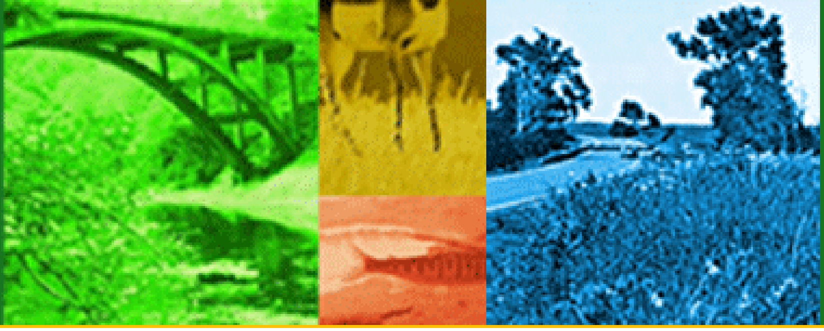
Eco-Logical
Webinar Series



Improving Aquatic Connectivity At the Landscape Scale In the Southeastern United States

Presenters

October 13, 2016

Mike Ruth, Federal Highway Administration, Office of Project Development and Environmental Review

Duncan Elkins and **Nate Nibbelink**, University of Georgia

Evan Collins, U.S. Fish and Wildlife Service

Thomas Prebyl, University of Georgia

[Learn more about Eco-Logical at the FHWA website]

Volpe The National Transportation Systems Center

U.S. Department of Transportation
Federal Highway Administration

Steps to Ensure Optimal Webinar Connection

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What is Eco-Logical?

- An ecosystem methodology for planning and developing infrastructure projects
- Developed by eight Federal agency partners and four State DOTs
- Collaboration between transportation, resource, and regulatory agencies to integrate their plans and identify environmental priorities across an ecosystem

Aquatic Connectivity

- Roadways have direct and indirect effects on wildlife
- Improving connectivity for aquatic organisms a key goal of improved infrastructure planning
- Most previous work focused on terrestrial connectivity

How Aquatic Connectivity tool fits into Eco-Logical

- Helps different agencies understand importance of connectivity from the outset of the planning process
- Communication tool for engaging stakeholders in discussing barriers to wildlife movement

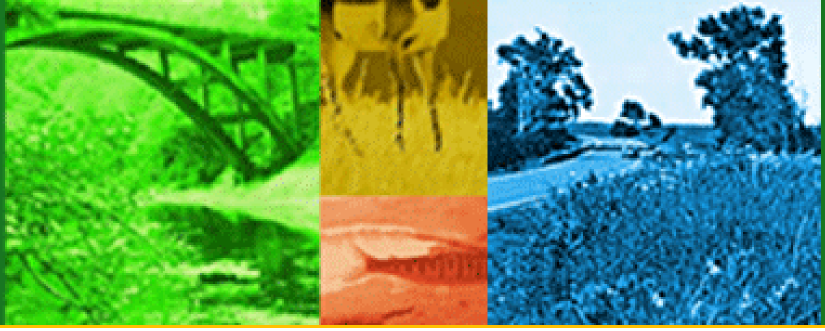
How Aquatic Connectivity tool fits into Eco-Logical

- Mapping Tools key to characterizing resources in preparation for developing Regional Ecosystem Framework (REF)
- Helps identify existing concerns for aquatic species
- Helps identify past impacts at critical locations

How Aquatic Connectivity tool fits into Eco-Logical

- Creating Regional Ecosystem Framework (REF) requires collecting geospatial data on resources and transportation plans
- Creating Planning Scenarios to define footprint of potential projects

Eco-Logical
Webinar Series



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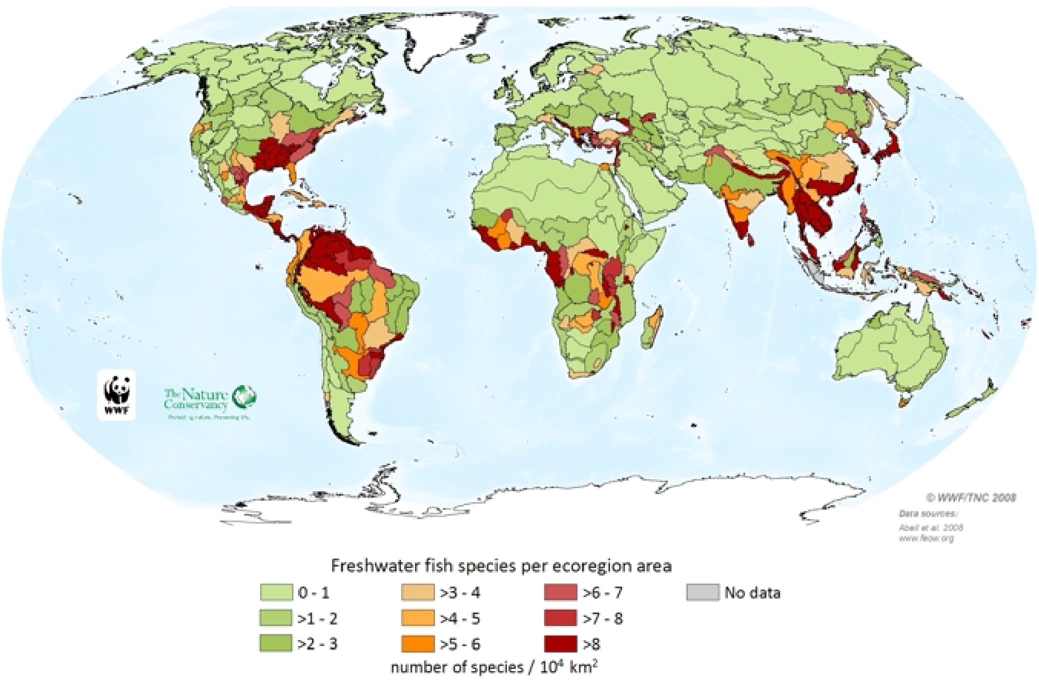
Project Background

- ~2010, Regional connectivity analyses focused on Dams
- 2011 SARP-funded assessment of culvert studies in Southeast
- Summer 2012, FHWA project: Predicting barrier presence and passability at road/stream xings
- Summer 2013, SA-LCC project: Expanded region, more GIS tools

