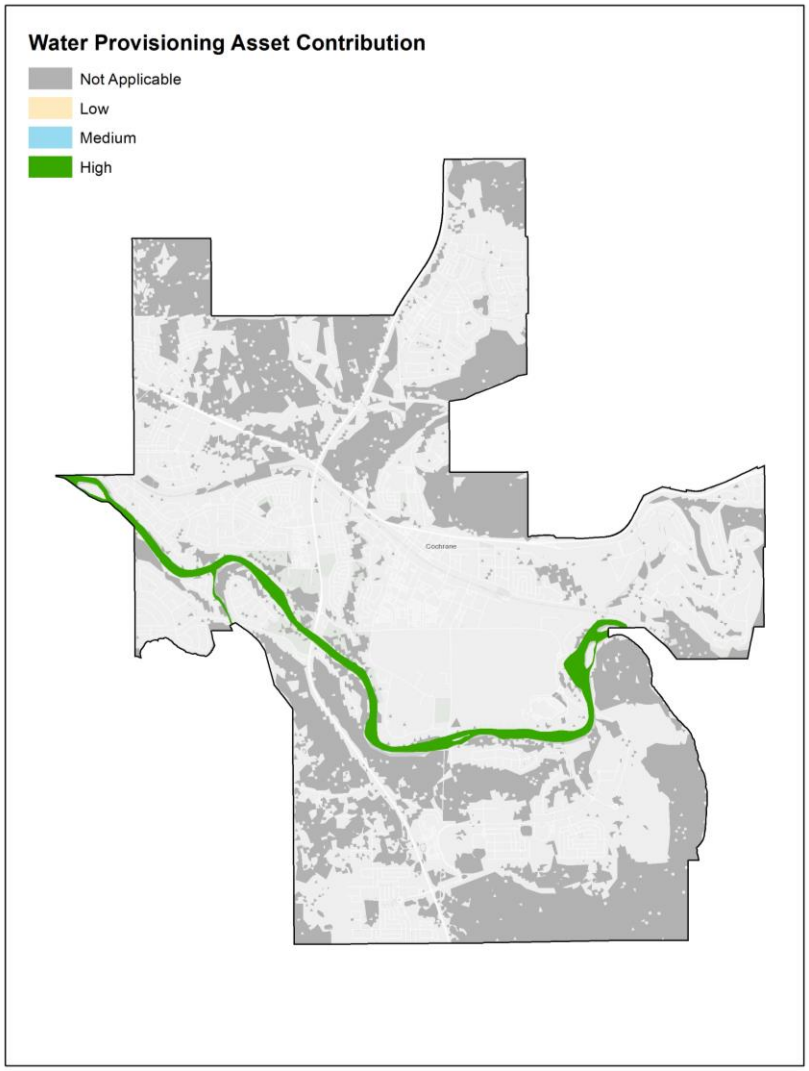

Figure 4: Water provisioning ecosystem service provided by natural infrastructure assets in the Town of Cochrane.

Urban Heat Island Regulation

Urban heat island regulation is defined as local scale temperature mitigation in an urban setting where human developments (e.g., pavement, buildings) increase the local temperature. NI assets were assigned values for contribution to urban heat island regulation as described in the table below and in Figure 5.

Asset Type	**Value**
Urban Tree	High
Coniferous, Broadleaf, and Mixedwood	High
Large River and Lake	High
Wetland and Riparian Shrublands and Riparian Grassland	Medium
Wetland, Small River and Stream, Storm Pond	Medium
Shrubland and Grassland	Low
Agriculture	Low

