# Nature-Based Climate Solutions (NBCS) Siting Tool: Final Report

Prepared by Toronto and Region Conservation Authority
for Canadian Wildlife Service

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## DISCLAIMER

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# 1. INTRODUCTION

Nature-based climate solutions (NBCS) offer ecosystem-based approaches to address societal challenges, while improving environmental health and addressing the threat of climate change (IUCN, 2016). NBCS can include the protection or restoration of natural features and areas such as forests, wetlands, and meadows, as well as the implementation of other green infrastructure such as street and backyard trees, green roofs, and rain gardens (e.g. ICF, 2018; Petsinaris et al., 2020). Nature-based solutions first emerged in mainstream scientific literature in the early 2000s, with an early focus on agricultural production and land management, land use planning, and water resource management (Potschin et al., 2016). Over time, the term has increasingly been used in relation to climate change in recognition of the important role that nature plays in combating climate change.

NBCS can offer both climate change mitigation and adaptation services by sequestering and storing carbon and increasing our resilience to acute (e.g. extreme weather) and slow-onset climate change impacts (e.g. drought), while providing additional co-benefits that enhance ecosystem health and community well-being (e.g. water quality and mental health benefits). For example, natural features such as wetlands can sequester and store carbon; decrease the amount and rate of stormwater runoff; stabilize eroding slopes in streams and valley corridors; recharge groundwater; maintain stream flows; regulate ground and air temperature; clean air and water; provide habitat for wildlife; and support recreational opportunities (e.g. fishing and bird watching).

Recent landmark global assessments by two intergovernmental bodies on Biodiversity and Ecosystem Services (IPBES, 2019) and Climate Change (IPCC, 2021) have found that human activities are driving rapid and widespread global biodiversity and nature loss and climate change at unprecedented rates. For example, natural ecosystems have declined by an average of 47 percent compared to their estimated natural baselines, and approximately 25 percent of plant and animal species that have been studied in sufficient detail are under the growing threat of extinction (IPBES, 2019). Meanwhile, human activities have unequivocally led to the warming of the atmosphere, land, and oceans (IPCC, 2021). Average global surface temperature has already warmed by over 1°C since the pre-industrial period (1850-1900), causing negative impacts on human and natural systems, which will worsen if climate change continues to accelerate (IPCC, 2022).

Since 2017, environmental risks have increasingly dominated the World Economic Forum's annual Global Risks Report as the most significant risks to economies around the world. For example, environmental risks made up half of the top ten global risks by severity in 2022, including climate action failure, extreme weather, and biodiversity loss, which were identified as the top three risks, while human environmental damage and natural resource crises, made the top seventh and eighth, respectively (World Economic Forum, 2022). These risks are interrelated and will continue to worsen without urgent and transformative action to address the threats of ecosystem degradation, biodiversity loss, and climate change simultaneously.

The concept of NBCS has received growing interest among the scientific and policy communities, recognizing that these solutions can cost-effectively help to address multiple threats, while offering additional co-benefits. The Government of Canada has embraced this concept and has committed to increase investment in NBCS over the next ten years such as by planting two billion trees and supporting actions through the Natural Climate Solutions Fund (NSCSF; Environment and Climate Change Canada, 2020). As the federal government commits to operationalize the concept of NBCS, the Canadian Wildlife Service (CWS) will play a key role in supporting habitat projects focused on carbon sequestration, and the conservation of ecosystems crucial to the protection of migratory birds, species at risk, and other wildlife.

In order to ensure effective use of funds from NBCS programs, CWS and its implementation partners require tools to guide the selection of project locations that maximizes benefits to biodiversity, human well-being, and climate change mitigation and adaptation. For example, The Nature Conservancy has developed an online siting tool to support natural hazard resilience planning in Massachusetts (Burns and Dietrich, 2020). This tool identifies opportunities to conserve, restore, and manage nature to help reduce the risk of inland and coastal flooding and drought, along with opportunities to conserve high quality habitat and regional connectivity to support biodiversity. A study by Meerow and Newell (2017) also demonstrated the benefits of mapping multiple ecosystem services to inform the spatial planning of multifunctional green infrastructure in Detroit, including stormwater management, social vulnerability, green space, air quality, urban heat island reduction, and landscape connectivity.

Building on these precedents and other local examples (e.g. TRCA's Integrated Restoration Prioritization [IRP] Tool and Sustainable Neighbourhood Action Plan [SNAP] neighbourhood screening processes), this project aims to develop a watershed-based methodology and proof-of-concept of a map-based screening tool. The purpose of this tool is to help identify strategic locations where nature-based projects can be established to protect, restore, or enhance the natural environment based on purposeful consideration of multiple benefits and potential trade-offs. The NBCS Siting Tool ("siting tool") is intended to be flexible to enable consideration of diverse types of NBCS and help local conservation practitioners plan nature-based projects more effectively. It does not prescribe specific types of nature-based projects, which will ultimately require further consideration of the local context and input from stakeholders.

As a proof-of-concept, this siting tool also has the potential to be scaled up and expanded to other jurisdictions to help focus funding for future NSCSF calls. Opportunities to scale and adapt the siting tool to fit the local context are noted throughout the report.

**Section 2** provides an overview of the Humber River watershed, which is the study area of focus for the development of the prototypical siting tool. **Section 3** presents the structure of the siting tool and how it can be used. **Section 4** provides details on the datasets and methods used to develop the siting tool. **Section 5** discusses limitations and possible future directions to further enhance the siting tool and continue to address NBCS knowledge and implementation gaps.

# 2. STUDY AREA: HUMBER RIVER WATERSHED

As a proof-of-concept, this project focuses on the Humber River watershed, the largest watershed located within TRCA's jurisdiction in southern Ontario (see Figure 1). It spans five regional or single-tier municipalities and ten local municipalities, including:

- City of Toronto
- Peel Region: Cities of Mississauga and Brampton, and Town of Caledon
- York Region: Cities of Vaughan and Richmond Hill, Township of King, and Town of Aurora
- Simcoe County: Township of Adjala-Tosorontio
- Dufferin County: Town of Mono

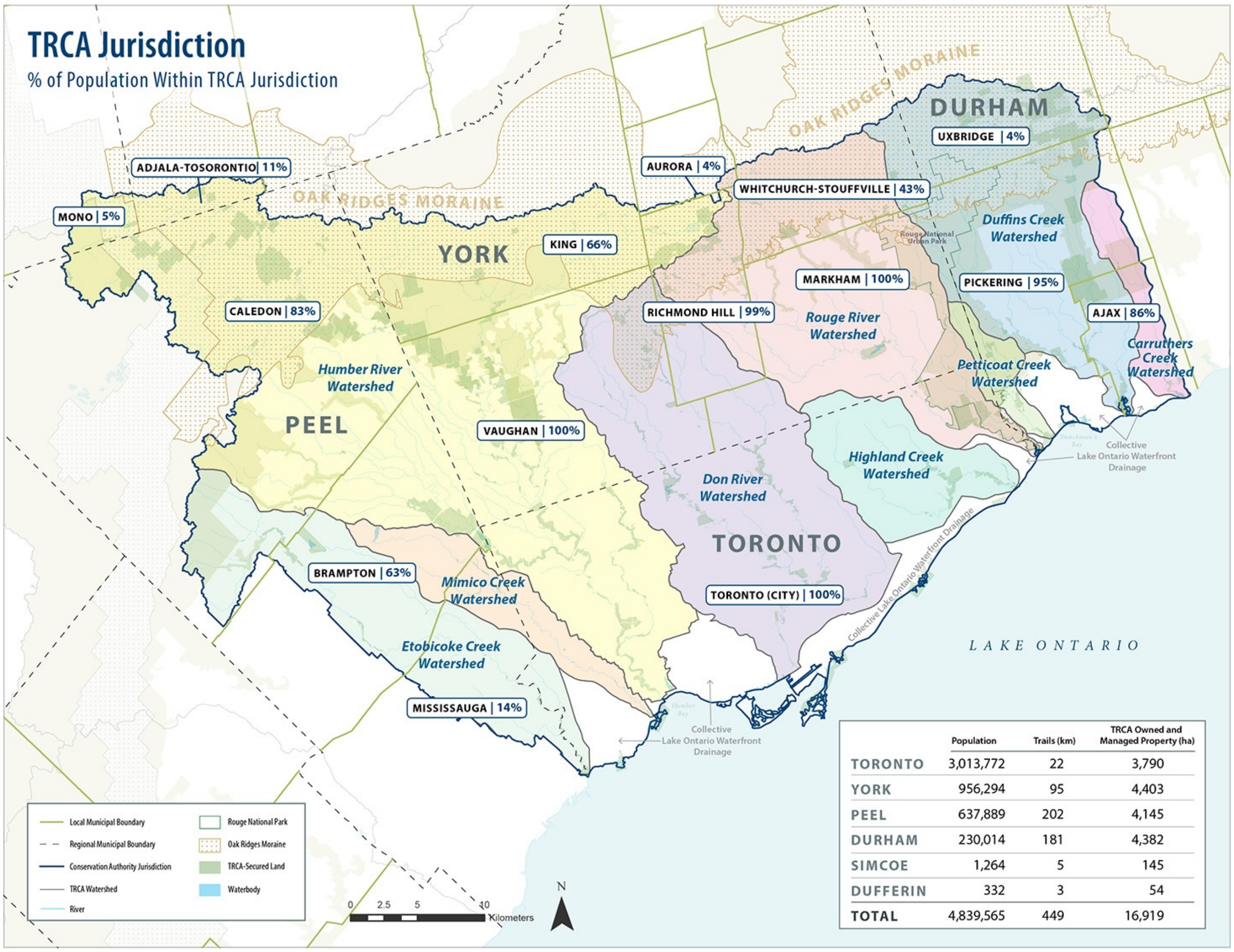


**FIGURE 1. MAP OF THE HUMBER RIVER WATERSHED AND TRCA'S JURISDICTION (SOURCE: TRCA, 2022A)**

**Why a Watershed-Based Approach?**

A watershed is an area of land that catches rain and snow that drains or seeps into a marsh, stream, river, lake, or groundwater.

Watersheds are natural ecological units of land that can extend across geopolitical boundaries. Hence, taking a watershed-based approach can help facilitate more integrated approaches to ecosystem management.

The watershed encompasses over 900 $km^2$ of land, 1,800 km of rivers and streams, and 600 bodies of water (TRCA, 2022b). It is home to nearly one million people, and more than 700 species of plants, 40 species of fish, and 180 other animal species (TRCA, 2020; 2022b). With a mix of urban, suburban, and rural communities, this study area was selected to help support the scalability and replicability of the siting tool in other areas in Canada.

The waters of the Humber River originate from the north on the ancient rocks of the Niagara Escarpment and rolling hills of the Oak Ridges Moraine, and flow south down into Lake Ontario through a variety of landscapes (TRCA, 2022b). These waters provide important sources of drinking water as drawn from wells or Lake Ontario (TRCA, 2008). The Humber River also provides a variety of recreational spaces, including hundreds of kilometres of trails and numerous conservation areas that provide picnicking, biking, hiking, fishing, and canoeing opportunities (TRCA, 2020).

Since 1999, the Humber River has been designated as a Canadian Heritage River in recognition of its contributions to the long history of human settlements, from the Carrying Place Trail and grand villages established by Indigenous communities for thousands of years, to the early European settlers in the late 18th century (TRCA, 2008; 2020). For thousands of years after the last ice age, the Humber River watershed was dominated by vast tracts of forest, interspersed with wetlands and meadows, offering rich resources used by Indigenous peoples (TRCA, 2008). Following the arrival of European settlers, major land conversions took place – forests were clear-cut for timber and farms, wetlands were drained, and dams were installed to generate power and build settlements.

Over the decades after the Second World War, much of the farmland and many rural settlements have been displaced by urban development, particularly in the southern and western portions of the watershed (TRCA, 2008). As a result, natural habitats have been further reduced and fragmented, hydrological patterns have been altered, and some plant and animal species have disappeared altogether from the watershed while others that thrive in disturbed areas have survived. In 2007, the watershed was given an overall grade of C (or fair) based on average results for 26 indicators of watershed health. Conditions ranged from very good for the protection of significant landforms to failing grades for stormwater management and surface water swimmability.

As reported in TRCA's Watershed and Ecosystems Reporting Hub, total natural land cover within the watershed has decreased from 32 percent in 2007 to 31 percent in 2017. The watershed is comprised of 69 percent non-natural land cover, followed by 19 percent forest cover, 7 percent meadow cover, 3 percent successional forest cover, and 2 percent wetland cover. Between 2007 and 2017, forest and wetland cover increased by 7 percent and 5 percent, respectively. While meadow and successional forest cover decreased by 20 and 19 percent, respectively. As urbanization continues and the impacts of climate change continue to intensify, further pressures are anticipated to affect the health and integrity of natural features and areas within the watershed. Bold and purposeful actions are needed to protect, restore, and enhance the natural systems and water quality of the Humber River on a watershed basis, which this siting tool aims to help support by identifying strategic locations to direct investment and resources to achieve the greatest ecological value and population need. TRCA will be embarking on a process to update the Humber River Watershed Management Plan (2008) later this year, which this siting tool can also help support by informing the recommendations and actions that will be set out in the updated plan.

