Attachment 1:
NHS Update Summary Report 2022

TRCA Updated Target Natural Heritage System: A Summary Report

Prepared By:
Watershed Planning and Ecosystem Science
Development and Engineering Services
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Region of Peel
City of Toronto
York Region
Durham Region
University of Toronto
Mitacs Inc.

Report Prepared by
Namrata Shrestha, Senior Manager, Watershed Planning and Reporting
Andrew Chin, Research Analyst, Ecosystem and Climate Science

Project Team
Alberta D'Souza, Technologist, GIS, Technologist, Business Intelligence and Data Analytics
Andrew Chin, Research Analyst, Ecosystem and Climate Science
Jonathan Ruppert, Senior Research Scientist, Ecosystem and Climate Science
Lyndsay Cartwright, Senior Research Analyst, Ecosystem and Climate Science
Namrata Shrestha, Senior Manager, Watershed Planning and Reporting
Steven Ling, Technologist, GIS, Business Intelligence and Data Analytics

Technical Advisory Committee
Andrew Ramesbottom, Senior Project Manager, Restoration Projects
Brad Stephens, Senior Manager, Planning Ecology
Jason Tam, Manager, Business Intelligence and Data Analytics
John Stille, Senior Manager, Restoration Projects
Karen MacDonald, Senior Manager, Ecosystem Management
Laura Del Giudice, Associate Director, Watershed Planning and Ecosystem Science
Mary-Ann Burns, Senior Manager, Provincial and Regional Policy
Noah Gaetz, Senior Manager, Ecosystem and Climate Science
Sue Hayes, Senior Manager, Terrestrial Inventory and Monitoring

Subject Matter Experts
Don Ford, Senior Manager, Hydrogeology
Gavin Miller, Flora Biologist, Terrestrial Inventory and Monitoring
Paul Prior, Fauna Biologist, Terrestrial Inventory and Monitoring
Tracy Timmins, Research Analyst, Ecosystem and Climate Science

Research Partner
Marie-Josee Fortin, Professor, Ecology and Evolutionary Biology, University of Toronto

EXECUTIVE SUMMARY

What is a Natural Heritage System (NHS)?

The impacts of urbanization and land conversion to urban uses have resulted in biodiversity habitat loss, fragmentation, and degradation that have affected ecosystem functions. Recognizing these impacts and the need to protect existing natural features/areas, as well as to restore potential ecologically functioning areas, the concept of an NHS was incorporated into the Provincial Policy Statement (PPS) in 1994. According to the PPS (2020), an NHS is:

> *"a system made up of natural heritage features and areas and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue".*

TRCA's updated regional target NHS (2022): An Overview

TRCA developed a regional strategy using a systems approach in 2007, referred to as the Terrestrial Natural Heritage System Strategy (TNHSS), to establish, protect, and restore a network of natural cover (forest, wetland, meadow, successional, bluffs and beach) across TRCA's jurisdiction. The primary focus was on improving terrestrial biodiversity (habitat and species) and ecosystem health. The natural heritage system identified in 2007 covered 30% of TRCA's jurisdiction including 25% existing natural cover and 5% potential areas to be restored to natural cover.

Building on the TNHSS, in 2022 TRCA completed an update to the technical component of the strategy using updated data and an integrated approach. TRCA's updated regional target NHS (2022) delineates key natural heritage features and areas that are important for TRCA's terrestrial and aquatic ecosystem health across the landscape. The updated regional target NHS:

- Builds on the systems approach of the TNHSS and ensures the regional target NHS remains current and relevant to achieve TRCA and its municipal partners' natural heritage objectives as land use and climate continue to change.
- Identifies the most strategic areas for the NHS that should be targeted for protection, restoration, and enhancements to improve terrestrial and aquatic ecosystem health and resilience within and across watershed boundaries based on the most up-to-date science and data.
- Provides an integrated and comprehensive decision support tool, as well as a series of stand-alone datasets, that helps to characterize terrestrial, aquatic, and hydrological priorities within and across the watersheds. This can inform various TRCA and municipal initiatives for ecosystem management and climate adaptation.

How was TRCA's updated regional target NHS identified?

Various datasets, both existing and new, that characterized ecosystem features and functions were used in the model to delineate the target NHS (2022).

These data are mainly classified into four major groups (described in Section 3.3. and Table 1):

- **Locked-in natural features and areas** – This group mainly includes 9 available datasets on natural features and areas that should be included by default within the NHS, such as all woodlands, wetlands, areas of scientific interest etc. In an urban landscape such as ours, these are the last remaining areas that contribute to overall ecosystem health.
- **Aquatic functions** – This group includes 6 datasets that identify the priority areas for aquatic species and habitat, including the upland areas that are important contributing areas for sensitive in-stream habitat and areas important for hydrological linkages.
- **Terrestrial functions** – This group includes 21 data layers that identify priority areas for terrestrial species and habitat, including areas predicted to have high suitability for multiple groups of species, connectivity priority areas, and areas with high diversity and/or combination of species and vegetation communities.
- **Municipal NHS** – This includes 1 consolidated data layer reflecting the areas that were identified as NHS priorities in municipal official plans (as of when the analysis was completed in 2020).

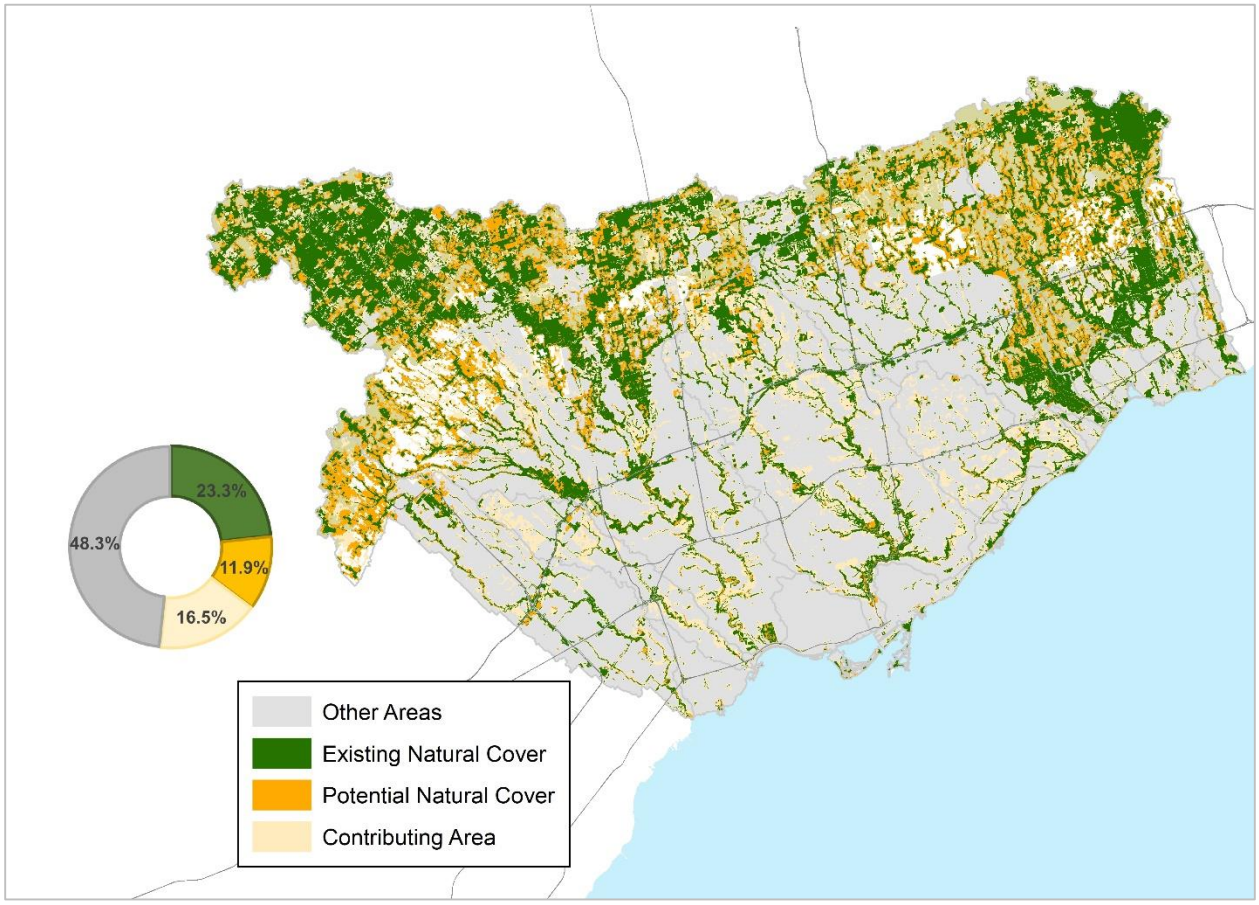
The locked-in natural features and areas were included by default in TRCA's regional target NHS as they represent mostly existing features. The other three groups of data layers were used to select additional areas, mostly for restoration and enhancements, using an optimization tool called Marxan (Ball et al. 2009). Marxan has been used globally to identify strategic areas for conservation based on various criteria and their set targets. It integrates and evaluates multiple criteria and their various combinations to identify the most optimal areas that can maximize the highest priority areas for all natural heritage functions selected for the target NHS.

In this analysis the proportion of representation for all criteria were set to select the highest functioning areas that equates to about 40% of the watershed area at watershed scale and 50% of the regional area at the regional scale. This allowed for identification of the most optimal and strategic areas for the target NHS that aligned with the ecological needs across TRCA's each individual watersheds and the region. These additional areas were merged with the locked-in areas to identify TRCA's regional target NHS.

The identified areas for TRCA's target NHS were then classified into three tiers with different yet related management focus based on their land use and land cover conditions as listed below:

- **Existing natural cover (ENC)** - Includes natural cover such as locked in features and areas that are important for natural heritage functions that could be targeted for protection
- **Potential natural cover (PNC)** – Includes expanded areas important for natural heritage functions that could be targeted for restoration, if feasible
- **Contributing areas** – Includes additional areas important for natural heritage functions *but* where traditional protection and restoration are likely not feasible and could be targeted for Low Impact Development and Green Infrastructure implementation. This is a new category

introduced in the TRCA's updated regional target NHS that aims to account for the contribution of the entire landscape including the built portions to achieve the NHS objectives.



What does TRCA's updated regional target NHS mean?

TRCA's updated regional target NHS is a science-based screening tool that highlights the existing and potential features and areas that are important for long term health and resilience of ecosystems in TRCA's jurisdiction. Provincial directions require municipalities to provide adequate protection and enhancements to the natural heritage system. TRCA's updated regional target NHS is intended to be a tool for TRCA and its municipal partners to inform various strategic and site level initiatives (with appropriate refinements). This includes informing watershed and subwatershed planning, land use and infrastructure planning, land securement and management, ecological restoration and green infrastructure implementation, municipal comprehensive reviews, and official plan review processes. TRCA's updated regional target NHS is not intended to disrupt existing decision-making processes, but rather to inform them based on up-to-date science and to identify partnership opportunities to facilitate collaborative conservation initiatives.

TRCA's updated regional target NHS identifies 35% of the TRCA's jurisdiction as target NHS comprising of existing natural cover (23.3%) and potential natural areas (11.9%). An additional 16.5% of the

jurisdiction is identified as the Contributing Areas that support the NHS features and functions, but where traditional restoration opportunities may be limited due to its existing conditions (e.g., built areas) and/or future plans (e.g., approved for future development). The Contributing Areas are mostly within the urban land uses that have been identified as important for various ecological functions.

In terms of management implications, existing natural cover should ideally be targeted for protection and the potential cover should be targeted for restoration to increase natural cover quantity and quality, where possible. Given that the TRCA's jurisdiction is highly urbanized, the existing natural cover is under various direct and indirect stress from urbanization as well as other stressors like climate change. The existing and potential natural areas identified in the target NHS will be a critical backbone of our ecological system across the jurisdiction for a healthier NHS. However, protecting and restoring these areas may not be enough to ensure long term resilience of the NHS given the exacerbated impacts and uncertainties associated with the combined effects of urbanization and climate change together.

TRCA's updated regional target NHS identifies additional areas in the form of Contributing Areas where various enhancement opportunities, especially through green infrastructure and LID implementation could be targeted to improve ecosystem functions and services. This ensures that both natural and built portions of TRCA's jurisdiction is strategically targeted for protection, restoration, and enhancements for a healthy and resilient NHS that can sustain ecosystem functions and services in the long run.

1. INTRODUCTION

1.1. Background

Urbanization pressure has continued to drive land conversion from natural cover to various land uses, dominated by impermeable built infrastructure. This has direct and indirect effects on ecological systems including its form and functions that provide various ecosystem services that humans benefit from and value. For example, the biophysical structures in the landscape (e.g., woodlands, wetlands) and the processes happening within them (e.g., net primary productivity and infiltration) enable proper functioning of the ecosystem (e.g., providing habitat for viable species populations and maintaining water flows). This produces important ecosystem services (e.g., wildlife viewing opportunities and flood protection) that benefit human well-being in various ways (e.g., improving mental health and safe communities). These ecosystem service benefits have numerous monetary and non-monetary values associated with them (e.g., savings in health care costs and insurance costs) that are important considerations to be accounted for in all aspects of decision-making at TRCA and its municipal partners for a resilient ecological and social system in Toronto and region. The interconnectedness between ecosystem function, services, and human well-being has been highlighted by United Nation's Millennium Ecosystem Assessment (2005).

Land conversion to urban uses have resulted in biodiversity habitat loss, fragmentation, and degradation that have affected ecosystem functions including wildlife populations' ability to persist in the landscape over long term (Saunders et al. 1991). Recognizing these impacts and the need to protect existing natural features and areas as well as to restore potential ecologically functioning areas the concept of Natural Heritage System (NHS) was incorporated into the Provincial Policy Statement (PPS) in 1994 (OMNR 2010). Based on the PPS (2020) NHS is defined as

> *"a system made up of natural heritage features and areas and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue."*

TRCA and partner municipalities continue to recognize the need for strengthening ecosystem health across the jurisdiction. There are several policies, plans, programs, strategies, and initiatives put it place that aims to achieve this. TRCA Terrestrial Natural Heritage System Strategy (hereafter referred to as the TNHSS or the Strategy) (TRCA 2007) is one such initiative that was developed, through support of TRCA municipal partners to establish, protect, and restore a network of natural cover (forest, wetland, meadow, successional, bluffs and beach) across TRCA's jurisdiction. The primary focus was on improving terrestrial biodiversity (habitat and species) and ecosystem health. The natural heritage system identified in 2007 covered 30% of TRCA's jurisdiction including 25% existing natural cover and 5% potential areas to be restored to natural cover. The core principle of the Strategy was to increase

quantity, quality, and distribution of terrestrial biodiversity across the entire jurisdiction, which would also enable a steady provision of other ecosystem services as co-benefits (e.g., flood protection, pest reduction, increased recreation, and aesthetic opportunities) that are vital for human well-being.

1.2. Rationale for TRCA's updated regional target NHS

TRCA's TNHSS has facilitated numerous initiatives to strengthen regional biodiversity, habitat, and ecosystems in the TRCA jurisdiction through protection, land acquisition and management, restoration, watershed planning, and development and infrastructure planning. In addition, TRCA staff has used the Strategy and the terrestrial NHS identified in 2007 to inform partner municipalities and Conservation Authorities to help achieve their natural heritage objectives and delineate the NHS by providing them with the technical advice, methodical approaches, and data. Given the utility of the regional target NHS to TRCA and its municipal partners in providing the systems-based information at watershed and regional scales, there is an ongoing need and interest in keeping it current and relevant with updated information from local and global science.

As such, TRCA completed a technical update to the 2007 terrestrial NHS to delineate TRCA's updated regional target NHS (2022). It provides an update to the technical component of the Strategy using new data and an integrated approach. It delineates key natural heritage features and areas that are important for TRCA's terrestrial and aquatic ecosystem health across the landscape. The updated regional target NHS:

- Aligns with the provincial guidance and builds on the systems approach of the TNHSS and ensure regional target NHS remains up-to-date to achieve TRCA and its municipal partners natural heritage objectives within the broader context of land use and climate change.
- Identifies most strategic areas for NHS that should be targeted for protection, restoration, and enhancements to improve terrestrial and aquatic ecosystem health and resilience within and across watershed boundaries based on the most up-to-date science and data.
- Provides an integrated and comprehensive decision support tool as well as a series of stand-alone datasets that helps to characterize terrestrial, aquatic, and hydrological priorities within and across the watersheds, which can inform various TRCA and municipal initiatives for ecosystem management and climate adaptation.