Predicting Culvert Passability in Three Southern Watersheds

Diversity

- Freshwater fish account for ≈ 25% of all vertebrate diversity

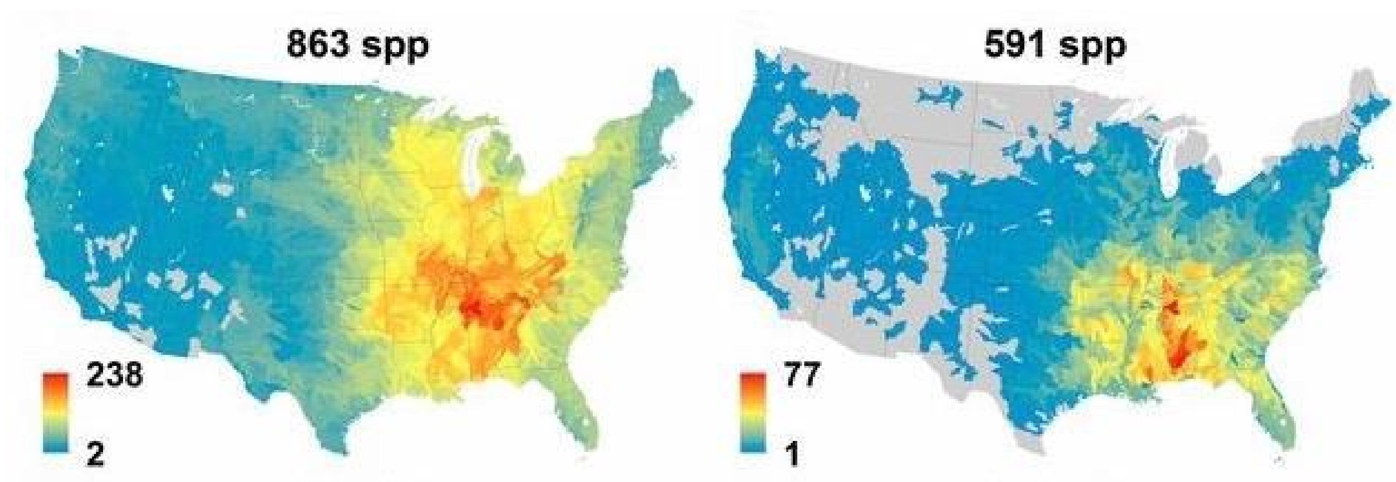


Abell, R., D.M. Olson, E. Dinerstein, P. Hurley, J.T. Diggs, W. Eichbaum, S. Walters, W. Wettengel, T. Allnutt, C. Louks, and P. Hedao. 2000. Freshwater Ecoregions of North American: A Conservation Assessment. Island Press, Washington, DC

Fish Diversity in the Continental U.S.

Freshwater Fish Richness

Endemism

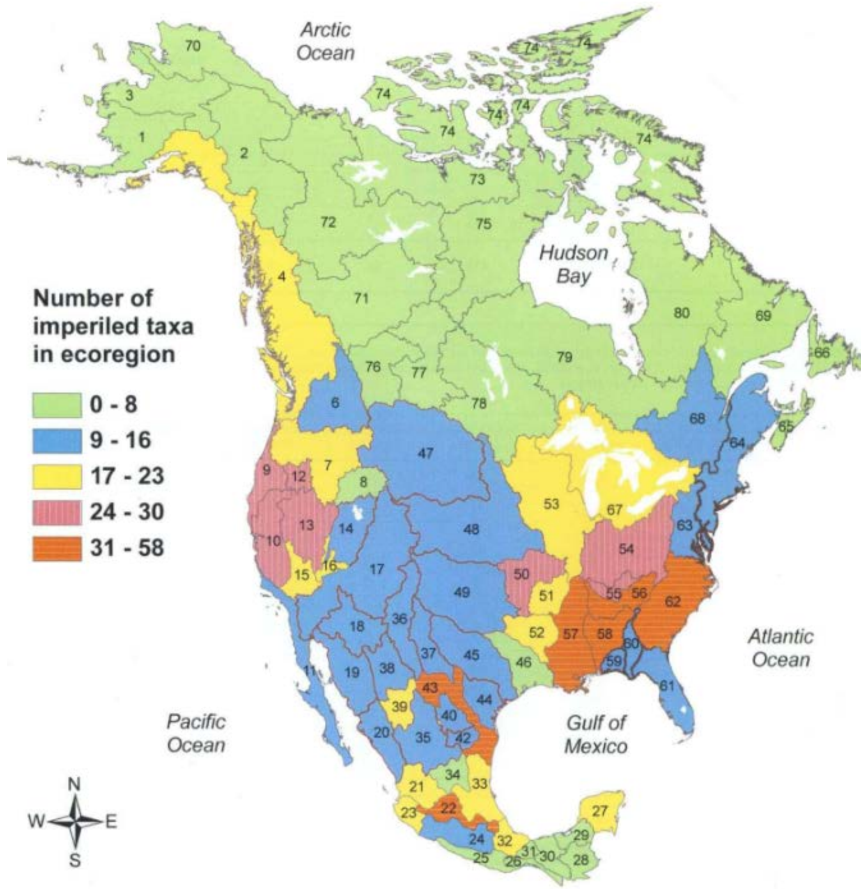


Jenkins, C., Houtan, K., Pimm, S. & Sexton, J. US protected lands mismatch biodiversity priorities. PNAS 112, 5081–5086 (2015).

Imperilment

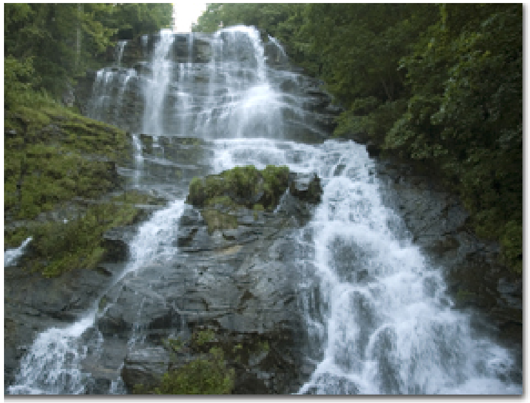
Key Threats

- Habitat degradation
- Water pollution
- Overexploitation
- Invasive species

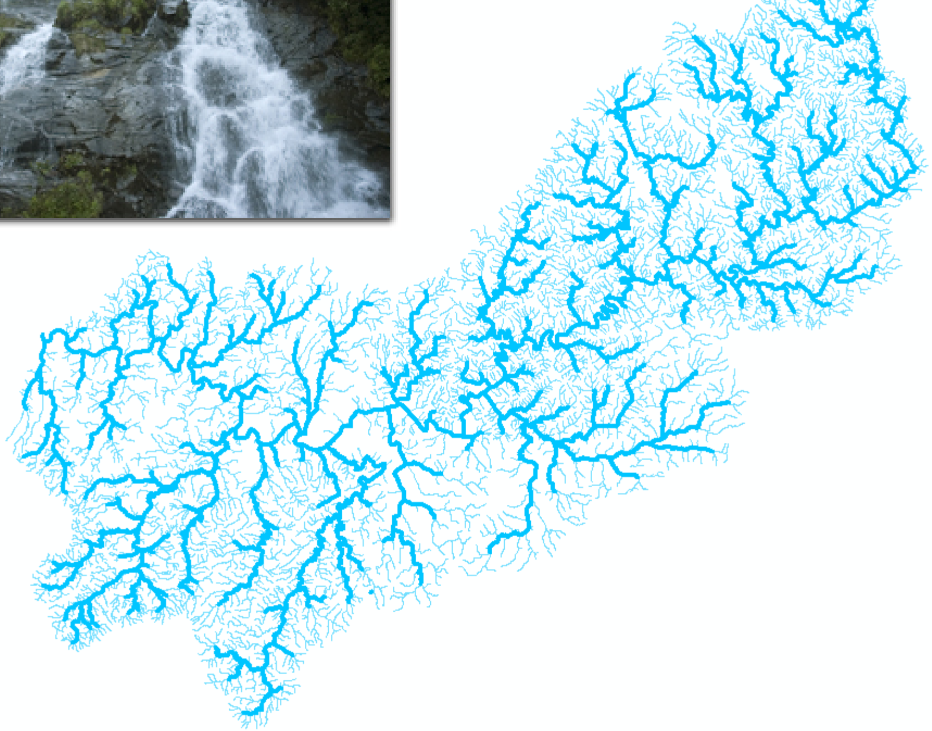


Abell, R., D.M. Olson, E. Dinerstein, P. Hurley, J.T. Diggs, W. Eichbaum, S. Walters, W. Wettengel, T. Allnutt, C. Louks, and P. Hedao. 2000. Freshwater Ecoregions of North American: A Conservation Assessment. Island Press, Washington, DC

