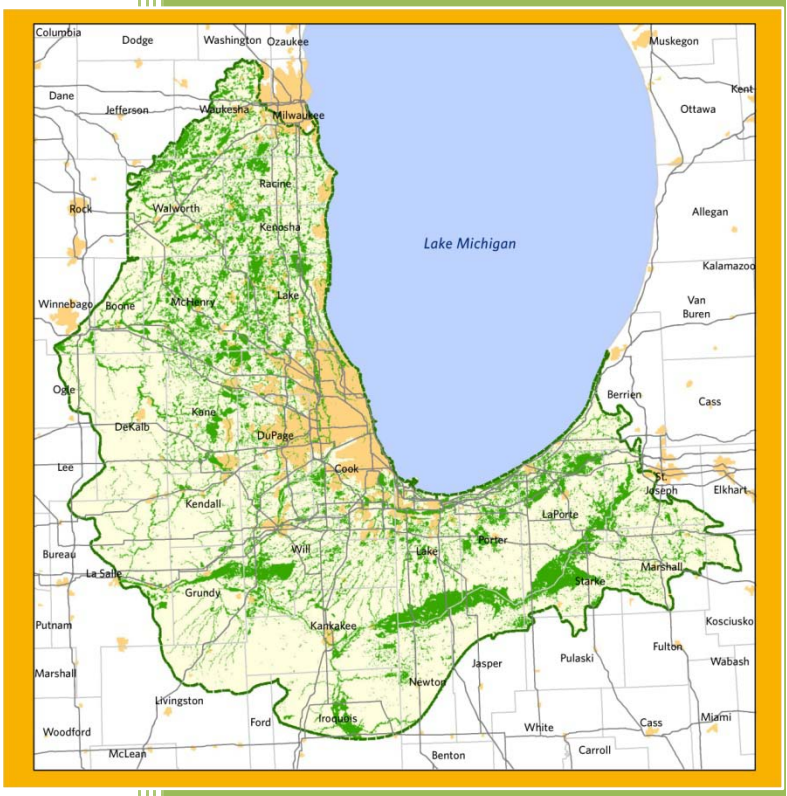
2012

Chicago Wilderness Green Infrastructure Vision 2.1



Chicago Wilderness

APPLIED ECOLOGICAL SERVICES, INC.

THE CONSERVATION FUND

Dear Chicago Wilderness members and other stakeholders,

Over the past year and a half the Chicago Wilderness Green Infrastructure Vision Task Force has worked to update and refine the original Green Infrastructure Vision (GIV), which was first developed in 2004. The project was meant to add detail to the original GIV as well as provide a set of GIS tools for conservation partners in the region to use to identify portions of the green infrastructure network on which they wish to concentrate their efforts.

Our "next-generation" regional green infrastructure map goes by the name of GIV 2.1 for the entire Chicago Wilderness region. An interim product called GIV 2.0 covered the seven-county northeastern Illinois metropolitan area. We believe that, to remain powerful and relevant, the Green Infrastructure Vision needs to be refined and updated at periodic intervals, and we hope that CW will extend the work presented in this effort – by developing a GIV 3.0 when the time comes for additional revisions or model development.

Many Chicago Wilderness members and others, through targeted workshops and numerous webinars and one-on-one meetings, participated in refining the GIV. They deserve thanks for their deep commitment to conserving the natural resources of the Chicago region. A project committee of Chicago Wilderness members guided our effort; its members included Jim Anderson (Lake County Forest Preserves), Steve Byers (Illinois Nature Preserves Commission), Jesse Elam (CMAP), Joe Exl (Northwest Indiana Regional Planning Commission), Jennifer Hammer (The Conservation Foundation), Kris Krouse (Shirley Heinze Land Trust), Jeff Mengler (Cardno ENTRIX), Chris Mulvaney (Chicago Wilderness staff), Jesse Oakley (U.S. Fish and Wildlife Service), Don Reed (Southeast Wisconsin Regional Planning Commission), Laurel Ross (The Field Museum), Sean Wiedel (City of Chicago), Nancy Williamson (Illinois Department of Natural Resources), Maggie Zoellner (Kettle Moraine Land Trust).

The green infrastructure network layers generated in this project are available through the CMAP website and the CW website as well as through other regional data providers.

Sincerely,

Jeff Mengler and Nancy Williamson

Co-Chairs, Chicago Wilderness Green Infrastructure Vision Task Force

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I. Introduction

A. Project Background

In 2004, the Northeastern Illinois Planning Commission completed a Green Infrastructure Vision ("GIV 1.0") for the Chicago Wilderness region. This product identified large Resource Protection Areas (RPAs) and recommended protection approaches for each, including additional land preservation, ecological restoration, or development restrictions. These recommendations were based primarily on charrettes that distilled the professional judgment of natural resource experts within Chicago Wilderness. GIV 1.0 resulted in a final report containing the recommendations as well as several printed maps and GIS data representing the RPAs.

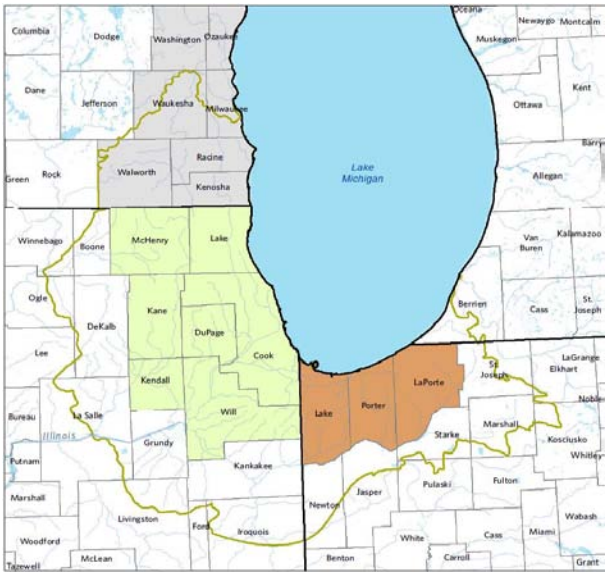

Figure 1. GIV 2.0 Study Area

The current project ("GIV 2.1"), along with its interim GIV 2.0 product for northeastern Illinois, is a refinement of the previous work that is intended to classify and characterize important resources in a consistent and analytically robust manner, as well as to define ecological and human connectivity needs and provide enhanced information to support conservation and development decisions. The Green Infrastructure Vision has often been described as a visual representation of the Chicago Wilderness Biodiversity Recovery Plan, and the refinements of GIV 2.1 are meant to help further advance the broad conservation agenda established by the Biodiversity Recovery Plan. The main products of the GIV 2.1 project are derived GIS datasets that describe and characterize the regional green infrastructure network.

The Conservation Fund and Applied Ecological Services (AES) carried out the work for GIV 2.1 through a contract with Chicago Wilderness through funding from the Gaylord and Dorothy Donnelley Foundation. The GIV 2.0 initial phase was completed through a contract with the Chicago Metropolitan Agency for Planning (CMAP) through funding from the Illinois Department of Transportation. The study area for GIV 2.1 is the Chicago Wilderness ecoregion in Wisconsin, Illinois, and Indiana, with a small portion of Berrien County, Michigan, shown in Figure 1. The ecoregion includes some or all of the MPO boundaries (shown in colors on Figure 1) of CMAP, the Northwestern Indiana Regional Planning Commission (NIRPC), and the Southeastern Wisconsin Regional Planning Agency (SEWRPC), along with portions of additional outlying counties in Illinois and Indiana.

The primary purpose of the GIV 2.1 planning initiative is to identify and refine a regionally important network of land and water that is critical to protect and restore. This regional green infrastructure network (Figure 2) was developed for the Chicago Wilderness region area using the core-hub-corridor approach (sometimes simplified to cores and corridors), as follows. The building blocks of the network are "core areas" that contain well-functioning natural ecosystems that provide high-quality habitat for native plants and animals. By contrast, "hubs" are aggregations of core areas as well as nearby lands that contribute significantly to ecosystem services like clean water, flood control, carbon sequestration, and recreation opportunities. Finally, "corridors" are relatively linear features linking cores and hubs together, providing essential connectivity for animal, plant, and human movement.

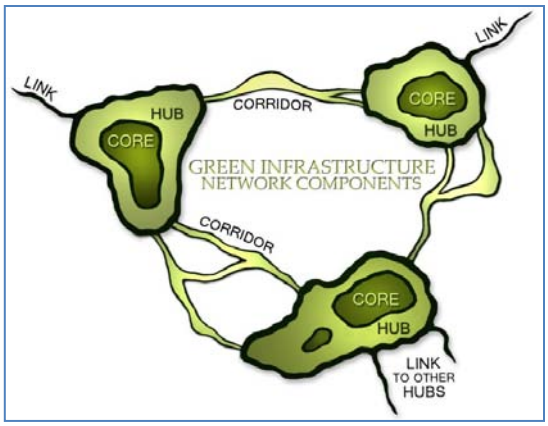

Figure 2. Conceptual green infrastructure network

B. Benefits of GIV 2.0

GIV 2.0 retains the emphasis on protecting biodiversity from the original Green Infrastructure Vision, but it also seeks to address a broader range of issues and provide a wide array of benefits. Continuing the original approach, the current product gives "a high priority… to identifying and preserving important but unprotected natural communities, especially those threatened by development, and to protecting areas that can function as large blocks of natural habitat though restoration and management." Thus GIV 2.1 addresses the following strategies:

- **Creation of large preserves**: The GIV 2.1 identifies the largest blocks of unfragmented landscapes based on ecological resources rather than property boundaries.
- **Creation of community mosaics**: The GIV 2.1 assembles blocks of forest/woodlands, prairie/savanna, wetlands, and aquatic systems into hubs of multiple landscape types to reflect the importance of a mix of habitats that support biodiversity.
- **Protection of priority areas, especially remaining high-quality sites**: The GIV 2.1 incorporates the best available data on high quality registered heritage sites, natural areas, and important bird areas regardless of the size of the site and current protected status.
- **Protection of any large sites with some remnant communities**: The GIV 2.1 includes adjacent compatible land cover around known remnant communities to buffer and hopefully expand them over time.

- **Protection of land that connects or expands existing natural areas**: The GIV 2.1 uses functional connectivity to link core areas and hubs together and identify potential locations for restoration.
- **Expansion of public preserves, acquisition of large new sites, and/or protection through the actions of private land owners where possible**: The GIV 2.1 can be used to identify gaps in protection and opportunities for private land stewardship that advances the goals of the Biodiversity Recovery Plan.

The regional green infrastructure network also provides multiple benefits. At its broadest, landscape- scale green infrastructure provides important ecosystem services like clean air and water, critical plant and animal species habitat, and wildlife migration corridors along with compatible working landscapes (Figure 3). At the regional scale, green space can help protect water quality and help ensure the availability of drinking water. Green infrastructure can also provide key recreational areas that link people to natural lands and facilitate the use of transportation modes other than automobiles to reach key community assets. At the site scale, green infrastructure enhances neighborhoods and downtowns through environmentally-sensitive site design techniques, urban forestry, and stormwater management systems that reduce the environmental impact of urban settlements. All of these scales of activity can be linked together and can ensure sustainability in urban, suburban, and rural areas of a region. Green infrastructure can be implemented at different scales. Finally, as surveys of conservation organizations by the Land Trust Alliance have documented, producing a strategic conservation plan is associated with a dramatic increase in the pace of land conservation (Amundsen, 2011).

Figure 3. Green infrastructure at multiple geographic scales.

While it is discussed in more detail in Appendix G, it is worth noting a few points here about the role of the green infrastructure network in aiding adaptation to climate change. The emerging consensus of climate adaptation planning is that well-defined spatial priorities are needed to facilitate adaptation for wildlife and ecosystem processes. This approach identifies those elements of the landscape most relevant to wildlife now, in the face of current threats, as well as in the future as the climate changes, and it provides a spatial framework for climate adaptation planning relevant to land conservation efforts. As new information becomes available through downscaled climate models and vulnerability assessments, the GIV 2.1 can be modified to incorporate such finer-scaled filters to test the adequacy of the network for climate

change. The approach has incorporated, to the extent practical, the Chicago Climate Action Plan impact analysis and the Chicago Wilderness Climate Action Plan for Nature. Most importantly, at a landscape scale, the GIV 2.1 network incorporates places where building resilience by conserving large habitat blocks and realigning corridors to build connectivity will ultimately help wildlife adapt to an altered climate. Please see Appendix G for more information about how large habitat blocks connected by corridors are hypothesized to aid ecological adaptation.

C. GIV 2.1 Products

The mapping products of the GIV 2.1 project are divided into two different versions: the Basic edition and the Analyst edition. For each edition, it is extremely important that users review this final report before spending time with the GIS layers and models.

The Basic edition contains GIV 2.1 raster GIS datasets and accompanying characterization outputs (for priority setting) using ESRI's Model Builder toolkit. It also contains file geodatabases that include vector data on base map layers, protected and managed lands, and urban and site scale green infrastructure features.

The Analyst edition contains all of the Basic edition data and models plus additional Model Builder toolboxes to re-run landscape core areas, landscape restoration complexes, and functional connectivity to link core areas. It also includes some data preparation models that may be useful to analysts, including merging protected lands layers into a single raster dataset. The Analyst edition tools will be most useful when wanting to try different functional connectivity scenarios and to update core areas when new data becomes available (e.g. a new version of the Illinois Natural Areas Inventory or finer-resolution land cover data).

D. Software Requirements

Both the Basic edition and the Analyst edition use the ESRI file geodatabase and raster grid formats for ArcGIS desktop version 10.0. As a result, ArcGIS Desktop version 10.0 at the ArcView license level is required to view the data. It is also recommended that users have the latest ArcGIS Desktop service pack. Currently, the latest desktop version 10.0 Service Pack is 5. The latest service pack can be downloaded by visiting:
http://support.esri.com/en/downloads/patches-servicepacks/list/productid/160

In order to run the GIV 2.1 characterization models and all Analyst edition models, the Spatial Analyst extension to ArcGIS Desktop version 10.0 is required. Users should contact their system administrators or ESRI about obtaining access to this extension.

Both the Basic edition and Analyst edition should be compatible with ArcGIS desktop version 10.1 service pack 1, but they have not been tested on this platform.

II. GIV 2.1 Landscape Types and Methodologies

A. Methodology Overview

This section describes a modeling methodology for rigorously defining the regional green infrastructure network in the Chicago Wilderness region. The GIV 2.1 methodology uses landscapes as the primary organizing principle. Landscapes are a mosaic of ecosystems or land uses that possess common attributes that are repeated across a large area (Forman & Godron, 1986). Landscapes provide the rationale for deciding which resource attributes or features to include and connect within a green infrastructure network. Based on the 2004 Chicago Wilderness Green Infrastructure Vision and Biodiversity Recovery Plan, along with existing mapping data available for the region, four broader categories of landscape types were identified for the study area, as follows: woodlands/forests, prairies/grasslands/savannas, wetlands, and streams and lakes. A fifth landscape type, regional recreation and urban scale green infrastructure, was also identified. While this landscape type is significantly different from the natural areas, these areas are important features that make human communities more livable and sustainable and enable people to take advantage of the region's ecological capital.

The GIV 2.1 methodology describes a sequence of GIS modeling steps to help differentiate core areas from other landscape patches, along with the data sources used to implement the modeling methods. Please note that these landscape types are not meant to be mutually exclusive. Inevitably, some important resource lands will meet the criteria and thresholds for more than one core area type, and this is acceptable from a methodological standpoint (as well as desirable from a conservation standpoint). Core areas are combined in a later step to create a more holistic hub and corridor network. The GIV 2.1 identifies the "best of the best" while providing a spatially explicit framework for habitat restoration and enhancement. It also lays the foundation for future quantification of ecosystem services.

The GIV 2.1 methodology also identifies functional connections that can help linking the GIV 2.1 landscape features. More information on landscape functional connections is provided in Section II G. The GIV 2.1 methodology also maps restoration building blocks for each landscape type. While pre-settlement vegetation was the primary data input for the woodland/forest and prairie/grassland/savanna landscape types, a variety of other data was used for the wetlands and streams and lakes landscape types. Please see the step-by-step technical methods sections starting with subsection C below for more details.

B. Defining Landscape Types

The landscapes identified in the 2004 Chicago Wilderness Green Infrastructure Vision report were used as a starting point for developing step-by-step technical methods for mapping each

landscape type. A second key input was the Chicago Wilderness Biodiversity Recovery Plan, which provides a series of acreage targets and core area size thresholds for consideration. A third key consideration was minimum core area thresholds that would maintain habitat for focal species of each landscape type. All of these were assessed in concert with feedback from the GIV 2.1 project committee and stakeholders as well as an analysis of the available GIS data that mapped each landscape type. For the most part, the aspirations of the GIV report and Biodiversity Recovery Plan had to be balanced against the reality of a very fragmented landscape as well as the desire to protect even small landscape blocks to serve as anchors for future restoration. For instance, 50 acres was chosen as an initial size threshold for woodlands, with the hope that areas adjacent to these woodland patches could eventually be restored to meet Biodiversity Recovery Plan goals.

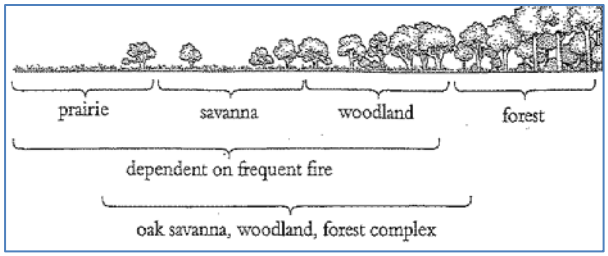

Figure 4. The prairie-forest continuum (Packard and Mutel, 1997)

Another key consideration was how to handle the prairie-forest continuum while maintaining the ability to map discrete landscape types (see Figure 4). As the figure demonstrates, there is rarely a discrete line but rather a blending of communities across the landscape gradient, so it can be difficult to pinpoint where one ends and the other begins. There was considerable discussion, for instance, on whether savannas should be grouped with woodlands or prairies or be left as a discrete landscape type. In the end, savannas were included with the prairies and grasslands in the technical methods mostly due to the similar approaches needed to map them, which were significantly different from the way woodlands/forest were mapped. That said, savannas are a separate data layer so they can be grouped or split as the users of the GIV 2.1 GIS data layers see fit to use them in their work.

GIV 2.1 has defined forests and woodlands as areas with greater than 50% tree canopy, which includes upland forest (>80% tree canopy) and floodplain forest, flatwoods, and woodlands (50-80% canopy cover). As accurate, high resolution canopy data were not available beyond the land cover data used in the step-by-step technical methods, woodlands and forest were grouped together for mapping purposes.

The woodlands guideline from the Chicago Wilderness Green Infrastructure Vision report states that approximately 50,000–100,000 acres of healthy forest and woodland complexes are needed in the region to meet Biodiversity Recovery Plan goals. It goes on to say that, ideally, as many 20 good-quality sites larger than 500 acres would provide a rich diversity of amphibians and other species and that several 800- to 1,000-acre sites with appropriate landforms (slope, soils, and hydrology) are needed to maintain a variety of woodland types.

Savannas are defined as grasslands with scattered trees (Packard, 1997), with a canopy cover between 10-50%. Prairie is defined as grassland with few or no trees (<10% tree canopy). Both

prairies and savannas are fire-dependent communities and trees, shrubs and ground layer must be fire resistant in order to survive.

According to the 2004 GIV report, savanna sites need to be large enough that landscape-scale processes can occur. Development of relatively complete savanna communities will be most cost-effective on larger sites, though smaller sites are also valuable and can be healthy if well managed. Viable amphibian populations require sites of 200 to 500 acres in size. As with all amphibian and reptile assemblages, multiple sites with functional connections for dispersal to sustain metapopulations are recommended.

The 2004 GIV report states that ten to twelve large prairie sites throughout the region, each approximately 3,000–4,000 acres in size, are needed to sustain viable populations of grassland birds and other prairie species. These large sites should consist of native vegetation in mosaics of grasslands, savannas, and wetlands, in order to contribute to the conservation of all prairie-community elements. Core areas of high-quality remnants need to be included in larger sites to provide a basis for re-colonization by prairie plants and insects. To conserve all of the region's reptiles and amphibians, it is recommended that as many medium-sized (500- to 1000-acre) grassland sites be created as possible. These sites should consist of core natural areas within a landscape that allows them to function as breeding habitat. A priority should be to expand as many existing 80- to 200-acre prairie remnants as possible into 500- to 1000-acre sites. As there are so few examples of gravel and dolomite prairies, all remaining examples should be protected, no matter how small. Beyond the rare prairie types, all remaining good-quality prairie sites (such as INAI grade C or above) should be protected and improved where possible.