The need for the update was primarily driven by the land use and land cover changes on the ground over past decade and half, policy updates, and availability of the new data and updated science on natural systems management, especially within urban and near-urban context. More specifically, the following four key points helped scope TRCA's updated regional target NHS:

- *Consolidated information on municipal Official Plan natural heritage systems as well as other updated land cover and land use information since 2007*
  Since 2007 there have been several land use and land cover changes in the TRCA's watersheds. In addition, TRCA's partner municipalities had advanced substantially in terms of developing their own NHS in their Official Plans. These regional and local municipal target NHS are the primary vehicles to protect and restore natural areas through their specific policy coverage. It is

important for TRCA's regional target NHS to account for the municipal priorities for NHS along with the science-based information on ecosystem forms and functions to ensure ecosystem and watershed health over long term.

- *Updated science and practice of natural systems planning (in an urban context):*
  Over the past decade and half the science and practice of natural systems planning has evolved substantially, especially in the urban context. Building on the principle of systems thinking, natural systems planning has progressed from focusing on only one component of the landscape (e.g., natural verses built, terrestrial verses aquatic) to an integrated mosaic of land, water, and built infrastructure, where all parts of the mosaic interact and contribute to ecosystem function at various levels. This evolved approach emphasizes expanded and creative ways of managing the landscape through protection, restoration, and urban design that can improve overall terrestrial and aquatic ecosystems in urban and near urban areas.
- *Identified existing climate change vulnerabilities of natural systems:*
  There has been an increased emphasis on the impact of climate change on ecosystem health over long term. TRCA has developed improved understanding and data that outlines climate change vulnerabilities of the natural system within its watersheds. This update to the target NHS provides an opportunity to incorporate this information to NHS planning and inform improve overall resilience of natural systems.
- *Available expanded field data and analytical capacity of TRCA:*
  TRCA's regional inventory and monitoring as well as special projects have amassed a large amount of field data and modelled ecological data that allows for advanced analysis to understand and inform NHS planning and implementation across TRCA jurisdiction. This includes field data on habitat and biodiversity as well as modelled data on habitat connectivity, habitat suitability, climate vulnerabilities etc.

1.3. Benefits of TRCA's updated regional target NHS?

TRCA's updated regional target NHS is intended to enable TRCA and its municipal partners to continue to be leaders in urban ecosystem planning and management. The target NHS and its associated data is intended to inform various initiatives of TRCA and its municipal partners. This includes watershed planning, policy planning, development and infrastructure planning, ecological restoration planning, and land management and acquisition. As more details become available at finer scales (e.g., watershed, sub-watershed, MESP, individual site) the regional information from the TRCA updated target NHS may be refined to add detailed information to reflect watershed and site level needs.

TRCA's updated regional target NHS will support many of the strategic objectives in the TRCA Strategic Plan 2013-2022, including Strategy 3: Rethink greenspace to maximize its value, Strategy 4: Create complete communities that integrate nature and built environment, and Strategy 8: Gather and share the best urban sustainability knowledge. More specifically, the project will benefit TRCA and its municipal partners by:

- Identifying strategic opportunities to protect, enhance, restore, and manage for terrestrial, aquatic, and hydrological functions across TRCA's jurisdiction.

- Maximizing impact and cost-efficiency by directing ecosystem protection, management, and restoration efforts to where they are most needed, will provide the greatest benefit to ecosystem service delivery, and are likely to be most successful.
- Demonstrating TRCA's value to its partner municipalities that provides the most up-to-date science and practice in ecosystem management.
- Positioning TRCA and its municipal partners as the leaders in urban ecology science, policy, and practice.

2. GOAL AND OBJECTIVES

The overarching goal of this project is to use the most-up-to-date data and systems and science-based information to identify TRCA's updated regional target NHS that provides information on the key natural heritage features and areas including areas important for various ecosystem functions and processes and should be targeted for protection, restoration, and enhancement to ensure healthy and resilient ecosystems and watersheds over long term.

In doing so, this project will deliver a series of technical data layers and science-based information that can be used as stand-alone decision support tools to inform various initiatives of TRCA and its municipal partners.

The science-based regional target NHS is intended to be refined through finer level information available at watershed and site level studies through additional scientific data collection or modelling, community and stakeholder input, and indigenous community engagement.

The key objectives for the project are to:

1. Identify the current state of science for natural systems management and TRCA and municipal partner needs for updated regional target NHS
2. Incorporate available data on municipal Official Plan NHS to inform TRCA's regional target NHS
3. Incorporate up-to-date information on habitat connectivity and climate vulnerabilities of the natural system to inform TRCA's regional target NHS
4. Generate and use new data on ecosystem functions and needs including terrestrial and aquatic habitat and biodiversity priorities as well as significant hydrological linkages to inform TRCA's regional target NHS
5. Integrate all science-based data to identify the most strategic areas for to be included within TRCA's updated regional target NHS for protection, restoration, and enhancements
6. Engage municipal partners, stakeholders, indigenous communities, and general public on TRCA's updated regional target NHS for gain feedback and facilitate implementation.

3. DATA AND METHODS

The TRCA updated regional target NHS was developed in three distinct phases, each achieving a set of project objectives as illustrated in Figure 1. This section will provide an overview of the general approach and details on individual data that was used as input criteria in NHS delineation, which is discussed further in the following subsections.

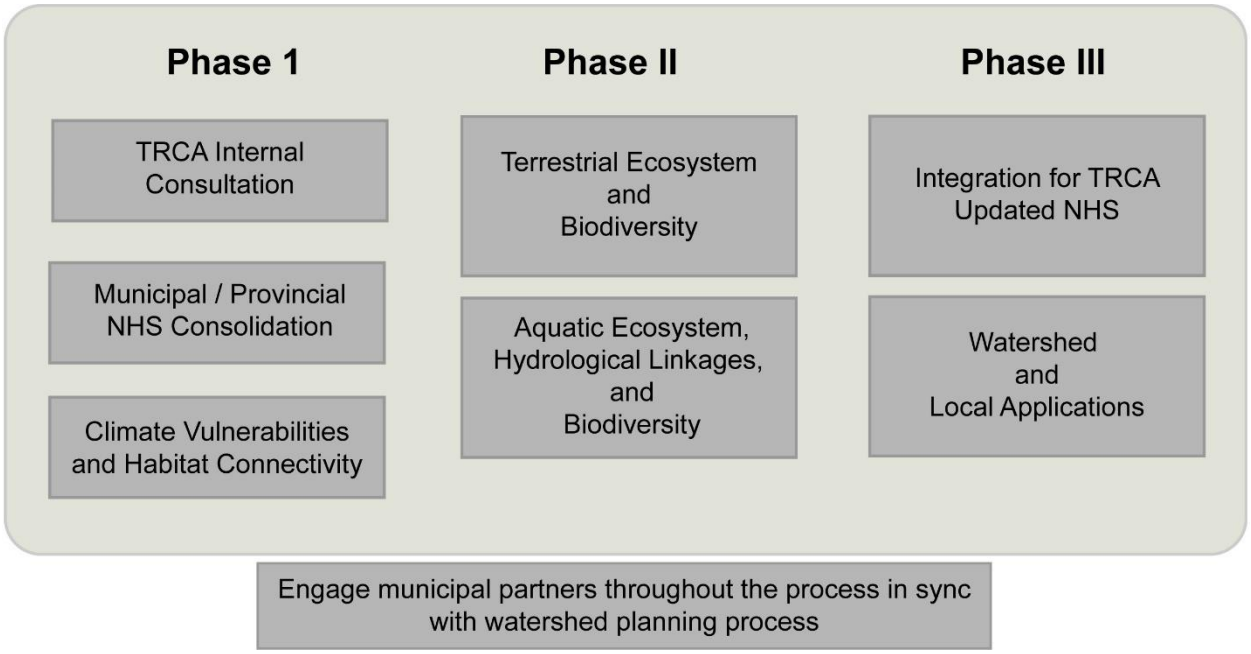


Figure 1: Project phases and objectives

3.1. Phase 1: Municipal NHS and Climate Vulnerability Data

Phase 1 of the project focused on achieving objectives 1 and 2. First, the internal consultation identified the update needs, helped define the project scope, and an overall approach. The Terms of Reference (ToR) and the internal technical advisory team was developed to guide the project. Second, all partner municipalities NHS was analyzed to inform TRCA updated target NHS as appropriate for biodiversity and habitat enhancement (discussed in Section 3.1.1). This was completed by strategically leveraging the financial support provided by the Great Lakes Sustainability Fund (GLSF) from 2015-2018 to evaluate the TRCA TNHS (2007) implementation success in municipal official plans and policies. Third, the existing climate change vulnerabilities of the terrestrial biodiversity and habitat were identified to inform TRCA updated target NHS (mostly based on the Peel NS VA framework (TRCA, 2017)) (discussed in Section 3.1.2.

3.1.1. Municipal NHS consolidation

Municipalities are the planning authority for local land use planning decisions and therefore play a critical role in the identification and protection of NHS. A mapped NHS is an important tool for land use

planning and can help ensure land use planning decisions are not compromising the ecological, social or economic benefits that natural areas provide. TRCA developed a study with the Great Lakes Sustainability Fund (TRCA 2018) to evaluate how the implementation of TRCA's Terrestrial Natural Heritage System Strategy (TNHSS) aligns with municipal NHS. The results of the study provided insights on where the synergies and gaps were in terms of delineating NHS that could inform future NHS initiatives.

A spatial overlap analysis was completed to compare NHSs delineated in municipal OP Schedules (as of 2015) with the target Terrestrial Natural Heritage System (TNHS) (TRCA 2007) to: (i) Understand the extent of TRCA TNHS adoption in municipal Ops (schedules & maps); (ii) Understand the extent of habitat protection in municipal natural heritage systems; (iii) Identify the reasons for differences and similarities between TRCA TNHS and municipal NHS.

Municipal NHS boundary layers were combined with the most up-to-date natural heritage system information from the Oak Ridges Moraine Conservation Plan, the Greenbelt Plan, and the Niagara Escarpment Plan to consolidate an up-to-date municipally adopted (final or in draft form) NHS layer. Federally protected natural heritage in the Rouge National Park, as it existed in 2015, was also included in this layer. The consolidated municipal adopted NHS layer was overlaid with the TRCA target TNHS to assess the extent of overlap between the two (Fig. 2). The consolidated NHS spatial overlap data was used in conjunction with the natural cover data and broad land use data to understand the synergies and discrepancies between municipal and TRCA NHS and implications on current and future habitat protection.

This analysis suggests there is almost 85% overlap between the TRCA TNHS and the consolidated municipal NHS (approximately 60 000 ha). This level of overlap indicates a high rate of adoption of TRCA recommendations by municipalities. Most of the overlap coincides with existing natural cover and areas with some level of policy protection, either as TRCA regulated areas (e.g., within flood plains) or from provincial legislation (e.g., Greenbelt and Oak Ridges Moraine). Nevertheless, 15% of the TRCA TNHS (12000 ha) was not captured within the consolidated municipal NHS. Despite these exclusions, municipal NHS added a further 26 000 ha in their NHS that might offset some of the gaps in habitat, provided that these areas have similar form and function when it comes to habitat and wildlife conservation.

Most of the 12 000 ha of TNHS areas that municipal NHS excluded are either classified as potential natural cover or existing meadows in the TRCA TNHS. This includes agricultural areas that are outside of the Greenbelt or Oak Ridges Moraine plans in rural zone and meadows and/or other open space areas in urban and urbanizing zones. As discussed earlier, this reflects the increased susceptibility of meadows to land use change given that they have limited protection status in the current policy framework. In addition, a few existing forests and wetlands in the TRCA TNHS were also excluded in municipal NHSs, mostly in rural and urbanizing zones. Though it is important to include them in a municipal NHS to prevent habitat loss, further investigation may be needed to confirm that these are in fact still present in the landscape given the time lag between the TRCA TNHS and municipal NHSs. Lastly, data processing errors such as slivers during data clipping or shift in digitizing boundaries also resulted in some mismatch between the TRCA TNHS and municipal NHS.

The 26,000 ha of the jurisdiction that were included in municipal NHSs and not in the TRCA TNHS have the potential to provide additional wildlife habitat. Some of these areas are forests and wetlands that were missed by the TRCA TNHS, likely due to data processing errors. The majority of these are in the uncategorized natural cover type, which means they are not existing habitat and may reflect areas that municipal Ops have targeted for habitat restoration and enhancement. A significant portion of these are agricultural lands in rural areas, especially where there are provincial designations.

The watershed analysis also highlighted that the NHS coverage is generally higher in watersheds such as the Humber, Rouge, Duffins, Petticoat, and Carruthers, which have higher natural cover as well as coverage of provincial plan policies because of the Oak Ridges Moraine Conservation Plan, the Niagara Escarpment Planning & Development Plan and the Greenbelt Plan. This highlights that the provincial policies are generally facilitating NHS protection as intended. In urban and urbanizing zones, the added areas in municipal NHS constitute areas zoned for different land uses such as active recreation (e.g., golf courses, parks) or institutional and commercial zoning.

The watershed analysis also indicated that in the highly urbanized watersheds and along the waterfront additional areas in municipal NHS seem to include active recreation areas, golf courses, and other "open" land uses. These areas are traditionally not included in NHS as defined by TRCA and other conservation authorities. This raises questions regarding whether the added NHS areas are inflating the perception of habitat protection or whether these areas provide opportunities to be innovative regarding habitat and wildlife conservation, especially in urban areas where natural cover is low and traditional restoration and protection opportunities may be limited. Cautious and innovative implementation of NHS may be needed in such areas to ensure that these function as NHS for habitat and wildlife.

Three key recommendations from this analysis highlighted that there is a need to

(i) Develop additional policy guidance to protect natural habitats not sufficiently addressed more fully in current policy frameworks, particularly in future urban growth areas as these are the most vulnerable to removal, and

(ii) Develop protection policies for local natural features not protected under provincial policy, particularly in rural areas that have defaulted to the provincial systems.

(iii) Recognize the contribution of the areas that may not traditionally fit the definition of NHS (e.g., open land uses in urban portions of the jurisdiction) but may provide ecological functions and services, especially in built portions of the landscape, that otherwise would not be available if these areas did not exist.

This information was used in the TRCA's updated regional NHS to ensure that the updated NHS would incorporate these elements more strongly based on science and data. Various ecological assessments were conducted to ensure that the strategic areas including those that are not sufficiently covered by policy frameworks are identified (further discussed in Section 3.2). Additionally, the final NHS delineation used the municipal NHS as one of the inputs to capture the municipal priorities, as appropriate (further discussed in section 3.3).

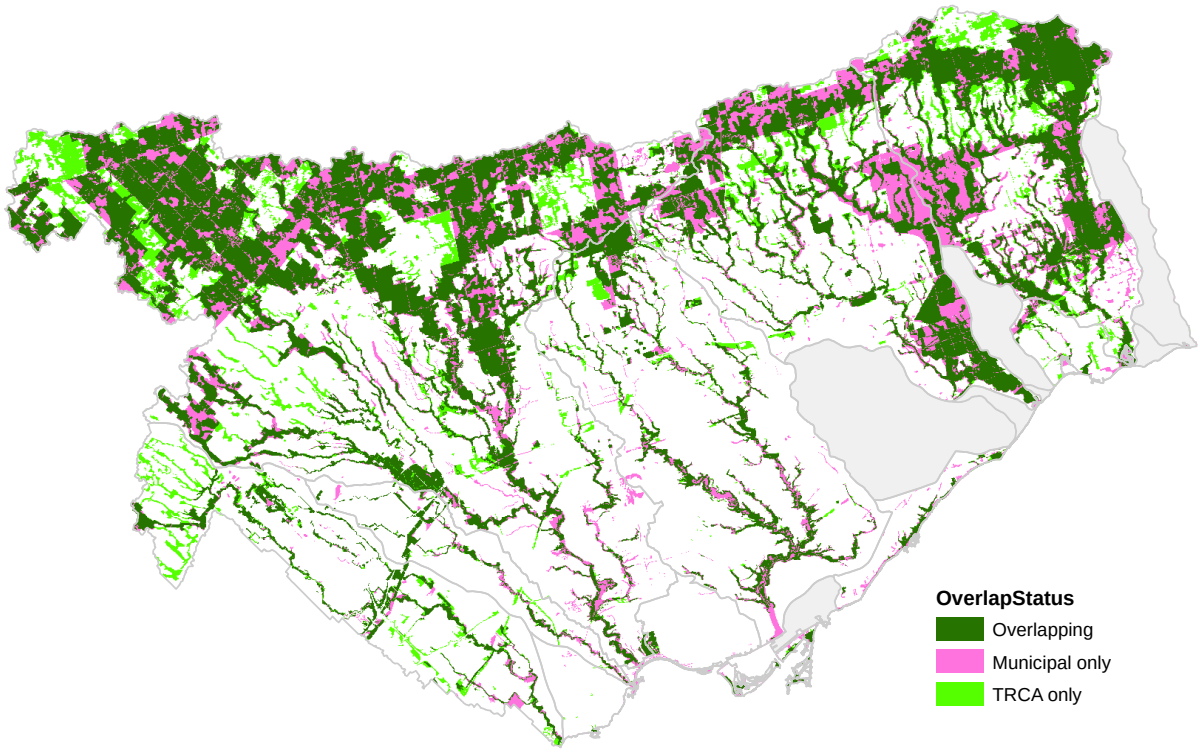


Figure 2 : Overlap of municipal and Terrestrial Natural Heritage System Strategy 2007.

