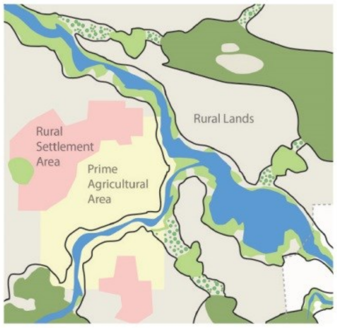

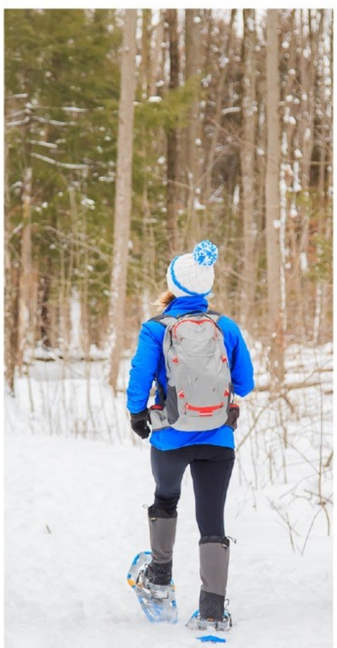

THE REGIONAL NATURAL HERITAGE SYSTEM FOR THE GROWTH PLAN FOR THE GREATER GOLDEN HORSESHOE

TECHNICAL REPORT ON CRITERIA, RATIONALE AND METHODS

Ontario

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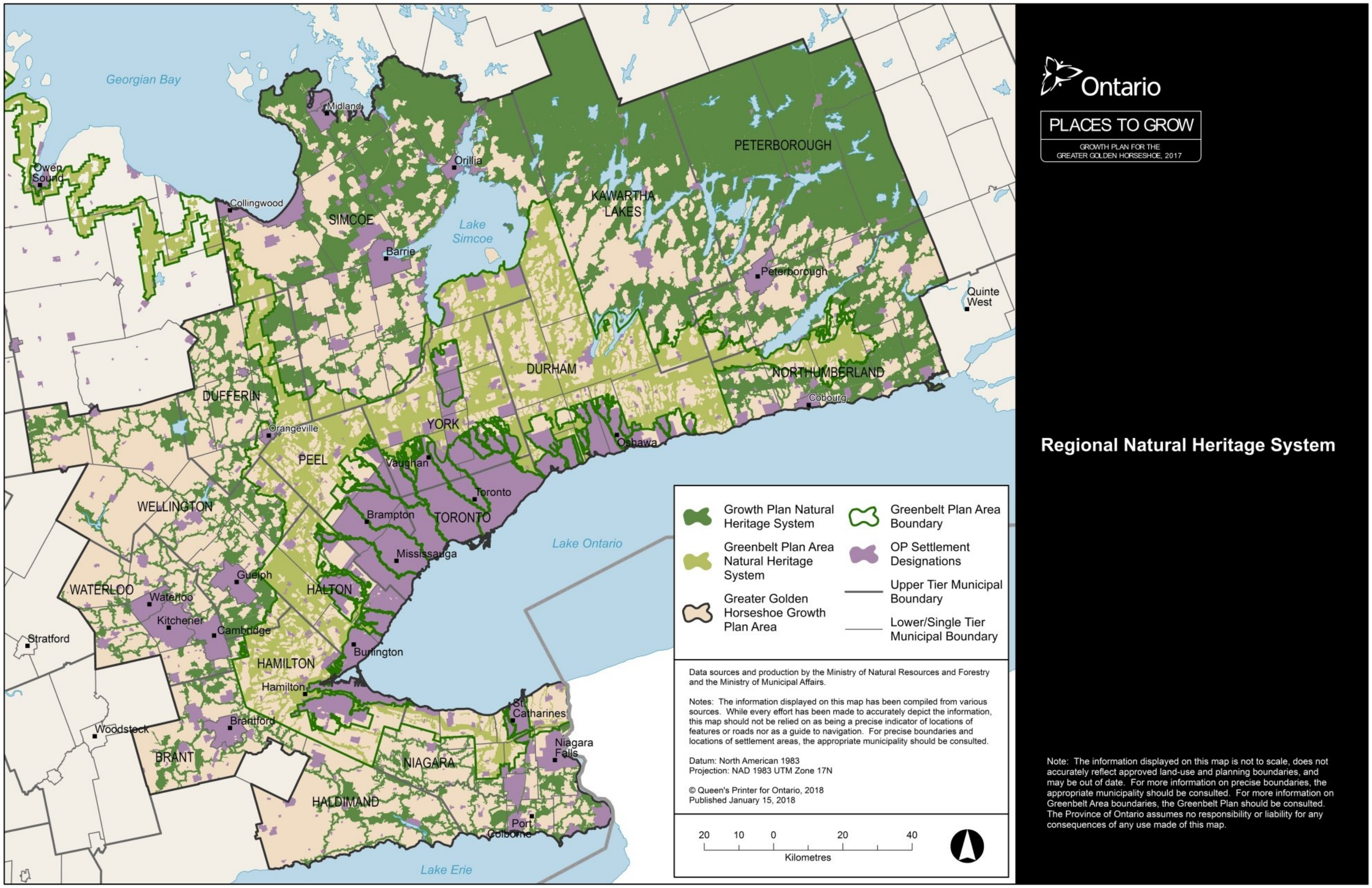
Summary

Natural heritage systems (NHSs) are connected networks of natural features intended to provide connectivity and support natural processes that are necessary to maintain viable populations of indigenous species, ecosystems and ecosystem functions. They consist of core areas with concentrations of natural features and linkages between core areas that allow the movement of organisms between cores. Natural heritage systems are particularly important in landscapes with high levels of habitat loss and fragmentation such as southern Ontario. Over the last 15 years, regional NHSs have been identified in provincial land use plans for the Greenbelt and Oak Ridges Moraine where development pressures are particularly high. The Ontario government is committed to mapping an NHS for the Growth Plan for the Greater Golden Horseshoe. This report provides a detailed technical overview of the criteria, rationale and methods used to develop the NHS for the Growth Plan area.

Guiding principles were used to develop an automated process for NHS mapping that is evidence-based and repeatable. Criteria were based on a literature review and existing guidance from the Natural Heritage Reference Manual and criteria used for the Oak Ridges Moraine and Greenbelt NHSs. Candidate core areas had to be at least 50% natural cover or public lands. The minimum size of core areas is set at 500 hectares (ha) but is reduced to 100 ha in portions of the Growth Plan area where natural cover is low and highly fragmented. The minimum width for linkages in this regional-scale NHS is 500 m. The automated process for identifying linkages placed a premium on riparian areas with adjacent natural habitat. After cores and linkages were identified, portions of significant river valleys that were not included were added to the NHS.

The regional NHS (see map below) comprises 45% of the Growth Plan area excluding settlements. Significant natural features in the Growth Plan area are well represented in the NHS - almost all Life Science Areas of Natural and Scientific Interest (ANSI), wetlands, provincially significant wetlands, provincially tracked species records, Endangered and Threatened species occurrences (after screening) and rare plant communities are included in the system. Twenty-four percent of the Prime Agricultural Areas identified in the Agricultural System for the Growth Plan area occur within the NHS. About one half of the area of existing aggregate licences (54%) and primary sand and gravel deposits (52%) in the Growth Plan area are included in the NHS; 77% of selected bedrock resources are also included.

Regional Natural Heritage System - Growth Plan for the Greater Golden Horseshoe



Résumé

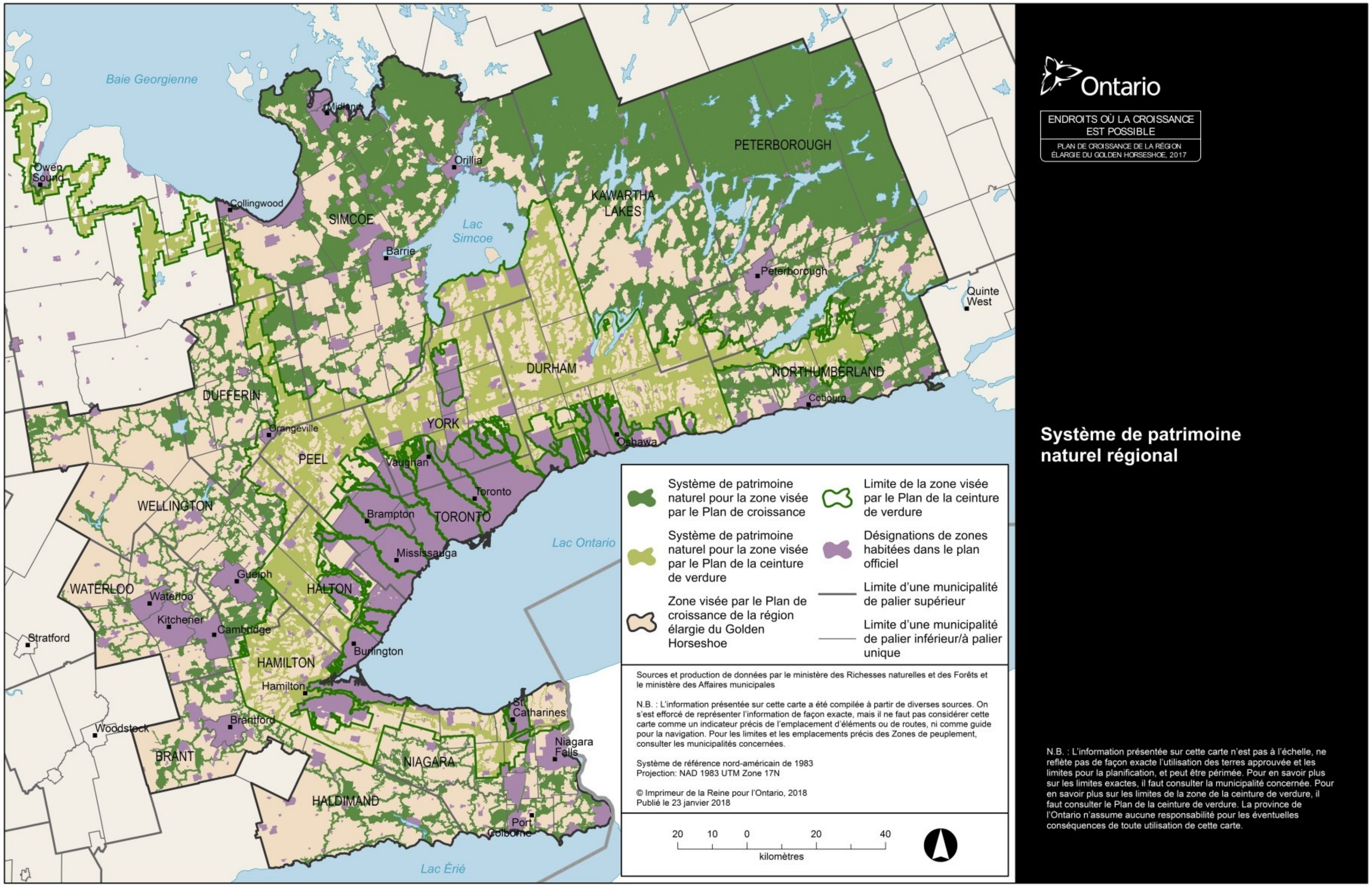
Les systèmes de patrimoine naturel sont des réseaux reliés d'éléments naturels visant à assurer la connectivité et à soutenir des processus naturels nécessaires pour maintenir des populations viables d'espèces indigènes, d'écosystèmes et de fonctions écosystémiques. Ils consistent en des zones centrales où l'on observe des concentrations d'éléments naturels, et en des liens physiques entre zones centrales qui permettent le déplacement d'organismes entre celles-ci. Les systèmes de patrimoine naturel sont particulièrement importants dans les paysages présentant un degré élevé de perte d'habitat et de fragmentation, comme le sud de l'Ontario. Au cours des 15 dernières années, des systèmes de patrimoine naturel régionaux ont été identifiés dans des plans provinciaux d'aménagement du territoire pour la ceinture de verdure et la moraine d'Oak Ridges, où la pression exercée par le développement est particulièrement élevée. Le gouvernement de l'Ontario s'engage à cartographier un système de patrimoine naturel pour le Plan de croissance de la région élargie du Golden Horseshoe. Ce rapport présente un survol technique détaillé des critères, de la justification et des méthodes utilisées pour élaborer le système de patrimoine naturel pour la zone du Plan de croissance.

Des principes directeurs ont orienté l'élaboration d'un processus automatisé pour la cartographie du système de patrimoine naturel qui soit fondé sur des données probantes et soit reproductible. Les critères étaient fondés sur un examen des textes et sur des orientations existantes figurant dans le Manuel de référence sur le patrimoine naturel, et des critères utilisés pour les systèmes de patrimoine naturel de la moraine d'Oak Ridges et la ceinture de verdure. Les zones centrales candidates devaient être constituées d'au moins 50 % de couverture naturelle ou de terres publiques. La superficie minimum des zones centrales est fixée à 500 ha, mais elle est réduite à 100 ha dans les parties de la zone du Plan de croissance où la couverture naturelle est faible et très fragmentée. La largeur minimale pour les liens physiques dans ce système de patrimoine naturel à l'échelle régionale est de 500 m. Le processus automatisé pour déterminer les liens physiques accordait une grande importance aux zones riveraines comportant un habitat naturel adjacent. Après la détermination des zones centrales et des liens physiques, des parties de vallées fluviales importantes non incluses ont été ajoutées au système de patrimoine naturel.

Le système de patrimoine naturel (voir la carte ci-dessous) comprend 45 % de la zone couverte par le Plan de croissance, sauf les secteurs habités. Les éléments naturels importants figurant dans le Plan de croissance sont bien représentés dans le système de patrimoine naturel– presque toutes les Zones d'intérêt scientifique et naturel pour les sciences de la vie, les terres humides, les Terres humides d'importance provinciale, les

données sur les espèces suivies, la présence d’espèces en voie de disparition ou menacées (après contrôle) et les communautés rares sont incluses dans le système. Vingt-quatre pour cent des zones agricoles de premier choix identifiées dans le système agricole pour le Plan de croissance figurent dans le système de patrimoine naturel. Environ la moitié de la superficie des permis d’exploitation de ressources en agrégats (54%) et des dépôts de sable et de gravier primaires (52%) dans la zone du Plan de croissance sont inclus dans le système de patrimoine naturel; 77 % des ressources du substrat rocheux sélectionnées sont également incluses.

Système de patrimoine naturel régional - Plan de croissance de la région élargie du Golden Horseshoe



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Introduction

As part of Ontario's Coordinated Land Use Planning Review that was initiated in 2015, the natural heritage policies of the Growth Plan for the Greater Golden Horseshoe (Figure 1) were reviewed. When phase 2 of the public consultation for the review was initiated in May 2016, the government announced that the Province would lead the development and mapping of an NHS for the Growth Plan for the Greater Golden Horseshoe. In the 2016 mandate letter to the Minister of Natural Resources and Forestry, a summer 2017 timeline was given to complete this mapping. The revised Growth Plan (MMA 2017) released in May 2017 also committed the Province to mapping an NHS for the Greater Golden Horseshoe, beyond the Greenbelt Area.

This technical document provides an overview of NHSs in general and detailed descriptions of the principles, criteria, data sources and methods used to develop the NHS map for the Growth Plan for the Greater Golden Horseshoe. A Summary Report is also available that briefly describes the criteria and methods (OMNRF 2018).

Figure 1. Location of Greater Golden Horseshoe within Ontario.

Natural Heritage Systems

In the settled landscapes of Ontario, habitat loss and fragmentation have had profound impacts on biodiversity and the ecosystem services that flow from it. Habitat loss is the leading factor that threatens species at risk in Ontario and other parts of the globe (OBC 2010). In southern Ontario about two thirds of the natural land cover has been converted to other uses and most of the land is privately owned. Several approaches and tools have been developed to address the protection and restoration of habitat at site-specific and landscape scales in this part of the Province. The identification of NHSs is an important approach for addressing habitat at the broader landscape scale.

NHSs are connected networks of natural features designed to maintain species, ecosystems and ecological functions. Robust NHSs can enhance the resilience of ecosystems to threats such as climate change and provide vital ecosystem services that we depend on (e.g., pollination, flood control, air and water purification, carbon sequestration). In southern Ontario, where habitat loss and fragmentation have been high, the identification and implementation of NHSs through land use plans such as the Growth Plan for the Greater Golden Horseshoe are essential conservation tools.