According to Chicago Wilderness (2011), the region contains a variety of wetlands. These are all grouped together for the purposes of GIV 2.1 landscape mapping. Based on scientific knowledge of habitat requirements of wetland birds, reptiles, and amphibians, a natural-area complex of approximately 1,000 acres, with several marshes of 100 acres or more and with smaller wetlands and ephemeral pools, appears to be an appropriate size for wetland complexes. There is the potential to create and restore around fifteen of these large wetland complexes in the region, and this number should allow sufficient acreage and diversity of condition to meet the habitat needs of breeding and migratory waterfowl. In addition, many more relatively small wetland complexes are needed throughout the region, but particularly in the southern and western parts, to connect existing wetlands. In particular, fens, sedge meadows, bogs, pannes, and seeps require continued protection of currently designated natural areas and protection of newly identified sites. Wetlands, particularly those fed by groundwater, require protection of their recharge areas as well as protection of their plants.

According to Chicago Wilderness (2011), "several endangered and threatened species live in the lakes, streams, and rivers of the Chicago region, most of them in the lakes of the Fox River watershed…" Chicago Wilderness (2004) recommended "protect[ing] high-quality streams and lakes through watershed planning and mitigation of harmful activities to conserve aquatic biodiversity. Much of the focus of the resource protection area identification proposed in [the 2004] project is tied to sensitive watersheds and stream-based greenway linkages."

Woodlands / Forest

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Methodology

A. Woodlands/Forest

The following describes the methods used to identify the woodland/forest portion of the GIV 2.1 green infrastructure network. The layers that result from a particular operation are in **boldface**; these layers are available as part of the Basic or Analyst GIS packages.

a) Define cover types for core areas: Forests and Woodlands (> 50% tree canopy) would include upland forest (>80% canopy cover), floodplain forest, flatwoods, and woodlands (50-80% canopy cover).

b) Identify woodlands and forest from land cover.

(1) Morphological Spatial Pattern Analysis (MSPA) provided by Jim Wickham, USEPA (See Vogt, 2010; Wickham et al., 2010) – based on 2006 National Land Cover Dataset – NLCD (including mixed forest, deciduous forest, evergreen forest and forested wetlands categories) was used as the base layer for forests. The ArcGIS tool workflow of <Reclass> & <RegionGroup> was then used to create discrete, unfragmented woodland/forest patches. The MSPA forest patch layer was refined based on aerial photo interpretation of 2010 NAIP (1-meter resolution, leaf-on) to identify any recent land cover changes since the 2006 and to correct obvious errors of omission and errors of commission from the NLCD layer. Additionally, a mixed forest category was identified during the refinement process that did not appear to fit the core forest criteria. These patches were removed from the core forest.

Data Source: Morphological Spatial Pattern Analysis (MSPA) provided by Jim Wickham, USEPA (See Vogt, 2010; Wickham et al., 2010) – based on 2006 National Land Cover Dataset – NLCD

c) Assemble large woodlands/forest blocks meeting a minimum size threshold. An initial size threshold of 50 acres was selected based on a review of the scientific literature, expert feedback provided at the October 6th GIV 2.1 work session, discussion with the Chicago Wilderness GIV Task Force, a statistical analysis of the MSPA forest layer, and a general assessment of the level of forest fragmentation in the Chicago Wilderness region.

(1) Woodlands/Forest patches were divided into two datasets, one above the initial size threshold and one below.

(2) Result = **Woodlands/Forest Layer 1: Woodland/Forest Patches > 50 acres**

(3) Result = **Woodlands/Forest Layer 2: Woodland/Forest Patches < 50 acres**

d) Add known locations of high quality forested lands or occurrences of rare, threatened, or endangered species that fall below the established size threshold.

(1) Extract all woodlands/forest patches from Forest Layer 2 that are designated as natural areas.

Data Sources: IL Natural Areas Inventory, IN Nature Preserves and Wisconsin Nature Preserves.

(2) Extract all woodlands/forest patches from Forest Layer 2 that have State and Federal threatened and endangered species sites.

Data Sources: IN Natural Heritage Database, IL Natural Heritage Database and WI Natural Heritage Inventory.

(3) Extract all woodlands/forest patches from Forest Layer 2 that have lands enrolled in Illinois Nature Preserves Commission (INPC) land protection programs including Nature Preserves, Land and Water Reserves, and Natural Heritage Landmarks [all lands within forest land cover were used]. Most forest patches in this step fall outside the pre-settlement forest extent.

(4) Extract selected woodlands/forest patches from Forest Layer 2 within Audubon's Important Bird Areas.
Data Source: Audubon Important Bird Areas.

(5) Extract City of Chicago forest sites included in City of Chicago Nature & Wildlife sites layer from Forest Layer 2.

(6) Combine extracted woodlands/forest patches from steps 1-6 (Result = **Woodlands/Forest Layer 3a**) with Woodlands/Forest Layer 1.

(7) Some high quality forest patches from step 2 were identified by AES through aerial photo interpretation and added back to the core woodland/forest once steps 1-7 were performed (only applicable to CMAP counties in IL).

(8) Complete the same forest patch extraction in 1-6 for Woodlands/Forest Layer 1 (Result = **Woodlands/Forest Layer 3b**). This will be used in the characterization phase of the protocol.

(9) Move features >50 acres that fall outside pre-settlement forest areas into the Woodlands/Forest Sites layer.

(10) Add existing oak woodlands remnants

Data Sources: McHenry County oak woodlands remnants (2005 only), Lake Co., WI Oak and Urban Oak Ecosystems, 2010.

(11) Result = **Woodland/Forest Layer 4: Core Woodlands/Forest** →Patches > 50 acres + inside pre-settlement forest + < 50 acres with high quality locations.

(12) Result = **Woodland/Forest Layer 5: Woodlands/Forest Sites** → Patches < 50 acres with no high quality designations + >50 acres outside pre-settlement forest areas

(13) Delineate potential woodlands/forest areas using documented pre-settlement forest. These are potential restoration and enhancement opportunities for future site scale investigation.

(14) Add pre-settlement forest vegetation areas from Illinois, Indiana and Wisconsin.

Data Source: Pre-settlement Vegetation Types of Indiana from Lindsey (1966).

(15) Develop a 'mask' raster dataset and remove developed land, roads, and other human-disturbed areas to remove areas likely less suitable for reforestation using the 2006 National Land Cover Dataset (NLCD) – Developed Low/Medium/High Intensity. Additional CMAP land use/land cover developed classes were also added. Roads – ESRI Roads (90 m buffer from center line of interstates, 60 m from U.S. and state highways, and 30 m from county roads).
Data Source: 2006 NLCD

(16) Result = **Woodland/Forest Layer 6: Pre-settlement Woodlands/Forest**

e) Develop functional woodlands/forest corridors (see Landscape functional connectivity for more details)

(1) Result = **Woodland/Forest Layer 7: Woodlands/Forest Corridors**

B. Prairie / Grassland / Savanna

The following describes the method used to identify the prairie/grassland/savannah portion of the GIV 2.1 green infrastructure network. The layers that result from a particular operation are in **boldface**; these layers are available as part of the Basic or Analyst GIS packages.

a) Define cover types: prairies and grasslands with <10% tree canopy coverage and savanna (10-50% tree canopy). Savannas include fine-textured soil and sand savannas.

b) Identify known prairies and grasslands.

(1) Add known prairie/grassland sites from existing datasets by identifying suitable landcover within their boundaries. No minimum size threshold was defined for the steps below to avoid missing remnant prairies or other small sites. *Data Sources: Illinois Natural Areas Inventory sites, IN Prairie Communities, WI Nature Preserves, Land and Water Reserves, and Natural Heritage Landmarks, IL Nature Preserves Commission and IL Natural Areas Inventory, IN Nature Preserves, City of Chicago Nature & Wildlife prairie sites.*

(2) Identify prairie/grassland dependent State and federal threatened and endangered species sites (Chicago Wilderness Biodiversity Recovery Plan, 1999). Search for Element Occurrences of any of the following (note: not all of these are listed species so element occurrences may not be available):

Animals: Franklin's ground squirrel*, bobolink, meadowlark, Fowler's toad, regal fritillary*, ottoe skipper*, gorgon checkerspot, grasshopper in the genus Arphia, Pseudopomala brachy ptera (grasshopper), plains froghopper, Aphrodite, scurfy pea flower moth, leadplant flower moth, Ammoea lacticlava (beetle). (* = listed species)

Plants: Schizachyrium scoparium, Andropogon gerardii, Carex bicknellii, Stipa spartea, Amorpha canescens, Euphorbia corollata, Helianthus occidentalis, Parthenium integrifolium, Dalea candida, Prenanthes aspera, Zizia aptera, Calomovilfa longifolia, Koleria cristata, Arenaria stricta, Artemisia caudata, Callirhoe tria ngulata, Lithospermum croceum, Monarda punctata, Opuntia compressa, Sorghastrum nutans, Sporobolus heterolepis, Gentiana puberulenta, Psoralea tenuiflora, Scutellaria parvula, Satureja askansana, Valeriana ciliata, Galium boreale, Dalea foliosa*. (* = listed species)

Data Sources: IN Natural Heritage Database, WI Natural Heritage Inventory, IL Natural Heritage Database.

(3) Existing sites from the Midewin National Tallgrass Prairie (PotentialVeg Layer)

(4) Result = **PGS Layer 1: Core Prairie**

c) Identify known savannas.

(1) Add all known savanna sites from existing datasets

Data Sources: IL Natural Areas Inventory, IN Dunes National Lakeshore Vegetation Mapping (fcl_INDU_veg_polys.Map_Class_Nm = 'Black Oak - Northern Pin Oak / Common Hairgrass Woodland' OR fcl_INDU_veg_polys.Map_Class_Nm = 'Black Oak / Lupine Barrens'), Will County FPD (savannas only), Natural and Wild Sites from City of Chicago.

Note: Savanna INDU classes according to TNC, 1995

(2) Savanna dependent state, federal, threatened and endangered species sites. Search for Element Occurrences of any of the following (note: not all of these are listed species so element occurrences may not be available):

Animals: eastern bluebird, red-headed woodpecker, field sparrow, fox squirrel, prairie deer mouse, silvery blue butterfly, northern flicker, eastern kingbird, black-billed cuckoo*, blue-winged warbler, hobomok skipper, silvery checked spot, Olympia marble, Karner blue butterfly*, Indian skipper. (* = listed species)

Plants: Quercus macrocarpa, Quercus velutina, Juglans nigra, Quercus alba, Quercus coccinea, Schizachyrium scoparium, Corylus americana, Helianthus divaricatus, Silene stellata, Smilax lasioneuron, Sorghastrum nutans, Andropogon gerardii, Heliopsis helianthoides, Lathyrus venosus, Thaspium trifoliatum, Quercus bicolor, Veronicastrum virginicum, Carex pensylvanica, Koeleria cristata, Lupinus perennis, Opuntia spp. Stipa spartea, Aster linariifolius, Comandra richardsonii, Phlox pilosa, , Betula papyrifera, Aralia nudicaulis, Maianthemum canadense, Cypripedium reginae*, Salix humilis. (* = listed species)

Data Sources: IN Natural Heritage Database, IL Natural Heritage Database, WI Natural Heritage Inventory.

(a) Result = **PGS Layer 2: Core Savanna**

d) Identify large grassland blocks with potential grassland areas that may support area sensitive grassland birds.

(1) Identify existing grassland sites

Data Sources: IL Natural Heritage Survey's Landscapes of Ecological Importance (LEIs), WI Grasslands within Southeastern Wisconsin

(2) Add any remaining 2006 National Land Cover Dataset (NLCD) – Grassland/Herbaceous (minimum 50 acres) using the <RegionGroup> function in ArcGIS. We included these with the understanding that many of these will not be in native grasslands but they still have the potential to support area sensitive grassland bird species. [Value = 71] Description: Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. [Note: We did not include pasture/hay areas in the final version, but earlier versions included pasture/hay and they could be considered as potential restoration areas in the future.]
Data Source: 2006 NLCD

(3) Mask out grassland blocks from b. above that fall within pre-settlement forest areas.

(4) Result = **PGS Layer 3: Grassland Blocks**

e) Delineate potential prairie **complexes** using documented pre-settlement prairie. These are potential restoration and enhancement opportunities for future site scale investigation.

(1) Add undeveloped pre-settlement prairie vegetation areas from Illinois Natural History Survey, developed by Bowles and based on the original 1800's surveys. *Data Sources: Presettlement Vegetation Types of Indiana from Lindsey (1966), WI "Original Vegetation Cover of Wisconsin" map by Robert W. Finley, Illinois Natural History Survey Presettlement (1843).*

(2) Use 'mask' raster dataset to remove developed land, roads, and other human-disturbed areas to remove areas likely less suitable for restoration.

(3) Result = **PGS Layer 4: Pre-Settlement Prairie/Grassland**

f) Delineate potential savanna complexes using documented pre-settlement savanna.

(1) Add undeveloped pre-settlement savanna (i.e. 'scattered timber') vegetation areas from Illinois Natural History Survey, developed by Bowles and based on the original 1800's surveys. *Data Sources: Presettlement Vegetation Types of Indiana from Lindsey (1966), WI "Original Vegetation Cover of Wisconsin" map*

by Robert W. Finley, Illinois Natural History Survey Presettlement (1843).

(2) Use 'mask' raster dataset to remove developed land, roads, and other human-disturbed areas to remove areas likely less suitable for restoration.

(3) Result = **PGS Layer 5: Pre-Settlement Savanna**

g) Develop functional prairie/grassland corridors (see landscape functional connectivity for details). Savannas were not connected primarily because there were not enough existing savanna sites to create functional connections and because there was no consensus on whether savanna should be combined with woodlands or prairies for analytical purposes. This issue will be revisited in GIV 2.1.

(1) Combine PGS Layer 1 and PGS Layer 3. **Result = PGS Layer 6: Prairie/Grassland Cores for Functional Connectivity Analysis**

(2) Functionally connect prairie/grassland linkages (see Corridors Section for step-by-step details).

(3) Result = **PGS Layer 7: Prairie/Grassland Corridor**

C. Wetlands

The following describes the method used to identify the wetland portion of the GIV 2.1 green infrastructure network. The layers that result from a particular operation are in **boldface**; these layers are available as part of the Basic or Analyst GIS packages.

a) Define cover types: This includes all types of wetlands. Some wetlands might also fall under other categories (e.g., forested wetlands falling under forest as well).

b) Assembly wetland landcover using input from different data sources to create a comprehensive wetland layer.

Data sources: Ducks Unlimited enhanced National Wetland Dataset (NWI) update (IL and IN), NWI, WI DNR wetlands, SEWRPC ADID wetlands, McHenry County (2005), Kane County (2004), Lake County - LCWI (2002) ADID wetlands, Kane County Fens Study (2004), CMAP land use wetland classes not in NWI

(1) Merge data to create composite wetland layer

(2) Result = **Wetland Layer 1: All wetlands**

c) Assemble large wetland blocks meeting a minimum size threshold

(1) Add natural land cover around wetlands (NLCD Classes Deciduous Forest (41), Evergreen Forest (42), Mixed Forest (43), Grassland/Herbaceous (71), Woody Wetlands (90), and Emergent Herbaceous Wetlands (95).
Data source: 2006 NLCD

(2) Subtract areas of water drawdown by identifying canals and ditches from National Hydrography Dataset (NHD+). *Data source: NHDPlus v.1.*

(3) From NHD, select ("FTYPE" = 'CanalDitch'). Buffer canals and ditches by 120 meters and artificial paths. Subtract these areas to estimate water drawdown effects

(4) Subtract edge effect zone by identifying roads, development, and other human disturbances and land use Buffer these features by 30 m. Subtract from wetlands + adjacent natural cover. Identify those contiguous areas of natural cover that contain wetlands as follows.

(5) Divide wetland patches into two datasets, one above an initial size threshold and one below.

(6) Initial size threshold for wetlands – 50 acres, which is based upon habitat requirements of wetland dependent species outlined in Appendix 1 of the Chicago Wilderness Biodiversity Recovery Plan.

(7) Result = **Wetland Layer 2: Wetland Patches > 50 acres**.

(8) Result = **Wetland Layer 3: Wetland Patches < 50 acres**.

d) Add known high quality locations of wetlands or occurrences of wetland dependent species that fall below the established size threshold.

(1) Extract all wetland patches from Wetland Layer 3 that are designated Illinois Natural Areas Inventory sites and state natural preserves, reserves and landmarks.

(2) Extract all wetland patches from Wetland Layer 3 that are State and federal threatened and endangered species sites. *Data Sources: IN Natural Heritage Database, WI Natural Heritage Inventory, and IL Natural Heritage Database.*

(3) Extract all wetland patches from Wetland Layer 3 that are managed for conservation.

Data Sources: WI Nature Preserves, Land and Water Reserves, and Natural Heritage Landmarks, Illinois Nature Preserves Commission (INPC) land protection programs including Nature Preserves, Land and Water Reserves, and Natural Heritage Landmarks, Illinois Audubon wetland dependent important bird areas.

(4) Combine extracted wetlands patches from 1-3 (**Result = Wetland Layer 4a**) with Wetland Layer 2.

(5) Identify shorebird and waterfowl priority habitats.

Data Sources: TNC's Shorebird Site Priority in the Chicago Wilderness Region and Waterfowl Site Priority in the Chicago Wilderness Region (Representative and high ranking (Very High = 5 points) stopover sites and their associated attributes in the Chicago Wilderness Region shorebirds and waterfowl (Byrne, 2008)).

(6) Complete the same wetland patch extraction in 1-3 for Wetland Layer 2 (Result = **Wetland Layer 4b**). This will be used in the characterization phase of the protocol.

(7) Result = **Wetland Layer 5: Core Wetlands** → Patches > 50 acres (Wetland Layer 2) + high quality locations (Wetland Layer 4a)

(8) Result = **Wetland Layer 6: Wetland Sites** → Wetland blocks that fall below the core wetland size thresholds that are not designated a high quality/priority location (i.e. Wetland Layer 3 minus Wetland Layer 4)

e) Delineate potential wetland complexes. Complexes are aggregations of favorable wetland conditions that are potential restoration and enhancement opportunities for future site scale investigation.

(1) Add undeveloped pre-settlement wetlands vegetation areas (bottomland, marsh, other wetland, slough, and wet prairie) from Illinois Natural History Survey, developed by Bowles and based on the original 1800's surveys.
Data Sources: Presettlement Vegetation Types of Indiana from Lindsey (1966), WI "Original Vegetation Cover of Wisconsin" map

by Robert W. Finley, Illinois Natural History Survey Presettlement (1843).

(2) Supplement with other high priority wetlands.
Data Source: 2004 Chicago Wilderness Wetlands Task Force data identifying (1) high potential for restoration (includes hydric soils), (2) wetlands associated with reptiles and amphibians, and (3) basin/marsh habitat important to threatened and endangered species.

(3) Add hydric soils for Kendall County (since no CW Wetland Task Force data available).

(4) Develop a 'mask' raster dataset and remove developed land, roads, and other human-disturbed areas to remove areas likely less suitable for restoration.

(5) Result = **Wetland Layer 7: Wetland Complexes**

(6) Develop functional wetlands corridors (see Landscape functional connectivity for more details).

(7) Result = **Wetland Layer 8: Wetland Corridor**

D. Streams and Lakes

The following describes the method used to identify the streams and lakes portion of the GIV 2.0 green infrastructure network. The layers that result from a particular operation are in **boldface**; these layers are available as part of the Basic or Analyst GIS packages.

a) Define cover types: Natural streams and lakes.

b) Identify streams/lakes from land cover.

Data Sources: National Hydrography Dataset Plus (NHDPlus) Waterbodies and Flowlines (Zones 4 and 7).

(1) Combine and buffer features by 90 meters. This will be used in the characterization phase of the protocol.

(2) Result = **Stream/Lakes Layer 1: NHD+ Raster Buffer**

(3) Develop a 'mask' raster dataset and remove developed land, roads, and other human-disturbed areas to remove developed areas.

(4) Result = **Stream/Lakes Layer 2: Undeveloped NHD+ Stream Buffer**

c) Identify and extract all headwaters in the Chicago Wilderness region using NHDPlus data extension for Strahler Stream Order**.** Strahler order follows dendritic networks from headwaters to the river outflow. At headwaters, stream/rivers are assigned a Strahler order of one (1st order). When two 1st order streams flow together, the downstream feature is assigned Strahler order of two (2nd order). Only when two features of the same order flow together does the Strahler order increment to the next largest order.

Data Sources: U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (USEPA) National Hydrography Dataset (NHD) Medium Resolution. Augmenting NHDPlus Strahler order values using Strahler calculator (http://www.horizon-systems.com/nhdplus/NHDPlusV1_download.php).

d) Add known high quality and priority locations of streams/lakes or occurrences of stream/lake dependent species. [See the Appendix E for an overview of how each dataset was used or modified to facilitate identifying high quality natural areas based upon the forest landscape type.] Data used as follows:
Data Sources: NHDPlus v1, Illinois Natural Areas Inventory sites, Illinois Nature Preserves Commission (INPC) land protection programs including Nature Preserves, Land and Water Reserves, and Natural Heritage Landmarks (all water classes), WI Nature Preserves, IN Nature Preserves, Illinois Audubon Society Important Bird Areas (IBAs).

(1) State and federal threatened and endangered species sites.
Data Sources: IN Natural Heritage Database, WI Natural Heritage Inventory, and IL Natural Heritage Database.

