Green Infrastructure Planning – Linking Arkansas Communities

Introduction

The methods outlined here define the steps taken to develop a GIS model for the expression of a Green Infrastructure Network Map for the Green Infrastructure Planning: Linking Arkansas Communities (GIP) grant project executed by Fayetteville Natural Heritage Association in partnership with Beaver Water District and the Arkansas Forestry Commission's Urban Forestry Program funded by the US Forest Service.

The model was developed using ESRI ArcMap 9.3 and is both reproducible and updateable; it is embedded in the Geodatabase: *Network.gdb,* in the toolbox: *Network map toolbox,* and named: *Network Map Model*. In this report, file names are represented in this font: *file name*, and ArcMap tools are in ALL CAPS.

Barbara Elaine Boland, a member of the Fayetteville Natural Heritage Association Board, served as the GIS technician and cartographer for the project and is responsible for its geospatial aspects.

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1.   **Define Study area**
        The study area for was ultimately defined as a simple box 1500m (4921 ft) outside
        an original irregular area that was developed from a combination of natural and
        manmade boundaries. City limits and city planning boundaries of Fayetteville,
        Farmington, Greenland, and Johnson (May, 2008) form the core of an area which
        was extended on the SE to the boundary of the watershed of the West Fork of the
        White River using National Resource Conservation Service 2006 Hydrologic Unit
        Code 12 water basin data. The Illinois River forms part of the boundary on the
        southwest and the line file was extracted from the National Hydrologic Dataset
        dated February 2006. The boundary of the Ozark National Forest Wedington
        Wildlife Management Unit was taken from Cadastral Public Land Boundaries file,
        dated May 2007, from the Arkansas State Highway & Transportation Department.
        All features were confined to the extent of Washington County; the county line file
        was obtained from the Washington County Assessor's Office, May 2008.

2.   **Mapping Parameters**
        Geodatabase Environments were set to standardize projection, cell size, and extent.

2.1.   Projection: all raster and vector files were given a common projection and boundary,
        raster cell size was made consistent with Arkansas Land Use Land Cover imagery,
        2006.

2.2.   Cell size (X, Y):   93.5ft x 93.5ft (28.5m x28.5m) unless stated otherwise
        Number of columns: 1359
        Number of rows: 869
        Boundary: TOP: 676992.595342
            LEFT: 593482.157256   RIGHT: 720548.657256
                        BOTTOM: 595741.095342

2.3.   Projected Coordinate System: NAD_1983_StatePlane_Arkansas_North_FIPS_0301
        Projection: Lambert Conformal Conic
         False Easting: 1312333.33333333
         False Northing: 0.00000000
         Central Meridian: -92.00000000
         Standard Parallel 1:   34.93333333
         Standard Parallel 2:   36.23333333
         Latitude of Origin: 34.33333333
         Linear Unit: Feet US

2.4.   Geographic Coordinate System: D North American 1983
         Datum: North American Datum 1983
         Prime Meridian: Greenwich
         Angular Unit: Degree

3. **Identify & Rank Hubs**

Hubs were identified from three sources: 1) areas designated as highly conservation worthy by a prior study, 2) public lands, and 3) already protected lands. The two types were merged, a minimum size of 100 acres was applied and they were ranked by habitat quality and size. Hub areas less than 100 acres in size were designated as sites.

3.1.   **Hubs from Prior Conservation Assessment**

The prior study used to designate habitat quality for hub delineation is the Urban Forest Conservation Assessment for Fayetteville, Arkansas (UFCA), October 2006. Developed by The Nature Conservancy in partnership with Fayetteville Natural Heritage Association and Arkansas Forestry Commission's Urban Forestry Program, the UFCA is a complex GIS model that ranks ownership parcels for their conservation value in terms of quality of both aquatic and terrestrial habitat, with emphases on forest coverage, absence of man-made structures, and parcel size among other characteristics. The UFCA project report can be found on the Fayetteville Natural Heritage website at: http://www.siteground176.com/~fayettev/pdfs/24.pdf

UFCA aquatic habitat ranking (UFCAA) and terrestrial habitat ranking (UFCAT) files were divided into ten equal classes (1-10). The top two most conservation worthy classes (1 & 2) were selected from both UFCAA & UFCAT then combined.

3.1.1.   *aquatic_ecology_10_class_generalized.shp* clipped and converted to raster named *UFCAA_grid*. *UFCAA_grid* reclassified: RECLASSIFY, Input raster = *UFCAA_grid*, Reclass Field = Value, Reclassification Old\New 1 = 1, 2 = 2, 3-10 = 0, NoData = 0, Output raster = *UFCAA_top2*

3.1.2.   *terrestrial_ecology_10_ class_generalized .shp* clipped and converted to raster named *UFCAT_grid*. *UFCAT_grid* reclassified: RECLASSIFY, Input raster = *UFCAT_grid*, Reclass Field = Value, Reclassification Old\New 1=10, 2=20, 3-10=0, NoData = 0, Output raster = *UFCAT_top2*.

3.1.3.   *UFCAA_top2* and *UFCAT_top2* added together using PLUS tool producing *UFCA_top2*. *UFCA_top2* reclassified: RECLASSIFY, Input raster = *UFCA_top2*, Reclass Field = Value, Reclassification Old\New 0 = NoData, 1-22 = 1-22, NoData = NoData, Output raster = *UFCA_Hubs_rcls*. Selected/Checked box for "Change missing values to NoData"

3.1.4.   Used REGION GROUP tool on *UFCA_Hubs_rcls* to group contiguous domains: REGION GROUP, Input raster = *UFCA_Hubs_rcls*, Output raster = *Hubs_UFCA_each*, Number of neighbors to use = eight, Zone grouping method = Cross. Selected/Checked box for "Add link field to output".

