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Algonquin to Adirondack Analysis Methodology

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Prepared for the A2A Collaborative

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Background and Project Goals

This project will identify a natural heritage system design for a focus area of the Algonquin to Adirondacks (A2A) region. The A2A region extends from the southern edge of Adirondack Park in New York State to the northern edge of Algonquin Provincial Park in Ontario and encompasses the general area between the two parks. This area has been identified as an important pathway for species movement between these two large core natural areas. The project will analyze the natural heritage features of the fragmented areas of this region that has considerable development pressures in Ontario and New York State.

The project goal is to provide natural heritage system mapping and information that will support land use planning, stewardship activities, land securement programs and conservation efforts by planning authorities, conservation groups, community organizations and residents in the A2A region.

Nature heritage systems are made up of core natural heritage features associated with land and water that are connected together by natural linkages. These areas can be defined as natural areas, have been restored or have the potential to be restored to a natural state. Natural heritage systems can be viewed as landscape networks for biodiversity conservation, ecological function and viability of native species and ecosystems (Riley & Mohr, 1994; OMNR, 2010).

Nature heritage systems have been defined in various ways based on the overall objective, the size and scale of the study area, and the data that is available (SWWV 2011; Y2Y 2004; WHCWG, 2010). It is important to understand the scale at which the analysis is being conducted as connectivity analyses can be used to produce broad-scale maps that serve as decision support tools or vision statements or to produce finer-scale connectivity maps that prescribe more local or site-specific interventions (Baldwin et al., 2010; Huber et al., 2010). Best practices have been developed for regional connectivity maps (Beier et al., 2011) which were consulted for this project.

The following components in this document outline the scale of the project, the intent of connectivity, and how cores and linkages are defined for the purpose of this project.

Study Area

The A2A region extends from the southern edge of Adirondack Park in New York State to the northern edge of Algonquin Provincial Park in Ontario and encompasses the general area between the two parks. This area has been identified as an important for species movement between these two large core natural areas. The study area developed for this analysis focuses on the natural heritage features of the fragmented areas of this region that has considerable development pressures, representing an area more than 3 million hectares in size (Figure 1).

The Ontario portion of the study area is described as ecodistricts 6E-12, 6E-16, 6E-10, 6E-11 as defined by the Ecological Land Classification system (ELC) (Crins 2002, Crins et al., 2009). The eastern portion of ecodistrict 6E-15 was included that but did not include Prince Edward County or the area of the ecodistrict west of the 2HM (Napanee) tertiary watershed. The lower western portion of the Ontario study area was modified to include aspects of the 2HM tertiary watershed that overlapped with ecoregion 6E. Ecodistrict 5E-11 was considered a low priority area since contiguous natural cover is present across the region with little development pressures.

The New York portion of the study area is described as ecoregion 83d, most of ecoregion 83e, portions of 58ab outside of the Adirondack Park boundary and the northern portion of ecoregion 83c. These ecoregions level IV boundaries are defined by Bryce et al., 2010. The southern portion of 83e has been modified for this study area and does not include the portion that extends between Adirondack Park and Tug Hill since there has been some connectivity analysis completed already in this area (Brown et al 2010). The southern portion of the New York study area that clips ecoregions 83e and 83c represents the HUC12 watershed boundaries as defined by US Department of Agriculture and the Natural Resource Conservation Service (Seaber et al., 1987).

A 2km buffer was added around this study area except for the area along the Quebec border where the 2km buffer zone was delineated back into Ontario and New York. A 2km buffer was added to the analysis to avoid edge effect in areas where data was available.

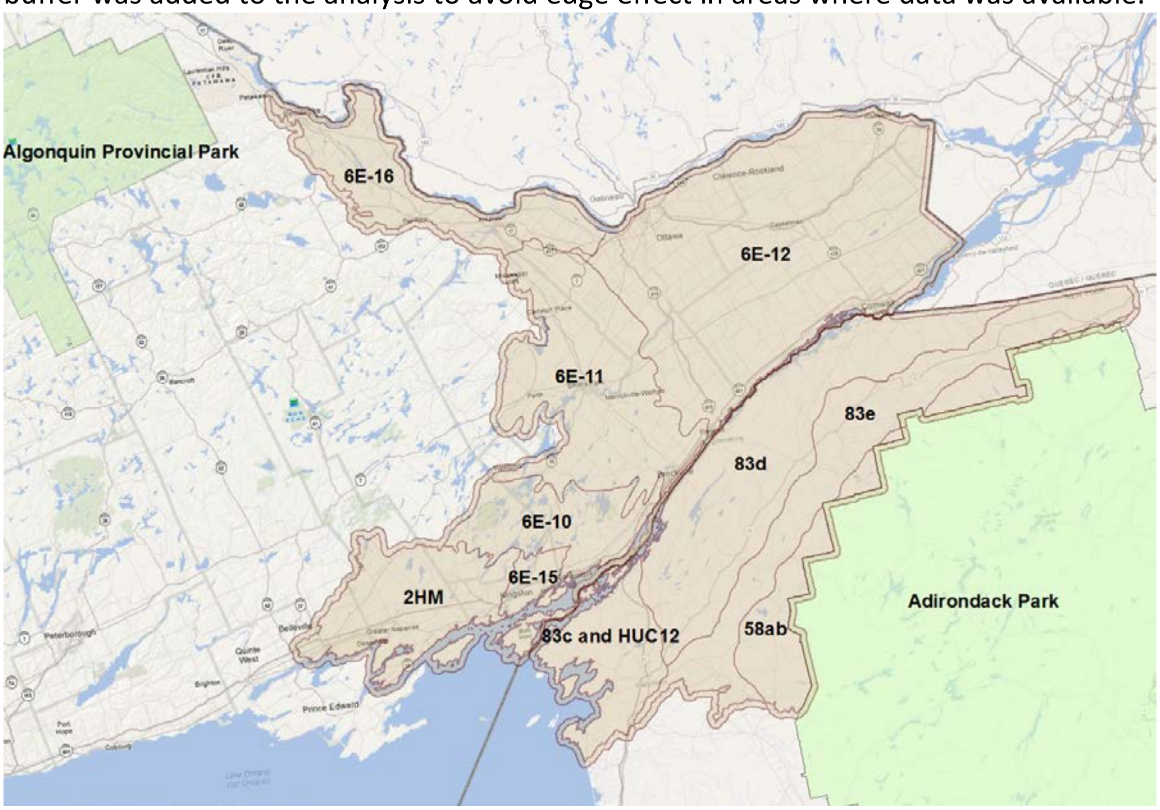

Figure 1: Study area boundary.

General Methodology

The core and linkage development is based on the original methodology constructed by Voros (2011) used to define the natural heritage features from Marxan analysis outputs to produce a connected system in 6E-10 and 6E-11. This criteria used in Voros, 2011 was consistent with the Natural Heritage Reference Manual, Second Edition (OMNR, 2010), the Significant Wildlife Habitat Technical Guide (OMNR, 2000) and expert-based input and recommendations from OMNR wildlife and landscape ecology specialists (Voros, 2011). The core and linkage methodology used in this analysis has been developed with regard to the Voros, 2011 methodology and modified for the A2A study area. The key divergence from Voros, 2011 was that all blocks of natural cover was identified for potential connections in the A2A study area rather than generating priority areas from Marxan first as cores and then connecting them across the landscape. The methodology draws from principles and recommendations developed through other connectivity analyses (Beier et al., 2011; Spencer et al., 2010). Three key components of this methodology were used in developing the connected system for the A2A study area. These components include:

1. **Core Areas** are the least fragmented natural areas (>500m wide).
2. **Primary Connection Zones** which are zones to derive the most efficient pathways (least cost paths) to create connections between cores
3. **Least Cost Paths** which connect land and water core areas together (50-200m wide).
4. **Riparian Linkages** which connect core areas and linkages along riparian systems (20-100m wide).

The key components of the methodology and described in the following sections of this document in more detail.

Core Areas

Definition

Core areas are intended to represent wide, contiguous areas of natural cover that provide a diversity of habitats and ecological functions to support a wide range of species. Core areas can consist of one or more natural cover types and may also include some non-natural cover. Some examples of non-natural cover that could be included are agricultural lands and bisecting roads. Some smaller inclusions (≤100m wide) of non-natural cover can occur if there is a limited amount of restoration required and has the potential to maintain the general integrity of the landscape node relative to other adjacent areas. Some non-natural features are never included in core areas; for example, interstate highways and developed urban areas are *fragmenting barriers* to core areas. Criteria used to delineate core areas were developed to identify the least fragmented areas of natural areas across the study area. The analysis was conducted on 10m resolution rasters in New York and 15m resolution rasters in Ontario.

Assembling input layers for identifying potential land core areas

A series of data classes were used to identify lands that had the potential to become land cores (Figure 2). These data classes include the following:

- All natural areas identified in the base land cover data
- Natural Heritage Program rare communities data
- Natural Heritage Program exemplary communities data
- Great Lakes coastal wetlands data (GLCWC)
- Small lakes (<20ha)
- Narrow rivers (<60m wide)

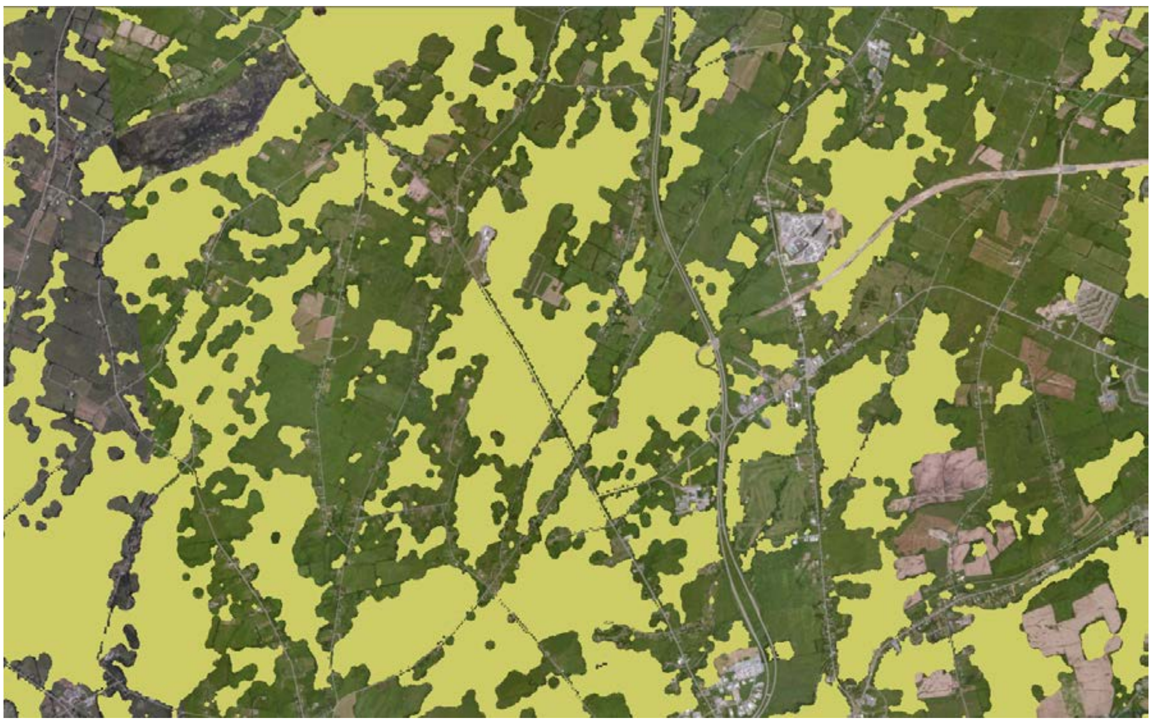

Figure 2: Potential land cores

Assembling input layers for identifying water core areas

The following data classes were gathered to identify potential water cores (Figure 3)

- Rivers more than 60m wide excluding any islands within the river.
- Lakes larger than 20ha.

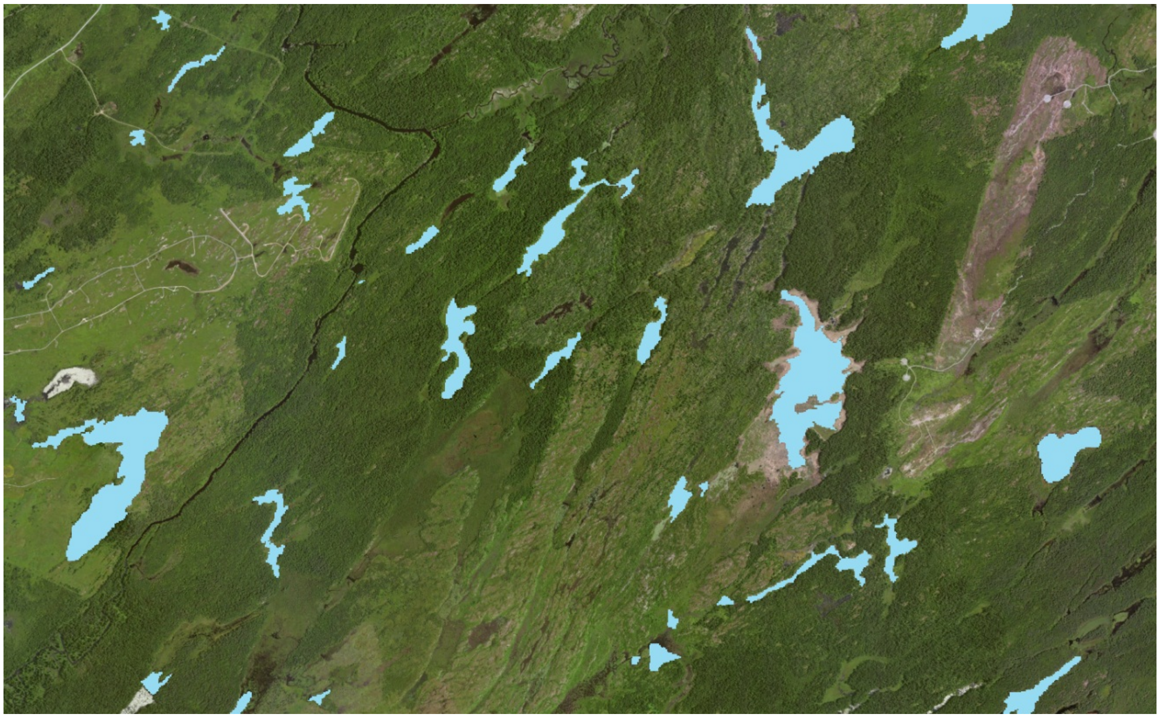

Figure 3: Potential water cores

Assemble all barriers that can fragment cores

Barrier features that can fragment cores were then assembled to divide the potential cores as final land and water cores were developed (Figure 4). Barriers to cores include:

- 400 series highways and interstates. Locations of bridges over rivers and rails were not included as a barrier. Road lines were buffered by 20m each side.
- Footprints of buildings for rural and urban development as identified in the base land cover dataset for Ontario. These areas should be more than 50m wide. Comparable data was not available for New York.
- Road Density. A kernel density analysis identified additional areas of development that can complement the areas already recognized as rural and urban development. The total length of road per total area within a 250 radius circle was calculated for each pixel. Pixels that were assigned more than 9 kilometres of roads per km^2 area within a circle was identified as a higher level of development considered a barrier and would fragment a core.
- Larger waterbody core areas
    - Rivers more than 60m wide excluding any islands within the river.
    - Lakes larger than 20ha.

Figure 4: Barriers that fragment cores (black)

Creating land cores

Once areas are identified as potential cores and barrier features developed, cores can be created (Figure 5). The following steps were used to create land cores:

1. Eliminate thin natural areas ≤ 40m wide. This ensures narrow natural areas (eg. hedgerows) are not captured as cores and therefore capture nearby larger areas of non-natural cover such as agricultural lands into core areas.
2. Identify non-natural areas that are ≤100m wide surrounded by natural areas that could be included in a core area and represent areas of restoration opportunity within a core.
3. Remove any barrier features that would fragment these cores.
    - All 400 series highways and interstates except for bridge crossings over watercourses and railways
    - Residential development of built-up pervious and impervious surfaces
    - Large waterbodies >20ha in size and rivers wider than 60m
4. After removing any barrier, core areas were reviewed again to ensure only those remaining were still >500m wide.
5. Any gaps or voids of non-natural cover within a core area that occur (>100m wide) but are ≤ 5ha were added back to the core area as long as they were not considered a fragmenting barrier.
6. Each core is then given a unique identifier.

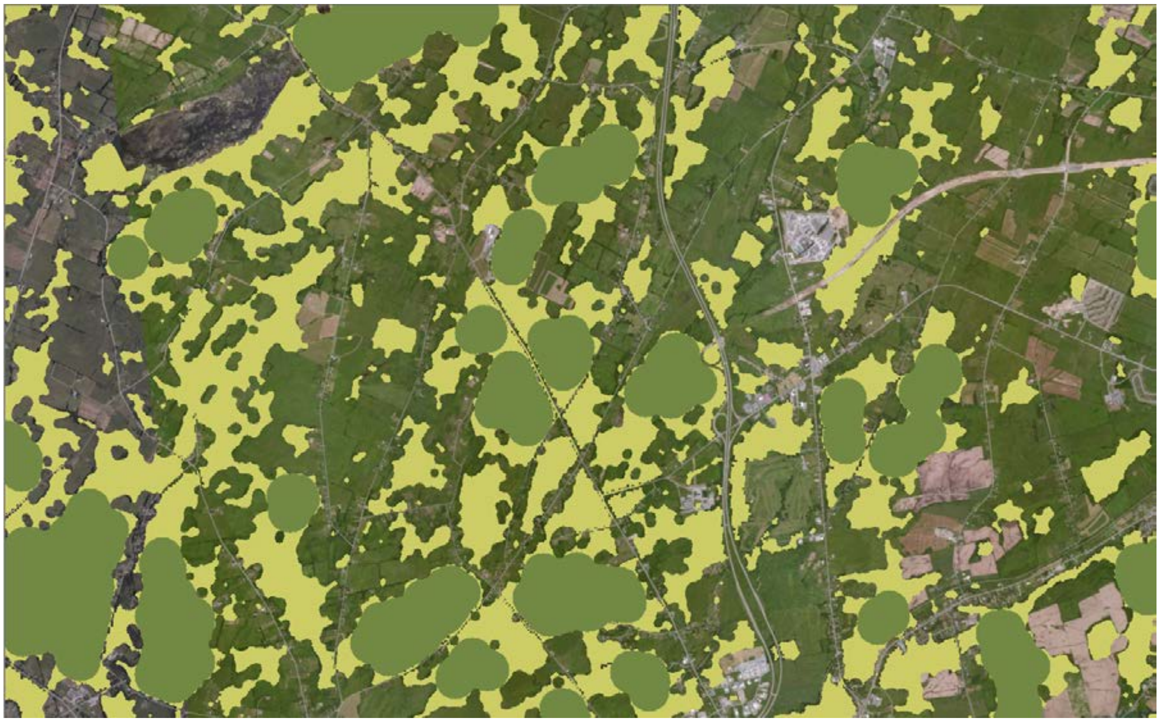

Figure 5: Core land areas (darker green) within potential land cores (light green)

Creating waterbody cores

Water cores (Figure 6) were created based on the following criteria:

- Lakes 20ha and larger were considered a waterbody core.
- Rivers 60m wide and wider were also considered a waterbody core.