(2) Incorporate important streams associated with reptiles and amphibians.
Data Source: 2004 Chicago Wilderness Wetlands Task Force data on streams associated with reptiles and amphibians. The mean + 1sd (>13.4) was used to get highest scoring regions within 90 meters of a stream or river.

(3) Other biologically Significant Streams dataset, which includes integrity and diversity attributes. All the information that contributed to integrity and diversity ratings were considered in identifying BSS. Specifically, BSS are defined as streams that have a high rating or score based on data from at least two taxonomic groups. This can be achieved by obtaining an A rating either for diversity or for integrity that is based on data from two or more taxonomic groups. A second way to achieve this status is for a stream segment to have class scores in the highest class for at least two different taxonomic groups when considering the combined data from the diversity and integrity ratings.
Data Sources: IN Salmonoid streams, IN Outstanding Rivers, IL Biologically Significant Streams.

(4) Add high quality ravines where data is available.
Data Source: Lake Michigan most stable ravines from the Alliance for the Great Lakes dataset: Carmel Park Ravine (in high priority sub-watershed for habitat restoration), Glen Flora Ravine (in high priority sub-watershed for habitat restoration), Gangster Ravine (in high priority sub-watershed for habitat restoration), Dead Dog Creek (in high priority sub-watershed for habitat restoration), Bull

Creek (in high priority sub-watershed for habitat restoration), and Waukegan River.

(5) Result = **Streams/Lakes Layer 3: Core Lakes and Streams**

e) Add freshwater systems.

(1) Add floodplains
Data Sources: DFIRM floodplains (Cook, DuPage, Kane, McHenry counties), WI, IN and IL FEMA Q3 floodplains (Will, Lake, Kendall counties in IL).

(2) Incorporate groundwater protection areas.
Data Sources: Illinois EPA Phase 2 wellhead protection areas, WI County Recharge zones (ncfaquifer27_region- SEWRPC). No data available for Indiana and Illinois Class III Groundwater Areas data not sufficiently complete to include.

(3) Add pre-settlement water areas.
Data Sources: WI Original Vegetation Cover of Wisconsin" map by Robert W. Finley (1976), Illinois Natural History Survey Presettlement (1843). Not available for Indiana.

(4) Add ravines not included in Streams/Lakes Layer 3 above. These have been identified as being in need of restoration by the Alliance for the Great Lakes.
Data Sources: Lake Michigan ravines from the Alliance for the Great Lakes dataset.

(5) Result = **Streams/Lakes Layer 4: Freshwater Systems**

(6) Develop a 'mask' raster dataset and remove developed land, roads, and other human-disturbed areas to remove developed areas.

(7) Result = **Streams/Lakes layer 5: Undeveloped Freshwater Systems**

E. Protected Lands and Open Space

Please see Appendix D section 11 for a complete list of the data sources used.

a) Inventory all protected and managed lands: parks, conservation easements, etc. Note: Due to the variety of sources, the datasets used have overlaps between them and occasionally have slightly different boundaries. Nonetheless, the inventory is believed to be current and comprehensive as of November 2012.

Data Sources: Protected Areas Database of the US (PAD-US) - CBI Edition 1.1, 2010, National Conservation Easement Database (NCED), IL Counties Forest Preserve Districts, Parks – City of Chicago, Land Trust Conservation Lands and Easements, IL Counties' Conservation Districts, IN DNR Managed Lands.

b) Identify regional, county, and local recreation trails and bike paths network.
Data Sources: 2009 CMAP Existing and Planned Greenways and Multi-use trails layer. County, municipal, and local recreational trails. NIRPC Trails, IDNR trails. Waukesha, Walworth, Racine, Milwaukee, Kenosha Parks and Open Space (SEWRPC).

F. Hubs

Hubs are aggregations of core areas that combine landscape types in an effort to treat areas as unfragmented blocks that include an array of habitats. Although it is important to identify discrete landscape types for analytical purposes, blocks with diverse habitat types often serve as high quality 'matrix' areas where the whole is greater than the sum of its parts. For the most part, previous hub delineation methods have focused on simply combining core areas and corridors and optionally adding surrounding buffer areas. Given the previous GIV 1.0 efforts and the interest in being able to compare the results of GIV 1.0 with the refinement completed for GIV 2.1, a merging of datasets was found to be the most useful approach.

a) Merge the following datasets:

(1) Core Woodlands/Forest (Woodland/Forest Layer 4),

(2) Woodland/Forest Corridors (Woodland Forest Layer 7),

(3) Core Prairies, Savannas and Grassland Blocks (PGS Layer 6)

(4) Core Wetlands (Wetland Layer 5),

(5) Wetland Corridors (Wetland Layer 8),

(6) Core Streams/Lakes (Streams/Lakes Layer 3),

(7) Undeveloped Freshwater Systems (Streams/Lakes Layer 5),

(8) Undeveloped Stream Buffer (Streams/Lakes layer 2), and

(9) Result = **Hub Layer 1: GIV 2.1 Ecological Network**

b) Convert protected lands layer feature classes to raster and merge rasters. The following datasets were used:
Data Sources: Protected Areas Database (PADUS), CMAP Open Space (excluded Golf Courses), Land Trusts Fee and Easements (Grand Victoria Foundation data), McHenry County NAIs, National Conservation Easement Database (NCED), Forest Preserve Districts, City of Chicago Parks, County Conservation Districts, IDNR Managed Lands, SEWRPC Parks and Open Space, WI DNR Managed Lands.

c) Result = **Hub Layer 2: Protected Lands Raster**

d) Combine Hub Layer 1, Hub Layer 2, and Streams/Lakes Layer 1

e) Result = **Hub Layer 3: GIV 2.1 Composite** (use for comparison with GIV 1.0 to demonstrate refinement)

G. Landscape Functional Connectivity

There is a significant body of peer reviewed literature that demonstrates that a system of interconnected habitats is more likely to maintain natural communities and ecological processes. Landscape ecology recognizes two different forms of habitat connectivity. Structural connectivity refers to the physical characteristics of landscape elements like shape, size and location of features in the landscape, ignoring the behavioral response of organisms to landscape structure. Functional connectivity, on the other hand, describes the degree to which landscapes actually facilitate or impede the movement of organisms and processes (Meiklejohn et al, 2010). A link or linkage in this analysis refers "to an arrangement of habitat (not necessarily linear or continuous) that enhances the movement of animals or the continuity of ecological processes through the landscape" (Bennett, 2003).

The emphasis of the analysis undertaken in GIV 2.1 is on functional connectivity. In other words, corridors were identified using a GIS analysis to link core habitat areas together, providing essential routes for animal and plant movement. These linkages were identified using techniques pioneered by Dr. David Theobald at Colorado State University and incorporated into the ArcGIS extension *FunConn*. For GIV 2.1, a next generation version of FunConn was developed as a result of a partnership between The Conservation Fund and Colorado State University.

The functional connectivity analysis works by analyzing the ability of a representative organism to move through the landscape. To do so, movement "suitability surfaces" are generated for forests, wetland, and the other two landscape types. The functional connections delineated here follow some features on the landscape that seems obvious while others are less intuitive. They are based on remaining pathways of natural vegetation and in many cases areas they need restoration in a landscape heavily modified by humans. Highways and urban areas are mostly avoided by wildlife. Because this region is so heavily fragmented, connectivity at the landscape scale is largely a function of both agricultural lands and suitable habitat. Landscape linkages include a wide variety of habitats including broad tracts of natural habitat, major river systems, hedgerows, roadside vegetation and forest linkages (Bennett, 2003).

Movement suitability is partly based on a layer that represents the resistance to movement as a "cost." Developing such a layer can be approached from many different perspectives; please

refer to the Appendix E-5 for details on the impedance values. The following procedure was used to build all impedance layers:

a) Identify impassable barriers like interstate highways and open water.

b) Identify least favorable habitat like roads and development.

c) Identify most favorable habitat for each organism.

d) Choose cost values. High and low values can be arbitrarily selected as long as they reflect the habitat suitability relative to each other.

e) Combine values to create a composite corridor suitability layer.

f) For each iteration, a set of randomly located points are selected within resource patches deemed as probable or potential sources of emigration by assessing the location of core areas. The result is a pathway and corridors that cross a route with the fewest number of obstacles.

H. Characterizing the GIV 2.1 Network

Besides simply delineating a network of green infrastructure in the Chicago region, this project includes GIS models to "characterize" sites – that is, to assess their relative suitability for a particular purpose. The two broad types of characterization models developed for this project are meant to help users evaluate sites for *conservation* or for *restoration*. This section describes the technical approach to building the characterization models and then provides some sample models for users to consider in their work.

The GIV 2.1 project used the Logic Scoring of Preferences (LSP) method to help users assess the relative value of the network for particular purposes. (For more information on the LSP method, please see Allen et al., 2011). LSP is a scientifically rigorous technique originally developed for computer science applications to design criteria and weightings that reflect fundamental properties of human reasoning and ensure that the benefits calculated accurately reflect the desired intent of decision makers. In the LSP method, criteria are developed through a collaborative process with stakeholders and subject matter experts to ensure all attributes that can be measured are included for evaluation and can represent an overall level of suitability.

Each criterion within the set of criteria spans a range of characteristics from most to least suitable in terms of answering a specific planning question known as an elementary (attribute) criterion. Each raster cell within the GIV 2.1 area is represented numerically on a standard suitability scale from 0 to 100% that represents how well it satisfies that particular criterion (100% being the most suitable or ideal). In addition, criteria have logic properties that designate them as mandatory, non-mandatory, or optional, based on their contribution to answering the planning question. Relative weights for criteria are assigned by stakeholders and subject matter experts since some factors are more important than others in evaluating suitability.

Table 1 shown below includes the set of GIV 2.1 layers available to describe or characterize the potential ecological and restoration importance of areas within the CMAP region. These data layers can also be combined in a GIS model to provide a map that shows the relative value of areas that advance Chicago Wilderness' and partner green infrastructure goals.

Table 1. GIV 2.1 GIS Data Layers Available for Characterization

	Attribute	Protocol Layer
GIV landscape features		
	Core woodland/forest designated areas	Woodland/Forest Layers 3a & 3b
	Core woodland/forest	Woodland/Forest Layer 4
	Core prairies	PGS Layer 1
	Core savannas	PGS Layer 2
	Core wetland designated areas	Wetland Layers 4a & 4b
	Core wetlands	Wetland Layer 5
	Core lakes and streams	Steams/Lakes Layer 3
Functional connections		
	Woodland/forest corridors	Woodland/Forest Layer 7
	Wetland corridors	Wetland Layer 8
	Undeveloped NHD+ stream buffer	Steams/Lakes Layer 2
	Undeveloped freshwater systems	Steams/Lakes Layer 5
Restoration building blocks		
	Woodland sites	Woodland/Forest Layer 5
	Pre-settlement woodland/forest	Woodland/Forest Layer 6
	Grassland blocks	PGS Layer 3
	Pre-settlement prairie/grassland	PGS Layer 4
	Pre-settlement savanna	PGS Layer 5
	Prairie/grassland corridors	PGS Layer 7
	Wetland sites	Wetland Layer 6
	Wetland complexes	Wetland Layer 7
	NHD+ raster buffer	Steams/Lakes Layer 1
	Freshwater systems	Steams/Lakes Layer 4
Composite layers		
	GIV 2.1 ecological network	Hub Layer 1
	Protected lands raster	Hub Layer 2
	GIV 2.1 composite	Hub Layer 3

a) Develop a GIS model that allows users to weight the relative importance of GIV 2.1 network elements.

(1) Establish list of GIV 2.1 network elements to be characterized. See Table 1.

(2) Use <weighted sum> to allow assignment of quantitative values to GIV 2.1 network features that creates a suitability surface for a particular planning objective. Set model to allow maximum of 100 points per the best practices of the LSP method.

(3) Allow results to be masked by subsets of areas (e.g. protected status, urban land use, near recreation trail network, etc.)

(4) Allow multiple model runs to be completed so that comparisons can be made.

b) Develop conservation suitability models

c) Develop restoration suitability models

The prioritization model breaks the green infrastructure network into small, identically sized cells and assesses each cell for its relative suitability for conservation. The output product will assign every cell in the area of interest to a value of 0-100. The existing protected lands can be removed from the results to help visualize where the gaps in high quality forest conservation opportunities exist. Shown below are some additional potential conservation models synthesized from feedback received at the March 20th GIV 2.0 workshop. An example of such a model is shown in Table 2. It prioritizes the protection of unprotected, high quality woodlands/forest resources:

Table 2. Woodlands/Forest Conservation Characterization Model

Attribute	Protocol Reference Layer	Importance	Logic
Core woodlands/forest designated areas	Woodland Layers 3a & 3b	30	Non-mandatory
Core woodlands/forest	Woodland Layer 4	40	Non-mandatory
Woodlands/forest corridors	Woodland Layer 7	15	Non-mandatory
Woodlands/forest sites	Woodland Layer 5	10	Non-mandatory
Pre-settlement woodland/forest	Woodland Layer 6	5	Non-mandatory

This model, as well as the models described below, is included as examples with the final GIV 2.1 map package.

Table 3. Prairie / Grassland / Savanna Conservation Characterization Model

Attribute	Protocol Layer	Importance	Logic
Core prairies	PGS Layer 1	35	Non-mandatory
Core savannas	PGS Layer 2	35	Non-mandatory
Prairie/grassland corridors	PGS Layer 7	10	Non-mandatory
Grassland blocks	PGS Layer 3	10	Non-mandatory
Pre-settlement grassland	PGS Layer 4	5	Non-mandatory
Pre-settlement savanna	PGS Layer 5	5	Non-mandatory

The model in Table 3 prioritizes existing prairie and savanna sites but also includes functional connections and restoration building blocks.

Table 4. Wetlands Conservation Characterization Model

Attribute	Protocol Layer	Importance	Logic
Core wetland designated areas	Wetland Layers 4a & 4b	30	Non-mandatory
Core wetlands	Wetland Layer 5	40	Non-mandatory
Wetland corridors	Wetland Layer 8	15	Non-mandatory
Wetland sites	Wetland Layer 6	10	Non-mandatory
Wetland complexes	Wetland Layer 7	5	Non-mandatory

The model in Table 4 prioritizes areas with wetland quality designations but also acknowledges the need to expand wetlands conservation within areas that used to be wetlands.

Table 5. Streams and Lakes Conservation Characterization Model

Attribute	Protocol Layer	Importance	Logic
Core lakes and streams	Steams/Lakes Layer 3	40	Non-mandatory
Undeveloped NHD+ stream buffer	Steams/Lakes Layer 2	20	Non-mandatory
Undeveloped freshwater systems	Steams/Lakes Layer 5	30	Non-mandatory
NHD+ raster buffer	Steams/Lakes Layer 1	5	Non-mandatory
Freshwater Systems	Steams/Lakes Layer 4	5	Non-mandatory

Returning to the forest example to begin a review of restoration opportunities, areas where restoration may be appropriate could be identified as places where the pre-settlement vegetation was forest, that are also within functionally connected corridors, but that do not currently include high quality woodlands/forest. In this way, the model in Table 6 could be changed to weight restoration opportunities more heavily:

Table 6. Woodlands / Forest Restoration Characterization Model

Attribute	Protocol Reference Layer	Importance	Logic
Core woodland designated areas	Woodland Layers 3a & 3b	5	Non-mandatory
Core woodland/forest	Woodland Layer 4	10	Non-mandatory
Woodland/forest corridors	Woodland Layer 7	35	Non-mandatory
Woodland/forest sites	Woodland Layer 5	20	Non-mandatory
Pre-settlement woodland complexes	Woodland Layer 6	30	Non-mandatory

In comparison to the conservation suitability model, however, there is more uncertainty about whether restoration would be the most appropriate action at that location. Many of these areas may be more suitable for other uses. In addition, some of these areas may include highly productive agricultural soils where it makes sense to maintain them in a working landscape. But some sites such as "trash woods" with box elders may be excellent restoration candidates, pending the completion of fieldwork to confirm the opportunity. Shown below in Table 7 are some additional potential restoration models.

Table 7. Prairie / Grassland / Savanna Restoration Characterization Model

Attribute	Protocol Layer	Importance	Logic
Core prairies	PGS Layer 1	5	Non-mandatory
Core savannas	PGS Layer 2	5	Non-mandatory
Prairie/grassland corridors	PGS Layer 7	30	Non-mandatory
Grassland blocks	PGS Layer 3	30	Non-mandatory
Pre-settlement grassland complexes	PGS Layer 4	15	Non-mandatory
Pre-settlement savanna complexes	PGS Layer 5	15	Non-mandatory

As with the forest example, the same data layers are used, but the weights have been changed to highlight areas more suitable for restoration rather than conservation of high quality habitat.

Table 8. Wetland Restoration Characterization Model

Attribute	Protocol Layer	Importance	Logic
Core wetland designated areas	Wetland Layers 4a & 4b	5	Non-mandatory
Core wetlands	Wetland Layer 5	10	Non-mandatory
Wetland corridors	Wetland Layer 8	30	Non-mandatory
Wetland sites	Wetland Layer 6	20	Non-mandatory
Wetland complexes	Wetland Layer 7	35	Non-mandatory

The wetlands model in Table 8 prioritizes areas with favorable wetland conditions, even if they are not currently mapped as wetlands.

Table 9. Streams and Lakes Restoration Characterization Model

Attribute	Protocol Layer	Importance	Logic
Core lakes and streams	Steams/Lakes Layer 3	5	Non-mandatory
Undeveloped NHD+ stream buffer	Steams/Lakes Layer 2	-10	Non-mandatory
Undeveloped freshwater systems	Steams/Lakes Layer 5	-10	Non-mandatory
NHD+ raster buffer	Steams/Lakes Layer 1	45	Non-mandatory
Freshwater systems	Steams/Lakes Layer 4	50	Non-mandatory

The model in Table 9 uses negative numbers to weight developed landscapes higher. All of the models above are representative of the types of planning questions that can be answered and the way in which the data can be weighted in models. The intent is for each GIV 2.1 user to construct models that meet their particular geographic and programmatic needs. For users of the Analyst edition of GIV 2.1, additional data can be incorporated into suitability models that can make them more useful for specific areas or purposes.

I. Regional Recreation and Urban Scale Green Infrastructure

A key goal of the Chicago Wilderness Green Infrastructure Vision 2.1 is to seamlessly link woodlands, grasslands, wetlands, streams and lakes within urban, suburban, and rural areas, ensuring that the whole is greater than the sum of its parts. The implementation of the Vision takes place at multiple geographic scales (Figure 3). The landscape scale provides critical plant and animal species habitat and wildlife migration corridors for priority species outlined in the Chicago Wilderness Biodiversity Recovery Plan along with compatible working landscapes that maintain the economic value of prime agricultural soils. The regional scale provides key recreational areas that link people to natural lands and community assets, with existing and planned greenways and multi-use trails mapped by CMAP as a backbone of the GIV 2.0 network. For GIV 2.1, trails data was added for Indiana from NIRPC and IDNR, and we also obtained trails information from Kankakee County, IL. A significant gap is the lack of digitized trail data for Wisconsin. This is a priority data gap to be filled in a future version of the GIV.

The site scale enhances urban neighborhoods and downtowns through environmentally-sensitive site design techniques, urban forestry, and non-engineered stormwater management systems that reduce the environmental impact of dense urban settlements. Green infrastructure at this scale includes tree-lined streets, community gardens, pocket parks, green roofs, and green boulevards. Recreational networks and stream corridors can be used as ways to physically connect each of these types of green infrastructure features. Protected and managed lands along the regional recreational network can be thought of as ‘pearls on the

necklace' and serve as 'hubs' for the recreation network. An overlay of the recreation network and protected lands can help identify the most important gaps in the network to fill.

One of the goals of GIV 2.1 is to identify the best ways to link together these scales of activity, which aligns perfectly with the Chicago Wilderness (2011) alliance strategy of implementation of the green infrastructure vision at different scales:

- "by working with regional planning agencies to redefine how we think about sustainability and community health by incorporating conservation development principles and natural resource preservation into land use and transportation plans;
- by incorporating principles of biodiversity conservation, sustainability, and people-friendly design into land use plans and ordinances;
- by promoting the preservation of natural spaces, conservation design and access to nature into developing communities; and
- by promoting native landscaping, the use of rain gardens and rain barrels, and through the greening of schoolyards and other community open spaces."

The mapping for landscape types primarily falls outside the 'urban mask' where site scale green infrastructure is usually implemented. The GIV 2.1 methods inside the urban mask focus on connecting the local/regional recreation network and assessing vacant lands for their potential suitability for:

- Stormwater management
- Urban forestry
- Community managed open space and gardens
- Pocket parks
- Expansions of existing protected and managed lands

a) Inventory site scale green infrastructure features

(1) Green Infrastructure Sites – Center for Neighborhood Technology

(2) Green Roofs – City of Chicago

(3) Tree Canopy – City of Chicago

(4) Boulevards – City of Chicago

(5) Malls and Plazas – City of Chicago

(6) Combined Sewer Outflows – City of Chicago

b) Inventory urban and neighborhood open space

(1) Neighbor Space Sites – City of Chicago

(2) Greencorps Garden Sites – City of Chicago

(3) Farmers Markets – City of Chicago

(4) Campus Parks – City of Chicago

(5) School Grounds – City of Chicago

(6) Cemeteries – City of Chicago

c) Inventory protected and managed lands: parks, conservation easements, etc.