3.1.5.   RECLASSIFY, Input raster = *Hubs_UFCA_each*, Reclass Field = VALUE Old\New 1-110 = 20, NoData = 0, Output raster = *Hubs_UFCA*.

3.1.6.   Use SINGLE OUTPUT MAP ALGEBRA tool with a conditional statement (CON): set RASTER CALCULATOR extent to box_stpl to give *Hubs_UFCA* full study area extent: Map Algebra Statement = CON (ISNULL (*Hubs_UFCA*), 0 (*Hubs_UFCA*)) i.e. if the condition is that the value of *Hubs_UFCA* is null then give it the value 0, if it is not null then give it the *Hubs_UFCA* value, Output raster = *Hubs_box_UFCA*.

3.2.   **Hubs from Public Lands**
Public lands held by any level of government were taken from a file provided by the Arkansas Highway and Transportation Department and include: city parks, county parks, National Forests, public use areas, Recreation Areas, State Parks, and Wildlife Management Areas within the study area.

3.2.1.   *CADAS_PUBLIC_LAND_BOUNDARIES_AHTD_poly.shp* projected, clipped, and output to raster as: *public_lands_grid*.

3.2.2.   Used REGION GROUP tool to aggregate contiguous domains: Number of neighbors to use = eight, Zone grouping method = within, Add link field to output = checked, output as: *public_lands_rgrp*.

3.2.3.   RECLASS *public_lands_rgrp*: Reclass field = VALUE, old values: 1-67= 200, NoData = 0, output as: *Hubs_pub_land*.

3.3.   **Hubs from Protected Lands**
Protected lands were garnered from files obtained from the City of Fayetteville and include one Army Corps of Engineers wetland mitigation site, conservation easements and land trust holdings.

3.3.1.   Three files of conservation easements and land trust holdings within Fayetteville boundaries were combined using UNION tool: Input features = *Consv_ease.shp*, *trust_prop.shp*, and *wet_mit_ACOE.shp*, JoinAttributes = ONLY_FID, gaps allowed = checked, output feature class: *protected_land.shp*, and converted to raster: *protected_grid*.

3.3.2.   REGION GROUP tool used on *protected_grid*: number of neighbors to use = eight, zone grouping method = Cross, output raster = *Hubs_protected*.

3.3.3.   RECLASS *Hubs_protected* to be able to add to other hubs: Reclass field = VALUE, Old value: 1-10 = 2, NoData = 0, output raster = *Hubs_protect*.

3.3.4.   Use SINGLE OUTPUT MAP ALGEBRA tool with a conditional statement (CON): set RASTER CALCULATOR extent to box_stpl to give *Hubs_protect* full study area extent: Map Algebra Statement = CON (ISNULL (*Hubs_protect*), 0 (*Hubs_protect*)) i.e. if the condition is that the value of *Hubs_protect* is null then give it the value 0, if it is not null then give it the *Hubs_protect* value, output as *Hubs_box_protect*.

3.4.   **Combine Hubs**

3.4.1.   Using SINGLE OUTPUT MAP ALGEBRA: Map Algebra expression: *Hubs_box_protect* + *Hubs_box_UFCA* + *Hubs_pub_land*, output raster: *Hubs*.

3.4.2.   RECLASS *Hubs*: VALUE Old value: 0 = NoData, 2-220 = 1, NoData = NoData, to create: *Hubs_rcls*.

3.4.3.   REGION GROUP tool used on *Hubs_rcls*: number of neighbors to use = eight, zone grouping method = Within, Add link field to output: checked, to create: *Hubs_rgrp*.

3.4.4.   Reclassify *Hubs_rgrp* twice to isolate hubs both larger than 100 acres and smaller than 100 acres.

3.4.4.1.   Larger than 100 acres: RECLASS *Hubs_rgrp*: Reclass field: COUNT, old value: 1-499 = NoData, 500-150533 = 1, NoData = NoData, to create: *Hubs_gt100acres*.

3.4.4.2.   Hubs smaller than 100 acres: See section 6.2 below for processing of site data.

4.   **Identify Cores**
         Three types of cores were designated by the GIP Environmental Working Group: Upland forest, Wetland/Prairie/Savannah, and Streams.

4.1.   **Upland Forest cores**
         Upland forest cores were developed from Land Use Land Cover 2006 imagery at the direction of the GIP Environmental Working Group, Upland Forest Subcommittee. Virtually all forest in the study area is oak hickory upland forest, although there are a few small patches of lowland forest/forested wetland that have been included as Sites (see section 6.1 below). Core size for interior forest areas was designated to be at least 20 acres based upon the minimum area that will support a varied population of birds. Following the guidelines of Maryland's Green Infrastructure Assessment (Chapters 4 & Appendix B 2.2.4, http://www.dnr.state.md.us/greenways/gi/gidoc/gidoc.html) a 300ft buffer from all paved roads was used to isolate interior forest areas.

4.1.1.   *IMAGE.LULC_FALL_CAST_2006.tif* was projected, extracted by mask to study area, output as: *LULC*.

4.1.2.   *LULC* was reclassified: Reclass field = VALUE, old value: 11-99 = NoData, 100 (forest) = 1, 101-210 = NoData, NoData = NoData, to create: *Forest_LULC*.

4.1.3.   Define interior forest areas: find suitable forest areas by intersecting them with areas without paved roads and apply a buffer of 300 ft from any paved road.

4.1.3.1.   *TRANSP_ROADS_ALL_AHTD_line.shp* projected, clipped, and converted to raster: *Road_grid*.