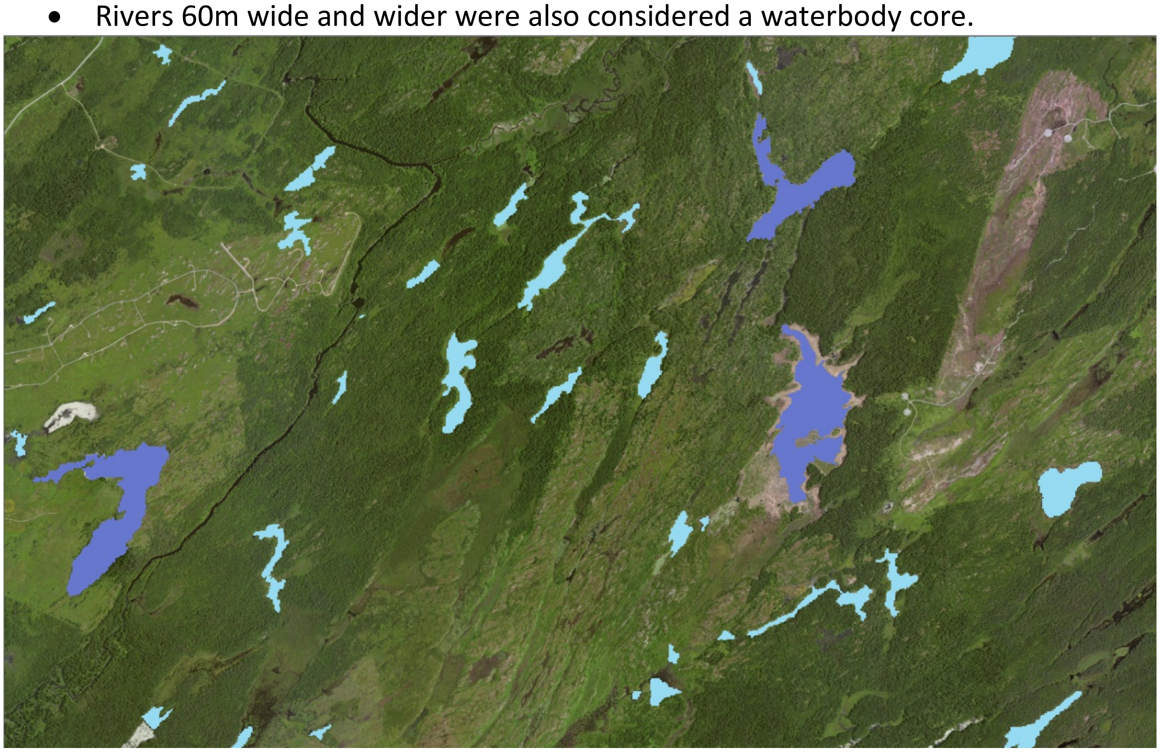

Figure 6: Core water areas (darker blue) and smaller lakes (lighter blue)

Assembling core areas

Each unique land cores, larger lake cores and contiguous larger river cores together create the final suite of 'core areas'. In some cases, waterbody cores may overlap land cores. For example, there are areas where wetlands, a terrestrial system, may overlap with waterbody cores. These areas would be considered water, but wetland data could then be used to identify key areas of the waterbody that could be used later to prioritize portions of the core.

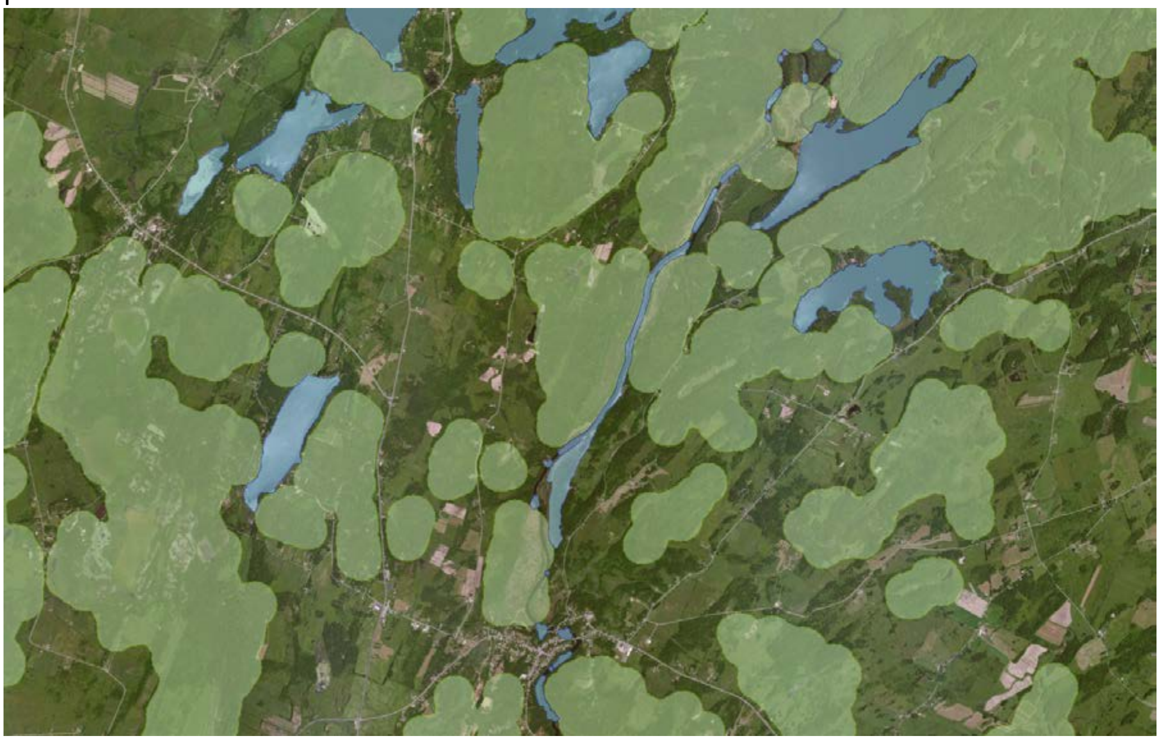

Figure 7: Water cores (blue) and land cores (green)

Linkages

Linkages are a key component of natural heritage systems and are intended to enable natural movement patterns of species between cores, to support ecological functions and promote the long-term viability and conservation of the system. Linkages will connect two or more core areas together. Based on the adapted criteria (Voros, 2011), some cores may not be connected and other cores may have one or more connections associated with them up to a distance of one kilometre. Similar to core areas, linkages can consist of one or more natural cover types and may include some non-natural cover. Examples of non-natural cover that could be included are agricultural lands and some types of bisecting roads. Some landscapes may require considerable restoration or rehabilitation to create connections and/or to develop continuous natural cover between core areas. Two types of linkages were defined in this study, least cost paths and riparian linkages. Least-cost modelling produces polygons are recommended as they are transparent and can be repeatable (Adriaensen et al., 2003; Beier et al. 2010, Beier et al., 2008). The width of connections has been defined in a variety of ways and can be categorized according to their width (regional, sub-regional, local) (Environment Canada et al., 1998, Fleury, 1997; Noss, 1992; OMNR, 2010). This project developed least cost paths (lines) that are identified as the optimal technical solution selected within a primary connection zone based on selected tool parameters. However, the primary connection zones can also be used to identify additional or alternative pathways that would provide further options for connectivity.

Primary connection zone development

Connections between cores are created through a series of iterative steps to determine potential land for connection and the extent of resistance to selecting components of that land. This is interpreted in this analysis as the development of the connection zone. Once the landscape features are selected as the most efficient zones to select a pathway for connection, these areas are used to develop the best options for creating pathways that will link cores based on cost weighted and Euclidean distance analysis. The Linkage Mapper tool developed by The Nature Conservancy for connectivity analysis was used for this connection process to develop least cost paths (McRae and Kavanagh, 2011). One of two key input layers required for connections is the connection zone raster which defines the primary connection zone. This primary connection zone enables two or more cores to be most efficiently connected by selecting areas within zones of the least fragmented natural cover. The other key input layer is the resistance raster which defined areas on the landscape that are least resistant (more natural) or more resistant (more developed) to enable the selection of the most efficient corridor options between two cores.

The primary connection zone raster is built through an iterative process and begins with identifying areas of the landscape that include existing land and water core areas as well as natural cover that be used to determine potential connections (Figure 7).

Figure 7: Potential connection zones (beige) available to connect land cores (green) and water cores (blue). More fragmented natural areas and barrier features are not available for connection (white).

Natural cover is identified through the attributes in the base land cover for the study area and included in this raster with the exception of any natural cover ≤40m wide. This is to avoid selecting thin, linear natural cover such as hedgerows. Remaining available natural and non-natural cover (that is not a barrier feature) is selected based on the following process:

1. Land cores and water cores that are adjacent or connected (distance of 0m) are dissolved together and are considered a single core.
2. These new single cores along with any cores that are not yet connected are processed again with the primary connection zones to select any cores that can connect within a *100m* distance from each other. Primary connection zones at this step include any natural cover as well as available non-natural cover within 100m of the cores.
3. Any cores that are connected at 100m are dissolved with the identified intervening landscape and identified as new interim single cores which, along with original cores that have yet to be connected, are processed again within the primary connection zones to select cores that can connect within a *200m* distance from each other.

4. This iterative process continues at increments of 100m until either all cores are connected *or* after 1000m connections are processed. Depending on the area, all cores can be either connected within 1km or some cores will remain unconnected as they are farther than 1km from another core (Figure 9).

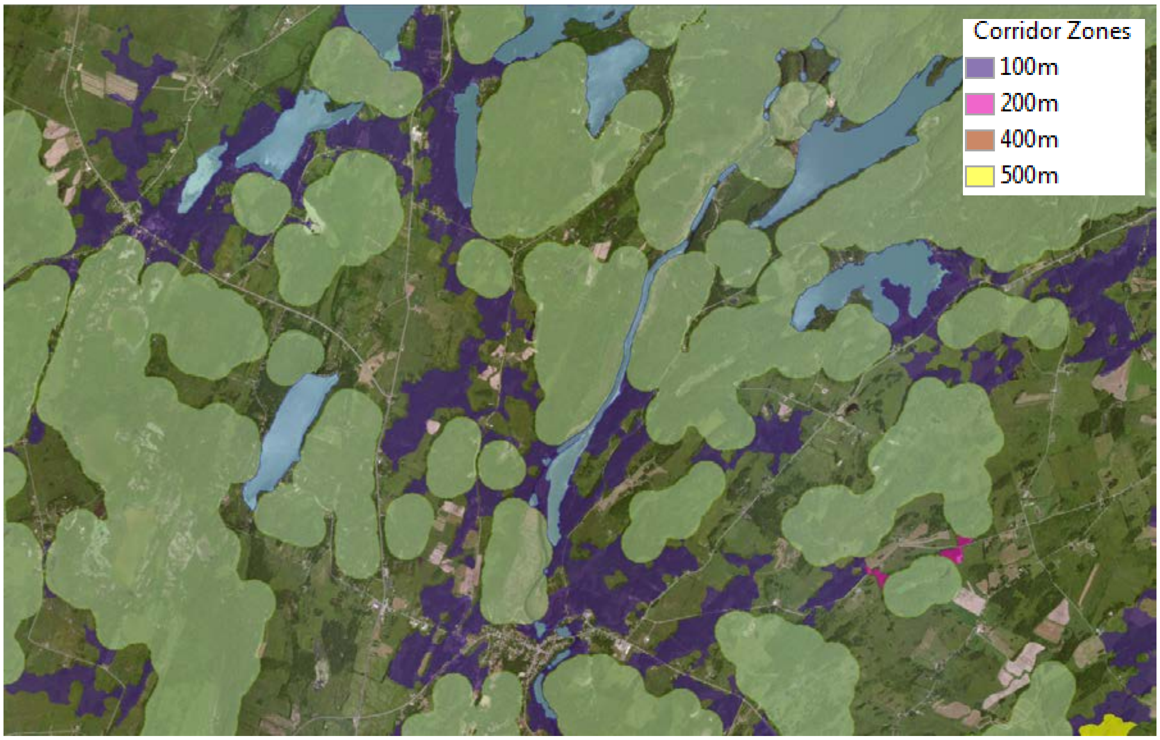

Figure 9: Primary connection zones (purple, pink and yellow) that demonstrate the most efficient pathways to create connection options between land cores (green) and water cores (blue) based on the defined criteria. Zone colour range varies based on distance required to connect cores.

The resulting primary connection zones raster identifies the most efficient options to connect as many cores as possible using the least fragmented areas of natural cover.

Least cost paths

The most efficient options for connection (the primary connection zones) were used along with the resistance raster in Linkage Mapper to identify the least cost paths. These paths are the most efficient pathways to connect cores within the primary connection zones based on the parameters given to the analysis tool. This is one option for connection and does not suggest that other options or pathways are not acceptable.

The resistance raster is created from certain land class types in the base land cover for the area as well as the barrier features layer that was used to develop the cores. Key features are identified in the resistance raster and given a resistance value (Table 1) which provides the guidance to Linkage Mapper to weigh features and determine the more efficient or cost effective connections based on user-defined parameters. The Linkage Mapper tool will select areas and pathways of lower resistance if possible. The tool will not be able to select any areas identified as NO DATA which are assigned to areas are comprised of barrier features. To minimize processing time, the resistance raster is only defined for the areas within the primary connection zones rather than identifying all resistance for the entire intervening landscape between cores (Figure 10).

Table 1: Resistance values for least cost path development

Resistance Value	Resistance Level	Description
1	Least resistance	• Natural cover • Potential core areas
10	Low resistance	• Agricultural lands
100	High resistance	• Urban footprint • Roads (not including 400 series highways and interstates)
NO DATA	Unavailable for selection	• Barrier features • Area outside the identified corridor zone

*see technical guidelines on how cores were accounted for with respect to resistance

Similar to core areas, the barrier features for corridors include:

- 400 series highways and interstates except for bridge crossings over watercourses and rail lines.
- Footprints of buildings for rural and urban development as identified in the Ontario base land cover dataset. Comparable data was not available in New York. Gaps, indents and holes between development footprints that were ≤40m wide were filled in to ensure that connections would not be delineated through narrow gaps between developed areas and to ensure that connections were at least 50m wide.
- Road Density. Within the New York State area, a kernel density analysis identified additional areas of development that can complement the areas already recognized as rural and urban development. Cells that were assigned more than 9 kilometres of roads per km^2 area within a circle was identified as a higher level of development considered a barrier.
- Larger waterbody core areas:
    - Rivers more than 60m wide excluding any islands within the river.
    - Lakes larger than 20ha.

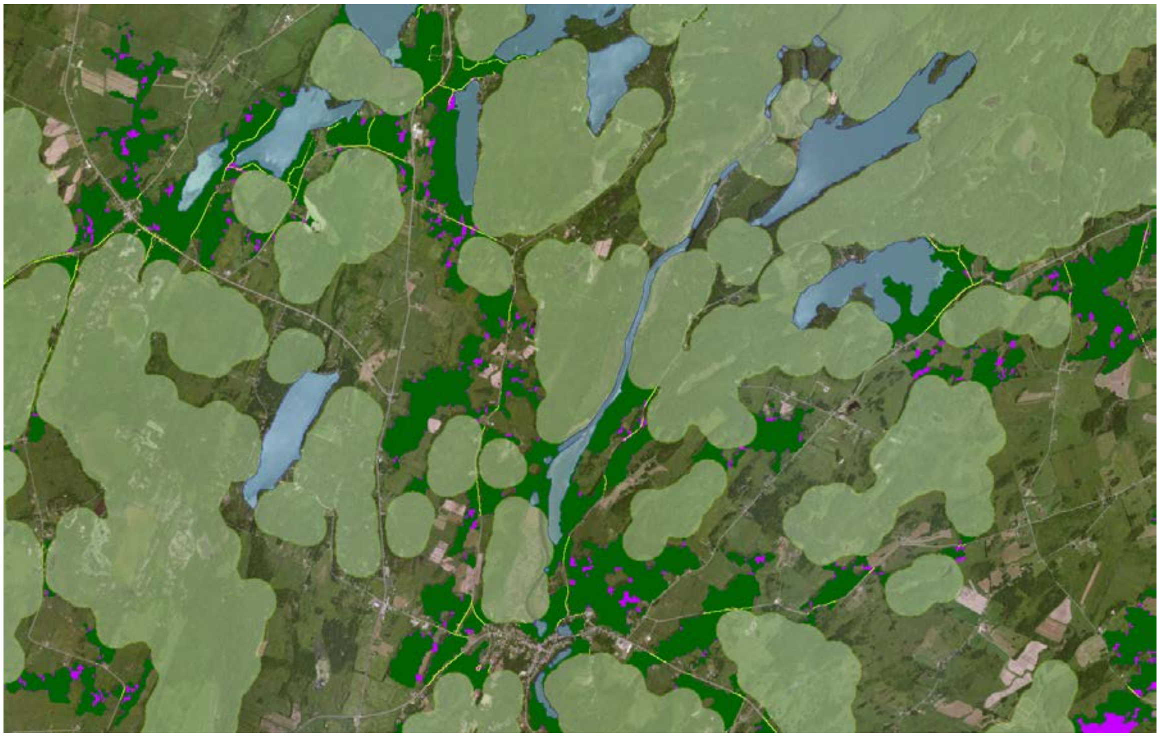

Figure 10: Resistance within corridor zones displaying least resistance areas (dark green), low resistance (purple) and high resistance areas (yellow).