(1) Protected Areas Database of the US (PAD-US) - CBI Edition 1.2, 2012

(2) National Conservation Easement Database (NCED) 2012 edition

(3) County Forest Preserve Districts

(4) Parks – City of Chicago

(5) 2005 Land Use Open Space categories – 7-County CMAP area

(6) Land Trust Conservation Lands and Easements

(7) McHenry County Conservation District

(8) IDNR Managed Lands and SEWRPC Park and Open Space Sites.

(9) Note that due to the variety of sources, the datasets listed below have some overlap between them and occasionally have slightly different boundaries. Nonetheless, the compilation is believed to be comprehensive.

d) Identify regional, county, and local recreation trail and bike path network.

(1) Establish the 2009 CMAP Existing and Planned Greenways and Multi-use Trails layer as the backbone of the regional recreational network for the 7-county area in Illinois.

(2) Inventory county, municipal, and local recreational trails in Illinois (data provided by CMAP, the City of Chicago, and Kankakee County)

(3) Inventory state, regional and local recreation trails data for Indiana (data provided by NIRPC and IDNR)

(4) Inventory county, municipal, and local recreational trails for Wisconsin (no available data, update in future release)

III. Using GIV 2.1

A. Potential applications for GIV 2.1

In terms of analytical applications, the GIV 2.1 datasets can be used by decision makers at the local, state, regional, and federal levels to provide information and guide existing planning efforts. Chicago Wilderness has expressed an interest in being able to evaluate conservation and restoration opportunities that will support implementation of the Green Infrastructure Vision. Green infrastructure can be protected through the work of many different kinds of organizations, including forest preserve and conservation districts, the state and federal governments, park districts, and private non-profit and for-profit organizations, among others. Many organizations have good reasons to collaborate to preserve portions of a large, connected network of open space. GIV 2.1 provides opportunities to help implement other plans and processes within the Chicago Wilderness region. The types of applications that can be supported through the use of GIV 2.1 data include:

- Measuring ecological value
- Assessing land acquisition opportunities
- Evaluating restoration potential at a regional scale
- Evaluating potential reforestation areas
- Identifying resource conservation areas for municipal comprehensive and open space planning
- Assessing watershed protection project opportunities
- Classifying the landscape to facilitate avoidance and/or minimization of impacts from infrastructure projects
- Identifying mitigation opportunities resulting from infrastructure projects

In terms of policy applications, broadly speaking, there are two complementary ways of using the GIV 2.1 in land protection. First, it could be used to target conservation investments directly, such as land purchases or restoration. The many organizations involved in land management could use the GIV 2.1 data to help guide their efforts to establish a planned network of open space. Secondly, GIV 2.1 could be used to help shape future growth, minimizing loss of green infrastructure as the region grows and develops. This latter approach is equally important to protect a planned network of open space.

Local governments are responsible for planning and permitting development. The most important way to help ensure that local development is balanced with the protection of critical green infrastructure is for local governments to use the GIV 2.1 data in developing their comprehensive plans. These plans guide local growth patterns and typically include an open space component that could be enhanced by also including the GIV 2.1 data. Local governments could also consider implementation strategies for ensuring that the regional green infrastructure network is legally protected from future disturbance, which could include such measures as an overlay ordinance for green infrastructure protection, a conservation design

ordinance that permits higher densities in exchange for protecting sensitive areas, or land donation requirements for green infrastructure areas, among many options.

A similar balancing approach can be considered at the regional level. One of the goals of CMAP's GO TO 2040 is to help make sure that "gray infrastructure" expansion does not come at the expense of the green infrastructure network. Two important kinds of gray infrastructure to consider are transportation -- particularly highways -- and wastewater. Thus, a potential application of the GIV 2.1 data is to utilize them in programming and project development for wastewater and transportation improvements. CMAP will be conducting more research in the upcoming year on how to incorporate green infrastructure data in existing decision-making processes for infrastructure investment.

The GIV can also be integrated selectively into planning and decision-making at the state and federal levels. One possibility is discussed here. Under the federal Wildlife Conservation and Restoration Program and the State Wildlife Grants Program, states are required to develop a statewide wildlife action plan to maintain funding eligibility. Some federal funding is targeted using these plans. The 2005 Illinois Wildlife Action Plan has relatively little map detail, but is expected to be formally revised in 2015. The GIV could be used for the northeastern Illinois element of the IWAP update.

B. Definitions and Consistency with Previous CW Work

"Green infrastructure" has emerged as a term to refer to two different but related planning concepts. Site-scale green infrastructure can be thought of as a suite of practices to handle stormwater that emphasize using vegetation, soils, and natural processes to mimic natural hydrology. Regional green infrastructure, on the other hand, is the focus of the Green Infrastructure Vision. According to The Conservation Fund, this can be considered a "strategically planned and managed network of natural lands, working landscapes, and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations" (Benedict & McMahon, 2006). Both site-scale and local green infrastructure can be thought of as critical complements and sometimes replacements for "gray infrastructure," like utilities and the road and rail networks. The concept of green infrastructure draws attention to its similarity to the other infrastructure networks that undergird prosperity. Like other forms of infrastructure, it also needs to be managed, restored, and expanded.

Historically, Chicago Wilderness' view of regional green infrastructure has hewed closely to biodiversity protection. In GIV 1.0, green infrastructure was considered to be:

> "[the] interconnected network of land and water that supports biodiversity and provides habitat for diverse communities of native flora and fauna at the regional scale. It includes large complexes of remnant woodlands, savannas, prairies, wetlands, lakes, stream corridors and other natural communities that have been identified in the Biodiversity Recovery Plan. Green infrastructure may also include areas adjacent to and connecting these remnant natural

communities that provide both buffers and opportunities for ecosystem restoration."

However, the generality and the attractiveness of the concept to a broad set of stakeholders is somewhat reduced by the sole focus on biodiversity and "large complexes." Stakeholder interviews with local officials carried out in a previous project related to the GIV suggested that developers would assume, however incorrectly, that the focus on large complexes would mean taking ever larger chunks of buildable land out of play. Having large swaths of green area on the GIV map, whatever their correct interpretation may be, does little to assuage these concerns. Tying the GIV specifically to biodiversity, although perhaps appropriate as an ultimate end given CW's mission, also reduces its seeming relevance to local officials.

In an effort to establish clear and logical rules for designating green infrastructure areas, mapping in GIV 2.1 was based primarily on existing land cover rather than merely on ownership or policy designation. On that basis, it is reasonable not to include all portions of all public lands, as for example some forest preserves contain golf courses, large parking lots, etc. One drawback of this approach is that it does not account for the future condition of the landscape if restoration is expected to occur on public lands. The GIV 2.1 data package includes all publicly-held land so that users can compare ownership/protection status with the delineated green infrastructure layer (the GIV 2.1 composite layer). This layer can be used to answer questions like, "how much of the GIV 2.1 composite layer is protected?" and "what lands might be restored in the future because they are owned by an agency with restoration as part of its mission?"

C. Next Steps for Chicago Wilderness and Its Partners

Below is a list of other potential enhancements for consideration after GIV 2.1.

- The primary data input for GIV 2.1 is 2006 land cover at 30 × 30 meter resolution. The GIS tools developed for GIV 2.1 were designed to be re-run when better land cover data becomes available. The most important benefits of this product would be: 1) the ability to reliably classify prairie, savanna, and grassland cover types, 2) the ability to distinguish between wetlands, wet prairies, dune/swale systems, and 3) to assess the relative quality and composition of forest stands. Through a combination of field surveys, aerial photo interpretation, and feature extraction capabilities of machine learning software, the errors of omission and commission of core area features would be reduced and would also result in improved results in functional connectivity analysis. CMAP could develop new land cover data using 2010 4-band NAIP imagery (already owned), but the image classification would require an unknown amount of staff time.

- An early version of the GIV 2.0 scope included economic valuation of the green infrastructure network in terms of the benefits it provides (flood storage, air pollutant removal, carbon sequestration, etc.). This could still be performed.

- Despite advances in mapping on the web, little progress has been made toward universalizing access to conservation information and keeping it up to date. Existing web mapping services paid for with grant funds are not maintained adequately afterward. CW could make more of a commitment to helping solve these problems, perhaps by trying to organize relevant stakeholders to devise solutions and providing some amount of money (in partnership with others) to implement them.

- We received some excellent comments from our public workshop with NIRPC on October 4, 2012. Many of the suggestions were worthy of consideration for future versions when there is more time to implement them. These include: updated land cover classification, include high slopes (>15%) and highly erodible lands for functional prioritization, calculate percent impervious surface per watershed, incorporate wetland functions for water quality and quantity.

- We were only able to receive limited comments from stakeholders in Wisconsin due to schedule conflicts during the key public feedback schedule for the project. We suggest scheduling a workshop with SEWRPC and other local partners soon after the release of GIV 2.1 to identify opportunities for using the data to advance Chicago Wilderness goals. In addition, the Wisconsin partners should be involved early in the development process of the next generation of GIV mapping products.

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V. Appendices

A. Project Background

The Conservation Fund is a national nonprofit organization dedicated to advancing America's land and water legacy. From its headquarters in Arlington, Virginia and field offices across the country, the Fund has protected land in all 50 states—close to 7 million acres, including almost 50,000 acres in Illinois. The Conservation Fund's Strategic Conservation Services use a green infrastructure planning approach—simultaneously focusing on the best lands to conserve and the best lands to accommodate development and human infrastructure—to help communities, state and federal agencies, and business organizations balance environmental and economic goals through strategies that lead to smarter, sustainable land use. Strategic Conservation recognizes that limited resources are available to identify and protect the lands most suitable for conservation, and that competing values, needs, and opportunities must be evaluated to develop the most efficient and effective land conservation strategies.

Applied Ecological Services, Inc. is one of the most experienced ecological planning firms actively engaged in conservation design in the Chicago region and throughout the U.S. With headquarters in southern Wisconsin and field offices from the east coast to the plains, AES has completed more than 7,000 conservation and restoration projects since 1975, including many pioneering efforts that have provided leadership and significant innovation in the conservation field. These include projects such as Prairie Crossing and the establishment of the Liberty Prairie Reserve in Grayslake, and broad-scale natural area inventory and restoration planning for the DuPage and Will County Forest Preserve Districts.

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B. GIV 2.0 Meeting Participants and Project Feedback/Support

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- Anderson, Jim* — Lake County Forest Preserves
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- Bettin, Cameron — Plainfield Park District
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- Birchfield, Jennifer — Save the Dunes
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C. Process Overview

The project officially commenced July 1, 2011, with the first few months focused on acquisition of existing, available GIS data. Project calls with the GIV Task Force were completed July 8th and August 8th as well as a Data Discovery webinar on August 2nd that included over 35 Chicago Wilderness partners reviewing data collected to date and known data gaps. A data quality assessment matrix was completed as an interim deliverable of the project.

A September 12th GIV Task Force called kicked off the development of the draft conceptual network design protocol for GIV 2.0, and an October 6th work session in DuPage County was convened to obtain important feedback from local resource professionals. Discussions will focus on technical methodologies to identify appropriate green infrastructure landscape types, techniques and appropriate data for delineating core and hub areas, and establishing functional connectivity for ecological and recreational networks.

Following the October 6th work session, the development of GIS models to implement the network design protocol commenced. GIV Task Force calls on October 17th, November 14th, January 9th, and February 13th covered specific priority topics during the network design process, including interim drafts of core area delineations and the functional connectivity analysis. A project portal website was established to provide a repository for PDF static maps and interactive map services throughout the project. A March 1st call focused on preparing materials for the upcoming March 20th GIV 2.0 network characterization work session at the Morton Arboretum that focused on reviewing the GIV 2.0 mapping to date and obtaining input on the best ways to characterize, rank, and prioritize elements of the GIV 2.0 that would help focus future implementation efforts.

The network design protocol was finalized on a GIV Task Force call on April 20th and final modeling was completed in May. The GIV 2.0 map packages were reviewed and completed in June 2012.

The GIV 2.1 project officially commenced July 1, 2012, with a focus on obtaining data for Indiana, Wisconsin, Berrien County MI, and the remaining portions of Illinois. We convened one GIV Task Force call in September, and an October 4th work session at NIRPC was held to review the Indiana portion of the project area. We were unable to schedule a work session or webinar for Wisconsin, so all feedback was provided through the distribution of the draft protocol to key resource experts in Wisconsin.

The GIV 2.1 network design protocol, modeling, and map packages were completed in November 2012. The GIV 2.1 was officially unveiled at the Chicago Wilderness Congress on November 15th, 2012.

D. Data Summary

1. Land Cover

- National Land Cover Dataset (NLCD) Land Cover - 2006
- NLCD forest classes (Deciduous Forest (41), Evergreen Forest (42), Mixed Forest (43), and Woody Wetlands (90)) were used in development of the EPA Morphological Spatial Pattern Analysis (MSPA). The MSPA dataset provided an initial set of woodland/forest patches with 30-meter resolution. These patches were refined based on aerial photo interpretation of 2010 NAIP (1-meter resolution, leaf-on) to identify any recent land cover changes since 2006 and to correct obvious errors of omission and errors of commission from the NLCD layer.
- NLCD Grassland/Herbaceous (71) class was used to help delineate Grassland Blocks.
- NLCD Classes Deciduous Forest (41), Evergreen Forest (42), Mixed Forest (43), Grassland/Herbaceous (71), Woody Wetlands (90), and Emergent Herbaceous Wetlands (95) were used to add natural land cover around wetlands.
- 2005 CMAP Land use
- Indiana Dunes National Lakeshore Vegetation Mapping

2. Pre-settlement and historic land cover

- Presettlement conditions are interpretations of the native vegetation that existed prior to significant human settlements. Wisconsin presettlement layer is intended to represent conditions in 1836. In Illinois, the surveys began in 1804 and were largely completed by 1843 while in Indiana, generalized presettlement vegetation types of Indiana, circa 1816 were based on original land survey records and modern soil maps of counties. Presettlement conditions were estimated for forest, prairies and savannas, wetlands and water.
- McHenry County historic oaks survey data was used to identify potential reforestation opportunities. This data was provided by Chicago Wilderness.

3. Midewin National Tallgrass Prairie

- Known sites from the Midewin National Tallgrass Prairie were used to help identify core prairies and savannas. For more information, please contract Renee Thakali or Bill Glass at the Midewin National Tallgrass Prairie.

4. Illinois Natural History Survey's Landscapes of Ecological Importance (LEIs)

- Grassland LEIs were used to identify Grassland Blocks since there were known gaps in other available datasets.
- Forests and wetland LEI sites were not used since they were coarser than other available data.

5. Wetlands

- We combined a series of datasets to create the best available wetlands layer: Ducks Unlimited enhanced National Wetland Dataset (NWI) update for IL and IN, ADID county wetland data for McHenry County (2005), Kane County (2004), Lake County - LCWI (2002), SEWRPC 2005 ADID Wetlands Inventory, 2005 WI Wetlands.
- Kane County Fens Study (2004)
- CMAP land use wetland classes not in NWI
- 2004 Chicago Wilderness Wetlands Task Force data identifying (1) high potential for restoration (includes Hydric soils), (2) wetlands associated with reptiles and amphibians, and (3) basin/marsh habitat important to threatened and endangered species
- Add hydric soils for Kendall County (since no CW Wetland Task Force data available)

6. Streams and lakes

- NHDPlus v1: Zones 4 and 7
- Biologically Significant Streams (BSS), Illinois Department of Natural Resources and Illinois Natural History Survey – August 2008. This data set was included in its entirety as part of the core streams and lakes layer and it represents stream segments identified as biologically significant based on integrity and diversity ratings.
- IN Salmonid Streams and IN Outstanding Rivers from NIRPC
- Lake Michigan Ravines, Alliance for the Great Lakes. This dataset analyzes 47 ravines to determine which face the greatest threat of rapid, unstable erosion. Only those ravines that are considered stable were included in the stream and lake cores.
- DFIRM floodplains (Cook, DuPage, Kane, McHenry counties) and FEMA Q3 floodplains (Will, Lake, Kendall counties) were used to extract the 100-year floodplain zones.

7. Natural heritage designations

- Natural Areas and Preserves Inventories – July 2010
  This layer was used to extract all landscape patches that contained high quality natural communities, specific suitable habitat for state-listed species, outstanding geological features, and unusual concentrations of flora or fauna and high quality streams. This data is license restricted, so individual INAI site boundaries are not included in any GIV 2.0 derived products. For more information, please contact Tara Kieninger, Illinois Nature Preserves Commission, tara.kieninger@illinois.gov, 217-782-2685, for Wisconsin contact, Rori Paloski, Incidental Take Coordinator, Wisconsin Department of Natural Resources Bureau of Endangered Resources, 608-264-6040, Rori.Paloski@Wisconsin.gov, for Indiana, for Indiana, Ronald Hellmich, rhellmich@dnr.IN.gov, Division of Nature Preserves, Indiana Dept. of Natural Resources.
- State and federal threatened and endangered species sites – May 2011
  This layer was used to extract all landscape patches that contained state and federal threatened and endangered species, rookeries, and high quality natural communities.

This data is license restricted, so individual T&E site boundaries are not included in any GIV 2.0 derived products. For more information, please contact Tara Kieninger, Illinois Nature Preserves Commission, tara.kieninger@illinois.gov, 217-782-2685, for Indiana, Ronald Hellmich, rhellmich@dnr.IN.gov, Division of Nature Preserves, Indiana Dept. of Natural Resources, for Wisconsin contact, Rori Paloski, Incidental Take Coordinator, Wisconsin Department of Natural Resources Bureau of Endangered Resources, 608-264-6040, Rori.Paloski@Wisconsin.gov.

- Illinois Nature Preserves Commission (INPC) – October 2010
  This layer was used to extract all landscape patches that contained lands enrolled in INPC's land protection programs, including Nature Preserves, Land and Water Reserves, and Natural Heritage Landmarks. This data is license restricted, so individual INPC site boundaries are not included in any GIV 2.0 derived products. For more information, please contact Tara Kieninger, Illinois Nature Preserves Commission, tara.kieninger@illinois.gov, 217-782-2685.
- Audubon Important Bird Areas – Summer 2010. This layer was used to extract all landscape patches that included designated IBAs. For more information, please contact Doreen Whitley, National GIS Coordinator, Audubon, Conservation & Strategic Planning, 614-732-5265 or Connie Chen Sanchez, Director, Important Bird Areas Program, Audubon, csanchez@audubon.org.

8. Analysis masks

- Urban and impervious surfaces mask: this mask was created using a combination of several data source including NLCD Developed classes. It was further complemented by using CMAP's land use data.
- Water Mask: a water mask was created from NHDPlusV1 using all the waterbodies within the Chicago Wilderness region.
- Interstate, State and US Highways mask: Using ESRI (ESRI, 2010) data and map we created masks for interstate highways and major State and US highways. This dataset was created to strategically remove developed land, roads, and other human-disturbed areas to eliminate areas less suitable for restoration in core areas.
- Key inputs include the 2006 National Land Cover Dataset (NLCD) – Developed Low/Medium/High Intensity, supplemented with CMAP land use/land cover and roads - ESRI Roads (90 m buffer from center line of interstates, 60 m from U.S. and state highways, and 30 m from county roads)

9. Site scale green infrastructure features

- Green Infrastructure Sites – Center for Neighborhood Technology: This dataset, which includes a detailed description, provides 56 sites within the 7-county area, with 14 of them within the City of Chicago municipal boundary. Site types include bioswales (10), naturalized detention (6), naturalized landscape (16), permeable pavement (7), and rain gardens (17). Additional records exist for additional private property owners, but they have not been included in GIV 2.0. For more information, please contact Cindy Copp, Senior GIS Analyst, Center for Neighborhood Technology, 773.269.4058, cindy@cnt.org. Intended use in GIV 2.0: Demonstration of site scale green infrastructure best practices.
- Green Roofs – City of Chicago: This dataset includes 488 records (although 242 of them do not have a specific square footage measurement for the green roof itself). Similar data outside the City of Chicago does not appear to have been compiled. For more information, please contact Jesse Elam at CMAP. Intended use in GIV 2.0: Demonstration of reductions in impervious surface through site scale green infrastructure techniques.
- Tree Canopy – City of Chicago: This dataset represents tree canopy for every 10 foot square within the City of Chicago. While it does not map individual trees, it provides an accurate overview of the relative distribution of trees from a snapshot in 2007. The Chicago Bureau of Forestry maintains more than 520,000 parkway trees and strives to trim 100,000 trees a year, plants new trees along the public right-of-way, addresses insect and disease problems, and otherwise promotes tree health throughout the City of Chicago. (http://www.cityofchicago.org/city/en/depts/streets/provdrs/forestry.html). For more information, please contact Jesse Elam at CMAP. Intended use in GIV 2.0: Identification of gaps in tree canopy and opportunities for future tree planting.
- Boulevards – City of Chicago: This dataset includes 23 records where the Open Space Section of HED's Sustainable Development Division works to increase the amount of publicly accessible open space within major thoroughfares. (http://data.cityofchicago.org/d/sd36-arzm). Intended use in GIV 2.0: Demonstration and opportunity for enhancement through 'Green Streets'.
- Malls and Plazas – City of Chicago: This dataset includes 57 City-owned properties maintained by the Chicago Department of Transportation for public open space. (http://data.cityofchicago.org/d/ixxk-b6xq) Intended use in GIV 2.0: While many of these may not be 'green', they are opportunities to potentially employ site scale green infrastructure techniques to enhance open space quality.
- Combined Sewer Outflows – City of Chicago: This datasets maps 495 combined sewer outfall points. When there is too much stormwater, the combined sewers overflow and release untreated waste and stormwater into the Chicago River. Managing stormwater and protecting the quality of our water resources requires a combination of upgrading built infrastructure and creating green infrastructure. (http://www.cityofchicago.org/content/city/en/depts/bldgs/supp_info/combined_sewers.html, data provided by IEPA Permit Compliance System via Jesse Elam at CMAP) Intended use in GIV 2.0: Targeting of locations for site scale green infrastructure investments to reduce stormwater reaching combined sewer infrastructure.