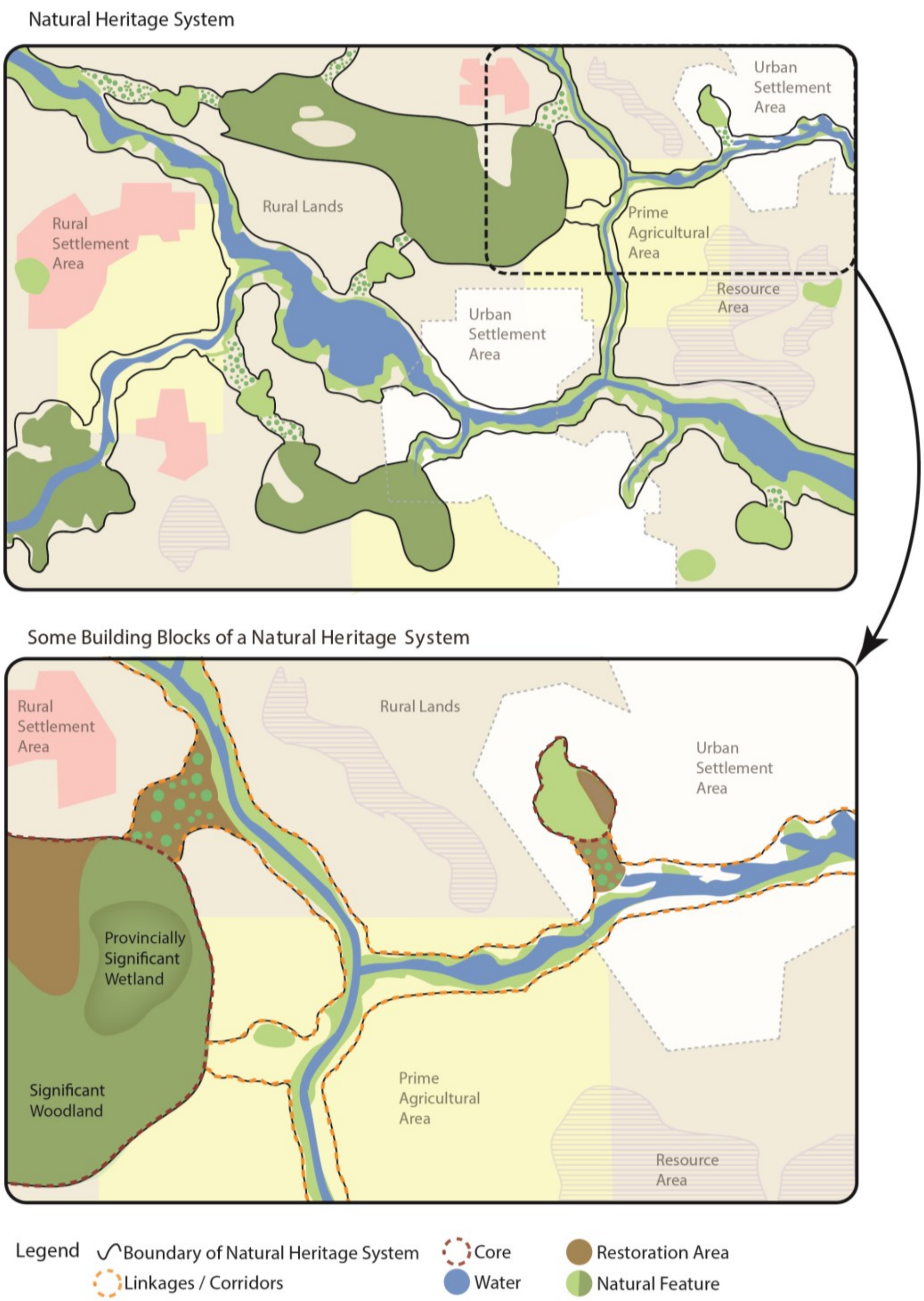
The *Growth Plan for the Greater Golden Horseshoe, 2017* defines an NHS as:

> "The system mapped and issued by the Province in accordance with this Plan, comprised 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. The system can include key natural heritage features, key hydrologic features, federal and provincial parks and conservation reserves, other natural heritage features and areas, lands that have been restored or have the potential to be restored to a natural state, associated areas that support hydrologic functions, and working landscapes that enable ecological functions to continue."

The Growth Plan NHS supports a comprehensive, integrated, and long-term approach to planning for the protection of the region's natural heritage and biodiversity.

A key concept in the development of an NHS is that everything is connected. The primary components of an NHS are core areas and linkages (see Figure 2). Core areas are the building blocks of an NHS and should be the most enduring natural areas within the landscape. They are usually the least disturbed and largest of remaining natural areas. Linkages are the corridors and functional routes between core areas that provide the connections. Linkages allow populations of species to survive through the movement of plants and animals, and enable ecological processes to continue across a landscape by reducing habitat fragmentation and isolation. In settings where natural features are limited, core areas and linkages may include lands without natural features, but with the potential to be restored to enhance habitat and connectivity as well as working landscapes that enable ecological functions to continue.

Figure 2. Schematic diagram of a natural heritage system on the landscape (Inset – shows core areas and linkages).



The Ministry of Natural Resources and Forestry (MNRF) has promoted an NHS approach for more than two decades. These efforts have included work with partners to identify NHSs for regions of the Province, the provision of guidance to assist municipalities in the development of local NHSs (Natural Heritage Reference Manual – OMNR 2010) and the formal identification of NHSs in provincial land use plans (Oak Ridges Moraine Conservation Plan [MMAH 2002], Greenbelt Plan 2005 [MMAH 2005]).

There are currently several NHSs that have been developed within the area of the Growth Plan for the Greater Golden Horseshoe. These include local NHSs that have been identified in some municipal Official Plans that receive protection through the *Provincial Policy Statement, 2014* (MMAH 2014) made under the *Planning Act*. There are also systems developed by collaborative partnership efforts that serve to guide conservation and stewardship efforts (e.g., Big Picture 2002, Kawarthas Naturally Connected). Natural Heritage Systems within the Oak Ridges Moraine Conservation Plan and Greenbelt Plan are within the boundaries of the Growth Plan area, but are governed by the policies of their respective plans as opposed to the Growth Plan policies for NHSs.

Guiding Principles for Natural Heritage System Development

It is important that a transparent method be used to map the NHS with well-defined criteria and rationale. There is also value in having a repeatable process that is not subject to the intuition of the particular individual doing the mapping. An automated mapping process was developed that could be used to identify an NHS in the Growth Plan area in a repeatable fashion. During the development of the automated process, the following general principles were used to guide the work:

- Well-documented and clearly explained criteria, rationale and methods are to be used;
- Scientific and empirical evidence are to be used to support decisions where possible;
- Consistency with current provincial NHS planning criteria and guidance (e.g., Natural Heritage Reference Manual and Greenbelt NHS) is to be maintained;
- Defendable and repeatable methodology is to be used (i.e., the same map would result from someone else using the same criteria and methods;
- Scale of the regional system is to focus on identifying larger core areas and broader linkages within a regional landscape context;
- Connection of the NHS mapping to existing regional mapping in adjacent areas is to be made as much as reasonably possible (i.e., connect to other NHSs in adjacent planning areas); and
- The criteria and methods are to have potential for application in another similar geography (i.e., could potentially be applied to other areas of southern Ontario).

It was also recognized that the scale of the NHS is important. Given that NHS mapping for the Growth Plan for the Greater Golden Horseshoe is on a broad, regional scale, it is focussed on identifying larger core areas and broad linkages. The mapping was not intended to identify all areas and connect features that may be important to consider at a local or smaller scale, however locally identified NHS mapping or other regional NHS mapping would be complementary and connect to the regional NHS for the Growth Plan.

Criteria for Developing the Natural Heritage System

The objectives of the regional NHS are not tailored to a particular species or species group, but are intended more generally to maintain and restore biodiversity and ecological functions over the long term. Therefore, core areas and linkages need to be large enough to encompass a wide range of species, habitats, and ecological functions. The Natural Heritage Reference Manual provides general guidance for the development of NHSs, but does not recommend specific quantitative criteria regarding the size of core areas and linkages (OMNR 2010). The manual does note that minimum size thresholds should consider landscape context – in areas where the landscape is highly fragmented and there is limited natural cover, smaller core sizes should be considered.

There is a need to develop a system that is based on consistently applied criteria and methods across the Growth Plan for the Greater Golden Horseshoe. Prior to developing criteria for the regional NHS, literature on effective sizes and composition of core areas and linkages, and criteria used in other NHSs were reviewed. The types of natural features and other lands that should be included in an NHS and the ecosystem functions that should be maintained or restored by an NHS were also reviewed. Because existing NHSs have used different criteria and methods at various scales, it is not possible to simply adopt them as a regional NHS. To be consistent with regional planning approaches in adjacent Provincial Plans, the criteria used for core areas and linkages in the Greenbelt Plan and the Oak Ridges Moraine Conservation Plan were used as a starting point.

Core Area Criteria

The criteria for selecting core areas depend to some extent on the approach used to identify core areas. Beier et al. (2011) identified six possible approaches for the identification of core areas and discussed the advantages and disadvantages of each (summarized in Table 1). Often two or more of these approaches are combined when developing an NHS. For example more generalized approaches focussed on ecological integrity or representation can be combined with the needs of specific species based on habitat modelling. In the Greenbelt, core areas were identified using the expert opinion approach, but were based on ecological integrity and the inclusion of existing protected areas and public lands. The approach used for the regional NHS in the Growth Plan combined the ecological integrity approach based on natural features and the existing protected areas approach.

Table 1. Approaches for identifying core areas in a natural heritage system (modified from Beier et al. 2011*).

Approach	Description
Expert opinion	• ecologists draw boundaries by hand – low cost, but not transparent, quantitative or repeatable.
Select areas of high ecological integrity	• based on natural cover/lack of intensive land use or presence of certain features - transparent, repeatable and simple.
Use existing protected areas	• all or a subset of protected areas within the planning area are included in the system - simple and transparent, although may be too few protected areas in region.
Optimization algorithms	• use of simulated annealing (e.g., Marxan) to maximize representation while minimizing costs - repeatable, but complex and may select only smallest areas.
Use existing mapping of conservation priorities	• identify areas based on existing mapping of high conservation priorities (e.g., Species at Risk habitat, rare ecosystems) - simple and transparent, but can omit intact areas without special features.
Select areas based on species needs	• areas selected based on modelled habitat requirements for a focal species or group of species – transparent (people can relate to species), but can be data intensive and complex and will ignore the needs of some species.

*Beier et al. (2011) refer to core areas as landscape blocks and regional natural heritage systems as regional connectivity maps.

Composition of core areas

In much of the fragmented landscape of southern Ontario, there are few large, contiguous patches consisting of natural features. In these cases, aggregations of habitat patches or patches with the potential for restoration should be considered for inclusion in an NHS to maintain ecological functions at a landscape level (OMNR 2010). Groupings of patches that are closer together are less fragmented and better than those that are farther apart. When aggregations of natural features are being considered for inclusion in a larger core area, the Natural Heritage Reference Manual recommends that a benchmark minimum for percent natural cover be established as a criterion (OMNR 2010). The NHS for the Oak Ridges Moraine Conservation Plan is cited as an example — core areas in this area are composed of at least 50% natural cover and/or protected area. A similar benchmark was used for the NHS in the Protected Countryside of the Greenbelt Plan where identified core areas consist of at least 50% natural features and/or public lands (MMAH 2016). If core areas were identified that were lower than the 50% natural cover threshold, they would be dominated by agricultural or rural lands and would contain a preponderance of edge habitat within natural features. Public lands are also important as they are often composed of natural features such as wetlands and forests or offer opportunities for restoration. A minimum 50% natural cover or public land threshold was selected for the Growth Plan area to be consistent with adjacent Provincial Plans and to ensure core areas were dominated by natural features. Public lands include Provincial Parks, Conservation Reserves, Wilderness Areas, National Parks, Migratory Bird Sanctuaries, National Wildlife Areas, Crown Lands and Agreement Forests.

Minimum size of core areas

Core areas are the building blocks of an NHS. To help achieve objectives of the NHS, it is better to have larger rather than smaller core areas. Larger areas generally have a broader array of habitat types, support more species, are more likely to sustain populations and ecological functions over time, are more resilient to disturbance and usually have interior habitat that is less subject to edge effects[1] (Forman 1995; OMNR 2000; Laurance et al. 2002; Fahrig 2003; Hilty et al. 2006; OMNR 2010). The diversity of habitat types and landforms in very large areas will also allow some species to find suitable habitat within the core area in the face of a changing climate (Beier 2012). Smaller forest patches (< 50 ha) have few area-sensitive forest birds (Environment Canada 2013) and small habitat fragments may consist entirely of edge habitats that are avoided by many species sensitive to habitat loss and fragmentation (Hilty et al. 2006). However, small habitat patches can cumulatively play an important role in protecting biodiversity and providing ecosystem services, especially in areas where there is limited natural cover on the landscape (Bentrup 2008; OMNR 2010). To be consistent with planning approaches in adjacent areas (Oak Ridges Moraine Conservation Plan and Greenbelt Plan), a minimum size threshold needed to be established for core areas in the Growth Plan area.

There is limited guidance available on the recommended minimum size of core areas in an NHS designed for general biodiversity conservation. Minimum patch size depends on the species being considered, the quality of available habitat and the landscape context (Bentrup 2008). Generally, smaller species and species with limited dispersal ability will tend to require a smaller amount of habitat (Kennedy et al. 2003). Based on a comprehensive review of available literature, Bentrup (2008) identified a general summary of patch area requirements for a variety of species groups (Figure 3). In the Growth Plan area, the objectives of the NHS are intended generally to maintain and restore biodiversity and ecological functions over the long term as opposed to meeting the needs of a specific species or group of species. Therefore, core areas need to be large enough to encompass a wide range of species, habitats, and ecological functions.

[1] Edge effects occur where natural habitats border the anthropogenic matrix (e.g., agricultural and urban areas). These areas often support generalist species that are not particularly sensitive to habitat loss as well as invasive species, and are generally avoided by sensitive, specialist species. In forest patches, edge effects can extend to 100 m or more (Austen et al. 2001; Hilty et al. 2006). The amount of interior habitat depends on the size and shape of habitat patches – round- or block-shaped habitat patches have more interior habitat than long, narrow patches or patches with an irregular boundary.

More general guidance on core area size is provided in the third edition of the document *How much habitat is enough?* (Environment Canada 2013) which makes several recommendations with respect to the amount of habitat of various types that should be protected and restored (Table 2). Ontario's Natural Heritage Reference Manual (NHRM) does not provide a specific recommendation on the minimum size of core areas, but acknowledges that the minimum size will vary depending on the landscape context of the planning area (OMNR 2010). In landscapes where the amount of natural feature cover is limited, core areas in the NHS would likely be smaller. The Big Picture NHS minimum core area sizes were based on principles of reserve planning to ensure that protected landscapes are 50-100 times the average size of disturbance events (e.g., wildfire, windthrow) in the planning area (Jalava et al. 2002). In the forested areas of southern Ontario, the average pre-settlement disturbance size was ≤ 2ha (Riley and Mohr 1994; Larson et al. 1999), so the target minimum size for core areas was set at 200 ha wherever possible south of the Canadian Shield and 500 ha on the Canadian Shield (Jalava et al. 2001). It was difficult to meet this threshold in some parts of the Carolinian Zone (Ecoregion 7E) and along the Great Lakes coast and so smaller, high quality core areas (as small as 4 ha) were identified in areas with minimal natural feature cover.

Figure 3. Summary of patch area requirements for species groups (modified from Bentrup 2008).

Example ranges of minimum patch area

Species group	Patch area
Plants	2 to ≥ 40 ha
Invertebrates	< 1 to ≥ 1 ha
Reptiles & Amphibians	1 to ≥14 ha
Grassland Birds	5 to ≥ 55 ha
Waterfowl	≥ 5 ha
Forest Birds	2 to ≥ 38 ha
Small Mammals	1 to ≥ 10 ha
Large Mammals	16 to ≥ 518 ha
Large Predator Mammals	900 to ≥ 220,000 ha

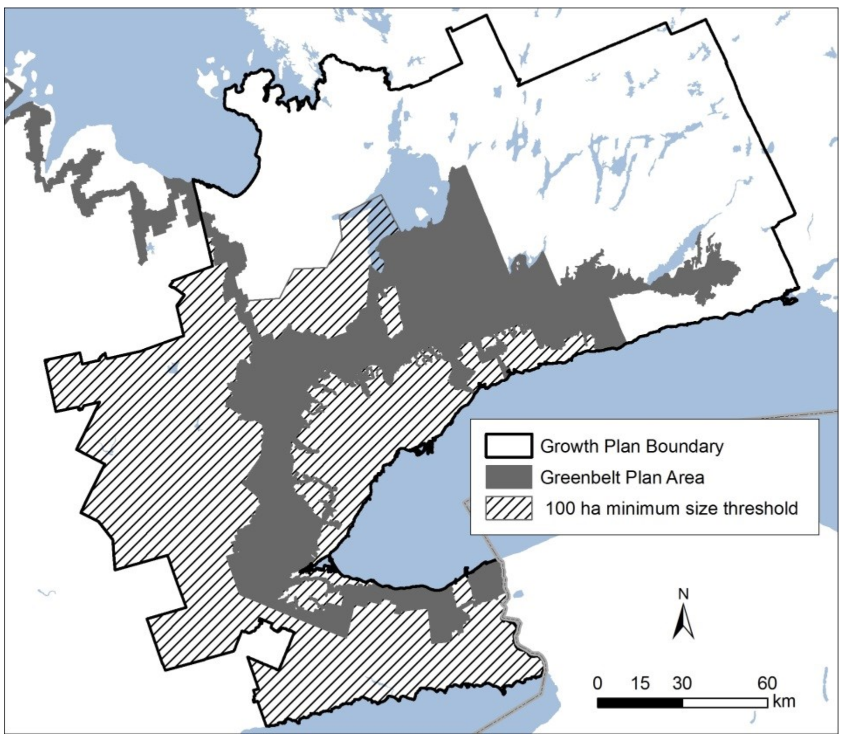
Table 2. Recommended area of various habitat types that should be protected and restored (from 3rd edition of *How much habitat is enough?* – Environment Canada 2013).