Linkage Mapper outputs

Connected land cores and water cores are processed in Linkage Mapper together in one dataset with each core attributed as either land or water to identify how connections are made between cores (land to land and land to water).

Linkage Mapper offers several connection options for the network adjacency method. The adjacent method allows the user to specify creating linkages between core areas that are adjacent in Euclidean distance (closest or shortest distance) or cost-weighted distance space (based on resistance) or a combination of both. First, the input core raster and the final primary connection zone resistance raster will be analyzed using the cost-weighted method to determine the least-cost connections between two cores. Then the cost-weighted & Euclidean method was used to determine connections. If the cost-weighted & Euclidean method created connections that were not found in the cost-weighted method alone, then these connections were added to the suite of connection options (Figure 11).

Figure 11: Linkage Mapper outputs

Linkage Mapper post-processing

The process of building connections create several options for pathway delineation between cores, however some of these may not be appropriate, are intermediate connections or are duplicates that need to be removed to result in the most appropriate representation of least cost paths (Figure 12). Additional post-processing is required to eliminate inappropriate linkages and is based on the following decision rules:

- Eliminate duplicate core pair linkages. These were duplicated between processing zones when the dataset was split into pieces to successfully process.
- Remove all 'intermediate' core pair linkages. The connection feature table attributes active core pair linkages or intermediate core pair linkages (created during processing but should be removed post-processing).
- Remove all aquatic-to-aquatic core linkages. Water will connect these features rather than land so any linkages crossing land that connected two aquatic cores are omitted. The primary connection zone effectively represents the connection tween two aquatic cores.
- Remove very small land-to-aquatic core linkages. If land and water cores are connected and are already adjacent to each other in another area of the core or the connection is one pixel length, these connections are irrelevant and removed.
- Identify additional 'intermediate' land-to-land core connections to be removed. Connections made between 3 or more *land* cores that are two cells apart or closer are identified as intermediate and are removed.

Figure 12: Post-processing Linkage Mapper outputs

Riparian linkages

Riparian linkages are developed to complement the least cost paths already identified between cores areas and can represent alternative pathways for connections. Many aspects of the linkage methodology development are similar to the methodology used to delineate the least cost paths described above. The riparian linkages represent the shortest hydrological pathway between cores based on the available waterflow network data (Ontario Hydrological Network watercourse lines and the New York National Hydrography Dataset flowlines). The hydrography data is represented by lines and any line outside core areas that can connect 2 or more cores together where identified for potential selection in Linkage Mapper.

Hydrographic lines that occur within cores areas were given a high resistance value to deter connections through cores and promote connections outside of cores. Linkage Mapper was used to generate the cost-weighted analysis to determine the shortest hydrological pathway between cores (Figure 13). Riparian linkages consist of a range of natural cover types and can also contain components of non-natural cover, particularly agricultural lands and bisecting roads. These linkages can provide species movement and hydrological function for particularly those species that rely on water to complete all or aspects of their life cycle.

Linkage Mapper riparian post-processing

Similar to the least cost paths analysis, the process of building connections create several options for riparian linkage delineation between cores, however some of these may not be appropriate, are intermediate connections or are duplicates that need to be removed. Additional post-processing is required to eliminate inappropriate riparian linkages and is based on the following decision rules:

- Eliminate duplicate core pair linkages. These were duplicated between processing zones when the dataset was split into pieces to successfully process.
- Remove all 'intermediate' core pair linkages. The connection feature table attributes active core pair linkages or intermediate core pair linkages (created during processing but should be removed post-processing).
- Remove very small core linkages. If land and water cores are connected and are already adjacent to each other in another area of the core or the connection is one pixel length, these connections are irrelevant and removed.

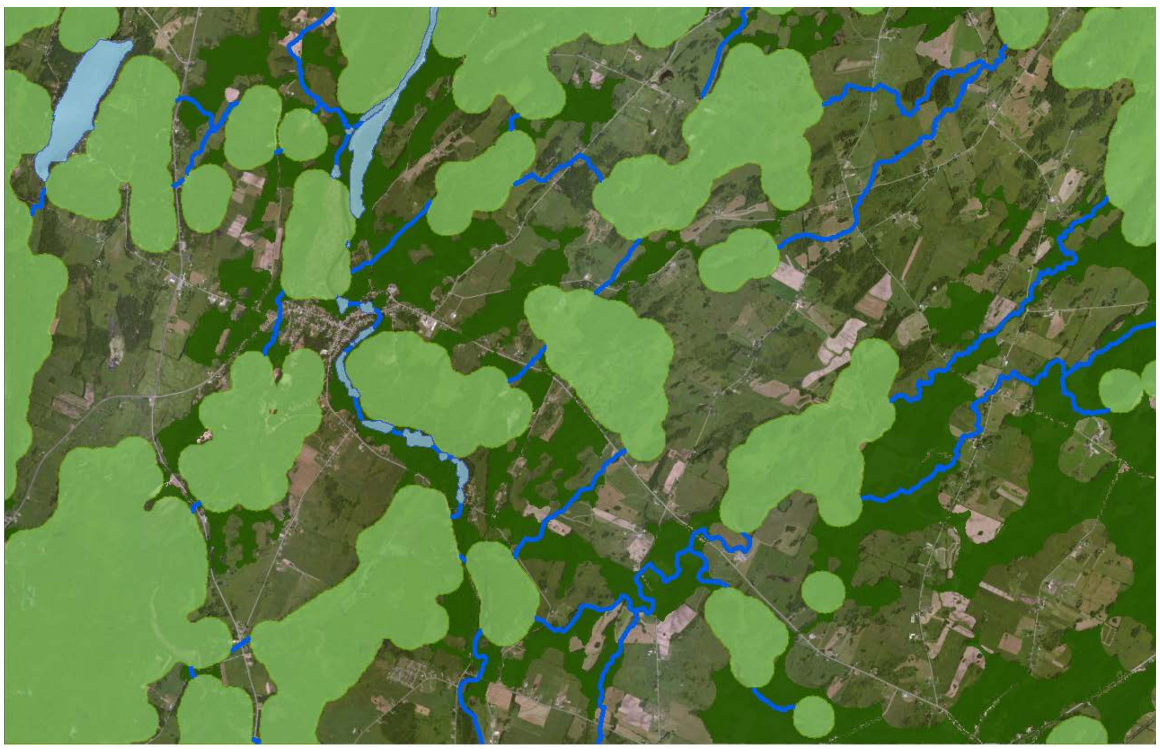

Figure 13: Post-processing Linkage Mapper outputs

Natural heritage program data corroboration

New York and Ontario natural heritage program data was overlaid with the cores and linkages to determine how congruent the generated natural heritage system is with existing species and vegetation community data. Safe guards were put into place to ensure that the data was analyzed and stored in compliance with Ontario and New York sensitivity requirements regarding detailed species and community information. A complete list of species and vegetation communities from the natural heritage program data used in the analysis can be found in Appendix B and C respectively.

In Ontario, the provincial record maintained by the Ontario Natural Heritage Centre was used to generate species records that intersect with the A2A study area. The data was filtered to remove the following:

- Any negative search results (SEARCH_RES = No, Negative)
- Observations have been processed by NHIC specialists but are not linked to element occurrences and do not have enduring conservation value (NHIC_R_ST = Processed – Not Linked to EO)
- Observations in the provincial record that have not yet been processed or validated by NHIC staff (NHIC_R_ST = Pending)
- Observation date prior to 1980 to remove historic information
- Independent records (EO ID = 0, NHIC_R_ST = Processed linked to EO)
- Low accuracy records (>1km accuracy)

In New York, a data license was arranged to receive data from the New York Natural Heritage Program that intersect with the A2A study area (NYNHP, 2013). The data was filtered to remove the following:

- Non-breeding records
- Low precision records (Precision = Low)
- Low accuracy records (>1km accuracy) that also have low or medium precision

The data from both jurisdictions was further filtered to remove bird species records that are associated only with anthropogenic habitats. Species that are anthropogenic grassland species or have detailed documented observation information as occurring in structures such as barns and chimneys would not be high priority to ensure habitat connectivity. These species are included in the species density values layers in the following characterization section of the report. These species include:

- Bobolink
- Eastern Meadowlark
- Loggerhead Shrike
- Barn Swallow
- Chimney Swift
- Barn Owl

Eighty-eight percent of natural heritage program data is captured within the cores, primary connection zones and riparian linkages (Table 2). It is important to make note that natural heritage programs maintain known observations of species, but the lack of information does not imply that the species does not occur outside of these known observation areas. Many of the remaining species records that do not occur within the natural heritage system are birds and mammals so although the observation falls outside the system, there are adjacent suitable habitats within the system that these species could be utilizing. Some plant observations are small and/or isolated, so they were not captured in this regional analysis, but this does not underrate its conservation importance and local conservation decisions should consider the value of using this information.

Table 2: Percent of species records that occur within the natural heritage system

Natural Heritage System Component	Ontario (%)	New York (%)	Total A2A area (%)
Intersect with cores	81	86	82
Intersect with primary connection zones	5	7	5
Intersect with riparian linkages (lines)	1	0	1
Within natural heritage system	87	93	88

All vegetation community data from both the New York Natural Heritage Program and the Ontario Natural Heritage Information Centre was included in the corroboration assessment. Tracked communities include globally rare, provincial/state rare and exemplary (outstanding examples of more common community types that are tracked and maintained at a provincial or state level).

Ninety-eight percent of natural heritage program data is captured within the cores, primary connection zones and riparian linkages (Table 3). The remaining vegetation communities that do not occur within the natural heritage system are small isolated communities. This does not underrate the conservation importance and local conservation decisions should consider the value of using this information.

Table 3: Percent of community records that occur within the natural heritage system

Natural Heritage System Component	Ontario (%)	New York (%)	Total A2A area (%)
Intersect with cores	96	99	97
Intersect with primary connection zones	1	0	1
Intersect with riparian linkages (lines)	0	0	0
Within natural heritage system	97	99	98

Characterizing cores and linkages

The cores, primary connection zones and riparian linkages were generated for the landscape based on potentially including all natural cover in the study area. There was no preliminary targets and selection of pieces of the landscape that should be connected together. Connectivity does not necessarily need to be limited to the smallest landscape areas required to meet a predetermined goal but rather identify large, intact natural landscape areas (Spencer et al., 2010). Therefore all the natural cover in its entirety was considered potential cores and connection zones. Once the analysis was completed, cores, connection zones and linkages were identified across the landscape that included natural and some non-natural features (Table 4).

Table 4: Representation of cores and connections across the study area

	Ontario	New York	Total A2A area
Total area of cores* (ha)	756,628	692,178	1,448,806
% land base as cores	39%	61%	47%
Total area of primary connection zones* (ha)	122,500	89,401	211,901
% of land base as connection zones	6%	8%	7%
Total length of riparian linkages** (km)	4,920	1,600	6,520

*cores and primary connection zones can include non-natural features
**linkages can overlap with primary connection zones

Selection of large blocks of intact natural cover, although valuable for inclusion within a natural heritage system, can be challenging to determine where to focus work for implementation. The landscape can be characterized by a series of surrogates related to biodiversity, ecosystem functions and constraints to help focus where opportunities and challenged may be within the system. Fourteen characterization criteria were developed for the study area based on these surrogates. Each criterion was defined by three categories (eg. high/medium/low) and a value was assigned to each pixel. Each of the 14 criteria are briefly summarized below and summarized in Table 5. This set of criteria is certainly not exhaustive and were derived based on the best digital data that was available at the time in each country. As more information is collected and new data sets are created, more criteria may contribute to the characterization of this landscape and can be used in conjunction with this set of criteria to inform land use decisions and resource management prescriptions.

Table 5: Characterization criteria as surrogates for biodiversity, ecosystem functions and constraints

Criteria code	Surrogate	Category	Weighting	Comments
	Biodiversity			
1	*Species* o Density of SAR federal and subnational rankings o Density of globally rare species (G1-G3) o Density of other tracked species (not globally rare or listed)	High (3) Medium (2) Low (1)	3 2 1	Density of total number of unique species within a 1km square with 3 natural break categories. *Raw data is medium sensitive and is generalized to 1km. Natural breaks are binational.*
2	*Vegetation Communities* o Density of globally rare vegetation communities o Density of other tracked vegetation communities (prov/state rare only) o Density of exemplary tracked vegetation communities	High (3) Medium (2) Low (1)	1 1 1	Density of total number of unique community types within a 1km square with 3 natural break categories. *Raw data is medium sensitive and is generalized to 1km. Natural breaks are binational.*
	Ecosystem Function			
3	Shape complexity for forests (area: perimeter ratio)	High (3) Medium (2) Low (1)	1 1 1	3 natural break categories: **New York** Low ratio of 2.5 - 124.84 Medium ratio of > 124.84 to 221.62 High ratio > 221.62 **Ontario** Low ratio of 3.75 - 67.37 Medium ratio of > 67.37 to 117.4 High ratio > 117.4
4	Shape complexity for wetlands, islands and water features (area: perimeter ratio)	Low (3) Medium (2) High (1)	1 1 1	3 natural break categories: **New York** Low ratio of 2.5 to 76.95 Medium ratio of > 76.95 to 220.58 High ratio > 220.58 **Ontario** Low ratio of 3.75 to 147.69 Medium ratio of >147.69 to 306.89 High ratio > 306.89

Criteria code	Surrogate	Category	Weighting	Comments
5	Hydrological function (riparian areas of rivers and lakes)	High (3) Medium (2) Low (1)	1 1 1	Distance from rivers and lakes based on 3 categories: High (natural cover within 100m) Medium (natural cover within 101-500m) Low (natural cover within 501-1000m)
6	Natural patch size	Large (3) Medium (2) Small (1)	10 5 2	Based on break categories of varying sizes of all natural cover types: Large (natural cover size of >2000ha) Medium (natural cover size of 201-2000ha) Small (natural cover size of 0-200ha)
7	Forest interior	Large (3) Medium (2) Small (1)	10 5 2	Based on break categories of varying sizes of contiguous patches 100m from edge: Small forest interior is > 0 to 90 hectares Medium forest interior is >90 to 230 hectares Large forest interior is > 230 hectares
n/a	Aquatic assessment values	n/a		****Data gap**. Stream overlay assessments looking at high quality area, degraded systems, etc.*
8	o Distance to regulated parks and protected areas o Distance to conservation lands with policy protection o Distance to other conservation lands	Coincident (3) Adjacent (2) Nearby (1)	10 7 2	Distance from regulated protected areas based on 3 categories: Coincident with conservation lands Adjacent (within 1000m from conservation area) Nearby (within 1001m-2000m from conservation area)
	Constraints			
9	Degree of existing natural cover	High (3) Medium (2) Low (1)	1 1 1	Degree of existing natural cover on 3 categories: High (90-100% natural cover) Medium (70-89.9% natural cover) Low (<69.9% natural cover)
10	Distance from agricultural lands	Coincident (-3) Adjacent (-2) Far (-1)	1 1 1	Coincidence = within agricultural lands Adjacent = Within 200m from agricultural lands Far = Greater than 200m from agricultural lands

Criteria code	Surrogate	Category	Weighting	Comments
11	Distance from developed lands	Coincident (-3) Adjacent (-2) Far (-1)	1 1 1	Coincident = within developed lands Adjacent = within 200m from developed land Far = > 200 m from developed land
12	Development density	High (-3) Medium (-2) Low (-1)	1 1 1	Density of urban/rural development footprint per square kilometre, based on 3 natural breaks: **New York** High (> 56.1% density of developed lands) Medium (> 15.6- 56.1% density of dev. lands) Low (0 - 15.6% density of developed lands) **Ontario** High (> 53.4% density of developed lands) Medium (16.9 - 53.4% density of dev. lands) Low (0 - 16.9% density of developed lands)
13	Distance from roads	Coincident (-3) Adjacent (-2) Far (-1)	3 2 1	Coincident = pixel contains roads Adjacent = 1-200m from roads Far = > 200 m from roads
14	Road density	High (-3) Medium (-2) Low (-1)	1 1 1	Density of the number of km of roads per square kilometre, based on 3 natural breaks: **New York and Ontario** High road density is 6.2 to 21.5 km/sq.km Medium road density is 1.5 to 6.2 km/sq.km Low road density is 0.0 to 1.5 km/sq.km

*these layers are provided as continuous surfaces for the Ontario and New York portions of the study area

Total density of species

Natural heritage program data was obtained from the Ontario Natural Heritage Information Centre and the New York Natural Heritage Program to develop a density surface of species records. This data was filtered to remove records such as low accuracy records and historic records to ensure that the density calculations were most meaningful for this criterion. This data was combined to develop a binational assessment of species records since both Ontario and New York programs use the Nature Serve methodology for recording and maintaining species data. The details of the species observations are classified as medium sensitive and licencing agreements are required. To allow this data to be provided to the general public, the detailed information was generalized to 1km squares. Each 1km square was assigned a value of the number of unique species that overlap with that square. This generated the density of species for that square. Natural breaks were then created to categorize the data into three natural break categories. The total density of species categories were incorporated into the composite data layer; however the source natural heritage program layer provides user access to the values and categories attributes for a variety of subsets of this data. The source data can be viewed for the following features:

- Total density of species
- Density of species with federal or subnational species at risk designations
- Density of globally rare species (G1-G3)
- Density of other tracked species that are not globally rare or species at risk

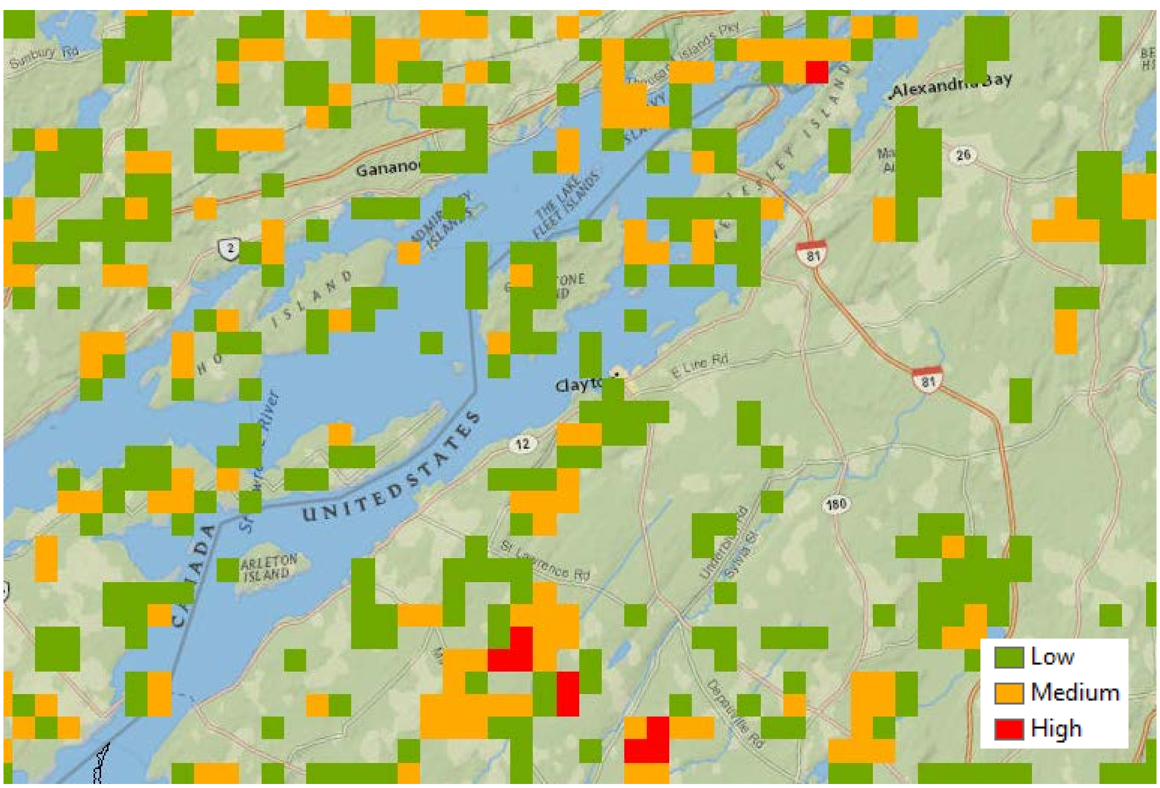

Figure 14: Total tracked species density categories based on three natural breaks.

Total density of vegetation communities

Natural heritage program data was obtained from the Ontario Natural Heritage Information Centre and the New York Natural Heritage Program to develop a density surface of vegetation community records. This data was filtered to remove records such as low accuracy records and historic records to ensure that the density calculations were most meaningful for this criterion. This data was also combined to develop a binational assessment of community records. The details of the community records are classified as medium sensitive and licencing agreements are required. To allow this data to be provided to the general public, the detailed information was generalized to 1km squares. Each 1km square was assigned a value of the number of unique communities that overlap with that square. This generated the density of communities for that square. Natural breaks were then created to categorize the data into three natural break categories. The total density of communities categories were incorporated into the composite data layer; however the source natural heritage program layer provides user access to the values and categories attributes for a variety of subsets of this data. The source data can be viewed for the following features:

- Total density of vegetation communities
- Density of globally rare communities (G1-G3)
- Density of other tracked communities that are rare in the state or province but not globally rare
- Density of exemplary tracked vegetation communities (not rare)

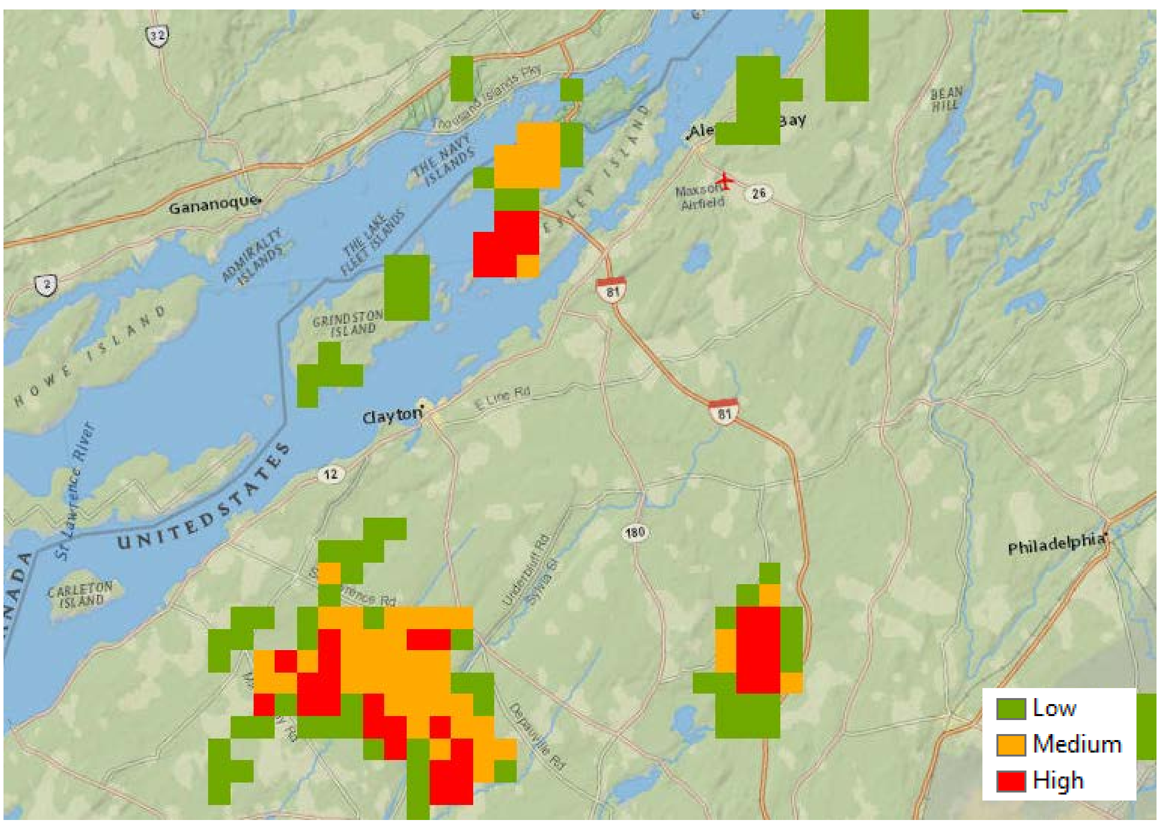

Figure 15: Total tracked community density categories based on three natural breaks.

Shape complexity for forests

Land cover inventory data was assembled to create base land cover layers for Ontario and New York. Consult Appendix A for sources and links to these data sets. The two nations' base land covers were then categorized based on general land types (eg. natural, non-natural, forest, wetland). Separate data sets were kept for each county since the sources and data resolution differs between countries. As well, there was no binational crosswalk of ecosystem names and types to ensure a consistent inventory across countries.

Forested ecosystems were identified as either forests or treed. Most treed ecosystems are defined as those that have less than 25% crown closure, with the exception of fens and bogs which are defined as having less than 10% crown closure. All ecosystems that were labelled as the forest general type were separated and selected to represent this criteria. The area and perimeter of each ecosystem polygon was calculated and each pixel was assigned the value of its area-to-perimeter ratio. Natural breaks were created for each country based on three categories: low, medium and high shape complexity.

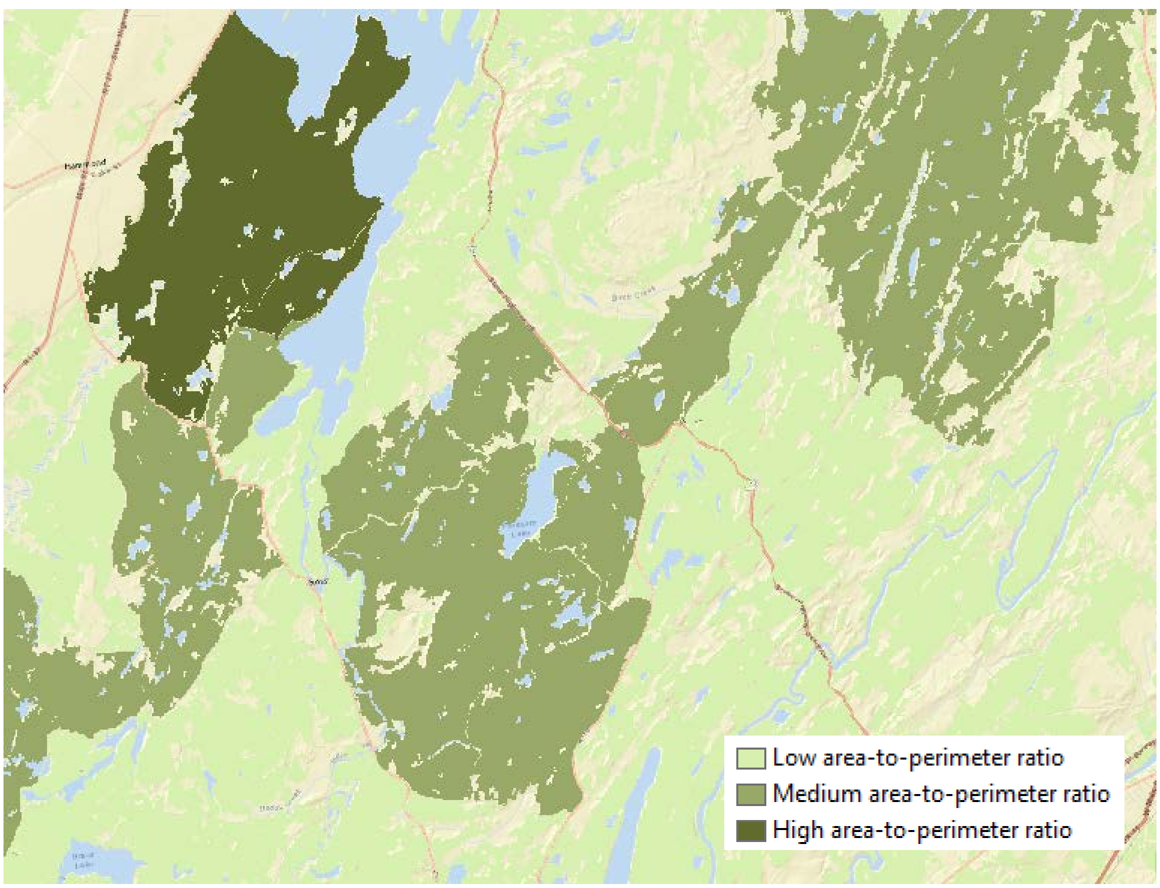

Figure 16: Shape complexity for forests based on three natural break categories.

Shape complexity for wetlands, islands and water features

Land cover inventory data was assembled to create base land cover layers for Ontario and New York. Consult Appendix A for sources and links to these data sets. The two nations' base land covers were then categorized based on general land types (eg. natural, non-natural, forest, wetland). Separate data sets were kept for each county since the sources and data resolution differs between countries. As well, there was no binational crosswalk of ecosystem names and types to ensure a consistent inventory across countries.

Features in the base land cover that were identified as wetlands and water were selected as well as features surrounded by water (islands) were separated and selected to represent this criteria. Great Lakes islands that were identified in the Great Lakes Islands for Life dataset were also included to ensure quality representation of islands within the St. Lawrence River. The area and perimeter of each ecosystem polygon was calculated and each pixel was assigned the value of its area-to-perimeter ratio. Natural breaks were created for each country based on three categories: low, medium and high shape complexity.

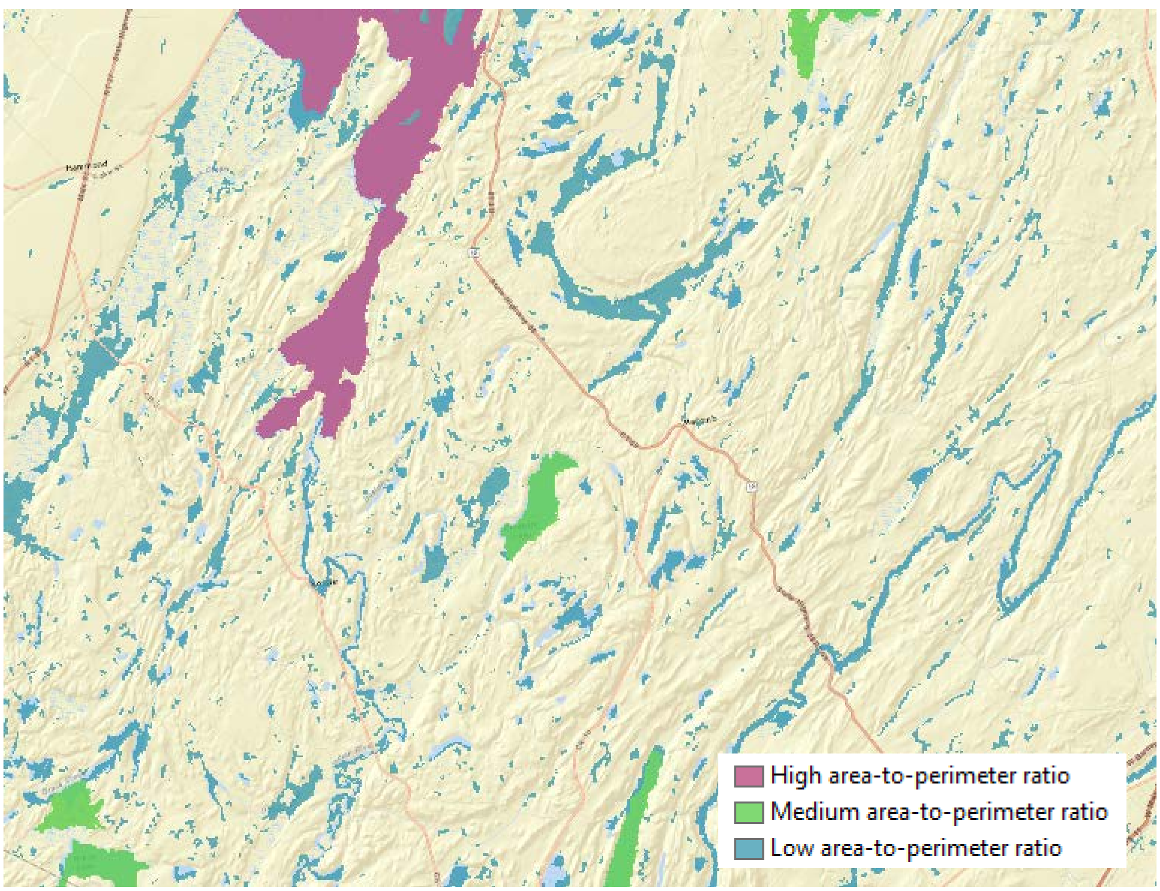

Figure 17: Shape complexity for wetlands, islands and water features based on three natural break categories.

Hydrological function (distance from rivers and lakes)

The Ontario Hydro Network suite of data and the New York NHDPlus suite of data were used to identify natural cover present within varying distances from rivers and lakes. Numerous studies and guidelines suggest a variety of appropriate riparian buffer widths (Semlitsch and Bodie, 2003; Snyder et al., 2003; Henson et al, 2005; Madden et al., 2007) and distances were selected for this study area as a generalized conservative estimate. All river and lake features were treated the same regardless of lake type or waterflow type (eg. river, stream etc.). For more information on the types of water features that are identified in this data, consult Appendix A and the associated information for the Ontario Hydro Network and NHDPlus data sets. This criterion is one of the several ways to describe a surrogate for hydrological function. Three categories were generated based on the high, medium or low hydrological function depending on the distance each pixel had to a water feature. Pixels beyond 1000m were not given a value as these pixels are neutral or may not provide enough value for hydrological function.