10. Urban and neighborhood open space

- Neighbor Space Sites – City of Chicago: This dataset includes 75 sites managed by NeighborSpace, a nonprofit organization whose mission is to acquire and support the community based management of open space in the City of Chicago for preservation, conservation, and educational public open space purposes. Site types include urban agriculture (16), community gardens (21), neighborhood parks (15), multi-use (19), and four other sites that overlap with other datasets (a greenway, two plazas/squares, and a rain garden). (http://data.cityofchicago.org/d/gacm-z663). Intended use in GIV 2.0: Demonstration of community managed urban and neighborhood open space.
- Greencorps Garden Sites – City of Chicago: This dataset includes 486 community gardens certified by Greencorps, Chicago's community landscaping and job training program. (http://www.cityofchicago.org/city/en/depts/cdot/provdrs/conservation_outreachgreenprograms/svcs/greencorps_chicago.html, GIS data provided by Dan Swick, City of Chicago, daniel.swick@cityofchicago.org). Intended use in GIV 2.0: Demonstration of linking green infrastructure and community economic development.
- Farmers Markets – City of Chicago: This dataset includes 38 sites where vendors sell fresh fruits, vegetables, plants and flowers to neighborhoods throughout the City of Chicago. (http://data.cityofchicago.org/d/36ke-zb8q). Intended use in GIV 2.0: While these sites may not be 'green', they are opportunities to potentially employ site scale green infrastructure techniques to enhance open space quality.
- Campus Parks – City of Chicago: This dataset includes 112 school sites where the City's Campus Parks Program has implemented projects addressing the shortage of parkland in Chicago's neighborhoods by targeting public school grounds for parkland improvements. Under a joint program funded by the City, Chicago Public Schools and the Chicago Park District, existing asphalt and concrete paving are replaced with new landscaping, play equipment, trees, fencing and lighting. Priority is given to neighborhoods identified as having insufficient parkland, Strategic Neighborhood Action Program districts, Empowerment Zones, Enterprise Communities and other special development districts. (http://data.cityofchicago.org/d/kfqm-mn72). Intended use in GIV 2.0: While these sites may not be 'green', they are opportunities to potentially employ site scale green infrastructure techniques to enhance open space quality.
- School Grounds – City of Chicago: This dataset includes 950 school grounds. (http://data.cityofchicago.org/d/qxjd-z277). Intended use in GIV 2.0: Opportunities to potentially employ site scale green infrastructure techniques to enhance open space quality, particularly where there are implementation gaps from programs listed above.
- Cemeteries – City of Chicago: This dataset includes 24 cemeteries. Intended use in GIV 2.0: Current open space and opportunities for green infrastructure on adjacent properties.

11. Protected and managed lands: parks, open space, conservation easements, etc.

- Protected Areas Database of the US (PAD-US) - CBI Edition 1.2, 2012: This is a standardized national dataset that includes an array of Federal, State, local, and private conservation lands. It does not include easements, recent acquisitions, and many local parks and open spaces. This is one of the starting points to inventory protected and managed lands outside the 7-county CMAP area for the remainder of the Chicago Wilderness service area. This is an updated dataset from the one used in GIV 2.0.
- National Conservation Easement Database (NCED), 2012 update: This includes many municipal and private conservation and agricultural easements. It does not include recent acquisitions or some of the area's land trust holdings. This is an updated dataset from the one used in GIV 2.0.
- County Forest Preserve Districts: To supplement the PAD-US data, we received updated Forest Preserve District ownerships from Cook, Will, and Lake Counties for GIV 2.0. We received an updated version of Cook County for GIV 2.1.
- Parks – City of Chicago: To supplement the PAD-US data, we received the latest parks data from the City.
- 2005 Land Use Open Space categories – 7-County CMAP area: To supplement the PAD-US data, we mapped areas thought to be open space by CMAP: 3100 – Open Space, Recreation, 3200 – Golf Course, 3300 – Open Space, Conservation, 3400 – Open Space, Private, and 3500 – Open Space, Linear. These include Federal, State, municipal, township, county, and private ownership.
- Land Trust Conservation Lands and Easements: We obtained fee and easement ownership data from a variety of land trusts: Land Conservancy of McHenry County, Parklands Foundation, Natural Lands Institute, Lake Forest Open Lands, Lake Bluff Openlands, Karst Conservancy, Jo Daviess Conservation Foundation, Illinois Audubon, Green Earth, Inc., McHenry County, Libertyville Township, Liberty Prairie Conservancy, Openlands Easements, and TNC Easements. Most of this data came from the Grand Victoria Foundation Vital Lands initiative. Note that due to the variety of sources, the datasets listed above have some overlap between them and occasional have slightly different boundaries. Nonetheless, the compilation is believed to be comprehensive.

12. Regional, county, and local recreation trail and bike path network

- The 2009 CMAP Existing and Planned Greenways and Multi-use Trails layer is the backbone of the regional recreational network for the 7-county area.
- County, municipal, and local recreational trails data was provided by CMAP and the City of Chicago.
- NIRPC provided their trails database along with two water trails: Lake Michigan and Kankakee River.
- Kankakee County, Illinois provided their trails database.
- We also obtained the State of Indiana's trails database from IDNR.
- Wisconsin did not have any digital trails data.

E. Technical methods for specific GIV 2.1 protocol steps

1. Projection, cell size, and mask parameters

USA Contiguous Albers Equal Area Conic
Projection: Albers
False Easting: 0.000000
False Northing: 0.000000
Central Meridian: -96.000000
Standard Parallel_1: 29.500000
Standard Parallel_2: 45.500000
Latitude Of Origin: 37.500000
Linear Unit: Meter
GCS North American 1983
Datum: D North American1983

Cell Size: 30 meters

2. Adding/Removing Forest from Core Forest Layer Using Aerial Photography (CMAP region only)

Figures 5 - 7 represent a sample of the process to refine the woodland/forest layer described in Section C(b)(1). The area is located in Lake County.

Figure 5. Initial forest classification. Green represents forest.

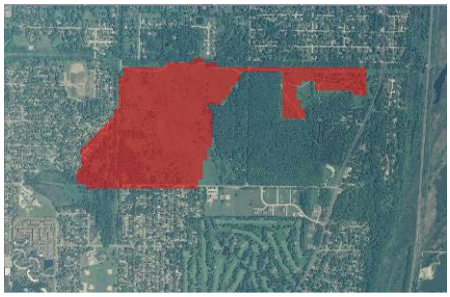

Figure 6. Same area flagged as non-forest by analyst. Red polygon represents areas to be removed.

Figure 7. Forest patch area after post-processing.

3. Adding Landscape Type Attributes to IBA Dataset (GIV 2.0 only)

The Illinois Important Bird Area (IBA) sites within the 7 county CMAP study area were each assigned the most relevant Landscape Type (Forest, Savanna, Prairie, Wetland, Water or Unknown) based upon the bird species or bird species type used by the Audubon Society to qualify the area as an IBA. Information from the Bird Conservation Network (http://bcnbirds.org/trends07/concern.html) was used to clarify the typical landscape type associated with a species when this was not directly stated in the qualifying criteria received from Chicago Region Audubon Society. If more than one landscape type was associated with the qualifying criteria, the dominant landscape within the site based upon the 2006 National Land Cover Dataset was used.

4. Adding Landscape Type Attributes to INAI Dataset (GIV 2.0 only)

Sites in the Illinois Natural Areas Inventory database (as of July 2011) that had qualifying Category I communities within them had the most relevant Landscape Type (Forest, Savanna, Prairie, Wetland, Water) assigned to them based upon the dominant qualifying community type. In some cases this could be inferred from the name of the site, but for most sites, the natural community polygon data for the sites were reviewed to determine which community was qualifying and/or dominant. Where more than one landscape type was represented by qualifying communities within the site, multiple Landscape Types were assigned, with the rarest communities being ranked first (such as prairies versus wetlands).

5. Terrestrial Movement Analysis Tool

The Terrestrial Movement Analysis tool models landscape connectivity, which is useful to identify and prioritize areas that are important to maintaining wildlife movement and gene flow within a human modified landscape. The tool treats the landscape as a circulatory system, identifying those pathways most likely to be followed by wildlife. This is done by generating random sets of starting locations (each location corresponding to an individual organism) and then calculating optimal (least cost) paths to all other habitat within the landscape. This process is executed iteratively, with each iteration having a different set of random start locations and corresponding least-cost paths. The tool calculates overall landscape connectivity by summing the least-cost paths from all iterations and then averaging these. This process creates a set of rasters that show pathway usage, the cost of moving through a corridor, and overall landscape movement potential.

Tool Processing Procedures:

The Terrestrial Movement Analysis tool (Figure 1) estimates connectivity within a landscape, first by identifying random start locations of organisms within habitat patches (cores), and then modeling movement away from these locations using least-cost path analysis. This process is repeated iteratively (with number of iterations set by user).

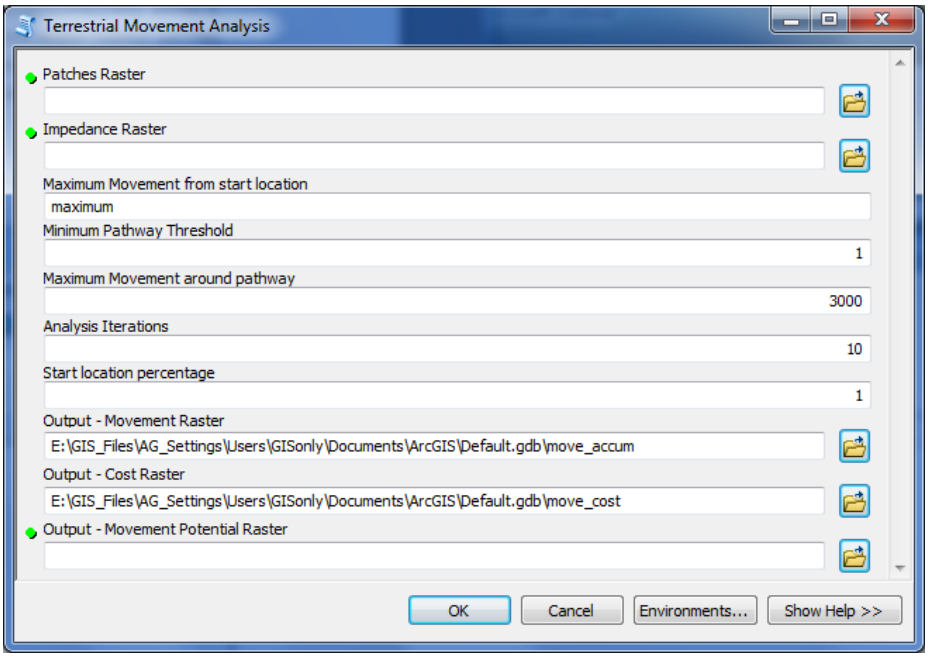

Figure 8 - Terrestrial Movement Analysis tool (for ESRI ArcGIS 10)

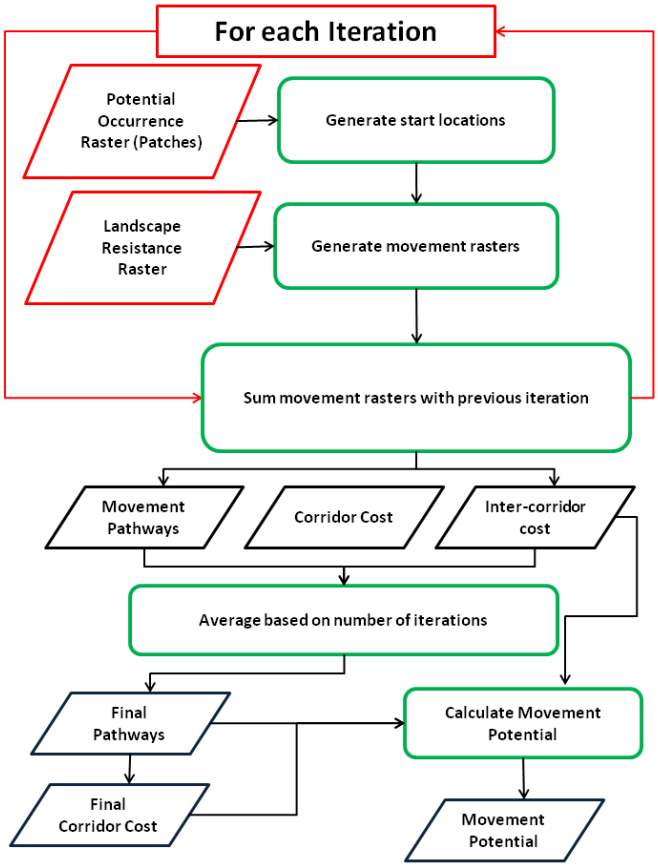

Figure 9 - Basic processing procedures involved in the model. Appendix 1 has a detailed flow chart of TMA procedures and Appendix 2 contains a table of all intermediate rasters (with a brief description) that are generated throughout the operation of the tool.

The tool sums outputs from each iteration and then divides by the number of iterations (Figure 2). The start locations are selected by comparing a random raster (with values between 0 and 1) against the user-defined patch or occurrence probability raster (values also between 0 and 1), and selecting the highest proportion of random values (user defined) that are greater than or equal to the patch cell value (Figure 3). NODATA values for the patches raster will not have seed locations. Pathways and corridors are estimated from start locations by "growing" a cost distance raster away from a "seed" and creating a movement direction raster.

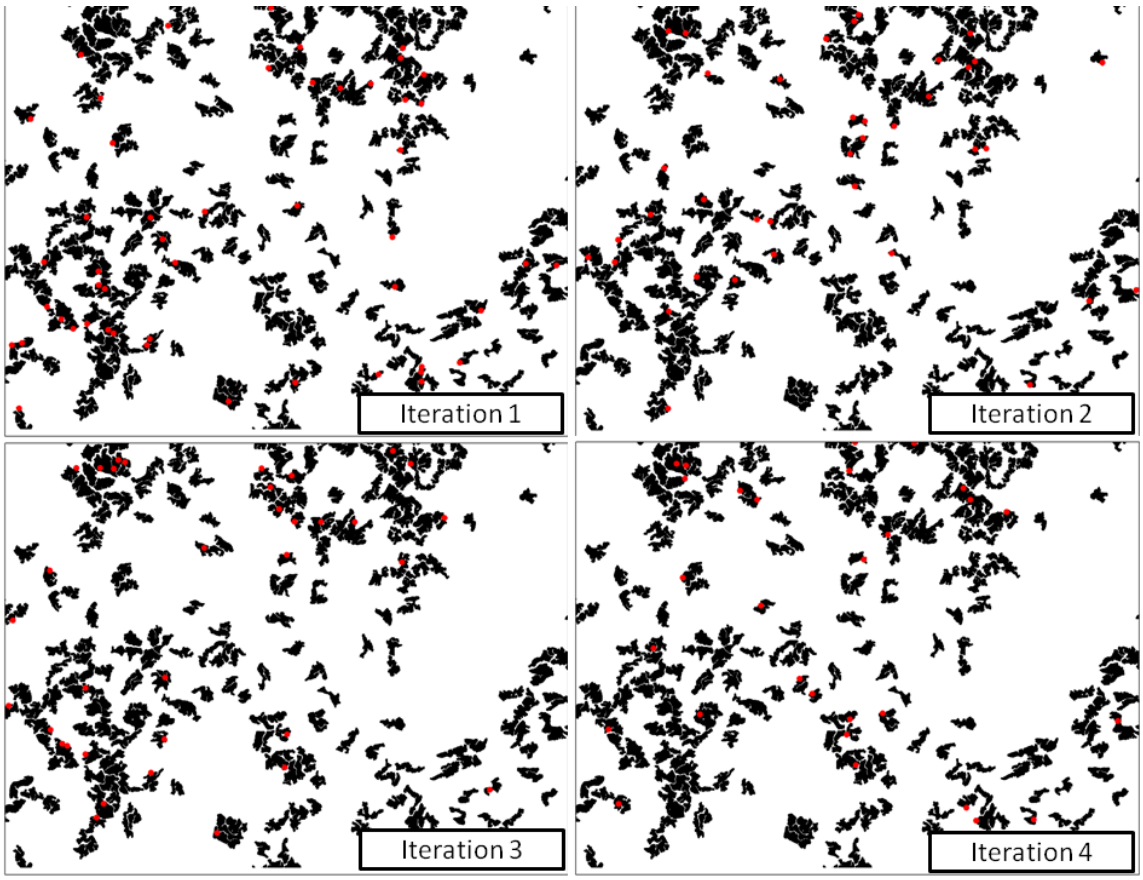

Figure 10 - Start locations example for four separate iterations

The movement direction raster assigns each cell with an 8-direction coding system that provides "directions" back to the start location (Figure 4).

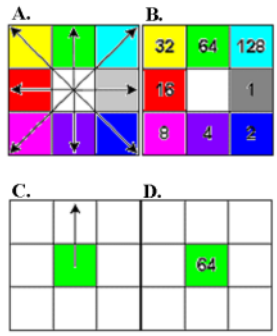

Figure 11 - Flow direction example. A) Demonstrates the eight directions of movement from center cell; B) contains the direction coding system for the eight directions; C) Demonstrates the direction of flow from the center cell if flow direction is north; D) The movement direction code to move to the north cell.

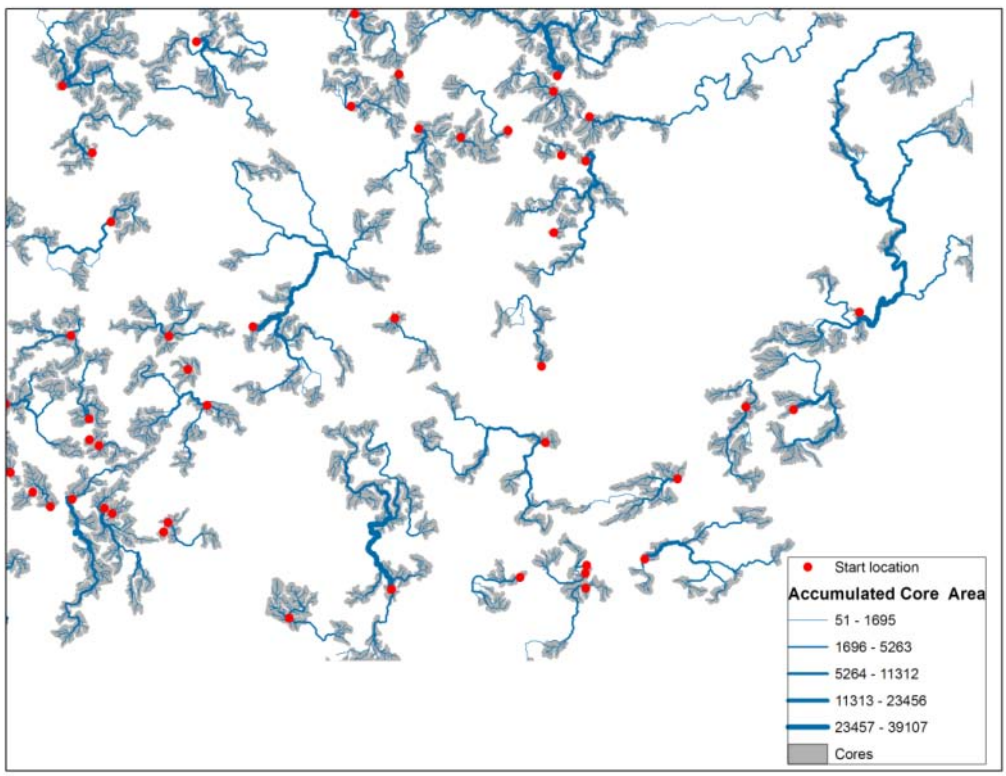

Figure 12 - Pathways to start locations for one iteration

The movement direction raster is used to accumulate patch areas back to the start locations creating the least-cost pathways weighted by accumulated patch area (Figure 5).
The value along the pathway represents the amount of patch area that it's connected to. Corridors are generated around pathways by "growing" cost distance from the pathways outward to a user-defined maximum cost distance (Input = "Maximum Movement Around Pathway") (Figure 6).