3.1.2. Climate change vulnerabilities

Climate change is currently impacting natural systems in the Toronto Region and future projected climate change is expected to intensify these impacts. These climate change projections predict increased frequency and magnitude of precipitation events as well as temperature extremes in the Great Lakes region (Magnuson et al. 1997). Improving natural systems planning require the consideration of factors that influence the function and resilience of natural systems. A better understanding of climate change resiliency is linked to the hydrological links between terrestrial and aquatic systems, the vulnerability of natural system components to climate change, and the contribution of the urban forest and other components of the urban matrix to the natural system.

To account for the effects of future climate change on natural systems, TRCA and the Ontario Climate Consortium (OCC) developed a framework (Tu et al. 2017) for the Region of Peel. The indicators used in the Peel framework were then expanded to be applied to TRCA's jurisdiction (TRCA 2020). Under this framework, vulnerability indicators were used to assess the degree of vulnerability of natural systems, and the key ecosystems they provide, to climate change and extreme weather impacts (TRCA 2020).

For a climate change vulnerability assessment (CCVA), a vulnerability indicator is considered a representation of a natural systems component or attribute able to provide information regarding its adaptive capacity in response to a climate-induced impact. The five vulnerability indicators were: habitat

patch score, climate sensitivity of native vegetation, wetland hydrological stability, soil drainage rating, and ground surface temperature (Figure 3).

- Habitat patch score is a strong indicator of ecosystem vulnerability because of its interrelations with multiple vulnerability factors. Habitat patch score represents the quality of habitat patch based on its size, shape, and influence of the surrounding matrix using the TRCA Landscape Analysis Model (TRCA 2007). TRCA's LAM analysis ranks patches from L1 to L5, where L1 is the highest quality (TRCA 2007). The lower quality habitat patches (L4, L5) have smaller sizes, linear shape with high edge effects, and are situated in areas with higher levels of urbanization. These lower quality patches are expected to be stressed and thus more vulnerable to climate change impacts.
- Sensitive vegetation that are more impacted by increasing seasonal temperatures and increasing variability in precipitation will be negatively affected by climate change due to disrupting functional processes. Namely, these functions include hydrological processes, fertility processes, and potential dynamic interaction between hydrology and fertility. Climate sensitivity of native vegetation is based on the number of vulnerable processes. The climate sensitive vegetation community's information was extracted from the TRCA Ecological Land Classification (ELC) field data with input from TRCA's biologists and broader literature. The list of ELC codes used to identify this indictor is provided in the Appendix in Tu et al. (2017).
- Wetland vulnerability increases where soils remain dry for extended periods are more vulnerable to colonization by upland vegetation and invasive species leading to potential adverse impacts. Wetland sensitivity to climate change would be based on receiving inputs of water only from precipitation and local catchment runoff were more vulnerable than wetlands receiving additional water inputs from groundwater or from larger riparian systems. The vulnerable wetlands may be areas that could be targeted for restoration to reduce the vulnerability to climate change.
- Soil drainage relating to poor drainage will produce shallower root networks and increased potential for localized inundation, contributing to higher relative vulnerability. Scoring for climate vulnerability was based on the soil surveys from well drained to poorly drained or no drainage (e.g., urban) classification. Although soil drainage is a climate change vulnerability indicator that cannot lead to actual actions to reduce the negative effects of climate change as it is a landscape condition. However, it can identify areas in the landscape where there is a greater risk to climate change.
- Ground surface temperature represents the potential heat and drought stress throughout the natural system leading to the drying of soil and forest understories, plant heat stress, reduction in natural system thermal regulation, and loss of thermal refuges for heat-intolerant species. Scoring was based on ground surface temperatures under three data percentiles of equal thirds. The areas in the landscape with high ground surface temperature are considered as having high vulnerability and any natural system component within such areas are considered more vulnerable.

Spatial mapping of vulnerability indicators, where data were available, provides large aid in understanding and characterizing current vulnerability. Ultimately, the vulnerable areas can be used as an overlay to inform NHS planning process to guide where climate adaptation measures are most needed.

Results of terrestrial system climate change vulnerability assessment for individual indicators show that for

1. 16% of all habitat patches (9% of TRCA's jurisdiction) are low quality and are thus have high vulnerability. Most of them are situated in urban zones. These habitat patches are already in degraded conditions and climate change impacts will further exacerbate their ecological form and functions.
2. 0.2% of all ELC vegetation communities surveyed (0.1% of TRCA's jurisdiction) are climate sensitive and are mostly located in the northern parts – mostly within Greenbelt zone including urban river valleys where there is habitat for sensitive species of vegetation. These vegetation communities are likely protected from land use changes but climate change impact may still affect these communities. Targeted adaptation measures are needed to protect and enhance these communities and/or assist them to transition to functionally similar vegetation that allows for ecosystem health.
3. 1% of wetlands used in this analysis (0.4% of TRCA's jurisdiction) are highly vulnerable because they are only precipitation-fed. 2% are moderately vulnerable because they are further from a groundwater or riparian source. The highly vulnerable wetlands should be explicitly targeted for further protection and/or climate adaptation measures focused on building its resilience through hydrological enhancements. These measures are especially important if these wetlands are in the urban or urbanizing landscapes where additional consideration may be needed to maintain and enhance its functionality. Further consideration includes wetland water balance measures, hydroperiod maintenance, etc. and will have direct and indirect affect on regional biodiversity as well.
4. 51% of TRCA's jurisdiction is highly vulnerable due to poor soil drainage. Any natural features and functions may be further compromised in these areas due to climate impacts.
5. 37% of TRCA's jurisdiction is highly vulnerable due to high ground surface temperature. These areas are vulnerable due to high imperviousness and the lack of natural cover. Further climate impacts will exacerbate the effects of the urban landscape.

The additive mapping of all vulnerability indicators (Fig. 3F) shows that in summary 52% of the TRCA jurisdiction is highly vulnerable (scores ≥ 0.66). Additive scores also show that 19% of natural cover is highly vulnerable (scores ≥ 0.66) and 36% of natural cover is moderately vulnerable (scores between 0.33 and 0.66).

These climate vulnerable areas were compared with the TRCA's updated regional NHS to ensure that the updated NHS would incorporate the vulnerable areas into the protection, restoration, and enhancement opportunities, as appropriate (further discussed in section 3.3.2.2).

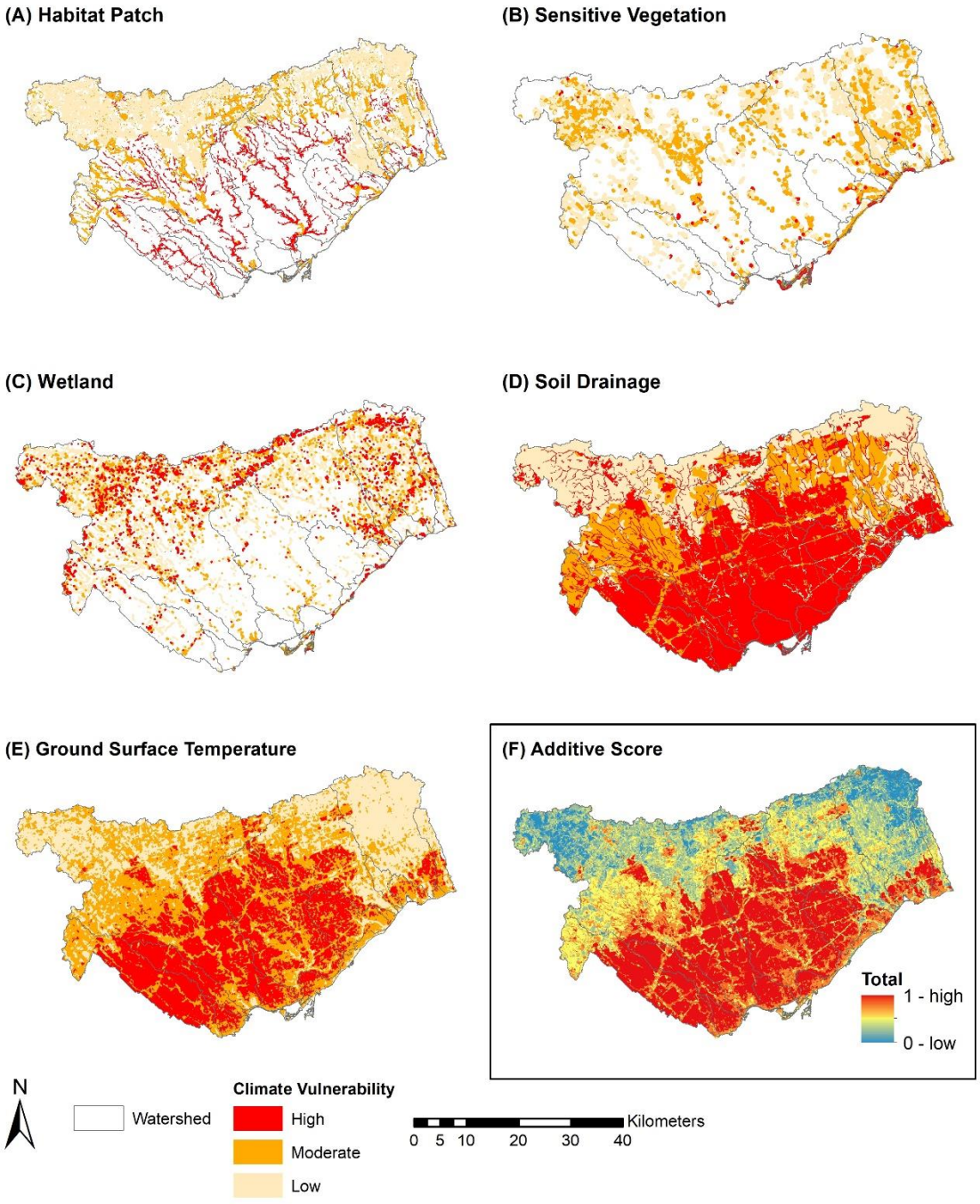


Figure 3: Summary of climate vulnerability indicators of (A) habitat patch score, (B) climate sensitivity of native vegetation, (C) wetland hydrological stability, (D) soil drainage rating, I ground surface temperature, and (F) additive vulnerability in the TRCA jurisdiction (total score 1 is the highest vulnerability) as 100-m grid unit.

3.2. Phase 2: Ecosystem Features and Functions

Phase 2 of the project includes analysis required to achieve objective 3, which focused on identifying strategic areas for conservation based on terrestrial and aquatic ecosystem needs across entire jurisdiction as well as their hydrological connections to ensure that the integrated system is resilient over long term.

As such, this phase focussed on generating a more comprehensive spatial data and models that could provide information on the priority areas for ecosystem functions and processes across urban-rural and natural-built gradient. This includes data on biodiversity distribution, habitat connectivity priorities for specific groups of species, and priorities based on habitat suitability for various groups of terrestrial and aquatic biodiversity that could be used as input to identify TRCA's regional target NHS. More specifically there were five key sub-objectives for this phase as listed below:

1. Quantify biodiversity metrics in terms of alpha, beta, and gamma diversity for avian species, flora species, and vegetation communities
2. Update the habitat connectivity models based on various movement groups of species to identify priority areas for connectivity
3. Complete a Functional Trait Analysis (FTA) for avian and amphibian species to identify key functional trait groups of species and complete a Habitat Suitability Analysis (I) to identify priority areas for terrestrial habitat function
4. Complete a Functional Trait Analysis (FTA) for fish species to identify key functional trait groups and complete a Habitat Suitability Analysis (I) to identify priority reach contributing areas for aquatic habitat function
5. Complete analysis to identify Ecologically Significant Groundwater Recharge Area (ESGRA) that reflects key hydrological linkages between terrestrial and aquatic systems that are responsible for replenishing groundwater systems that directly support sensitive areas like coldwater streams and wetlands

3.2.1. Biodiversity metrics (alpha and beta diversity)

TRCA's vision is to strive for human settlement that can flourish alongside nature's beauty and diversity. An assessment of key biodiversity metrics in the TRCA jurisdiction can help to improve understanding of species richness (alpha), site-to-site differences in community composition (beta), and overall diversity (gamma) within the jurisdiction (TRCA 2022b). Alpha diversity is commonly used biodiversity metric and is important to highlight where highest species richness occur in the jurisdiction. Beta diversity, however, is generally less discussed due to its inherent complexity. Generally, it helps determine areas of high biodiversity where species diversity overlaps between two different habitats (representing 'ecotones') which are unique areas relative to other sites in the jurisdiction (e.g., areas containing unique composition of species or vegetation communities indicating unique habitat conditions or presence of less common species). As such, beta diversity often complements alpha diversity sites for conservation.

In addition, TRCA has species L-rank (local rank) system, which is a species scoring and ranking system to provide guidance for natural heritage protection and management within the jurisdiction. The L-rank system uses scoring and ranking to convey individual species' ecological needs or constraints and to portray such complexities on a simple ordinal scale (TRCA 2010). For example, for fauna species their local occurrence, population trends, habitat dependence, area sensitivity, mobility restriction and sensitivity to development determines whether they are more or less of a concern from the regional perspective overall. Generally, L1 to L3 species and/ or vegetation communities are considered regional species / vegetation communities of conservation concern. In this analysis 27 L1 to L3 avian species, 278 flora species, and 19 ELC vegetation communities were used to calculate alpha, beta, and gamma diversity across the jurisdiction (see TRCA 2022b for details and methods using avian species).

Using the data on 27 avian L1-L3 species found in TRCA's jurisdiction, 144 locations were identified as areas with high alpha diversity (Figure 4). These areas contained more than eight L1-L3 species and indicated areas with high species richness. In addition, 62 locations were identified as areas with high beta diversity indicating areas with specific habitat conditions that supports less common species and species composition (Fig. 4). In these locations relatively rare species of birds across TRCA jurisdiction were found such as least bittern (*Ixobrychus exilis*) and yellow-billed cuckoo (*Coccyzus americanus*). Conservation of areas with high alpha diversity (species richness) and beta diversity (species turnover) will contribute towards conservation of overall gamma diversity that includes the overall species richness of TRCA's jurisdiction.

In Phase 3, both alpha and beta diversity data would be used as input criteria to identify strategic biodiversity areas to be included in TRCA's regional target NHS.

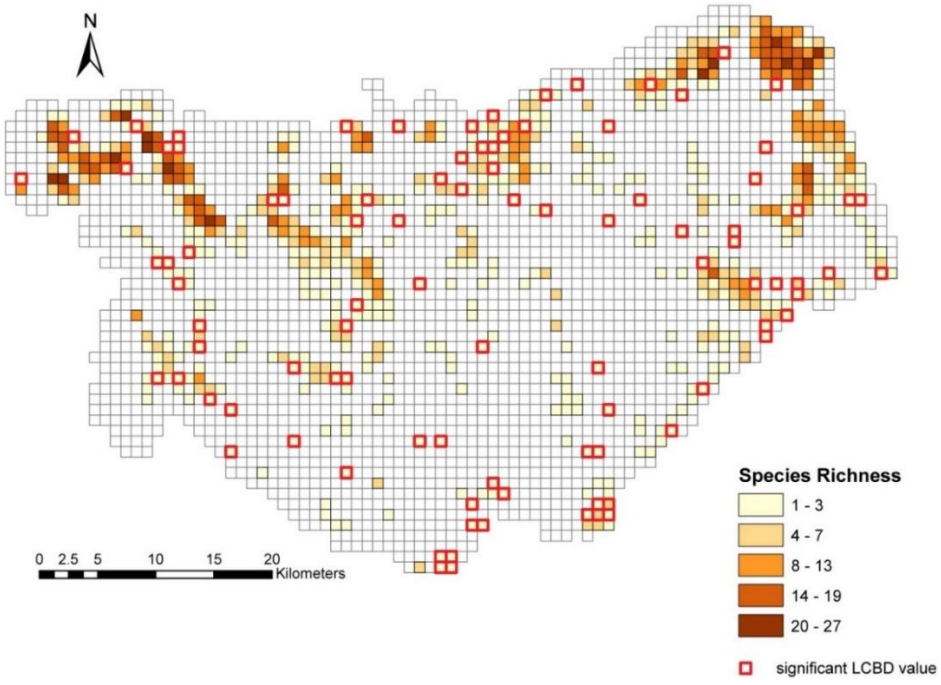


Figure 4: Avian alpha diversity across the entire TRCA's jurisdiction in 1-km cells with urban-adapted species (L4 species) excluded. Significant sites for beta diversity in the entire extent with high local contribution to beta diversity (LCBD) values are indicated.

3.2.2. Habitat connectivity

Habitat connectivity and movement corridors are important for wildlife to access resources for various life cycle processes including feeding, breeding, limiting competition, avoiding predation, and to adapting to the habitat changes caused by various disturbances such as land use and climate change. Changes in landscapes that alter the amount and configuration of habitat can either facilitate or impede critical wildlife movements.