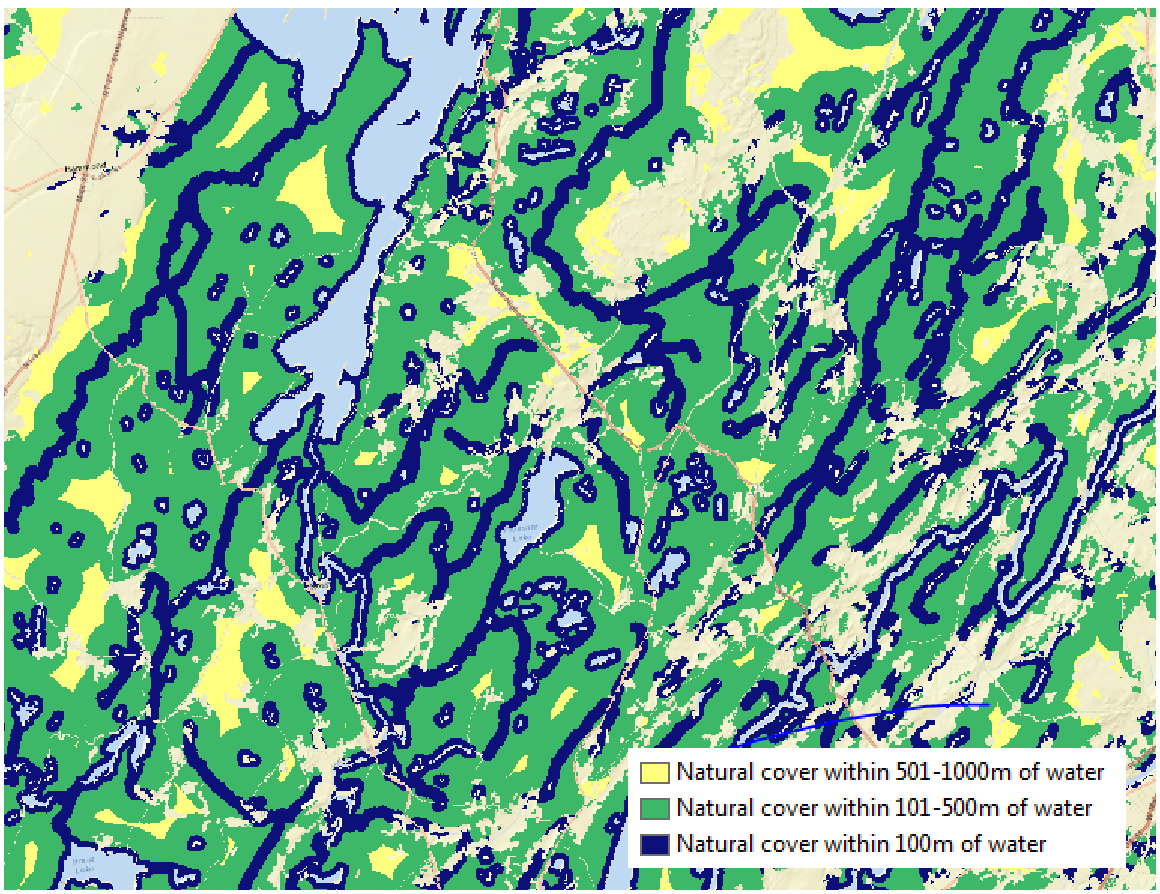

Figure 18: Hydrological function based on three classified categories.

Natural patch size

The Ontario and New York base land cover described earlier was used to identify all natural cover types (excluding water) and each contiguous natural cover patch was assessed regardless of the cover type. For example, a wetland adjacent to a forest was considered one natural cover patch as there was contiguous natural cover. Once all natural cover patches were accounted for and its area was generated, the natural patches were separated into three categories based on their size representing large, medium and small patches depending on the size of the contiguous natural cover patch. Forests, specifically, are more commonly studied in terms of effects on species abundance and population subsistence rather than generalized natural cover. Forest patch size has been studied to determine effects on species biodiversity and conservation, particularly bird species (Villard et al., 1999; Burke and Nol, 2000; Lee et al., 2002) and distances were selected for this study area as a generalized conservative estimate.

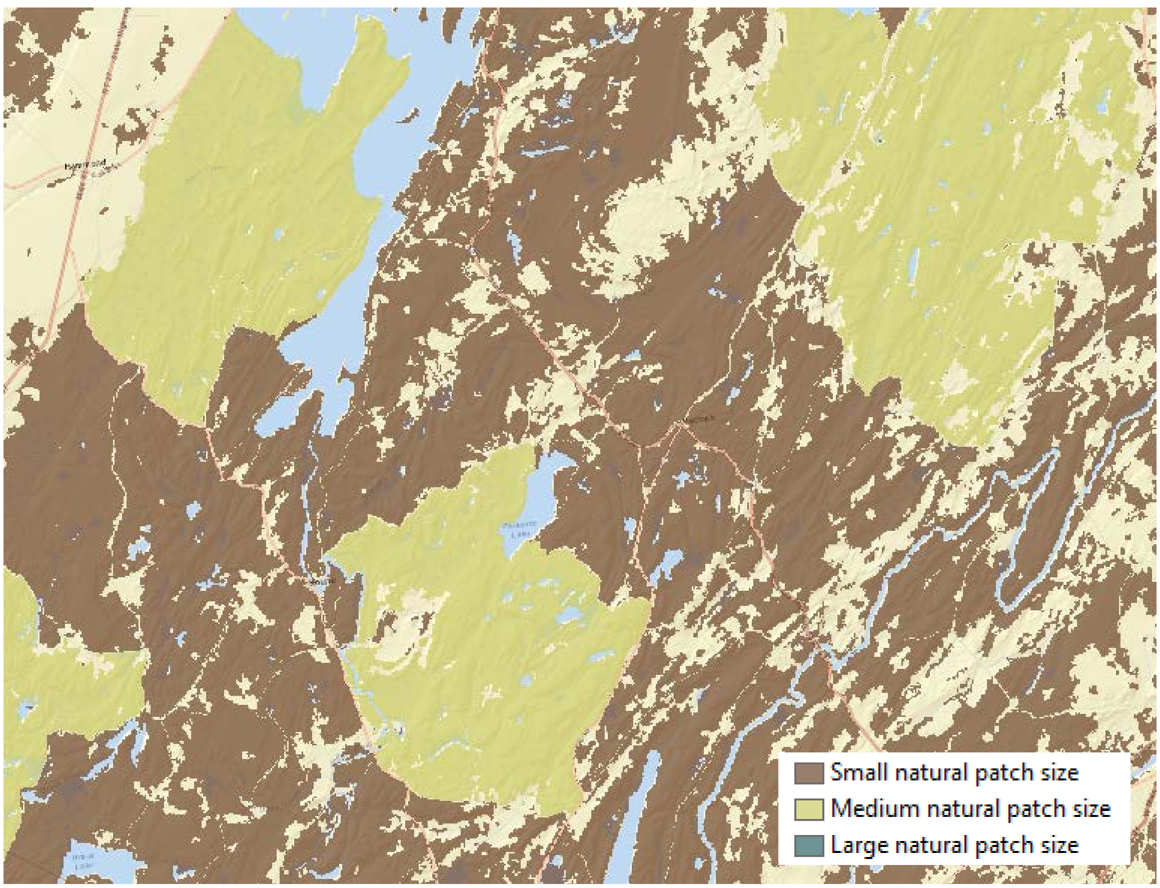

Figure 19: Natural patch size based on three classified categories.

Forest interior

Forest land cover types were identified from the Ontario and New York base land cover layers generated for this study area. Forested ecosystems were recognized as either forests or treed. Most treed ecosystems are defined as those that have less than 25% crown closure, with the exception of fens and bogs which are defined as having less than 10% crown closure. All ecosystems that were labelled as the forest general type were separated and selected to represent this criteria. Each contiguous patch was buffered in by 100m from the edge of the polygon. The remaining forest patches were then assessed, its total area was generated and the contiguous interior forest patches were separated into three categories based on their size representing large, medium and small patches. The size category thresholds were determined based on core area requirements for four bird species in Southern Ontario and suggestions that at least 90-230 hectares of 'core' area is needed to maintain source populations (Nol et al., 2005; Environment Canada, 2013).

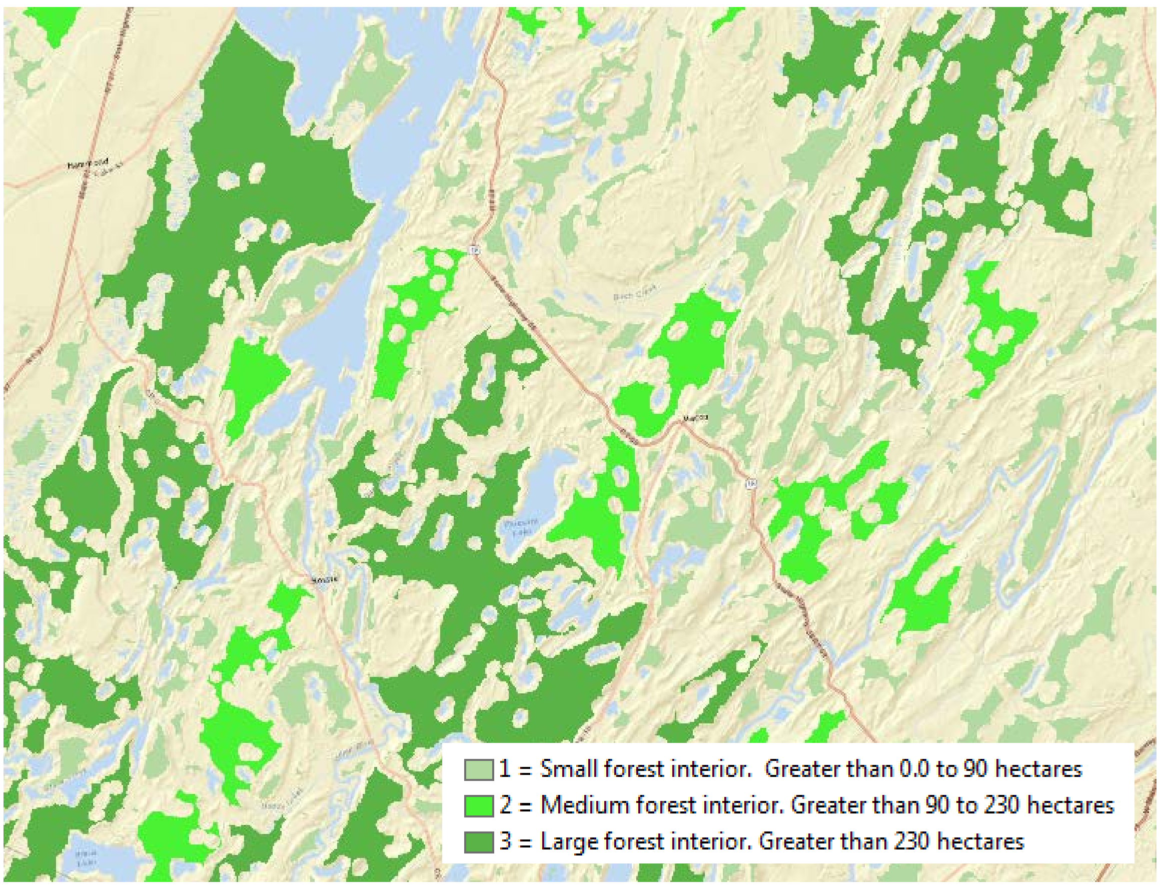

Figure 20: Forest interior based on three classified categories.

Distance to regulated parks and protected areas and conservation lands

A series of three criterion layers were generated to represent conservation lands and the value of having components of a natural heritage system within, adjacent or near a conservation land. There are a variety of ways to describe a conservation land; these lands also have a wide spectrum of protection and management prescriptions. These criteria were separated into three general categories: regulated parks and protected areas that have protection in perpetuity, conservation lands that have a level of protection that is identified in policy and other types of conservation lands that cannot be described as belonging to the previous two categories. Pixels overlapping, within 1km or within 2km of each of these groups of conservation land types were identified and scored accordingly.

The availability of spatial information for conservation lands varies greatly. Some conservation land spatial boundaries require license agreements to acquire and/or disseminate boundaries; other organizations do not have the technical capacity or resources to digitize their conservation lands boundaries, and other conservation land types are scattered between these two ends of the spectrum. For the purpose of this study, in Ontario, only 'open data' obtained from Land Information Ontario (LIO) was included in the criterion layers. In New York, the New York Protected Areas Database (NYPAD, 2014) is intended to be the authoritative source of conservation lands in New York. These criterion layers do not contain a complete representation of conservation lands in the study area. Other spatial boundaries may be obtained by data custodians with associated license agreements as required.

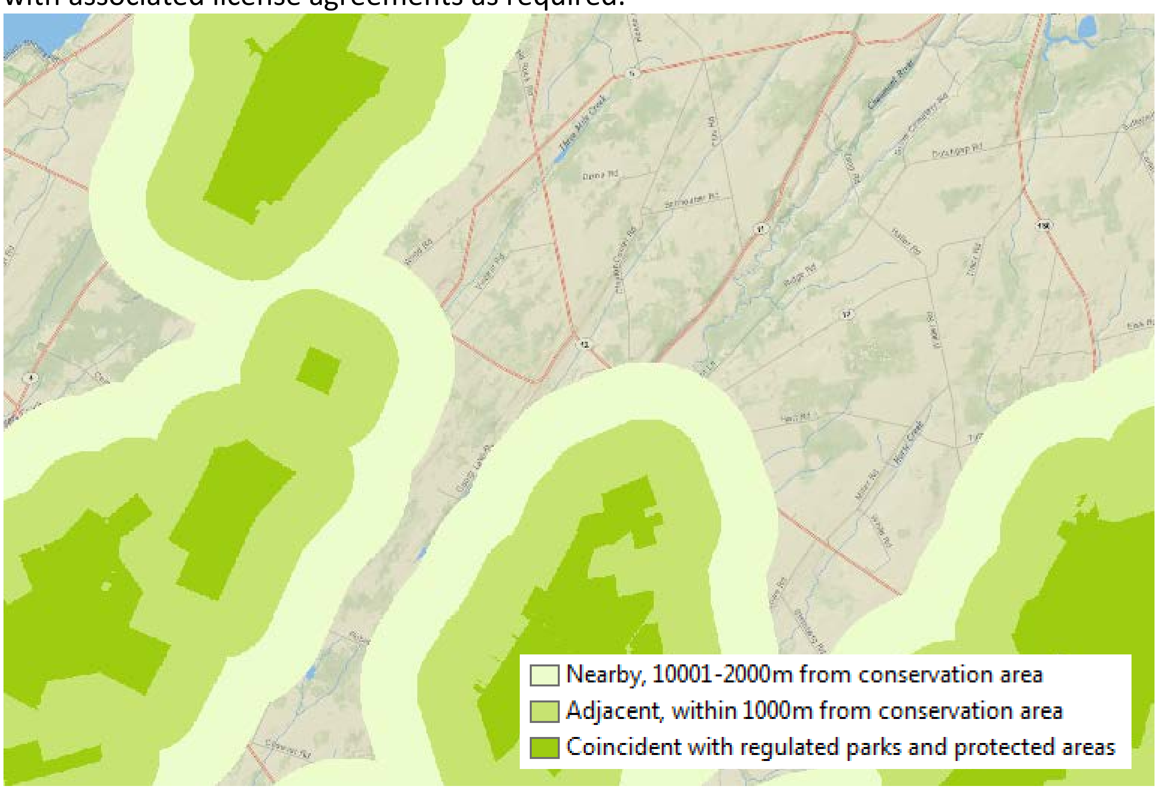

Figure 21: Distance to regulated parks and protected areas

Degree of existing natural cover

Natural land cover types (which exclude water) were selected from the Ontario and New York base land cover layers. Focal statistics were then generated by first selecting each pixel and calculating the total number of cells that are any land types (including non-natural land types) within a 1000m radius. Then the total number of cells is calculated that are *natural* land types within a 1000m radius of that same pixel. The degree of natural cover is the result of dividing the total number of cells in the focal area that is natural cover by the total number of cells in the area that in any land types. Only pixels within the study area that were assigned a natural land cover types (excluding water) was given a value for the degree of existing cover. Once these values were generated, they were separated into three categories based on high, medium or low degree of natural cover. The thresholds for the categories were based on generalized previous conservation planning efforts and provide a sense of the overall condition of the landscape (Henson et al., 2005).

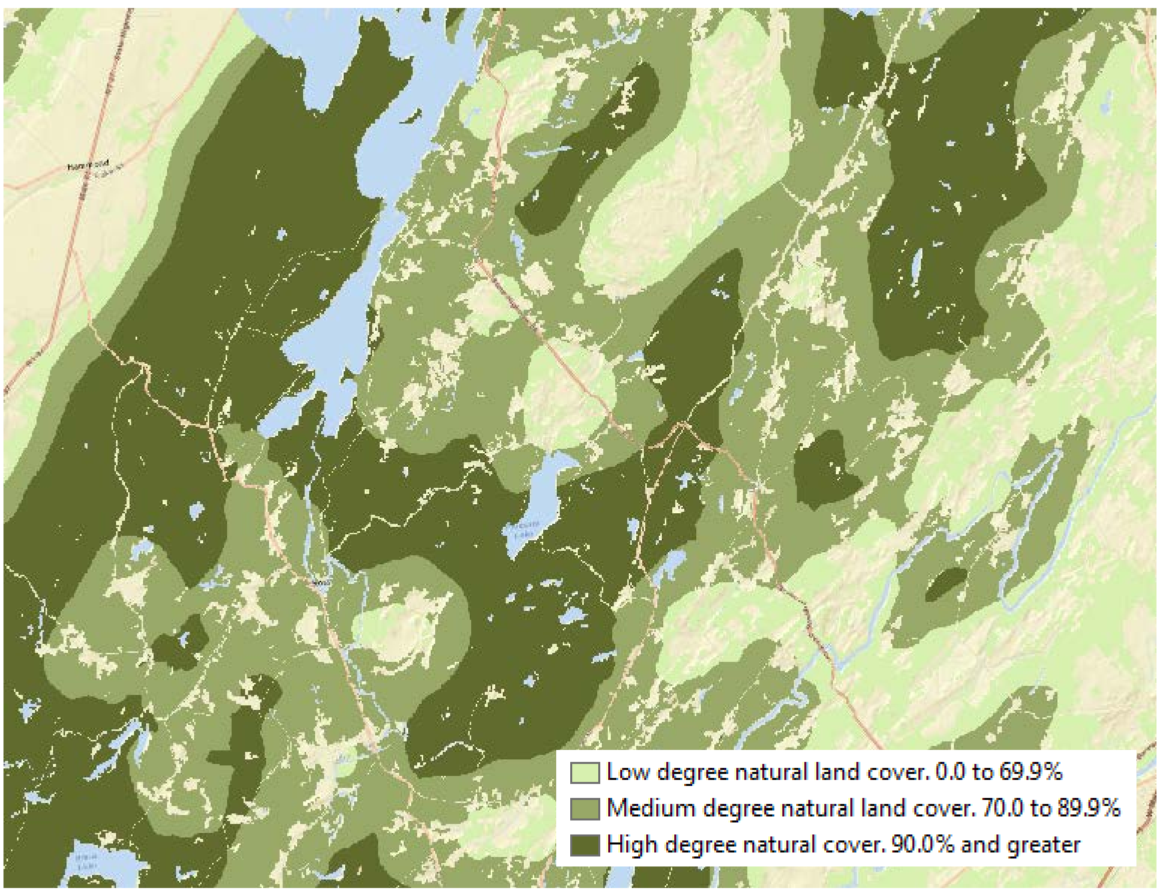

Figure 22: Degree of existing natural cover based on three classified categories.