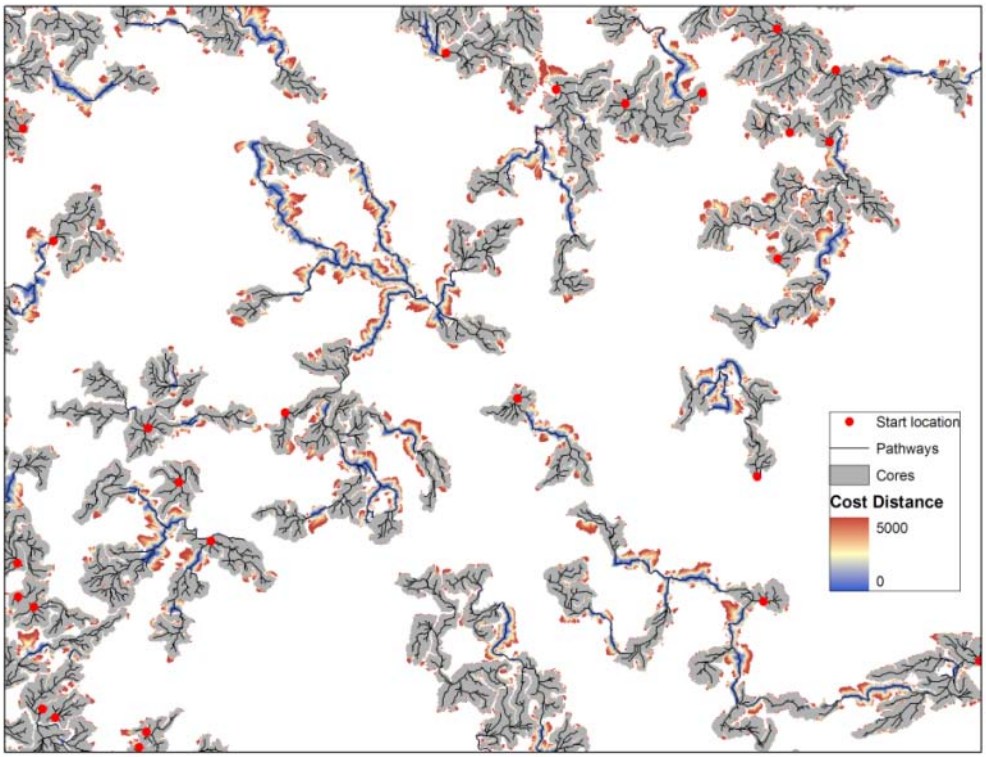

Figure 13 - Inter-corridor cost distance for one iteration

This process also generates the inter-corridor movement (Figure 6) and corridor cost rasters (Figure 7), which are used to calculate the movement potential raster.

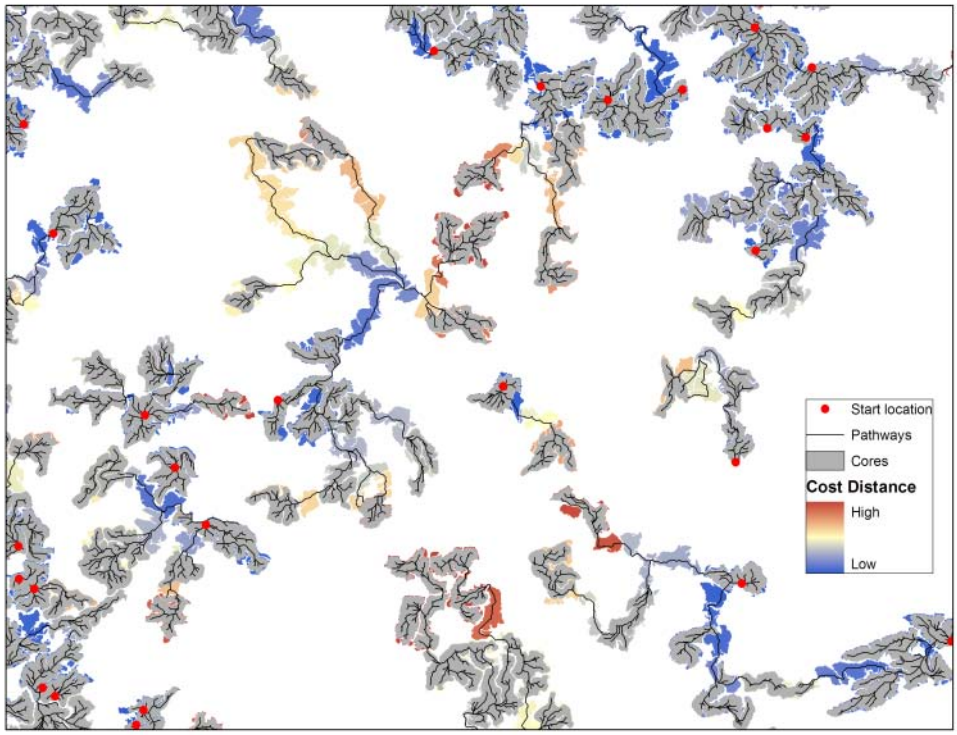

Figure 14 - Corridor cost raster for one iteration

General Tool Processing Information:

The Terrestrial Movement Analysis tool is designed to run in ESRI ArcGIS 10 Service Pack 4. The tool generates a temporary workspace (directory) to C:\temp, named LANDCONN followed by a date stamp (year/month/day/hour/minute/second). If the directory C:\temp doesn't exist, the tool will stop and report an error message. Since the tool relies on the COST DISTANCE tool to develop the movement based rasters, refer to the ESRI COST DISTANCE help for details on its operation and limitations. The tool assumes that the patches and resistance rasters have the same projection, cell size and extent (cell alignment). <u>If the cell size or extents are not the same, the tool will run but may produce results that are incomplete.</u>

Tool Input Details:

1. Patches Raster:

   This raster can be a binary, integer, or continuous floating point raster with a range of values between 0 and 1. For example, a layer of core areas might only contain values of 1 (core areas) and 0 or No Data (areas outside cores); whereas a habitat suitability layer might contain continuous values between 0 and 1, with 1 representing higher suitability or (in the case of Maxent logistic output) probability of organism occurrence. The values in this raster are also used as weights during the pathway analysis. For example, if core areas have a value of one, then pathway values will represent the average number of core cells that it is connected to. Or the raster values could range between 0 and 1, which would represent the average cumulative resource quality that a pathway is connected to.

2. Landscape Resistance Raster:

   Raster used to weight movement through cells in the development of pathways and corridors based on cost distance analysis. Values should be greater than zero, with NODATA values treated as absolute barriers to movement. The parameterization of this raster should reflect the difficulty of an organism to travel through a given raster cell given terrain, vegetation and human modification. For example, if an organism has an affinity for flat grasslands, then flat grassland cells should have a weight of 1, and cells that are steep and forested should have a value greater than 1, based on the difficulty of travel through it (e.g., 10 to 1000 times greater). Roads and other human disturbances should have a resistance value that is 2-4 orders of magnitude greater than suitable habitat, with buildings and highways treated as absolute barriers except where wildlife-friendly underpasses or overpasses occur.

3. Maximum Movement from Start Locations:

   This represents the maximum allowed movement from start locations (based on cost distance units). These values are usually much larger than Euclidean distances. An input value of "maximum" indicates that movement from start locations is unlimited, and will result in every cell having a cost distance value. Figure 8 shows

how different movement thresholds changed the analysis extent around each start location. As this value increases so do the number and length of corridors in the output. A good practice is to run the tool first set at "maximum", then assess the corridor output and choose a value that matches the most reasonable looking corridors. The optimal value will depend on the landscape being analyzed; values in the range of 2-4 million generally produce good output.

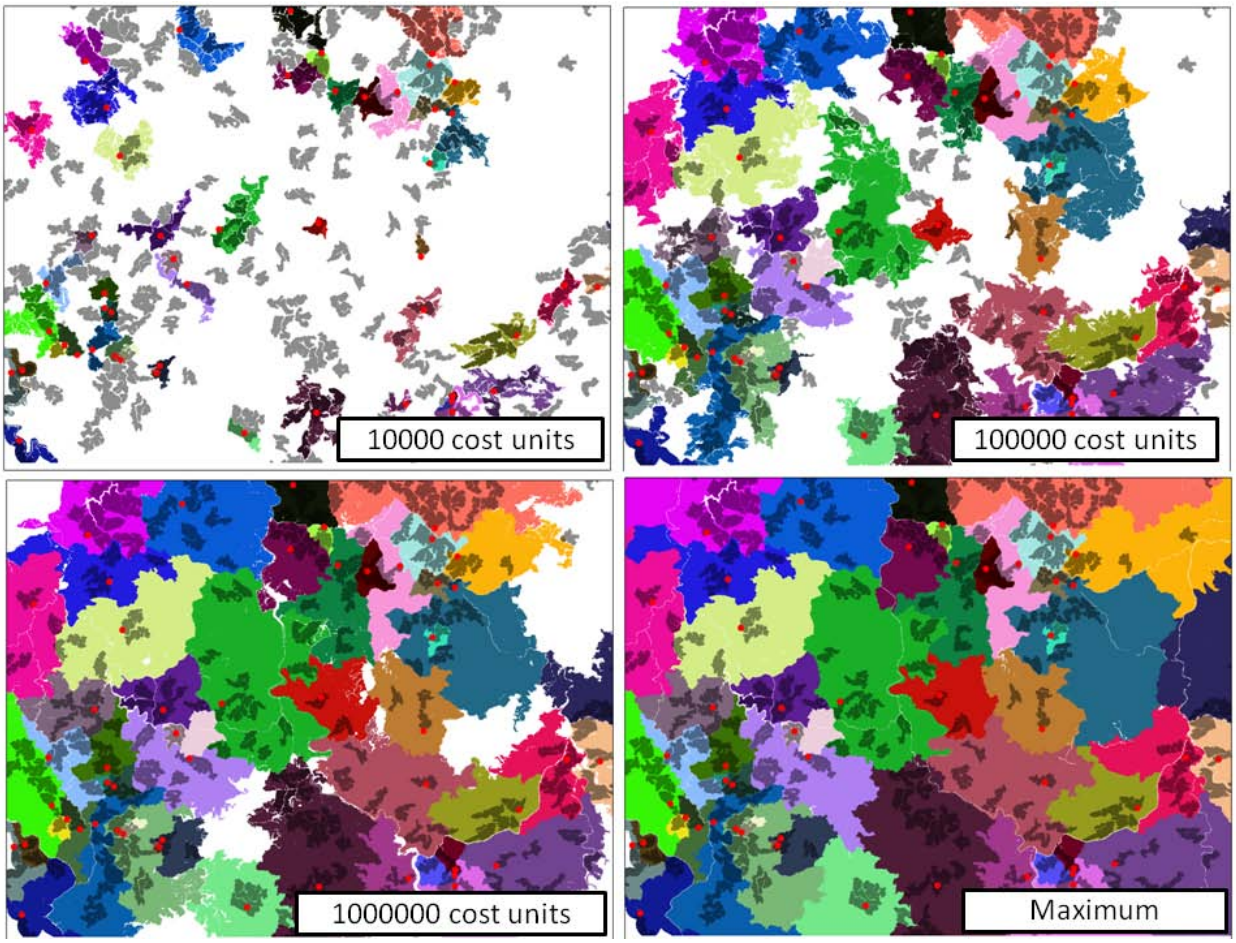

Figure 15 - Cost distance allocation zones for start locations using different maximum movement from start location values

4. Minimum Pathway Threshold:

This value is the minimum number of accumulated patch raster values (i.e. the number of cells accumulated back to the start locations) that make up a pathway that a corridor will be generated for. For example, a value of one (the default input value) means that all pathway cells with a value greater than or equal to one will have a corridor generated. Figure 9 demonstrates how this value influences the configuration of pathways that corridors will be generated for. This value is analogous to flow accumulation threshold values when generating hydrologic

networks based on an elevation model. As this value increases, the number of corridors in the output will decrease.

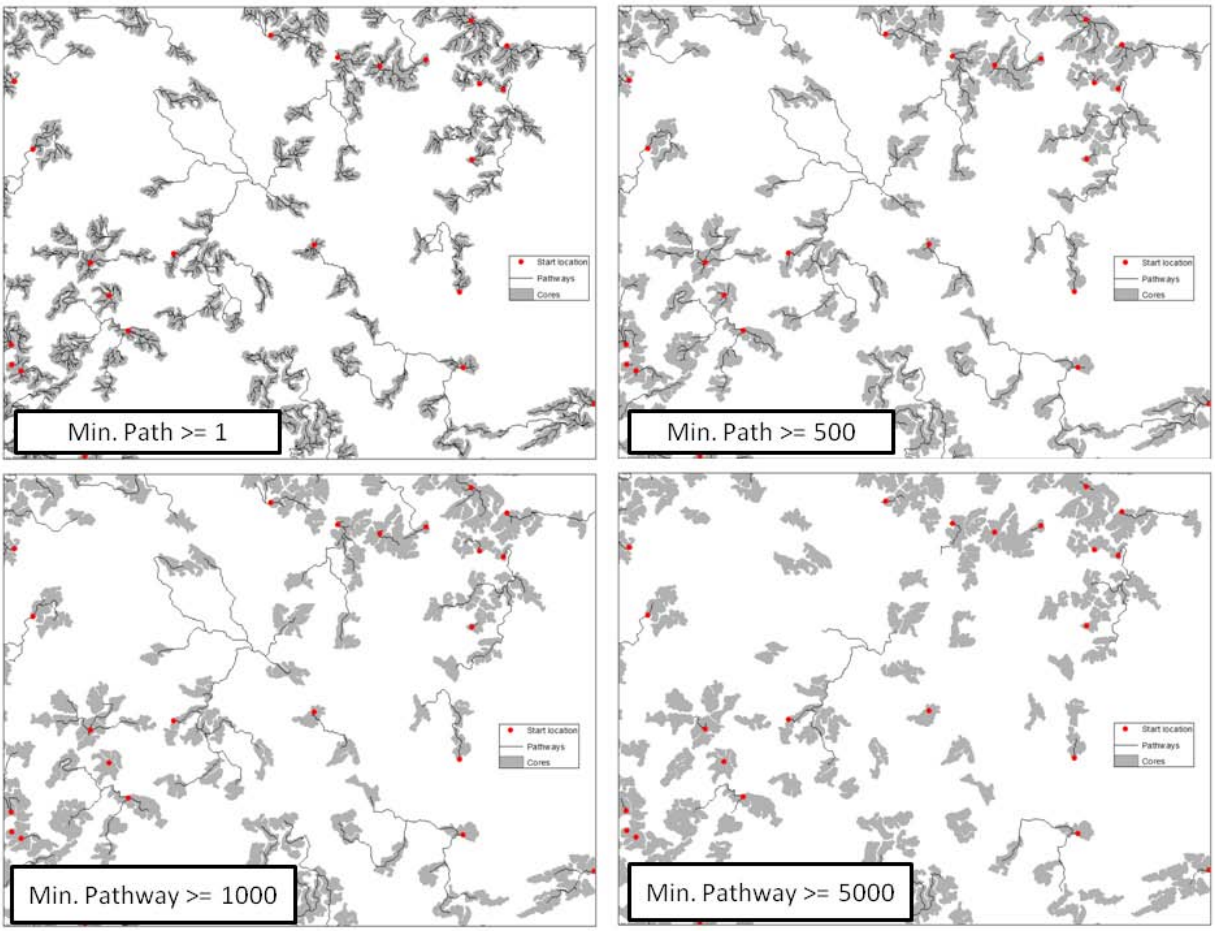

Figure 16 - Minimum pathway threshold values based on accumulated core cells to start locations

5. Maximum Movement Around Pathways:

This value can be thought of how wide a corridor around a selected pathway is, but is based on cost instead of Euclidean distance. This value can be thought of the degree of movement that would occur while moving along a pathway. Figure 10 depicts how corridor shape changes with different maximum values. As this value increases, the corridors in the output become wider. A value of 3,000 – 6,000 is generally sufficient.

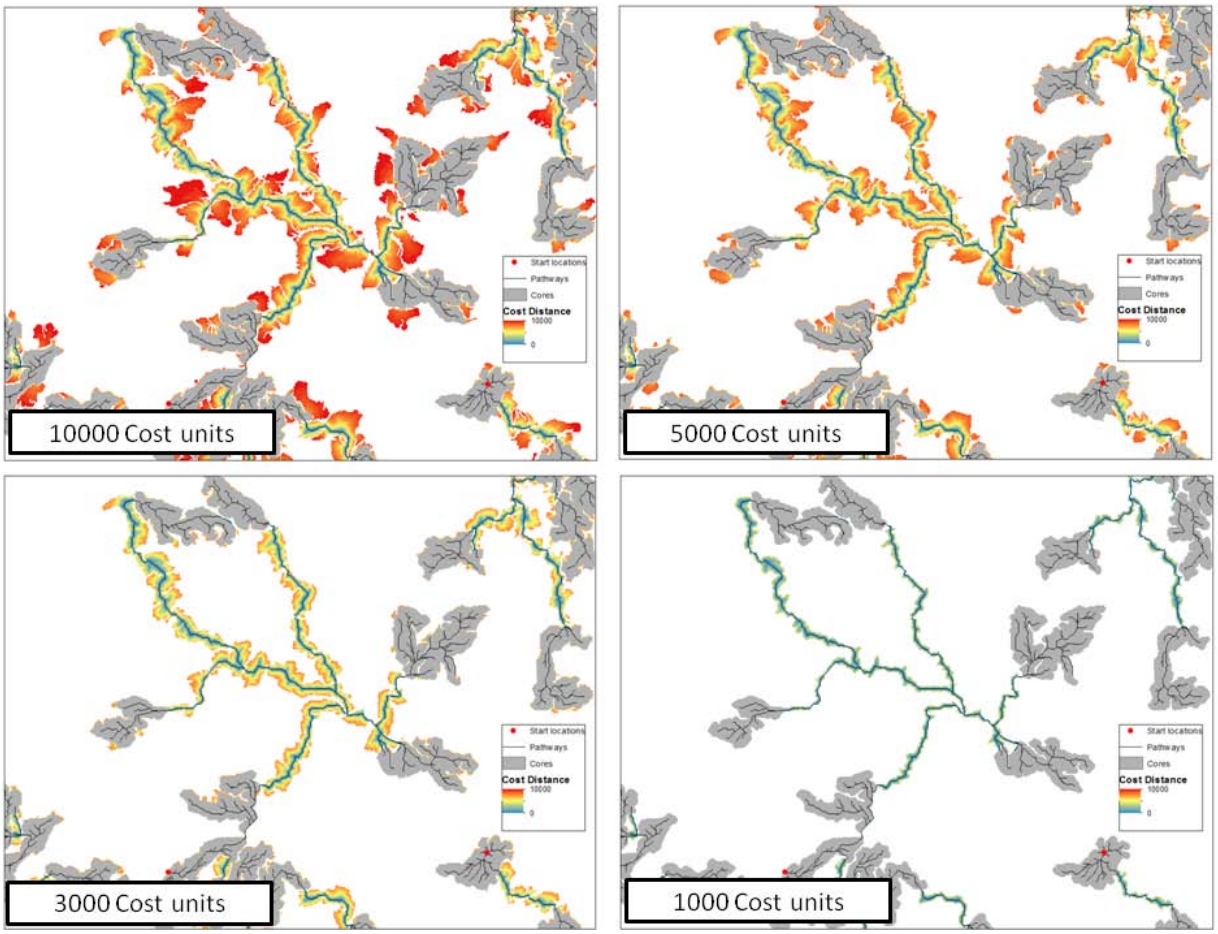

Figure 17 - Maximum movement around pathways example, showing inter-corridor movement and width based on different maximum movement values.

6. Number of Iterations:

The number of iterations involved in the analysis. This number can range from 1 to ~1000 depending on processing time constraints and the maximum movement from start locations threshold. Since start locations are based on a random process, the larger the number of iterations, the greater the chance that all core areas will have a start location. More iterations also create a better representation of connectivity within a landscape. An optimal iteration value has not been evaluated, but the default value of 10 generally works well (particularly for exploratory analyses - see below) when the maximum movement from start locations value is set to MAXIMUM. When maximum movement from start locations values is less than MAXIMUM, more iterations are necessary to connect the landscape due to a smaller window of analysis (Figure 8).

Using 10-20 iterations is adequate when running sensitivity analyses for a new project area. Once the final parameters are determined, the model should be run with 100 iterations. Values higher than this are infeasible for any area greater several thousand square miles due to excessive runtimes (Appendix 3). As the number of iterations increases, the mean cost of the corridor network decreases,

while the area of the network increases slightly (Appendix 3). Thus, using 100 iterations provides a compromise in terms of producing the least cost, but most extensive corridor network.