# 3. STRUCTURE OF THE SITING TOOL

The purpose of this map-based, multi-criteria assessment siting tool is to identify and screen priority locations for the protection, restoration, and enhancement of nature. Recognizing that the implementation of NBCS is ultimately context- and site-specific, the intent of this project is to develop a high-level screening tool.

**Protection** is the process of ensuring that natural features and areas that are of higher quality and have high ecosystem functions and services are safeguarded from loss or degradation for current and future generations. Protection is targeted in areas with existing natural cover that are functioning well and have good ecosystem service provision. For example, Areas with existing natural cover with either high carbon storage in 2013 (≥ 355.2 metric tons of carbon/ha) or an increase in carbon sequestration between 2007 and 2013 are recommended for protection.

**Restoration** is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed to ensure that ecosystem structure, function, and services are maintained over the long term. Restoration is targeted in areas with existing natural cover that have been impaired but have a high potential for improved ecosystem functions and services and ample opportunities to restore natural cover. For example, areas with existing or potential natural cover[1] with a decrease in carbon sequestration between 2007 and 2013 are recommended for restoration.

**Enhancement** is the process of (re)establishing ecosystem functions and services where opportunities for traditional restoration may be limited. Enhancement is targeted in areas with no existing natural cover that have limited opportunities to restore natural cover but have a high potential for improved ecosystem functions and services. For the purposes of a TRCA-focused application, and to reduce overlap with the Restoration classification, only areas outside TRCA's Natural Heritage System (NHS; existing and potential natural cover) have been considered for enhancement opportunities. For example, areas with no existing or potential natural cover that have space available for tree planting[2] with no carbon stored in 2013 and a decrease in carbon sequestration between 2007 and 2013 are recommended for enhancement.

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[1] **Potential natural cover** refers to unbuilt areas or open land uses with higher contributions to natural heritage system functions, which have been delineated through TRCA's Natural Heritage System (NHS) Update. For further information, please see section 4.3.2.

[2] **Plantable space** refers to areas where trees can theoretically be planted based on land use and cover type. For further information, please see section 4.3.3.

The siting tool will help maximize co-benefits and facilitate discussions about trade-offs by incorporating various ecosystem functions and services under four broad themes: Carbon, Hazard, Community Health, and Ecosystem (see Table 1). These themes were selected to reflect the variety of ecosystem functions and services provided by NBCS, while also enabling users to target specific opportunities (such as carbon storage and sequestration) separately if they wish. The indicators were selected based on best available geospatial information and through discussions with subject matter experts. The next section provides further details on the datasets used and analyses conducted to support the scalability and replicability of the siting tool in other jurisdictions.

TABLE 1. OVERVIEW OF THEMES, INDICATORS, AND ECOSYSTEM SERVICE CATEGORIES

| Themes | Indicators | Ecosystem Service Category |
|---|---|---|
| **Carbon** | 1. Carbon storage | Regulating services |
| | 2. Carbon sequestration change | |
| **Hazard** | 3. Stormwater quantity | |
| | 4. Stormwater quality | |
| | 5. Current state of erosion hazard management | |
| | 6. Ground surface temperature | |
| **Community Health** | 7. Dimensions of deprivation | Cultural services |
| | 8. Chronic (or non-communicable) diseases | |
| | 9. Residential accessibility to greenspaces | |
| | 10. Exposure to nature | |
| **Ecosystem** | 11. Habitat suitability (fish, birds, and amphibians) | Supporting and Provisioning services |
| | 12. Landscape connectivity (regional and local) | |
| | 13. Aquatic ecosystem (groundwater features) | |
| | 14. Biodiversity (species richness and turnover) | Supporting services |

Pending further discussion with CWS, the tool may be made available through a public-facing web-based platform (e.g. ArcGIS online). The tool will be designed to provide the following key functions:

- Ability to view results by individual indicators and themes and their scores
- Ability to view results by different management recommendations (i.e. protection, restoration, and enhancement) and their scores
- Ability to view results by ecosystem service categories (i.e. regulating, provisioning, supporting, cultural) and their scores
- Ability to interact with the map at different scales, viewing their own mapping layers, and export/print the map as an image or PDF

If the online tool does become publicly accessible, appropriate disclaimers and contextual information will be added to the online tool to aid the interpretation of the prioritization results.

# 4. METHODOLOGY

This section describes the process of developing the NBCS Siting Tool; the datasets that were gathered and analyzed for each indicator; the rules developed to prioritize the indicators under each management recommendation (i.e. protection, restoration, and enhancement); the process of creating the online visualization tool; and a rapid comparison with two existing TRCA prioritization and screening tools.

## 4.1 Siting Tool Development Process

The development of the siting tool was divided into two modules and the following key steps (see Figure 2):

- **Module 1: Showcase each data layer to summarize the current state of ecosystem functions and services within the Humber River watershed**
    - Identify indicators and required data based on a literature review of existing tools and frameworks, as well as review of TRCA research and initiatives
    - Collect data and identify data gaps that need to be filled
    - Engage with subject matter experts (SMEs) to confirm analysis and assessment approaches
    - Compile data layers in ArcMap 10.7.1
    - Score and rank individual layers to describe current conditions, including high value areas and high need areas
- **Module 2: Showcase the priority areas for management and adaptation action where NBCS can be sited to maximize co-benefits**
    - Develop and apply a prioritization scheme to identify priority areas for protection, restoration, and enhancements using a combination of individual layers developed in Module 1
    - Create and finalize the online mapping platform

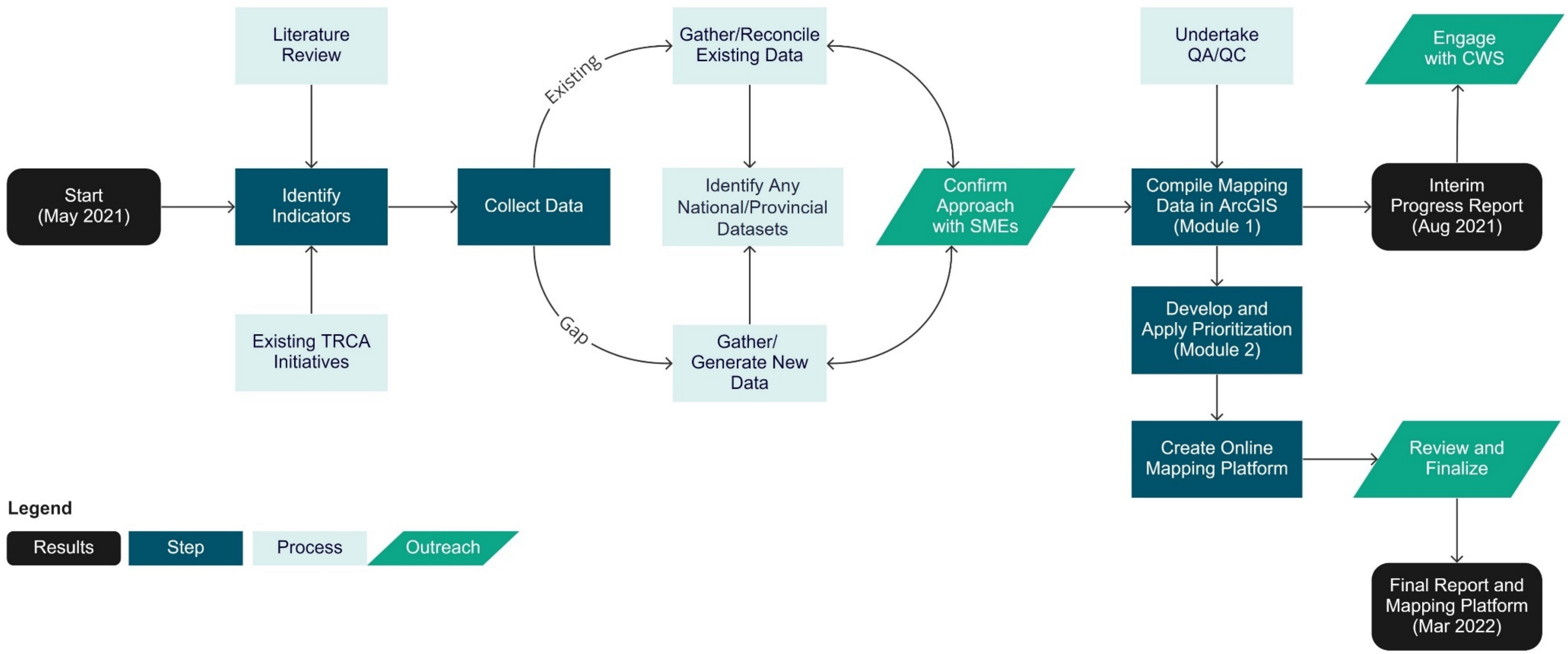


FIGURE 2. PROCESS OF DEVELOPING THE NATURE-BASED CLIMATE SOLUTIONS SITING TOOL

## 4.2 Data Collection and Analysis

The siting tool leveraged existing geospatial datasets from a variety of sources including TRCA, governmental databases, and research partners. Half of the indicators were created based on new analysis conducted by the project team and project partners using the best available data (as detailed in sections 4.2.3 to 4.2.5, and 4.2.7 to 4.2.10). Other sources of geospatial data that provide broader geographic coverage have been identified where available and can be found in the Appendix. The following subsections provide an overview of what was assessed by each indicator, the datasets used, and the data/geospatial analysis conducted where applicable.

### 4.2.1 Carbon Storage

The amount of carbon stored and sequestered on land was modelled for TRCA's jurisdiction in 2020 using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Carbon Storage and Sequestration model. The modelling was based on TRCA's 2013 natural cover raster data, which depicted five broad categories of natural terrestrial habitat types: forests, wetlands, successional forests, meadows, and beach/bluff.

InVEST is a suite of open-source models that can help map and value ecosystem goods and services (Stanford University, n.d.). The Carbon Storage and Sequestration model maps carbon stocks (i.e. the absolute quantity of carbon held in a reservoir at a given time) based on the amount of carbon stored in four carbon pools across each habitat type: aboveground biomass (e.g. bark, trunk, branches and leaves); belowground biomass (i.e. living root systems); soil organic matter; and dead organic matter (e.g. litter and dead wood; The Natural Capital Project, n.d.).

Based on the natural terrestrial habitat types, the highest carbon storage (in metric tons) was estimated for forests, followed by successional forests, meadows, and wetlands. No beach/bluff cover is found within the watershed, therefore no carbon storage for beach/bluff was estimated.

### 4.2.2 Carbon Sequestration Change

The net change in the amount of carbon sequestered by terrestrial ecosystems was also modelled for TRCA's jurisdiction using the InVEST Carbon Storage and Sequestration model in 2020. **Carbon sequestration** refers to the process of removing and storing atmospheric carbon dioxide over time such as in plants and soil. **Net sequestration** is the difference between total carbon sequestered and carbon lost through emissions (such as from deforestation or vegetation decomposition). The change in the amount of carbon stored was determined based on the difference in carbon stocks between 2007 and 2013 on a pixel-by-pixel basis, using TRCA's natural cover data for each respective year. The model calculates net sequestration by summing up the losses and gains for each pixel across the landscape. A negative value indicates that there has been an overall loss of carbon stocks, while a positive value indicates a net gain.

A quick overlap analysis conducted in ArcMap by the project team confirmed that areas with a loss in carbon stocks corresponded with areas that have either lost natural cover between 2007 and 2013 or changed from a habitat type with higher carbon storage potential to another with lower carbon storage potential (e.g. forest to successional forest). Meanwhile, for areas that have gained carbon stocks over this period, the change was confirmed to be attributed to the establishment of new habitats or change from a habitat type with lower carbon storage potential to another with higher carbon storage potential (e.g. meadow to successional forest).

### 4.2.3 Stormwater Quantity

As a proxy for the amount of stormwater runoff that could be generated under any given storm within the Humber River watershed, total percent impervious (TIMP) cover was estimated for each land use category based on the TIMP values that were assigned to each land use and cover type in the 2018 Humber River Hydrology Update – Final Report, prepared by Civica Infrastructure Ltd. for TRCA (see Table 2). TIMP area ($m^2$) was calculated by the project team by multiplying the TIMP value (%) with the area of each land use parcel ($m^2$).

TABLE 2. TOTAL PERCENT IMPERVIOUS (TIMP) COVER BY LAND USE AND COVER TYPE

| Land Use | TIMP | Cover Type |
|---|---|---|
| **Cemetery** | 35 | 35% Impervious + 65% Lawns |
| **Commercial** | 95 | 95% Impervious + 5% Lawns |
| **Conservation Lands** | 0 | 80% Woods + 20% Meadows |
| **Estate Residential** | 40 | 40% Impervious + 60% Lawns |
| **Farm** | 0 | Cultivated |
| **Golf Course** | 0 | Lawns |
| **Hydro Corridor** | 10 | 10% Impervious + 90% Meadows |
| **Industrial** | 95 | 95% Impervious + 5% Lawns |
| **Institutional** | 80 | 80% Impervious + 20% Lawns |
| **Open Space** | 0 | 50% Woods + 50% Meadows |
| **Park** | 10 | 10% Impervious + 45% Woods + 45% Meadows |
| **Recreational** | 20 | 20% Impervious + 80% Lawns |
| **Residential High** | 80 | 80% Impervious + 20% Lawns |
| **Residential LowMed** | 60 | 60% Impervious + 40% Lawns |
| **Road (ROW)** | 90 | 90% Impervious + 10% Lawns |
| **Rural Residential** | 20 | 20% Impervious + 80% Lawns |
| **Transportation** | 60 | 60% Impervious + 40% Lawns |
| **Water** | 100 | Impervious[3] |
| **Natural** | 0 | 50% Woods + 50% Meadows |

An estimate of the amount of directly connected percent impervious (XIMP) area was also calculated based on values available in the Humber River Hydrology Update – Final Report (2018). XIMP refers to the portion of total percent impervious area that is hydraulically connected to the storm sewer system (Ebrahimian et al. 2015). It is considered a more important parameter of urban stormwater runoff than total impervious (TIMP) cover.