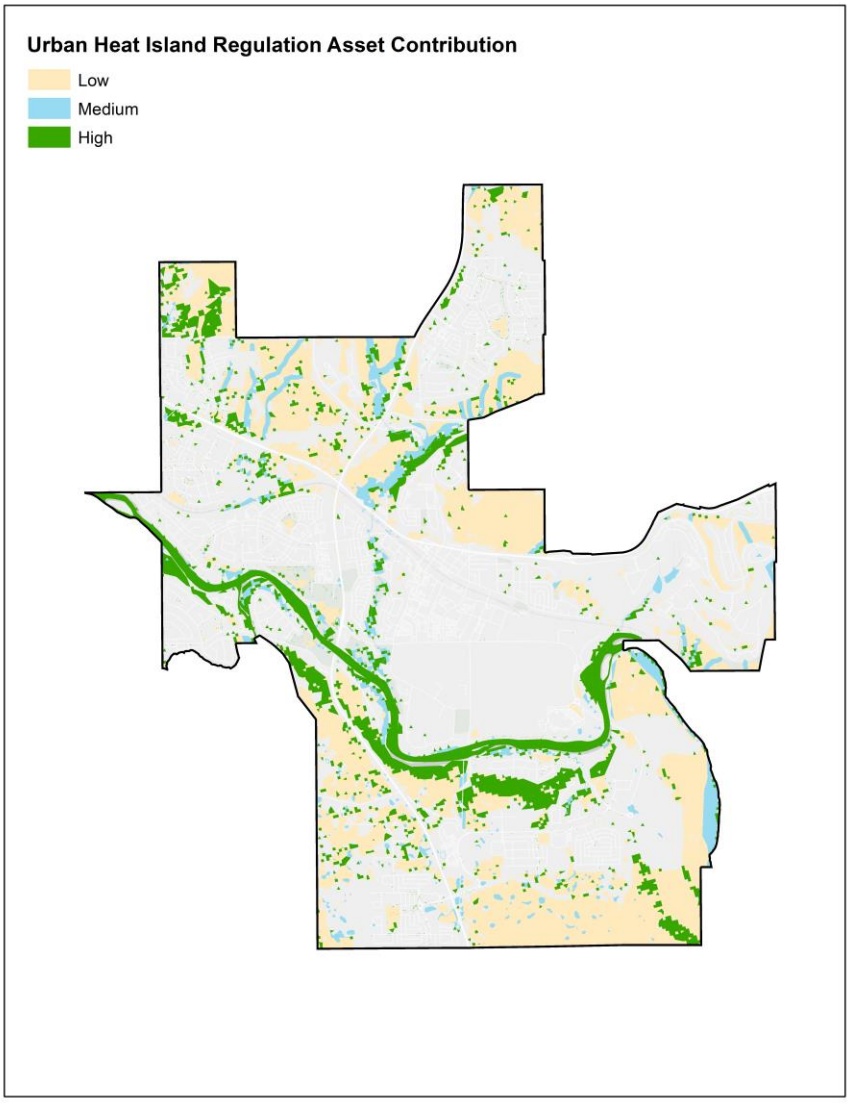

Figure 5: Urban heat island regulation ecosystem service provided by NI assets in the Town of Cochrane.

Moisture Retention

Moisture retention is defined as resisting general drying trends to ensure vegetation stays moist even as ambient temperatures rise. It means maintaining soil moisture during times of high temperature or water scarcity, reducing fire risk and maintaining vegetation. NI assets were assigned values for contributions to moisture retention as described in the table below and in Figure 6Figure 5.

Asset Type	**Value**
Wetland	High
Wetland and Riparian Shrubland, Riparian Grasslands, Riparian Agriculture, Riparian Forest, Riparian Coniferous, Riparian Broadleaf, and Riparian Mixedwood	High
Forest, Coniferous, Broadleaf, and Mixedwood	Medium
Shrubland and Grassland	Low
Agriculture	Not applicable
Small River and Stream, Large River and Lake and Storm Pond	Not applicable
Urban tree	Not applicable

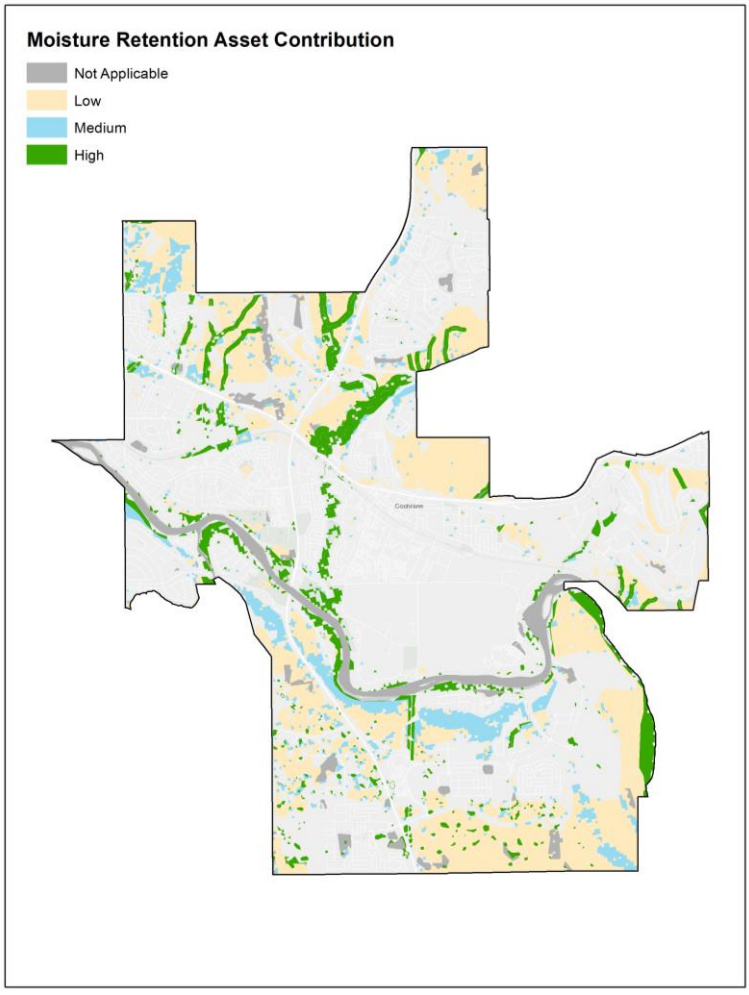

Figure 6: Moisture retention ecosystem service provided by NI assets in the Town of Cochrane.

Water Flow Regulation (Conveyance)

Water flow regulation (conveyance) is the management of both the volume and the speed at which stormwater flows from one point to another (Fiera Biological Consulting Ltd., 2020). Forests play an important role in water flow regulation (conveyance), and conifer and mixedwood forests were assigned higher importance than broadleaf forests (Kermavnar & Vilhar, 2017; Kuehler et al., 2017) for water flow regulation (conveyance). NI assets were assigned values for contributions to water flow regulation (conveyance) as described in the table below and in Figure 7.