4.1.3.2.   RECLASSIFY *Road_grid*: Reclass field = VALUE: value changes in table below, output as *not_paved*.

Road type	Old Value in *road_grid*	New value in *not_paved*
US Highway HTB	1	NoData
County road unpaved	2	1
County road graded drained	3	1
Miscellaneous roads (mostly paved)	4	NoData
County road paved	5	NoData
City street paved	6	NoData
City street unpaved	7	1
County road unimproved	8	1
State Highway HTB	9	NoData
Interstate Highway	10	NoData
State highway LTB	11	NoData
Not roads	NoData	1

4.1.3.3.   Use SINGLE OUTPUT MAP ALGEBRA tool to isolate suitable forest areas: Map Algebra expression: *Forest_LULC* x *not_paved*, output = *Forest_suit*.

4.1.3.4.   Define 300 ft buffer around suitable forest areas by defining unsuitable areas, measuring out from them and reclass 300 ft as a buffer, leaving interior forest cores.

4.1.3.4.1.   Unsuitable forest areas: Reclassify *Forest_suit*: Reclass field = VALUE, old Value: 1 = NoData, NoData = 1, output = *not_forest*.

4.1.3.4.2.   Measure distance from edge of *not_forest*: EUCLIDEAN DISTANCE tool to create file: *forest_Euclid_dist*, output cell size = 93.5 ft, output direction raster = null.

4.1.3.5.   Create 300 ft buffer by using RECLASS on *forest_Euclid_dist*: Reclass field = VALUE, old value: 0-300.000000 = NoData, 300.000001-5330.3203125 = 1, NoData = NoData, output as: *forest_300ftint*.

4.1.3.6.   Apply REGION GROUP to get contiguous domains of forest input *Forest_300ftint*: number of neighbors to use = eight, zone grouping method = within, check add link field to output raster: *upl_forest*.

4.1.3.7.   Define forest cores by size: Use EXTRACT BY ATTRIBUTE on *upl_forest*: where clause = COUNT ≥ 100 pixels (100 pixels = 100 (93.5ft x 93.5ft) = 8742.25ft^2 x 1acre /43,560ft^2 = 20.007 acres) to create file: *upl_forest_cores*.

4.1.3.8.   Reclassify *upl_forest_cores:* Reclass field = VALUE, old values: 2-712 = 1, NoData = 0, output as forest_cores.

4.2.   **Wetland/Prairie/Savannah Cores**
Wetland/Prairie/Savannah polygons were developed by heads-up digitization of areas identified by the GIP Environmental Working Group, Wetland/Prairie/ Savannah Subcommittee. There are 5 types of wetland/prairie/savannahs recognized: (1) oak barrens (2) perennial forested wetlands (3) seasonal wetlands (4) upland prairie (former) and (5) wet prairie; all types were given equal consideration as cores regardless of size due to habitat rarity.

4.2.1.   *Prairie_Grassland.shp* projected to *Prairie_prj*.

4.2.2.   *Prairie_prj* Make file full extent of study area.

4.2.2.1.   Use CREATE CONSTANT RASTER tool: Output raster = *Box_Prairie*, Constant Value = 0, Output data type = integer, output cell size = 93.5, output extent: same as *Box_stpl*.

4.2.2.2.   APPEND: Input datasets = *Prairie_prj*, target dataset = *Box_Prairie*, Schema type = NO_TEST.

4.2.3.   Converted = *Box_Prairie*, to raster file: Field = Id, output raster = *Prairie_types*, output cell size = 93.5.

4.2.4.   Reclassify *Prairie_types*: Reclass field = VALUE, old value: 0 = 0, 1-5 = 100, NoData = 0, output as: *prairie_cores*.

4.3.   **Aquatic Cores**
Aquatic core definitions were based on two sources: 1) recommendations of the GIP Environmental Working Group, Streams Subcommittee to include streams with a 2nd order or higher designation and 2) State of Maryland Detailed GIS procedures for inclusion of named lakes and reservoirs. Flood zones or 100 feet buffer (whichever was greater) applied to all.

4.3.1.   Identify 2nd order and higher streams and buffer them with 100 ft riparian zone.

4.3.1.1.   *WATER_STREAM_ORDER_ADEQ_LINEZ.shp* projected, clipped, and converted to raster, output as: *stream_order_grid*.

4.3.1.2.   Reclassify *stream_order_grid* to isolate 2nd order and higher streams: Reclass field = VALUE, 0-1 = NoData, 2-6 = 2-6, NoData = NoData, output as *stream_order2up*.

4.3.1.3. Measure distance from stream using EUCLIDEAN DISTANCE tool on *stream_order2up*: output raster = *stream_Euclid_dist*, output cell size = 93.5, output direction raster = null.

4.3.1.4. Reclassify *stream_Euclid_dist*, to create 100 ft buffer: Reclass field = VALUE, old values: 0-100 = 1, 100.000001–13034.11425 = 0, NoData = 0, output raster = *stream_buff*.

4.3.2. Isolate named lakes and buffer them with a 100 ft buffer

4.3.2.1. *WATER_NHD_HIGH RES_WATERBODY.shp* projected, clipped, and converted to raster file: *waterbody_grid*.

4.3.2.2. Reclassify *waterbody_grid*: Reclass field = GNIS_NAME, 0 = NoData, all named lakes = 1, NoData = NoData, output raster = *Lakes*.

4.3.2.3. Measure distance from lakes using EUCLIDEAN DISTANCE tool on *Lakes*: output raster = *lakes_Euclid_dist*, output cell size = 93.5, output direction raster = none.

4.3.2.4. To buffer lakes, reclassify *lakes_Euclid_dist*: Reclass field = VALUE, old values: 0-100 = 1, 100.000001-40398.60156 = 0, NoData = 0, output raster = *lakes_buff*.