[3] Water is assigned a 100 percent impervious value because rain that falls on a water surface is considered pure runoff.

However, recognizing that data on TIMP is more commonly available than XIMP, the TIMP area was used in this siting tool to maximize scalability and replicability.

### 4.2.4 Stormwater Quality

As a proxy for the quality of possible stormwater runoff, the concentrations of total suspended solids (TSS; mg/L) and total phosphorous (TP; mg/L) were estimated by the project team for each land use and cover type found in the Humber River Hydrology Update – Final Report (2018), using the land cover Event Mean Concentrations (EMCs; see Table 3) employed in version 1.2.1 of the Low Impact Development Treatment Train Tool (LID TTT) (STEP, 2018). Land cover EMCs are used to estimate the concentrations and loads of TSS and TP leaving an area, carried by stormwater runoff, based on land cover type. The land cover EMCs used in the LID TTT are based on local water quality data measured by TRCA and Credit Valley Conservation (CVC) and data from the International Stormwater Best Management Practices Database (BMPDB).

**Table 3. Land Cover Event Mean Concentrations (EMCs)**

| Land Cover | TSS (mg/L) | TP (mg/L) |
|---|---|---|
| **Paved Surface** | 90 | 0.23 |
| **Roof** | 7 | 0.09 |
| **Landscaped Area** | 100 | 0.32 |
| **Row Crop** | 100 | 0.23 |
| **Open Space/Parkland** | 27 | 0.20 |
| **Forest** | 55 | 0.23 |
| **Wetland** | 13 | 0.81 |

The first step was to reconcile the land cover types in Table 3 with the land use categories identified for the Humber River watershed in Table 2, resulting in Table 4. Given that Table 2 does not differentiate by impervious cover type, building footprint data from Statistics Canada was used to represent roof area. Roof area was subtracted from the TIMP area to determine the total paved surface area for each land use parcel. Where roof area was greater than the TIMP area for a parcel (e.g. on farms, open space, or natural areas), the TIMP area was used. TRCA's wetland layer was also used to capture wetland locations within the watershed that may be masked by the broad land use categories shown in Table 3. No EMCs were assigned to water as sediment and nutrients are expected to be deposited in or transported through water.

**Table 4. Assigning Land Cover EMCs to Humber River Watershed's Land Use and Cover Type for Stormwater (SW) Quality Calculations**

| Land Use | Cover Type for SW Quantity Calculations | Cover Type for SW Quality Calculations |
|---|---|---|
| **Cemetery** | 35% Impervious + 65% Lawns | 35% Paved Surface + 65% Landscaped Area |
| **Commercial** | 95% Impervious + 5% Lawns | 95% (Paved Surface + Roof) + 5% Landscaped Area |
| **Conservation Lands** | 80% Woods + 20% Meadows | 80% Forest + 20% Open Space/Parkland |

| Land Use | Cover Type for SW Quantity Calculations | Cover Type for SW Quality Calculations |
|---|---|---|
| **Estate Residential** | 40% Impervious + 60% Lawns | 40% (Paved Surface + Roof) + 60% Landscaped Area |
| **Farm** | Cultivated | Row Crop |
| **Golf Course** | Lawns | Landscaped Area |
| **Hydro Corridor** | 10% Impervious + 90% Meadows | 10% Paved Surface + 90% Open Space/Parkland |
| **Industrial** | 95% Impervious + 5% Lawns | 95% (Paved Surface + Roof) + %% Landscaped Area |
| **Institutional** | 80% Impervious + 20% Lawns | 80% (Paved Surface + Roof) + 20% Landscaped Area |
| **Open Space** | 50% Woods + 50% Meadows | 50% Forest + 50% Open Space/Parkland |
| **Park** | 10% Impervious + 45% Woods + 45% Meadows | 10% (Paved Surface + Roof) + 45% Forest + 45% Open Space/Parkland |
| **Recreational** | 20% Impervious + 80% Lawns | 20% (Paved Surface + Roof) + 80% Landscaped Area |
| **Residential High** | 80% Impervious + 20% Lawns | 80% (Paved Surface + Roof) + 20% Landscaped Area |
| **Residential LowMed** | 60% Impervious + 40% Lawns | 60% (Paved Surface + Roof) + 40% Landscaped Area |
| **Road (ROW)** | 90% Impervious + 10% Lawns | 90% Paved Surface + 10% Landscaped Area |
| **Rural Residential** | 20% Impervious + 80% Lawns | 20% (Paved Surface + Roof) + 80% Landscaped Area |
| **Transportation** | 60% Impervious + 40% Lawns | 60% (Paved Surface + Roof) + 40% Landscaped Area |
| **Water** | Impervious | n/a |
| **Natural** | 50% Woods + 50% Meadows | 50% Forest + 50% Open Space/Parkland |

### 4.2.5 Current State of Erosion Hazard Management

This indicator presents the current state of TRCA's erosion hazard management within the Humber River watershed based on the density of:

- Erosion hazard monitoring sites (245)
- TRCA-owned or monitored erosion control structures (284)
- Region of Peel and York Infrastructure Hazard Monitoring Program sites (622)
- Toronto Water Infrastructure Monitoring Program sites (2359)
- Toronto Water erosion control structures (814)

In support of this project, a heat map analysis was conducted by staff in TRCA's Erosion Risk Management (ERM) team. The Kernel Density tool in ArcMap was used to calculate the density of erosion hazard sites/structures within a circular neighbourhood (1-km radius) around those features. Weighting was applied to give more weight to some sites/structures based on their priority ranking (see Table 5).

TABLE 5. WEIGHTING EROSION HAZARD SITES/STRUCTURES BASED ON PRIORITY RANKING

| Dataset | **Weighting** (from low to high) |
|---|---|
| **Erosion hazard monitoring sites** – sites where erosion hazard may be impacting private properties or public infrastructure on valley slopes or river/stream banks. Inspections are conducted on a voluntary (as-requested) basis.<br>Priority ranking is based on the normalized primary inspection score. | • No score = 0<br>• ≤29% = 1<br>• 30 to 49% = 2<br>• 50 to 69% = 3<br>• ≥70% = 4 |
| **Erosion control structures** – these structures are either owned by TRCA or monitored regularly for municipal partners.<br>Priority ranking is based on the overall structure condition. | • Excellent = 1<br>• Good = 2<br>• Fair = 3<br>• Poor = 4 |
| **Region of Peel and York Infrastructure Hazard Monitoring Program sites** – sites where Regional linear underground infrastructure (e.g. sanitary or watermain pipes) are located near watercourses.<br>Priority ranking is primarily based on the infrastructure's exposure to erosion hazard (e.g. the closest distance from the infrastructure to the watercourse bank, or the depth of cover from the watercourse bed for crossing sites). | • Not assigned = 0<br>• None = 1<br>• Low = 2<br>• Medium = 3<br>• High = 4<br>• Critical = 5 |
| **Toronto Water Infrastructure Monitoring Program sites** – sites where an erosion hazard may be impacting Toronto Water's infrastructure, including stormwater, sanitary, or watermain lines; outfalls; manholes; crossings, etc.<br>Priority ranking is based on TRCA's recommended priority ranking. | • No concern = 0<br>• To be monitored = 1<br>• Tolerable = 2<br>• Immediate follow-up required = 3<br>• Urgent = 4 |
| **Toronto Water erosion control structures** – these structures are only identified and inspected if they are part of Toronto Water's known infrastructure located within the City's ravine system.<br>Priority ranking is based on structure condition. | • N/A = 1<br>• Good = 2<br>• Acceptable = 3<br>• Needs repair = 4<br>• Failed = 5 |

It is important to note that this indicator reveals the current state of erosion hazard management within the watershed, which is primarily driven by erosion hazard monitoring program funding. It does not represent the full scope of erosion hazards or erosion risk across the watershed, and so areas with no features does not necessarily indicate areas with no erosion risk. As further erosion risk assessments are conducted by ERM, improved erosion risk data (e.g. erosion rates of change, etc.) will become available.

### 4.2.6 Ground Surface Temperature

As a proxy for the surface heat island effect, existing ground surface temperature available for TRCA's jurisdiction for a typical summer day in 2014 (June 18) with minimal cloud cover was used. The surface heat island effect is a component of the **urban heat island effect** where day and night-time temperatures in built-up urban areas tend to be higher than surrounding areas with more natural land cover. Ground surface temperature is employed as a proxy and does not include factors such as air temperature and humidity.

Ground surface temperature was derived from Landsat 8 satellite imagery available from the United States Geological Survey's (USGS) Earth Explorer and processed using PCI Geomatica's Atmospheric Correction (ATCOR) module. Each satellite image was processed separately to extract surface temperature data and then mosaiced to cover the entire Greater Toronto Area. This was work was completed for TRCA in support of the State of the Urban Forest in the Greater Toronto Area report (GIO, 2016).

While the ground surface temperature dataset is a bit dated now, the temperatures are generally still reflective of current natural and built environment conditions. As anticipated, areas with natural land cover, such as parks and watercourses are cooler, while built-up areas and parking lots recorded higher surface temperatures. Ground surface temperatures within the Humber River watershed range from 21˚C to a high of 54˚C.

### 4.2.7 Dimensions of Deprivation

The Ontario version of the Canadian Index of Multiple Deprivation (CIMD) developed by the Canadian Centre for Justice Statistics (CCJS) at Statistics Canada was used to assess different dimensions of deprivation within the Humber River watershed (Statistics Canada, 2019). The CIMD builds upon the 2006 Canadian Marginalization Index, which was developed jointly by CCJS and Dr. Matheson and others at St. Michael's Hospital, Unity Health Toronto. Throughout the development of the CIMD, Dr. Matheson, Dr. Dunn, and others at St. Michael's Hospital, Unity Health Toronto were consulted about the inception of the CIMD and continuously provided feedback and support to aid the index's development.

The Ontario version of the Canadian Index of Multiple Deprivation (CIMD) offers a province-wide index of multiple dimensions of deprivation at the dissemination area (DA) level based on 2016 Census data. DAs are the smallest standard geographic unit with all census data available across Canada. Each DA generally encompasses a population of approximately 400 to 700 people. Four dimensions of deprivation are captured by the national and provincial/regional indices, including:

- **Residential instability** – the tendency of neighbourhood inhabitants to fluctuate over time, taking into consideration both housing and familial characteristics
- **Economic dependency** – the degree of reliance on the workforce, or a dependence on sources of income other than employment income
- **Ethno-cultural composition** – the community make-up of immigrant populations
- **Situational vulnerability** – variations in socio-demographic conditions in the areas of housing and education, while accounting for other demographic characteristics

The provincial index was created using the same 24 initial input variables as the national index and was subsequently narrowed down to 17 indicators (see Table 6) using factor analysis to identify key variables driving each of the four dimensions. Variables that explain the least amount of variance within each dimension were typically discarded. As a result, the provincial index is composed of a different set of indicators as compared to the national index, and so the indices should not be compared directly. The national index enables comparison of deprivation between provinces, or between Canada and a province. Meanwhile, the provincial index enables comparison of deprivation within the province.

TABLE 6. INDICATORS OF THE ONTARIO VERSION OF THE CANADIAN INDEX OF MULTIPLE DEPRIVATION

| Dimension | Indicator |
|---|---|
| **Residential Instability** | 1. Proportion of dwellings that are apartment buildings<br>2. Proportion of dwellings that are rented (i.e. not owned)<br>3. Proportion of persons living alone<br>4. Proportion of the population who moved within the past five years<br>5. Proportion of population that is single, divorced, separated, or widowed (i.e. not married or common-law) |
| **Economic Dependency** | 6. Proportion of population aged 65 and older<br>7. Proportion of population (aged 15 and older) not participating in the labour force<br>8. Ratio of unemployment to population (i.e. not employed)<br>9. Dependency ratio (i.e. population aged 0-14 and aged 65 and older, divided by population aged 15-64)<br>10. Proportion of population receiving government transfer payments |
| **Ethno-cultural Composition** | 11. Proportion of population that is foreign-born<br>12. Proportion of population who self-identify as visible minority<br>13. Proportion of population with no knowledge of either official language (i.e. English or French)<br>14. Proportion of population who are recent immigrants (i.e. arrived in five years prior to 2016 Census) |
| **Situational Vulnerability** | 15. Proportion of population that identifies as Aboriginal<br>16. Proportion of population aged 25-64 without a high school diploma<br>17. Proportion of dwellings needing major repairs |

Scores are available for each dimension, including factor scores and quintile rankings for each DA assessed in Ontario (n = 19,897). The factor scores were derived from the factor analysis, whereby a lower factor score means less marginalization in that dimension within a DA, while a higher factor score means greater marginalization. The quintile scores, ranked from 1 (least deprived) to 5 (most deprived), divide the factor scores into five equally-sized groups from lowest scores to highest scores.