Asset Type	**Value**
Wetland and Large Lake	High
Conifer and Mixedwood	High
Broadleaf	Medium
Storm pond	Medium
Shrubland, Grassland and Agriculture	Low
Urban Tree	Low
Small River and Stream, Large River	Not applicable

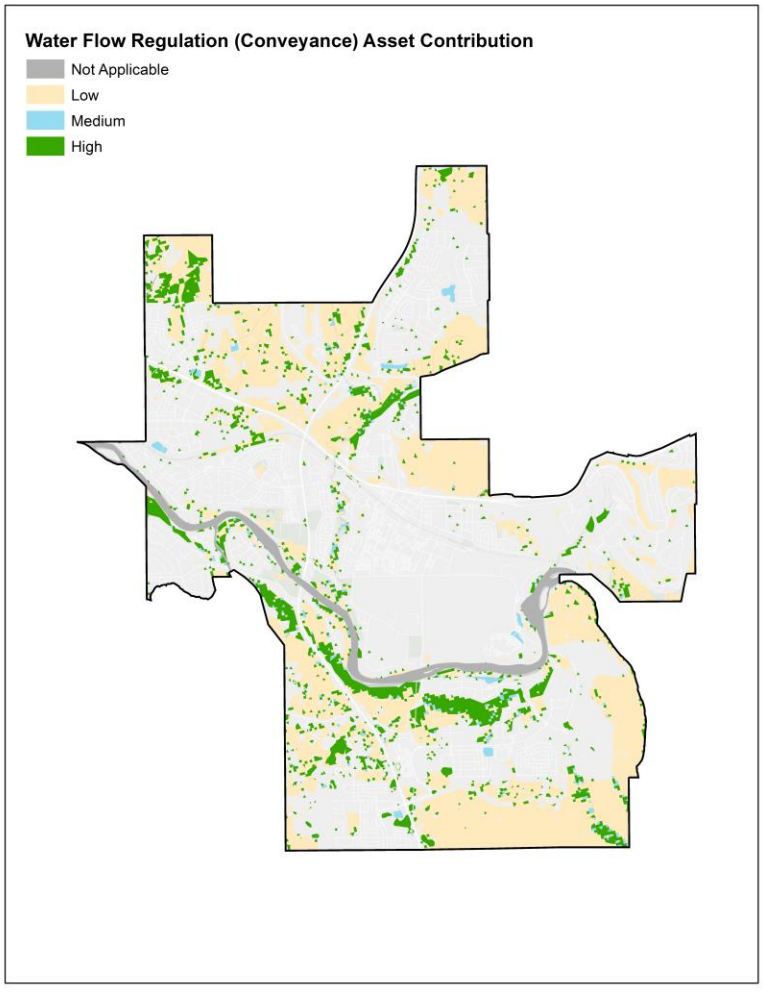

Figure 7: Water flow regulation (conveyance) ecosystem service provided by NI assets in the Town of Cochrane.

Water Storage

Water storage buffers freshwater flow during flood events and retains water in periods of drought. NI assets were assigned values for contributions to water storage described in the table below and in Figure 8.

Asset Type	**Value**
Wetland and Riparian Shrubland, Riparian Grasslands, Riparian Forest, Riparian Coniferous, Riparian Broadleaf, and Riparian Mixedwood	High
Wetland, Large Lake and Storm Pond	High
Forest, Coniferous, Broadleaf, and Mixedwood	Medium
Shrubland and Grassland	Low
Agriculture	Not applicable
Urban tree	Not applicable
Small River and Stream, Large River	Not applicable