4.3.3. Develop flood zones layer

4.3.3.1. *WaCo_flood_zones2009.shp* clipped and converted to raster file: *flood_zone_grid*.

4.3.3.2. Reclassify *flood_zone_grid*: Reclass field = VALUE, old values: 1-813 = 10, NoData = 0, output raster = *flood_zone*.

4.3.4. Combine all aquatic core types
Combine buffered lakes and stream with flood zone files using SINGLE OUTPUT MAP ALGEBRA tool: Map Algebra expression: *flood_zone* + *lakes_buff* + *stream_buff*, output raster = *aqua_cores*.

4.4. **Combine Core Types**

4.4.1. Reclassify core files so it is possible to tell if they are aquatic, prairie, or upland forest or a combination.

4.4.1.1. Reclassify *upl_forest_cores*: Reclass field = VALUE, old values: 2-712 = 1, NoData = 0, output raster = *forest_cores*.

4.4.1.2. Reclassify *prairie_types*: Reclass field = VALUE, old values: 0 = 0, 1-5 = 100, NoData = 0, output raster = *prairie_cores*.

4.4.1.3. Reclassify *aqua_cores*: Reclass field = VALUE, old values: 0 = 0, 1-12 = 10, NoData = 0, output raster = *aquatic_cores*.

4.4.1.4. Combine cores using SINGLE OUTPUT MAP ALGEBRA tool: *forest_cores* + *prairie_cores* + aquatic_cores , output raster = *cores*.

4.4.2. Sort cores by size

4.4.2.1. Reclassify *cores* reclass field = VALUE, old values: 0 = NoData, 1-111 = 1, NoData = NoData, output raster = *cores_all*

4.4.2.2. Use REGION GROUP tool to isolate contiguous core areas: input raster = *cores_all*, number of neighbors to use = eight, zone grouping method = within, output raster = *cores_rgrp*.

4.4.2.3. Reclassify *cores_rgrp* twice to create layers of cores greater than 20 acres and cores less than 20 acres in size.

4.4.2.3.1. Use RECLASS tool: input raster = cores_rgrp, reclass field = COUNT, old values: 1-99 = NoData, 100-148708 = 1, NoData = NoData, output raster + cores_gt20acres.

4.4.2.3.2. Cores smaller than 20 acres: See section 6.2 below for processing of site data

5. **Impedances**
This study lacked the data and expertise to define corridors in the most ideal manner, i.e., based upon habitat needs of unique local species. However, that is not an unusual situation based upon review of several Green Infrastructure case studies, and Fischer (2001) gives this advise, "We cannot wait to have all the 'answers' and scientific information – we must accept that we need more knowledge but cannot wait to establish networks of corridors." The State of Maryland's Green Infrastructure Assessment that has been relied upon heavily here even says that "Ideally, these impedances (corridor definition parameters) would be based on actual data." General guidelines can be used quite effectively to delineate a first pass at corridors that have both validity and utility; and corridor definition can be refined when more data become available.

The technical execution of a corridor assessment requires the development of impedance layers that represent the degree of difficulty that wildlife would experience crossing certain types of terrain.

5.1.   **Impedance Definitions**
            Impedance layers were created for several forms of impedance: land cover, riparian
            forest, interior forest, proximity to urban development (both high and low intensity),
            roads and bridges, slope, hubs, and cores.

5.1.1.   **Land Cover Impedance**
            Cells with urban coverage are considered unsuitable for wildlife corridors. Values
            were along the lines of Maryland's Green Infrastructure Assessment, Land cover
            impedance values (Appendix B, 4.1.4.1.2)

5.1.1.1.   Convert Land Use Land Cover to impedance layer.
            Reclassify *LULC* (2006): Reclass field = VALUE, old values per table below, output
            imp_LULC.

LULC class definition	Old value VALUE = LULC class number	New value VALUE = Impedance value
Urban, low intensity (1)	11	5000
Urban, high intensity (2)	13	5000
Barren	31	150
Water	41	150
Herbaceous/woody transitional	51	150
Forest, unclassed	100	50
Soybeans	201	250
Bare soil/Seedbed	208	150
Warm season grasses	209	150
Cool season grasses	210	150
NoData	NoData	0

5.1.2.   **Riparian Forest Impedance**
            Reduce impedance of forest cells adjacent to water based on Maryland's Green
            Infrastructure Assessment, Riparian forest impedance (Appendix B, 4.1.4.3.)

5.1.2.1.   Reclassify *stream_order_ grid*: Reclass field = VALUE, 0-6 = 1, NoData = NoData, output
            raster = *imp_strm_notstrm*.

5.1.2.2.   Compute distance from stream using EUCLIDEAN DISTANCE tool on *imp_strm_notstrm*:
            output raster = *imp_strm_euclidist*, output cell size = 93.5, output direction raster =
            null.

5.1.2.3.   Reclassify *imp_strm_euclidist*: reclass field = VALUE, old values: 0-98.499999 = 1, 98.5-
            6380.646973 = 0, NoData = 0, output raster = *imp_strm_100ftbuff*.

5.1.2.4.   Overlay buffered streams with forest using PLUS tool: Input raster = *imp_strm_100ftbuff,* Input raster + *Forest_LULC*, output raster = *imp_strm_forest*.

5.1.2.5.   Subtract 25 from impedance of forest cells adjacent to water by reclassifying *imp_strm_forest:* reclass field = VALUE, old values: 1 = 0, 2 = -25, NoData = 0, output raster = *imp_rip_forest*.

5.1.3.   **Interior Forest Impedance**
Compensate for the higher value of interior forest as habitat by subtracting 13 from impedance if forest is at least 300 ft from the edge based on Maryland's Green Infrastructure Assessment, interior forest impedance (Appendix B, 4.1.4.4.)