7. Start Location Percentage

This value determines the number of random start locations per iteration based on the top nth percentile (Figure 11) of randomly generated values. The default value of 1 selects the top one percentile highest random values as start locations. The smaller this number, the fewer number of start locations (Figure 12), which is necessary for landscapes that are not fragmented to ensure that connectivity between all cores is at its maximum. This number should be larger than 1 for landscapes that are highly fragmented (i.e. lots of NODATA barriers), so that smaller subnetworks will have start locations across all iterations. If too many start locations are generated, movement between patches will be limited. Thus, as this value increases, the number of corridors in the output will decrease.

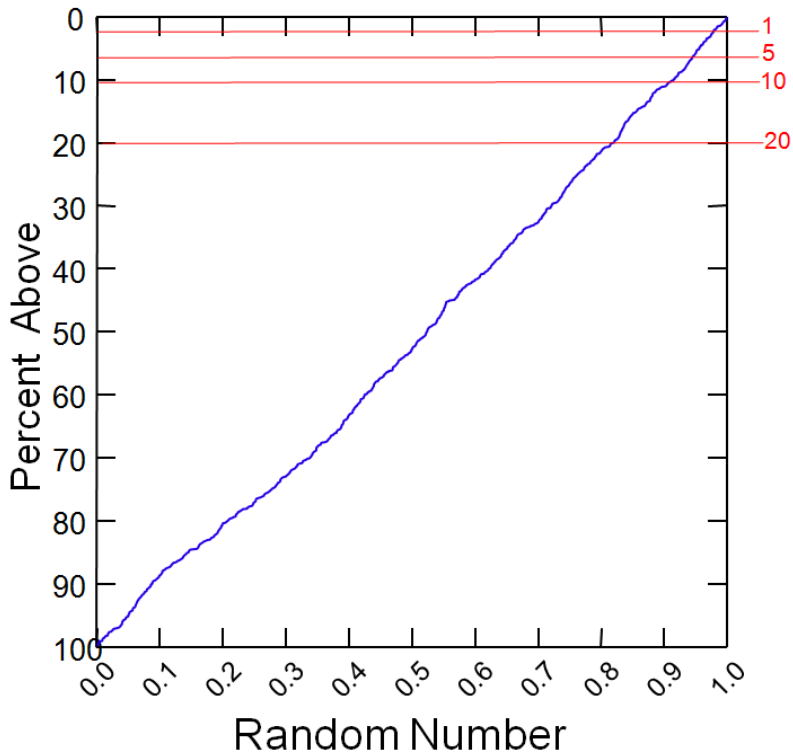

Figure 18 – Cumulative Distribution Function (CDF) of random values (0 to 1) showing the percentage of random values above a given Start Location Percentage threshold. The four red threshold breaks were used to generate the start locations in Figure 12.

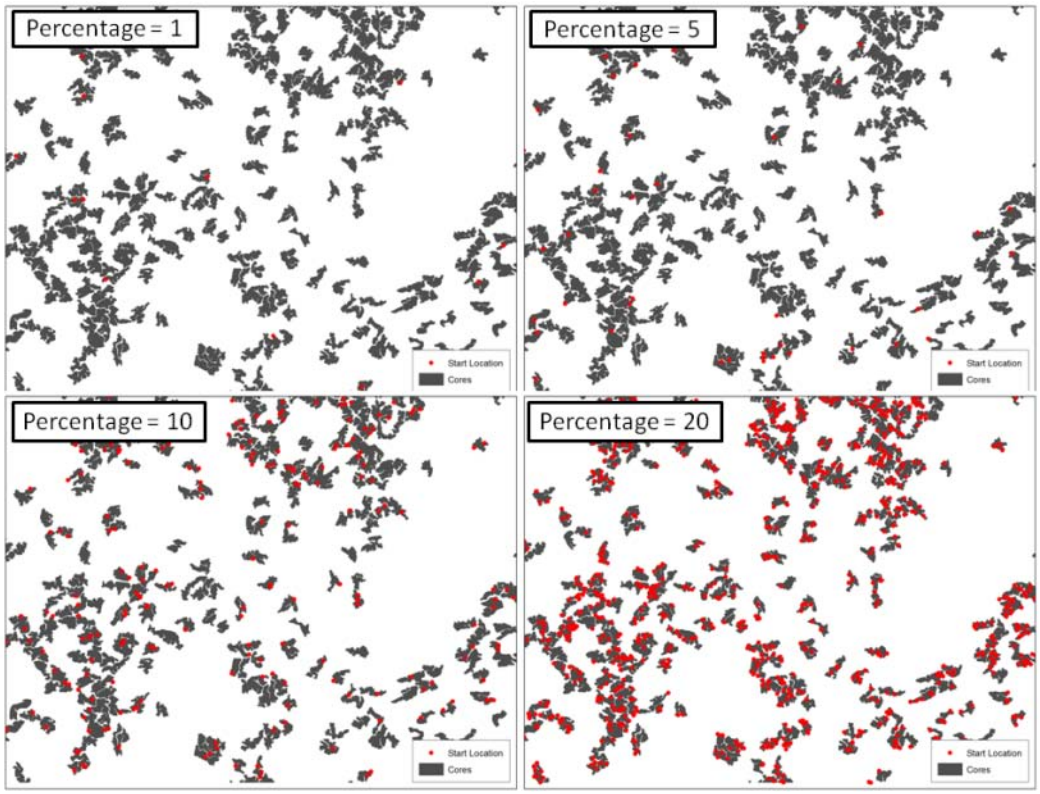

Figure 19 – Start location percentage example, demonstrating how the density of start locations change based on an increasing percentage. The four percentage breaks used are shown graphically in Figure 11.

Tool Output Details:

1. Movement Raster

   This raster represents potential movement pathways, with higher values indicating greater connection to non-zero cells in the patches raster. Pathways are represented as single cell wide paths that end at a start location (not patch edges). The cell values along the pathway are the summed area (number of patch/core cells) that a pathway is connected to at that point. If a pathway value is equal to the sum of all patch/core area in the landscape, this indicates that it is connected to every patch/core cell within the landscape. This is rare because of the permutation process, other competing locations, and no data areas that prevent movement. Figure 13 demonstrates how pathways generated at a given iteration have different pathway configurations, and Figure 14 shows the result of averaging the four iterations in Figure 13 into the final average pathway raster.

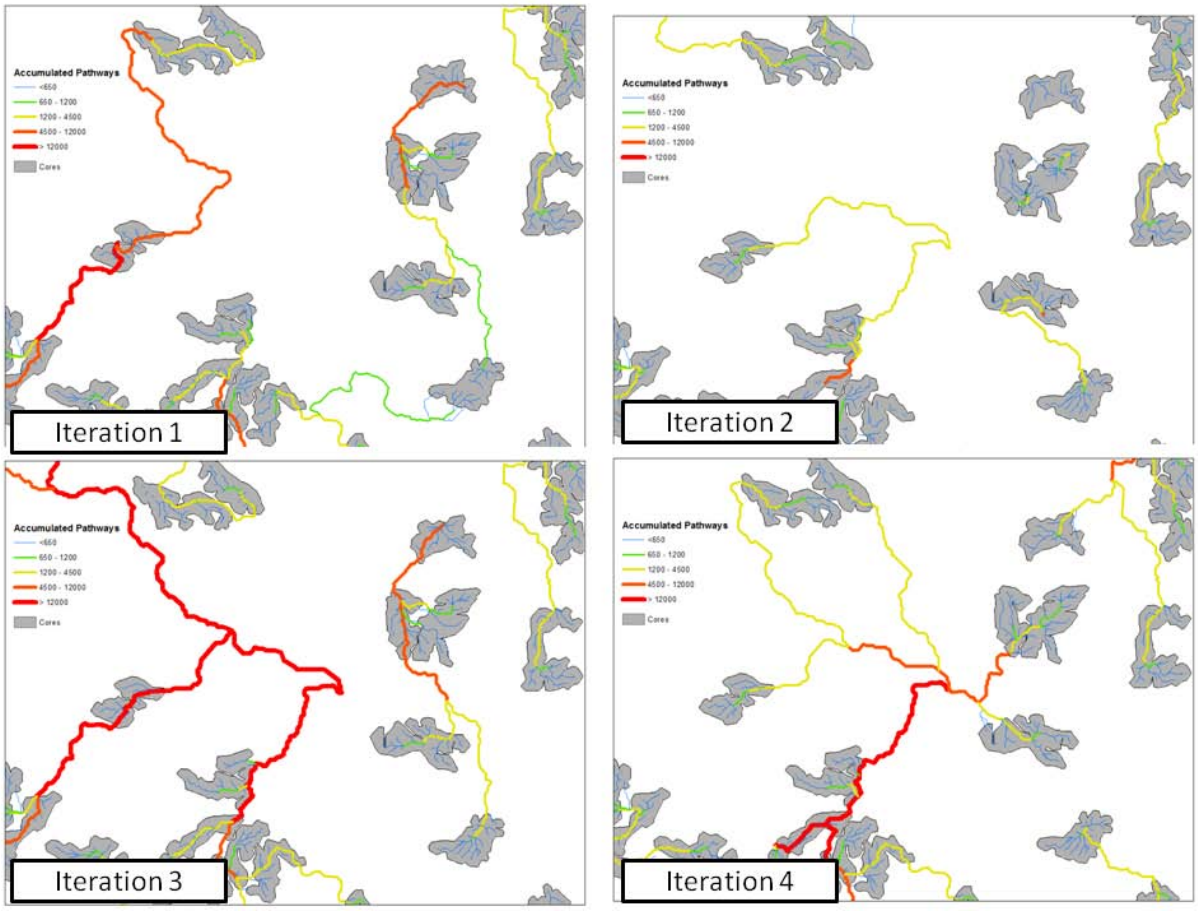

Figure 20 - Accumulated patch area pathways for four different iterations

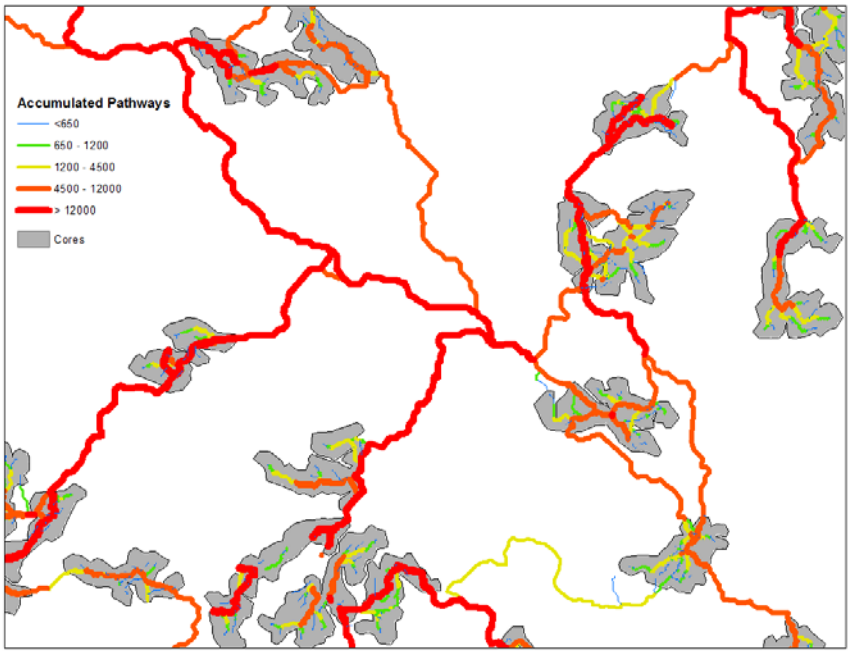

Figure 21 – Final pathways raster based averaged pathways from Figure 11

2. Corridor Cost Raster

The Corridor cost raster represents the average cost of moving through a given corridor from all start locations that are connected to each other. The average cost is calculated by dividing the total cost of moving through the corridor by the number of times the corridor was used in the analysis which usually is less than the number of iterations in the analysis. Figure 15 shows the average cost of a given corridor and with blue tones having low average cost values and red being the highest. This is useful in evaluating corridor importance as well as identifying isolated patches that are connected to high cost corridors.

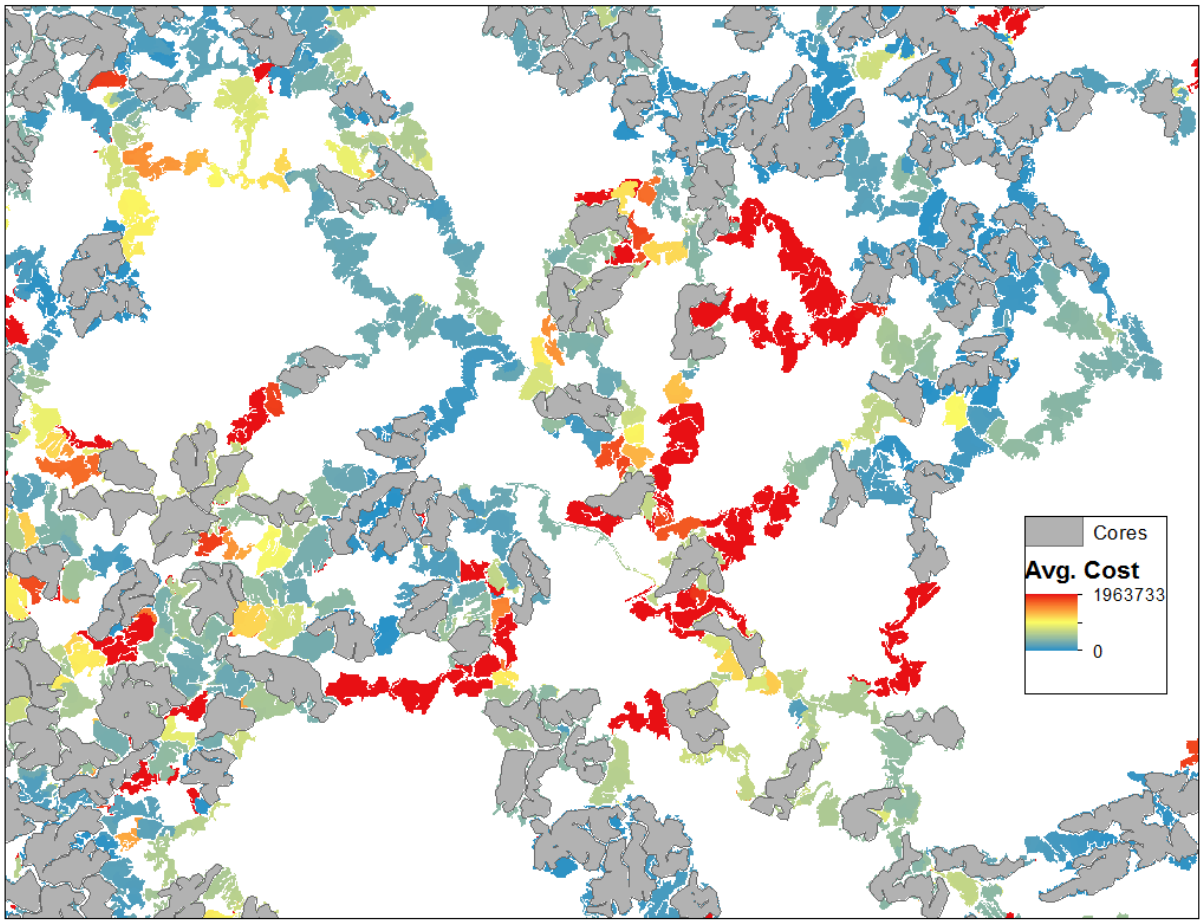

Figure 22 - Average corridor cost from start locations for ten iterations.

3. Movement Potential Raster

The movement potential integrates patch connectivity (pathways), corridor cost, and inter-corridor movement into a single value that ranges between 0 and 1 with one indicating the highest potential for movement. The movement potential integration is a simple metric that ranks pathways (Figure 14), corridor cost (Figure 15) and inter-corridor movement (Figure 6) between 0 and 100 using a cumulative distribution function (CDF) to generate a new raster. The three CDF rasters are

averaged together using a weighting scheme (pathways = 0.3, corridor cost = 0.35, and inter-corridor movement = 0.35). The weighted averaged raster is then normalized between 0 and 1 to generate the final movement potential raster (Figure 16).

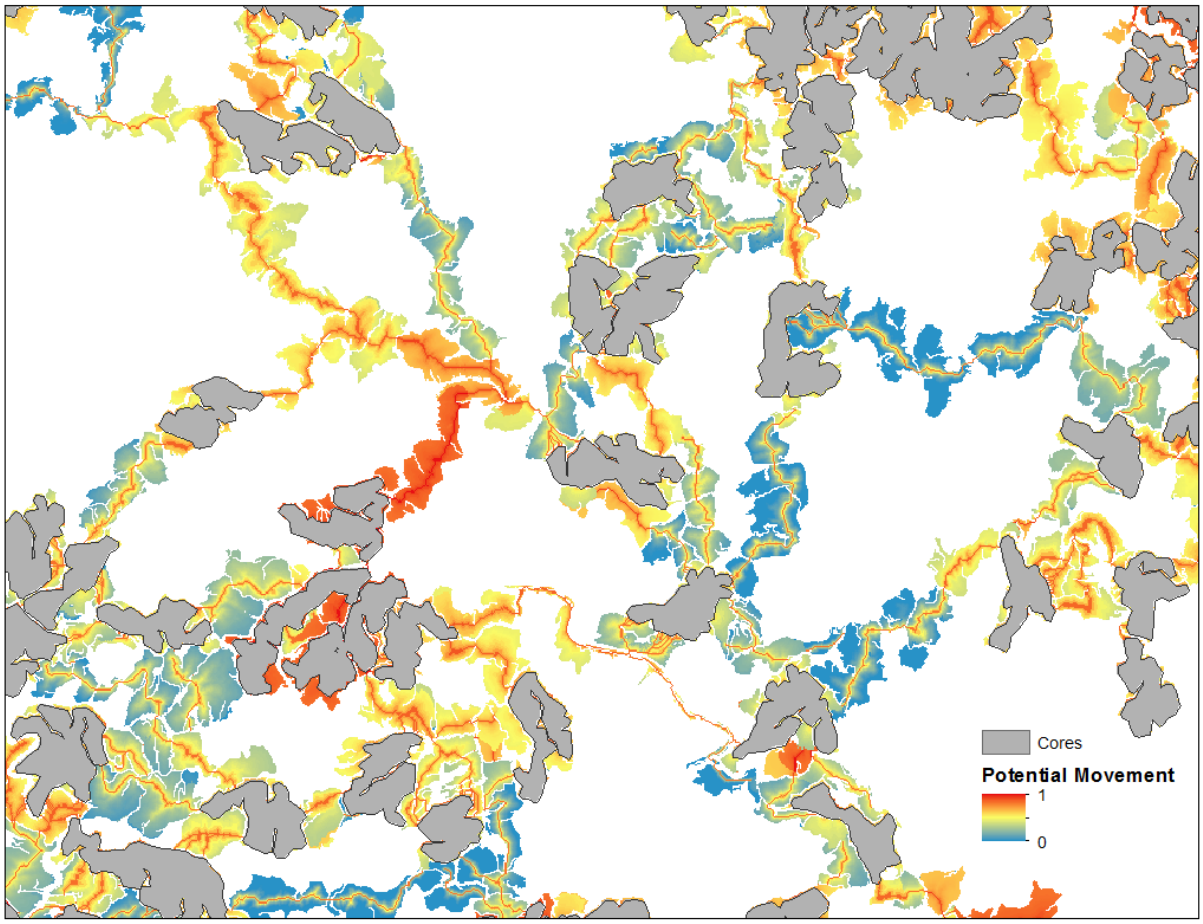

Figure 23 - Movement potential raster ranking pathways and corridors between 0 and 1.

a) Impedance Tables

(1) Forest Impedance

Table 10. Forest Impedance Table

Land Cover Class	Weight	Comments
Presettlement layer opportunities	1	Highly suitable
Forest (all combined)	1	Highly suitable
NLCD 21 - Developed, Open Space	10	Suitable
NLCD 71 Grassland	100	Suitable
NLCD 90 - WoodyWetlands	200	Less suitable
NLCD 52 - Shrub/Scrub	2000	Less suitable
NLCD 95 - Emergent Herbaceaous Wetlands	5000	Less suitable
NLCD 31- Barren Land	10000	Likely not suitable
NLCD 82 - Cultivated Crops	20000	Likely not suitable
US and State Roads	100000	Undesirable
Developed (NLCD and CMAP land use)	100000	Undesirable
Interstate Highways	NoData	Barrier
NLCD 11 - Open Water	NoData	Barrier

<u>Thresholds:</u>
Maximum movement from start locations: 4,000,000
Minimum Pathway Threshold: 1 (default)
Maximum movement around pathways: 38,000
The use of this number was based on the average cost of a cell across the landscape multiplied by a distance of 1Km (approx. 33 cells) and the approximate movement for forest depended small mammals
Number of iterations: 20
Start Location Percentage: 5%
.