A summary score[4] of deprivation was created for each DA by taking the average of the quintile scores across all four dimensions. Within the Humber River watershed, there is a total of 1,115 DAs based on 2016 Census boundaries. Data was not available for three DAs for which a summary score of 0 was assigned. Therefore, the summary scores for the Humber River watershed are comprised of the following:

- 5 = Most deprived (very high)
- 4 = High deprivation (high)
- 3 = Medium deprivation (medium)

[4] TRCA would like to acknowledge and thank Dr. Matheson for reviewing this section. During the next phase of development of the prototype tool, TRCA will address Dr. Matheson's recommendation to remove the summary score to avoid conflating the dimensions of deprivation.

- 2 = Low deprivation (low)
- 1 = Least deprived (very low)
- 0 = No data

### 4.2.8 Chronic Diseases

As a proxy of population health status, the rate of adults (aged 20 and older) with two or more chronic conditions (on April 1, 2019) was analyzed and mapped at the aggregate dissemination area (ADA) level by the Ontario Community Health Profiles Partnership (OCHPP) in support of this project.

Chronic disease data, representing the numerator for the rate of individuals with two or more chronic conditions, was derived from validated disease registries maintained by ICES. These include Asthma, Diabetes, Congestive Heart Failure, Hypertension, Chronic Obstructive Pulmonary Disease, Cancer, Rheumatism, and Dementia (OCHPP, 2020). These registries were created using hospital discharge abstracts from the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD) and physician service claims from the Ontario Health Insurance Plan (OHIP) database.

For the denominator, total adult population available from the Ontario Ministry of Health and Long-Term Care's Registered Persons Database (RPDB) was used, representing the population who were alive and living in Ontario on April 1, 2019. OCHPP excluded those with a date of last contact (DOLC) of more than 10 years.

Rates include both sexes (male and female; other and unknown were excluded) and were standardized by age using the 2011 Canada population as the standard population to account for differences in age structures to enable more representative comparisons among ADAs.

ADAs are a new geographic unit created for the 2016 Census and cover the entire country (Statistics Canada, 2016). Each ADA generally encompasses a population of approximately 5,000 to 15,000 people and was determined to be of sufficient scale to disseminate health data while protecting individual privacy. A rigorous approach was adopted by OCHPP to remove or suppress data where re-identification was possible. Data specific to First Nations communities was also removed to align with the First Nations principles of ownership, control, access, and possession (OCAP), which establish how First Nations' data should be collected and used. Thus, the data provided by OCHPP cover all of Ontario, excluding First Nations communities and areas where data is not available for reporting. This resulted in data for 1,531 ADAs out of 1,685 ADAs in Ontario in 2016 (or approximately 91 percent coverage). Within the Humber River watershed, data is available for all 128 ADAs.

In addition to age-standardized rates, OCHPP also calculated the following metrics to enable comparisons across the ADAs assessed:

- **Rate ratios** – the local area (ADA) rate relative to the rate for the aggregate of all ADAs assessed
- **The 95 percent confidence interval of the rate ratios** – the chances are at least 19 out of 20 (or 95 percent) that the local area rate of adults with two or more chronic conditions (on April 1, 2019) is:
    - H = Higher than the rate for the aggregate of all ADAs assessed
    - L = Lower than the rate for the aggregate of all ADAs assessed
    - NS = Not significantly different than the rate for the aggregate of all ADAs assessed

### 4.2.9 Residential Accessibility to Greenspaces

This indicator assesses residential accessibility based on the average linear distance from each "populated" dissemination block (DB) to greenspaces that are at least 1 ha (or 10,000 $m^2$) in size within the watershed. This analysis was conducted by the project team using existing greenspace data available to TRCA, including municipal parks and open spaces, lands owned/operated by TRCA, greenways, walkways, and hydro corridors. Spaces identified as being leased as recreational facility lands or operations/administrative facilities were excluded to focus the analysis on publicly accessible greenspaces as much as possible.

The greenspace size threshold of 1 ha was adopted based on research by Annerstedt van den Bosch and others (2016) who recommend 1 ha as the minimum size to capture a range of greenspace uses across different age groups and their associated benefits.

DBs are smaller than DAs and are the smallest standard geographic unit for which census population and dwelling counts are disseminated across Canada (Statistics Canada, 2017). DBs identified as "not populated" (i.e. population is zero in the 2016 Census) were excluded to help prioritize greenspace deserts based on where people live (i.e. residential access) rather than highways or industrial zones where people do not live or cannot easily access. Within the Humber River watershed, 638 non-populated DBs were excluded out of a total of 4,849 DBs, representing 87 percent coverage.

Accessibility is classified based on 400-m increments (or 5-minute walking distance) as follows:

- High accessibility (H) = 0 to 400 m (or within 5-minute walking distance)
- Medium accessibility (M) = > 400 to 800 m (or within 10-minute walking distance)
- Low accessibility (L) = > 800 to 1200 m (or within 15-minute walking distance)
- Very low accessibility (VL) = > 1200m (or beyond 15-minute walking distance)

### 4.2.10 Exposure to Nature

This indicator assesses the presence/availability of nature (or greenness) at the DB level based on the Normalized Difference Vegetation Index (NDVI) as past research studies have done (e.g. Gascon et al. 2016; Jarvis et al. 2020; Lantz et al. 2021). NDVI is a commonly used index for evaluating vegetation density and health based on the degree of visible and near-infrared sunlight reflected (or absorbed) by plants. In general, the chlorophyll in healthy vegetation absorbs more visible (red) light for photosynthesis, while the cell structure of the leaves reflects more near-infrared light (The Earth Observatory, 2000). Meanwhile, unhealthy or sparsely distributed vegetation reflects more red light and less near-infrared light. NDVI values range from -1 and +1 and in general, high NDVI values represent more dense vegetation; lower positive values represent sparse vegetation (e.g. shrubs and grasslands); and very low NDVI values (0.1 and below) represent dead plants, barren rock, sand, snow, water, or impervious surfaces (Remote Sensing Phenology, 2018; Lantz et al. 2021).

NDVI was derived by the project team for TRCA's jurisdiction for a typical summer day in 2020 (July 2) with minimal cloud cover from Landsat 8 satellite imagery available from USGS' Earth Explorer, using the method delineated by USGS for Landsat 8 (Landsat Missions, n.d.). The output is a raster layer with a resolution of 30 m.

The presence/availability of nature (or level of greenness) is classified by dividing local NDVI values within the Humber River watershed into four equally-sized groups as follows:

- High greenness (H) = 0.372544 to 0.635166
- Medium greenness (M) = 0.272497 to 0.372544
- Low greenness (L) = 0.169324 to 0.272497
- Very low greenness (VL) = -0.165207 to 0.169324

For all 4,849 DBs within the Humber River watershed, the level of exposure was determined based on the majority of NDVI values within each DB. Non-populated DBs were included as part of this indicator in recognition of past research demonstrating the benefits of nature exposure beyond residential settings (e.g. Ulrich, 1984; Gilchrist et al. 2015; Wolf et al. 2020).

### 4.2.11 Habitat Suitability (Fish, Birds, and Amphibians)

Analysis of fish habitat suitability was completed by TRCA in 2019 based on functional trait groups (FTGs) that respond similarly to landscape characteristics (riparian cover, imperviousness, and stream order) in reach contributing areas (RCAs) based on presence-absence records from 2010-2019 in the Toronto region. Four fish FTGs were analyzed including: cold water, continuous-slow flow, warmwater, and strong flow. The functional traits were based on migration, adult substrate preference, thermal tolerance, spawning temperature, stream flow preference, nest guarding, and maximum total length. The habitat suitability analysis then used a Boosted Regression Tree (BRT) analysis to predict the probability of occurrence of each FTG within RCAs using the landscape characteristics (Elith et al. 2008). The fish habitat suitability was summarized by RCAs based on the total number of FTGs that have predicted proportions greater than 70 percent of the total number of species in that FTG (e.g. 3 out of 4 species of the coldwater FTG would be greater than 70 percent).

Analysis of habitat suitability for birds and amphibians was also completed in 2019 based on nine FTGs (5 avian: aerial insectivore, forest canopy, forest insectivore, grassland, ground-nesting; 4 amphibian: arboreal, wetland, woodland, swamp). The avian FTGs were based on key species traits (diet, foraging, nesting, and territoriality) and their association with natural cover and landscape characteristics (landcover types, patch quality, and habitat connectivity) within Toronto region. The amphibian FTGs were grouped by expert opinion due to the lack of sample sizes to complete the statistical analysis for the functional trait analysis. The habitat suitability analysis based on the FTG was derived from the relationship with landscape characteristics to predict species occurrence. To complete the habitat suitability analysis, a Boosted Regression Tree (BRT) analysis (Elith et al.) was used to predict the probability of occurrence of each FTG within 100-m grids based on landscape characteristics. Habitat suitability was summarized by the total number of FTGs within the 100-m grid greater than 70 percent occurrence probability.

### 4.2.12 Landscape Connectivity (Regional and Local)

TRCA conducted a habitat connectivity analysis in 2015 and produced a model for general movement across the landscape for regional and local priority areas of connectivity across the jurisdiction. For this work, the critical pinch points of movement were considered, which represent habitat connections of high importance across the region defined by habitat connections of high importance between habitat patch types using Circuitscape. Circuitscape produces values as cumulative current density, where the highest values are the pinch points. The top 50 percent were characterized using quantile distribution of cumulative current density values as high connectivity importance.

Local connectivity aims to capture the importance of connectivity between habitat types such as forest-forest and forest-wetland patches. For local connectivity of forest-forest patches, a 300-m buffer around each forest patch was considered and adjoining buffers would link the connectivity of nearby patches through a convex hull. For local connectivity of forest-wetland patches, a 300-m buffer around each wetland patch was applied and adjoining forest patches with more than 30 percent overlap within the forest patch to the buffer would be linked together through a convex hull.

### 4.2.13 Aquatic Ecosystem (Groundwater Features)

An **Ecologically Significant Groundwater Recharge Area (ESGRA)** can be defined as an area of land that is responsible for replenishing groundwater systems that directly support sensitive areas like coldwater streams and wetlands (Ministry of Municipal Affairs, 2017). The protection of groundwater-dependent ecologically sensitive areas depends, in part, on understanding where on the landscape the groundwater comes from and taking steps to ensure the recharge function of these areas is protected. ESGRAs are identified using regional-scale modelling that was completed by TRCA in 2019 to predict where groundwater recharge at a given location will emerge or "discharge" within ecologically sensitive areas (TRCA, 2019).

Mapping ESGRAs and protecting the groundwater recharge function they provide helps to ensure the streams and wetlands they are connected to continue to support important ecological functions, including provision of habitat for groundwater-dependent plants and wildlife.

**Significant Surface Water Contribution Areas (SSWCA)** are comprised of areas representing High Volume Significance Groundwater Recharge (HVGRA) that overlap with Ecologically Significant Groundwater Recharge Areas (ESGRA). The HVGRA consists of significant groundwater recharge areas (SGRA) and includes areas within TRCA that are fully serviced by Lake Ontario and meet the following criteria assessed in 2021. The data is derived from the Average Annual Recharge (mm/year) found in Chapter 3 of Toronto and Region Source Protection Authority's (TRSPA) Assessment Report (2022). Specifically, the HVGRA are areas where recharge is greater than 215 mm/year (Tier 3 water budget, 30-year recharge model) and greater than 150 mm/year (from Tier 1 water budget for the Etobicoke watershed which was not included in the Tier 3 model). SSWCAs imply the need to consider groundwater recharge areas including urban areas where these areas should be priority locations for increasing the opportunities for infiltration including implementation of LID/green infrastructure techniques.

### 4.2.14 Biodiversity (Species Richness and Turnover)

A state of biodiversity assessment across the TRCA jurisdiction was completed in 2018 using alpha (species richness) and beta diversity (species turnover) metrics. TRCA's terrestrial monitoring data was used to identify areas with high species richness indicating areas with high alpha diversity for flora, fauna (avian), and vegetation (ELC) communities. Using TRCA species inventory data collected from 2007-2017, species richness was assessed for each 1-km grid cell in the study area. For the purposes of this study, alpha diversity metrics were based on the total number of species of regional concern (TRCA's L-rank L1 to L3) present in each grid cell between 2007-2017.

Species turnover, also known as beta diversity, can be used as a measure to assess change in species diversity across sites. The focus was placed on beta diversity that could be assessed through Local Contribution to Beta Diversity (LCBD; Legendre and De Cáceres, 2013) to calculate the species community composition uniqueness within each grid cell compared to all other grid cells in the jurisdiction. Using the same TRCA dataset as the species richness analysis, beta diversity was analyzed as 1-km grids across the jurisdiction for species of regional concern (TRCA's L-rank L1 to L3) present within each grid. LCBD values determine which cells are significantly different across sites with other cells with species present ($p < 0.05$). This analysis indicated additional areas across the jurisdiction that are composed of rare species assemblages but with lower species richness. These rare species assemblages may be only composed of regional species of conservation concern. Managing these areas demonstrate that beta diversity complements species richness to identify more sites at risk to support biodiversity than with species richness alone.