5.1.3.1.   Reclassify existing internal forest file: *forest_300ftint*: reclass field = VALUE, old values: 1= -13, NoData = 0, output raster = *imp_int_forest*.

5.1.4.   **Proximity to Urban Development Impedance**
Urban development is the source of many kinds of disturbance: human disturbance, noise, harassment of wildlife by pets, pollution, runoff, microclimate changes, exotic species, etc. Maryland's Green Infrastructure Assessment, proximity to urban development impedance (Appendix B, 4.1.4.5.) calculates disturbance effect decreasing with the inverse of distance from the source.

5.1.4.1.   Isolate high intensity development

5.1.4.1.1.   Reclassify *LULC*: Reclass field = VALUE, old values: 11 = NoData, 13 = 1, 31-210 = NoData, NoData = NoData, output raster = *imp_LULC_urbhigh*.

5.1.4.1.2.   Measure Euclidean distance on *imp_LULC_urbhigh*: output raster = *imp_urbhigh_euclidist*, cell size = 93.5, output direction raster = null.

5.1.4.1.3.   Reclassify *imp_urbhigh_euclidist* along lines of Maryland's Green Infrastructure Assessment (Appendix 4. Section 4.1.4.5.3) in table below, raster output = *imp_urbhigh*.

Distance (cells = 93.5 ft)	Distance (ft)	Disturbance intensity	Impedance value
0	0 – 93.4999999	2000	2000
1	93.5 – 131.999999	1000	950
√2	132 – 186.999999	568	518
2	187 – 208.999999	262	212
√5	209 – 299.999999	184	134
	300 - max	50	0
		NoData	0

5.1.4.2.   Isolate low intensity development.

5.1.4.2.1. Reclassify *LULC*: Reclass field = VALUE, old values: 11 = 1, 13-210 = NoData, NoData = NoData, output raster = *imp_LULC_urblow*.

5.1.4.2.2. Measure Euclidean distance on *imp_LULC_urblow*: output raster = *imp_urblow_euclidist*, cell size = 93.5, output direction raster = null.

5.1.4.2.3. Reclassify *imp_urblow_euclidist* along lines of Maryland's Green Infrastructure Assessment (Appendix 4. Section 4.1.4.5.5) in table below, raster output = *imp_urblow*.

Distance (cells = 93.5 ft)	Distance (ft)	Disturbance intensity	Impedance value
0	0 – 93.4999999	1000	1000
1	93.5 – 131.999999	500	450
√2	132 – 186.999999	284	234
2	187 – 208.999999	131	81
√5	209 – 299.999999	92	42
	300 - max	50	0
		NoData	0

5.1.4.3.   Combine urban impedances by selecting the maximum value for each cell. Use SINGLE OUTPUT MAP ALGEBRA tool: Map Algebra expression: MAX (*imp_urbhigh*, *imp_urblow*), output: *imp_urban*.

5.1.5.   **Road Impedance**
Following suggested impedance values in Maryland's Green Infrastructure Assessment (Appendix 4. Section 4.1.4.6.), primary state roads and interstate highways are significant barriers (5000), secondary state roads provide less of an impedance but still significant (1000), county roads (500), unpaved roads are not considered an impedance (0).

5.1.5.1.   Reclassify *Road_grid*:reclass field = ROAD_TYPE, old values in table below, output raster = *imp_road*.

Old values: ROAD_TYPE	New values
US Highway HTB	5000
County road umpaved	0
County road graded drained	0
Miscellaneous roads	0
County road paved	500
City street paved	0
City street unpaved	0

County road unimproved	0
State Highway HTB	5000
Interstate Highway	5000
State Highway LTB	1000
NoData	0

5.1.5.2.   Bridges provide less impedance than roads (300). Since the digital data for bridges is in vector point data type format, buffer the points by 150 ft.

5.1.5.2.1. The National Bridge Database Region 6 file: *Region6.shp* was projected, clipped and converted to raster as: *bridg_grid_pt*.

5.1.5.2.2. Measure the Euclidean distance from the bridge points: output distance raster = *bridge_euclidist*, cell size = 93.5, output direction raster = null.

5.1.5.2.3. Reclassify *bridge_euclidist*: reclass field = Value, old values: 0-150 = 1, 150.000001-49484.38281 = 0, NoData = 0, output raster = *bridge_buff*.

5.1.5.2.4.   Aggregate pixels for each bridge using REGION GROUP tool: output raster = *bridge_buff_rgrp*, number of neighbors to use = eight, zone grouping method = within.

5.1.5.2.5. Reclassify *bridge_buff_rgrp:* reclass field = COUNT, old values: 9, 12, 18, 21 = 300, 1180458 = 0, NoData = 0, output raster = *imp_bridges*.

5.1.5.2.6. Combine road and bridge impedances using PLUS tool: input raster = *imp_roads*, input raster = *imp_bridges*, output raster = *imp_rd_bridge*.

5.1.5.2.7. Reclassify *imp_rd_bridge* to reduce impedances everywhere bridges occur (can tell by value having a component of 300). Reclass field = VALUE, old values in table below, output raster = *imp_road_bridge*.

Old values	New values
0	0
300	300
500	500
1000	1000
1300	300
5000	5000
5300	300
NoData	0

5.1.6.   **Slope Impedance**

Steep slopes can be an impediment to land-bound wildlife movement, valley floors and ridgelines offer easier traverse.

5.1.6.1. Use SLOPE tool on *box_elev*: output raster = *box_slope*, output measurement = percent_rise, Z factor = 1.

5.1.6.2. Reclassify *box_slope*: reclass field = VALUE, old values/new values in table below, output raster = *imp_slope*.