(2) Prairie Impedance

Table 11. Prairie Impedance Table

Land Cover Class	Weight (cost)	
Presettlement layer opportunities	-10000	Highly suitable
NLCD 71 Grassland	10	Highly suitable
NLCD 81 - Pasture Hay	10	Highly suitable
NLCD 21 - Developed, Open Space	100	Suitable
NLCD 52 - Shrub/Scrub	100	Suitable
All Wetlands	1000	Less suitable
All Forest	10000	Likely not suitable
NLCD 82 - Cultivated Crops	20000	Likely not suitable
US Highways	100000	Undesirable
Other roads	100000	Undesirable
Developed	100000	Undesirable
Interstate Highways	NoData	Barrier
NLCD 11 - Open Water	NoData	Barrier

<u>Thresholds:</u>

Maximum movement from start locations: 4000000
Minimum Pathway Threshold: 1 (default)
Maximum movement around pathways: 16,000
We constrained this input with a value of 200,000 cost units based on a movement distance of 1 km for wetland species. Again, the assumption is that connectivity is not only linear movement but also suitable or restorable land cover where species can forage.
Number of iterations: 20
Start Location Percentage: 5%

(3) Wetland Impedance

Table 12. Wetland Impedance Table

Land Cover Class	Weight	
Presettlement layer opportunities	1	Highly suitable
AllWetlands	1	Highly suitable
Wetland Layer 6	1	Highly suitable
NLCD 71 Grassland	100	Suitable
NLCD 21 - Developed, Open Space	500	Less suitable
NLCD 11 - Open Water	500	Less suitable
Forest (NLCD 41, 42,43)	1000	Less suitable
NLCD 52 - Shrub/Scrub	5000	Less suitable
NLCD 81 - Pasture Hay	5000	Less suitable
NLCD 82 - Cultivated Crops	10000	Likely not suitable
US and State Highways	100000	Likely not suitable
NLCD 22 - Developed	100000	Likely not suitable
Interstate Highways	NoData	Barrier

Thresholds:

Maximum movement from start locations: 4,000,000
Minimum Pathway Threshold: 1 (default)
Maximum movement around pathways: 20,000
A distance of 400 meters or approximately 14 cells for wetland depended species. The 250,000 value corresponds to the average cost of cells multiplied by 14.

Number of iterations: 20
Start Location Percentage: 5%

F. Chicago Wilderness Green Infrastructure Vision 2.1 LSP Attribute Tree

1 GIV 2.0 Network Characterization Criteria
- 11 Landscapes
  - 111 Woodlands / Forest
    - 1111 Conservation suitability
      - 11111 Core woodland designated areas
        - 111111 INAI woodland/forest sites
        - 111112 T&E species
        - 111113 INPC sites
        - 111114 Audubon Important Bird Areas
        - 111115 City of Chicago Nature & Wildlife sites
      - 11112 Core woodland / forest
        - 111121 Woodland patch size
        - 111122 Oak woodlands (McHenry County)
        - 111123 Location within pre-settlement forest area
        - 111124 High quality mixed forest patches (aerial interpretation)
    - 1112 Restoration suitability
      - 11121 Woodland sites
        - 111211 Woodland patch size
        - 111212 No quality designations
      - 11122 Pre-settlement woodland complexes
        - 111221 Illinois Natural History surveys
        - 111222 Location outside urban mask
      - 11123 Woodland functional connections
        - 111231 Impedance values
        - 111232 Core area locations
  - 112 Prairies / Grasslands / Savannas
    - 1121 Conservation suitability
      - 11211 Core prairies
        - 112111 INAI sites
        - 112112 INPC sites
        - 112113 T&E occurrences - prairie/grassland dependent
        - 112114 Audubon Important Bird Areas
        - 112115 Other known sites (e.g. Midewin, City of Chicago)
      - 11212 Core savannas
        - 112121 INAI sites
        - 112122 T&E occurrences - savanna dependent
        - 112123 Audubon Important Bird Areas
        - 112124 Other known sites (e.g. Midewin, City of Chicago)
      - 11213 Grassland blocks
        - 112131 High ranking grassland sites (LEI)
        - 112132 NLCD grassland/herbaceous block size
        - 112133 Pre-settlement prairie locations
    - 1122 Restoration suitability

11221 Prairie/grassland corridors
112211 Impedance values
112212 Core area locations
11222 Pre-settlement grassland complexes
112221 Illinois Natural History surveys
112222 Location outside urban mask
11223 Pre-settlement savanna complexes
112231 Illinois Natural History surveys
112232 Location outside urban mask
113 Wetlands
1131 Conservation suitability
11311 Core wetland designated areas
113111 INAI sites
113112 T&E species - wetland dependent
113113 INPC sites
113114 Audubon Important Bird Areas
11312 Core wetlands
113121 Wetland size
113122 Wetlands occurrence (e.g. NWI, ADID, Fens)
113123 Presence of canals/ditches (NHD+)
113124 Level of disturbance (roads, development)
1132 Restoration suitability
11321 Wetland corridors
113211 Impedance values
113212 Core area locations
11322 Wetland sites
113221 Wetland size
113222 No quality designations
11323 Wetland complexes
113231 Illinois Natural History surveys
113232 CW Wetlands Task Force - restoration potential
113233 Hydric soils (when no CW data)
113234 Location outside urban mask
114 Streams and Lakes
1141 Conservation suitability
11411 Core lakes and streams
114111 Absence of human-made canals, ditches, streams
114112 INAI Sites
114113 INPC sites
114114 T&E species occurrence - stream/lake dependent
114115 Audubon Important Bird Areas
114116 CW Wetlands Task Force streams - reptile & amphibian
114117 Biological significant and headwater streams
114118 Stable ravines

- 11412 Undeveloped freshwater systems
  - 114121 Location outside urban mask
  - 114122 Location with floodplain and groundwater protection areas
  - 114123 Illinois EPA Phase 2 wellhead protection areas
  - 114124 Illinois Natural History Survey areas
- 11413 Undeveloped NHD+ stream buffer
  - 114131 Proximity to stream
  - 114132 Location outside urban mask
  - 114133 No quality designations
- 1142 Restoration suitability
- 11421 Developed freshwater systems
  - 114211 Ravines in need of restoration
  - 114212 Location inside urban mask
- 11422 Developed NHD+ stream buffer
  - 114221 Proximity to stream
  - 114222 Location inside urban mask

12 Protected Lands, Recreation, and Urban Scale Green Infrastructure

- 121 Protected and managed lands
  - 1211 Forest Preserve Districts
  - 1212 Conservation districts
  - 1213 City, municipal, and county parks and open space
  - 1214 Land trust conservation lands and easements
  - 1215 State owned protected lands
  - 1216 Federally owned protected lands
  - 1217 Agricultural easements
  - 1218 Other open space (from CMAP Land Use)
- 122 Recreational trail and bike network
  - 1221 Existing and planned greenways and multi-use trails (CMAP 2009)
  - 1222 County, municipal, and local recreational trails
- 123 Urban scale green infrastructure features
  - 1231 Site scale green infrastructure features
    - 12311 Green infrastructure sites (e.g. CNT)
    - 12312 Green roofs
    - 12313 Urban tree canopy
    - 12314 Boulevards
    - 12315 Malls and plazas
    - 12316 Combined sewer outflows
  - 1232 Urban and neighborhood open space
    - 12321 Neighborhood open space (e.g. Neighbor Space - Chicago)
    - 12322 Community gardens (e.g. Greencorps sites - Chicago)
    - 12323 Farmers Markets
    - 12324 Campus parks
    - 12325 School grounds
    - 12326 Cemeteries

G. How GIV 2.1 Addresses Climate Change Adaptation

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According to the National Academy of Sciences (2010), climate scientists overwhelmingly agree that the climate is changing and that the changes are largely due to increased levels of carbon emissions into the atmosphere caused by human activities. Climate change refers to major changes in temperature, rainfall, snow, or wind patterns lasting for decades or longer. Global climate change can and has been caused by natural factors in the past including shifts in the Earth's orbit or the circulation of the oceans, volcanic activity or even the intensity of the sun. Today, human activities are changing the climate by increasing the amount of greenhouse gases like carbon dioxide in the atmosphere. Increases in carbon emissions come from burning fossil fuels like oil and gas, deforestation, developing land for farms, cities and roads.

Climate change predictions are based on Atmospheric-Oceanic General Circulation Models (GCMs) combined with projected carbon emissions scenarios and other variables like the amount of sea ice. However, there is uncertainty associated with these predictions because emissions scenarios will vary depending on how humans choose to use energy in the future. There is also uncertainty due to incomplete knowledge of the climate system. These are: equilibrium climate sensitivity (temperature sensitivity to a doubling of carbon dioxide), the rate of ocean heat uptake and the role of historical aerosol forcing (scattering, absorption and reflectance of radiation), and enhancement of cloud formation by fine aerosol particles (Rowlands et al., 2012). While there are limits to the accuracy of future climate projections-long-term projections from GCM's that are based on the average of multiple models and many climate simulations represent robust information for aspects of future climate (National Research Council, 2010). For instance, there is high confidence that the global average temperature will continue to rise; recent work suggests a mid-range greenhouse-gas emissions scenario without mitigation could lead to a warming of between 2.5 and 5.4 °F by the middle of the twenty-first century, relative to 1961–1990 baseline (Rowlands et al., 2012). Projections for future precipitation, however, are more complicated. There is less certainty regarding projections for the directionality and range of annual precipitation, but agreement that the pattern is likely to shift to fewer but more extreme storm events (National Research Council, 2010).

The global grids of the earth associated with these GCMs that are used to predict changes in temperature and precipitation are large and downscaled modeling is required to determine projected changes at a sub-regional level that are relevant to site level conservation planning and land conservation. Regional downscaled models are indeed emerging, as evidenced by analyses from the Intergovernmental Panel on Climate Change in 2007 (Parry et al.) and the US Climate Change Science Program in 2009 (Karl et al.). These analyses suggest that over the next century the Midwestern U.S. will experience an overall increase in temperatures with hotter summers, more frequent, severe and long lasting heat waves, and milder winters with less snow accumulation.

However, the Midwest will also experience more extreme weather events including increases in precipitation in the form of heavy downpours, especially in winter and spring. Such downpours are now twice as likely as they were 100 years ago and extreme weather events are expected to increase by another 50% by the end of the century. Flooding will likely accompany the increased precipitation as evidenced by the two record-breaking floods that have occurred there in the last 15 years (Hayhoe et al., 2009). The impact of flooding and flash flooding in the Midwest will be further magnified by the practice of tile drainage under farmland and the treatment of creeks and streams as regulated drains. The combination of these expected patterns- increased evaporation which is expected to offset the increased precipitation and increased flooding that will likely reduce the amount of water available to recharge groundwater levels- is expected to lead to a drier and warmer environment (Galatowitsh et al., 2009, Chicago Wilderness, 2012).

Agriculture may have short-term benefits from some of these changes such as increased plant growth due to higher carbon dioxide levels, longer growing seasons, and more frost-free days. However, flooding and severe drought-like conditions may occur more frequently leading to decreased soil moisture and less groundwater recharge that can reduce crop productivity and quality (Jablonski et al., 2002; Takle, 2009). Increases in the number and range of pests and diseases are also expected as winters become milder and shorter. These changes will have economic consequences for rural and urban communities that could lead to crop damage and urban heat waves or water shortages, but they will also have associated ecological impacts including increases in insect outbreaks, invasive species, and more thermal stress to coldwater fisheries (Karl et al., 2009).

Climate change is already affecting the aquatic systems of the Upper Midwest. For example, all of the Great Lakes have experienced reduced ice cover during the last several decades. Researchers at NOAA's Great Lakes Environmental Research Laboratory have found that ice cover on the Great Lakes declined 71% between 1973 and 2010 (Wang et al., 2012). During this time, Lake Michigan saw a 77% decline. The decline in ice cover is linked to increasing winter air temperatures over the Great Lakes, which have risen by 2.7 °F in the south, and by 4 - 5 °F in the north. Furthermore, the warming of the lakes exacerbates the ice melt by generating an ice-albedo feedback, where the dark water exposed by melted ice absorbs more sunlight and thus heats more quickly and melts more ice. In light of the decline in ice cover, it is anticipated that areas surrounding the Great Lakes will have heavier lake effect snows, and an increased incidence of warm spring weather.

How these changes may impact lake levels has been an active field of research with multiple approaches being used in modeling this function. Recent models for Lake Michigan, derived from using an energy budget-based approach to adjusting the potential evapotranspiration (PET) instead of using air temperature as a proxy to compute PET, suggest either a smaller decrease in net basin supply and smaller drop in lake levels than using the temperature proxy, or a reversal to increased net basin supply and slightly higher lake levels (Lofgren et al., 2011).

In other words, lake levels are highly variable, making it imperative that we manage and restore our systems to handle that fact.

Because it is hard to predict climate change at local levels, it becomes challenging to plan for natural resources, although some general directions do seem to be emerging. For thousands of years the Upper Midwest has been an ecologically transitional area between prairie and forest and more transition is expected as a result of climate change along this tension zone. Phenological evidence shows some species have already shifted the timing of their use of habitats during the year (Wisconsin Initiative on Climate Change Impacts, 2011). That evidence suggests some species have the ability to make transitions in space and time. However, the natural and human-made barriers to movement that exist like roads, urban areas or even the Great Lakes themselves may limit the ability of species to disperse to new areas, instead favoring invasive species which tend to be more aggressive at colonizing fragmented ecological patches (Galatowitsch et al., 2009).

The recommended response from society to climate change involves two sets of activities: Mitigation and Adaptation. Mitigation activities encompass those attempts to reduce emissions by using less energy or alternative forms of energy that produce fewer emissions of heat trapping gases. Efforts to offset carbon emissions can also count as mitigation and include activities that will sequester more carbon emissions in trees, other vegetation, soils, oceans or even rock. These activities bring attention to the need for societies across the globe to make every effort possible each year to bring down the levels of emissions into the atmosphere that cause global warming by adopting cleaner technologies like solar, wind, geothermal and conserving energy where possible while at the same time increasing the amount of carbon sequestration that occurs on a global scale.

Adaptation is the complementary component of a comprehensive climate change response strategy and includes activities that attempt to adjust or respond to the inevitable changes that are and will continue to occur to the environment caused by global warming. Advocates argue that effective mitigation reduces the need for adaptation, however changes to the climate already put into motion now cannot be reversed in the near future simply by cutting emissions, even if that were feasible, and may extend for 1,000 years (Solomon et al., 2009). Adaptation recognizes that the climate is already changing and increased carbon dioxide levels are the new reality that we must plan for, including anticipated impacts from more severe weather and the effect this will have on both people and nature. Adaptation specifically for wildlife involves planning and taking actions that will allow wildlife to respond to this climate change with viable populations as society takes steps toward mitigation to keep the climate from changing even faster and with even more impacts. Climate change exacerbates the threats that are already on the landscape, but in our rush to mitigate our use of fossil fuels with cleaner energy sources, we are being forced to plan for impacts to wildlife that come from these new technologies such as wind energy turbines and transmission grids.

Evaluating how species are expected to be impacted by climate change by conducting vulnerability assessments or downscaling climate information to be used in climate envelope

models to predict shifts in the ranges of species (Association of Fish and Wildlife Agencies, 2009; United States Fish and Wildlife Service, 2010; Hannah et al., 2007) is an important approach to planning adaptation strategies. These steps are useful, but they each have associated uncertainties. Climate envelope models predict species range shifts based on GCM's and uncertain projected emissions scenarios (Beale et al., 2008; Sinclair et al., 2010); their accuracy at a regional level is at best uncertain. Additionally this type of analysis assumes that climatic data is a good predictor of the ecological changes that a species will face with a changing climate. Depending on the ecological features of a species' niche, some species will respond much as the changes in their climate envelopes suggest that they should, while others will respond more slowly, and still others will face more rapidly changing ecological conditions than the climate models indicate.

Vulnerability assessments which predict a species, habitat or ecosystem's overall vulnerability by estimating its exposure and sensitivity to climate change (Glick et al., 2010; NatureServe, 2010) require extensive expert knowledge or data on species movements and life history that often does not exist. Once a vulnerability assessment or climate envelope model becomes available it must be placed in a spatial context and compared to existing identified conservation priorities in order to be of practical use to adjust land conservation priorities. Conservation biologists and natural resource managers are now engaged in hundreds of vulnerability assessments around the country, but few have been used to modify spatial conservation priorities to date. This species-based approach to climate adaptation planning has obvious limitations. It is not practical to think that all species can be evaluated, nor can responses to climate change be tailored to each species.

A consensus is forming around an approach to adaptation planning that addresses the limitations of these and other tools while still being able to incorporate the best of what they offer. The proposed framework would improve the ability of an ecosystem to resist dramatic changes to habitats; build resilience into the ecosystem to recover from extreme weather events and changes in temperature and precipitation that may cause increased floods, wildfires, insect outbreaks, etc.; and lastly build realignment into our ecosystems through wildlife corridors or other connections through matrix landscape types that allows species to shift their ranges and transition into new areas when the need becomes inevitable (Millar et al., 2007; Galatowitsch et al., 2009). Together this Resistance, Resilience, and Realignment or Transition framework should provide a solid basis to allow species to adapt to climate change. It also supports conserving multiple examples of habitats that support native biodiversity (Groves, 2003). The framework also has the advantage of being able to use existing principles of landscape ecology to map a network of areas for climate change at a larger landscape scale that is important to retain the function of ecosystems to support wildlife.

Patterns of biological diversity, or why certain species are found on the landscape where they are, have much more to do with the geophysical factors such as geology, latitude, and topographic features like elevation rather than just climatic properties like temperature and precipitation. These geophysical factors create different places or niches for wildlife to use and could be the focus of efforts to preserve ecological settings for retaining species diversity

(Anderson et al., 2010; Hunter, 1988; Beier and Brost, 2010). As the climate changes, those geophysical pieces of the landscape will remain static, but the vegetation and associated wildlife species will move, sometimes at different rates and unpredictably. This adaptation planning approach will also tend to identify those places which are currently supporting wildlife populations while also emphasizing the need for ecological corridors to retain the function of those places for future wildlife populations moving into and out of the area. In planning for adaptation to future climate change, a recommended strategy involves protecting and providing ecological connectivity so that species can shift their ranges (Heller and Zavaleta, 2009). The real difference then, compared to previous conservation planning approaches, is that this climate adaptation planning recognizes the ranges of species are no longer static and focuses on saving the settings for wildlife to use and worries less about keeping individual species in place. It is therefore a coarse filter tool designed to identify key pieces of the landscape to create a spatially explicit and ecologically functional network of lands and waters to help wildlife adapt to climate change making it ideal for professionals involved in wildlife habitat protection.

Given the uncertainties in projecting the extent and rate of climate change, the Global Climate Change and Wildlife in North America technical report (Inkley et al., 2004) recommends managing for a range of possible future conditions. This means identifying actions that provide relatively high returns on the conservation investment for a relatively wide range of future climate conditions. These measures are often referred to as “no-regret” strategies, or options that would be justified under all plausible future scenarios, including the absence of human-induced climate change. In 2012, the CW Climate Change task force completed a climate change update of their Biodiversity Recovery Plan- a tool that assists land managers, policy makers and individuals in creating and implementing strategies for biodiversity recovery and adaptation in the region- and it was designed to reflect this conservative principle.

One of the best no-regret strategies for helping species to adapt to a changing climate is to restore or create connectivity on a regional landscape through green infrastructure planning (Lerner and Allen, 2012). Green infrastructure planning uses fundamental principles of conservation biology and landscape ecology (Benedict and McMahon, 2006 and, is consistent with climate adaptation planning, producing well-defined spatial priorities to facilitate adaptation. Green infrastructure planning has been used for years to plan for networks of ecologically functional lands which support biodiversity and other ecosystem services like watershed protection, recreation, and working lands (Mell, 2008). Collectively, the green infrastructure network will incorporate places that build resilience by conserving large habitat blocks and realigning corridors to build connectivity in these landscapes. This connectivity will provide the opportunity for species to respond to climate change by moving through the landscape.

Green Infrastructure planning is consistent with climate adaptation planning because the network design should capture the major ecological settings in the landscape that will allow species to adapt to climate change brought about by increased carbon dioxide in the atmosphere. Vulnerability assessments, downscaled climate models and species envelope

range shift predictions can be used to modify the networks once they are planned or used to test the adequacy of the networks as such information becomes available over time. Green infrastructure networks are comprehensive assessments of biodiversity needs across all taxa in the face of climate change.

This approach can be used to identify those pieces of the landscape which are most relevant to wildlife now in the face of current threats and in the future as the climate changes. It is an approach which can deliver planning for resistance, resilience, and realignment while saving settings and serve as a spatial framework for climate adaptation planning relevant to land conservation efforts.

Given the extensive habitat modification that has occurred in the Midwest over the last 200 years, areas that have remained largely intact are the best places to conserve wildlife. A green infrastructure design for Chicago Wilderness will allow the development of an approach for creating the connectivity between these high quality sites that will allow species to move effectively through the landscape. Without this connectivity, the highly fragmented natural systems of the Midwest will not maintain their diversity in the face of changing conditions over the next few decades.

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