### 4.2.15 Summary and Evaluation of Individual Indicators

The following table presents a summary of how each indicator was evaluated to determine ecological value or population need.

TABLE 7. SUMMARY OF DATASETS COLLECTED AND ANALYZED

| Themes | Indicators | Evaluation |
|---|---|---|
| **Carbon** | 1. Carbon storage | Based on terrestrial habitat type:<br>Forest = 376.9 metric tons of carbon/ha[5]<br>Successional forest = 355.2 metric tons of carbon/ha[5]<br>Meadow = 105 metric tons of carbon/ha[6]<br>Wetland = 71.3 metric tons of carbon/ha[6]<br>Beach/bluff = 0 metric tons of carbon/ha (no beach/bluff cover is found within the Humber River watershed)<br>Where high carbon storage is taken as ≥ 355.2 metric tons of carbon/ha |
| | 2. Carbon sequestration change | Based on the difference between carbon stored in 2007 and 2013:<br>Gain = Increase in the amount of carbon stored between 2007 and 2013<br>Loss = Decrease in the amount of carbon stored between 2007 and 2013<br>Unchanged = No change in the amount of carbon stored between 2007 and 2013 |
| **Hazard** | 3. Stormwater quantity | Based on total percent imperviousness (TIMP) of a catchment:<br>High: > 25%<br>Medium: 10-25%<br>Low: < 10% |
| | 4. Stormwater quality | Based on the Canadian Water Quality Guideline (CWQG) for total suspended solids[7]:<br>High = < 30 mg/L (high stormwater quality or low TSS concentration)<br>Low = > 30 mg/L (low stormwater quality or high TSS concentration) |
| | | Based on interim Provincial Water Quality Objectives (PWQO) for total phosphorous (TP)[7]: |

[5] Based on Woodrising Consulting Inc. and ArborVitae Environmental Services Ltd., 2010

[6] Based on Wilson, 2008

[7] As referenced in Watershed Planning and Ecosystem Science, 2021

| Themes | Indicators | Evaluation |
|---|---|---|
| | | High = < 0.03 mg/L (high stormwater quality or low TP concentration)<br>Low = > 0.03 mg/L (low stormwater quality or high TP concentration) |
| | 5. Current state of erosion hazard management | Divided by tertile (equal thirds):<br>High = Score 6-62<br>Medium = Score 2-6<br>Low = Score < 2<br>No data = 0 |
| | 6. Ground surface temperature | Divided by tertile (equal thirds):<br>High = 35 to 54˚C<br>Medium = 28 to 34˚C<br>Low = 13 to 27˚C |
| **Community Health** | 7. Dimensions of deprivation | Based on summary score (average):<br>Most deprived (very high) = 5<br>High deprivation (high) = 4<br>Medium deprivation (medium) = 3<br>Low deprivation (low) = 2<br>Least deprived (very low) = 1<br>No data = 0 |
| | 8. Chronic (non-communicable) diseases | Based on 95 percent confidence:<br>High = Higher than the rate for the aggregate of all ADAs assessed<br>Low = Lower than the rate for the aggregate of all ADAs assessed<br>NS = Not significantly different than the rate for the aggregate of all ADAs assessed |
| | 9. Residential accessibility to greenspaces | Based on 400-m increments:<br>High = 0 to 400 m (or within 5-minute walking distance)<br>Medium = > 400 to 800 m (or within 10-minute walking distance)<br>Low = > 800 to 1200 m (or within 15-minute walking distance)<br>Very Low = > 1200m (or beyond 15-minute walking distance) |
| | 10. Exposure to nature | Divided by quartile (equal fourths):<br>High = 0.372544 to 0.635166<br>Medium = 0.272497 to 0.372544<br>Low = 0.169324 to 0.272497<br>Very Low = -0.165207 to 0.169324 |
| **Ecosystem** | 11. Habitat (aquatic and terrestrial) | Based on functional trait groups (FTGs):<br>Aquatic (i.e. fish):<br>High = 3-4 FTGs<br>Medium = 1-2 FTGs<br>Low = < 1 FTG |
| | | Based on functional trait groups (FTGs):<br>Terrestrial (i.e. birds and amphibians):<br>High = 7-9 FTGs<br>Medium = 1-6 FTGs<br>Low = < 1 FTG |
| | | Based on regional connectivity:<br>High = Greater than the median (top 50%): 3508 cumulative current density |

| Themes | Indicators | Evaluation |
|---|---|---|
| | 12. Landscape connectivity (terrestrial) | Based on local connectivity:<br>High = Presence of forest-forest connectivity + presence of forest-wetland connectivity |
| | 13. Aquatic ecosystem | Based on presence of Ecologically Significant Groundwater Recharge Area (ESGRA) |
| | | Based on presence of Significant Surface Water Contribution Area (SSWCA) |
| | 14. Biodiversity | Based on species richness:<br>High = Any 1-km grid site greater than the median (top 50%) for:<br>• Flora: 12-278 species<br>• Fauna (avian): 4-27 species<br>• Vegetation community (ELC): 9-19 communities |
| | | Based on species turnover:<br>High = Any statistically significantly different 1-km grid site ($p < 0.05$) for Local Contribution to Beta Diversity (LCBD) value |

## 4.3 Prioritization by Management Recommendations

Prioritization criteria were developed for each indicator to identify strategic locations for protection, restoration, and enhancement. The following sections provide further details on each of the three management recommendations and how priority locations were determined.

### 4.3.1 Protection

**Protection** is the process of ensuring that natural features and areas that are of higher quality and have high ecosystem functions and services are safeguarded from loss or degradation for current and future generations. Protection is targeted in areas with existing natural cover that are functioning well and have good ecosystem service provision. **Existing natural cover** was delineated through TRCA's Natural Heritage System (NHS) Update in 2021 and includes existing wetlands, fish habitat, woodlands, valleylands, other wildlife habitat (e.g. migratory bird areas), Areas of Natural and Scientific Interest (ANSI), areas of high terrestrial and aquatic ecological function, and municipal NHS. In total, existing natural cover comprise of 24 percent of TRCA's land area.

### 4.3.2 Restoration

**Restoration** is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed to ensure that ecosystem structure, function, and services are maintained over the long term. Restoration is targeted in areas with existing natural cover that have been impaired but have a high potential for improved ecosystem functions and services and ample opportunities to restore natural cover.

Restoration aims to identify areas with the best potential outcomes for restoration efforts, which were generally identified based on the potential natural cover layer developed through TRCA's NHS Update in 2021. **Potential natural cover** identifies areas where natural cover is needed to support ecological functions (e.g. terrestrial habitat suitability and connectivity). It targets areas within unbuilt or open land uses with potential opportunity for restoration projects or initiatives. In total, 12 percent of TRCA's land area was identified as potential natural cover.

### 4.3.3 Enhancement

**Enhancement** is the process of (re)establishing ecosystem functions and services where opportunities for traditional restoration may be limited. Enhancement is targeted in areas outside of existing or potential natural cover where opportunities to restore natural cover are limited but there is space for smaller-scale NBCS for improved ecosystem functions and services.

Areas with the greatest opportunities for enhancement were determined based on available space for tree planting in areas with no existing or potential natural cover (i.e. areas outside TRCA's NHS). This analysis was adapted for the Humber River watershed based on the approach applied as part of the Etobicoke Creek Watershed Plan (ECWP) development. It is intended to support the high-level screening provided by the siting tool, recognizing that tree planting decisions will require further site-level assessments (e.g. soil quality and access to light). This approach also considers only one type of NBCS, but if there is enough space for tree planting, one can infer that there may be sufficient space for other types of NBCS as well (e.g. bioswales, rain gardens, and constructed wetlands).

Plantable space was determined based on the land use and cover type found in the Humber River Hydrology Update – Final Report (2018). Planting rules were developed for each land use category based on the planting rules developed for the ECWP and input from subject matter experts (see Table 8). Areas with existing natural cover were excluded from analysis.

TABLE 8. TREE PLANTING RULES FOR THE HUMBER RIVER WATERSHED

| Land Use | Cover Type | Planting Rules |
|---|---|---|
| **Cemetery** | 35% Impervious + 65% Lawns | 65 trees per ha |
| **Commercial** | 95% Impervious + 5% Lawns | 5 trees per ha |
| **Conservation Lands** | 80% Woods + 20% Meadows | No enhancement |
| **Estate Residential** | 40% Impervious + 60% Lawns | 60 trees per ha |
| **Farm** | Cultivated | No enhancement |
| **Golf Course** | Lawns | No enhancement |
| **Hydro Corridor** | 10% Impervious + 90% Meadows | 25 trees per ha |
| **Industrial** | 95% Impervious + 5% Lawns | 5 trees per ha |
| **Institutional** | 80% Impervious + 20% Lawns | 20 trees per ha |
| **Open Space** | 50% Woods + 50% Meadows | 10 trees per ha |
| **Park** | 10% Impervious + 45% Woods + 45% Meadows | No enhancement |
| **Recreational** | 20% Impervious + 80% Lawns | 10 trees per ha (assuming 40% lawn*) |
| **Residential High** | 80% Impervious + 20% Lawns | 20 trees per ha |
| **Residential LowMed** | 60% Impervious + 40% Lawns | 40 trees per ha |
| **Road (ROW)** | 90% Impervious + 10% Lawns | 5 trees per ha (assuming 5% lawn*) |
| **Rural Residential** | 20% Impervious + 80% Lawns | 80 trees per ha |
| **Transportation** | 60% Impervious + 40% Lawns | No enhancement |
| **Water** | Impervious | No enhancement |

| Land Use | Cover Type | Planting Rules |
|---|---|---|
| **Natural** | 50% Woods + 50% Meadows | No enhancement |

*Adjusted percent lawn cover based on input from subject matter experts

For Community Health indicators, areas with the greatest opportunities for enhancement were also determined based on a 400-m buffer around residential buildings to target areas where people live. Within residential land uses (i.e. Residential LowMed, Residential High, Rural Residential, and Estate Residential), the centre point (or centroid) of buildings from Statistics Canada's building footprint layer was used to delineate the 400-m buffer. 2016 Census population density data was also used for residential accessibility to greenspaces and exposure to nature to account for higher population densities in urban areas where NBCS can offer benefits to more people.

### 4.3.4 Summary of the Prioritization Criteria by Management Recommendation

Table 9 presents the prioritization criteria for each mapping layer using Boolean logic, where:

- AND = All specified conditions must be met
- OR = Any of the specified conditions must be met

Several indicators were paired together including carbon storage and sequestration, and stormwater quantity and quality to ensure that they were prioritized together. A total of 16 individual mapping layers were developed.

TABLE 9. DESCRIPTION OF MANAGEMENT RECOMMENDATIONS AND ASSOCIATED PRIORITIZATION CRITERIA BY THEME AND MAPPING LAYER. MANAGEMENT RECOMMENDATIONS ARE DENOTED BY [P] FOR PROTECTION, [R] FOR RESTORATION, AND [E] FOR ENHANCEMENT

| Themes | Mapping Layer | Description by Management Recommendation | Prioritization Criteria by Management Recommendation |
|---|---|---|---|
| **Carbon** | 1. Carbon storage and carbon sequestration change | **[P]:** Areas with existing natural cover with either high carbon storage in 2013 (≥ 355.2 metric tons of carbon/ha) or an increase in carbon sequestration between 2007 and 2013 are recommended for protection<br>**[R]:** Areas with existing or potential natural cover with a decrease in carbon sequestration between 2007 and 2013 are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available for tree planting with no carbon stored in 2013 and a decrease in carbon sequestration between 2007 and 2013 are recommended for enhancement | **[P]:** [(High carbon storage OR Gain in carbon sequestration) AND (Existing natural cover)]<br>**[R]:** [(Loss in carbon stocks) AND (Existing natural cover OR Potential natural cover[8])]<br>**[E]:** [(No carbon storage) AND (Loss in carbon stocks) OR (Plantable space[9])] |
| **Hazard** | 2. Stormwater quantity and stormwater quality | **[P]:** Areas with existing natural cover, low impervious surface cover (less than 10 percent of total area), and high-quality stormwater runoff characterized by low pollutant concentrations (< 0.03 mg/L of total phosphorous) are recommended for protection<br>**[R]:** Areas with potential natural cover, high impervious cover (greater than 25% of total area) and low-quality stormwater runoff characterized by high pollutant concentrations (> 0.03 mg/L of total phosphorous) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available for tree planting and low-quality stormwater runoff characterized by high pollutant concentrations (> 0.03 mg/L of total phosphorous) are recommended for enhancement | **[P]:** [(Low total impervious area) AND (High stormwater quality (TP[10])) AND (Existing natural cover)]<br>**[R]:** [(High total impervious cover) AND (Low stormwater quality (TP)) AND (Potential natural cover)]<br>**[E]:** [(High total impervious cover) AND (Low stormwater quality (TP)) AND (Plantable space)] |
| | 3. Current state of erosion hazard management | **[P]:** Areas with existing natural cover with a low density of erosion hazard monitoring sites/control structures are recommended for protection<br>**[R]:** Areas with existing or potential natural cover that have a high density of erosion hazard monitoring sites/control structures are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available for tree planting and a high density of erosion hazard monitoring sites/control structures are recommended for enhancement | **[P]:** [(Low density of erosion hazard sites/structures) AND (Existing natural cover)]<br>**[R]:** [(High density of erosion hazard sites/structures) AND (Existing natural cover OR Potential natural cover)]<br>**[E]:** [(High density of erosion hazard sites/structures) AND (Plantable space)] |
| | 4. Ground surface temperature | **[P]:** Areas with existing natural cover that have a low summertime surface temperature (13 to 27˚C) are recommended for protection<br>**[R]:** Areas with existing or potential natural cover that have a high summertime surface temperature (35 to 54˚C) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available for tree planting and a high summertime surface temperature (35 to 54˚C) are recommended for enhancement | **[P]:** [(Low ground surface temperature) AND (Existing natural cover)]<br>**[R]:** [(High ground surface temperature) AND (Existing natural cover OR Potential natural cover)]<br>**[E]:** [(High ground surface temperature) AND (Plantable space)] |
| **Community Health** | 5. Dimensions of deprivation | **[P]:** Areas with existing natural cover near residential buildings where the population is characterized by high or very high levels of deprivation are recommended for protection<br>**[R]:** Areas with potential natural cover near residential buildings where the population is characterized by high or very high levels of deprivation are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that are near residential buildings, have space available for tree planting, and a population characterized by high or very high levels of deprivation are recommended for enhancement | **[P]:** [(Very high OR high deprivation) AND (Existing natural cover) AND (Within 400-m buffer of a residential building)]<br>**[R]:** [(Very high OR high deprivation) AND (Potential natural cover) AND (Within 400-m buffer of a residential building)]<br>**[E]:** [(Very high OR high deprivation) AND (Plantable space) AND (Within 400-m buffer of a residential building)] |
| | 6. Chronic (non-communicable) diseases | **[P]:** Areas with existing natural cover near residential buildings where the adult population has a higher rate of two or more chronic health conditions (relative to the rate for the aggregate of all ADAs) are recommended for protection | **[P]:** [(The rate of adults with 2+ chronic conditions is higher than the rate for the aggregate of all ADAs (95 CI)) AND |