Habitat type	Recommendation
Wetland	• At a minimum, the greater of (a) 10% of each major watershed and 6% of each subwatershed, or (b) 40% of the historic watershed wetland coverage, should be protected and restored.
Forest	• A watershed or other land unit should have at least one, and preferably several, 200-ha forest patches (measured as forest area that is more than 100 m from an edge ≈ 250 ha for a round patch). • Forest cover – 30% at the watershed scale (high-risk approach) to 50% at the watershed scale (low-risk approach).
Grassland	• Maintain and create small and large grassland patches in existing and potential local grassland landscapes, with an average grassland patch area of ≥ 50 ha and at least one 100-ha patch.

In the Oak Ridges Moraine Conservation Plan, 500 ha was used as a minimum area threshold for core areas in the NHS although most core areas are much larger (average 2,570 ha; maximum 17,000 ha – OMNR unpublished data). In the NHS for the Greenbelt Plan, a minimum core area threshold of 500 ha was applied to areas south of the Oak Ridges Moraine, west of the Niagara Escarpment and on the Niagara Peninsula. North of the Oak Ridges Moraine and east of the Niagara Escarpment where there is more natural feature cover, a minimum core area size threshold of 1,000 ha was used (MMAH 2016).

Core areas for the Growth Plan area were initially mapped with a minimum size of 500 ha consistent with approaches in the Greenbelt Plan and Oak Ridges Moraine Conservation Plan. These areas are large enough to include a wide range of habitats and ecological functions. However, this approach left large gaps in the NHS in much of the southern and western portion of the Growth Plan area. Recognizing that the minimum size threshold for core areas is dependent on landscape context, the extent of natural cover and habitat fragmentation within the Growth Plan area was compared with the Greenbelt Plan and Oak Ridges Moraine Conservation Plan areas to determine if smaller minimum size thresholds should be considered for parts of the Growth Plan area. Fragmentation was assessed using the landscape metric Effective Mesh Size (EMS), which is a measure of average size of habitat patches adjusted by the probability that two randomly located points (i.e., organisms) are found in the same habitat patch (Jaeger 2000; OBC 2015). The algorithm assesses the effective habitat mesh size for one or more spatial summary features (e.g., ecodistrict) and reports on a continuous range from small to large where smaller EMSs equate to greater fragmentation. Based on this analysis, a smaller minimum core area size threshold of 100 ha was applied to southern and western portions of the Growth Plan area where there is limited natural feature cover and high levels of fragmentation (Figure 4). This approach is consistent with guidance in the Natural Heritage Reference Manual (OMNR 2010) and provides for valuable habitat and fills gaps in the system in areas of the Growth Plan area where little natural habitat remains. In landscapes with a high level of fragmentation and little natural cover, smaller core areas can be extremely important to maintaining remnants of biodiversity and can serve as anchors for future restoration efforts (Bentrup 2008; OMNR 2010). Details of the EMS analysis can be found in the methods section of this document, and the results are appended (Appendix I).

Figure 4. Growth Plan for the Greater Golden Horseshoe showing areas where core areas have a minimum size of 100 ha (minimum core area size is 500 ha in the rest of the Growth Plan area).



A summary of the criteria used to identify core areas in the Growth Plan area NHS is provided in Table 3.

Table 3. Criteria for identification of core areas.

Attribute	Criterion	Rationale
Composition	At least 50% natural cover or public lands	• Ensures that natural features are the predominant type of cover in core areas consistent with Oak Ridges Moraine Conservation Plan and Greenbelt Plan.
Size	Minimum size of 500 hectares	• Sufficient size to encompass a wide range of species, habitats, and ecological functions [equals minimum size in Oak Ridges Moraine Conservation Plan and Greenbelt Plan].
Size in fragmented landscapes	Minimum size of 100 hectares in areas with low natural cover that are severely fragmented	• Provides habitat and addresses NHS gaps in portions of the planning area that have little natural cover remaining [The Natural Heritage Reference Manual recommends adjusting minimum core size based on landscape context].

Linkage Criteria

If core areas are the building blocks of an NHS, linkages represent the mortar that holds the blocks together. The main functions of linkages are to facilitate the movement of organisms between otherwise isolated habitat patches thereby increasing gene flow within populations, promoting recolonization of habitat patches and increasing species persistence and diversity (Tewksbury et al. 2002). In addition to providing connectivity between habitat patches, linkages can provide habitat in their own right, support healthy functioning ecosystems, and can provide several benefits to humans (open spaces for recreation, limits on urban sprawl, and ecosystem services) (Hilty et al. 2006). Studies evaluating the effectiveness of linkages have reached different conclusions. However, a recent meta-analysis of 78 controlled, replicated experiments from 35 studies found that linkages increased movements between habitat patches by 50% for a broad range of taxa (Gilbert-Norton et al. 2010). The utility of linkages is affected by habitat quality and continuity, the dimensions of the linkage and landscape context. Width is perhaps the most contentious issue in the design of linkages as there is little empirical evidence on effectiveness of linkage widths (Hilty et al. 2006; Haddad 2008; Gilbert-Norton et al. 2010).

Composition and connectivity

Wherever possible, linkages were identified that consist of natural features to facilitate the movement of plants and animals. In many cases, continuous natural cover was not present between core areas, so connections were made between patches of natural features as stepping stones between core areas. A premium was placed on natural cover in riparian areas to build linkages because these habitats serve as natural corridors and are extremely important to plants and animals. Linkages avoid barriers such as major highways and developed urban areas without natural features. Each core area has multiple linkages to provide options for movement and to serve as a safety net in case one of the linkages becomes compromised. The NHS is connected to nearby core areas and linkages within the Greenbelt Plan as well as to features beyond the boundary of the Growth Plan for the Greater Golden Horseshoe.

Length of linkages

There is no predetermined minimum or maximum length for linkages in the NHS. The length of linkages is driven by the configuration of core areas on the landscape combined with the position of natural features between core areas.

Width of linkages

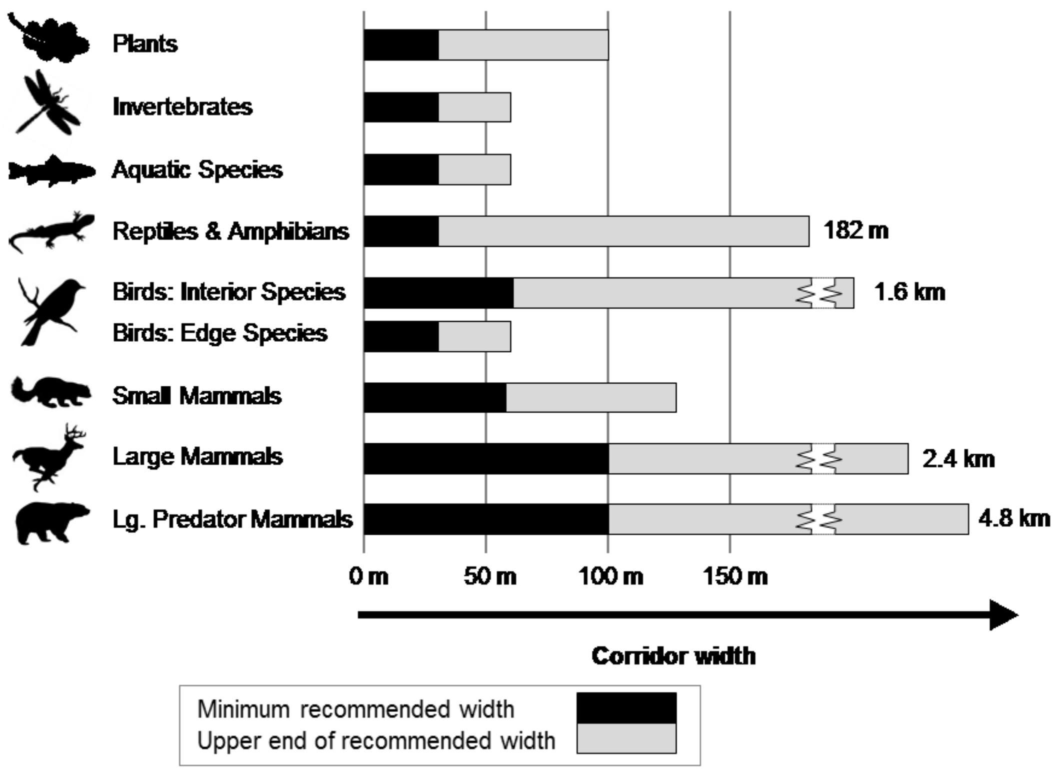
Guidance on specific recommended minimum widths of corridors is very limited. Based on a comprehensive review of available literature, Bentrup (2008) identified a range of recommended linkage widths for a variety of species groups that vary from 30 m to 4.8 km (Figure 5). Environment Canada (2013) recommends that linkages to facilitate species movement between forest patches should be a minimum of 50 to 100 m in width, but recognizes that larger widths (up to 500 m) may be required to accommodate specialist species. The Natural Heritage Reference Manual does not include specific recommendations on the minimum width of linkages as this depends on the species and the landscape context (OMNR 2010). The Natural Heritage Reference Manual does note the recommendations of Environment Canada above as well as those of Noss (1992) that long corridors (> 16 km long) should be at least 1.6 km wide and that shorter corridors should be at least three times as wide as measurable edge effects. For forested corridors this would equate to a minimum linkage width of 300 m. The Big Picture 2002 used a minimum linkage width of 200 m and included any adjacent natural cover (Jalava et al. 2002).

There are several generalizations that can be made regarding linkage width from available literature and guidance:

- Large species and area-sensitive species require wide linkages to facilitate movement and to provide habitat (Bentrup 2008; Environment Canada 2013). The width of linkages may be more important than length for plant propagules that are randomly dispersed (Tilman et al. 1997);
- Longer linkages should be wider; shorter corridors are more likely to provide high connectivity than longer corridors (Hilty et al. 2006; Bentrup 2008; OMNR 2010);

- Wide corridors are required where the matrix has limited habitat and is heavily influenced by human use (Bentrup 2008);
- Linkages that are designed to function at the landscape scale should be wide (several hundred metres or more) (OMNR 2010);
- Linkages designed to function over decades or centuries need to be wide to facilitate functions such as the dispersal of slow-moving organisms, gene flow and distribution shifts in response to climate change (Bentrup 2008);
- Linkages designed to facilitate movement of multiple species and entire communities need to be wide (Hilty et al. 2008); and
- Wide corridors provide increased habitat and reduce edge effects that can otherwise hinder movements of sensitive species and promote widespread generalist species and invasive species (Noss 1992; Hilty et al. 2006; Bentrup 2008; OMNR 2010).

Figure 5. Summary of the minimum and upper end of recommended linkage widths for a variety of species groups (adapted from Bentrup 2008).



Prior to identifying a minimum width criterion for linkages in the Growth Plan area, widths of linkages in the NHSs of the neighbouring Greenbelt and Oak Ridges Moraine were reviewed. Although there was no minimum width set for linkages in the NHS for the Greenbelt Plan, the minimum width of a sample of 69 linkages measured throughout the NHS ranged from 100 m to 520 m. Linkages in the Oak Ridges Moraine tend to be very wide with the main east-west linkages being about 2 km wide, while narrower linkages (~ 200 m wide) provide north-south connections to features off the moraine.

Available evidence suggests that the minimum width of linkages in the NHS for the Growth Plan area should be relatively wide (hundreds of metres) as it is a landscape-scale system intended to conserve biodiversity and ecological functions over the long term. The minimum width of linkages for the NHS in the Growth Plan for the Greater Golden Horseshoe was set at 500 m. In some cases, linkages are wider where there are adjacent natural features. In other cases, linkages are narrower where they are constrained by barriers such as highways and urban development. It must be noted that in most cases identified linkages will not consist entirely of natural features as they will include agricultural and rural lands. Many linkages may not be fully functional in the absence of restoration efforts.

River Valleys

The valleylands of large stream systems have disproportionately high species diversity, are important corridors for the movement of plants and animals, and play a vital role in aquatic habitats and regulating water quality and hydrological function (Hilty et al. 2006; OMNR 2010; Beier 2012). These riparian areas can also play an important role in serving as natural linkages that can allow organisms to adapt to climate change (Beier 2012). The valleys of major stream systems were included in the NHS recognizing their importance to biodiversity and hydrologic functions. Stream systems were also used to provide linkages between core areas and Lake Ontario similar to the approach used for the NHS in the Greenbelt Plan.

A summary of the criteria used to identify linkages in the Growth Plan area NHS is provided in Table 4.

Table 4. Criteria for identification of linkages.

Attribute	Criterion	Rationale
Composition	Consist of natural features and rural/agricultural lands without barriers to animal and plant movement	• Natural features provide best dispersal routes for plants and animals. Where continuous natural cover is not available to connect cores, natural features were used as stepping stones. • Linkages are not created where there are permanent and substantial barriers to movement.
Connectivity	Multiple connections between core areas	• Multiple linkages provide options for species movements and provide a safety net in case linkages are lost.
	Connections to NHSs in adjacent lands	• Linkage to adjacent regional NHSs ensures connectivity beyond the landscape planning area.
Length	No minimum or maximum length	• Length determined by distances between core areas and location of natural features between core areas.
Width	500 m + natural features that extend beyond boundary	• Wide linkages are required for landscape-scale NHSs intended to conserve biodiversity and ecological functions over the long term. Wide linkages also minimize edge effects.

Land Cover Data Used to Identify the Natural Heritage System

Land Cover data

To ensure that the NHS in the Growth Plan area would be linked to natural features beyond its boundaries, the geographic extent of the land cover data considered included lands within 10 km beyond the outer boundary of the Growth Plan area. For the identification of core areas and linkages, land cover data were assembled from five sources:

- Southern Ontario Land Resources Information System (SOLRIS) version 2.1 (OMNRF 2015a) – Land cover for southern Ontario current to 2011. The minimum mappable unit for this information is 0.5 ha;
- Ontario Hydro Network (OHN) version 1.2 (OMNRF 2015b) – line and polygonal data for streams and waterbodies (1:10,000 scale);
- Ontario Road Network (ORN) Segment with Address version 3 (OMNR 2015c) – line network data identifying natural heritage barriers such as highways and freeways and passage ways such as bridges over streams (+/- 10 metres or better)
- Where The Trees Are (WTTA) (OMNRF 2015d) – Areas that have had successful afforestation from the 50 Million Trees Program, but are not included as natural areas in SOLRIS;
- Annual Crop Inventory data (AAFC 2015) – Four consecutive years of satellite and crop insurance based mapping of the agricultural landscape including crop types, grasslands, and shrublands. Agricultural data is not included in SOLRIS, so this layer was intended to fill data gaps in landscape coverage. The shrub and grassland areas in these data were considered to be pollinator habitat in MNRF's landscape pollinator habitat mapping project (OMNRF unpublished data). These data classes were included because it is recognized that semi-natural landscapes (such as regenerating pasturelands) have the potential to provide ecological functions and serve as habitat.

A natural features layer (Figure 6) was assembled by including the SOLRIS classes in Table 5, afforestation areas from WTTA, and areas that were consistently shrubland and grassland for the four consecutive years of the AAFC annual Crop Inventory data.

Figure 6. Natural features within and adjacent to the Growth Plan area.

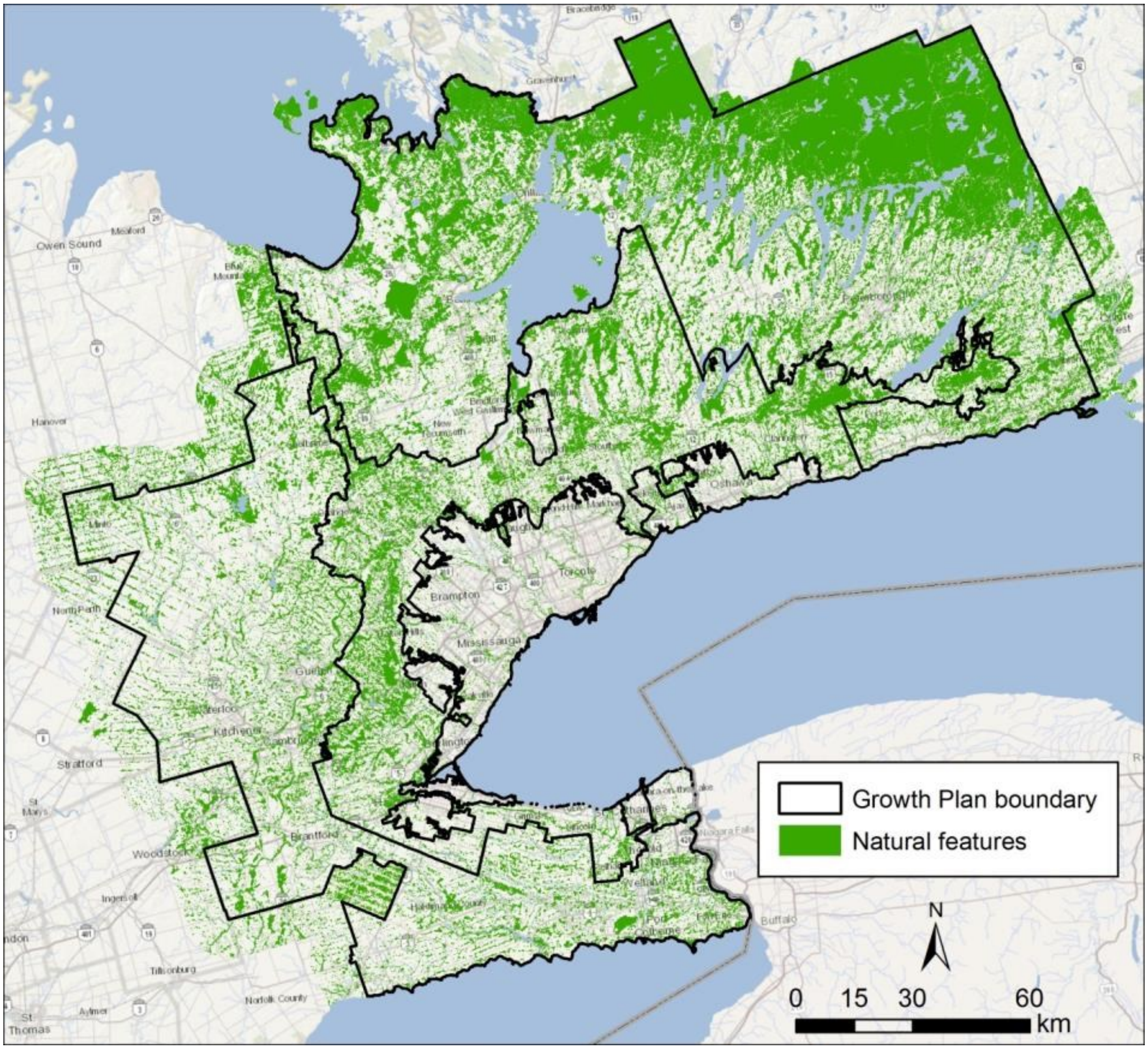


Table 5. SOLRIS v 2.1 classes included as natural features for natural heritage system mapping.