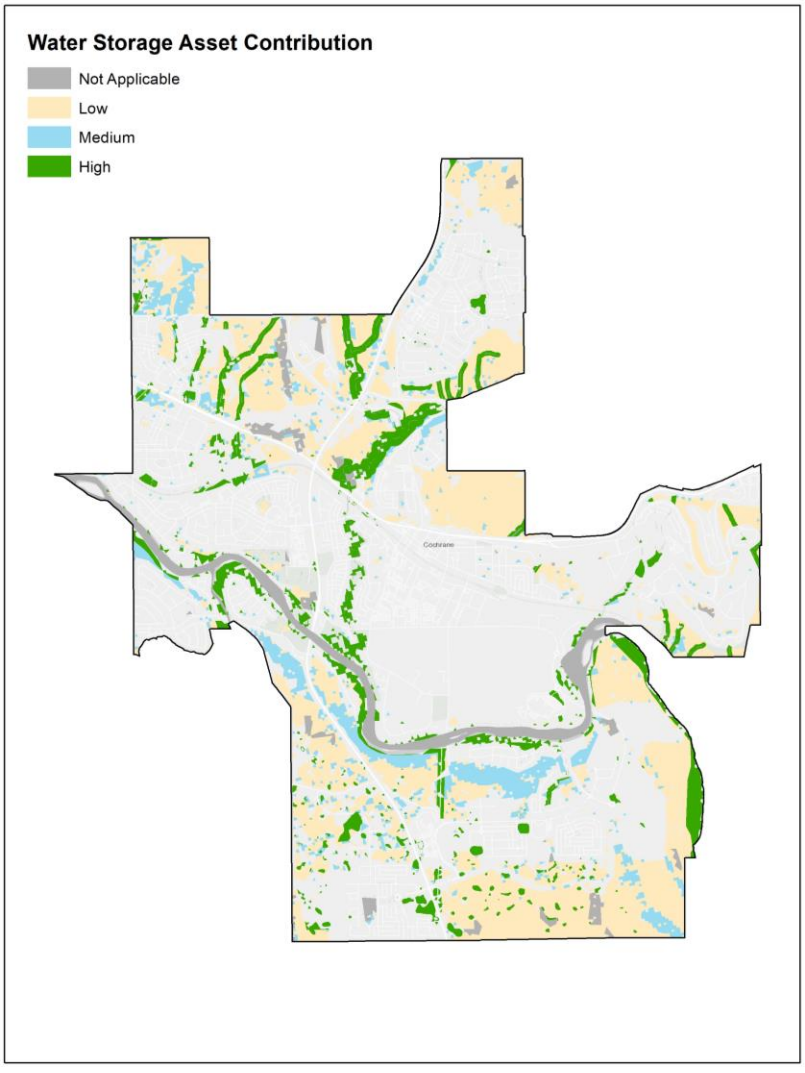

Figure 8: Water storage ecosystem service provided by NI assets in the Town of Cochrane.

Ground Water Recharge

Groundwater recharge provides egress for rain and surface water to pass into underground aquifers and reservoirs. NI assets were assigned values for contributions to ground water recharge as described in the table below and in Figure 9.

Asset Type	**Value**
Wetland and Riparian Shrubland, Riparian Grasslands, Riparian Forest, Riparian Coniferous, Riparian Broadleaf, and Riparian Mixedwood	High
Wetland, Large Lake and Storm Pond	High
Forest, Coniferous, Broadleaf, and Mixedwood	Medium
Shrubland and Grassland	Low
Agriculture	Not applicable
Urban tree	Not applicable
Small River and Stream, Large River	Not applicable

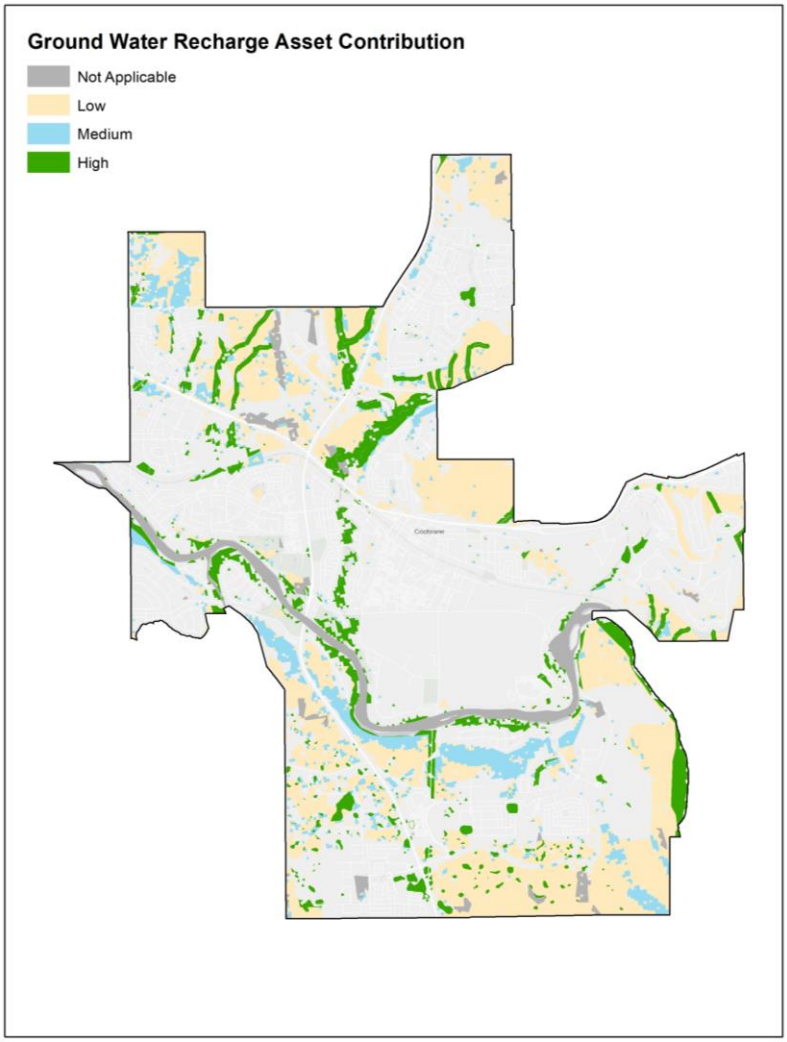

Figure 9: Groundwater recharge ecosystem service provided by natural infrastructure assets in the Town of Cochrane.

Erosion Control

Vegetated NI assets (shrubland, grassland, forests) were considered to contribute to erosion control if a portion of the asset occurred in an area with a steep slope (> 15% grade). The percentage of area covered by steep slopes was then assigned high, medium or low values using geometric intervals as described in the table below and in Figure 10.