The habitat connectivity analysis completed for this study identified the priority areas for habitat connectivity and wildlife movement for general high quality habitat patches (regional connectivity) and for four specific groups of species of birds and amphibians (species group specific regional connectivity).

For birds, habitat connectivity between forest patches and between wetland patches were deemed important and for amphibian species habitat connectivity between wetland patches and between forests and wetlands were deemed important to model to identify priority areas for connectivity. These species movement groups were selected based on the species composition in TRCA's jurisdiction and their habitat movement needs. This information provides a refinement to TRCA's habitat connectivity analysis completed for general habitat patches (TRCA 2015).

Habitat connectivity analyses were completed using a modeling tool called Circuitscape (McRae et al 2008). Circuitscape uses a circuit theoretic approach, which has widely used for habitat connectivity analyses (Caroll et al. 2011, Urban et al. 2009, McRae et al. 2008). Here, landscapes are represented through land use and land cover maps as resistance surfaces. Low resistance values are assigned to land use and land cover classes such as habitat patches and other natural areas that are most permeable to movement. High resistance values are assigned to land covers such as fully built-up areas that are hostile and may impede wildlife movement. Based on the resistance map and the distance between the habitat patches regional connectivity metric, cumulative current density, is calculated. This reflects the relative probability of wildlife movement from every habitat patch to every other habitat patch in the landscape. This metric helps identify the least cost path among habitat patches to identify potential corridors for movement and places higher emphasis on pathways that represent the last remaining pathway left for movement. Thus, relatively higher values indicate that any changes to it will have larger impact on the overall regional connectivity among all habitat patches. In this study these relatively higher current density areas (top 50%) were delineated to identify the priority areas for regional connectivity for all habitats as well as between forests, wetlands, and forests-wetlands.

Figure 5 shows that the priority areas for regional connectivity is higher in the northern and eastern portions of the TRCA's jurisdiction including north Humber, Rouge, and Duffins watersheds. In addition, the connectivity priority is higher in the ravine system across TRCA's jurisdiction (Figure 5). These areas contain most of the natural cover and habitat, thus also provide important linkage corridors. However, the priority areas for different species group vary substantially based on which habitat types are targeted for connections (Figure 6). This indicates that different species groups have different habitat needs and thus needs a functional approach to assess habitat connectivity.

For example, the priority areas for habitat connectivity between forest patches for bird species, were identified along the ravine corridors and areas in and around large patches of forest areas (Figure 6A). This is intuitive given that most of forest patches are concentrated in these areas and provides stepping-stone habitat during life stages (hatch-year birds) and certain times of the year such as migratory periods. However, for connectivity between wetland patches for birds the corridor priorities are a bit dispersed (Figure 6B). This is attributed to the fact that the wetlands do not follow the linear pattern that forest patches may follow through ravines. Thus, for bird species to get to the nearest wetland with least cost path, they might have to fly through the broader landscape rather than the ravine system. As such, having a more hospitable and less hostile landscape matrix is important for bird species in this group.

For amphibian species groups (e.g., wood frogs (*Lithobates sylvaticus*), gray treefrogs (*Dryophytes versicolor*), and spring peepers (*Pseudacris crucifer*)) the connectivity priority between forests and wetlands follows the natural areas in the ravine system and the broader areas in the greenbelt areas. These areas have less hostile landscape through which amphibians can move and contain most of the forests and wetland patches. As for the wetland patch connectivity for amphibians, the connectivity priorities are a bit dispersed yet more concentrated than for birds given that their movement is more limited as it needs to be across the landscape, which may have higher resistance for these species.

The regional connectivity priorities among high-quality habitats as well as for species group specific habitat patches provide important criteria for delineating TRCA's regional target NHS. Some of these priorities are within existing natural features and areas but many are outside, which allows for delineation of potential areas for linkages and connectivity restoration for long term resilience of NHS.

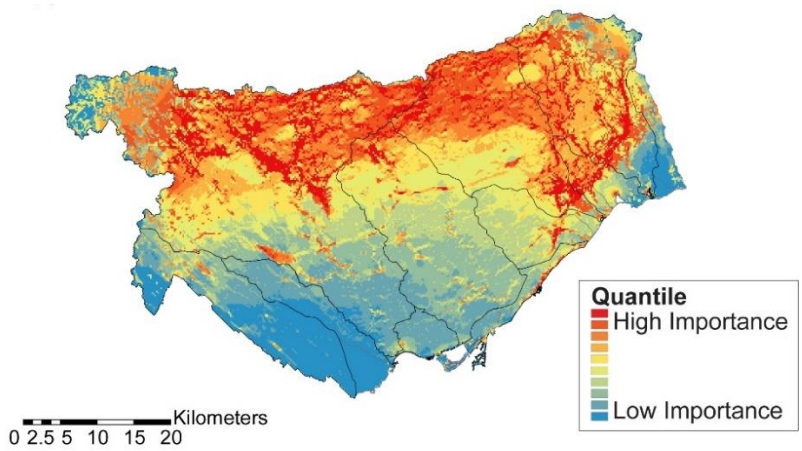


Figure 5: Target regional connectivity across TRCA jurisdiction.

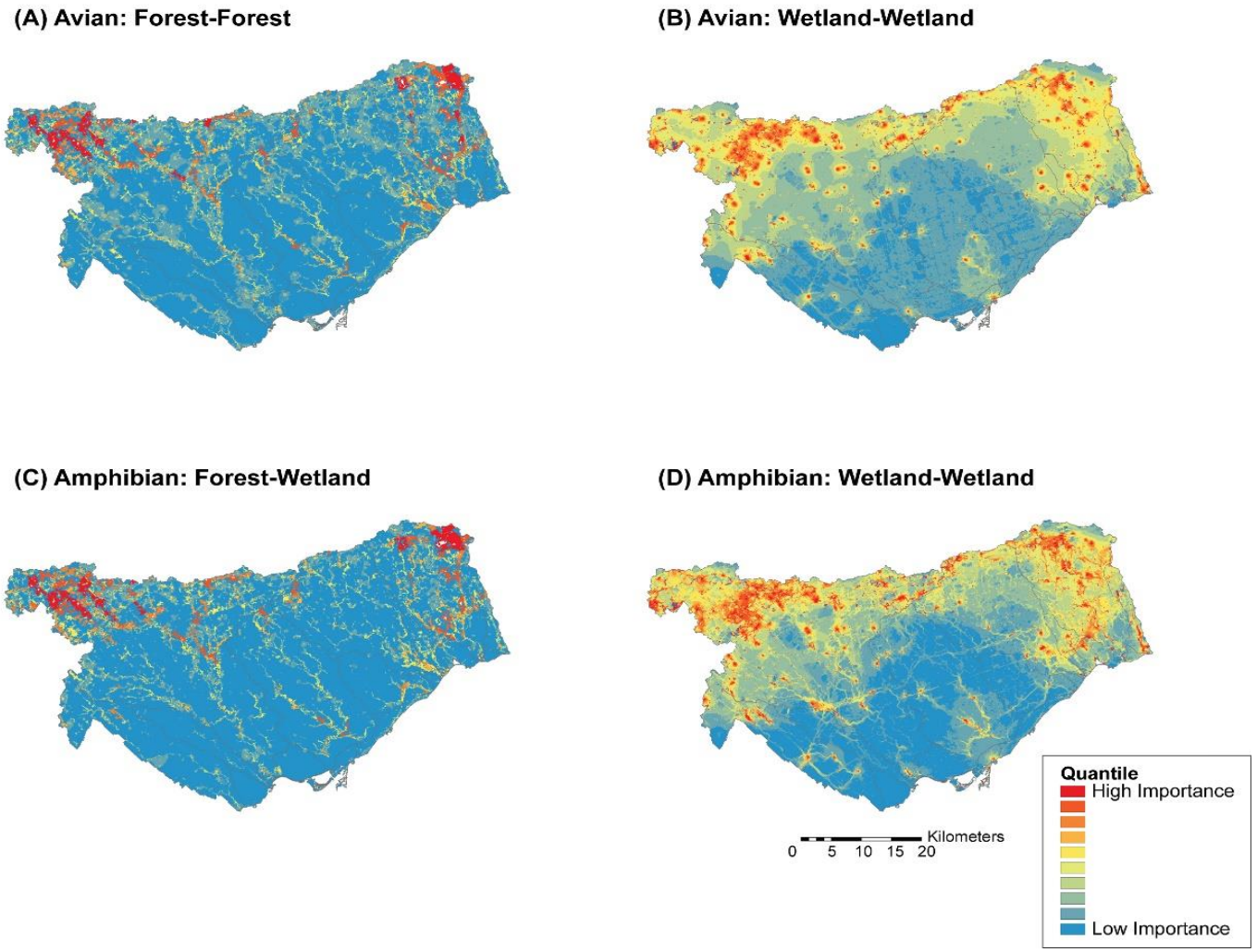


Figure 6: Habitat connectivity of movement guilds for: (A) avian forest-forest, (B) avian wetland-wetland, (C) amphibian forest-wetland, and (D) amphibian wetland-wetland habitat.

3.2.3. Terrestrial habitat suitability

Urbanization and climate change have various direct and indirect impacts on ecosystem structure, function, and services. This includes changes in habitat quantity, quality, and connectivity as well as changes in the characteristics of the surrounding landscape and their climatic conditions. These changes interact with various species needs and requirements, which ultimately determines their persistence in the landscape and the overall health and resilience of our ecosystems, habitats, and biodiversity. Assessments such as the Habitat Suitability Analysis (HSA) aims to understand the capacity of any landscape to provide habitat provisioning service across its boundary given its current characteristics and species composition and can help identify priority areas for conservation to ensure long term health and resilience of the ecosystem.

HSA for TRCA's jurisdiction was completed for various Functional Trait Groups (FTGs) of avian and amphibian species in the TRCA jurisdiction. FTGs are distinct groups of species classified based on their similar requirements, characteristics, and ability to adapt to their environment (TRCA 2022b). The environment could span from natural to urban areas. Using the avian and amphibian data collected between 2007-2017 and information on their key characteristics (e.g., breeding, foraging, diet), a functional trait analysis was completed to identify 21 FTGs of birds and four FTGs of amphibian within TRCA's jurisdiction. For avian species, the RQL fourth-corner analysis (Dray et al. 2014) was used and for amphibian FTGs TRCA's internal expert knowledge was used due to fewer number of species in the jurisdiction to statistically determine these groupings.

Out of all FTGs, only five FTGs of birds (aerial insectivores, forest insectivores, forest canopy, grassland, and ground-nesting) and all four FTGs of amphibians (arboreal, swamp, wetland, woodland) were used for HSA. This was based on data availability and model accuracy of each of these FTGs. The presence data of these FTGs were used to create pseudo-absences (Dray and Legendre 2008), which were then used together as the response variable in the HSA model. The HSA model used the Boosted Regression Tree technique (Elith et al. 2006), where the species data were related to the independent variables such as quantity and quality of habitat patches, Ecological Land Classification (ELC) vegetation communities, landscape connectivity metrics, various land use and land cover information (e.g., total amount of land use and natural cover), and other landscape characteristics (e.g., patch quality of natural cover based on maximum patch size and amount of edge). (For additional details refer to the technical report TRCA 2022b)

Figure 7 shows habitat suitability for the selected FTGs across TRCA's jurisdiction. All FTGs were strongly influenced by natural cover distribution, which is as expected given that most core habitat for these species are present within natural cover boundaries like forests and wetlands. For avian FTGs the results indicate that some groups such as Forest Canopy dependent group showed higher habitat suitability close to existing forests and wetlands indicating their need for natural cover in the landscape. Others such as Aerial Insectivores showed high suitability close to natural cover, but they also depicted more medium suitability in older residential neighborhoods with high urban canopy indicating that urban street and backyard trees play an important role in biodiversity habitat provision.

The has results provide important input to delineate TRCA's updated regional target NHS as they help identify existing and potential habitat areas that are priority for our regional biodiversity.

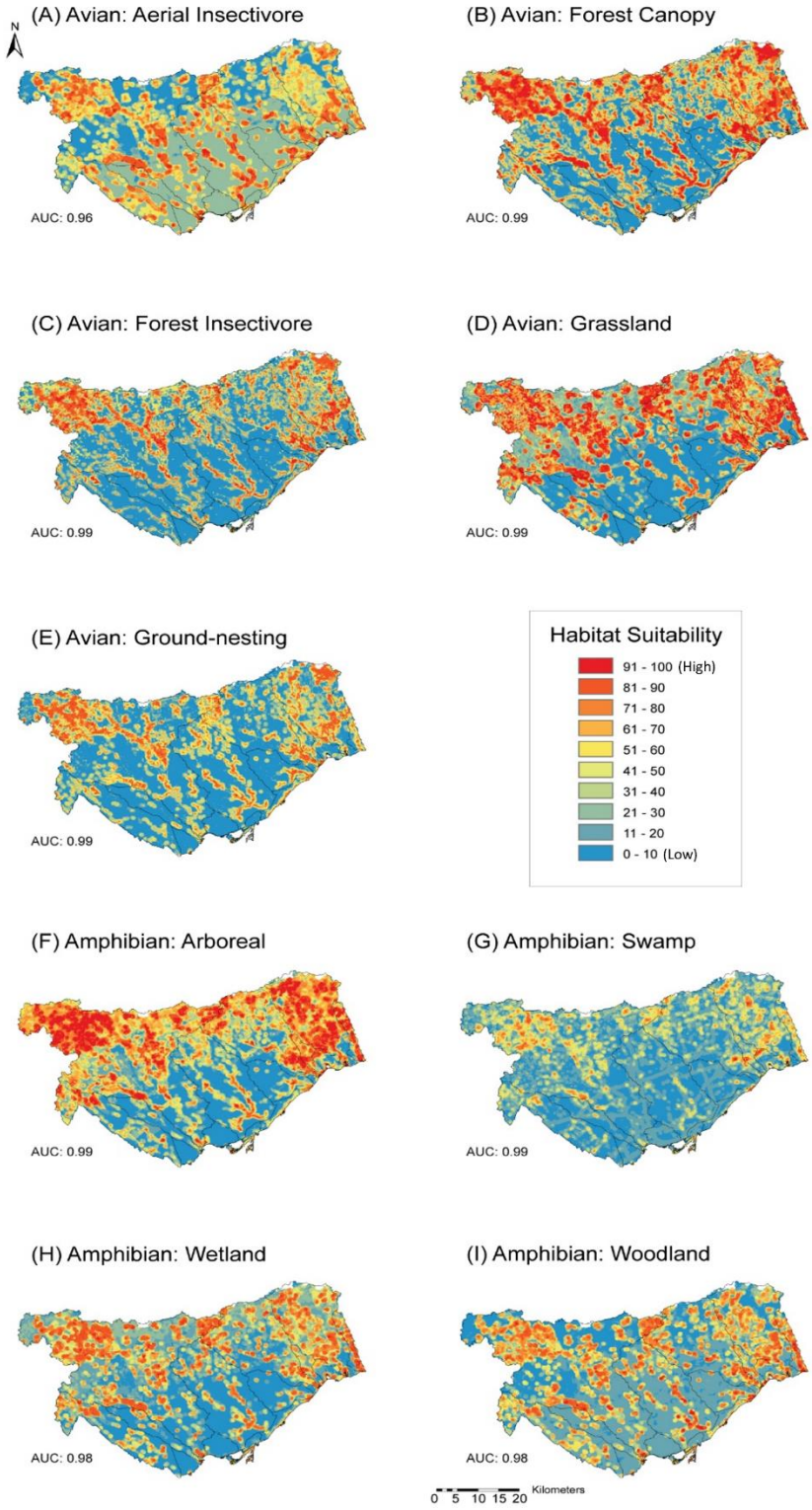


Figure 7: Habitat suitability maps of five avian (A-E) and four amphibian (F-I) functional trait groups.

3.2.4. Aquatic habitat suitability

TRCA's jurisdiction has the most densely populated watersheds within Canada where more than 50% of land use and land cover is urbanized and is dominated by impervious built cover such as roads, parking lots, buildings etc. This high amount of imperviousness, mostly resulting from natural cover changes to impervious surfaces, represents a key driver of change to fish habitat in urban streams. To better understand the effect of urbanization on fish habitat, a modelling approach to assess habitat suitability for fish species was used across TRCA's jurisdiction. This aligns with the terrestrial Habitat Suitability Analysis (HSA) discussed in section 3.2.3.