SOLRIS Class name	ELC Code	Raster value
Open Beach / Bar	BBO	11
Open Sand Dune	SDO	21
Treed Sand Dune	SDT	23
Open Cliff and Talus	CTO	41
Treed Cliff and Talus	CTT	43
Open Alvar	ALO	51
Shrub Alvar	ALS	52
Treed Alvar	ALT	53
Open Bedrock		64
Sparse Treed		65
Open Tallgrass Prairie	TPO	81
Tallgrass Savannah	TPS	82
Tallgrass Woodland	TPW	83
Forest	FO	90
Coniferous Forest	FOC	91
Mixed Forest	FOM	92
Deciduous Forest	FOD	93
Treed Swamp	SWC/SWM/SWD	131
Thicket Swamp	SWT	135
Fen	FE	140
Bog	BO	150
Marsh	MA	160
Open Water	OA	170
Plantations – Tree Cultivated	CUP	191
Hedge Rows	CUH	192

Growth Plan Natural Heritage System GIS Technical Methodology

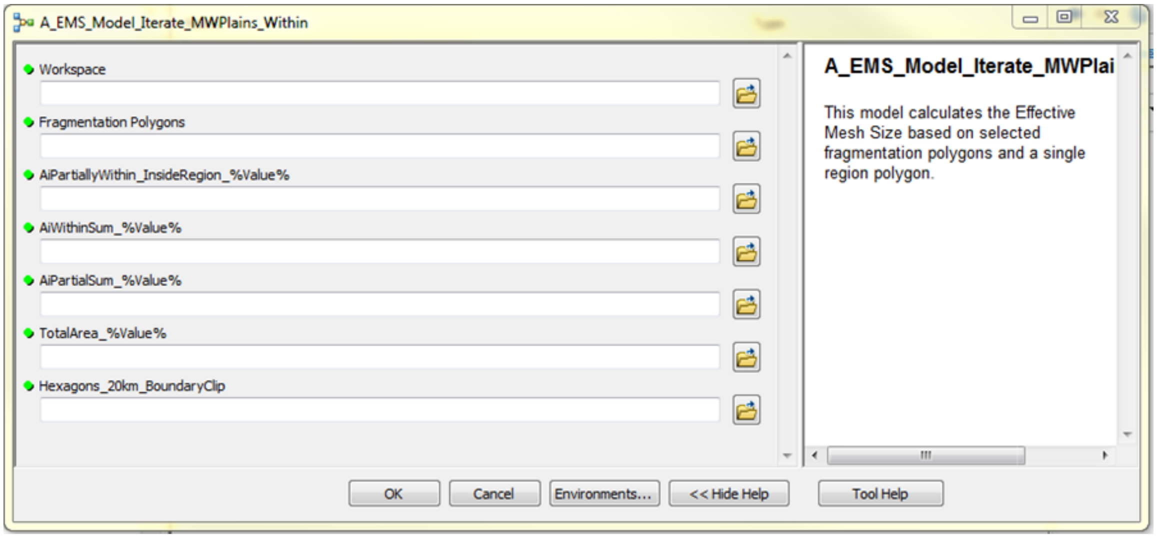
The NHS was developed with automated processes using ArcGIS 10.1 Geographic Information System (GIS) software (ESRI 2012). Identification of the NHS was divided into three phases (core areas, linkages, and creating the NHS) each with several steps that are described in detail below.

Core Areas

The following process was used to automate the identification of core areas:

1) Effective Mesh Size (EMS) analysis
   - The Effective Mesh Size (EMS) Toolbox (Figure 7) was used to run a model designed to calculate the effective mesh size based on selected fragmented polygons and a single region polygon. This tool was developed for the Mixedwood Plains Ecozone for Ontario State of Biodiversity Reporting.
   - The EMS toolbox input included all natural cover classes from SOLRIS 2.1 from Land Information Ontario (values 11 – 192) (see Table 5) except for Lake Simcoe.
   - The Lake Simcoe boundary identified in the Ontario Hydro Network was removed from the analysis as natural cover because of its extensive size which would skew the results to under-represent the level of fragmentation around the lake.
   - All SOLRIS natural cover data was assigned a raster value of 1 and combined with the Lake Simcoe raster set to No Data and clipped to the planning area boundary.
   - The tool used 20-km hexagon grids across the growth plan area to assess the landscape level analysis of natural cover and fragmentation.
   - The results helped determine and rationalize the minimum size threshold for cores across the Growth Plan area.
   - The core area minimum size threshold, based on this EMS analysis, varied across the Growth Plan area depending on degree of fragmentation and amount of remaining natural cover in certain regions (see step 10).

Figure 7. Effective Mesh Size (EMS) Toolbox.



2) Natural Features layer creation. This layer is binary (1,0 values) representing data from:
   - SOLRIS 2.1 all natural cover classes, including plantations and hedgerows (values 11 – 192 inclusive) from Land Information Ontario (LIO) formed the base of the natural features layer (see Table 1).
   - Where The Trees Area (WTTA) (2015) from Trees Ontario which capture areas that have been afforested through the 50 Million Trees Program. Data captured from the WTTA layer identify additional or newly planted natural areas that are identified in SOLRIS as undifferentiated lands.
   - Annual Crop Inventory (ACI) data from Agriculture and Agri-food Canada. Datasets for each year (2012 – 2015) were selected for shrubland and grassland classes (values 50 and 120). Areas were selected for inclusion for the natural features only if the shrubland or grassland were identified for the four consecutive years. Data captured from the ACI identify additional natural areas that are identified in SOLRIS as undifferentiated lands. Cell size was reclassified from 30 m to 15 m to be consistent with other data layers.
   - Annual Crop Inventory (ACI) data from Agriculture and Agri-food Canada was also used to ensure vineyard and orchards (values 190 and 188) were not included in the natural features layer and misrepresented in SOLRIS as a plantation for example.
   - GRCA Wetlands – Grand River Conservation Authority (GRCA) provided local mapping data that includes finer resolution data on wetlands that were used to reclassify those areas classified in SOLRIS as undifferentiated lands.
   - All inputs were reclassified to 1(natural) or 0 (non-natural) and the processing extent was set to the buffered Growth Plan boundary (10-km buffer).
   - The inputs were added together using raster calculator and the output was reclassified so that all values greater than 0 are equal to 1.
   - The output was then clipped to the buffered Growth Plan boundary.

3) The Moving Window - spatially averaged natural cover thresholds: Focal statistics were run on the natural features layer which calculates a statistic for each cell based on its location in relation to its neighbouring cells. This tool requires a Spatial Analyst license in ArcMap. In this step, a focal mean was calculated on each 15 m pixel of the natural features layer using a 1-km radius circle (neighbourhood is a circle, with map units at 3000 m) which calculates the mean (average value) of the cells in the circle neighbourhood. Each cell (15-m pixel) is assigned an associated focal mean value from 0 to 1. These values were multiplied by 100 to give a percentage value (0.4 X 100 = 40%). See Appendix II for a full description.
    - Input: Natural Features Grid (Natural = 1, Non-Natural = 0)
    - Neighbourhood = Circle
    - Radius = 1000 m or 67 cells
    - Statistic Type = Mean
    - Check the “Ignore No Data in Calculations” Check Box.

4) The Moving Window analysis: Percent threshold layers were created from the focal mean to identified natural features based on a percentage of the natural feature within 1 km of each pixel. This was identified in the first steps of the Step 1 Model described below. Thresholds of 35%, 40%, 45%, and 50% natural cover were mapped into layers for review. The cores at each % threshold and their associated natural cover intersections were clipped to the GGH boundary. For each of these thresholds, core areas larger than 500 ha and with 50% or more natural cover had the following statistics generated:
    - Number of core areas
    - Size of core areas (total, mean and range)
    - Total % natural cover within core areas.

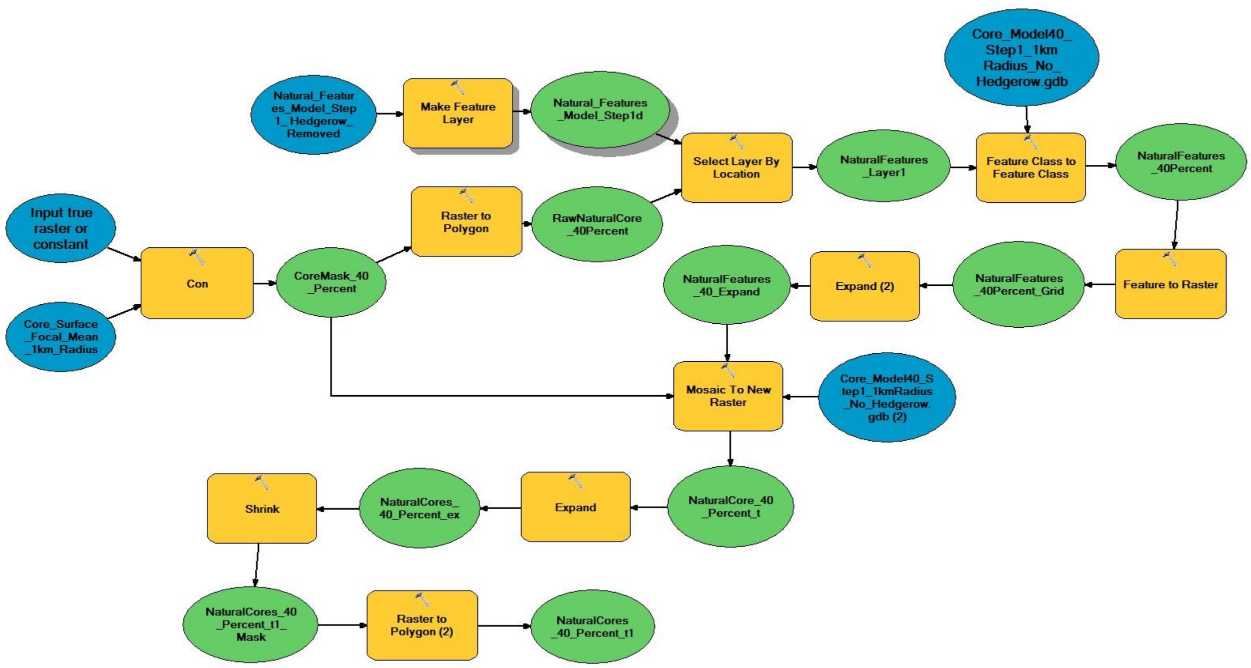
5) The % threshold value that maximized the number and size of core areas while ensuring that all core areas at least 500 ha in size had more than 50% natural cover was selected to continue through the step models and methodology criteria to develop the cores. The analysis determined 40% was the most appropriate threshold to develop core areas for the Growth Plan area.

6) Step 1 Model (Figure 8) created preliminary NHS cores based on the following processes:
    - Identified all pixels that had a 40% or greater threshold value and then converted them to vector (polygon layer).
    - Selected natural features from the natural features layer that intersect with “40% natural cover” with a 30-m search distance to create a natural features 40% output layer. This layer was converted back to raster with 15-m cell size. The natural features layer used in this step had hedgerows removed so that hedgerows alone would not result in growing the boundary of a core area.
    - The raster natural features layer was then expanded by 2 cells (30 m) to ensure natural features within the core included a 30-m buffer (any portion of the buffer was eliminated later if it overlapped with a barrier of urban impervious or major highway).

- The raster layer was again expanded by 8 cells (120 m) and then reduced by 8 cells (120 m) and converted back to a polygon layer. This modified cores to ensure that narrow embayments were included in the core area to reflect spatial natural heritage principles (Figure 9).

Figure 8. Step 1 model to produce preliminary NHS core areas.

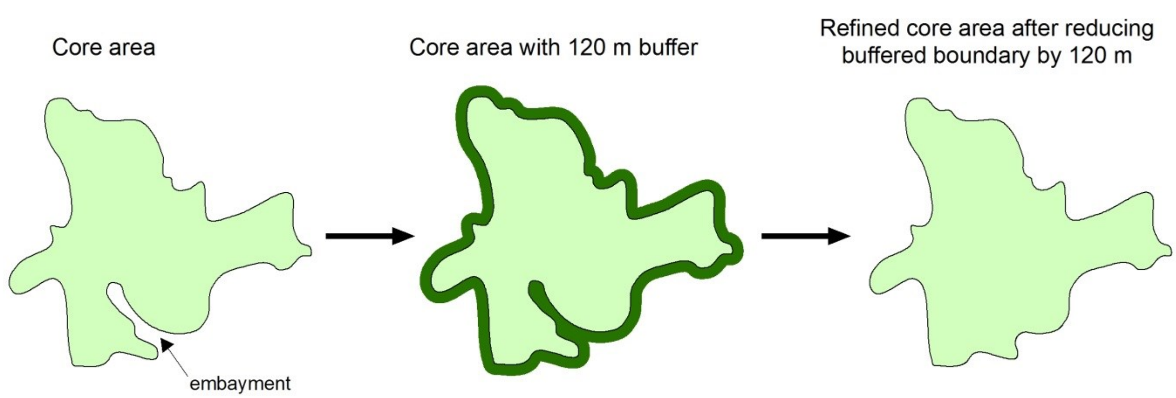
<u>Run the Step1_NaturalHeritageCores Model</u>



Input: Focal mean results

Output: Raw cores cut off at desired percentile (35%, 40%, 45%, 50%) where model was run for each percentile separately.

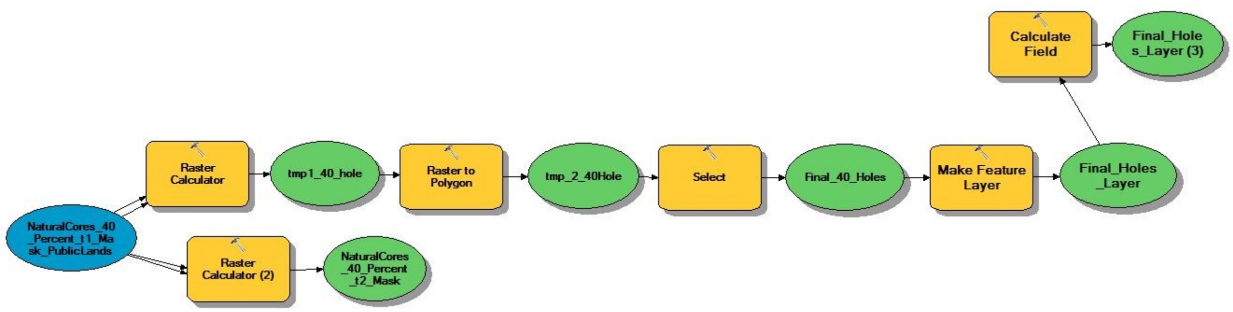
Figure 9. Schematic diagram of process used to eliminate narrow embayments in core areas by adding and subsequently removing a buffer.



7) The Step 2 Model (Figures 10,11) addressed holes within Step 1 cores and was based on the following processes:
   - Identified all the polygons not included within core areas, but within the outer boundaries of the core areas and selected those that are equal to or smaller than 250 ha and created a new layer for these holes.
   - These polygons representing holes were then put back into the cores layer to fill in the holes 250 ha or smaller.

Figure 10. Step 2a model to identify holes in core areas.