Old values (percent slope)	New values
0 – 8	0
9 – 15	2
16 – 25	5
26 – 29.971493	10
NoData	0

5.1.7. **Hub iImpedance**
Hubs were defined from high value aquatic and terrestrial habitat, from protected lands, and from public lands. Hubs were ranked by habitat quality, by source, and by size; combined and converted into a single impedance layer.

5.1.7.1. Rank hubs by habitat quality
UFCAA & UFCAT class rankings 1 & 2 were given unique values so that when the files were added together it would be apparent what pixels contained what habitat types. For instance, class 11 pixels are both ranked 1 for aquatic and terrestrial habitat conservation worthiness; see table below.

Class value in *UFCA_top2*	UFCA Aquatic rank	UFCA Terrestrial rank	Class value in *Hubs_rank_UFCA*
0	0	0	0
1	1	0	3
2	2	0	3
10	0	1	3
11	1	1	1
12	2	1	2
20	0	2	3
21	1	2	2
22	2	2	2
NoData	NoData	NoData	NoData

Reclassify *UFCA_top2*: reclass field = VALUE, old values = left column above, new values = right column of table above, output raster = *Hubs_rank_UFCA*.

5.1.7.2. Rank Hubs by size
Reclassify *Hubs_gt100acres*: reclass field = COUNT, old values divided into three groups by natural breaks: 514-6547 = 3, 8456-22153 = 2, 140922-150533 = 1, NoData = NoData, output raster = *Hubs_rank_size*.

5.1.7.3. Rank Hubs by source
Hub sources were coded (Section 3. above) such that protected lands = 2, UFCA areas = 20, and public lands = 200. Ranking was based on the ideas that protected lands would provide lower impedance than the other two sources based upon more favorable management, yet UFCA lands have a habitat quality edge over public lands; also combined sources were deemed more valuable than single sources.

Reclassify *Hubs*: reclass field = VALUE, old values: see table below, output raster = *Hubs_rank_source*.

Old values: *Hubs*	New values: Hubs_rank_source	Class description
0	0	0
2	1	Protected land
20	2	UFCA areas
22	1	Protected & UFCA areas
200	3	Public land
220	2	Public land & UFCA area
NoData	0	NoData

5.1.7.4. Combine ranking files for hubs using SINGLE OUTPUT MAP ALGEBRA tool: *Hubs_rank_size + Hubs_rank_source + Hubs_rank_UFCA*, output raster = *Hubs_rank_score*.

5.1.7.5. Score hubs using RECLASSIFY on *Hubs_rank_score* into 3 categories such that higher combined scores out of 9 is better ranking: reclass field = VALUE, old values: 3 = 3, 4-6 = 2, 7-9 = 1, NoData = NoData, output raster = *Hubs_rank*.

5.1.7.6. Maryland's Green Infrastructure Assessment (Appendix 4. Section 4.1.4.9.-4.1.4.10.1) suggests calculating separate impedances for hubs and for protected lands, they have been combined here.

Reclassify *Hubs_rank*: reclass field = VALUE, to make *imp_Hubs*: reclass field = VALUE, old values: 1 = -11, 2 = -4, 3 = -2, NoData = 0, output raster = *imp_Hubs*

5.1.8. **Core Impedance**
Decrease the impedance in core areas based on their sources. Maryland's Green Infrastructure Assessment (Appendix 4. Section 4.1.4.12.) suggests reducing impedance values within core areas to 0. Not finding their methodology workable,

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values were devised that would compensate for the highest possible impedance values from all other sources, insuring that core areas would have lowest impedance.

Reclassify *cores*: reclass field = VALUE, old values in table below, output raster = *imp_cores*.

Old values in: *cores*	New value in: *imp_cores*	Source of cores
0	0	NoData
1	1	Forest cores
10	3	Aquatic cores
11	1	Forest & Aquatic cores
100	3	Prairie cores
101	2	Prairie & Forest cores
110	2	Prairie & Aquatic cores
111	1	Forest, Aquatic & Prairie cores
NoData	0	NoData

5.2.   **Combine All Impedance Layers into One Layer**

5.2.1.   Used SINGLE OUTPUT MAP ALGEBRA tool: Map Algebra expression = (*imp_LULC + imp_rip_forest + imp_urban + imp_road_bridge + imp_int_forest + imp_Hubs + imp_slope + imp_cores),* output raster = *imp_combo*.

5.2.2.   Reclassify *imp_combo*: reclass field = VALUE, old values change only NoData = 0, output raster = *imp_all*.

6.   **Corridor Development**
Corridor development is a computationally intensive process. In the interest of expediting corridor assessment, a selection of the largest hubs was linked.

6.1.   **Isolate Six Largest Hubs**:

6.1.1.   REGION GROUP tool used on *Hubs_rank*: output raster = *Hubs_rank_rgrp*, Number of neighbors to use = eight, Zone grouping method = Cross, Add link field to output is checked.