Connectivity



- Hydrologic connectivity – “water-mediated transfer of matter, energy, and/or organisms between elements of the hydrologic cycle”

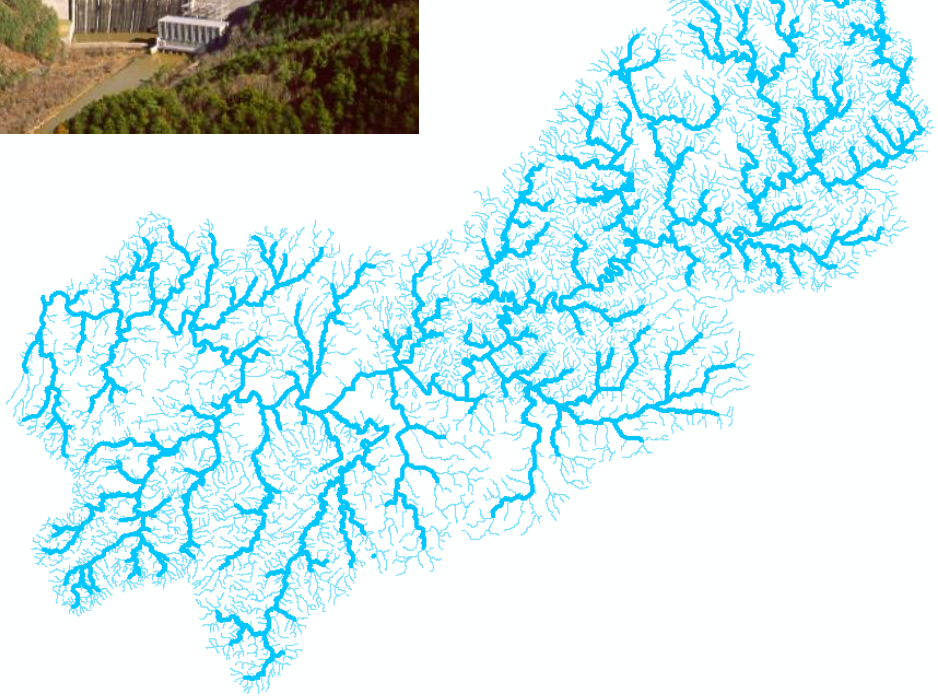


- Longitudinal
- Lateral
- Vertical

Fragmentation

Dams

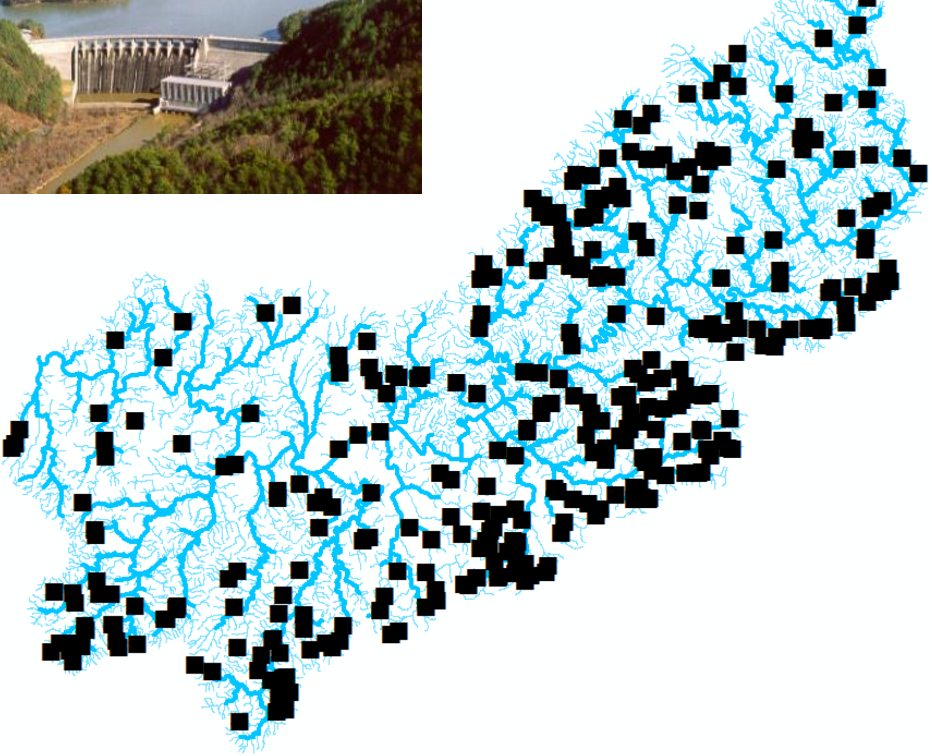
- Barriers
  - Animal movement
  - Nutrient and Sediment transport
- Fragment/alter habitat



Fragmentation

Dams

- Barriers
  - Animal movement
  - Nutrient and Sediment transport
- Fragment/alter habitat
- Growing knowledge of their location