[8] **Potential natural cover** refers to unbuilt areas or open land uses with higher contributions to natural heritage system functions, which have been delineated through TRCA's Natural Heritage System (NHS) Update. For further information, please see section 4.3.2 in the full report.

[9] **Plantable space** refers to areas where trees can theoretically be planted based on land use and cover type. For further information, please see section 4.3.3 in the full report.

[10] TSS was excluded as most of the watershed was identified with high potential TSS concentration based on the Canadian Water Quality Guideline (CWQG) of 30 mg/L (Watershed Planning and Ecosystem Science, 2021).

| Themes | Mapping Layer | Description by Management Recommendation | Prioritization Criteria by Management Recommendation |
|---|---|---|---|
| | | **[R]:** Areas with potential natural cover near residential buildings where the adult population has a higher rate of two or more chronic health conditions (relative to the rate for the aggregate of all ADAs) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that are near residential buildings, have space available for tree planting, and an adult population characterized by a higher rate of two or more chronic health conditions (relative to the rate for the aggregate of all ADAs) are recommended for enhancement | (Existing natural cover) AND (Within 400-m buffer of a residential building[11])]<br>**[R]:** [(The rate of adults with 2+ chronic conditions is higher than the rate for the aggregate of all ADAs (95 CI)) AND (Potential natural cover) AND (Within 400-m buffer of a residential building)]<br>**[E]:** [(The rate of adults with 2+ chronic conditions is higher than the rate for the aggregate of all ADAs (95 CI)) AND (Plantable space) AND (Within 400-m buffer of a residential building)] |
| | 7. Residential accessibility to greenspaces | **[P]:** Areas with existing natural cover near residential buildings in neighbourhoods with high or medium population density (> 41 people/ha) that have medium or high access to greenspace (within a 5-minute walk or 10-minute walk, respectively) are recommended for protection<br>**[R]:** Areas with potential natural cover near residential buildings in neighbourhoods with high or medium population density (> 41 people/ha), that have low or very low access to greenspace (within a 15-minute walk or beyond a 15-minute walk, respectively) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that are near residential buildings in neighbourhoods with high or medium population density (> 41 people/ha), low or very low access to greenspace (within a 15-minute walk or beyond a 15-minute walk, respectively), and space available for tree planting are recommended for enhancement | **[P]:** [(High OR medium residential accessibility to greenspace) AND (Existing natural cover) AND (High OR medium population density) AND (Within 400-m buffer of a residential building)]<br>**[R]:** [(Very low OR low residential accessibility to greenspace) AND (Potential natural cover) AND (High OR medium population density) AND (Within 400-m buffer of a residential building)]<br>**[E]:** [(Very low OR low residential accessibility to greenspace) AND (Plantable space) AND (High OR medium population density) AND (Within 400-m buffer of a residential building)] |
| | 8. Exposure to nature | **[P]:** Areas with existing natural cover near residential buildings in neighbourhoods with high or medium population density (> 41 people/ha) that have high or medium levels of greenness (i.e. density of healthy vegetation) are recommended for protection<br>**[R]:** Areas with potential natural cover near residential buildings in neighbourhoods with high or medium population density (> 41 people/ha) that have low or very low levels of greenness (i.e. density of healthy vegetation) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that are near residential buildings in neighbourhoods with high or medium population density (> 41 people/ha), low or very low levels of greenness (i.e. density of healthy vegetation), and space available for tree planting are recommended for enhancement | **[P]:** [(High OR medium greenness exposure) AND (Existing natural cover) AND (High OR medium population density) AND (Within 400-m buffer of a residential building)]<br>**[R]:** [(Very low OR low greenness exposure) AND (Potential natural cover) AND (High OR medium population density) AND (Within 400-m buffer of a residential building)]<br>**[E]:** [(Very low OR low greenness exposure) AND (Plantable space) AND (High OR medium population density) AND (Within 400-m buffer of a residential building)] |
| Ecosystem | 9. Habitat suitability – Fish | **[P]:** Areas with existing natural cover and high or moderate habitat suitability for fish (predicted presence of a minimum of 1 functional trait group) are recommended for protection<br>**[R]:** Areas with potential natural cover and high or moderate habitat suitability for fish (predicted presence of a minimum of 1 functional trait group) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available to plant trees and high or moderate habitat suitability for fish (predicted presence of a minimum of 1 functional trait group) are recommended for enhancement | **[P]:** [(High OR moderate habitat suitability) AND (Existing natural cover)]<br>**[R]:** [(High OR moderate habitat suitability) AND (Potential natural cover)]<br>**[E]:** [(High OR moderate habitat suitability) AND (Plantable space)] |
| | 10. Habitat suitability – Birds and Amphibians | **[P]:** Areas with existing natural cover and high or moderate habitat suitability for birds and amphibians (predicted presence of a minimum of 1 functional trait group) are recommended for protection<br>**[R]:** Areas with potential natural cover and high or moderate habitat suitability for birds and amphibians (predicted presence of a minimum of 1 functional trait group) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available to plant trees and high or moderate habitat suitability for birds and amphibians (predicted presence of a | **[P]:** [(High OR moderate habitat suitability) AND (Existing natural cover)]<br>**[R]:** [(High OR moderate habitat suitability) AND (Potential natural cover)]<br>**[E]:** [(High OR moderate habitat suitability) AND (Plantable space)] |

[11] As one reviewer has noted, the rate of adults with 2+ chronic conditions is assessed at a larger geographical scale and should not be extrapolated to the residential buffers used for prioritization. The purpose of the prioritization criteria is to identify where people with health needs might benefit from the protection, enhancement, or restoration measures. The 400-m residential buffer identifies where the population is distributed within each ADA, and the prioritization results should be seen as areas within the larger geographic unit of analysis (i.e., ADAs) where the population is concentrated and might benefit from the proposed measures.

| Themes | Mapping Layer | Description by Management Recommendation | Prioritization Criteria by Management Recommendation |
|---|---|---|---|
| | | minimum of 1 functional trait group) are recommended for enhancement | |
| | 11. Landscape connectivity – Regional | **[P]:** Areas with existing natural cover and high regional connectivity (reflecting critical 'pinch points' for wildlife movement) are recommended for protection<br>**[R]:** Areas with potential natural cover and high regional connectivity (reflecting critical 'pinch points' for wildlife movement) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available to plant trees and high regional connectivity (reflecting critical 'pinch points' for wildlife movement) are recommended for enhancement | **[P]:** [(High regional connectivity) AND (Existing natural cover)]<br>**[R]:** [(High regional connectivity) AND (Potential natural cover)]<br>**[E]:** [(High regional connectivity) AND (Plantable space)] |
| | 12. Landscape connectivity – Local | **[P]:** Areas with existing natural cover and high local connectivity (reflecting overlap between adjacent habitat patches) are recommended for protection<br>**[R]:** Areas with potential natural cover and high local connectivity (reflecting overlap between adjacent habitat patches) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space available to plant trees and high local connectivity (reflecting overlap between adjacent habitat patches) are recommended for enhancement | **[P]:** [(High local connectivity) AND (Existing natural cover)]<br>**[R]:** [(High local connectivity) AND (Potential natural cover)]<br>**[E]:** [(High local connectivity) AND (Plantable space)] |
| | 13. Aquatic ecosystem – ESGRA | **[P]:** Areas with existing natural cover and the presence of Ecologically Significant Groundwater Recharge Area (ESGRA) are recommended for protection<br>**[R]:** Areas with potential natural cover and the presence of ESGRA are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space for tree planting and the presence of ESGRA are recommended for enhancement | **[P]:** [(ESGRA) AND (Existing natural cover)]<br>**[R]:** [(ESGRA) AND (Potential natural cover)]<br>**[E]:** [(ESGRA) AND (Plantable space)] |
| | 14. Aquatic ecosystem – SSWCA | **[P]:** Areas with existing natural cover and the presence of Significant Surface Water Contribution Area (SSWCA) are recommended for protection<br>**[R]:** Areas with potential natural cover and the presence of SSWCA are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space for tree planting and the presence of SSWCA are recommended for enhancement | **[P]:** [(SSWCA) AND (Existing natural cover)]<br>**[R]:** [(SSWCA) AND (Potential natural cover)]<br>**[E]:** [(SSWCA) AND (Plantable space)] |
| | 15. Biodiversity – Species richness (alpha diversity) | **[P]:** Areas with existing natural cover and high alpha diversity (flora, fauna, and vegetation community species richness greater than the median value measured for each site) are recommended for protection<br>**[R]:** Areas with potential natural cover and high alpha diversity (flora, fauna, and vegetation community species richness greater than the median value measured for each site) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space for tree planting and are characterized by high alpha diversity (flora, fauna, and vegetation community species richness greater than the median value measured for each site) are recommended for enhancement | **[P]:** [(High species richness) AND [(Existing natural cover)]<br>**[R]:** [(High species richness) AND (Potential natural cover)]<br>**[E]:** [(High species richness) AND (Plantable space)] |
| | 16. Biodiversity – Species turnover (beta diversity) | **[P]:** Areas with existing natural cover and high beta diversity (species turnover for species of regional concern) are recommended for protection<br>**[R]:** Areas with potential natural cover and high beta diversity (species turnover for species of regional concern) are recommended for restoration<br>**[E]:** Areas with no existing or potential natural cover that have space for tree planting and high beta diversity (species turnover for species of regional concern) are recommended for enhancement | **[P]:** [(Significant species turnover) AND (Existing natural cover)]<br>**[R]:** [(Significant species turnover) AND (Potential natural cover)]<br>**[E]:** [(Significant species turnover) AND (Plantable space)] |

### 4.3.5 Multiple Hits Analysis

A Multiple Hits Analysis (MHA) was completed to summarize the prioritization of areas for protection, restoration, and enhancement. The MHA was assessed for each individual theme (Carbon, Hazard, Community Health, and Ecosystem), as well as the overall priorities by combining all themes. For each individual theme, priorities for protection, restoration, and enhancement were delineated and mapped based on their respective criteria (see Table 9). The mapped priorities were then converted into 100-m grids and scored from 1 for priority and 0 for no priority in a grid cell. The total score for each theme formed the total number of criteria for each protection, restoration, and enhancement priority. In summary, the Carbon theme has a total possible score of 1, the Hazard theme has a total possible score of 3, the Community Health theme has a total possible score of 4, and the Ecosystem theme has a total possible score of 9.

Given the different number of criteria in each thematic area, an equal weighted sum for each management recommendation layer (protect, restore, enhance) with the MHA was used to ensure that there was an overall equal representation of each theme. The final score of the three overall management recommendation layers was scaled to a score of 0 to 1, with 1 as the highest priority areas (see Figure 3).