HSA for fish species was completed for six identified Functional Trait Groups (FTGs) of fish species (coldwater, coolwater, continuous-slow flow, strong flow, warmwater, and slow-warmwater) found in TRCA's jurisdiction. FTGs are distinct groups of species classified based on their similar requirements, characteristics, and ability to adapt to the urban environment (TRCA 2022a). The environment could span from natural to urban areas. The Functional Trait Analysis was used to identify these FTGs using the presence-absence data on 30 fish species collected between 2001-2019 and their key traits/characteristics including migration, adult substrate preference, thermal tolerance, spawning temperature, stream flow preference, nest guarding, and maximum total length. The identified six FTGs' instream habitat segments were then related to the broader landscape by delineating a Reach Contributing Area (RCA) and calculating three key landscape characteristics including riparian cover, imperviousness, and stream order for each RCA. These variables were used as independent variable in HSA (using the Boosted Regression Tree method (Elith et al. 2006)) that identified the priority ranking of each RCA for fish FTGs. (For additional details refer to the technical report TRCA 2022a)

Figure 8 from the HSA results for four FTGs of fish with the best predictive models (continuous-slow flow, coldwater, warmwater, strong flow). Notably, these FTGs were influenced by the type of riparian cover and/or were sensitive to stream order at the RCA-level. It is evident that most of the priority RCAs for coldwater fish species groups are concentrated in the RCAs with less built/impervious and more natural areas. For other FTGs of fish the results are more scattered and individual RCAs characteristics become more important determinant of priorities. Unfortunately, not all FTGs (slow-warmwater, coolwater) produced well-fitting models for habitat suitability based on RCA-level landscape characteristics potentially due to rarity or unmeasured in-stream habitat characteristics. While the rarer slow-warmwater species group is more adapted to lower amounts of natural cover, coolwater species are sensitive to landcover that would result in the increase of in-stream temperatures. This demonstrates the importance modelling with in-stream temperatures such as identifying coolwater streams that could not be identified from landscape characteristics.

The HSA results for fish FTGs provide important information on priority conservation areas in the upland areas that contribute to the quality of in-stream fish habitat. These data layers will be used as input layers in TRCA's updated regional target NHS to ensure aquatic habitat and biodiversity needs are incorporated.

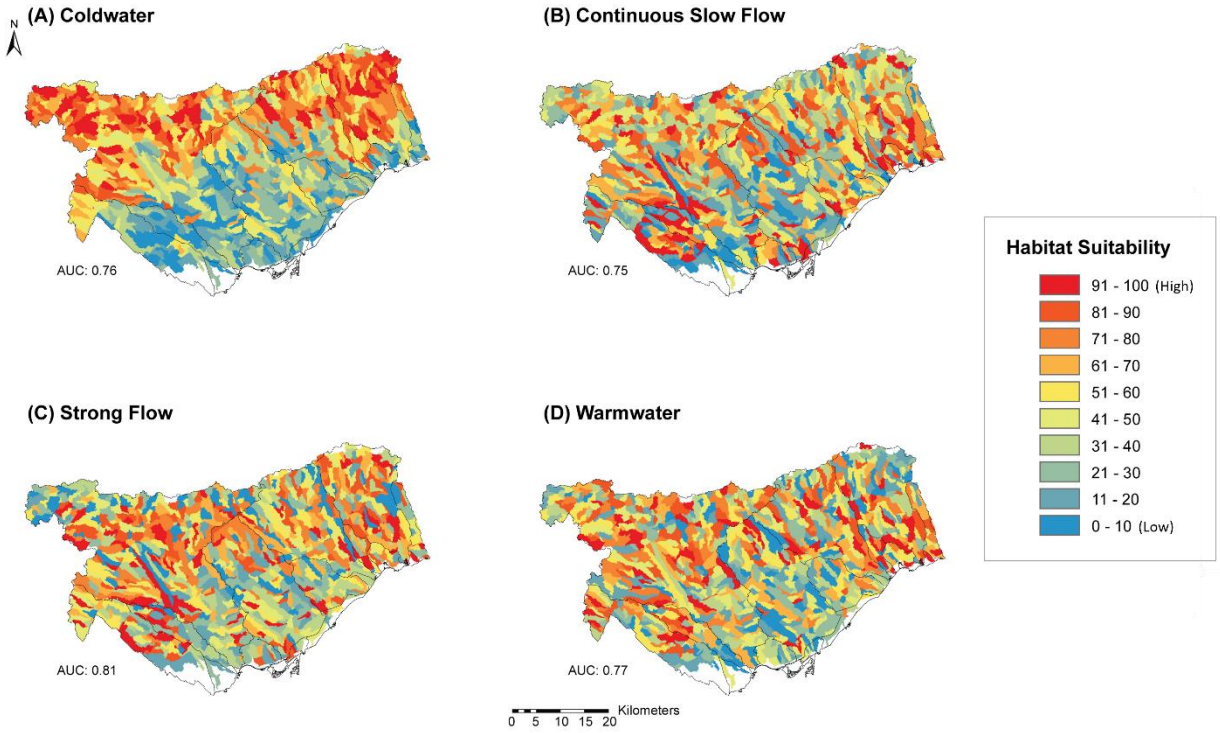


Figure 8: Habitat suitability maps of fish functional trait groups: (A) coldwater, (B) continuous slow flow, (C) strong flow, and (D) warmwater within 125-ha reach contributing areas.

3.2.5. Ecologically Significant Groundwater Recharge Area (ESGRA)

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 (Greenbelt Plan 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 to predict where groundwater recharge at a given location will emerge or "discharge" within ecologically sensitive areas (for more details on methods refer to TRCA 2019).

Figure 9 shows the distribution of ESGRAs in TRCA's jurisdiction. Many of the ESGRAs are concentrated in the natural areas across the jurisdiction indicating the importance of linkages for groundwater-dependent ecosystems including groundwater-obligate wetland flora, coldwater aquatic habitat, and fen wetland communities. Particularly, the Greenbelt and northern parts of the jurisdiction as well as ravines act as major recharge areas. Additionally, some ESGRAs extend beyond natural areas into built portions of the landscape because of the hydrological linkages of these ground water dependent ecosystems as recharge areas through their subsurface linkages.

Mapping ESGRAs helps to identify areas important for groundwater recharge functions that can inform various protection, restoration, and green infrastructure and LID implementation initiatives. The protection of natural heritage features and areas, such as streams and wetlands, are connected to ESGRAs and their recharge function. This will continue to support important ecological functions, including provision of habitat for groundwater-dependent plants and wildlife. ESGRAs are also identified as important component of watershed planning and are included in the definitions of significant groundwater recharge areas in the Growth Plan for the Greater Golden Horseshoe (Growth Plan) (2019) and Greenbelt Plan (2017). Mapping of ESGRAs is used as one of the inputs in the updated NHS.

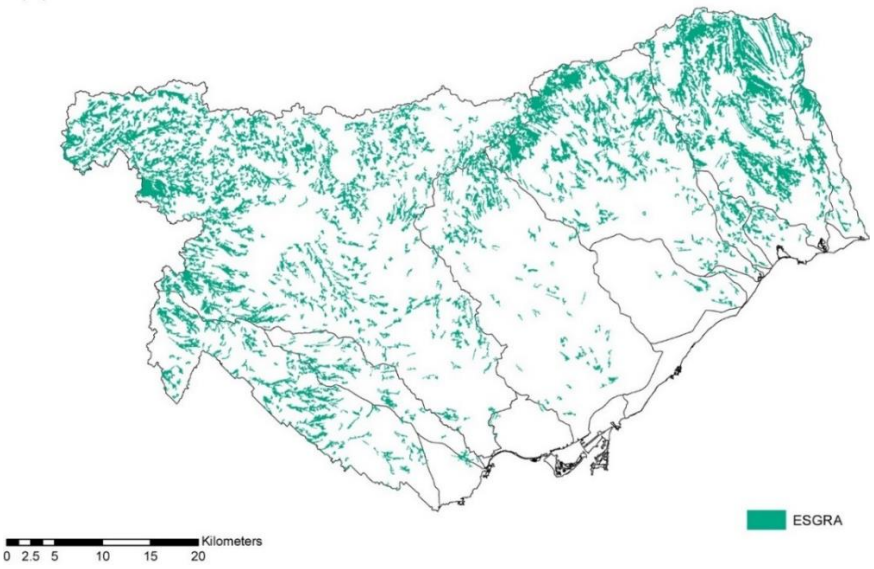


Figure 9: Map of the Ecologically Significant Groundwater Recharge Area (ESGRA) across TRCA jurisdiction.

3.3. Phase 3: Integration for target NHS

Phase III of the project focuses on objective 6 and 7 to integrate all the data layers to delineate the TRCA's updated regional target NHS and to engage TRCA's partner municipalities and conservation authorities, indigenous communities, and key stakeholders for their feedback and information on the mapping products. This phase also includes a rapid assessment of implications of potential land use and climate change on the TRCA's updated regional target NHS mapping.

3.3.1. Delineating TRCA's updated regional target NHS

TRCA's updated regional target NHS was delineated based on 36 criteria that represents different natural heritage features and areas, ecological functions, and municipal NHS priorities. Many of existing key natural heritage features and areas were included within TRCA's updated regional target NHS in line with the Natural Heritage Reference Manual (OMNR 2005).

To identify additional areas an optimization model called Marxan was used that helped integrate all criteria and identify the most strategic locations to maximize the highest functioning areas for each criteria. The model output was then processed further based on refined information and expert knowledge. The following sections will describe each step in more detail (additional details are provided in the technical document available upon request).

3.3.1.1. Criteria

In total, 36 ecological criteria and an additional landscape cost variable reflecting the difficulty to be included in the NHS were used in the Marxan analysis (Appendix I). These criteria were selected based on the Provincial Policy Statement (2020) definition of NHS that highlights the importance of existing natural cover as well as other areas that support various ecological and hydrological features and functions including linkages that could be existing currently and/or restored in future across the landscape.

The 36 criteria used are broadly classified into four groups for ease of communications – namely locked-in features and areas, aquatic ecological function-based criteria, terrestrial ecological function-based criteria, and municipal NHS.

Locked-in Criteria

Locked-in areas include eight criteria that represent key natural heritage features and areas such as wetlands, woodlands etc. that are based on available data and are deemed critical for the NHS and are included by default into the TRCA's updated regional target NHS. This aligns with the definition of the NHS in PPS (2020) with the difference that PPS focuses on significant features, however for TRCA's updated regional target NHS all existing natural heritage features are included. This is important given

that TRCA's jurisdiction is highly urbanized and has limited and fragmented natural cover, which should be protected and enhanced, where possible, to make the overall NHS more resilient. These key natural heritage features and areas include the following

1. ***Wetlands:*** This layer encompasses TRCA's natural cover data (TRCA 2017) identified from orthophotos, Ecological Land Classification (ELC) at vegetation communities' level (TRCA 2021), and provincial wetland data including provincially significant wetlands (NDMNRF 2021), and restored wetlands in TRCA's jurisdiction (2021).
2. ***Fish Habitat:*** These features are associated with the regulated watercourse layer (TRCA) and a 10-m buffer and directly account for aquatic habitat. All fish habitat are considered equal under the *Fisheries Act* of Canada.
3. ***Woodlands:*** All forest and successional forest natural cover derived from orthophotography and restored forests through TRCA were considered as woodland due to the importance of protecting remnant existing natural cover in this landscape.
4. ***Valleylands:*** Valleylands are represented by the crest of slope, which therefore include all areas that are riparian within valleys and ravines. The crest of slope is within regulation mapping as part of TRCA Regulated Area throughout the jurisdiction.
5. ***Wildlife Habitat:*** Ecologically Significant Areas (ESAs 2015) identified by the City of Toronto, Areas of Natural and Scientific Interest (ANSIs) identified by province (NDMNRF 2020), and migratory habitat for birds including all natural cover within 5-km buffers from the Lake Ontario shoreline (OMNR 2005; Archibald et al. 2017) were included as additional wildlife habitat.
6. ***TRCA Conservation Lands:*** Natural cover including wetlands, forests, successional areas, meadows, and beach and bluffs within TRCA property were included in the TRCA's updated regional target NHS.
7. ***Areas of Natural and Scientific Interest (ANSI):*** Areas of Natural and Scientific Interest (ANSI) are relevant to natural heritage protection in addition to scientific study or education. ANSI areas are protected under the Planning Act (1990) and Natural Heritage policies of the Provincial Policy Statement (2020). These areas have natural landscapes or features that have been identified as important for life science or earth science values. Life science is relevant for biodiversity and natural landscapes that are relatively undisturbed vegetation and landforms. Earth science is geological in nature and represent significant landforms in Ontario and may be exemplar for ongoing geological processes.
8. ***Habitat of Endangered and Threatened Species:*** As part of the consideration of the previous 7 criteria, habitat of endangered and threatened species relies on the protection of these features. Any habitat loss and disturbances to natural cover will result in greater vulnerability for these species. Similarly, these criteria are in line the focus of L-rank fauna, flora, and vegetation communities at TRCA to maintain both the quality and quantity of natural cover (TRCA 2017).

Terrestrial and Aquatic Ecology Functions-based Criteria

Other planning units were then based on 27 ecological function-based criteria in addition to the municipal natural heritage systems (Table 1). Ecological criteria were based on terrestrial and aquatic ecosystem features that would indicate planning units that were valuable to conserve. Terrestrial features were based on habitat suitability, connectivity, biodiversity, and natural cover (Table 1). Ecological criteria for aquatic ecosystem features were based on habitat suitability, Ecologically Significant Groundwater Recharge Areas (ESGRAs), and percentage of riparian natural cover and forest cover at the reach contributing area (RCA) level (Table 1). Percentage of riparian natural cover and forest cover was summarized by 30-m buffers of the watercourse accounting for estimated stream width.

Municipal NHS

Finally, we deemed that the municipal natural heritage systems (see section 3.1.1) may add protection to prevent development in these areas and account for the municipal priorities that may be associated in these areas. Consequently, municipal natural heritage planning units are not guaranteed to be protected and are not locked-in for the Marxan analysis.

Table 1: List of 36 criteria and cost relating to ecological and natural heritage system (NHS) features that are included in the Marxan analysis. Beige sections are locked-in criteria. Bracketed numbers are the number of criteria involved in each of the categories.

Category	Type	Date	Source	Summary
Locked-in ecological & NHS feature and area (8)	Wetlands	2020	TRCA	• TRCA updated wetland for Water Resource System (2020) including Provincially Significant Wetlands (PSWs), wetlands identified using ELC, natural cover (orthophotos), planner notes • Restored wetlands • All wetlands are represented
	Fish Habitat	2020	TRCA	• Existing mapped watercourses with a 10-m buffer • All watercourses are represented
	Woodlands	2017	TRCA	• All forests and successional forest are represented
	Valleylands	2019	TRCA	• Represented by crest of slope
	Wildlife Habitat	2017	City of Toronto TRCA	• Includes Toronto Environmentally Significant Areas (ESA), migratory bird habitat (all natural cover 5 km from shoreline; OMNR 2005; Archibald et al. 2017)
	TRCA Conservation Lands	2015	City of Toronto	• All natural cover within TRCA property are represented
	Areas of Natural and Scientific Interest (ANSI)	2020	Ontario Ministry of Natural Resources and Forestry	• Consists of Earth and Life Science
	Habitat of endangered and threatened species	2017	TRCA	• Mainly included by criteria above
Ecological Function-based Criteria: Terrestrial (20)	Remaining natural cover	2017	TRCA	• Includes any remaining natural cover not locked-in above
	9 Habitat suitability analysis (HSA)	2020	TRCA	• Habitat suitability of avian and amphibian functional trait groups (see section 3.2.1.3)
	4 Connectivity	2020	TRCA	• Pinchpoint connectivity of avian and amphibian movement guilds (see section 3.2.1.2)
	3 Alpha diversity (richness)	2020	TRCA	• L1-L3 types of flora, avian, ELC (see section 3.2.1.1)
	3 Beta diversity	2020	TRCA	• L1-L3 types of flora, avian, ELC (see section 3.2.1.1)
Ecological Function-based Criteria: Aquatic (7)	2 Riparian natural cover	2020	TRCA	• All natural cover and forest cover as riparian cover summarized for reach contributing areas (RCAs)
	4 HSA	2020	TRCA	• Habitat suitability of fish functional trait groups (see section 3.2.2.1)
	ESGRA	2020	TRCA	• Presence of ESGRA (see section 3.2.2.2)
Municipal NHS (1)	Municipality NHS in their existing Official Plans (as of 2017 but refined for major changes by 2020)	2020	TRCA	• Municipal Terrestrial Natural Heritage System (see section 3.1.1)

3.3.1.2. Criteria Integration

The 36 criteria for delineating TRCA's updated regional target NHS was integrated using a tool called Marxan and then conducting additional post-processing to incorporate expert knowledge and refined information on the ground that was available through engagement process.

Marxan Modeling

Marxan is an optimization modelling tool that has been widely used for conservation planning purposes to identify reserve systems (Ball et al. 2009). It achieves the targeted conservation goals, such as ecological representation within individual planning units (e.g., one hectare hexagons) based on a set of criteria. Marxan functions as a separate software and data was compiled in ArcGIS to support the input in Marxan. Targets were then set for the individual criterion and Marxan aims to identify the most strategic areas that maximizes the set target for all criteria with minimal cost. Locked-in criteria are first included in the selection and the remaining solution accounts for the rest of the criteria for the optimization. The final output from Marxan identifies the specific planning units as the solution from the optimization process. The resulting data layer was further refined using expert knowledge, land cover and land use data, and feedback from the engagement process to recommend management options (see below).