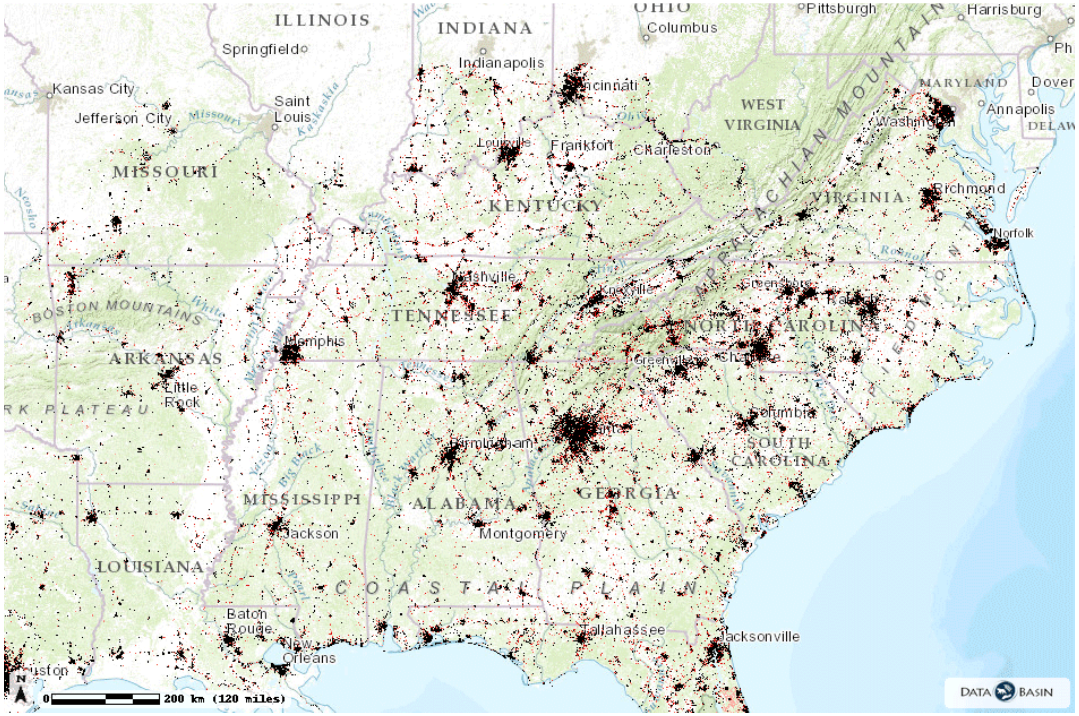


Fragmentation

Road Crossings

- Fragment habitat
- Obstruct fish movement
- Passability variability

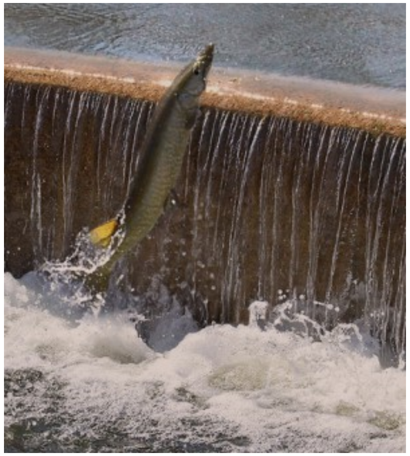
Projected Growth



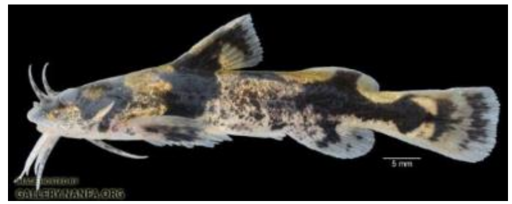
SLEUTH urbanization potential, 2020-2070, by Clarke and Doato, salcc.databasin.org

Passability

- Attributed to the structure
- Needs to be discussed in terms of a species or group of species



Southeastern Fishes



Images by:
David Neely,
Noel Burkhead,
Steve Ross

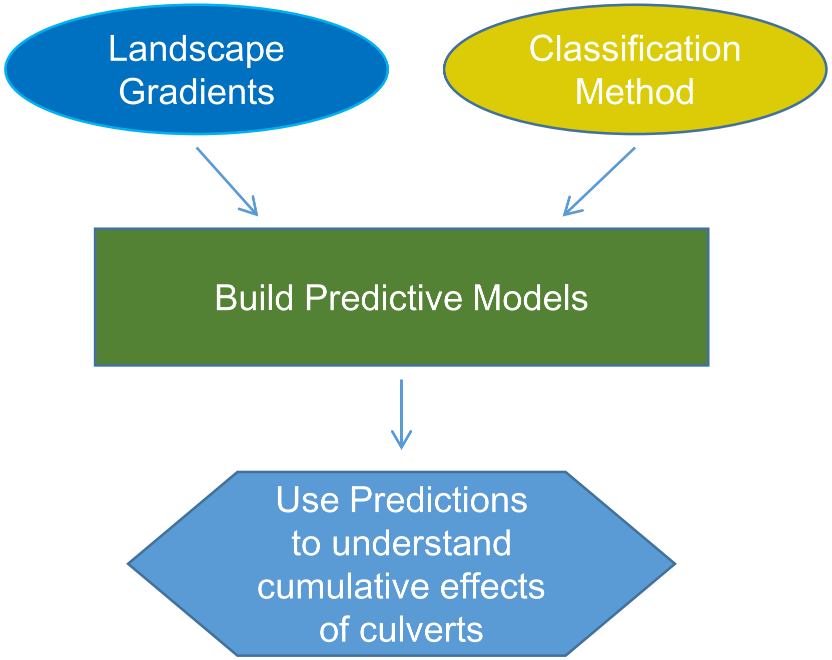
The Good

The Bad

The Ugly

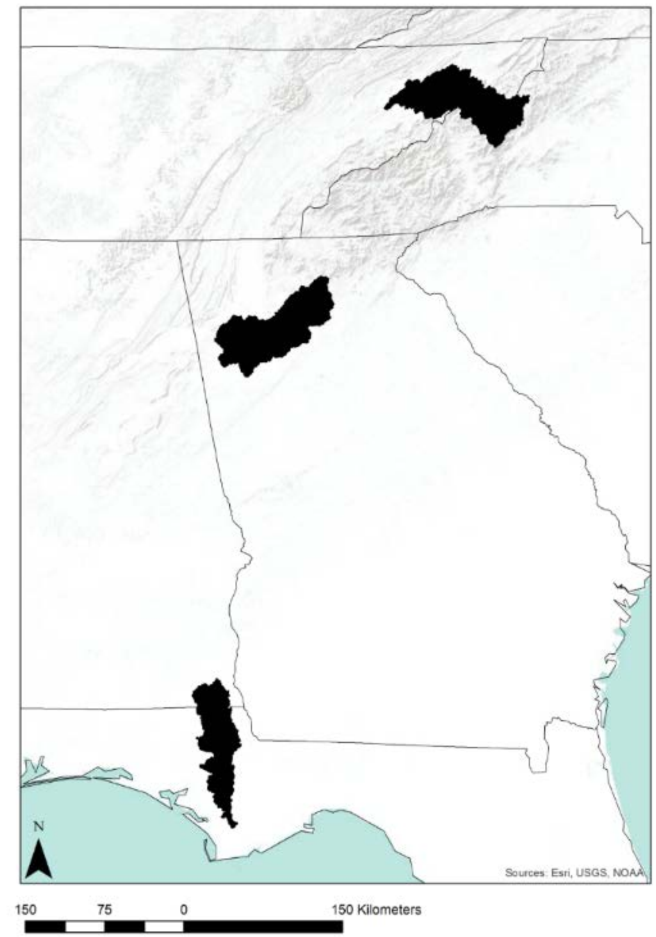
Objectives

1. Can we use spatial modeling to predict impassable or problematic structures on the ground?



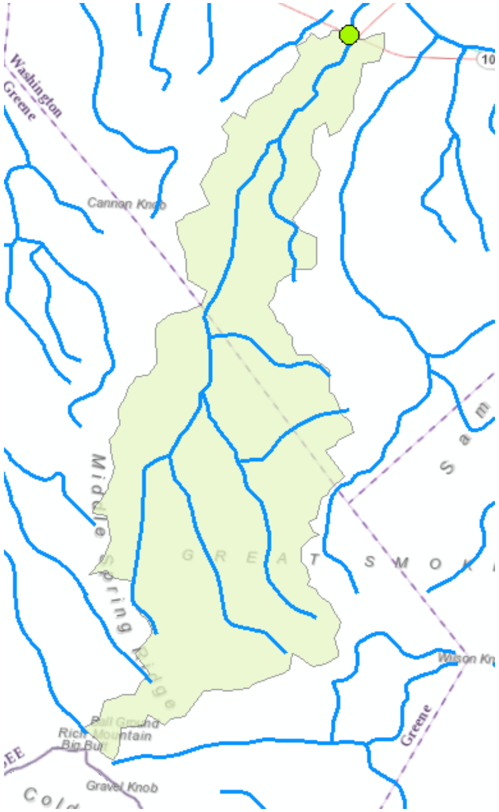
Study Area

- Three watersheds that reflect the geographic diversity of the Southeast
- Sites of previous connectivity studies