% of Asset Occupying Steep Slope	**Value**
> 98.3%	High
86.4% – 98.3%	Medium
< 86.4%	Low

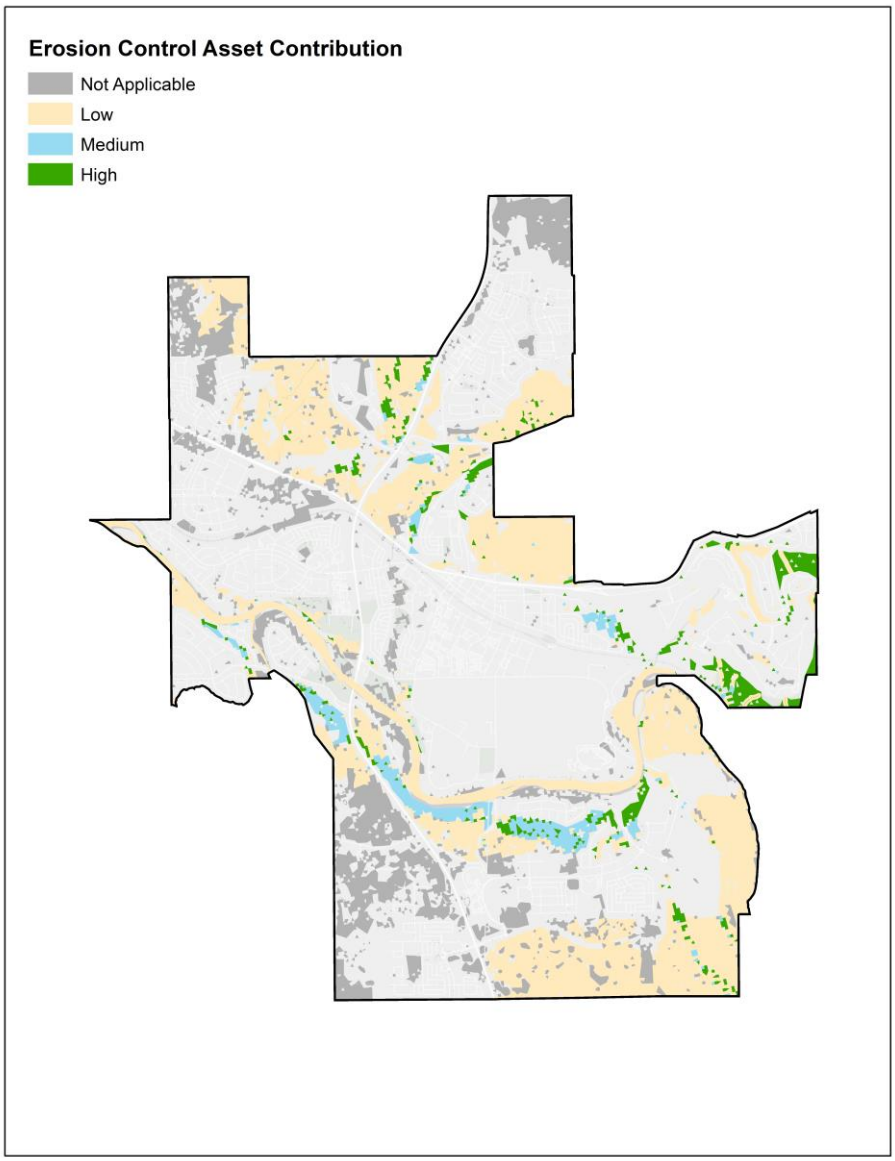

Figure 10: Erosion control ecosystem service provided by natural infrastructure assets in the Town of Cochrane.

Combined NI Asset Contribution to Flood and Drought

To demonstrate the NI contribution to flood and drought mitigation across the study area, NI assets values (0–3) for each ecosystem service (Table 6) were summed and combined with the corresponding value for erosion control (combined, range 0–18). High values (12–18) therefore represent NI assets that contribute the most to flood and drought mitigation (Figure 11) in the Town of Cochrane.

Table 6: Ecosystem service values for each natural infrastructure asset type.

	Ecosystem service values					
NI Asset	Water Provisioning	Urban Heat Island	Moisture Retention	Water Flow Mitigation	Water Storage	Ground Water Recharge
Riparian (unvegetated)	NA	NA	NA	NA	NA	NA
Wetland	0	2	3	3	3	3
Shrubland	0	1	1	1	1	1
Riparian Shrubland	0	2	3	1	3	3
Wetland Shrubland	0	2	3	1	3	3
Grassland	0	1	1	1	1	1
Riparian Grasslands	0	2	3	1	3	3
Wetland Grassland	0	2	3	1	3	3
Agriculture	0	1	0	1	0	0
Riparian Agriculture	0	1	3	1	0	0
Wetland Agriculture	0	1	3	1	0	0
Forest (undifferentiated)	NA	NA	NA	NA	NA	NA
Riparian Forest	NA	NA	NA	NA	NA	NA
Wetland Forest	NA	NA	NA	NA	NA	NA
Coniferous	0	3	2	3	2	2
Riparian Coniferous	0	3	3	3	3	3
Wetland Coniferous	0	3	3	3	3	3
Broadleaf	0	3	2	2	2	2
Riparian Broadleaf	0	3	3	2	3	3
Wetland Broadleaf	0	3	3	2	3	3
Mixedwood	0	3	2	3	2	2
Riparian Mixedwood	0	3	3	3	3	3
Wetland Mixedwood	0	3	3	3	3	3
Stream and Small River	0	2	0	0	0	0
Large River	3	3	0	0	0	0
Lake	0	1	0	3	3	3
Cochrane Storm Pond	0	1	0	2	3	3
Cochrane Urban Tree	0	3	0	1	0	0