Distance from agricultural lands

Agricultural classes identified in the Ontario and New York base land cover were selected for this criterion. This includes agricultural land cover types such as row crops, orchards, horticultural fields, hay and pastures. Contiguous patches of agricultural lands were identified and each pixel was assigned a value based on their coincidence or adjacency to agricultural lands. These values were negative values so as to penalize areas associated within or near agricultural lands as less desirable for connectivity. The classified categories were based on criteria previously used in southern Ontario and the Great Lakes ecoregion (Henson et al., 2005).

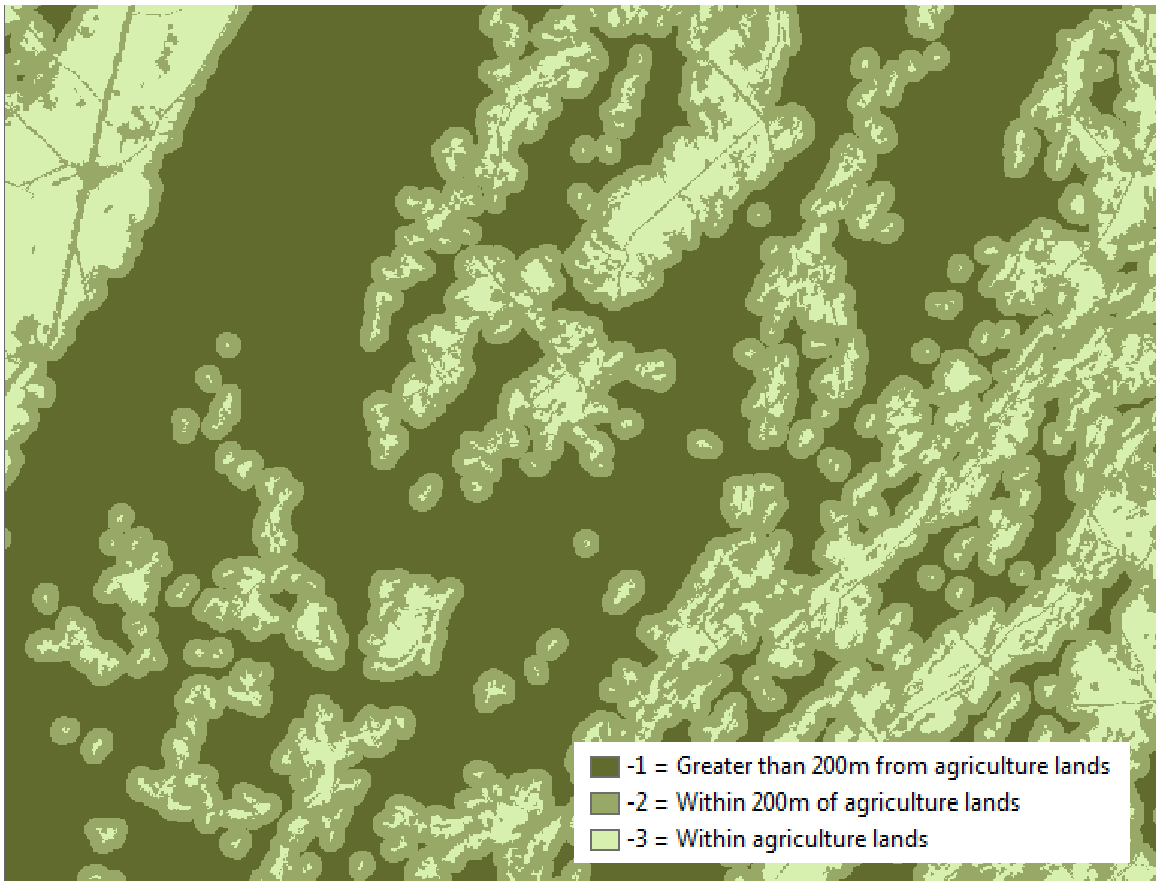

Figure 23: Distance from agricultural lands based on three classified categories.

Distance from developed lands

Development types identified under the anthropogenic general category in the Ontario and New York base land cover were selected for this criterion. This included developed land types such as high intensity developed land, medium intensity developed land, and low intensity developed land as well as urban open space and utility and transportation lines such as roads, railways and transmission lines. Contiguous patches of developed lands were identified and each pixel was assigned a value based on their coincidence or adjacency to these developed lands. These values were negative values so as to penalize areas associated within or near developed lands as less desirable for connectivity.

Figure 24: Distance from developed lands based on three classified categories.

Development density

The density of urban and rural developed lands is also valuable to characterize the landscape in addition to the distance to development. Development types identified under the anthropogenic general category in the Ontario and New York base land cover were selected for this criterion. This included developed land types such as high intensity developed land, medium intensity developed land, and low intensity developed land, as well as urban open space and utility and transportation lines such as roads, railways and transmission lines. Due to data gaps and insufficient ability to separate types of urban and rural density, all types of development were considered equal.

This criterion was generated based on assigning each pixel with a value based on the percentage of developed land occurring within one square kilometre around that pixel. Once each pixel is assigned its unique value for development density, the data was assigned to three general categories of high, medium or low development density based on natural breaks. Natural breaks were generated separately for each county since the sources and data resolution of the base land cover differs between countries.

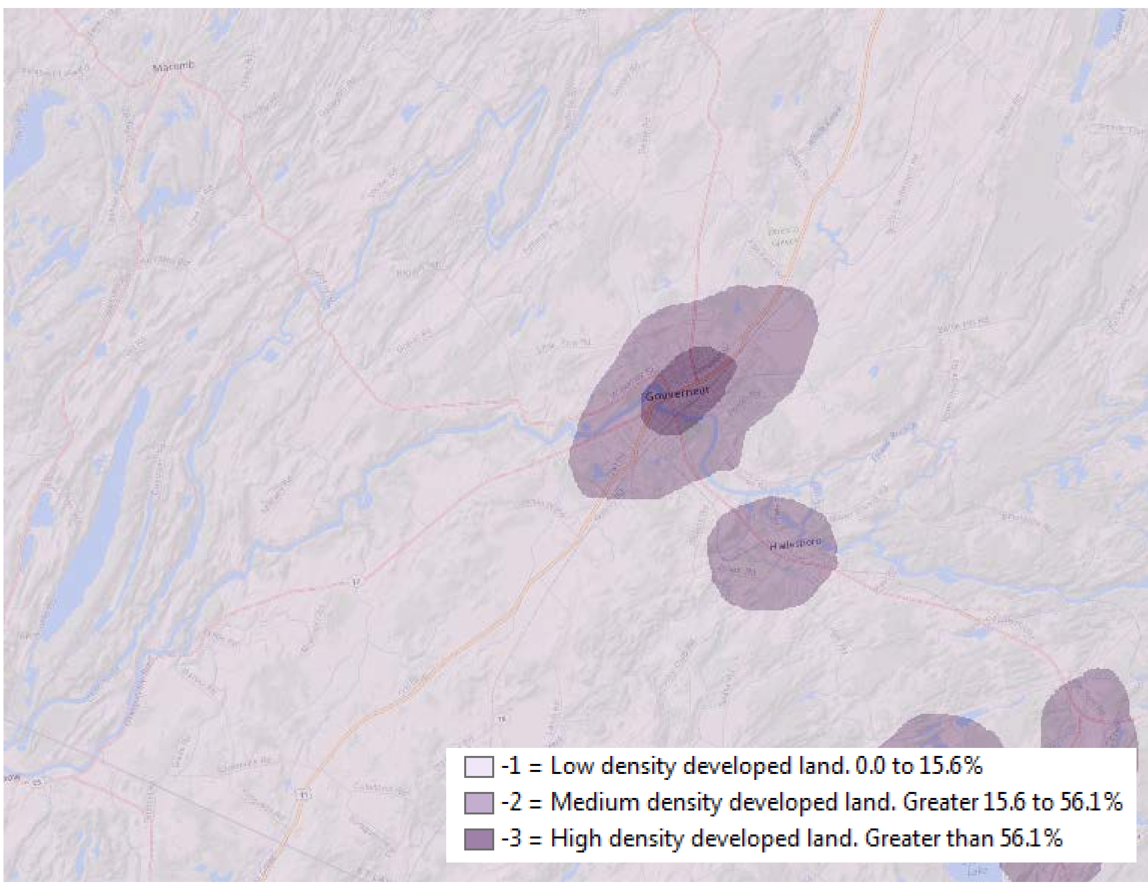

Figure 25: Development density based on three natural break categories.

Roadlessness

This criteria was derived by identified all roads in the study area from the Ontario Roads Network and the New York Streets data classes. Each pixel that overlaps with, adjacent to or farther away from roads was assigned a value based on their distance from those roads. These values were negative values so as to penalize areas associated within or near roads as less desirable for connectivity. Studies have been conducted to determine how species or groups of species tolerate roadways. 200 metres was chosen for this criterion since several studies looking at road avoidance by deer, wolves, forest-nesting birds and amphibians and other water-dependent species seem to have stronger negative effects within this distance (Rost and Bailey, 1979; Rich et al, 1994; Mladenoff, 1995; Bergin et al., 1997; Findlay and Houlahan, 1997).

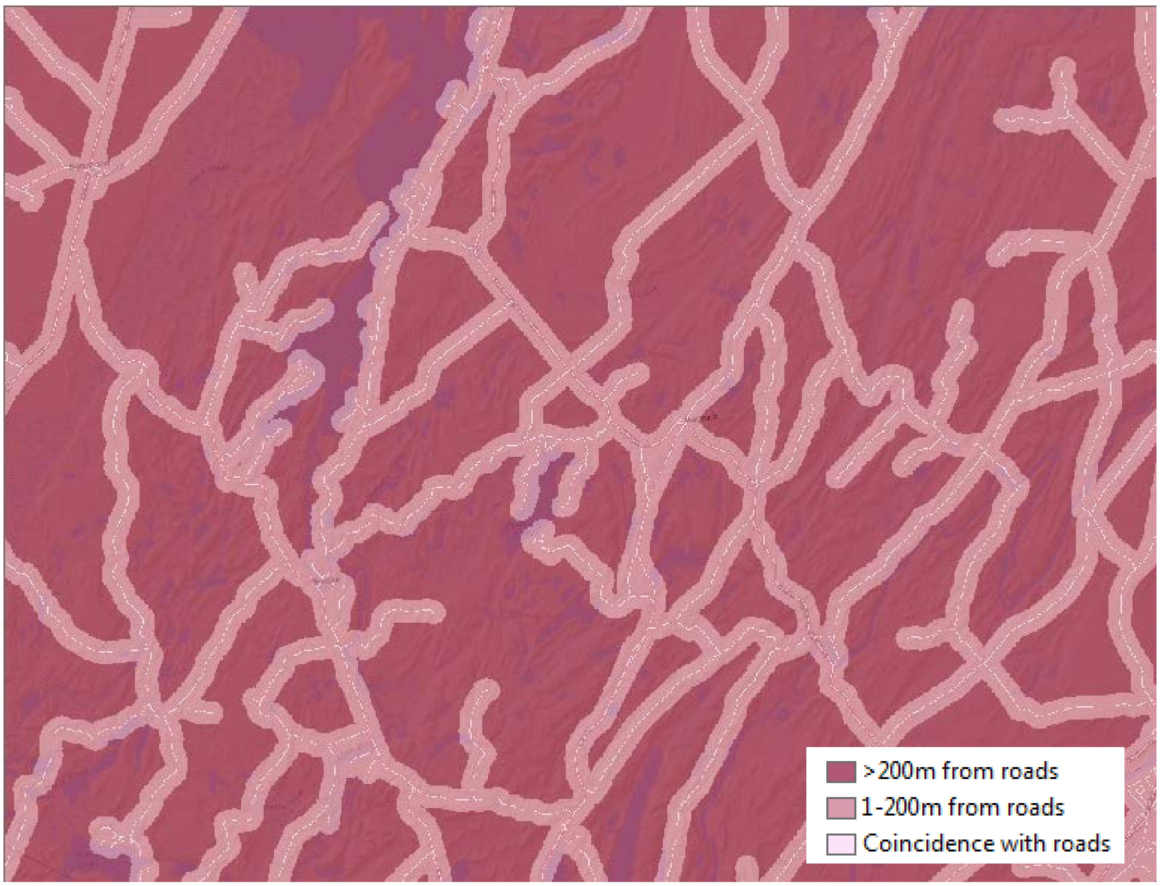

Figure 26: Distance from roads based on three classified categories.

Road density

The density of roads is also valuable to characterize the landscape in addition to the distance to roads. This criterion was generated based on assigning each pixel with a value based on the total length of roads (in kilometres) occurring within one square kilometre around that pixel. Once each pixel is assigned its unique value for road density, the data was assigned to three general categories of high, medium or low development density based on natural breaks. The Ontario Road Network data and the New York Streets data have been represented in similar ways at similar scales, therefore natural breaks were generated separately for each county and the highest category classes, which were identified in Ontario, were used to represent the natural breaks across both countries so that road density classes are consistent across jurisdictions.

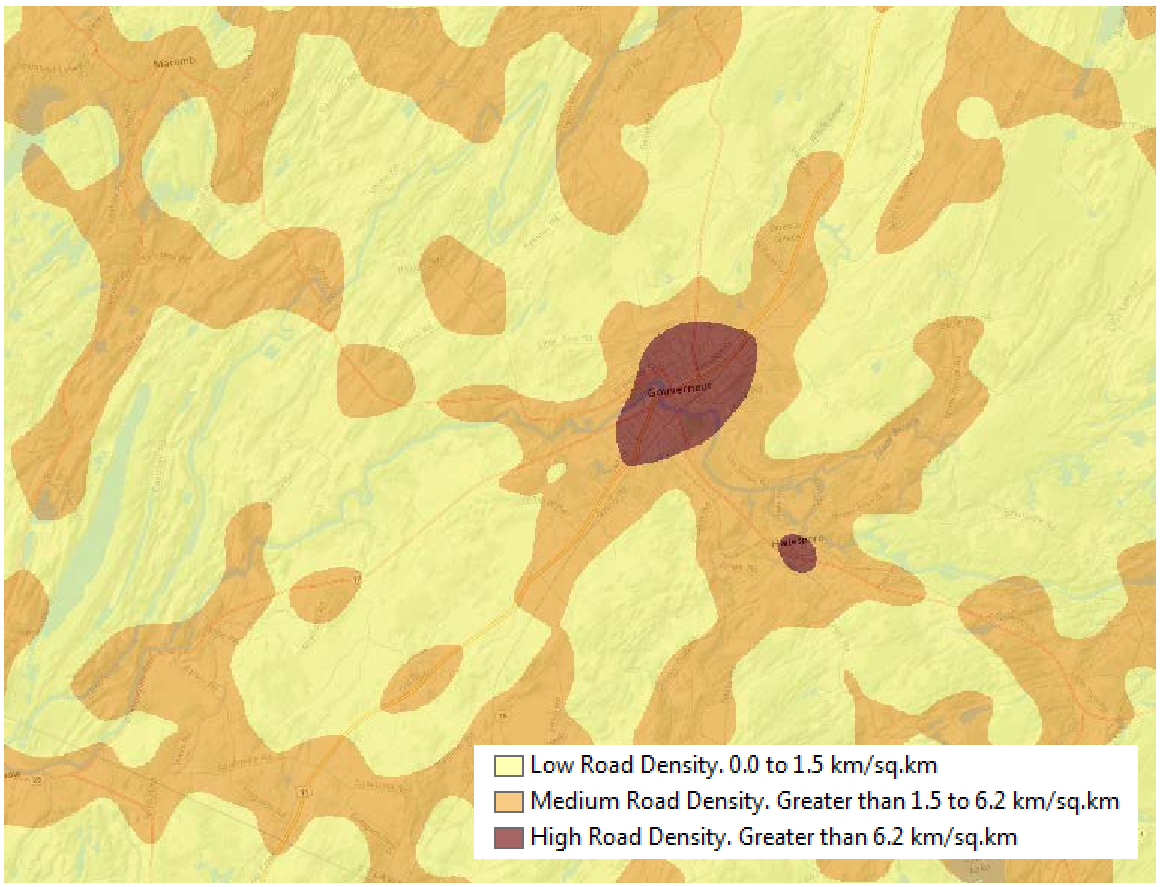

Figure 27: Road density based on three natural break categories.

Creating a composite scoring layer

The characterization criteria layers can then be scored together to generate a total score for each pixel based on the associated category scores (eg. 1, 2, 3) identified in Table 5. A weighting is also applied to each value and summarized for each of these categories and criteria. The weighting identified in Table 5 are preliminary weights that can be modified with GIS analysis or database analysis to allow different weights to be applied to each category and criteria depending on the user needs. The ***combined_criteria*** raster in the deliverables has all the attributes that determines the values for each pixel as their associated criteria and weights as well as a total score for the entire analyzed landscape. For more information on the spatial layers and their associated attributes, refer to the layer metadata file. The total score value is used to create a composite ***score*** layer that assigned a value to each pixel that is associated with the cores and corridor zones of the natural heritage system (not the entire landscape).