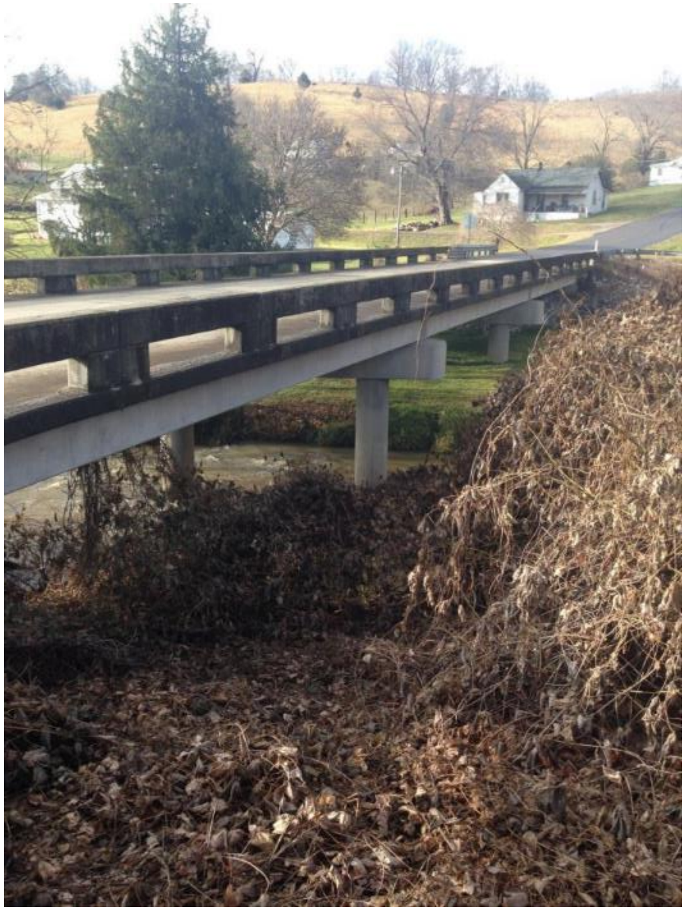
Survey Site Selection

- Upstream catchment area attributed with land cover types, uses, and ownership
- Only sites with an upstream catchment area < 60 km^2 were selected



Bridges

60 km^2?



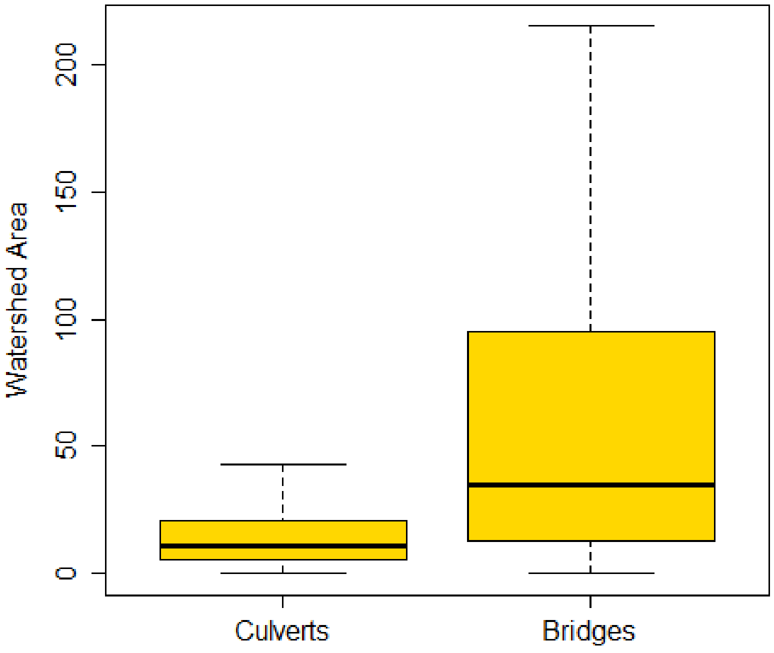
Bridge Threshold

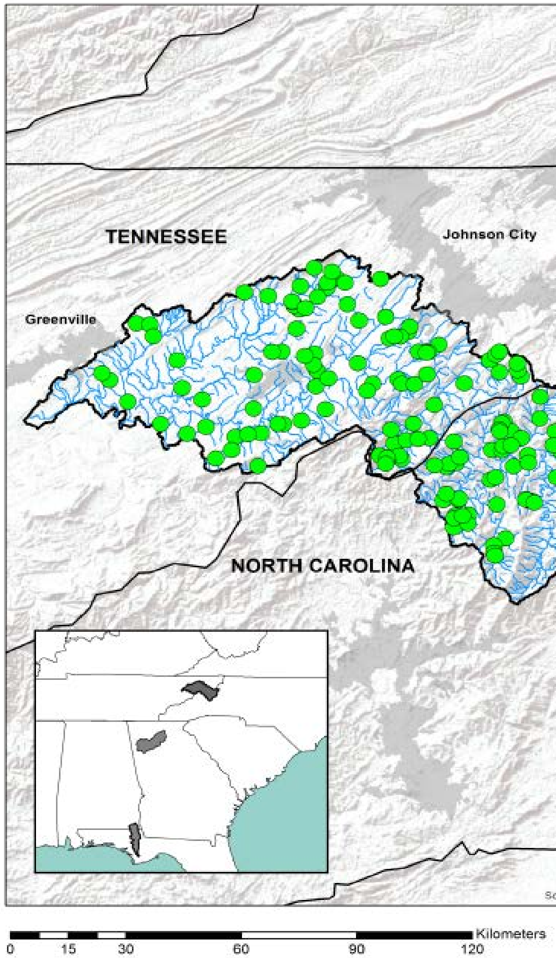
- 95% of all culverts cross a stream with a watershed