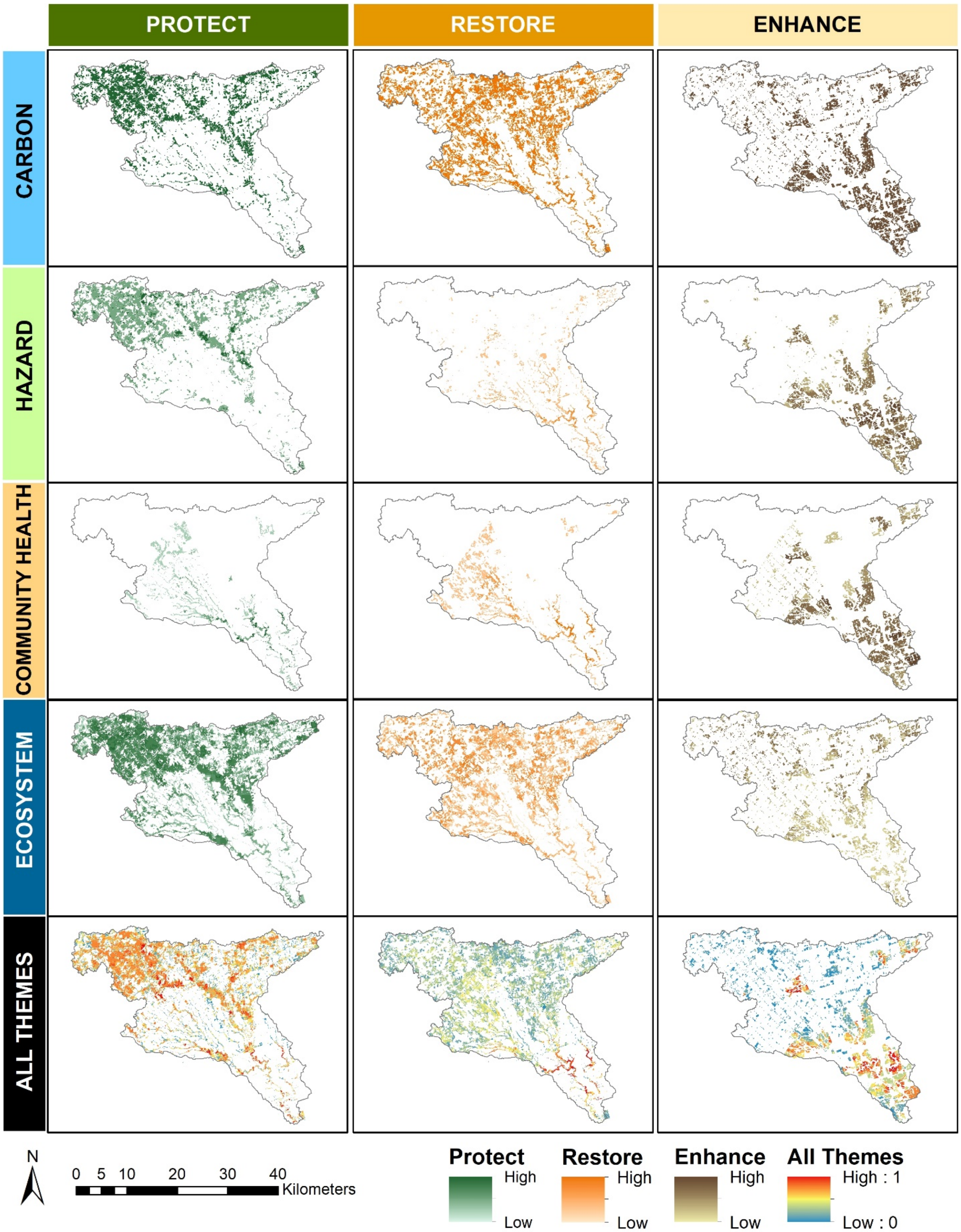


**FIGURE 3. PRIORITIZATION RESULTS (PROTECT, RESTORE, ENHANCE, ALL THEMES) FOR CARBON, HAZARD, COMMUNITY HEALTH, AND ECOSYSTEM**

## 4.4 Creation of the Online Visualization Tool

An online visualization tool was created using ArcGIS Experience Builder to enable users to view and interact with the prioritization results. The web app was created by staff in TRCA's Business Intelligence and Data Analytics (BIDA) team and was designed with a simple and modern interface for an intuitive and user-friendly experience. The interface is centred on the mapping to enable a content-focused web experience. The prioritization results are listed on the left for ease of navigation and are organized as follows (see Figure 4):

- **Management Recommendations** (All Themes) – allows users to view priorities summarized by protection, restoration, and enhancement based on the combination of all themes
- **Carbon Priorities** – presents the protection, restoration, and enhancement prioritization results for the Carbon theme
- **Carbon Indicators** – allows users to further explore the single Carbon indicator that informed the Carbon Priorities
- **Hazard Priorities** – presents the protection, restoration, and enhancement prioritization results for the Hazard theme
- **Hazard Indicators** – allows users to further explore the 3 individual Hazard indicators that informed the Hazard Priorities
- **Community Health Priorities** – presents the protection, restoration, and enhancement prioritization results for the Community Health theme
- **Community Health Indicators** – allows users to further explore the 4 individual Community Health indicators that informed the Community Health Priorities
- **Ecosystem Priorities** – presents the protection, restoration, and enhancement prioritization results for the Ecosystem theme
- **Ecosystem Indicators** – allows users to further explore the 9 individual Ecosystem indicators that informed the Ecosystem Priorities

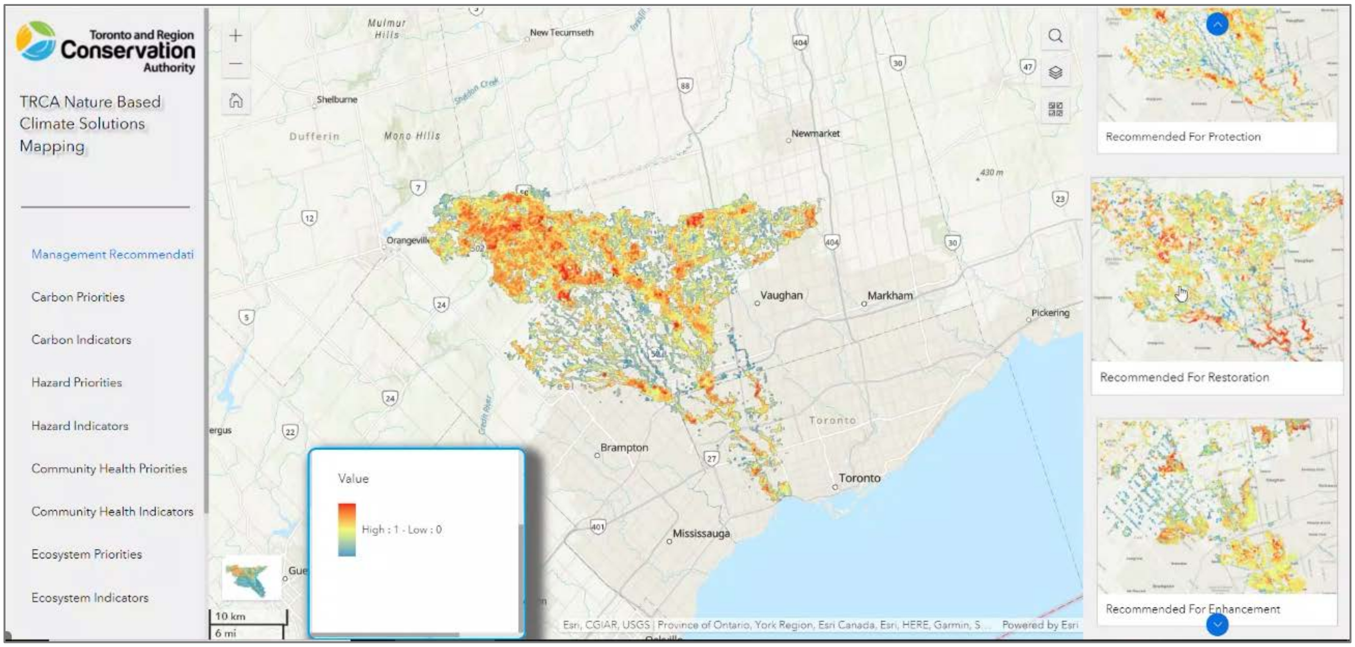


**FIGURE 4. SCREENSHOT OF DRAFT VERSION OF THE ONLINE NATURE-BASED CLIMATE SOLUTIONS (NBCS) SITING TOOL**

The online visualization tool also allows users to toggle on and off different layers if they would like to view an overlay of different layers together. A variety of basemaps are available to support further exploration of the mapping data.

## 4.5 Rapid Comparison with Existing TRCA Prioritization and Screening Tools

A rapid, visual comparison of the prioritization results (i.e. protection, restoration, and enhancement) was conducted by the project team with two existing TRCA prioritization and screening tools, for the purpose of validating, in a qualitative manner, the outputs of this project. The tools compared included the Integrated Restoration Prioritization (IRP) Tool and Sustainable Neighbourhood Action Plan (SNAP) Toronto Neighbourhood Screening Process.

IRP was developed by the Restoration and Resource Management (RRM) team with internal and external partners in 2015 to identify priority restoration opportunities based on ecological impairments (which negatively impact natural processes) and ecosystem function (TRCA, 2015). A simple overlay analysis indicated a moderate amount of overlap in the designation of comparable priorities. Where divergence between priorities was present, it could be fully explained by key differences in the design and intended application of these tools. Notably, the NBCS Siting Tool operates at a finer resolution using 1-ha grids, whereas IRP assigns priorities to 30-ha catchments; this explains why IRP recommends a greater total land area for restoration. In addition, these tools utilize different datasets to inform the selection of priorities for restoration. For example, the NBCS Siting Tool mainly relies on TRCA's potential natural cover spatial data layer, which was not available when IRP was developed. Meanwhile, IRP focuses on areas with low natural cover and high ecological impairments (e.g. in-stream barriers, and altered hydrology). Finally, the NBCS Siting Tool also incorporates decision criteria not considered by IRP, notably carbon and community health, which drive the selection of additional areas for protection, restoration, and enhancement. Overall, these tools appear to be highly complementary and any discrepancies between the priorities generated can be explained by the items noted above.

The SNAP Toronto Neighbourhood Screening Process was developed in 2019 by TRCA and partners to guide the selection of candidate SNAP neighbourhoods that would benefit from targeted urban renewal and climate resilience initiatives. Two aspects of SNAP's screening results were compared with the NBCS Siting Tool priorities, including the overall neighbourhood priority scores and a specific subcomponent result focused on Low Impact Development (LID) retrofit opportunities. The overlay analysis found that areas recommended for enhancement by the NBCS Siting Tool captured neighbourhoods with the highest priority identified by SNAP's screening process. There was also a high degree of overlap between the NBCS Siting Tool's enhancement priorities and the LID retrofit priorities identified by the neighbourhood screening process.

# 5. DISCUSSION AND FUTURE DIRECTIONS

This section discusses limitations of the siting tool, considerations regarding scalability and replicability, and possible future directions to further enhance the siting tool and continue to address NBCS knowledge and implementation gaps.

## 5.1 Limitations

- **Carbon storage** modelling is based on an assumed constant rate of carbon storage (tons of carbon/ha) across each natural cover type, whereas in reality this depends on many factors such as local biophysical conditions, the age of the ecosystem, and soil health (The Natural Capital Project, n.d.).
- **Carbon sequestration** modelling is based on an assumed linear change in carbon sequestration over time, while most sequestration follows a nonlinear path (The Natural Capital Project, n.d.).
- **Stormwater quantity** is based on percent impervious cover and does not consider soil type, which can affect the level of infiltration and runoff. TIMP and XIMP values were assigned based on the best available land use mapping at the time of the Humber Hydrology Update – Final Report (2018) based on municipal Official Plans. Land use mapping may be developed and updated at different times and maintained differently across municipalities. The current method does not calculate the volume and rate of stormwater runoff. Existing stormwater reduction measures such as stormwater ponds and other Low Impact Development are also not considered.
- **Stormwater quality** does not consider existing stormwater quality improvement measures such as stormwater ponds and other Low Impact Development. TIMP and XIMP values were assigned based on the best available land use mapping at the time of the Humber Hydrology Update – Final Report (2018) based on municipal Official Plans. Land use mapping may be developed and updated at different times and maintained differently across municipalities. The current method does not calculate TSS and TP loads (in mg) due to lack of information about the volume of stormwater runoff.
- **Current state of erosion hazard management** reflects TRCA's erosion hazard monitoring activities. While these activities focus on areas affected by current and/or past erosion hazards, they are also

driven by available program funding and, in some cases, voluntary enrolment/requests. Therefore, areas with no activity do not necessarily represent areas of no erosion risk. As further risk assessments are conducted by TRCA's Erosion Risk Management team, improved erosion risk data (e.g. erosion rates of change, etc.) will become available. Future improvements to the kernel density analyses could involve assigning the weighted scores (Table 5) to more specific areas such as ERM's screening layer (slope crest) and TRCA's regulation mapping (crest of slope).