* Soil Erosion was an additional ecosystem service evaluated using GIS
* Forest (undifferentiated) do not occur in Cochrane and are therefore NA
* Riparian (Unvegetated) was removed from Cochrane's analysis because the urban environment was too modified for the dataset to be useful

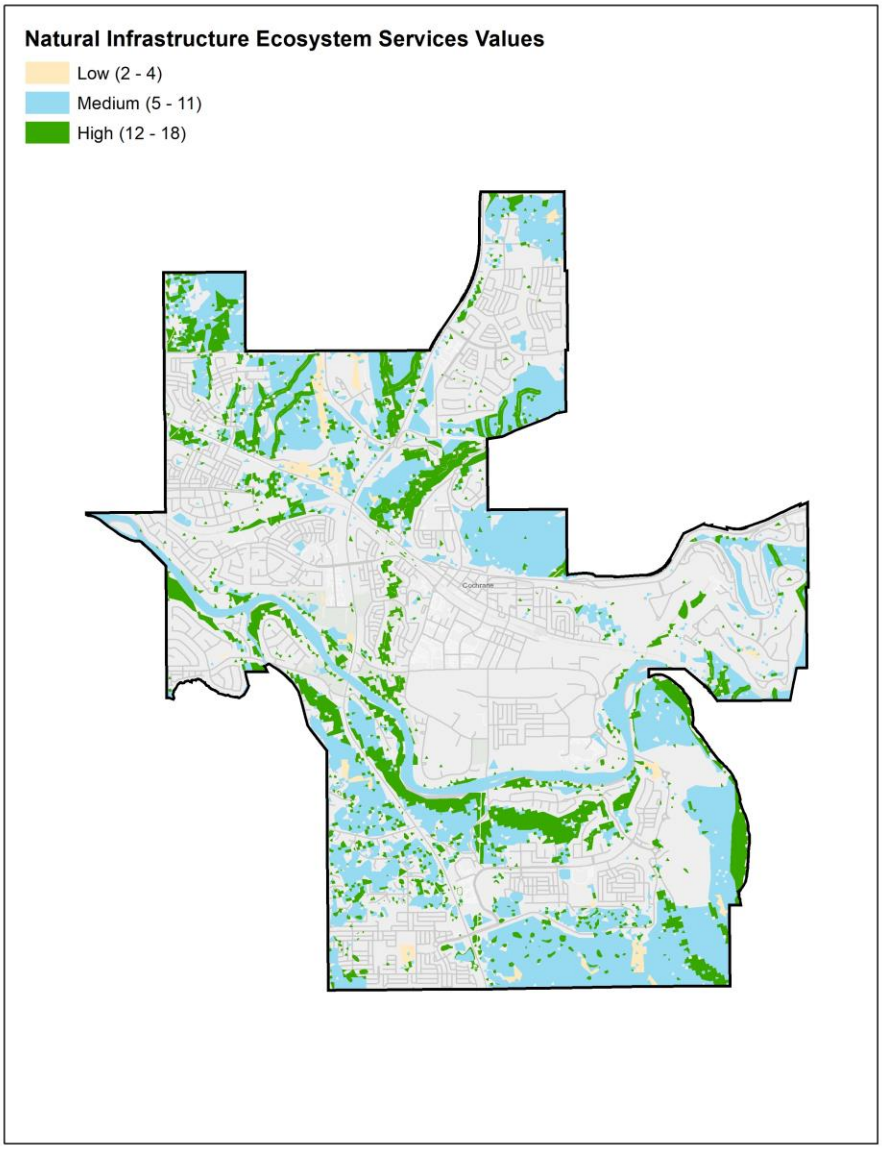

Figure 11: NI asset contribution to flood and drought mitigation.

Condition of NI Assets Relevant to Flood and Drought Mitigation

Some natural infrastructure inventories include condition assessments of NI assets. Generally, NI assets need to be in good condition to be effective in providing ecosystem services (Fiera Biological Consulting Ltd., 2020; Municipal Natural Assets Initiative (MNAI), 2021b). We selected two metrics to evaluate the condition of NI assets: asset patch size and percent of human disturbance. Asset patch size is relevant because the larger an asset is the greater its contribution to flood and drought mitigation. Human disturbance is relevant because disturbance reduces an asset's function and thus its ability to contribute to flood and drought mitigation. Low, medium and high values (1–3, respectively) were assigned to each asset and values were summed to generate an overall condition value in the NI asset inventory.

Patch Size Metric

NI asset area (m^2) were grouped into three size categories (based on geometric intervals) and assigned low, medium and high values. It is important to note that groups do not represent biological or engineering thresholds. Assets were assigned values for the patch size metric as described in the table below.

Area (m^2)	**Value**
> 5600	High
19–5600	Medium
< 19	Low

Human Disturbance Metric

We used the ABMI human disturbance feature classes to include in the analysis (Appendix C). From this we calculated the percent human disturbance per asset and assigned low, medium and high values as described in the table below. Again, these are not ecologically derived categories.

% of Human Disturbance	**Value**
<10%	High
11-50%	Medium
>50%	Low

Condition Rating

The two metrics (patch size and human disturbance) were then summed to create an overall value ranging from 2 to 6 (poorest to best; Figure 12) Figure 12: NI asset condition (size and human disturbance). .