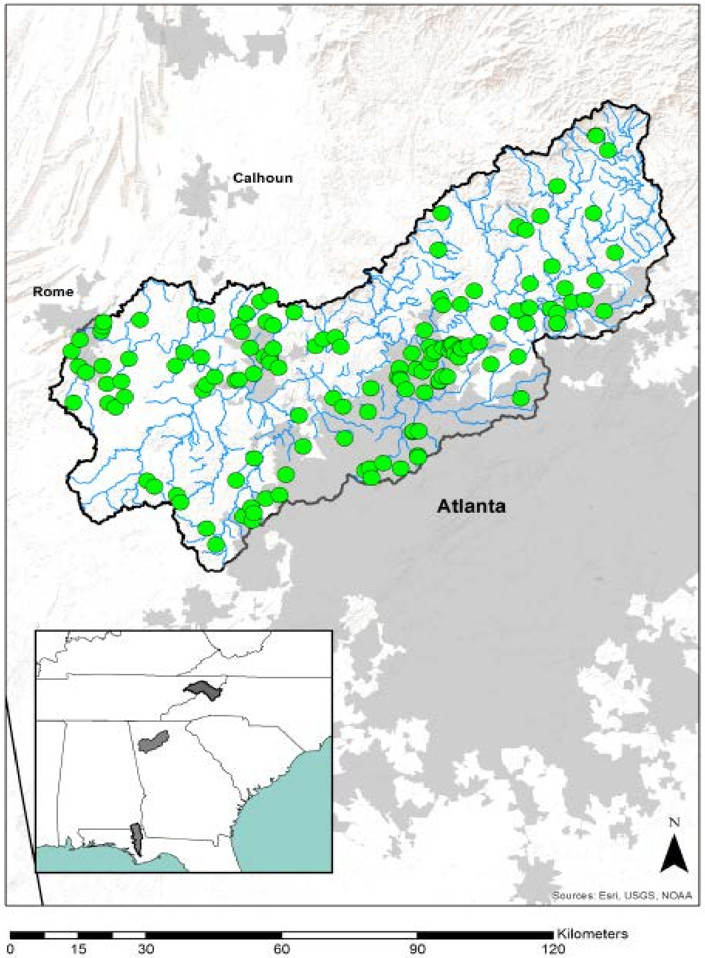
  <60 km^2

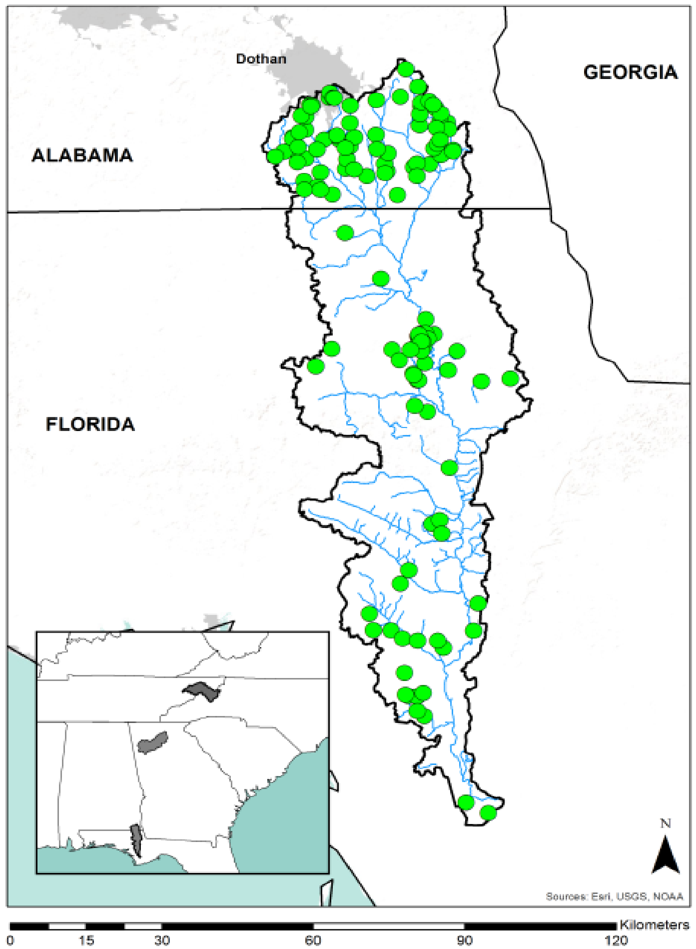
- 95% of bridges cross a stream with a watershed area of

  >84 km^2




TENNESSEE
Johnson City
Greenville
NORTH CAROLINA
N
Sources: Esri, USGS, NOAA
0
15
30
60
90
120
Kilometers

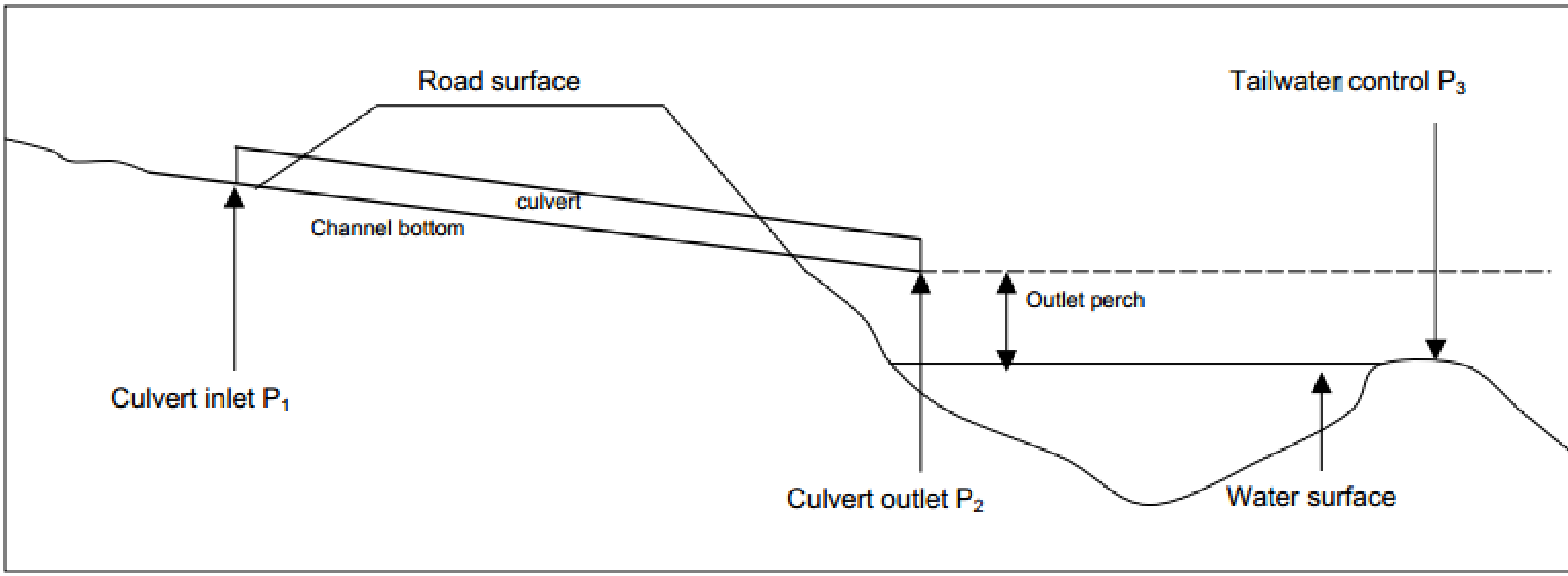

Calhoun
Rome
Atlanta
N
Sources: Esri, USGS, NOAA
0
15
30
60
90
120
Kilometers


Dothan
GEORGIA
ALABAMA
FLORIDA
N
Sources: Esri, USGS, NOAA
Kilometers
0
15
30
60
90
120