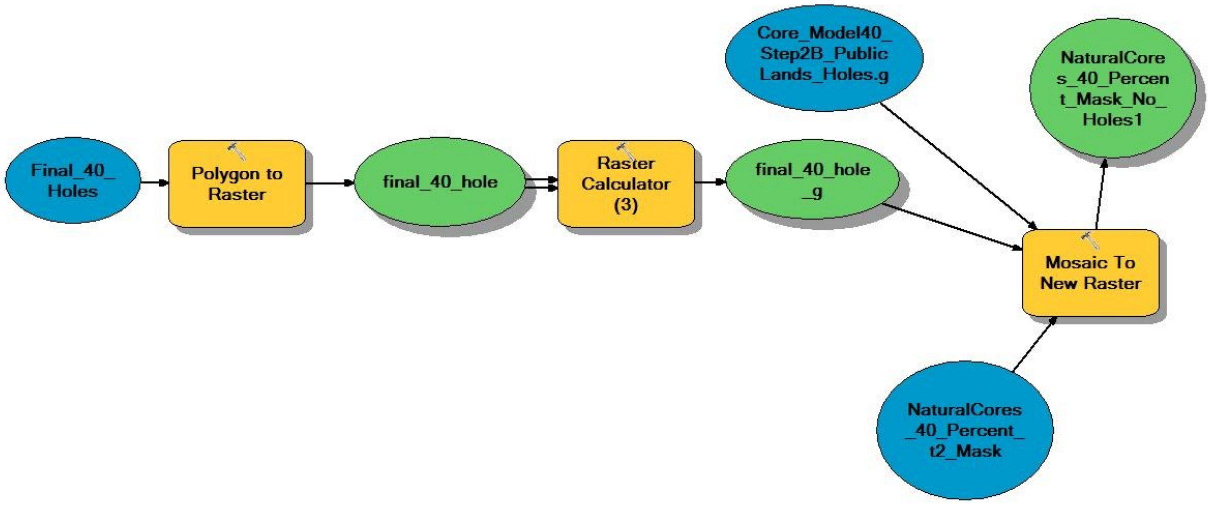
<u>Run the Model Step2a_NaturalCoreHoleIdentifier_Modified:</u>



Input: Natural_Cores_XX_Percent_T1_Mask [raster output from Step1Model]
Outputs: Final_XX_Holes (Core holes ≤ 250 ha) [polygon feature class]
Natural_Cores_XX_Percent_t2_Mask [raster where cores = 1 and NoData = 0]

Figure 11. Step 2b model to fill holes in core areas where appropriate.

Run the Model Step2b_NaturalCoreHoleIdentifier_Modified



Inputs: Final_XX_Holes (Core holes ≤ 250ha) [polygon feature class]
Natural_Cores_XX_Percent_t2_Mask [raster where cores =1 and NoData = 0]

Outputs: NaturalCores_XX_Percent_No_Holes1 [raster where cores within holes ≤ 250ha filled in

8) Public lands were added to the core area layer to ensure public lands, despite being less than 50% natural cover, were included in the system. Public lands included Provincial Parks, Conservation Reserves, Wilderness Areas, National Parks, National Wildlife Areas, Migratory Bird Sanctuaries, Agreement Forests and Crown Land (patented and unpatented).

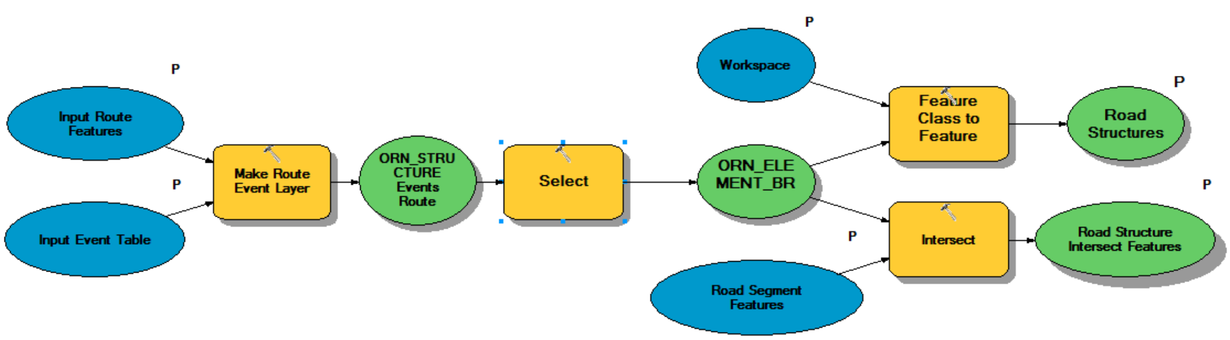
   Input: Reclassify Natural Cores_40_Percent_Marsk_No_Holes1 to Core = 1, No Core = NoData, then convert to polygon and clip to study area boundary

   - The boundaries of core areas were extended to include any public lands that intersected or were immediately adjacent (touching) to a buffered core area boundary by selecting the public lands that intersect with cores and saving it to a new layer. The intersected public lands data were clipped to the study boundary to remove public lands that extend beyond the Growth Plan area.
   - Natural features (excluding hedgerows) within these additional areas of public lands were buffered by 30 m. This was accomplished by intersecting the erased public lands data with natural features and the results were exported to a new layer. The intersected natural features data were erased using the core area layer so that only natural features that intersected with public lands and go beyond the boundary of cores were included. These areas were buffered by 30 m and the results were clipped to the study area boundary.

- Isolated public land parcels at least 500 ha and less than 50% natural cover should be considered for core area designation. No public lands were in this category in the Growth Plan area.
- The buffered natural features and erased public lands were converted to grid and incorporated back into NaturalCores_40_Percent_Mask_No_Holes1. Model 2a and Model 2b were run again to fill in any holes that were 250 ha or smaller that were created during this process. This step was done so that any holes less than or equal to 250 ha that resulted from the extension of core areas with public land parcels were filled in and included as part of the core area (similar to step 7 above).

9) The Step 3 Model (Figures 12, 13) removed impervious areas from cores based on the following steps to determine barrier features. The data preparation for this model includes the following items:
    - The SOLRIS impervious data class was identified as value 203 or Built-Up Area-Impervious. SOLRIS z17 and z18 were mosaicked into a new grid and clipped to the buffered study area boundary. Grid code 203 was extracted and reclassified to 2. All other values were set to 0.
    - The grid lines of local urban streets that lie within SOLRIS impervious areas appear as a grid webbing of roads that are not desirable. These grid lines were removed by using the Expand tool to grow the Urban Impervious Class (2) by 1 cell and then using the Shrink tool to contract the Urban Impervious by 1 cell to remove inner grids while maintaining the shape of original impervious area.
    - Bridges were extracted from the Ontario Road Network (ORN) using the Extract_Bridges_ORN model from the Toolbox to identify bridges over highways and rails. The intersected bridges with ORN highway/expressway and freeway were exported to a feature class along with bridges intersected with ORN_Rail (railway). These layers were then merged together and the bridges were converted to raster (value of 1) with a background value of 0 to create the Bridge Grid.

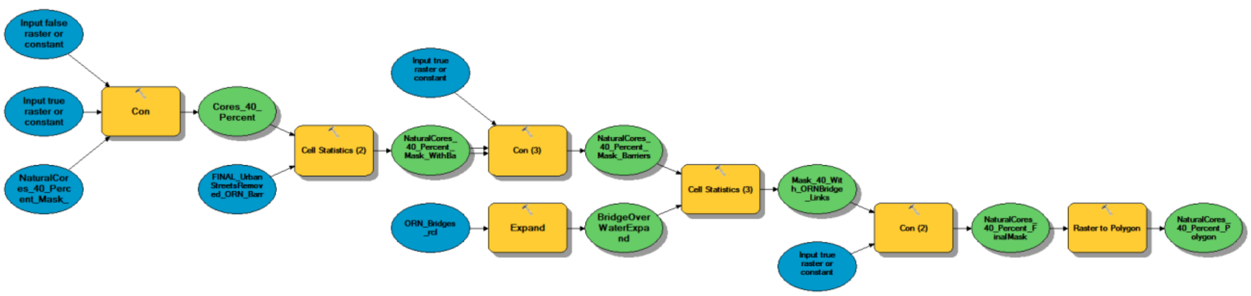
Figure 12. Portion of Step 3 model to identify impervious surfaces within core areas.



- Highways, expressways and freeways from the ORN road segment were extracted by querying Road Class – Expressway/Highway or Freeway. This selection was exported to a feature class and the feature class was converted to grid where highways received a score of 2 and background values were 0. This represents the term “major highways”.
- Raster calculator was used to add SOLRIS Urban Impervious and ORN Barriers together and reclass the result so that all values greater than 0 were equal to 2.

Figure 13. Portion of Step 3 Model to remove barriers and insert bridges into core areas.

Run the NaturalCoreBarrierInclusion_Step3 Model



Input: Cores with public lands, Barrier Grid and Bridge Grid
Output: Cores with barriers removed and bridges added as cores

10) The output from running the Step 3 Model resulted in all potential cores identified for the study area. These polygons needed to be further analyzed to select out only eligible cores based on the criteria.

- All core areas should be at least 50% natural cover.

    i. This was done by using the cores generated from the Step 3 Model, clipping the cores to the Growth Plan boundary, exploding any multi-part polygon to a single part polygon, generating a new double field of unique integers (FID + 1) and calculating area in hectares for each core.

    ii. The intersect tool was used to intersect this core layer with the natural features polygon layer. The attribute table for the intersected layer was opened and the geometry of the hectares attribute was recalculated and summarized using the core unique ID with the hectares (sum).

    iii. The summary table was joined to the core layer from above based on the Core ID and a new field for % natural cover was created. The field calculator was used to calculate the percent natural cover using the formula =(ha from summary table/total ha of core)*100.

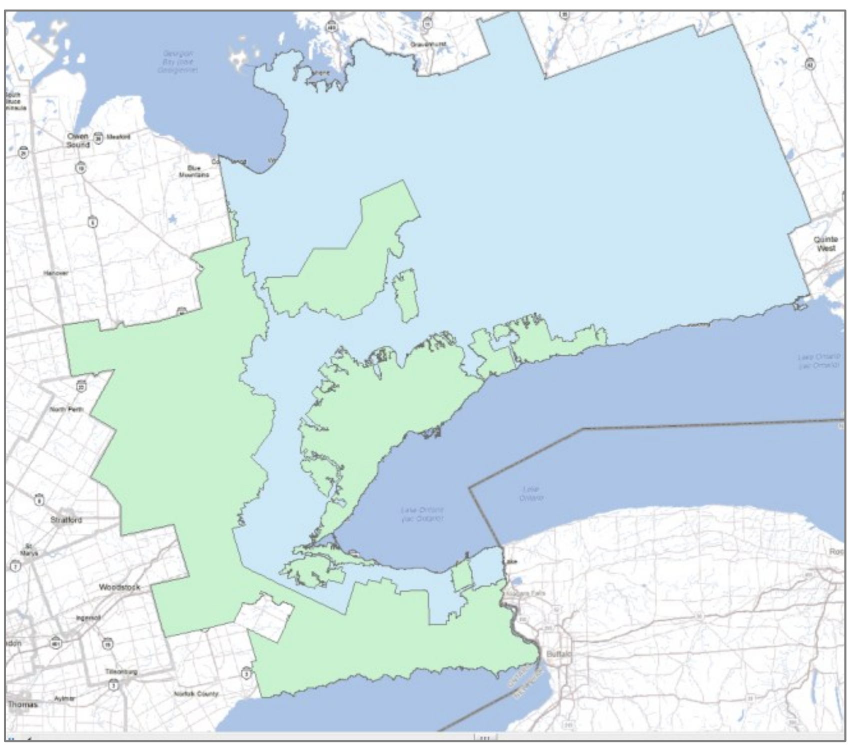
iv. All of the core areas that were at least 50% natural cover and ≥ the desired core area threshold size (i.e., 500 and/or 100ha as described below) were selected.

- All core areas that were greater than 500 ha were included as part of the NHS. Areas of the Growth Plan area that have low effective mesh size (e.g., 30 ha or smaller) and low percent natural cover (e.g., less than 25%), had smaller core areas identified for inclusion. Regions were identified in the Growth Plan area that would indicate where core areas 100 ha or greater should be included. These areas are west and south of the Greenbelt, the inner ring, the Newmarket area, and south of Camp Borden in southern Simcoe County (Figure 14).

i. Cores were intersected with the 100-ha boundary (green) and those ≥ 100 ha were selected.

ii. Cores were then intersected with the 500-ha boundary (blue) and those ≥ 500 ha were selected, and the two resulting feature classes were merged together to create a single core feature class.

Figure 14. Growth Plan area showing regions with a minimum core area size of 500 ha (blue) and 100 ha (green).



11) Additional core areas in the Growth Plan area that are less than 100 ha in these regions, or less than 500 ha in the eastern or northern Simcoe County regions, were reviewed to determine if they were actually edges of larger intact natural cover polygons outside of the Growth Plan boundary that met the minimum size

thresholds. There were four additional core areas that fit this criterion and these smaller areas were also included in the core areas layer to develop linkages to larger areas of natural cover just outside the boundary.

Note: the review of core delineation resulted in the flag of the following:
- Manual updates were required to reconnect core areas that were incorrectly broken by roads because of missing bridge data. These cores should continue along the river.
- Some cores may visually seem to be missing areas of nearby natural cover. These natural areas were not captured as part of a core in the automated process because their focal means are less than the 40% threshold.
- Core area boundaries were extended to include adjoining natural features which were then buffered by 30 m. If there were additional nearby natural features that fell within the 30-m buffer, they were not picked up and included in the core. Core area boundaries were only extended once with adjoining natural features rather than having a cascading effect.

Linkages

The automated identification of linkages took into account the following considerations:

- Where continuous connections of natural habitat are not available, linkages should incorporate stepping stones of natural habitat.
- All core areas need to be linked and there should be a minimum of two linkages between each pair of core areas where possible.
- Linkages should not be bisected by impermeable barriers so that movement between core areas through the linkage is possible.
- Riparian and shoreline linkages are important as areas of high species diversity and natural corridors for movements.
- Linkages in the Growth Plan need to complement linkages and core areas in adjacent regional planning areas (Greenbelt, Oak Ridges Moraine, Niagara Escarpment).

Identification of linkages was automated through the use of the ArcGIS tool Linkage Mapper (McRae and Kavanagh 2014) that uses the resistance of the landscape to animal and plant movement to identify least cost paths between core areas. The following process was used to automate the identification of linkages:

1) The various data sources were prepared and classified for the resistance features layer as follows:

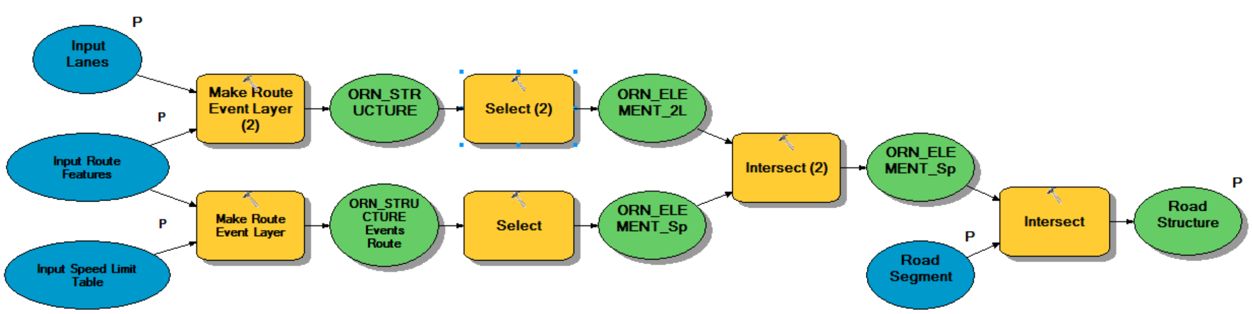
   Data preparation for SOLRIS data
   - SOLRIS Impervious – set to 1000.
   - SOLRIS natural cover classes – set to 10.
   - Pervious built-up areas – set to 100.

- Extraction classes – aggregates and peat/topsoil – set to 1000.
- SOLRIS tilled and undifferentiated classes – set to 100.
- The SOLRIS Transportation (201) class was not assigned a resistance value as the ORN roads do not perfectly align with SOLRIS roads and create pockets of "No Data". Therefore SOLRIS roads were eliminated from the resistance layer by use of the EXPAND tool on SOLRIS to grow classes 10, 100 and 1000 by 50 cells making sure that the analysis extent was set to the SOLRIS resistance grid. This grew the cells adjacent to SOLRIS roads (201) and eliminated SOLRIS roads from the SOLRIS resistance grid, leaving no "No Data Cells".

Data preparation for ORN data

- Freeways and highways with speed limits greater than 90 km/hr or with four lanes or more, were targeted to have higher resistance than other roads. A multiple step process was required to determine which road segments fell into this category.
- The ORN attribute of "Freeway" was selected to extract the majority of divided highways in the study area (e.g., 400 series).
- A model was created to work with the ORN Net Element and ORN Segment with Address to identify and extract the highways or expressways with speed limits at or above 90 km/hr (Figure 15).

Figure 15. Model to identify and extract highways and expressways.



- These two layers were merged together and given a "G-Code" field and temporarily calculated to 10000 (rationale for this is described below).
- The expand and shrink tools were used on freeways and highways with speed limits greater than 90 km/hr or with four lanes or more and service roads to reclassify the ditch between separated highways to the same class as the roads to avoid providing lower resistance in the medians.
- All virtual roads and ferry crossings were deleted from the ORN feature class.

- The remaining features that were not freeways, or 4 lane highways with speed limits greater than 90 km/hr were classified and scored (see Table 6).

Table 6. Resistance values of remaining ORN features.

Road Class	Resistance Value
Rapid Transit	1,000
Ramp	1,000
Freeway	n/a
Expressway/Highway	1,000
Arterial	1,000
Service	1,000
Winter	100
Resource/Recreation	100
Local / Unknown (non-urban)	100
Local / Street (non-urban)	100
Local / strata (non-urban)	100
Alleyway / Laneway (non-urban)	100
Collector (non-urban)	100

Data preparation for OHN data

- OHN streams were buffered by 30 m on each side of the line (60 m total) and converted to raster.
- Virtual segments occur in OHN streams and run through the middle of lakes. Since SOLRIS natural cover types (which include lakes) adjacent to OHN streams received the lowest resistance, the combination of these two layers would result in false positives in lakes where the lowest resistance would occur in the middle of lakes along stream segments. Therefore OHN water polygons were extracted and converted to raster with a unique value (998). This value was used to build the final resistance surface, and did not reflect its final resistance value.