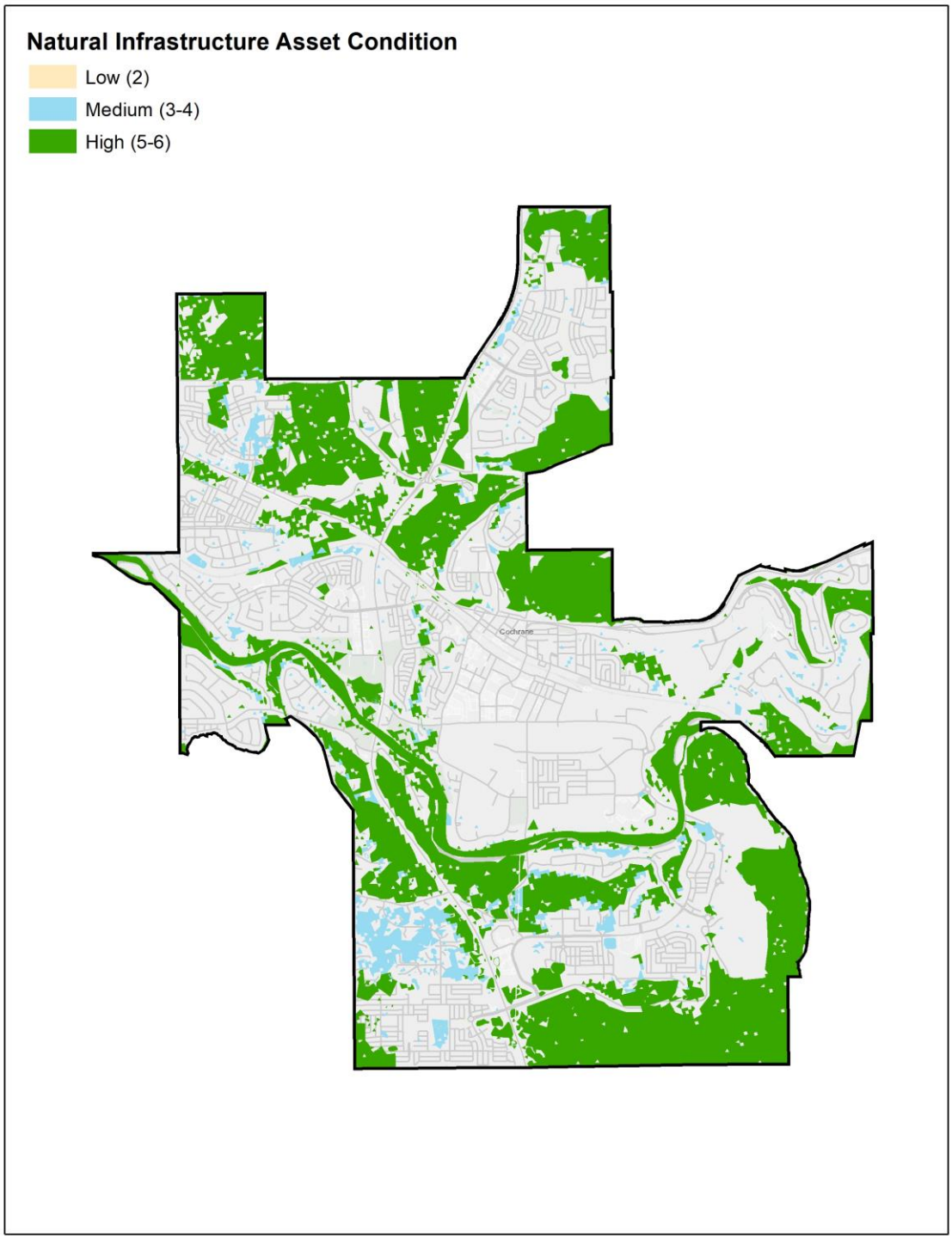

Figure 12: NI asset condition (size and human disturbance).

Conclusion

Gone are the days when municipalities can assume that natural infrastructure assets will provide ecosystem services without the need for planning, management, and maintenance. Natural infrastructure provides ecosystem services critical to flood and drought mitigation as well as additional services that cannot be provided by grey infrastructure (e.g., recreation, cultural and historical value, mental health, and biodiversity). Although natural infrastructure cannot provide all flood and drought mitigation, the multitude of services it will provide can support many municipal goals.

A first step in considering natural infrastructure is to build a business case to support investments to protect and restore NI. To build a business case, a municipality must know what natural assets they have and where they are. This project seeks to assist municipalities by identifying a five-step process for creating a *Municipal Natural Infrastructure Asset Inventory*. The resulting NI asset inventory is provided in a user-friendly format for planners and other municipal staff, and can be adapted for viewing by the public, or for presentation to Municipal Council.

If your municipality is interested in creating a natural infrastructure asset inventory and you have questions related to this methodology, please reach out to us at The Miistakis Institute.