Field Surveys

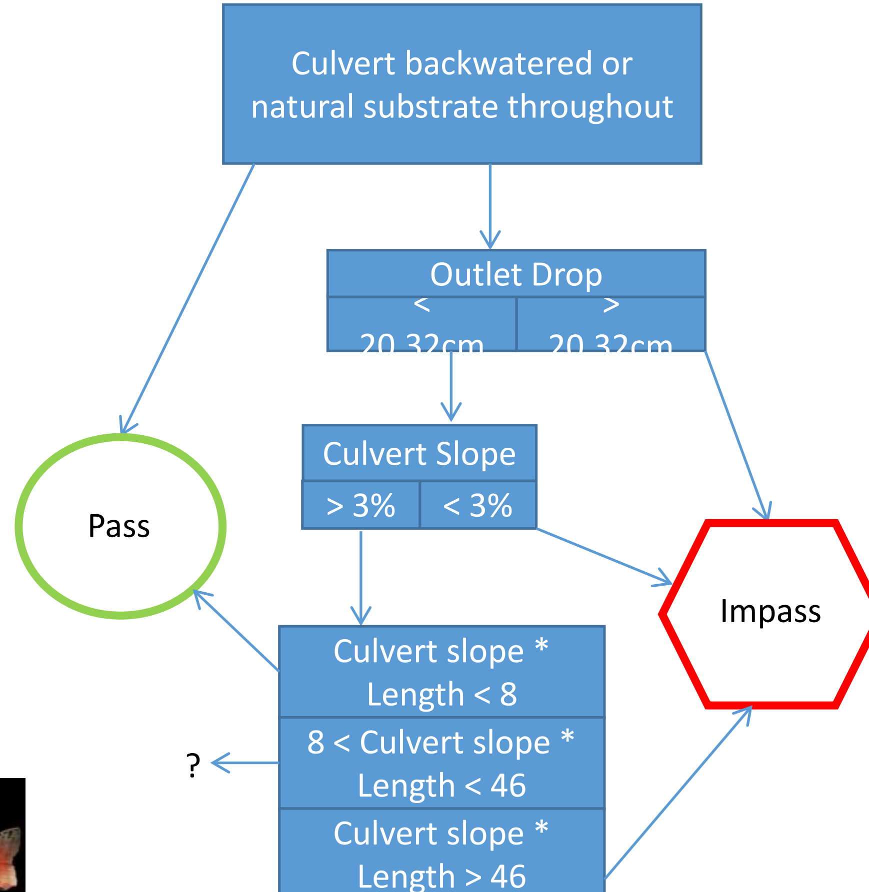
June 2013 – February 2014

- Perch Height
  - To Water
  - To Sediment
- Culvert Length
- Culvert Slope
- Sediment in Culvert
- Scour pool presence


Road surface
Tailwater control P3
culvert
Channel bottom
Outlet perch
Culvert inlet P1
Culvert outlet P2
Water surface

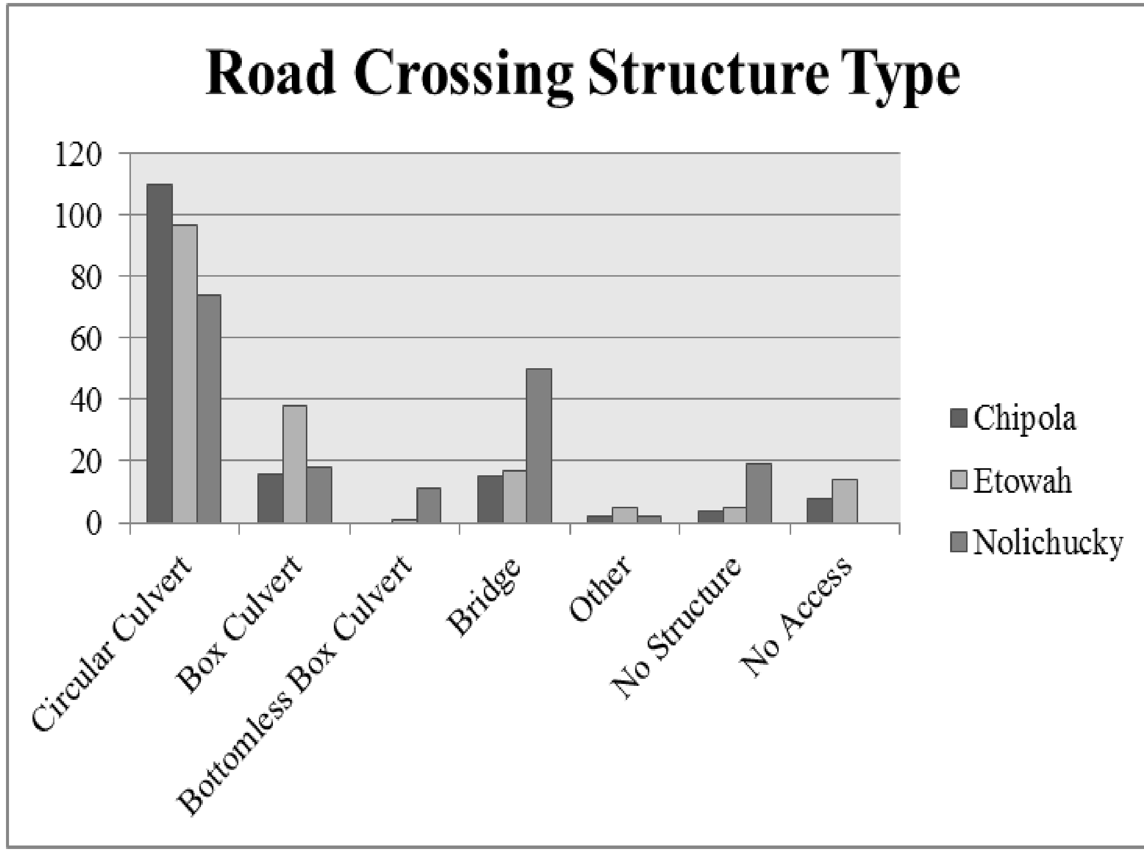
Passability Classification

- Passability in terms of three families
  - Percidae
  - Cyprinidae
  - Salmonidae



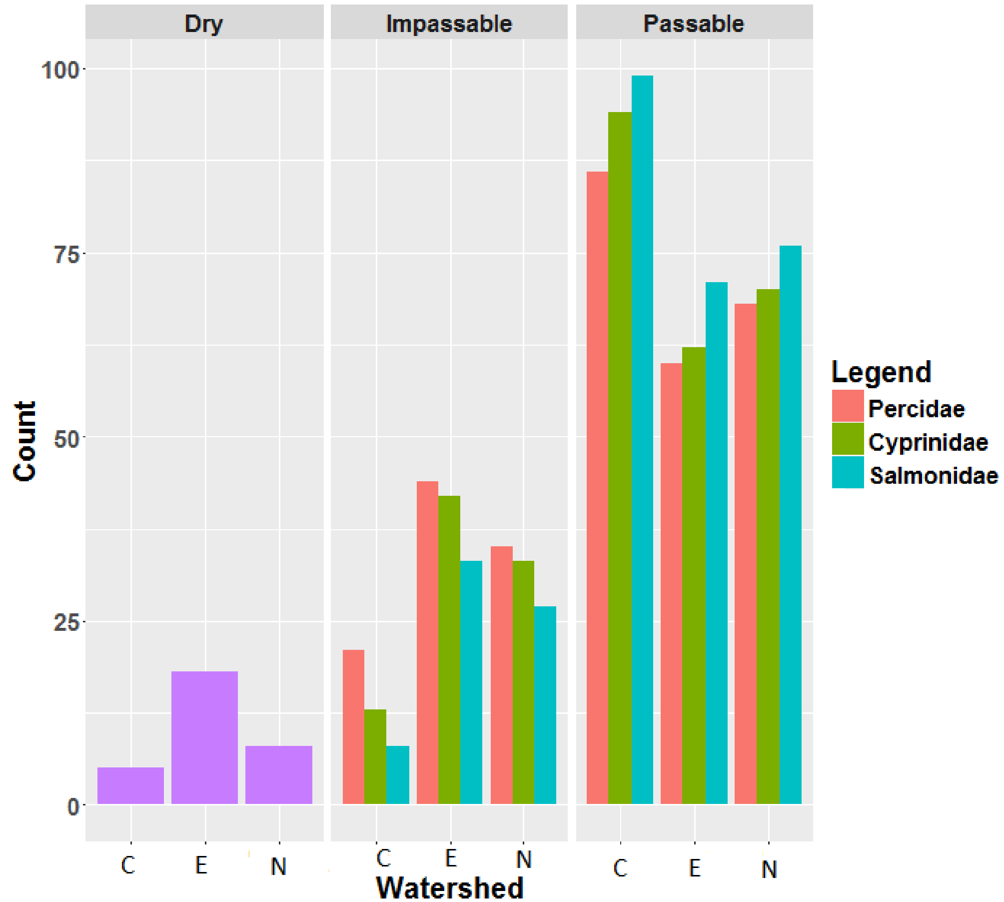
Field Data Summary

- 52% pipe culverts
- 16% bridges
- 14% box culverts



Field Data Summary

- Mostly passable for all families
- 7 indeterminate culverts (removed from analysis)
- 35 dry crossings (removed from analysis)