The composite score layer provides the user a view of the landscape based on the current criteria identified and the weightings as identified in Table 5. This score layer does not reflect the value of the landscape outside of the identified system and does not suggest that there is not value in these areas. The natural heritage system developed in this analysis is the results of a technical GIS exercise that provides some options for connectivity, however there are many other alternate pathways for different or redundant connections that are also valid on the landscape. The results of this analysis are not suggested as the authoritative blueprint to connect this landscape but can be used as one of several tools to identify practical solutions that take environmental, economic and social values into account.

Viewing the data

The spatial data can be viewed in an ESRI ArcGIS suite. The data may be viewed with software that supports access to an ArcGIS 9.3 *file geodatabase* format. A sample review map has been developed for *ArcExplorer*, a free GIS viewer, to provide users with an ability to peruse the data. Additional modifications or analysis of the data would require the full ESRI ArcGIS suite.

To download the ArcExplorer viewer, click the link provided: http://www.esri.com/software/arcgis/explorer-desktop/download and follow the instructions. This application will require administrative rights to complete the installation. Once installed, open ArcExplorer application first, then open file the Review_Map1 file supplied in the information package by clicking on the coloured globe symbol in the top upper left corner, select 'Open' and browse to the information package ArcGIS Explorer Sample titled Review_Map1 and click Open. If there is an attempt to open the Review_Map1 file first, before opening the application for the first time, a file error will appear.

Depending on where the data is saved, the links to the data may become broken. If the links to the datasets are broken, right click the layers in the left column, select Properties, and select the Source Data field from the left side bar of the pop-up menu. The Repair button will be highlighted under the Layer Summary section. Click the Repair button to change the data source of the broken layer by browsing to the location where the data has been saved. The sample map will open with a default view of the A2A study area. If there is a wish to modify the location and scale that the map opens to or add additional spatial data, it is highly recommended to save the changes under a different file name. This can be done by click on the coloured globe symbol and clicking Save As, or selecting the save as an ArcGIS Explorer Map option.

Land cores and water cores are outlined in grey, primary connection zones are outlined in green. Least cost paths are purple lines and riparian linkages are magenta lines (Figure 28). The remaining colours on the map for the scores layer are a gradient of green to red, with lower scoring to higher scoring respectively. The combined criteria layer colours includes negative values and are represented as a gradient or blue to green to red. Layers can be drawn or not drawn on the map by checking or unchecking the checkbox next to the layer name. Clicking a core will provide an information box to appear which describes the core type (land or water). Additional assistance with ArcGIS Explorer can be found by selecting the question mark icon in the upper right corner.

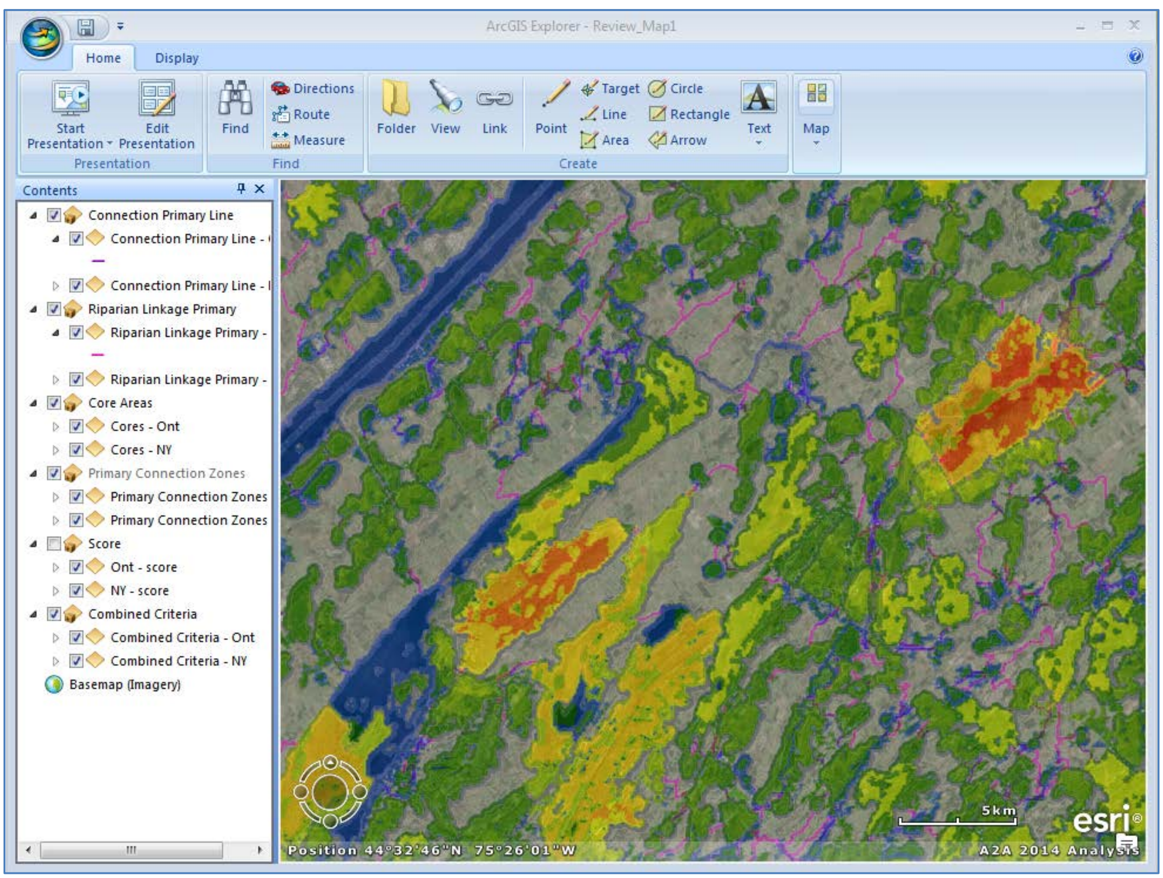

Figure 28: ArcGIS Explorer review map sample for viewing spatial data.

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Appendix A: Data sources

The following categories identified the data sources used for the delineation of the A2A analysis study boundary, the development of cores and linkages and the characterization criteria. Associated hyperlinks were included where possible. For more information on these data sets including current ownership, access and distribution limitations and other aspects of metadata, consult the appropriate data owner.

GIS software is required to view or use spatial data. If you do not have access to a GIS software suite, you can use a free GIS data viewer.

Study area boundary delineation

- Adirondack Park boundary obtained by the New York State Adirondack Park Agency
- Ecological Land Classification (ELC) of Ontario obtained from LIO
- Ecoregions of New York obtained from the U.S. Environmental Protection Agency
- HUC10 (Hydrology Unit Watershed Boundary) obtained from the US Department of Agriculture Geospatial Data Gateway
- International boundary line obtained from the OMNR
- Tertiary Watersheds of Ontario obtained from LIO

Base Land Cover compilation and Core and Linkage development

- Ecosite-based Land Cover Mapping in Eastern Ontario for the Eastern Ontario Model Forest
- Forest Resource Inventory Planning Composite Inventory for the Ottawa Valley Forest Management Unit obtained from the OMNR
- Great Lakes Coastal Wetlands obtained from Great Lakes Information Network (GLIN)
- Land Use Land Cover (NLCD) obtained from the Geospatial Data Gateway
- NHDPlus Version 2 (National Hydrography Dataset) from Horizon Systems Corporation
- Northeast Terrestrial Habitat Map obtained from The Nature Conservancy
- NYS Streets obtained from NYS GIS Clearinghouse
- OHN – Waterbody (Ontario Hydrology Network) obtained from LIO
- Ontario Road Network (ORN) Segment with Address obtained from LIO
- NYS Railroad Lines obtained from NYS GIS Clearinghouse
- SOLRIS (Southern Ontario Land Resource Information System) obtained from LIO
- Wooded Area obtained from LIO

Characterization criteria development

- ANSI (Areas of Natural and Scientific Interest) obtained from LIO
- Conservation Reserve Regulated obtained from LIO
- Crown Game Preserves obtained from LIO
- Great Lakes Islands (International) obtained from LIO
- New York Natural Heritage Program (NYNHP) species and vegetation community data
- New York Protected Areas Database (NYPAD) obtained from the NYNHP

- NHDPlus Version 2 (National Hydrography Dataset) from Horizon Systems Corporation
- NYS Streets obtained from NYS GIS Clearinghouse
- OHN – Waterbody (Ontario Hydrology Network)
- Ontario Road Network (ORN) Segment with Address obtained from LIO
- Plant Community, Provincially Tracked obtained from ONHIC
- Provincial Park Regulated obtained from LIO
- Species Observation, Provincially Tracked obtained from LIO
- Wetland for evaluated wetlands data obtained from LIO

Appendix B: Species list

Scientific Name	Common Name	Ontario					New York				
		ON	Global status	Prov status	Federal listing	Prov listing	NY	Global status	State status	Federal listing	State listing
Amphibians											
Pseudacris triseriata pop. 2	Western Chorus Frog (Great Lakes / St. Lawrence - Canadian Shield Population)	Y	G5TNR	S3	THR	NAR					
Birds											
Gavia immer	Common Loon						Y	G5	S4		SC
Podilymbus podiceps	Pied-billed Grebe						Y	G5	S3B,S1N		THR
Ixobrychus exilis	Least Bittern	Y	G5	S4B	THR	THR	Y	G5	S3B,S1N		THR
Ardea herodias	Great Blue Heron						Y	G5	S5		Prot
Ardea alba	Great Egret	Y	G5	S2B							
Bubulcus ibis	Cattle Egret						Y	G5	S2		Prot
Nycticorax nycticorax	Black-crowned Night-heron	Y	G5	S3B,S3N							
Haliaeetus leucocephalus	Bald Eagle	Y	G5	S2N,S4B	NAR	SC	Y	G5	S2S3B,S2N		THR
Circus cyaneus	Northern Harrier						Y	G5	S3B,S3N		THR
Falco peregrinus	Peregrine Falcon	Y	G4	S3B	SC	THR	Y	G4	S3B		END
Rallus elegans	King Rail	Y	G4	S2B	END	END					
Bartramia longicauda	Upland Sandpiper						Y	G5	S3B		THR
Larus marinus	Great Black-backed Gull	Y	G5	S2B							
Hydroprogne caspia	Caspian Tern	Y	G5	S3B	NAR	NAR	Y	G5	S1		Prot
Sterna hirundo	Common Tern						Y	G5	S3B		THR
Chlidonias niger	Black Tern	Y	G4	S3B	NAR	SC	Y	G4	S2B		END
Tyto alba	Barn Owl	Y	G5	S1	END	END					
Asio flammeus	Short-eared Owl						Y	G5	S2		END
Caprimulgus vociferus	Whip-poor-will	Y	G5	S4B	THR	THR					
Chaetura pelagica	Chimney Swift	Y	G5	S4B,S4N	THR	THR					
Melanerpes erythrocephalus	Red-headed Woodpecker	Y	G5	S4B	THR	SC	Y	G5	S2?B		SC
Hirundo rustica	Barn Swallow	Y	G5	S4B	THR	THR					
Cistothorus platensis	Sedge Wren						Y	G5	S3B		THR
Lanius ludovicianus	Loggerhead Shrike	Y	G4	S2B	END	END					

		Ontario					New York				
Scientific Name	**Common Name**	**ON**	**Global status**	**Prov status**	**Federal listing**	**Prov listing**	**NY**	**Global status**	**State Status**	**Federal listing**	**State listing**
Birds continued											
Vermivora chrysoptera	Golden-winged Warbler	Y	G4	S4B	THR	SC					
Dendroica discolor	Prairie Warbler	Y	G5	S3B	NAR	NAR					
Dendroica palmarum hypochrysea	Yellow Palm Warbler	Y	G5TU	S1B							
Dendroica cerulea	Cerulean Warbler	Y	G4	S3B	END	THR					
Seiurus motacilla	Louisiana Waterthrush	Y	G5	S3B	SC	SC					
Ammodramus henslowii	Henslow's Sparrow	Y	G4	SHB	END	END	Y	G4	S3B		THR
Dolichonyx oryzivorus	Bobolink	Y	G5	S4B	THR	THR					
Sturnella magna	Eastern Meadowlark	Y	G5	S4B	THR	THR					
Euphagus carolinus	Rusty Blackbird						Y	G4	S2B		Prot
Fish											
Ichthyomyzon fossor	Northern Brook Lamprey						Y	G4	S1		
Acipenser fulvescens	Lake Sturgeon						Y	G3G4	S1S2		THR
Acipenser fulvescens pop. 3	Lake Sturgeon (Great Lakes - Upper St. Lawrence River population)	Y	G3G4TNR	S2	THR	THR					
Lepisosteus oculatus	Spotted Gar	Y	G5	S1	THR	THR					
Hiodon tergisus	Mooneye						Y	G5	S1		THR
Exoglossum maxillingua	Cutlip Minnow	Y	G5	S1S2	NAR	THR					
Hybognathus regius	Eastern Silvery Minnow	Y	G5	S2	NAR	NAR					
Notropis anogenus	Pugnose Shiner	Y	G3	S2	END	END	Y	G3	S1		END
Notropis heterodon	Blackchin Shiner						Y	G5	S1		
Moxostoma carinatum	River Redhorse	Y	G4	S2	SC	SC					
Moxostoma valenciennesi	Greater Redhorse						Y	G4	S2		
Noturus insignis	Margined Madtom	Y	G5	SU	DD	DD					
Aphredoderus sayanus gibbosus	Western Pirate Perch						Y	G5T5	S1		
Ammocrypta pellucida	Eastern Sand Darter						Y	G4	S2		THR
Etheostoma exile	Iowa Darter						Y	G5	S2		
Percina copelandi	Channel Darter	Y	G4	S2	THR	THR	Y	G4	S2		
Mammals											
Myotis sodalis	Indiana Bat						Y	G2	S1	END	END
Myotis leibii	Eastern Small-footed Myotis	Y	G3	S2S3			Y	G1G3	S2		SC
Myotis septentrionalis	Northern Myotis	Y	G4	S3		END					
Pipistrellus subflavus	Tri-colored Bat	Y	G5	S3?							

		Ontario					New York				
Scientific Name	**Common Name**	**ON**	**Global status**	**Prov status**	**Federal listing**	**Prov listing**	**NY**	**Global status**	**State Status**	**Federal listing**	**State listing**
Reptiles											
Chelydra serpentina	Snapping Turtle	Y	G5	S3	SC	SC					
Clemmys guttata	Spotted Turtle	Y	G5	S3	END	END					
Glyptemys insculpta	Wood Turtle	Y	G3	S2	THR	END					
Emydoidea blandingii	Blanding's Turtle	Y	G4	S3	THR	THR	Y	G4	S2S3		THR
Graptemys geographica	Northern Map Turtle	Y	G5	S3	SC	SC					
Sternotherus odoratus	Eastern Musk Turtle	Y	G5	S3	SC	THR					
Apalone spinifera	Spiny Softshell	Y	G5	S3	THR	THR	Y	G5	S2S3		SC
Plestiodon fasciatus pop. 2	Common Five-lined Skink (Southern Shield population)	Y	G5T3	S3	SC	SC					
Pantherophis spiloides pop. 1	Gray Ratsnake (Frontenac Axis population)	Y	G5T3	S3	THR	THR					
Lampropeltis triangulum	Milksnake	Y	G5	S3	SC	SC					
Thamnophis sauritus	Eastern Ribbonsnake	Y	G5	S3	SC	SC					
Insects											
Cicindela hirticollis	Hairy-necked Tiger Beetle						Y	G5	S1S2		
Cicindela lepida	Little White Tiger Beetle	Y	G3G4	S2							
Siphlonisca aerodromia	Tomah Mayfly						Y	G2G3	S1		END
Bombus affinis	Rusty-patched Bumble Bee	Y	G1G2	S1	END	END					
Erynnis martialis	Mottled Duskywing	Y	G3	S2	END						
Euchloe olympia	Olympia Marble						Y	G4G5	S1		SC
Callophrys gryneus	Juniper Hairstreak	Y	G5	S2							
Callophrys lanoraieensis	Bog Elfin	Y	G3G4	S1							
Digrammia denticulata	A Geometrid Moth						Y	G4	S1		
Digrammia mellistrigata	Honey-streak						Y	G4G5	SU		
Stenoporpia polygrammaria	Faded Gray Geometer						Y	GU	S1		
Leptostales rubromarginaria	Dark-ribboned Wave						Y	GNR	SU		
Eacles imperialis imperialis	Imperial Moth						Y	G5T5	SU		
Hemileuca sp. 1	Bogbean Buckmoth	Y	G1Q	S1	END	END					
Virbia aurantiaca	Orange Holomelina						Y	G5	SU		
Grammia anna	Anna Tiger Moth						Y	G5	SU		
Paectes abrostolella	A Notodontid Moth						Y	G4	S1		
Chytonix ruperti	A Noctuid Moth						Y	G3G4Q	S1		
Orthodes obscura	A Notodontid Moth						Y	G4	S1?		