6.1.2.   EXTRACT BY ATTRIBUTE used six times to isolate Hubs : Input raster = *Hubs_rank_rgrp*, Where clause: value = 9, 17, 6, 1, 19, 24, Output rasters: *Hub_9, Hub_17, Hub_6, Hub_1, Hub_19, Hub_24*

6.1.3.   Determine "costdistance" between each of the six hubs: used COST DISTANCE tool six times: Input rasters or feature source data = *Hub_9, Hub_17, Hub_6, Hub_1, Hub_19, Hub_24*, Input cost raster = *imp_all*, Output distance rasters = *CostDist_9, CostDist_17, CostDist_6, CostDist_1, CostDist_19, CostDist_24*, Maximum distance = Null, Output backlink raster = *Costbacklink_9, Costbacklink_17, Costbacklink_6, Costbacklink_1, Costbacklink_19, Costbacklink_24*

6.2.   **Define Corridors**
Determine "costdistance" between each of the six hubs: used COST DISTANCE tool six times: Input rasters or feature source data = *Hub_9, Hub_17, Hub_6, Hub_1, Hub_19, Hub_24*, Input cost raster = *imp_all*, Output distance rasters = *CostDist_9, CostDist_17, CostDist_6, CostDist_1, CostDist_19, CostDist_24*, Maximum distance = Null, Output backlink raster = *Costbacklink_9, Costbacklink_17, Costbacklink_6, Costbacklink_1, Costbacklink_19, Costbacklink_24*

6.2.1.   Corridors connecting selected hubs were generated using three processes: CORRIDOR, EXTRACT BY ATTRIBUTE, RECLASS. Values were determined by visual inspection of hubs and least cost pathways overlaid on cost distance. Minimum values were used to just maintain connectivity. The Maryland Green Infrastructure Assessment refined corridors to a 1000ft minimum but no minimum width was applied here.

6.2.1.1.

CORRIDOR		
Input cost distance raster 1	Input cost distance raster 2	Output raster
CostDist_6	*CostDist_9*	*Corr_69*
CostDist_17	*CostDist_6*	*Corr_176*
CostDist_1	*CostDist_9*	*Corr_19*
CostDist_9	*CostDist_19*	*Corr_919*
CostDist_1	*CostDist_6*	*Corr_16*
CostDist_6	*CostDist_19*	*Corr_619*
CostDist_1	*CostDist_24*	*Corr_124*
CostDist_19	*CostDist_24*	*Corr_1924*

EXTRACT BY ATTRIBUTES		
Input raster	Where clause: value < minimum for connectivity	Output raster
Corr_69	value < 4300000	*Corr_6to9*
Corr_176	value < 2490000	*Corr_17to6*
Corr_19	value < 900000	*Corr_1to9*
Corr_919	value < 3100000	*Corr_9to19*
Corr_16	value < 6000000	*Corr_1to6*
Corr_619	value < 1020000	*Corr_6to19*
Corr_124	value < 22000	*Corr_1to24null*
Corr_1924	value < 10000	*Corr_19to24null*

RECLASS				
Input raster	Reclass field	Reclassification		Output raster
		Old values	New values	
Corr_6to9	Value	4193993.5 − 4299986.0	1	*corr_6to9rcls*
		NoData	0	
Corr_17to6	Value	2051721.75 − 2486571.462	1	*corr_17to6rcls*
		NoData	0	
Corr_1to9	Value	440628.625 − 899999.5625	1	*corr_1to9rcls*
		NoData	0	
Corr_9to19	Value	2942251.25 − 2999999.0	1	*corr_9to19rcls*
		NoData	0	
Corr_1to6	Value	5686415.5 − 5999999.5	1	*corr_1to6rcls*
		NoData	0	
Corr_6to19	Value	744294.375 − 1019999.437	1	*corr_6to19rcls*
		NoData	0	

6.3.   **Merge Corridors into Single File**

6.3.1.   Used SINGLE OUTPUT MAP ALGEBRA tool: Map Algebra expression = (*corr_6to9rcls + corr_17to6rcls + corr_1to9rcls + corr_1to6rcls + corr_9to19rcls + corr_6to19rcls)*, Output raster = *Corr*

6.3.2.   RECLASSIFY, Input raster = *Corr*, Reclass field = Value, Reclassification in table below, Output Raster = *Corr_rcls*

Old values:	New values:
0	NoData
1 – 139999	1
NoData	NoData

7.   **Identify Sites**

7.1.   **Sites from Wetlands**
Wetlands as identified by the Army Corps of Engineers were included in order to retain their value as ecological resources but as sites rather than cores or hubs based on their small size. Digital data was not available for the entire study area and was limited to the Fayetteville 1:24,000 Quadrangle.   Four wetland types (513 sites total) were identified: Freshwater ponds, Riverine wetlands, Freshwater emergent wetlands, and Freshwater forested/shrub wetlands. Freshwater ponds were represented elsewhere in the dataset and deleted from this file. Forested wetlands (lowland forests) are particularly rare.

7.1.1.   ACOE file: *lower_48_wetland_polygons.shp* was projected to yield file: *ACOE_prj.shp*. *ACOE_prj.shp* was converted from a feature to a raster file using a 10m x 10m cell size in order to capture all the polygons: *ACOE_grid*. *ACOE_grid* was reclassified to create file: *ACOE_wetlands* according to the table below:

Wetland type Old value: *ACOE_grid*	Wetland type New Value: *ACOE_wetlands*	Number of domains
Freshwater ponds	NoData	491
Riverine	1	11
Freshwater Emergent wetlands	2	7
Freshwater forested/shrub wetlands	3	4
NoData	NoData	

7.1.2.   File: *ACOE_wetlands* data were grouped in contiguous domains using the Region Group tool with these parameters: NUMBER OF NEIGHBORS TO USE = 8, ZONE GROUPING METHOD = WITHIN, ADD LINK FIELD TO OUTPUT = √, to create file: *Site_ACOE_wetlands*.

7.2.   **Sites from Hubs**

Hubs smaller than 100 acres were designated as sites due to their high habitat value and/or their protected status.

7.2.1.   RECLASS *Hub_rgrps*: Reclass field: COUNT, old value: 1-499 = 1, 500-150533 = NoData, NoData = NoData, to create: *Site_hubs_lt100ac*.