Data preparation for ORN Bridges

- Bridges on highways over water or rail were also important to represent in the resistance layer.

- Bridges along freeways that cross a body of water or railway (identified during the core identification and selection process above) were converted to raster.
- Once bridges were converted to raster, many of them were not wide or large enough to completely span the road raster, leaving cells of high resistance, or in some cases, No Data.
- In order for linkages to be potentially formed through these areas without the barrier, the rasterized bridge features were expanded by 1 cell to ensure they spanned across the entire width of road cells.

Data preparation on other remaining layers was as follows:

- Where The Trees Are (WTTA) – set to 10.
- GRCA wetlands – set to 10.
- ACI data (AAFC) – set to 10.

Once data preparation was complete, a series of overlaying and scoring was executed to create the final resistance surface:

- Raster Calculator and the Reclassify function were needed to identify relationships between the data and assign the proper resistance value.
- All inputs needed the same extent as the SOLRIS data (clipped to study area) and NODATA cells need to be reclassified to 0.
- The SOLRIS data set with roads removed was used as the base foundation, with all other data sets added on top and given temporary values, one at a time in the following order:
    - WTTA, AAFC and GRCA data were added to SOLRIS data (roads removed). Any of these natural areas that overlapped with scores of 100 or 1000 were reclassified to 10.
    - OHN waterpoly was added to identify OHN stream virtual segments and classify them appropriately. The default values were accepted as long as the features received a unique value (e.g., 998).
    - OHN streams were added to the surface and reclassified so that: a) areas that had a score of 10 that overlapped with stream buffers received a score of 5 as a water course with adjacent natural cover; b) areas of 100 or 1000 that overlapped with streams received a score of 50; and c) water polygon cells that overlapped with streams received a score of 10.
    - ORN data classified with scores of 100 or 1000 (not the freeways and 4 lane highways yet) were added. The grid was reclassified so that: a) areas that had a score of 5, 10 or 50 that overlapped roads received a score of 100 or 1000; b) areas that had a score of 100 that overlapped 1000 resistance roads received a score of 1000; and c) areas that had a score of 1000 that overlapped 100 resistance roads received a score of 1000.

- ORN freeways, 4+ lane highways, and highways with speed limits of at least 90 km/hr were added and reclassified to 10000 (temporary value).
- ORN bridges were added and the grid was reclassified so that areas that had scores of 1000 or 10,000 that overlapped bridges received a score of 10.
- The compiled grid was reclassified so that all the temporary values became the final associated resistance values with the exception of the temporary values of 0 and 10,000 which were reclassified to NoData.
- The final resistance raster was clipped to the study boundary so that no resistance cells were outside the study area boundary.

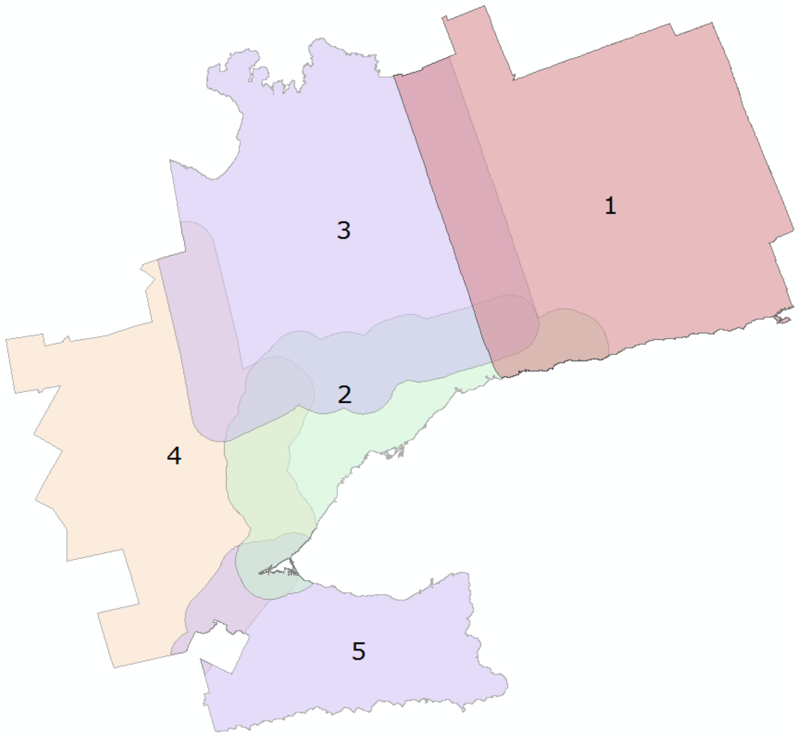
The final resistance surface grid was comprised of six key values and their associated resistance value (Table 7).

Table 7. Values for final resistance surface grid.

Data Type	Resistance Value
Streams with adjacent natural cover	5
Natural cover not adjacent to streams	10
Streams without adjacent cover	50
Rural lands, pervious built up areas, streets, roads with speed limits less than 90km/hr	100
Impervious built-up areas, extraction areas, other highways	1000
Major highways (e.g., 400 series and 4+ lane) and highways with speed limits at least 90km/hr	No Data

2) Creating processing clip boundaries
   - To reduce overall processing time and to avoid technical errors from crashing the Linkage Mapper tool due to ArcMap administrative settings, the study area was divided into five processing areas with a 10-km buffer that overlap along shared boundaries (Figure 16).
   - The areas were buffered by 10 km then re-clipped to the outer study boundary to ensure that linkages were only created within the Growth Plan boundary.

Figure 16. Processing areas identified to run Linkage Mapper tool in the Growth Plan area.



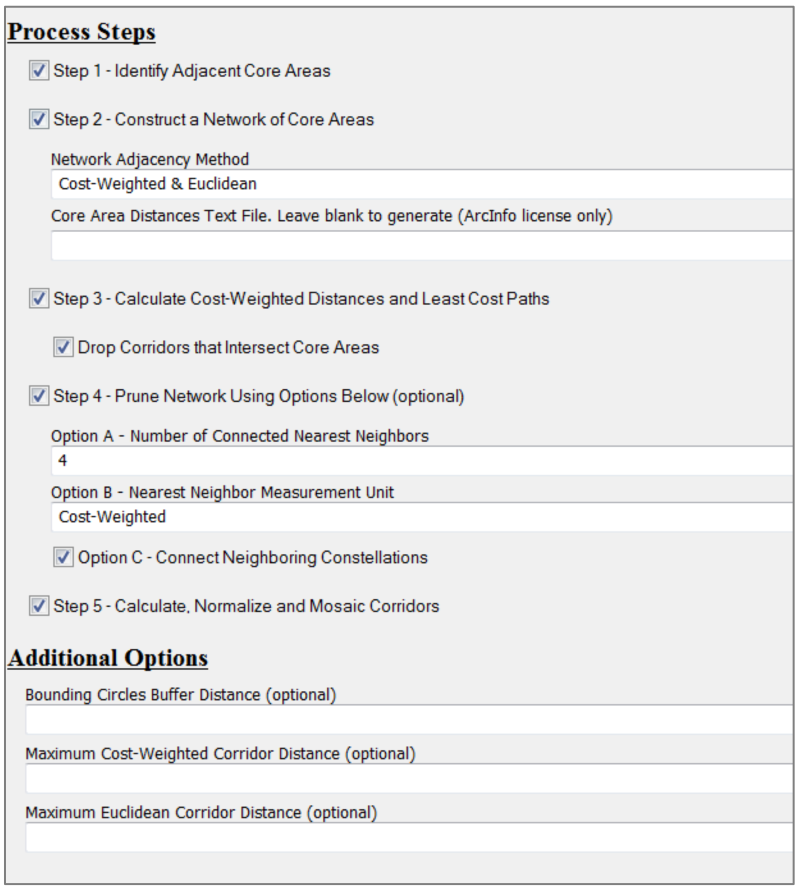
3) Running the Linkage Mapper tool (www.circuitscape.org/linkagemapper)
   - Linkage Mapper was run separately for each individual processing area (1-5).
   - The Resistance Surface and Core Areas were clipped to each individual processing boundary.
   - Once clipped, a new field called "Core_ID" was created for each individually clipped Core feature class and calculated to equal the "ObjectID", which was used as the "Core Area Field Name" in Linkage Mapper.
   - In some cases, the clip to the processing boundary created multi-part polygons. The Core feature class was not exploded into single part polygons to retain the polygon represented as a single core so that a linkage would try to connect to the shape as a single multi-part core rather than creating links to each individual piece of the core broken by the processing boundary.
   - The Linkage Mapper tool was run with the following settings (Figure 17):
     - Select Step 1 – Identify Adjacent Core Areas.
     - Select Sept 2 - Construct a network of core areas based on cost-weighted and Euclidean network adjacency.
     - Select Sept 3 - Calculate cost-weighted distances and least cost paths and select "drop corridors that intersect core areas".

- Select Step 4 - Prune the network using 4 connected nearest neighbours using a cost-weighted nearest neighbour unit, and connect neighbouring constellations.
- Select Step 5 - Calculate, normalize and mosaic corridors.

- There were no additional options included in the inputs or arguments in Linkage Mapper.

The results of the run produced polylines of potential linkages for each core area.

Figure 17. Setting used for Linkage Mapper runs.



4) Post Linkage Mapper cleanup overview

- Least Cost Path (LCP) lines generated from Linkage Mapper were buffered by 250 m on each side of the line (500 m wide total).
- The area of buffered linkages that overlapped with cores and any isolated or sliver polygons that resulted from this step were removed.
- Public lands that intersected or touched an existing linkage were added. Areas that overlapped with cores were removed.
- All natural features (excluding hedgerows) that intersected with the buffered linkages were selected. Portions of the selected natural features that overlapped

with cores were removed. The remaining natural features were buffered by 30 m.

- Buffered natural features that grew during the buffer to overlap with cores were removed and any isolated or sliver polygons that resulted from this step were also removed.
- Buffered line linkages and buffered natural features were combined into one product.
- Impervious features and freeways were removed from the buffered linkages product. Any isolated or sliver polygons that resulted from this step were also removed.
- Linkages that follow rivers that were broken based on road data were reconnected if bridges were present. In some cases, the bridges were not identified on roads, particularly in urban areas, so the linkages were broken during the removal of impervious features.
- Cores and linkages from the Greenbelt NHS were reviewed to determine if there were linkages that were not connected to the Growth Plan NHS or were orphaned. Existing linkages were modified or new linkages were created as appropriate using the Linkage Mapper tool.
- Linkages were reviewed to determine if double-lined streams identified in 1:100,000 scale OHN were accounted for in the linkages (generally streams ≥ 15 m wide). Additional linkages were created for these double-lined streams as appropriate. These streams were buffered by 250 m from each bank as per centre lines of linkages and overlapping natural features (excluding hedgerows) were included, as well as a 30-m buffer. The same approach was used to buffer double-lined streams included in core areas.
- Holes within the linkages ≤10 ha were filled in. Areas of overlap with cores and any impervious features and freeways were removed from the buffered linkages product. Isolated or sliver polygons resulting from this step were removed and any bridges that were eliminated during the removal of impervious features were added back in.

<u>GIS technical description for buffering lines and intersecting linkages with natural features</u>

Erase Features Methodology

- All SOLRIS Urban Impervious, ORN freeways and 4+ lane highways were required to be erased from the linkages/natural features data.
- Urban Impervious (Value = 203) areas from SOLRIS were extracted through a reclassification operation (Impervious cells were set to a value of 10000 and all other values to 0).
- To eliminate the streets and roads from within the Impervious layers:
  - The Impervious (10000) class was expanded by 2 cells filling in all the roads within Impervious areas.
  - The resulting raster was shrunk by 2 cells to bring Impervious areas back to their original size/shape.

  - *NOTE: The size and shape of Impervious will be slightly off but this will be remedied (for the most part) later in the process.*
- The ORN freeway and 4+ lane highway data that were created for the Resistance Surface creation were reclassified (if required) so that background values were 0 and highway values were 10000.
  To eliminate the space between divided highways:
  - Freeway/Highway data were expanded by 2 cells.
  - The resulting raster was shrunk by 2 cells to bring back Freeway/Highway data back to its original size and shape.
- The Highway Bridges over Water or Rail data that were created for the Resistance Surface were reclassified so that Bridges received a value of 3 and background values were 0.
  To eliminate any gaps in bridges on divided highways:
  - Bridges data were expanded by 2 cells.
  - The resulting raster was shrunk by 2 cells to bring back Bridges data back to its original size and shape.
- Natural Features data (no Hedgerow) were reclassified so that Natural Features received a score of 1 and background values received a score of 0.
- RASTER CALCULATOR was used to combine the Urban Impervious, Freeways/Highways, Bridges and Natural Features rasters together.
  - The raster was reclassified to ensure that any natural features were not overwritten during the EXPAND and SHRINK exercises and to allow linkages to be maintained under bridges on highways.
  - The grid was reclassified as follows:

0 = NoData	1 = NoData
2 = NoData	3 = NoData
10000 = 1	10001 = NoData
10003 = NoData	10004 = NoData
20000 = 1	20001 = NoData
20002 = NoData	20003 = NoData
20004 = NoData	

- The resulting reclassified raster was converted to a polygon feature class.

Buffering and Intersecting Natural Features with Linkages Methodology

- The linkages were buffered by 250 m to generate 500-m wide linkages.
  - The DISOLVE ALL option was applied.
- To eliminate overlap with cores, ERASE was used on the area of overlap between cores and linkages (ERASE Linkages with the Cores).
  - The multi-part to single-part tool was run on the result.
  - Any island/sliver polygons generated from the ERASE tool were eliminated.
- "Select by Location" was used to select all natural features that intersected the buffered linkages.

    - Results were exported to a new feature class.
- ERASE was used to eliminate natural features that overlapped with cores (ERASE Natural Features with the Cores).
    - The multi-part to single-part tool was used on the result.
        - Any island/sliver polygons generated from the ERASE tool were eliminated. Remaining natural features were intersected with buffered linkages.
        - The result was exported to a new feature class.
- The remaining Natural Features were buffered by 30 m.
    - The DISSOLVE ALL option was applied.
- To eliminate buffered natural features that overlapped with cores, the ERASE tool was used (ERASE Buffered Natural Features with the Cores).
    - The multi-part to single-part tool was run on the result.
    - Any island/sliver polygons generated from the ERASE tool were eliminated.
        - The remaining buffered natural features were intersected with buffered linkages.
        - The result was exported to a new feature class.
- The remaining Natural Feature Buffers were combined with buffered linkages using the UNION tool (Core overlap eliminated).
- A new field called "Dissolve" was created and Calculate was used to:
    - DISSOLVE unioned natural features and linkage features using the "dissolve" field (ensuring that "Create Multi-part features" was unchecked).
- To eliminate areas of impervious and freeways from the buffered linkages and natural features, the ERASE tool was used on the buffered linkages with the Impervious/Freeway features created above in the "ERASE FEATURES METHODOLOGY".
    - The multi-part to single-part tool was run on the result.
- All islands and slivers created during the ERASE function were eliminated.
    - This was a manual process of inspection to determine features that should actually be eliminated.
    - All features < 0.1 ha were eliminated.

Building the Natural Heritage System

The NHS is a combination of the core areas and linkages that were identified in the previous steps. The core area and linkage layers were combined and the following process was used to review and refine the NHS:

1) Core areas and linkages were reviewed against the most recent aerial imagery available through Land Information Ontario.

2) In a few instances, the imagery revealed that there where small areas of land cover that had not been correctly classified in the base data. In some of these cases, there had been changes to the landscape after the latest land cover update in 2011. Boundaries of the NHS were adjusted (expanded or reduced) accordingly based on the imagery.

3) In a few cases, review of the imagery identified linkages that needed to be remapped using Linkage Mapper or simply deleted as they traversed highly developed areas.
4) Natural features that were identified adjacent to the Greenbelt NHS that are contiguous and extend beyond the Greenbelt boundary into the Growth Plan area were considered for addition to the Growth Plan NHS. A buffer of 30 m was included with these natural features except where barriers exist (major highways and impervious areas). Natural areas including a 30-m buffer that were at least 0.5 ha were added to the Growth Plan NHS.
5) Natural features that were identified adjacent to the Greenbelt Urban River Valley designations in the inner ring that are contiguous and extend into the Growth Plan area were added to the Growth Plan NHS. A buffer of 30 m was included with these natural features except where barriers exist (major highways and impervious areas).
6) Any provincially tracked plant community greater than 0.5 ha in area and within 120 m of the adjacent land to the original non-buffered NHS was included in the system provided they were not separated by an impermeable barrier (i.e., major highway or urban development).
7) Any confirmed Life Science ANSI or provincially significant wetland greater than 0.5 ha and overlapping or adjacent to the NHS were identified for inclusion in the NHS. For multi-part polygons, only exploded single polygons were included (for example, several PSWs are complexes that can extend considerable distances across the fragmented landscape). Selected polygons were buffered by 30 m, with impervious features removed, and then dissolved into either core or linkage areas.
8) Areas under federal jurisdiction (i.e., Indian Reserves and CFB Borden) were stamped out of the NHS except for areas managed for conservation (eg. Wye Marsh National Wildlife Area).
9) Additional finer-scale natural features data (eg. wetlands and woodlands) that were supplied by Conservation Authorities were used to refine the NHS. Natural features that intersected the boundary of the NHS were included and given a 30m buffer.
10) As a result of consultation and feedback received, the final map shows the NHS across the entire Greater Golden Horseshoe outside the Greenbelt. As per policy 4.2.2 of the Growth Plan, the NHS doesn't apply to lands within settlement area boundaries that were approved and in effect as of July 1, 2017. For the precise boundaries and locations of settlement areas, please refer to the Official Plan that was in effect on July 1, 2017.
11) Portions of the NHS that fell within strategic settlement employment areas and economic employment districts in the Simcoe Sub-area of the Growth Plan were removed.
12) The boundaries of the NHS were smoothed using the Polynomial Approximation with Exponential Kernel (PAEK) algorithm with smoothing tolerance set to 70%.