For TRCA's updated regional target NHS, Marxan model was run at one hectare resolution at two different spatial extents – a regional and a watershed extent. Out of the 36 criteria layers, 8 were locked-in and was automatically included in all models runs. The remaining 28 criteria were used to identify additional strategic priority areas that helped to meet the set targets for each of the 36 criteria layers at both scales.

The targets were set such that at the top 50% and top 40% of the highest functioning areas were selected at the regional scale and the watershed scale, respectively. In other words, TRCA's updated regional target NHS would identify close to 50% of the areas regionally and 40% of the areas for each watershed that are priority for natural heritage features and functions. These targets are in line with the updated recommendations that suggest that in highly fragmented landscapes such as areas dominated by urban and/or agricultural land uses, close to half of the area is needed to ensure natural system resilience (Chan et al. 2006, Crossman et al. 2007, Vallecilli et al. 2018, Crist et al. 2021).

Final Results and Refinements

Figure 10a and 10b shows the outputs for the regional and watershed scale analysis, which were then combined to get the final priorities that captured the needs of both regional and watershed scales (Figure 10c). This approach ensured that the updated NHS recognized the overall regional needs without undermining the individual watershed priorities, needs, and opportunities. For example, the priorities, needs, and opportunities for protection, restoration, and enhancements in a highly urbanized watershed (e.g., Etobicoke) may not be captured if only a regional scale is evaluated, which will be biased towards a

more natural area dominated watershed. This will compromise the health of the urban watersheds that would then compromise the overall health and resilience of the region over the long term.

The regional scale output (Figure 10a) includes about 48.3% of TRCA's jurisdiction to meet the set criteria of top 50% ecologically functioning areas. Out of this about half comprising of 25% of the region are locked-in area and remaining are selected based on the ecological functions as identified by the ecological criteria used. As expected, most of the selected areas at the regional scale are in the relatively natural parts of the region (e.g., northern and eastern portions of the region and in the ravine systems) as these are ecologically most functioning areas. Thus, at regional scale the priorities are biased towards the naturalized portions of the region and does not capture a more local priorities such as of urbanized watersheds.

The watershed scale output (Figure 10b) includes about 48.6% of TRCA's jurisdiction, which totals to the similar amount as the regional scale. However, the distribution of the selected areas is different at this scale. The locked-in area in each watershed is different and varies from about 20% in a more urbanized watersheds such as Mimico to about 64% in a more naturalized watershed such as Duffins. To meet the set target of 40% of each watershed Marxan algorithm selected all the locked in areas first and then tried to represent top 40% of the ecological functions for each watershed. In doing so, the algorithm identified same amount of priority areas in urbanized watersheds as in the more naturalized watersheds (which is close to 40%). This when combined resulted in the total of about 48.6% of the jurisdiction.

It is worth noting that in urbanized watersheds, not all identified areas may have opportunities for traditional management actions for NHS like protection or restoration activities such as in areas with built forms like parking lots and residential houses. However, these areas could be targeted for enhancements through various green infrastructure and low impact development implementation including urban canopy enhancements through tree planting, native gardens, naturalized ponds, permeable pavements etc. These management actions along with protection and restoration together can strengthen the health and resilience of NHS functions across urban-rural gradient in TRCA's jurisdiction.

Given that the regional and watershed level analysis identifies different but important areas for conservation of ecosystem functions and services across urban-rural gradient, TRCA's updated regional target NHS combined the identified priorities as a hybrid solution (Figure 10c). The hybrid map includes about 52% of the jurisdiction and ensures that the top 50% of the region and top 40% of all watersheds are represented in the TRCA's regional target NHS.

Furthermore, the hybrid map was further refined based on available land use and land cover data, expert knowledge, and engagement feedback from stakeholders and identified priority areas were classified into three tiers to inform appropriate management recommendations using the decision tree presented in Figure 11.

The final output mapping showcases the:

- **Existing natural cover (ENC)** - Includes about 23.3% of the jurisdiction that comprise of natural cover such as locked in features and areas that are important for natural heritage functions that could be targeted for protection.
- **Potential natural cover (PNC)** – Includes about 11.9% of the jurisdiction and comprise of expanded areas important for natural heritage functions that could be targeted for restoration, if feasible, with willing landowners.
- **Contributing areas** – Includes additional 16.5% of the jurisdiction that comprise of areas important for natural heritage functions BUT where traditional protection and restoration are likely not feasible and could be targeted for Low Impact Development and Green Infrastructure implementation with willing landowners. This could be further classified by built or un-built/open area land use types which can provide further insights into what type of activities are possible with willing landowners.

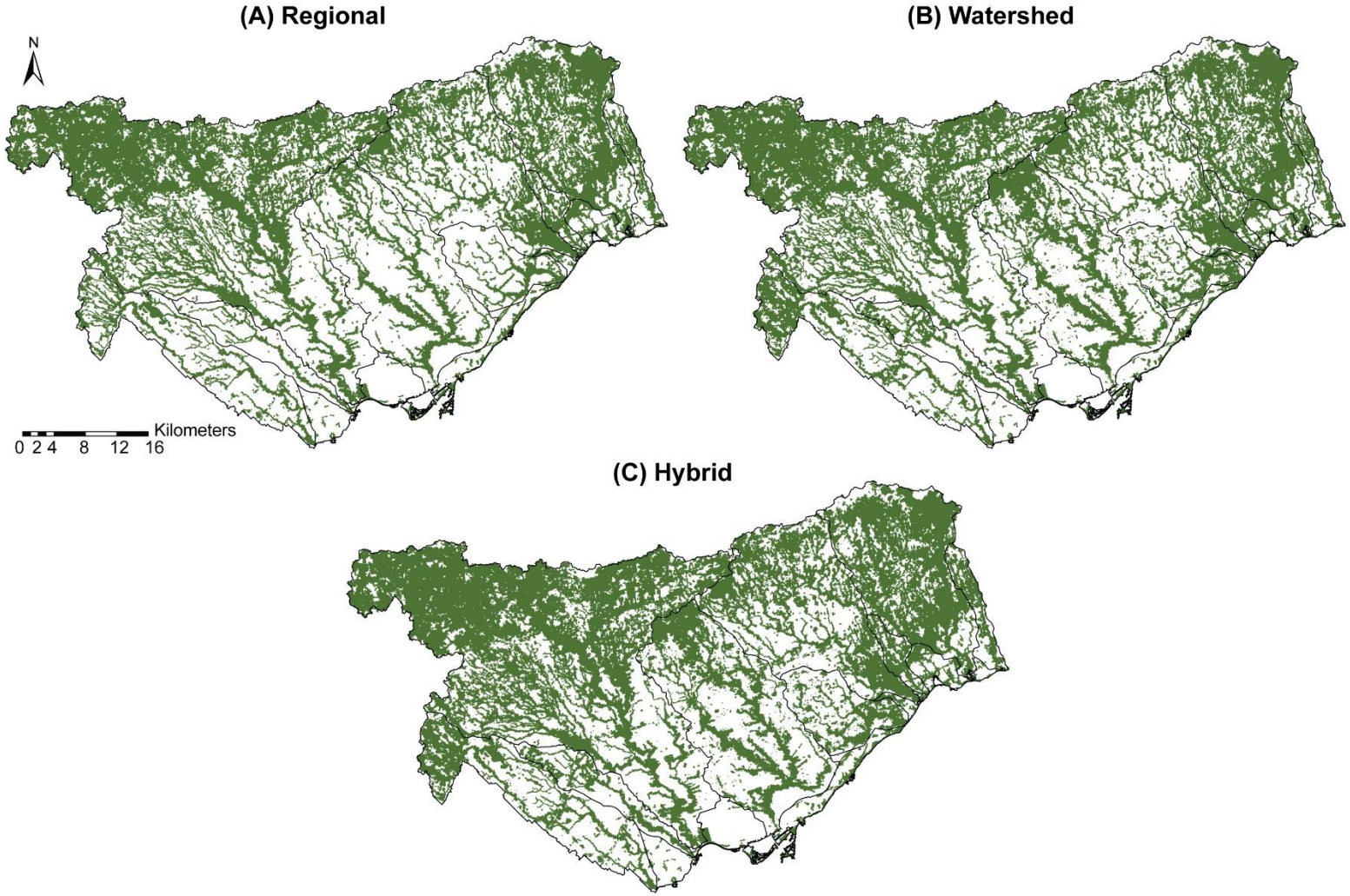


Figure 10: Comparison of Marxan solutions for (A) regional level, (B) watershed level, and (C) hybrid approach.

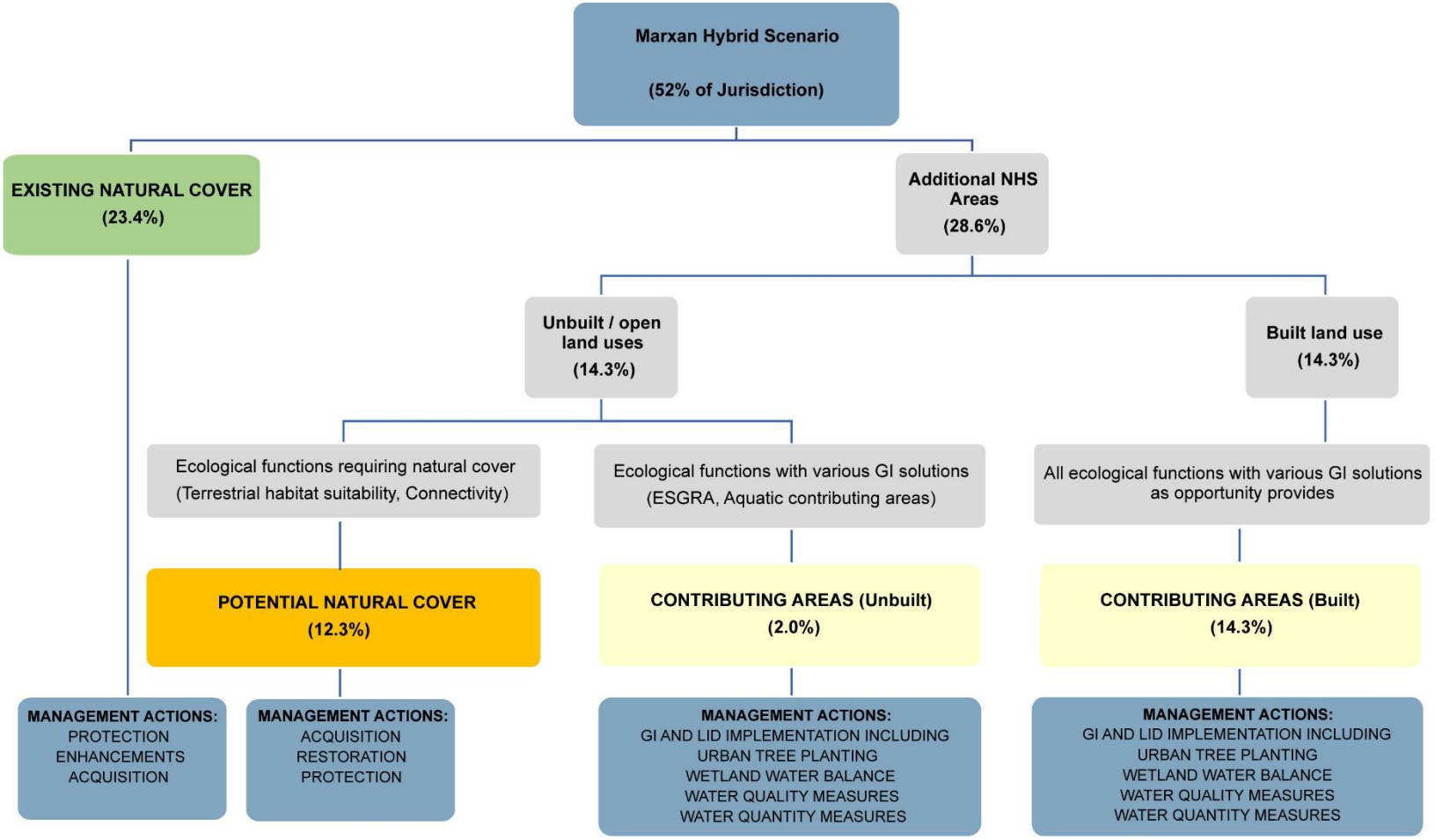


Figure 11: Tiered classification of the TRCA's updated regional target NHS into the Existing Natural Cover, Potential Natural Cover, and Contributing Areas.

TRCA's updated regional target Natural Heritage System (NHS)

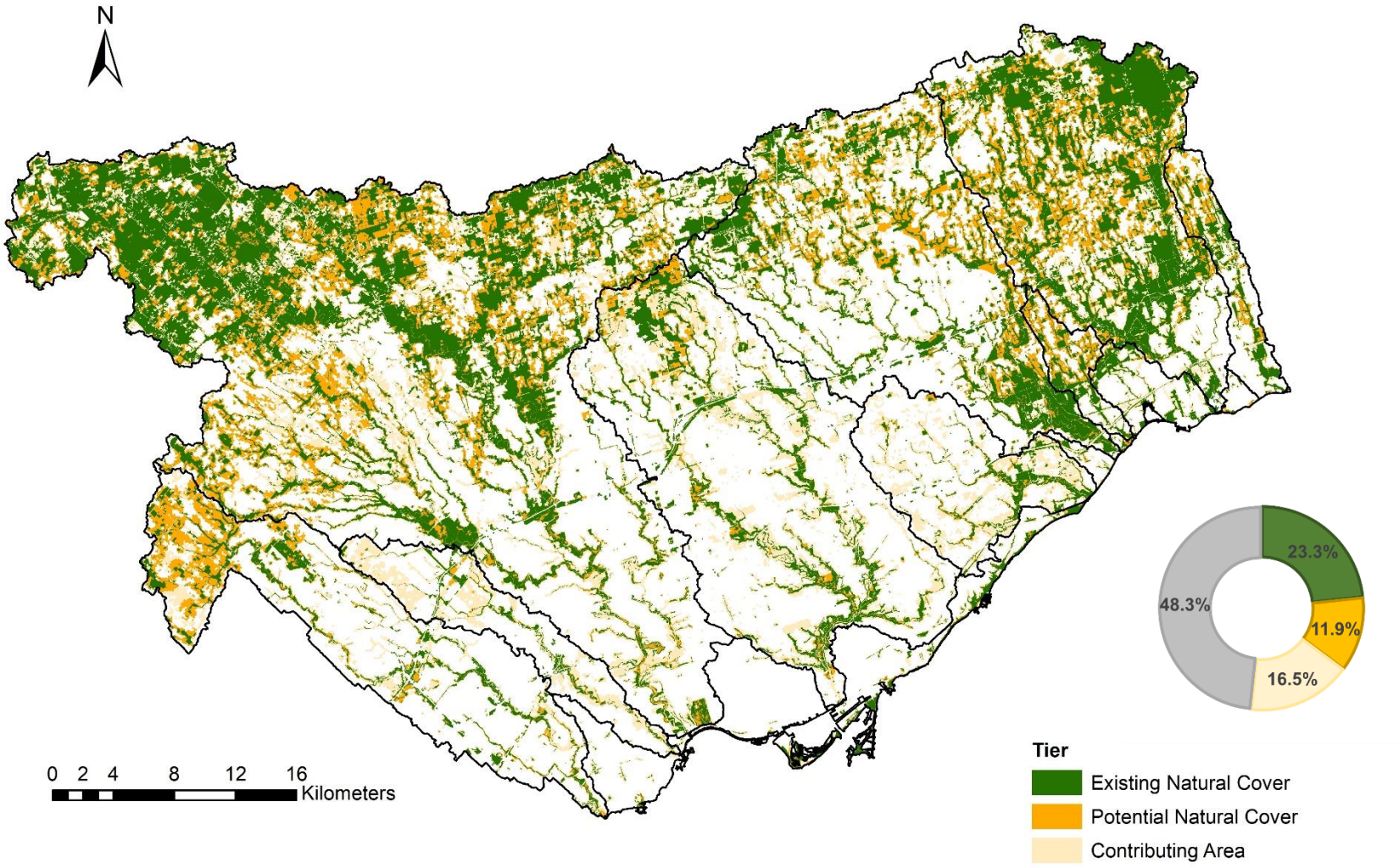


Figure 12: TRCA's updated regional target NHS with the Existing Natural Cover, Potential Natural Cover, and Contributing Areas.

Table 2: TRCA's updated regional target NHS distribution across watersheds based on the percentage of the jurisdiction.