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Appendix A: Canadian Municipalities with a Natural Infrastructure Asset Inventory

The following municipalities have completed natural asset inventories:

- City of Calgary, Alberta
- City of Saskatoon, Saskatchewan
- City of Surrey, British Columbia (MNAI)
- Township of Langley, British Columbia (MNAI)
- City of Prince George, British Columbia (MNAI)
- More inventory projects can be found on the MNAI website: https://mnai.ca/

Appendix B: Geodatabase Field Attributes

Attribute	Description
classcode	A number representing the asset class type
NAME	Name of asset when known
UHI	Asset contribution towards improving Urban Heat Island regulation effect. Value range: 1 (low), 2 (medium), 3 (high).
moisture_retention	Asset contribution towards improving moisture retention. Value range: 0 (not applicable), 1 (low), 2 (medium), 3 (high).
waterflow_flow_mitigation	Asset contribution towards improving water flow regulation (conveyance). Value range: 0 (not applicable), 1 (low), 2 (medium), 3 (high).
water_provision	Asset contribution towards improving water provision. Value range: 0 (not applicable), 3 (high).
water_storage	Asset contribution towards improving water storage. Value range: 0 (not applicable), 1 (low), 2 (medium), 3 (high).
ground_water_recharge	Asset contribution towards improving ground water recharge. Value range: 0 (not applicable), 1 (low), 2 (medium), 3 (high).
erosion_protection	Asset contribution towards improving erosion control. Value range: 0 (not applicable), 1 (low), 2 (medium), 3 (high).
ES_SCORE	Combined ecosystem score as a sum of the seven included ecosystem service asset contribution values.
size_condition	Asset's contribution towards size condition score. Value range: 1 (low), 2 (medium), 3 (high).
disturbance_condition	Asset's contribution towards disturbance score. Value range: 1 (low), 2 (medium), 3 (high).
CONDITION_SCORE	Combined condition score as a sum of the two included condition values.
sqkm	Area of asset in square kilometers

Appendix C: Human Footprint Disturbance Rating

Feature Type	Disturbance Rating	Included in Human Disturbance Metric
AIRP-RUNWAY	High	Yes
BORROWPIT-DRY	Med	Yes
BORROWPIT-WET	Med	Yes
BORROWPITS	Med	Yes
CAMP-INDUSTRIAL	High	Yes
CAMPGROUND	Med	Yes
CFO	High	Yes
CLEARING-UNKNOWN	Low	No
CLEARING-WELLPAD-UNCONFIRMED	High	Yes
CONVENTIONAL-SEISMIC	Low	No
COUNTRY-RESIDENCE	Med	Yes
FACILITY-OTHER	High	Yes
FACILITY-UNKNOWN	High	Yes
GOLFCOURSE	Med	Yes
GREENSPACE	Low	No
GRVL-SAND-PIT	Med	Yes
INTERCHANGE-RAMP	High	Yes
LANDFILL	High	Yes
LOW-IMPACT-SEISMIC	Low	No
MILL	High	Yes
MINES-COAL	High	Yes
MINES-OILSANDS	High	Yes
MINES-PITLAKE	High	Yes
MISC-OIL-GAS-FACILITY	High	Yes
OIL-GAS-PLANT	High	Yes
OPEN-PIT-MINE	High	Yes
PIPELINE	Low	No
RECREATION	Low	No
RESIDENCE_CLEARING	Med	Yes
RLWY-ABANDONED	Low	No
RLWY-DBL-TRACK	Med	Yes
RLWY-FORMER	Med	Yes
RLWY-MLT-TRACK	Med	Yes
RLWY-SGL-TRACK	Med	Yes
RLWY-SPUR	Med	Yes

ROAD-GRAVEL-1L	Med	Yes
ROAD-GRAVEL-2L	Med	Yes
ROAD-PAVED-1L	High	Yes
ROAD-PAVED-2L	High	Yes
ROAD-PAVED-3L	High	Yes
ROAD-PAVED-4L	High	Yes
ROAD-PAVED-5L	High	Yes
ROAD-PAVED-6L	High	Yes
ROAD-PAVED-7L	High	Yes
ROAD-PAVED-DIV	High	Yes
ROAD-PAVED-UNDIV-1L	High	Yes
ROAD-PAVED-UNDIV-2L	High	Yes
ROAD-PAVED-UNDIV-4L	High	Yes
ROAD-UNCLASSIFIED	Low	No
ROAD-UNIMPROVED	Low	No
ROAD-UNPAVED-1L	Low	No
ROAD-UNPAVED-2L	Low	No
ROAD-WINTER	Low	No
ROAD-WINTER-ACCESS	Low	No
RUNWAY	Med	Yes
RURAL-RESIDENCE	Med	Yes
SURROUNDING-VEG	Low	No
TAILING-PILE	High	Yes
TAILING-POND	High	Yes
TRAIL	Low	No
TRANSFER_STATION	Med	Yes
TRANSMISSION-LINE	Low	No
TRUCK-TRAIL	Low	No
URBAN-INDUSTRIAL	High	Yes
URBAN-RESIDENCE	High	Yes
VEGETATED-EDGE-RAILWAYS	Low	No
VEGETATED-EDGE-ROADS	Low	No
WELL-ABAND	Low	No
WELL-BIT	Med	Yes
WELL-CASED	Med	Yes
WELL-CLEARED-NOT-DRILLED	Med	Yes
WELL-GAS	Med	Yes
WELL-OIL	Med	Yes
WELL-OTHER	Med	Yes
WELL-UNKNOWN	Med	Yes
WINDMILLS	Low	No