Municipal Refinement

Growth Plan policy 4.2.2.5 identifies that municipalities may refine provincial mapping with "greater precision" in a manner that is consistent with the Plan through a municipal comprehensive review (MCR):

> 4.2.2.5. In implementing the *Natural Heritage System*, upper- and single-tier municipalities may, through a *municipal comprehensive review*, refine provincial mapping with greater precision in a manner that is consistent with this Plan.

Upper- and single-tier municipalities will incorporate the provincially issued NHS mapping into their official plans through a MCR.

Refinements that are consistent with the policies of the Growth Plan are as follows:

- Minor, technical adjustments (e.g., to account for distortion from map projections, discrepancies based on map scales);
- Addition of natural features[2] continuous with the boundary of the provincially mapped NHS. When natural features are added, the boundary of the NHS will be extended to include a 30 m vegetation protection zone beyond the edge of the feature consistent with the methods used for provincial mapping (see Figure 18);
- Removal of small portions of the provincial NHS where there is built-up impervious development or infrastructure[3] (that would act as barriers) that was not identified and stamped out of the provincial mapping;
- Removal of small, isolated portions of the NHS that protrude from the Greenbelt Plan boundary or settlement areas provided these areas have no natural features *and* are not connected to the larger provincial NHS.

Proposed refinements to the NHS shall be accompanied by supporting documentation, including any fine-scale mapping of natural features or infrastructure that was used to adjust the boundaries, and shall be submitted to the Province for review along with the proposed official plan or official plan amendment implementing the results of the MCR process.

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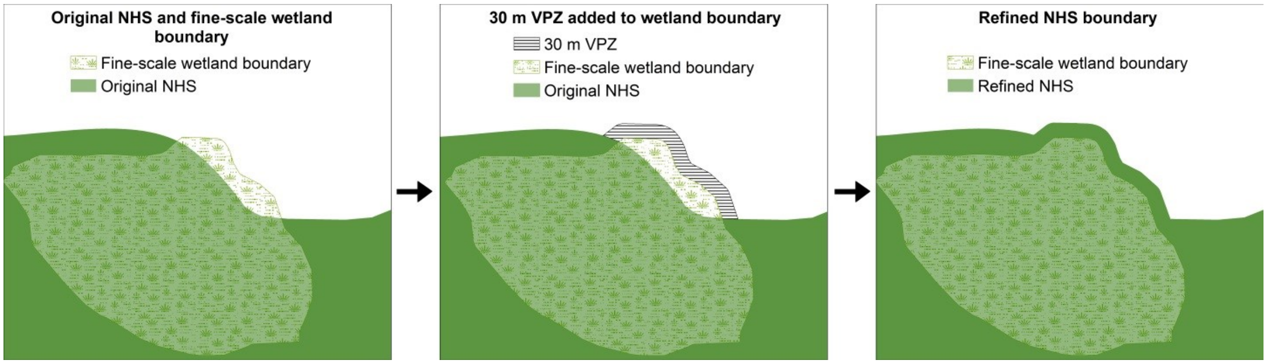
[2] Natural features include the following classes: beaches, sand dunes, alvars, open bedrock, tallgrass prairie and savannah, all forested (excluding hedgerows) and wetland classes, and open water.

[3] The built-up impervious class is defined in SOLRIS (Southern Ontario Land Resource Information System) as buildings, pavement and other impervious anthropogenic structures in urban areas with a threshold of at least 10 buildings/500 m or 4/ha. This class does not include constructed features such as farmsteads (silos, barns, and houses) or extraction sites.

Figure 18. Refinement of the Natural Heritage System to account for a natural feature that is shown to extend beyond the original boundary based on fine-scale data.



Assessment of the Natural Heritage System

The NHS (Figure 19) was reviewed to determine its extent and the degree to which natural features were incorporated into the system. The overlap between the NHS and the Agricultural System as well as aggregate resources was also assessed.

Extent of the Natural Heritage System

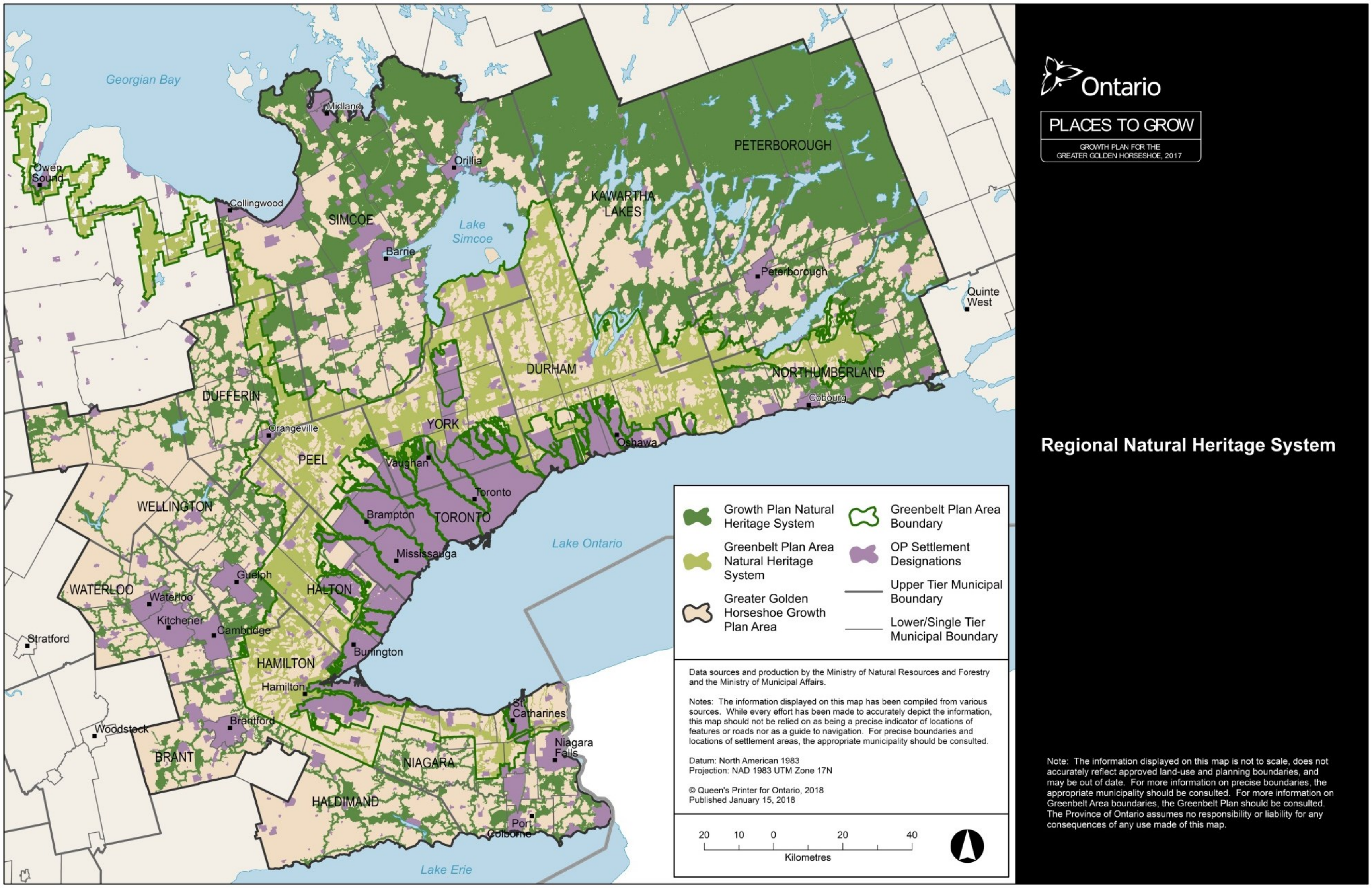
The total area of the NHS excluding settlement areas is about 1.18 million ha or 45% of the Growth Plan for the Greater Golden Horseshoe (Figure 18). Seventy-two percent of the NHS consists of natural cover (land or water).

Inclusion of natural heritage and hydrological features

The methods used to identify core areas and linkages in the NHS for the Growth Plan area were based on concentrations of natural cover and so did not specifically address the significance of natural features on the landscape. However, the key building blocks of NHS mapping were natural and semi-natural vegetated areas (including rare plant communities) and aquatic features provided by SOLRIS as well as public conservation lands. These building blocks, and the guiding NHS mapping principles applied (i.e., areas greater than 50% natural cover or public lands and minimum core areas of 100 or 500 ha), ensured the inclusion of many Areas of Natural and Scientific Interest (ANSI's), Provincially Significant Wetlands, element occurrences for species at risk and rare plant communities, and coldwater streams by default. It is difficult to include all significant natural heritage features within a regional-scale NHS as it is challenging to connect small isolated features to the rest of the system. Significant features not included in the regional-scale NHS are usually protected by feature-based planning policies and could be included in local NHSs at the municipal level.

After adding adjacent significant natural heritage features to the NHS, an assessment was completed to determine the total number and total area of these features within the Growth Plan area and the proportion of the features included within the NHS. Data for most significant natural features for this analysis were available through Land Information Ontario. The provincially tracked species occurrence database was used for Endangered and Threatened species occurrences. Endangered and Threatened bird species dependent on anthropogenic habitats (buildings and cultural grasslands) were not included in the analysis (Bobolink, Eastern Meadowlark, Loggerhead Shrike, Barn Swallow, Chimney Swift and Barn Owl). Low accuracy records and historic records (> 30 years old) were also not included. Tallgrass prairie communities occurring along railroad tracks were excluded from the analysis of rare plant communities. Stream inventory data from the Aquatic Ecosystem Classification (Jones and Schmidt 2017) and their associated base flow index were used to identify coldwater streams.

Figure 19. Regional Natural Heritage System for the Growth Plan for the Greater Golden Horseshoe.



Significant natural features are well represented in the NHS (Table 8). Within the Growth Plan area, almost all protected areas and provincially and regionally significant Life Science ANSIs are included in the NHS. The proportion of tracked species occurrences, Endangered and Threatened species occurrences, rare plant communities, wetlands, provincially significant wetlands and candidate ANSIs included in the NHS was also very high. Coldwater streams and provincially and regionally significant Earth Science ANSIs are also well represented in the NHS, although at a lower level than the other features (Table 8).

Table 8. Amount of protected area and natural heritage features in the Growth Plan area excluding settlement areas and the proportion included in the Natural Heritage System (NHS).

Feature	Amount in Growth Plan	Amount in NHS	Percent of feature in NHS
National Parks	0	0	0
Migratory Bird Sanctuary	0	0	0
National Wildlife Area	47 ha	47 ha	100
Provincial Parks	69,707 ha	69,619 ha	99.9
Conservation Reserves	1,061 ha	1,061 ha	100
Wilderness Areas	4 ha	4 ha	100
Life Science ANSI[1]	66,560 ha	65,916 ha	98
Candidate LS ANSI[1]	5,595 ha	5,449 ha	97
Earth Science ANSI[1]	15,374 ha	10,424 ha	68
Candidate ES ANSI[1]	1,391 ha	1,268 ha	91
Wetlands	336,419 ha	290,607 ha	86
PSWs only[2]	145,568ha	130,402 ha	90
Tracked species records	1,275 EOs[3]	1,105 EOs	87
E&T species only[4]	601 EOs	530 EOs	88
Rare communities	1,811 ha	1,721 ha	95
Coldwater streams	5,837 km	4,287 km	73

[1] ANSI – Area of Natural and Scientific Interest; LS – Life Science; ES – Earth Science
[2] PSW – Provincially Significant Wetland
[3] EO – Element Occurrence
[4] E&T – Endangered and Threatened

Overlap with the Agricultural System and Aggregate Resources

Prime Agricultural Areas in the Agricultural System (1.17 million ha) for the Growth Plan are similar in total area to the NHS. Twenty-three percent of the lands classed as Prime Agricultural Areas lie within the NHS (Table 9). Just over one half of the area of existing aggregate licences (54%) are included in the NHS (Table 9). The inclusion of areas with high aggregate potential in the NHS was assessed by overlaying the NHS with selected resources from Aggregate Resources of Ontario mapping (OGS 2015). Fifty-two percent of primary and secondary sand and gravel resources within the Growth Plan area are included in the NHS (Table 9). About three quarters of the selected bedrock resources are included in the system – 89% of the bedrock resources in the NHS are found in the Havelock Ecodistrict (6E-9) that borders the southern edge of the Canadian Shield.

Table 9. Area and proportion of the Agricultural System and aggregate resources in the Growth Plan area and the Natural Heritage System (NHS).

Feature	Amount in Growth Plan	Amount in NHS	Percent of feature in NHS
Agricultural System			
Prime Agricultural Areas	1,172,045 ha	276,382 ha	24
Aggregate Licences (active)	24,662 ha	13,364 ha	54
Aggregate Resources			
Bedrock	221,133 ha	169,559 ha	77
Sand and gravel	115,853 ha	60,179 ha	52
Buried resources	143 ha	95 ha	67

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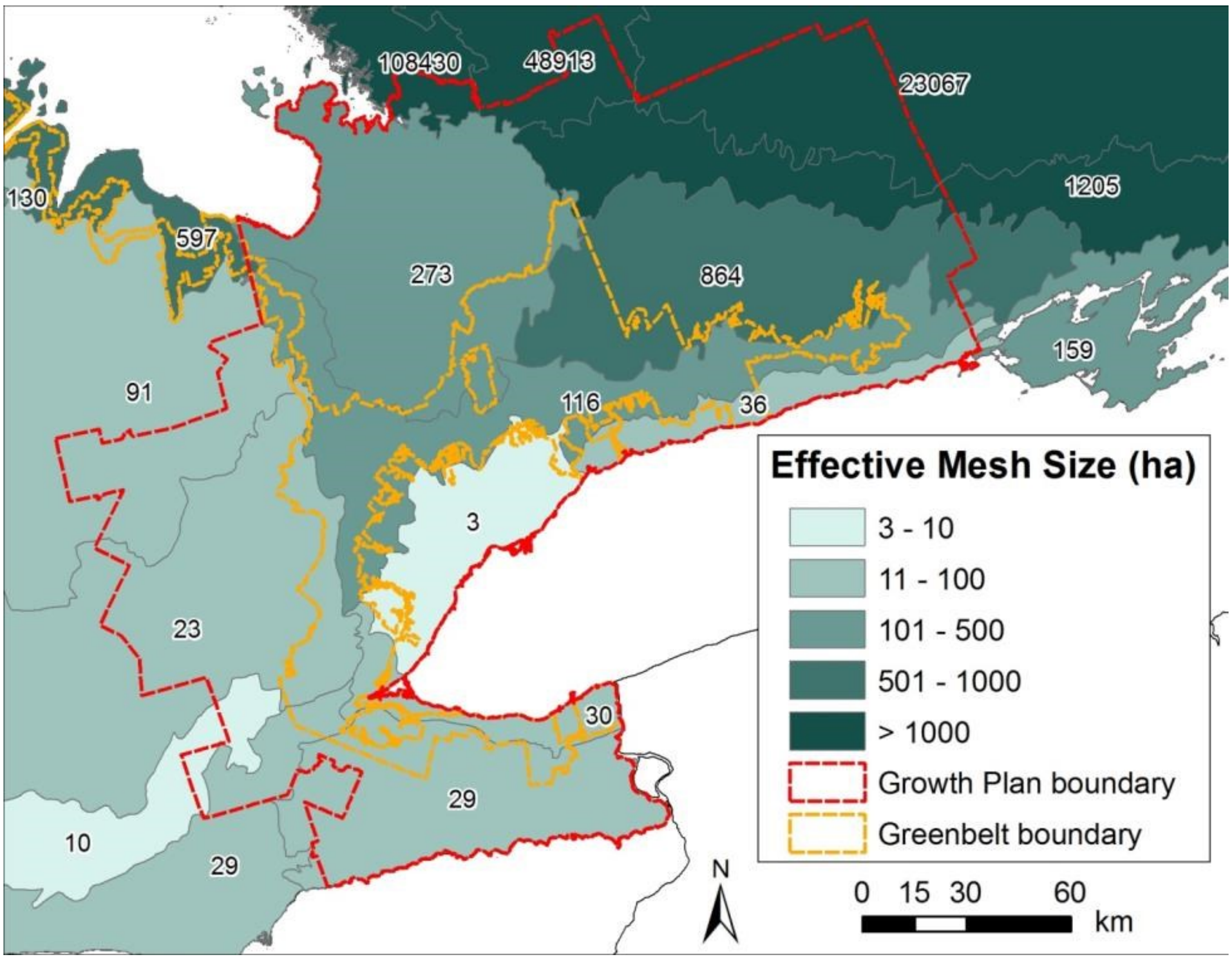
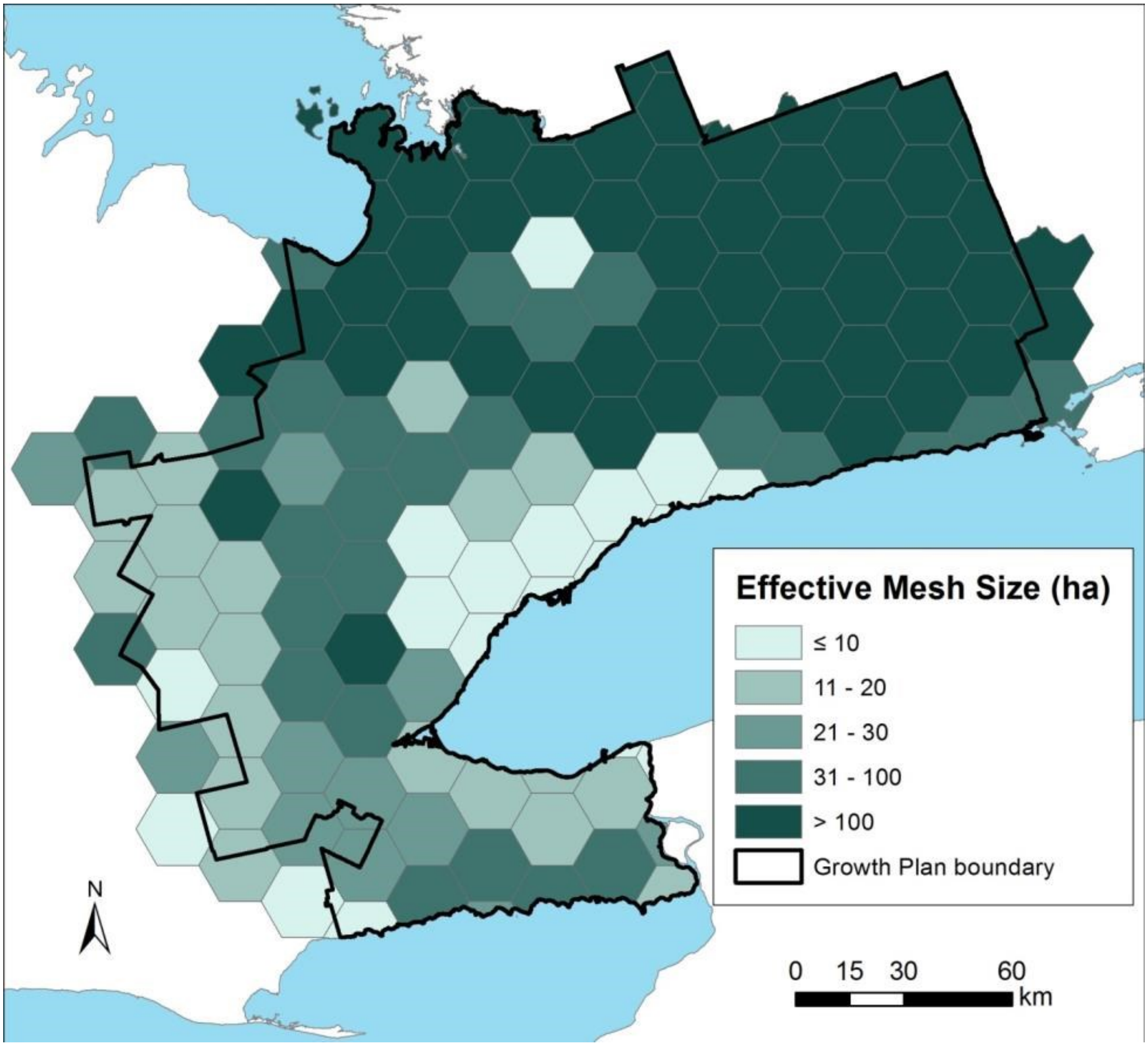
Appendix I – Habitat fragmentation and natural cover within the Growth Plan for the Greater Golden Horseshoe.