Tier	Percentage of jurisdiction										
	Total tier	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers	Waterfront
Existing natural cover	**58001 ha**	2293 ha	560 ha	28053 ha	4361 ha	991 ha	7499 ha	661 ha	11154 ha	949 ha	1480 ha
	(23.3%)	(0.9%)	(0.2%)	(11.3%)	(1.8%)	(0.4%)	(3.0%)	(0.3%)	(4.5%)	(0.4%)	(0.6%)
Potential natural cover	**29614 ha**	2614 ha	129 ha	13677 ha	1203 ha	208 ha	4623 ha	622 ha	5543 ha	670 ha	260 ha
	(11.9%)	(1.1%)	(0.1%)	(5.5%)	(0.5%)	(0.1%)	(1.9%)	(0.3%)	(2.2%)	(0.3%)	(0.1%)
Contributing areas	**40989 ha**	3033 ha	2224 ha	14418 ha	8113 ha	2955 ha	4340 ha	295 ha	3290 ha	518 ha	1642 ha
	(16.5%)	(1.2%)	(0.9%)	(5.8%)	(3.3%)	(1.2%)	(1.7%)	(0.1%)	(1.3%)	(0.2%)	(0.7%)
Grand total	**128604 ha**	**7940 ha**	**2912 ha**	**56148 ha**	**13678 ha**	**4154 ha**	**16531 ha**	**1578 ha**	**19987 ha**	**2137 ha**	**3382 ha**
	(51.7%)	**(3.2%)**	**(1.2%)**	**(22.6%)**	**(5.5%)**	**(1.7%)**	**(6.6%)**	**(0.6%)**	**(8.0%)**	**(0.9%)**	**(1.4%)**

Table 3: TRCA's updated regional target NHS distribution across watersheds based on the percentage of each watershed.

Tier	Percentage of each watershed									
	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers	Waterfront
Existing natural cover	10.8%	7.4%	30.8%	12.2%	9.4%	22.4%	27.4%	39.5%	23.9%	10.2%
Potential natural cover	12.3%	1.7%	15.0%	3.4%	2.0%	14.0%	25.8%	19.6%	16.9%	1.8%
Contributing areas	14.3%	29.4%	15.8%	22.7%	27.9%	13.4%	12.2%	11.7%	13.0%	11.3%
Watershed total	**37.4%**	**38.6%**	**61.7%**	**38.3%**	**39.3%**	**49.8%**	**65.3%**	**70.8%**	**53.8%**	**23.3%**

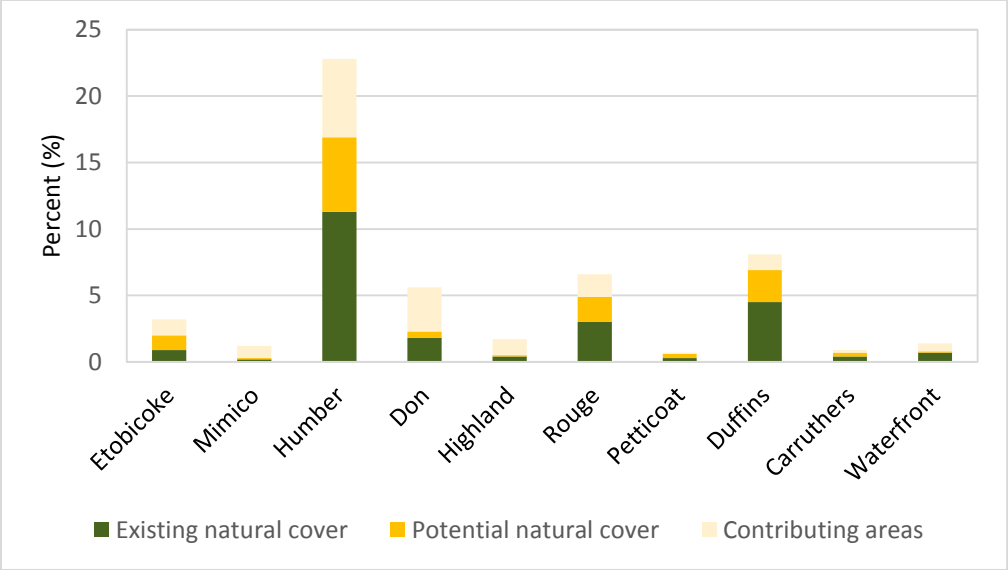


Figure 13: TRCA's updated regional target NHS across watersheds based on the percentage of the jurisdiction.

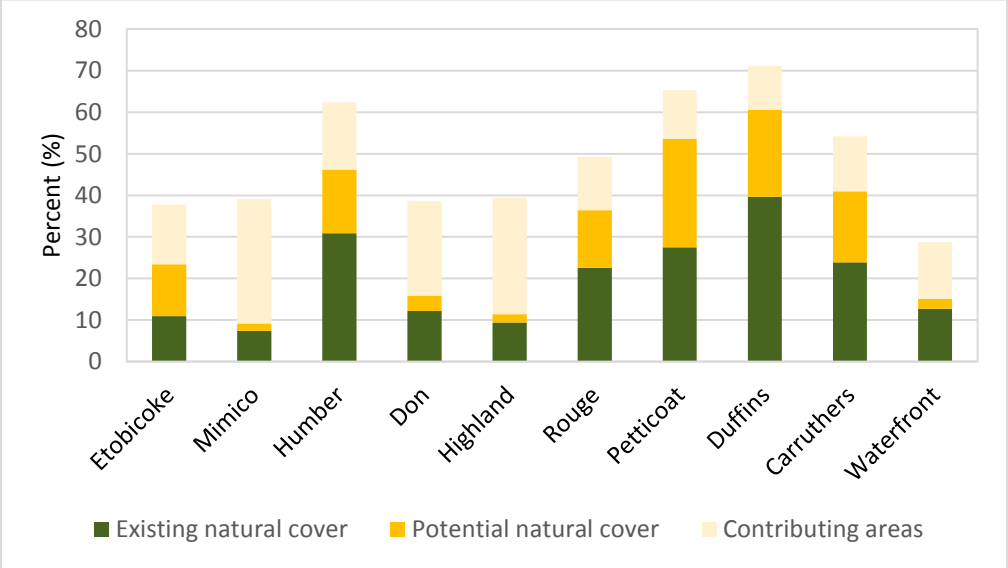


Figure 14: TRCA's updated regional target NHS across watersheds based on the percentage of each watershed.

3.3.2. Target NHS and future land use and climate implications

3.3.2.1. Future land use implications

Urbanization in Toronto and region is ever increasing with urban land uses making up more than half of land cover within the jurisdiction. This is expected to continue with population growth expected to increase towards the mid-century (Ontario Ministry of Finance 2020). Many municipalities in Toronto and Region have included potential urban expansion areas in their recent draft Official Plan updates to accommodate these increases (Peel Official Plan, Durham Official Plan, York Official Plan). Urbanization alters biodiversity across the landscape by converting natural landcover to urban land uses dominated by built surfaces, which adversely affects habitat and biodiversity (Johnson and Munshi-South 2017, Nelson et al. 2009, Turrini and Knop 2015). These negative impacts can be mitigated to some extent by reducing urban sprawl and intensifying development within city boundaries using sustainable urban design and ecosystem sensitive design solutions. These solutions help support human population growth as well as provide opportunities for healthy and resilient ecosystem functions and services that benefit ecology and community well-being (Milder 2012, Norton et al. 2016).

In Ontario the Provincial Policy Statement (PPS 2020) recognizes the challenges associated with urbanization and thus provides guidance to municipalities to identify and adequately protect the important areas for natural heritage and water resource systems. It provides guidance through multiple provincial plans such as the Greenbelt Plan (2020), Oak Ridges Moraine Plan (2020), Niagara Escarpment Plan (2020), and the Growth plan (2020). Furthermore, PPS directs municipalities to identify NHS and WRS in their Official Plans and provide details on protecting and enhancing them. TRCA's updated regional target NHS provides a science-based information and screening tool for partner municipalities to achieve their NHS goals and objectives in their Official Plans as well as in subsequent land use and infrastructure planning processes.

Table 4 and Figure 15 highlights the distribution of TRCA's regional target NHS across the three broad land use zones in TRCA's jurisdiction; Greenbelt, Whitebelt, and Urban Zones. This analysis provides a breakdown of TRCA's updated regional target NHS distribution in each of these land use zone to provide insights on implementation opportunities and challenges.

Table 4: TRCA's updated regional target NHS distribution across Greenbelt, Whitebelt, and Urban portions of TRCA jurisdiction.

Tier	Total	Percent of TRCA Jurisdiction that is Target NHS and Contributing Areas		
		Greenbelt Zone	Whitebelt Zone	Urban Zone
Existing Natural Cover	23.3%	38063 ha	2624 ha	17287 ha
		(15.3%)	(1.1%)	(7.0%)
Potential Natural Cover	11.9%	18774 ha	5242 ha	5592 ha
		(7.5%)	(2.1%)	(2.2%)
Contributing Area	16.5%	9042 ha	2851 ha	29085 ha
		(3.6%)	(1.1%)	(11.7%)

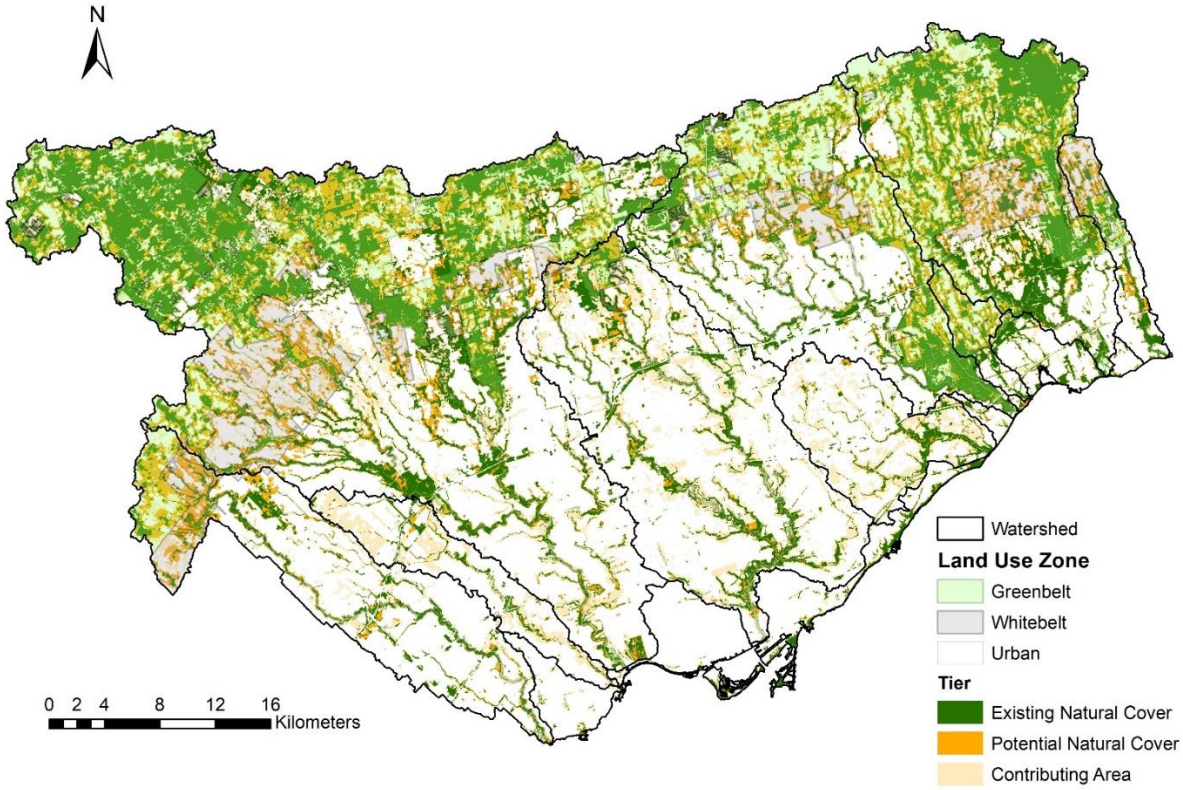


Figure 15: Land use zones and their overlap with the target Natural Heritage System 2022.

Greenbelt Zone includes areas within the Greenbelt including the provincial NHS and protected countryside designations. These areas are deemed safer from land use changes unless modifications are made to the Greenbelt Act. These areas are often restricted from development and provides greater level of protection from urbanization and land use changes. Most of the existing natural cover (15.3% out of 23% jurisdiction wide) is found to be within the Greenbelt, which indicates that they have better protection from future land use changes. It also contains some potential natural cover areas (7.5% out of 12%) that provides opportunities for restoration with willing landowners. The contributing areas in the Greenbelt Zone are limited (about 3.6% out of 16%) and could provide a good opportunity for implementation of various green infrastructure and LID in rural context, where restoration may not be possible.

Whitebelt Zone includes areas that are not currently urban but may be open to future urbanization as deemed necessary through Official Planning processes. These areas mostly include farmlands and some natural areas, mostly within the valley and stream corridors and conservation lands. These areas do not warrant same level of protection from urbanization, unless there are other regulatory provisions in place (e.g. wetlands, flood and erosion hazard etc.). This zone includes limited amount of existing and potential natural cover of TRCA's updated regional target NHS at about 1% and 2% respectively. There is also limited contributing areas (about 1%). This is largely because most of this zone is dominated by agricultural lands and has limited natural cover to start with. In addition, these areas mostly have undefined valley and stream corridors that limits riparian natural areas as well. Despite the limited natural areas, the identified target NHS areas in this zone still make up about 10,000 hectares that could be either protected, restored, and enhanced through land use and infrastructure planning

processes and/or conservation planning initiatives or alternately, degraded and lost to future urbanization, which will affect the overall regional NHS objectives.

Urban Zone includes areas within current urban boundaries. Most of the areas have already been converted to urban land uses with some remnant natural cover, mostly within valley and stream corridors and conservation lands. Despite being heavily urbanized, this zone includes about substantial portion of existing natural cover identified in the TRCA's updated regional target NHS (7% out of 23%). These areas warrant protection that are often provided through regulations related to valley and stream corridors and wetland protection and other municipal regulations such as City of Toronto's Ecologically Significant Areas. This zone also includes some potential natural cover areas for restoration (2.2% out of 12% identified in the target NHS), which are often around existing natural cover that can bolster the ecological functions of the existing natural heritage. Additionally, the urban zone includes large portion of the contributing areas (11.7% of the 16% identified in the target NHS) that can support the ecological functions of the existing and potential natural cover areas. These are largely in the built land uses and implementation of various green infrastructure and low impact development such as urban forest canopy enhancement, native gardens, meadow restoration, naturalized ponds, green roofs, permeable pavements etc. to make urban areas more ecological and hydrologically functional and reduce the negative impacts of urban matrix.

The urban areas, which remnant habitat are the existing natural cover representing 17,287 ha (7%) of the NHS in the jurisdiction. There is the smallest opportunity for potential natural cover with 5,592 ha (2.2%) available compared to all the land use zones due to the majority of areas being built in the jurisdiction. In urban areas, enhancement opportunities will rely heavily on contributing areas (29,085 ha, 11.7%). By considering these contributing areas, whether through green infrastructure implementation such as urban forest canopy or low impact development, the influence of the urban matrix could be reduced and enhance the habitat quality of the remnant existing natural cover to ensure ecosystem function.

Across Toronto and region, there are areas where future urban development and infrastructure is being planned through various land use and infrastructure planning processes (e.g., Seaton lands, Highway 413) as this analysis was being completed. Where information was available, they were used in a post-processing step to refine the TRCA's updated regional target NHS. Mostly, the potential natural cover areas identified in the models were converted to contributing areas recognizing that these areas are important ecologically but may not have the opportunities to undertake traditional restoration. In such cases, TRCA's recommendation is to treat them as contributing areas and prioritize for green infrastructure and LID implementation as appropriate through sustainable urban planning and design principles that incorporates ecological and/or hydrological functions identified for the area.

Furthermore, since the land use and infrastructure planning processes are on-going as per municipal needs, it is important to note that the TRCA's regional target NHS is used as a screening tool and a science-based information for NHS planning at finer scales to achieve the regional NHS goals and objectives, as appropriate. Achieving the protection, restoration, and enhancement opportunities at site level can scale up to ensure a functioning NHS that supports healthy and resilient ecosystems and communities across the region.

3.3.2.2. Future climate change implications

Climate change is one of the major drivers of change for natural systems globally. In Toronto and region, the future projected climate change is expected to intensify climate impacts on the regional natural systems. To mitigate and adapt to the climate impacts for resilient natural systems, it is important to better understand the vulnerability of natural systems to climate change. Improved understanding of what and how climate drivers affect different natural system components can guide impact mitigation and adaptation actions on the ground.

Using the climate change vulnerability assessment (CCVA) results (described in Section 3.1.2.), the TRCA's updated regional target NHS was evaluated to identify how much of medium and high vulnerability areas are included in the target NHS. The improved understanding of the NHS' ability to address climate vulnerabilities of the ecosystem components will help inform management actions as appropriate. Five key vulnerability indicators were used to assess the climate vulnerabilities of natural systems in TRCA's jurisdiction: habitat patch score, climate sensitivity of native vegetation, wetland hydrological stability, soil drainage rating, and ground surface temperature (described in Section 3.1.2). For each of the indicator high and medium vulnerability classes were spatially overlapped with the TRCA's updated regional target NHS to assess how much of these areas are included in the NHS. Table 5, Figure 16, and Figure 17 highlight the results of this analysis.