- **Ground surface temperature** is only a proxy measure of the urban heat island effect and does not include other contributing variables such as air temperature and humidity. It also does not include existing cooling measures such as presence of air conditioning, tree cover, and other shade structures. The data used for this indicator are due to be updated within the next few years; however, they are still generally reflective of the built and natural environment within the watershed.
- **Dimensions of deprivation** is based on demographic and other available census data, which represent a snapshot in time. While the index used for this indicator considers multiple dimensions of deprivation, there may be other factors at the individual level that are not considered by the index (e.g. food security, access to care, and barriers to transportation and mobility). The index also does not consider existing community/individual strengths or adaptability (e.g. social cohesion, attitudes, values, and skills). Additionally, as noted in section 4.2.7, TRCA would like to acknowledge and thank Dr. Matheson for the recommendation to remove the summary score to avoid conflating the different dimensions of deprivation. The project team plans to incorporate these changes in the next phase of the siting tool's development.
- **Chronic diseases** is one measure of population health status. In disseminating health data, a fine balance had to be struck between the granularity of analysis (to be useful for the siting tool) and health data privacy. As a result, a sex-based analysis was not advised, and so the rates of individuals with two or more chronic conditions encompass both sexes. Additionally, as noted in section 4.2.15, the rate of adults with two or more chronic conditions is assessed at a larger geographical scale and should not be extrapolated to the residential buffers used for prioritization. The 400-m residential buffer identifies where the population is distributed within each ADA, and the prioritization results should be seen as areas within the larger geographic unit of analysis (i.e., ADAs) where the population is concentrated and might benefit from the proposed measures.

  While the natural environment is recognized as a social determinant of health, the inclusion of this indicator does not imply any form of causation. Additionally, it is important to note that research has at times found positive, negative, and no associations between nature and chronic conditions such as cardiovascular health, diabetes, and asthma (e.g. Wolf et al. 2020). The strength of evidence also varies by chronic condition. Hence, focusing on the prevalence and rate of two or more chronic conditions may mask differences between chronic conditions and opportunities to address them (e.g. planting species that emit less pollen in areas with high asthma rates).
- **Residential accessibility to greenspaces** is based on a linear (Euclidean) distance to greenspace and does not consider the routes and access points available that people can take, which likely overestimates accessibility (Annerstedt van den Bosch et al. 2016; Jarvis et al. 2020). This indicator also

measures one aspect of accessibility (i.e. geography) and does not consider other aspects such as cost, safety, and connectivity. Additionally, this indicator does not measure the actual uses of greenspaces, population pressures (e.g. Mears and Brindley, 2019), and people's willingness to travel to visit greenspaces.

- **Exposure to nature** is based on satellite imagery, representing a snapshot in time. NDVI values can also vary depending on the type of satellite images used, the season, study area, atmospheric effects, soil type, and humidity (Lantz et al. 2021). This indicator measures greenness (i.e. density of healthy vegetation) and does not consider benefits associated with exposure to blue infrastructure (e.g. lakes and ponds).
- **Habitat suitability** is modelled based on land cover variables and the mapping produced is based on the likelihood of the presence of functional trait groups. As this is a high-level representation of suitability, on-the-ground conditions (beyond natural cover) are not captured in these models which may impact the suitability of certain functional trait groups. For example, trail networks and understory vegetation may affect habitat suitability differently when comparing equivalent suitable patches based on this analysis.
- **Landscape connectivity** is modelled as part of a jurisdiction-wide analysis at a coarse resolution and represents important corridors of movement across TRCA's jurisdiction. It does not reflect actual crossings at a certain point but will help identify areas where mitigation measures should be maintained to ensure that connectivity can persist.
- **Aquatic ecosystem** criteria are focused on important groundwater features. Other indicators such as land use within reach contributing areas that could impact aquatic ecosystems based on surface water are not considered. The influence of surface water was indirectly captured through the habitat suitability analysis of fish functional trait groups and stormwater quality and quantity.
- **Biodiversity** is based on the species inventory collected within the recent decade. The time period is relevant to the impact of the current landscape on the state of biodiversity. Assessing more historical biodiversity data could be beneficial to identify areas where current land cover and climate change may have impacted biodiversity by comparing the historic state of biodiversity with the current state.

## 5.2 Scalability and Replicability

- **Scalability:** Throughout the development of the siting tool, consideration was given to the watershed's mix of urban, suburban, and rural communities to support future opportunities to scale the tool to other jurisdictions – particularly jurisdictions that are experiencing urbanization pressures similar to the Humber River watershed. The prioritization criteria have been developed to balance the prioritization of rural areas where there may be space for protection, restoration, and enhancement measures, and urban areas where space may be more limited but there is a high concentration of people who may benefit from such measures.

- **Replicability:** The siting tool has been developed on a watershed basis to enable replication or adaptation of the tool for other watersheds across Canada. The indicator-based approach enables the substitution of different datasets where available. While this siting tool leveraged many existing TRCA geospatial datasets, it also incorporated publicly available data such as data from Statistics Canada and Landsat. Other sources of geospatial data that provide broader geographic coverage have also been identified to support the scalability and replicability of the siting tool as listed in the Appendix.

## 5.3 Future Research and Enhancements

In the short term, opportunities to refine and expand the tool include:

- Making the recommended changes to the dimensions of deprivation layer by replacing the summary score with the four dimensions of deprivation as noted in section 4.2.7
- Refining the accessibility and functionality of the online visualization tool (e.g. enabling users to add their own data layers)
- Seeking feedback from additional subject matter experts and potential tool users via interactive workshops
- Further validating the siting tool and the prioritization results using quantitative comparative analyses with existing prioritization tools and processes and stakeholder engagement to confirm priorities
- Expanding the siting tool to include all watersheds within TRCA's jurisdiction to directly inform watershed planning and other TRCA programming
- Working with CWS to disseminate the siting tool and transfer knowledge to interested researchers and practitioners
- Exploring the application of user-defined weights or rankings to the themes/indicators such that management recommendations can be tailored to each user's objectives or the shared objectives of the residents of a community
- Developing an adaptable template or shell with clear instructions for replication to support widespread uptake outside of TRCA's jurisdiction
- Working with partners to map asthma and diabetes as separate layers to further understand community health needs and inform the identification of appropriate protection, restoration, and enhancement measures
- Incorporating directly connected impervious cover (XIMP) into the prioritization process

In the medium and longer term, opportunities for further research and improvements include:

- Identifying protection, restoration, and enhancement priorities focused on reducing flood risk, including riverine and urban flooding

- Seeking and incorporating available data and information on air quality (e.g. ozone, and fine particulate matter)
- Incorporating other measures of community health and well-being (e.g. obesity, physical activity, heat-related morbidity and mortality, self-reported mental health status, health-adjusted life expectancy, crime)
- Seeking and incorporating available data and information on the quality and uses of greenspace (e.g. trail use, park visits, ParkSeek)
- Exploring the possibility of integrating existing walkability/other mobility indices (e.g. Creatore et al. 2016; Mukhtar et al. 2019)
- Integrating the consideration of future conditions/scenarios (e.g. climate change, population change, and downscaled Shared Socioeconomic Pathways [SSPs][12])

[12] SSPs were incorporated into the IPCC's Sixth Assessment (AR6) Report (2021). Five SSPs have been developed to illustrate possible future socio-economic trends that may present varying challenges for climate change mitigation and adaptation by the end of the century. SSPs were combined with representative concentration pathways (RCPs) to form five illustrative emissions scenarios in the IPCC's AR6 Report.

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## APPENDIX

| Themes | Indicators | Data Layer | Geographic Coverage | Data Type | Source | Other Sources of Geospatial Data (where available[13]) |
|---|---|---|---|---|---|---|
| **Carbon** | 1. Carbon storage | Modelled amount of carbon stored and sequestered by terrestrial natural habitats in 2013 | TRCA | Raster (200 m) | Existing TRCA dataset | - Carbon storage and distribution in terrestrial ecosystems of Canada (Sothe et al. 2021; national) |
| | 2. Carbon sequestration change | Net change in the modelled amount of carbon sequestered by terrestrial natural habitats between 2007 and 2013 | | | | n/a |
| **Hazard** | 3. Stormwater quantity | Area of total percent impervious cover (TIMP) based on assigned land use/cover type | Humber River watershed | Vector (land use) | TRCA analysis completed for this project | - Southern Ontario Land Resource Information System (SOLRIS; southern Ontario) |
| | | Area of directly connected percent impervious cover (XIMP) based on assigned land use/cover type[14] | | | | n/a |
| | 4. Stormwater quality | Concentration of total phosphorous (TP) based on land cover Event Mean Concentrations (EMCs) assigned by land use/cover type, roof area, and wetland area | Humber River watershed | Vector (land use) | TRCA analysis completed for this project | - Southern Ontario Land Resource Information System (SOLRIS; southern Ontario) |
| | | Concentration of total suspended solids (TSS) based on land cover EMCs assigned by land use/cover type, roof area, and wetland area | | | | |
| | 5. Current state of erosion hazard management | Kernel density of current TRCA erosion hazard monitoring sites/control structures | Humber River watershed | Raster (50 m) | TRCA analysis completed for this project | n/a |
| | 6. Ground surface temperature | Ground surface temperature derived from satellite imagery for a typical summer day in June 2014 | TRCA | Raster (100 m) | Existing TRCA dataset | - Landsat (international)<br>- MODIS (international)<br>- ECOSTRESS (international) |
| **Community Health** | 7. Dimensions of deprivation | Average score[4] of four dimensions of deprivation for each dissemination area (DA) based on the Ontario version of the Canadian Index of Multiple Deprivation (CIMD) | Humber River watershed | Vector (DA) | TRCA analysis completed for this project | - CIMD (national, provincial/regional)<br>- Material and Social Deprivation Index (national)<br>- Ontario Marginalization Index (provincial) |
| | 8. Chronic (non-communicable) diseases | The 95 percent confidence interval of the rate of adults with two or more chronic conditions relative to the rate for the aggregate of all aggregate dissemination areas (ADAs) assessed | Ontario[15] | Vector (ADA) | OCHPP analysis completed for this project | - Canadian Community Health Survey (CCHS) – Annual Component (national) |
| | 9. Residential accessibility to greenspaces | Average linear distance from each populated dissemination block (DB) to greenspaces that are at least 1 ha (or 10,000 m$^2$) in size | TRCA | Vector (DB) | TRCA analysis completed for this project | - Municipal Park (provincial) |
| | 10. Exposure to nature | Majority of NDVI values (derived from satellite imagery) within each dissemination block (DB) | | Raster (DB) | | - Landsat (international)<br>- MODIS (international)<br>- CANUE Greenness datasets (national) |
| **Ecosystem** | 11. Habitat suitability (fish, birds, and amphibians) | Fish habitat suitability of functional trait groups (FTGs) across the landscape using spatial and statistical modelling with existing data layers | TRCA | Raster (100 m) | Existing TRCA dataset | - NatureServe Canada's Ecosystem-based automated range maps (EBAR; national) |
| | | Avian and amphibian habitat suitability of functional trait groups (FTGs) across the | | | | |

[13] To the project team's knowledge, other sources of geospatial data that provide broader geographic coverage have been identified to support the scalability and replicability of the siting tool

[14] XIMP cover was calculated but was not carried forward in the prioritization process. For further information, please see section 4.2.3

[15] Except First Nations communities and areas where data is not available for reporting. For further information, please see section 4.2.8

| Themes | Indicators | Data Layer | Geographic Coverage | Data Type | Source | Other Sources of Geospatial Data (where available[13]) |
|---|---|---|---|---|---|---|
| | | landscape using spatial and statistical modelling with existing data layers | | | | |
| | 12. Landscape connectivity (regional, and local) | Regional connectivity priorities for habitat connectivity were identified and modelled using Circuitscape | TRCA | Raster (100 m) | Existing TRCA dataset | - Pelletier et al. 2017 (national) |
| | | Local connectivity of forest-forest and forest-wetland habitat patches that provide local linkages for species movement across these patches | TRCA | Vector | Existing TRCA dataset | n/a |
| | 13. Aquatic ecosystem (groundwater features) | ESGRA and SSWCA identified through modelling representing important areas relating to groundwater | TRCA | Vector | Existing TRCA dataset | - Groundwater Information Network (GIN) (national) |
| | 14. Biodiversity (species richness and turnover) | TRCA's field collected regional inventory data on avian species, plant species, and vegetation community types was used to calculate alpha and beta diversity between 2007-2017 | TRCA | Vector (1-km grid) | Existing TRCA dataset | - Provincially tracked species (1km grid; provincial)<br>- Ontario Breeding Bird Atlas (provincial) |
| Prioritization | 15. Existing natural cover | Includes existing wetlands, fish habitat, woodlands, valleylands, other wildlife habitat (e.g. migratory bird areas), Areas of Natural and Scientific Interest (ANSI), areas of high terrestrial and aquatic ecological function, and municipal NHS | TRCA | Vector | Existing TRCA dataset | - Natural Heritage System Area (provincial)<br>- Natural Heritage Information Centre's natural areas database (provincial) |
| | 16. Potential natural cover | Areas where natural cover is needed to support ecological functions (e.g. terrestrial habitat suitability and connectivity) | TRCA | Vector | Existing TRCA dataset | n/a |
| | 17. Plantable space | Areas where trees can theoretically be planted based on land use and cover type | TRCA | Vector | TRCA analysis completed for this project | - Southern Ontario Land Resource Information System (SOLRIS; southern Ontario) |
| | 18. 400-m residential building buffer | 400-m buffer from the centre point (or centroid) of buildings within residential land uses (i.e. Residential LowMed, Residential High, Rural Residential, and Estate Residential) | Humber River watershed | Vector | TRCA analysis completed for this project | - Statistics Canada's Open Database of Buildings (ODB) (national) |
| | 19. Population density | Areas with high or medium population density (> 41 people/ha) | Humber River watershed | Vector | TRCA analysis completed for this project | - Statistics Canada's 2016 Census data products (national) |

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