7.3.   **Sites from Cores**
Cores smaller than 20 acres were designated as sites due to their high habitat value

7.3.1.   RECLASS *Hub_rgrps*: Reclass field: COUNT, old value: 1-499 = 1, 500-150533 = NoData, NoData = NoData, to create: *Site_hubs_lt100ac*.

7.4.   **Sites from Springs**
Springs were digitized from a Digital Raster Graphic (DRG) of the study area and field tested. It is certain that not all springs are mapped and some that are mapped may be intermittent or have ceased to flow. No processing was necessary for this file, *springs.shp*, it is merely added to the layers.

7.5.   **Sites from Cemeteries**
Cemeteries were taken from a GNIS data layer of cultural features.

7.5.1.   *CULTURAL_all_GNIS.shp* was cropped to the study area. No other processing was necessary for this file, *cemeteries.shp*, it is merely added to the layers.

8.   **Notes and Recommendations**

8.1.   **Theoretical Basis**

8.1.1.   The principles for development of a Green Infrastructure Network Map arise from the tenets of the sciences of Conservation Biology and Landscape Ecology. The results are predicated upon specific local data where available and upon general principles where data is lacking.

8.2.   **Procedural Resources**

8.2.1.   Throughout these procedures the Maryland Department of Natural Resources 2003 document: Maryland's Green Infrastructure Assessment: A Comprehensive Strategy for Land Conservation and Restoration, "Appendix B: Maryland's Green Infrastructure Assessment: Detailed GIS Methods" was used as a guideline to implement decisions made by the GIP Working Groups and to provide the basis for decisions required to complete the project for which insufficient data or expertise were available. The report can be found on the State of Maryland's DNR website: (http://www.dnr.state.md.us/greenways/gi/gidoc/gidoc.html). This document has proved invaluable in the completion of this study, even to the extent of providing a genuinely comprehensible formatting style for difficult technical procedures such as these and many thanks are due to the creators of that work.

8.2.2.   GIS methodologies were also gleaned from a Green Infrastructure-GIS tools workshop sponsored by The Conservation Fund, the US Fish & Wildlife Service, and the National Oceanic & Atmospheric Administration held in Charleston, South Carolina in June of 2009.

8.3.   **Data Inputs**

Data were acquired from many sources and, as is often the case, dates of acquisition vary widely. Most files were downloaded from GeoStor, Arkansas's central geospatial data server; however Washington County, Fayetteville, The Nature Conservancy, and Northwest Arkansas Regional Planning Commission also provided data. A few layers were created using heads-up digitization.

Description	File name	source	Date
Boundary: study area	Box.shp	Created	2008
Land use land cover	IMAGE.LULC_FALL_CAST2006.tif	GeoStor	2006
Public lands	CADAS_PUBLIC_LAND_BOUNDARIES_AHTD_poly.shp	GeoStor	2008
Conservation easements	Consv_ease.shp	City of Fayetteville	2009
Land trust properties	Trust_prop.shp	City of Fayetteville	2009
ACOE wetland mitigation sites	Wet_mit_ACOE.shp	City of Fayetteville	2009
Streams	WATER_STREAM_ORDER_ADEQ_linez.shp	GeoStor	2009
Waterbodies	WATER_NHD_HIGH_RES_WATERBODY_USGS_polyz.shp	GeoStor	2008
Floodplains	WaCo_flood_zones2009	Washington County Assessor's Office	2009
UFCAA	aquatic_ecology_10class_generalized.shp	The Nature Conservancy	2006
UFCAT	terrestrial_ecology_10class_generalized.shp	The Nature Conservancy	2006
Wetland/Prairie/Savannah	Prairie_grass.shp	Created	2009
Springs	NW_springs.shp	Created	2009
Roads	TRANSP_ROAD_ALL_AHTD_line.shp	AHTD	2009
Bridges	Region6.shp	National Bridge Inventory	2009
Elevation	ELEV.DEM_STATEWIDE_2006	GeoStor	2006
Cemeteries	CULTURAL_all_GNIS.shp	GeoStor	2008

8.4.   **Data Quality**

8.4.1.   Only one Army Corps of Engineers wetland mitigation polygon was included here, surely there are more and perhaps there are other governing bodies that identify/administer mitigation sites for different habitat types.

8.4.2.   Land trust properties may exist outside of Fayetteville's boundaries, but no more were found by contacting these local conservation entities: The Nature Conservancy, Ozark Regional Land Trust, City of Fayetteville, Fayetteville Natural Heritage Association, and the Humane Society of the United States Wildlife Land Trust.

8.4.3.   Springs were mapped from the USGS Digital Raster Graphic 1:24,000 and the field work of Judy and Duane Woltjen (2008). Judging by comments from viewers of the maps, many springs are not mapped, some and they may be grossly under-represented.

8.5.   **Future Refinements**

8.5.1.   There was a great deal of refinement and evaluation made to the cores, hubs, and corridors in Maryland's Green Infrastructure Assessment that were not made here due to lack of time, information or expertise and the difference in scale of the projects.

8.5.2.   There is a lack of habitat data, particularly faunal distributions. The UFCA study (used to define hubs which were then linked for corridor development) included faunal habitat data in its model but the data were too sparse to actually include; floral habitat parameters formed the basis. As was mentioned in Section 6: Corridor Development, it is not at all unusual for habitat data to be lacking and general floral parameters provide a good first pass at core/hub/corridor development.

8.5.3.   Corridors were developed between the six largest hubs. Further corridor assessment should be done involving the rest of the hubs.

8.5.4.   Many of the wetland/prairie/savannah cores and do not have hubs enclosing them; a core-to-core analysis would provide valuable insight into where to establish corridors and where to place conservation/remediation attention for developing buffers to protect wetland/prairie/savannah areas.