Table 5: Distribution of climate vulnerable areas (medium and high) in TRCA's updated regional target NHS.

	Climate Vulnerability Indicators									
	Habitat Patch		Climate Sensitive Vegetation		Wetland Vulnerability		Soil Drainage		Ground Surface Temperature	
	Med	High	Med	High	Med	High	Med	High	Med	High
Existing Natural Cover	25209	16069	4333	157	2040	964	10299	16273	23864	2040
	89.6%	75.8%	94.5%	74.0%	100%	100%	19.6%	12.9%	23.7%	2.2%
Potential Natural Cover	1181	1008	80	20	0	0	10937	5298	18794	1520
	4.2%	4.8%	1.7%	9.6%	0%	0%	20.9%	4.2%	18.6%	1.6%
Contributing Areas	948	1496	98	13	0	0	7873	24010	23381	13096
	3.4%	7.1%	2.1%	6.0%	0%	0%	15.0%	19.0%	23.2%	14.2%
Non-NHS areas	805	2629	75	22	0	0	23326	80745	34784	75776
	2.9%	12.4%	1.6%	10.4%	0%	0%	44.5%	63.9%	34.5%	82.0%

Note: Percentages represent the total tier in each climate vulnerability indicator

Overall, most of the identified medium and high vulnerability habitat patches, climate sensitive vegetation, and wetlands are included within the target NHS. However, there are still some areas outside of the target NHS, mostly related to meadow cover that have relatively lower ecological value and was not included in the target NHS. In contrary, for soil drainage and ground surface temperature indicators, the target NHS included much lower percent of the identified medium and high vulnerability areas. This is largely because the first three

indicators are associated with natural cover that NHS could provide better support and the last two indicators are reflective of the landscape conditions and helps to identify where the natural systems have added vulnerability and thus is at a greater risk from climate change impacts. For these two indicators target NHS alone cannot be enough to address the vulnerabilities, rather a broader urban matrix management is needed. Further discussion and distribution of these indicators are illustrated in Figure 14 and 15 and discussed below.

Most of the **habitat patches** with medium and high vulnerabilities to climate are included within the target NHS (17,076 ha or 88% of the high and 26,391 ha or 97% of the medium vulnerability areas) (Figure 15a). Existing natural cover includes about 76% high and 90% medium, potential natural cover includes 5% high and 4% medium, and contributing areas includes about 7% high and 3% medium vulnerability areas. This indicates that in TRCA's jurisdiction most of the climate vulnerable habitat patches are included within the target NHS, thus achieving the target NHS will ensure that the climate vulnerabilities of the habitat patches are mostly addressed, thus ensuring resilient habitats. In addition, this also indicates that the target NHS has substantial areas that are vulnerable to climate impacts, which can act as a threat multiplier when combined with the land use change impacts. Thus, adequate climate adaptation and land use impact mitigation measures need to be put in place in habitat conservation initiatives. There are some climate vulnerable areas (12% of the high and 3% of medium vulnerability areas) are outside the target NHS, which mainly consists of low ecological function meadow habitat patches such as along highway corridors.

Most of the **climate sensitive vegetation** vulnerable to increasing seasonal temperatures and increasing variability in precipitation are included in target NHS (190 ha or 90% of the high and 4,512 ha or 99% of the medium vulnerability areas) (Figure 15b). Existing natural cover includes about 74% high and 95% medium, potential natural cover includes 10% high and 2% medium, and contributing areas includes about 6% high and 2% medium vulnerability areas. Like the first indicator, this one also shows that the target NHS provides adequate support to the climate sensitive vegetation in TRCA's jurisdiction if the management recommendations are achieved in these areas. However, some areas (about 23 ha or 11% of high and medium vulnerability areas) are outside the target NHS. These include mostly coastal vegetation outside of the boundaries of NHS. These areas can be addressed by maintaining the existing natural cover or considering potential natural cover in nearshore areas.

Vulnerable wetlands with limited sources of water inputs (e.g., precipitation fed wetlands), the climate change impacts, specifically replated to precipitation pattern changes, may result in dry conditions for extended periods of time. This makes them more vulnerable to colonization by upland vegetation and invasive species leading to potential adverse impacts. All vulnerable wetlands were included the target NHS (1,021 ha or 100% of the high and 2,141 ha or 100% of the medium vulnerability areas) (Figure 15c). Existing natural cover includes all high and medium vulnerability areas. For these areas, protecting the feature is important but also focus should be on enhancing hydrological connections to the wetland to ensure their long-term resilience. All wetlands were locked-in features and none would be outside of the target NHS.

Unlike the first three indicators, most areas with poor **soil drainage** across the region that may produce shallower root networks and increased potential for localized inundation, contributing to higher relative vulnerability are not included in the target NHS. This indicator helps to identify where the natural systems have

added vulnerability and thus is at a greater risk from climate change impacts. About less than half of the areas with medium and high vulnerability due to soil drainage conditions are included in the target NHS (45,581 ha or 36% of the high and 29,109 ha or 56% of the medium vulnerability areas) (Figure 15d). Existing natural cover includes about 13% high and 20% medium, potential natural cover includes 4% high and 21% medium, and contributing areas includes about 19% high and 15% medium vulnerability areas. All these areas that amounting to thousands of hectares highlight a major challenge to the target NHS. In these areas protecting and restoring features and functions of natural cover alone may not be enough to ensure resilience, given the uncertainties and extreme events that climate change brings about. Additional adaptation measures to address the hydrological and soil conditions will need to be incorporated in the management framework to ensure NHS functions over long term. This analysis also highlights that more than half of the high (67%) and medium (45%) vulnerability areas for soil drainage are outside of target NHS that may have implications on other climate adaptation initiatives that should be addressed to avoid unintended consequences of climate change.

Ground surface temperature represents the potential heat and drought stress throughout the natural system leading to the drying of soil and forest understories, plant heat stress, reduction in natural system thermal regulation, and loss of thermal refuges for heat-intolerant species. Like soil drainage this indicator also helps to identify where the natural systems have added vulnerability and thus is at a greater risk from climate change impacts. About 16,656 ha or 18% of the high and 66,039 ha or 66% of the medium vulnerability areas were included in the target NHS (Figure 15e). Existing natural cover includes about 2% high and 24% medium, potential natural cover includes 2% high and 19% medium, and contributing areas includes about 14% high and 23% medium vulnerability areas. These thousands of hectares of high and medium vulnerability areas in the target NHS are largely due to the high ground surface temperature of the surrounding matrix that is affecting the natural systems, including in the existing features. This vulnerability is reflective of the greater imperviousness and the urban heat island effect. The existing cover might be protected physically but the high vulnerability due to this indicator needs to be managed / mitigated if the ecosystem component is to sustain itself over long term. Likewise, the potential and contributing areas should be restored and enhanced through increasing urban forest canopy by increasing vegetation cover and reducing impervious surfaces, which could reduce the heat impacts on the natural systems overall.

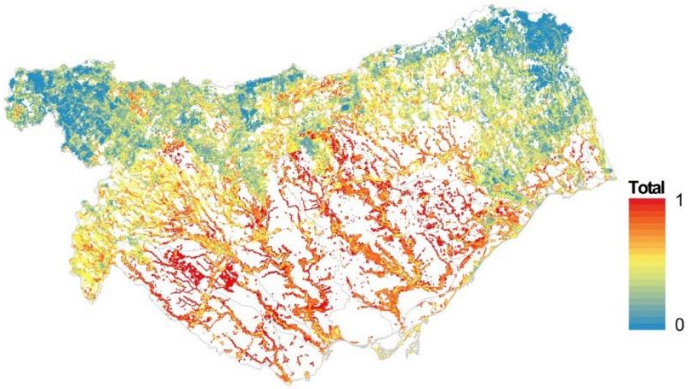


Figure 16: Distribution of additive scores of climate change vulnerability assessment indicators in the TRCA's updated regional target Natural Heritage System (0 indicates low vulnerability and 1 indicates higher vulnerability).

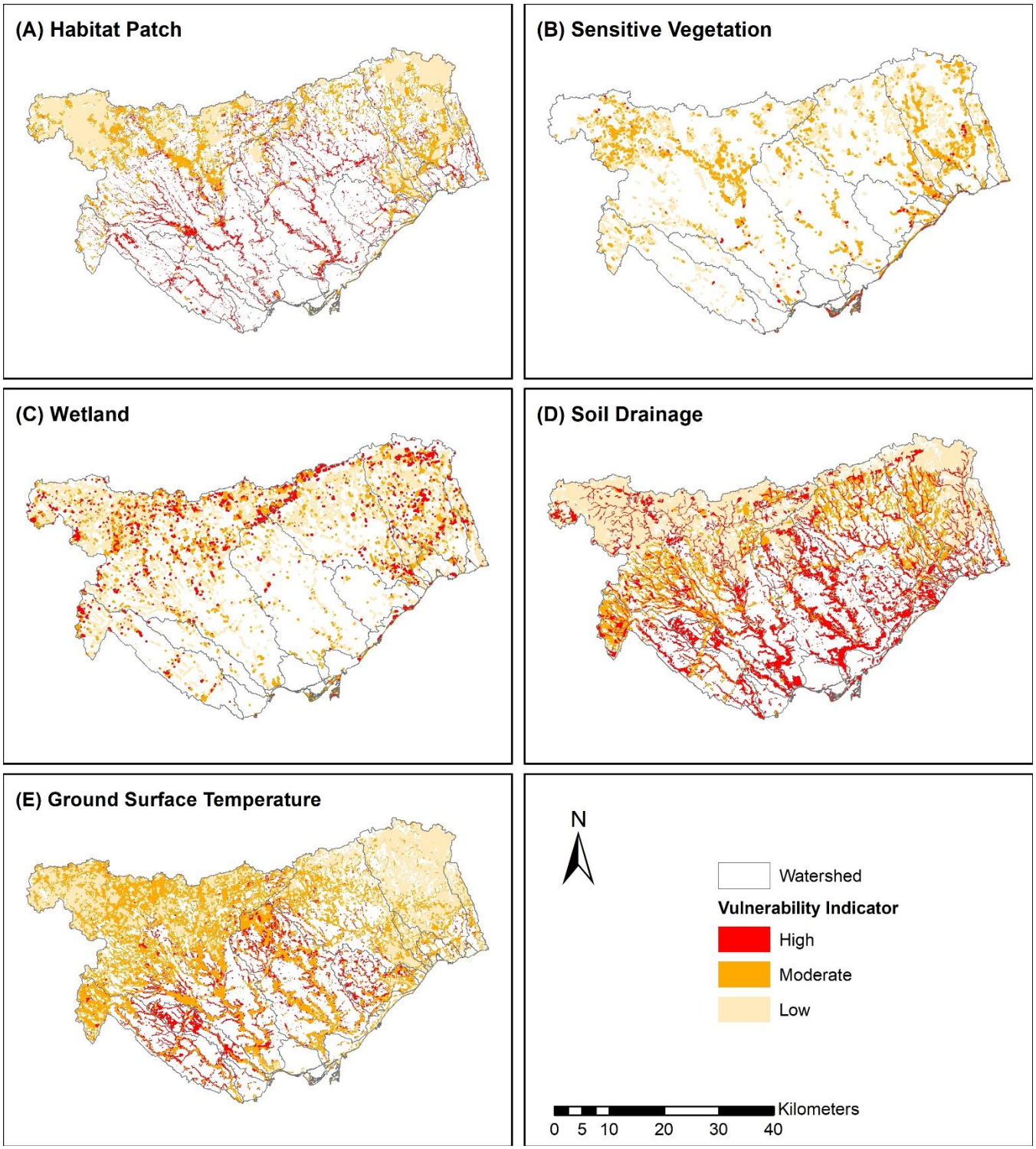


Figure 17: Distribution of climate change vulnerability assessment indicators in the TRCA's updated regional target Natural Heritage System.

3.3.3. Watershed and local-level refinement

TRCA's updated regional target NHS was used to inform the Watershed Planning process for Etobicoke Creek Watershed Plan (ECWP) for watershed-level refinements in addition to local-level refinements from engagement sessions with conservation authorities, municipalities, BILD, and agricultural advisory communities. For Watershed Planning, the updated regional target NHS was refined using further detail from additional finer-level data that informed additional potential natural cover based on Restoration Opportunities Planning (ROP) as well as future development (ROPA Mayfield West and Whitebelt) in the watershed. From the engagement sessions, comments were addressed using additional detail provided through internal discussion or requested data internally/externally that led to local-level refinements.

The watershed-level refinements for ECWP identified additional potential natural cover, but also the conversion of the regional target NHS due to future land use changes from ROPA Mayfield West and the Whitebelt. First, for additional potential natural cover, ECWP had finer-level data for aquatic and terrestrial ecological function (Appendix 1) that was used to identify high scoring areas with high ecological function that may require restoration not included in the updated regional target NHS. Second, detailed data defining the future development in this watershed were used to refine the updated regional target NHS using ROPA Mayfield West and identified natural areas maintained their existing natural cover, potential natural cover and contributing area designations. All built-up areas identified in the ROPA were converted as built-up contributing areas. Third, the Whitebelt development assumed that a separately derived Conservation Authority NHS (TRCA and Credit Valley Conservation) served as the backbone for refining existing and potential natural cover within the Whitebelt. This maintains the goal that adding potential natural cover would widen corridors and enhance connectivity of the Conservation Authority NHS in addition to the high scoring areas.

The local-level refinements from the NHS engagement sessions were first addressed with site-level comments. Site-level comments include the refinements of existing natural cover, where there were further land use changes that were not present in the TRCA natural cover (2017) layer. These areas were flagged by comments indicating that the existing natural cover had already been removed or will be undergoing development. Potential natural cover was added where possible when comments were received, including alignments with the municipal NHS where warranted. In areas where potential natural cover would not be possible due to future development, these areas were converted into contributing areas. The assumption is that the ecological function that once drove the selection of these areas in the updated regional target NHS remain necessary in an urbanized landscape.

4. CONCLUSION

TRCA's updated regional target Natural Heritage System (NHS) provides science-based information and a screening tool that highlights the existing and potential features and areas that are important for long-term health and resilience of ecosystems in TRCA's jurisdiction. It is based on the systems approach and the principles of NHS as outlined by the province as well as TRCA's Terrestrial Natural Heritage System Strategy (2007). The core principle includes increasing quantity, quality, connectivity, and distribution of ecosystems, both structurally and functionally, across the entire jurisdiction. This would enable a steady provision of various ecosystem services (e.g., clean air and water, flood protection, pest reduction, increased recreation, and

aesthetic opportunities) that are vital for human well-being. The target NHS accounts for current and future changes in land use and climate and identifies areas where impact mitigation and adaptation actions could strategically benefit the long-term health and resilience of the natural systems across the region.

Provincial directions require municipalities to provide adequate protection and enhancements to natural heritage system. TRCA's updated regional target NHS is intended to be a tool for TRCA and its municipal partners to inform various strategic and site level initiatives (with appropriate refinements). This includes informing watershed and subwatershed planning, land use and infrastructure planning, land securement and management, ecological restoration and green infrastructure implementation, and municipal comprehensive review and official plan review processes. TRCA's updated regional target NHS is not intended to disrupt existing decision-making processes, but rather to inform them based on up-to-date science and to identify partnership opportunities to facilitate collaborative initiatives.

TRCA's updated regional target NHS identifies 36% of the TRCA's jurisdiction as target NHS comprising of existing natural cover (24%) that should ideally be targeted for protection and potential natural areas (12%) that should be targeted for restoration, where opportunities exist with willing landowners. This will help increase natural cover quantity and quality across TRCA's jurisdiction. Given that the TRCA's jurisdiction is highly urbanized, the existing natural cover is under various direct and indirect stress from urbanization as well as other stressors like climate change. The existing and potential natural areas identified in the target NHS will be a critical backbone of our ecological system across the jurisdiction for a healthier NHS.

However, protecting and restoring existing and potential natural cover areas may not be enough to ensure long term resilience of NHS given the exacerbated impacts and uncertainties associated with the combined effects of urbanization and climate change together. Thus, TRCA's updated regional target NHS identifies additional 16% of the jurisdictional area in the form of Contributing Areas that are intended to support the NHS features and functions, but where traditional restoration opportunities may be limited due to its existing conditions (e.g., built areas) and/or planned objective (e.g., approved for future development). The Contributing Areas are mostly within the urban land uses, that have been identified as important for various ecological functions. Here, various enhancement opportunities, especially through green infrastructure and LID implementation could be targeted to improve ecosystem functions and services. This ensures that both natural and built portions of TRCA's jurisdiction is strategically targeted for protection, restoration, and enhancements for a healthy and resilient NHS that can sustain ecosystem functions and services on the long run.

5. REFERENCES

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