Figure I-1. Effective Mesh Size (ha) of ecodistricts that overlap the Growth Plan for the Greater Golden Horseshoe (source: OBC 2015).



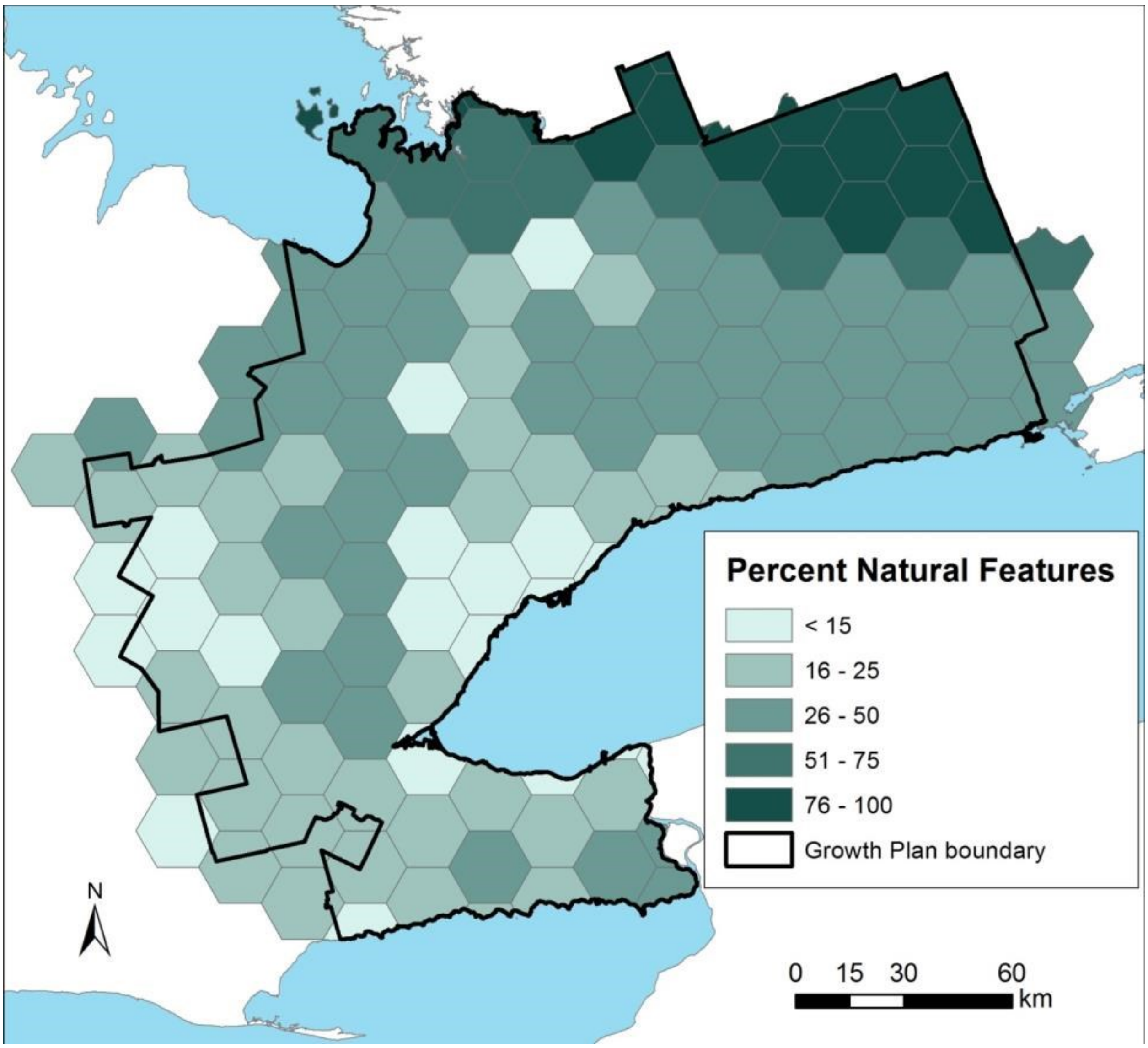
Appendix I – continued

Figure I-2. Effective Mesh Size (ha) for 20-km hexagons in the Growth Plan for the Greater Golden Horseshoe.



Appendix I – continued

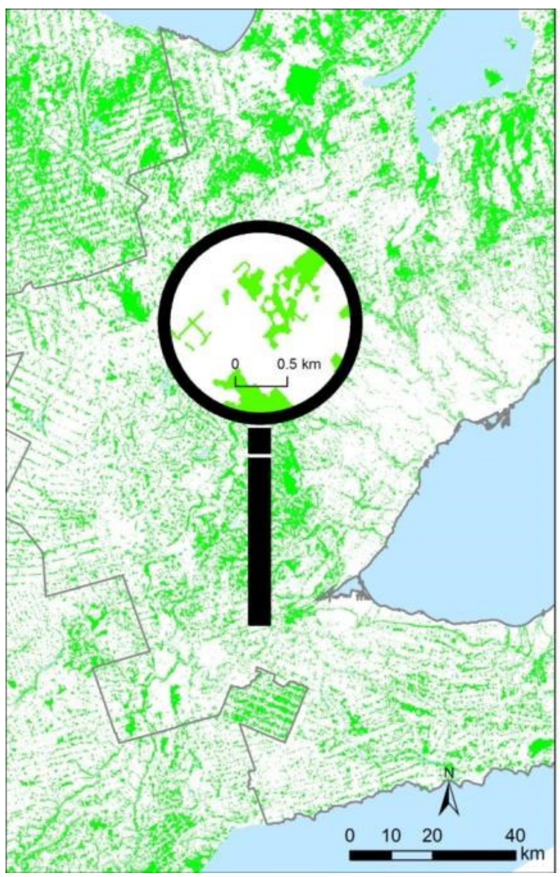
Figure I-3. Percent natural feature cover for 20-km hexagons in the Growth Plan for the Greater Golden Horseshoe.



Appendix II. Detailed description of process to develop spatially averaged natural cover layer.

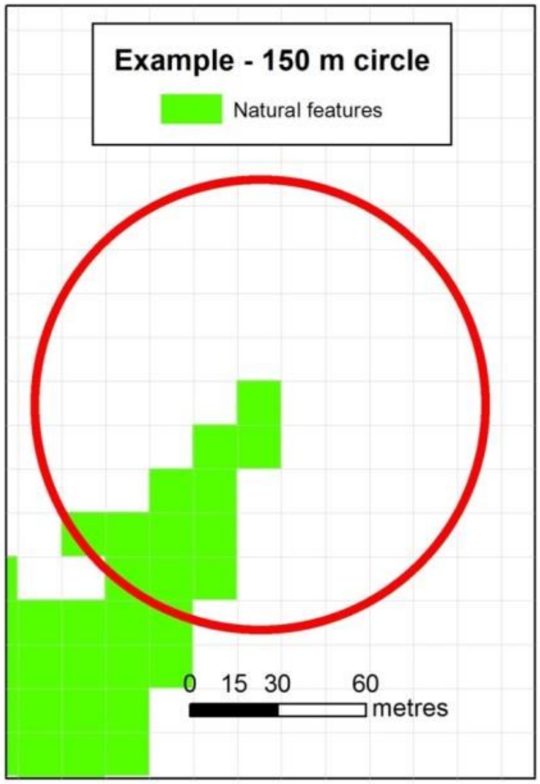
To automate the identification of core areas it was necessary to identify concentrations of natural features. This was achieved by creating a smooth, continuous gridded surface (i.e., image) of percent natural feature cover throughout the study area. The spatial averaging technique involved using focal statistics to assign a natural cover value to each 15-m pixel that reflects the percentage of natural feature cover within a distance of 1-km radius of that pixel. It is analogous to moving a 2-km wide magnifying glass across the landscape. The pixel at the centre is assigned a natural cover value equal to the percent natural cover in the field of view of the magnifying glass (Figure II-1). The magnifying glass is then moved by one pixel at a time and the process is repeated until the coverage in the entire study area has been calculated. The resulting product is best described as an image of tens of thousands of 15-m pixels, where each pixel is representative of the percent total natural features within 1 km in any direction.

Figure II-1. Broad-scale map of natural features in the Growth Plan area showing the 2-km field of view within a 'magnifying glass' used for spatial averaging.



To illustrate how the spatial averaging technique works, it is easier to visualize using a 'magnifying glass' with a finer field of view. Figure II-2 shows a 150-m field of view so that the individual 15-m pixels can be seen. Pixels that are green consist of natural features and those that are white consist of anthropogenic features.

Figure II-2. Natural features within a 150-m circle.



Within the field of view, pixels with and without natural features are tallied to produce a value for the central pixel that represents the percent natural features within 75 m of the pixel. The magnifying glass is then shifted by one pixel and the process is repeated (Figure II-3). Once this has been completed for all pixels within the area of interest, a smooth surface is produced whereby the percent natural features changes gradually from one pixel to the next (see lower right hand image in Figure II-3). With the 2-km circle used for the Growth Plan area, the change in percent natural features between adjacent pixels is even more gradual than in the example for the 150-m circle included here.

The gradual change in neighbourhood natural feature cover between adjacent pixels creates a smooth, continuous gridded surface (i.e., image) throughout the study area (Figure II-4). This allows "contour" lines to be drawn around groups of pixels that have neighbourhood natural cover values above a certain threshold (e.g., 30%, 50%) similar to elevation contours on a topographic map. The resulting polygons are concentrations of natural features that can be considered as potential core areas in the NHS.

Figure II-3. Percent natural features within 150-m field of view. The first five images from upper left to the lower right show the resulting percent natural features for each central pixel as the field of view is shifted to the right one pixel at a time. The image in the lower right shows the percent of neighbourhood natural features for each pixel within the original field of view.

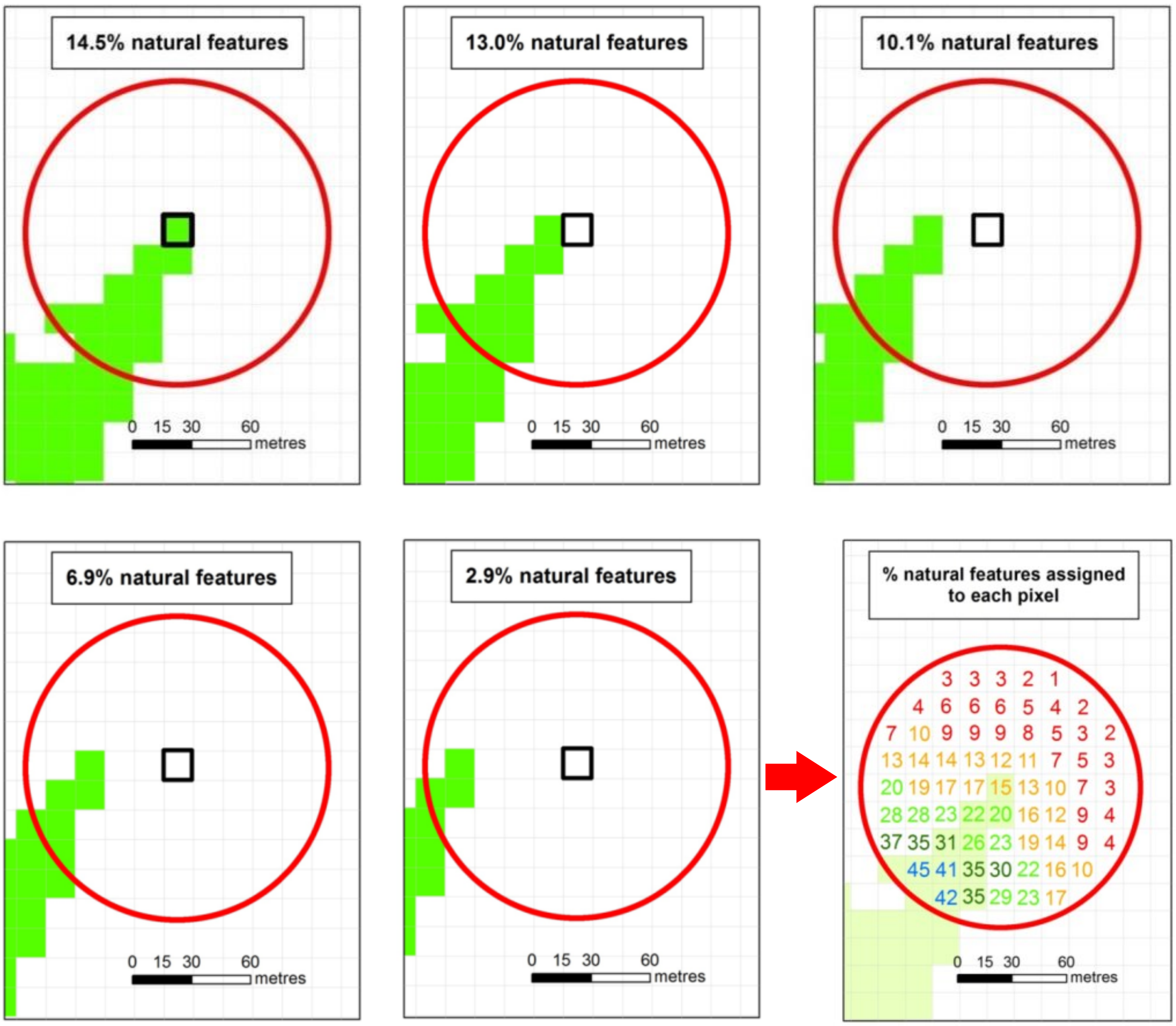


Figure II-4. Contour map of percent natural features within and adjacent to Growth Plan boundaries based on the amount of natural cover within 1 km of each 15-m pixel (based on land cover information from SOLRIS 2.1).