		Ontario					New York				
Scientific Name	**Common Name**	**ON**	**Global status**	**Prov status**	**Federal listing**	**Prov listing**	**NY**	**Global status**	**State Status**	**Federal listing**	**State listing**
Insects continued											
Euxoa pleuritica	Fawn Brown Dart						Y	G4	S2S3		
Abagrotis orbis	Well-marked Cutworm						Y	G5	S1		
Cordulegaster obliqua	Arrowhead Spiketail						Y	G4	S3		
Gomphus ventricosus	Skillet Clubtail						Y	G3	S1		
Gomphus quadricolor	Rapids Clubtail	Y	G3G4	S1	END	END	Y	G3G4	S3		
Ophiogomphus anomalus	Extra-striped Snaketail						Y	G4	S2S3		SC
Ophiogomphus aspersus	Brook Snaketail						Y	G4	S3		
Aeshna clepsydra	Mottled Darner	Y	G4	S3							
Rhionaeschna mutata	Spatterdock Darner						Y	G4	S2		
Aeshna verticalis	Green-striped Darner	Y	G5	S3							
Epiaeschna heros	Swamp Darner	Y	G5	S2S3							
Gomphaeschna furcillata	Harlequin Darner	Y	G5	S3							
Nasiaeschna pentacantha	Cyrano Darner	Y	G5	S3							
Epitheca semiaquea	Mantled Baskettail						Y	G5	S2		
Somatochlora forcipata	Forcipate Emerald	Y	G5	S3			Y	G5	S1		
Williamsonia fletcheri	Ebony Boghaunter						Y	G4	S1		
Sympetrum corruptum	Variegated Meadowhawk	Y	G5	S3							
Lestes eurinus	Amber-winged Spreadwing	Y	G4	S3							
Enallagma aspersum	Azure Bluet	Y	G5	S3							
Stylurus notatus	Elusive Clubtail	Y	G3	S2							
Arigomphus cornutus	Horned Clubtail	Y	G4	S3							
Arigomphus furcifer	Lilypad Clubtail	Y	G5	S3							
Freshwater Mussels											
Lampsilis cariosa	Yellow Lampmussel						Y	G3G4	S3		
Lampsilis ovata	Pocketbook						Y	G5	S2S3		
Ligumia nasuta	Eastern Pondmussel	Y	G4	S1	END	END					
Ligumia recta	Black Sandshell						Y	G4G5	S2S3		
Margaritifera margaritifera	Eastern Pearlshell						Y	G4	S2		
Terrestrial Snails											
Vertigo elatior	Tapered Vertigo	Y	G5	S2S3							
Vertigo paradoxa	Classification Uncertain	Y	G4G5Q	S2S3							
Catinella aprica	Diurnal Ambersnail	Y	G2	S2							
Appalachina sayana	Spike-lip Crater	Y	G5	S3	NAR	NAR					

		Ontario					New York				
Scientific Name	**Common Name**	**ON**	**Global status**	**Prov status**	**Federal listing**	**Prov listing**	**NY**	**Global status**	**State Status**	**Federal listing**	**State listing**
Mosses and Lichens											
Fontinalis sullivantii	A Moss	Y	G3G5	S1							
Plagiothecium latebricola	Lurking Leskea	Y	G3G4	S2							
Sphagnum andersonianum	Anderson's Peat Moss						Y	G3?	S1		
Pseudocalliergon turgescens	Curving Feather Moss						Y	G3G5	S1		
Arthothelium spectabile	A Lichen	Y	G4G5	S1							
Leptogium rivulare	Flooded Jellyskin	Y	G3G5	S3	THR	THR					
Physconia subpallida	Pale-bellied Frost Lichen	Y	GNR	S2	END	END					
Vascular Plants											
Justicia americana	American Water-willow	Y	G5	S1	THR	THR					
Panax quinquefolius	American Ginseng	Y	G3G4	S2	END	END					
Asclepias quadrifolia	Four-leaved Milkweed	Y	G5	S1	END	END					
Lactuca hirsuta	Downy Lettuce						Y	G5?	S1		END
Solidago nemoralis var. longipetiolata	Gray-stemmed Goldenrod	Y	G5T5	S1S2							
Solidago puberula	Downy Goldenrod	Y	G5	S2							
Symphyotrichum boreale	Northern Bog Aster						Y	G5	S2		THR
Symphyotrichum dumosum	Bushy Aster	Y	G5	S2							
Symphyotrichum ciliolatum	Lindley's Aster						Y	G5	S1		END
Betula pumila	Swamp Birch						Y	G5	S2		THR
Cynoglossum virginianum var. boreale	Northern Wild Comfrey						Y	G5T4T5	S1S2		END
Hackelia deflexa var. americana	Northern Stickseed						Y	G5T5	S1		END
Lithospermum canescens	Hoary Puccoon	Y	G5	S3							
Lithospermum caroliniense	Golden Puccoon	Y	G4G5	S3							
Lithospermum parviflorum	Soft-hairy False Gromwell	Y	G4G5T4	S2							
Boechera stricta	Drummond's Rock-cress						Y	G5	S2		THR
Rorippa aquatica	Lake-cress						Y	G4?	S2		THR
Draba reptans	Carolina Whitlow-grass	Y	G5	S3			Y	G5	S2		THR
Boechera grahamii	Purple Rock-cress						Y	G5	S2		THR
Cerastium brachypodum	Short-stalked Chickweed	Y	G5	S2							
Stellaria longipes	Longstalk Starwort						Y	G5	S2		THR
Ceratophyllum echinatum	Prickly Hornwort	Y	G4?	S3?							
Rhododendron canadense	Rhodora						Y	G5	S2		THR
Vaccinium stamineum	Deerberry	Y	G5	S1	THR	THR					
Euphorbia commutata	Wood Spurge	Y	G5	S1							

Scientific Name	Common Name	Ontario					New York				
		ON	Global status	Prov status	Federal listing	Prov listing	NY	Global status	State Status	Federal listing	State listing
Vascular plants continued											
Corydalis aurea	Golden Corydalis						Y	G5	S2		THR
Gentianopsis virgata	Lesser Fringed Gentian						Y	G5	S1		END
Hippuris vulgaris	Common Mare's-tail						Y	G5	S1		END
Juglans cinerea	Butternut	Y	G4	S3?	END	END					
Dracocephalum parviflorum	American Dragonhead						Y	G5	S1		END
Hedeoma hispida	Mock-pennyroyal						Y	G5	S2S3		THR
Pycnanthemum verticillatum var. verticillatum	Whorled Mountain-mint						Y	G5T5	S1S2		END
Linum medium var. texanum	Southern Yellow Flax						Y	G5T5	S2		THR
Hibiscus moscheutos	Swamp Rose-mallow	Y	G5	S3	SC	SC					
Epilobium hornemannii ssp. hornemannii	Alpine Willow-herb						Y	G5T5	S1		END
Persicaria arifolia	Halberd-leaved Tearthumb	Y	G5	S3							
Polygonum aviculare ssp. buxiforme	Small's Knotweed						Y	G5	S1		END
Podostemum ceratophyllum	Riverweed						Y	G5	S2		THR
Pyrola asarifolia ssp. asarifolia	Pink Wintergreen						Y	G5T5	S2		THR
Myosurus minimus	Tiny Mousetail	Y	G5	S2							
Ceanothus herbaceus	Prairie Redroot						Y	G5	S1		END
Geum triflorum var. triflorum	Prairie-smoke						Y	G5T5	S2		THR
Geum virginianum	Rough Avens						Y	G5	S2		THR
Prunus pumila var. pumila	Low Sand-cherry						Y	G5T4	S1		END
Galium brevipes	Limestone Swamp Bedstraw	Y	G4?	S2S3							
Salix cordata	Sand Dune Willow						Y	G4	S2		THR
Salix pyrifolia	Balsam Willow						Y	G5	S3		Rare
Castilleja coccinea	Scarlet Indian-paintbrush						Y	G5	S1		END
Gratiola quartermaniae	Limestone Hedge-hyssop	Y	G3	S2							
Celtis tenuifolia	Dwarf Hackberry	Y	G5	S2	THR	THR					
Ulmus thomasii	Cork Elm						Y	G5	S2S3		THR
Valeriana uliginosa	Marsh Valerian	Y	G4Q	S2			Y	G4Q	S1S2		END
Valerianella chenopodiifolia	Goosefoot Cornsalad	Y	G5	S1							
Viola nephrophylla	Northern Bog Violet						Y	G5	S1		END
Pinus rigida	Pitch Pine	Y	G5	S2?							
Alisma gramineum	Water-plantain						Y	G5	S2S3		THR
Sagittaria cristata	Crested Arrowhead	Y	G4?	S3							

		Ontario					New York				
Scientific Name	Common Name	ON	Global status	Prov status	Federal listing	Prov listing	NY	Global status	State Status	Federal listing	State listing
Vascular plants continued											
Peltandra virginica	Green Arrow-arum	Y	G5	S2							
Carex atherodes	Awned Sedge						Y	G5	S3		Rare
Carex backii	Back's Sedge						Y	G5	S2		THR
Carex bicknellii	Bicknell's Sedge	Y	G5	S2							
Carex buxbaumii	Brown Bog Sedge						Y	G5	S2		THR
Carex careyana	Carey's Sedge						Y	G4G5	S1S2		END
Carex chordorrhiza	Creeping Sedge						Y	G5	S2		THR
Carex crawei	Crawe's Sedge						Y	G5	S2		THR
Carex emoryi	Emory's Sedge						Y	G5	S1S2		END
Carex formosa	Handsome Sedge						Y	G4	S2		THR
Carex gynocrates	Northern Bog Sedge						Y	G5	S1		END
Carex haydenii	Cloud Sedge						Y	G5	S1		END
Carex houghtoniana	Houghton's Sedge						Y	G5	S2		THR
Carex lupuliformis	False Hop Sedge						Y	G4	S2		THR
Carex merritt-fernaldii	Fernald's Sedge						Y	G5	S2S3		THR
Carex molesta	Troublesome Sedge						Y	G4	S2S3		THR
Carex oligocarpa	Eastern Few-fruited Sedge	Y	G4	S3							
Carex sartwellii	Sartwell's Sedge						Y	G4G5	S1S2		END
Carex tenuiflora	Sparse-flowered Sedge						Y	G5	S1		END
Carex albicans var. albicans	White-tinged Sedge	Y	G5T4T5	S3							
Carex juniperorum	Juniper Sedge	Y	G3	S1	END	END					
Cyperus schweinitzii	Schweinitz's Flatsedge						Y	G5	S3		Rare
Schoenoplectus heterochaetus	Slender Bulrush						Y	G5	S1		END
Scleria verticillata	Low Nutrush	Y	G5	S3							
Elodea nuttallii	Nuttall's Waterweed	Y	G5	S3							
Sisyrinchium mucronatum	Michaux's Blue-eyed-grass						Y	G5	S1		END
Juncus acuminatus	Sharp-fruited Rush	Y	G5	S3							
Juncus secundus	One-sided Rush	Y	G5?	S3							
Allium tricoccum var. burdickii	Narrow-leaved Wild Leek	Y	G5T4T5	S1?							
Lilium michiganense	Michigan Lily						Y	G5	S1		END
Anticlea elegans ssp. glaucus	Mountain Death Camas						Y	G5T4T5	S2		THR
Najas marina	Prickly Naiad	Y	G5	S1							
Arethusa bulbosa	Dragon's Mouth Orchid						Y	G4	S2		THR

Scientific Name	Common Name	Ontario					New York				
		ON	Global status	Prov status	Federal listing	Prov listing	NY	Global status	State Status	Federal listing	State listing
Vascular plants continued											
Corallorhiza odontorhiza	Autumn Coral-root	Y	G5	S2							
Cypripedium arietinum	Ram's-head Ladyslipper	Y	G3	S3			Y	G3	S2		THR
Liparis liliifolia	Purple Twayblade	Y	G5	S2	THR	THR					
Listera australis	Southern Twayblade						Y	G4	S1S2		END
Platanthera leucophaea	Eastern Prairie Fringed-orchid	Y	G2G3	S2	END	END					
Ammophila breviligulata ssp. champlainensis	Champlain Beachgrass						Y	G2G3Q	S1		END
Bouteloua curtipendula	Side-oats Grama	Y	G5	S2							
Bouteloua curtipendula var. curtipendula	Side-oats Grama						Y	G5T5	S1		END
Calamagrostis stricta ssp. inexpansa	New England Northern Reedgrass						Y	G5T5	S2		THR
Calamovilfa longifolia var. magna	Great Lakes Sand Reed	Y	G5T3T5	S3							
Panicum flexile	Wiry Panic Grass						Y	G5	S3		Rare
Sphenopholis obtusata	Prairie Wedgegrass						Y	G5	S1		END
Sporobolus heterolepis	Northern Dropseed	Y	G5	S3			Y	G5	S2		THR
Potamogeton alpinus	Northern Pondweed						Y	G5	S2		THR
Potamogeton hillii	Hill's Pondweed						Y	G3	S2		THR
Potamogeton strictifolius	Straight-leaf Pondweed						Y	G5	S1		END
Scheuchzeria palustris	Pod Grass						Y	G5	S3		Rare
Sparganium natans	Small Bur-reed						Y	G5	S2		THR
Ferns and relatives											
Pellaea atropurpurea	Purple-stemmed Cliff-brake	Y	G5	S3							
Pellaea glabella ssp. glabella	Smooth Cliff Brake						Y	G5T5	S2		THR
Woodsia obtusa	Blunt-lobed Woodsia	Y	G5	S1	THR	END					
Equisetum palustre	Marsh Horsetail						Y	G5	S2		THR
Equisetum pratense	Meadow Horsetail						Y	G5	S2		THR
Isoetes riparia	Riverbank Quillwort	Y	G5	S3							
Diphasiastrum complanatum	Northern Running-pine						Y	G5	S1		END
Botrychium rugulosum	Rugulose Grape Fern	Y	G3	S2			Y	G3	S1		END
Phegopteris hexagonoptera	Broad Beech Fern	Y	G5	S3	SC	SC					
Thelypteris simulata	Bog Fern	Y	G4G5	S1							

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Appendix C: Communities list

Common Name	Global status	Prov/State status	Type
NEW YORK			
Wetland /Aquatic Communities			
Great Lakes Aquatic Bed	G4	S3	rare
Great Lakes Exposed Shoal	G4	S4	exemplary
Winter-stratified Monomictic Lake	G3G4	S2	rare
Red Maple-Hardwood Swamp	G5	S4S5	exemplary
Silver Maple-Ash Swamp	G4	S3	rare
Perched Swamp White Oak Swamp	G3G4	S1S2	rare
Hemlock-Hardwood Swamp	G4G5	S4	exemplary
Spruce-Fir Swamp	G3G4	S3	rare
Red Maple-Tamarack Peat Swamp	G3G4	S2S3	rare
Northern White Cedar Swamp	G4	S2S3	rare
Black Spruce-Tamarack Bog	G4G5	S3	rare
Deep Emergent Marsh	G5	S5	exemplary
Shallow Emergent Marsh	G5	S5	exemplary
Shrub Swamp	G5	S5	exemplary
Cobble Shore Wet Meadow	G3?	S2	rare
Sinkhole Wetland	G3?	S1	rare
Rich Graminoid Fen	G3	S1S2	rare
Rich Shrub Fen	G3G4	S1S2	rare
Medium Fen	G3G4	S2S3	rare
Dwarf Shrub Bog	G4	S3	rare
Confined River	G4	S3S4	rare
Upland/Terrestrial Communities			
Boreal Heath Barrens	G3G4	S1	rare
Sandstone Pavement Barrens	G2	S1	rare
Calcareous Pavement Woodland	G3	S2S3	rare
Limestone Woodland	G3G4	S2S3	rare
Alvar Woodland	G2?	S2	rare
Calcareous Talus Slope Woodland	G3G4	S3	rare
Pitch Pine-Oak-Heath Rocky Summit	G4	S3S4	exemplary
Appalachian Oak-Hickory Forest	G4G5	S4	exemplary
Appalachian Oak-Pine Forest	G4G5	S4	exemplary
Maple-Basswood Rich Mesic Forest	G4	S3	rare
Pine-Northern Hardwood Forest	G4	S4	exemplary
Successional Northern Hardwoods	G5	S5	exemplary
Sand Beach	G5	S3	rare
Great Lakes Dunes	G3G4	S1S2	rare

Common Name	Global status	Prov/State status	Type
Upland/Terrestrial Communities continued			
Riverside Ice Meadow	G2G3	S1	rare
Calcareous Shoreline Outcrop	G3G4	S2	rare
Wet Alvar Grassland	G2	S1	rare
Dry Alvar Grassland	G2	S1	rare
Alvar Pavement Grassland	G3	S2	rare
Successional Old Field	G5	S5	exemplary
Successional Shrubland	G5	S5	exemplary
Successional Northern Sandplain Grassland	G4?	S3	rare
ONTARIO			
Terrestrial Communities			
Philadelphia Panic Grass - False Pennyroyal Alvar Pavement Type	G1Q	S1	rare
Northern Dropseed - Little Bluestem - Scirpus-like Sedge Alvar Grassland Type	G2G3?	S2S3	rare
Tufted Hairgrass - Canada Bluegrass - Philadelphia Panic Grass Alvar Grassland Type	G2G3?	S2S3	rare
Common Juniper - Fragrant Sumac - Hairy Beardtongue Alvar Shrubland Type	G2?	S2	rare
White Cedar - Jack Pine - Shrubby Cinquefoil Treed Alvar Pavement	G1G2	S1	rare
White Cedar - White Spruce - Philadelphia Panic Grass Treed Alvar Grassland Type	G3?	S3	rare
Red Cedar - Early Buttercup Treed Alvar Grassland Type	G2?	S3	rare
Sea Rocket Sand Open Beach	G2G4	S2S3	rare
Pitch Pine Treed Granite Barren Type	G3G5	S1	rare
Terrestrial Communities – Sand Dune			
Little Bluestem - Switchgrass - Beachgrass Dune Grassland Type	G?	S2	rare
Dry Tallgrass Prairie Type	G3	S1	rare
Wetland Communities			
Cotton-grass Graminoid Bog Type	G3G4	S5	rare
Leatherleaf Shrub Bog Type	G5	S5	exemplary
Black Spruce Treed Bog Type	G5	S5	exemplary
Leatherleaf - Forb Shrub Fen Type	G5	S5	exemplary
Tamarack Treed Fen Type	G4?	S5	exemplary
Tamarack - White Cedar Treed Fen Type	G4?	S5	exemplary
Gray Birch Treed Fen Type	G4?	S2S3	rare
Black Spruce - Tamarack - Leatherleaf Patterned Fen Type	G4	S5	exemplary
Slender Sedge Graminoid Fen Type	G4G5	S5	exemplary
Sweet Gale Shrub Fen Type	G?	S5	exemplary
Graminoid Coastal Meadow Marsh Type	G2?	S2	rare
Cattail Organic Shallow Marsh Type	G5	S5	exemplary
Black Spruce Coniferous Organic Swamp Type	G5	S5	exemplary

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