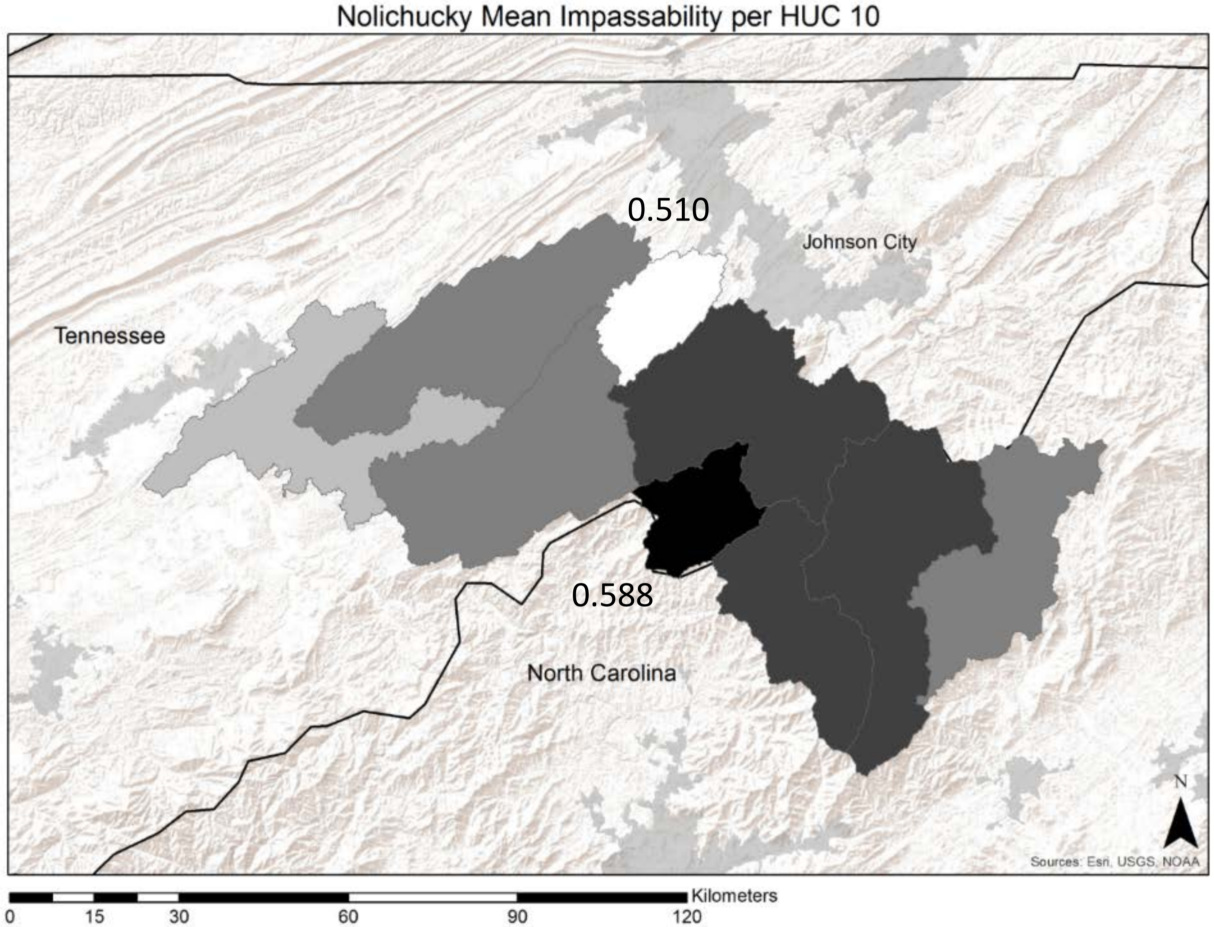
Landscape Gradients

- Landscape characteristics around in the upstream catchment area of a culvert and within a 100 m buffer are likely to influence erosional processes
- Increased erosion at a culvert will cause more scour and increase the perch height of a culvert and prevent a fish from entry

- Percent land cover type
- Percent impervious surface
- Roughness
- Compound topographic index
- Stream power
- Slope position of culvert
- Stream reach gradient
- Road type
- Flow accumulation
- Upstream catchment area
- Discharge for a 5 year flood

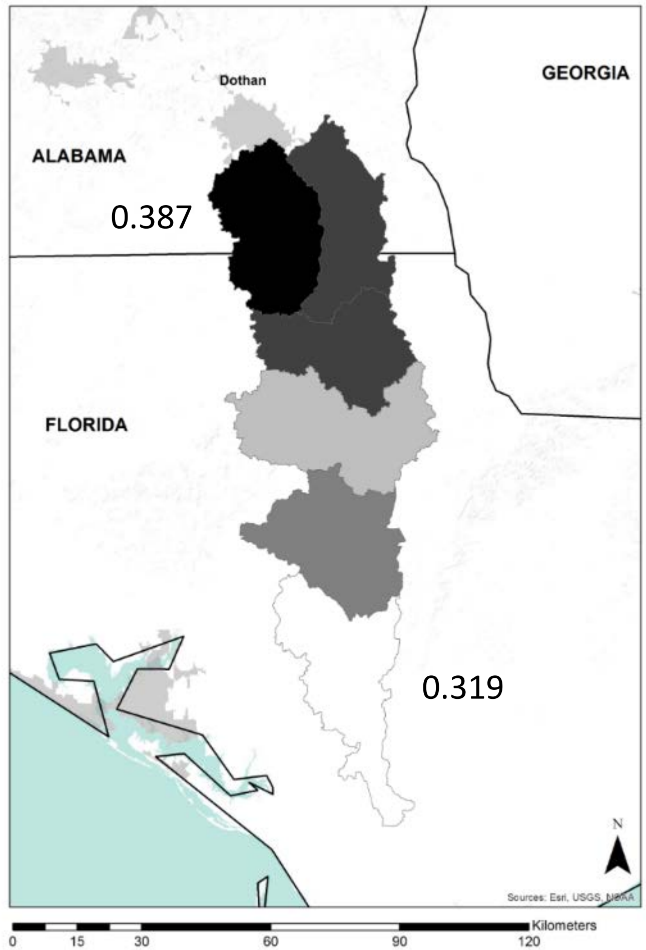
Model Performance

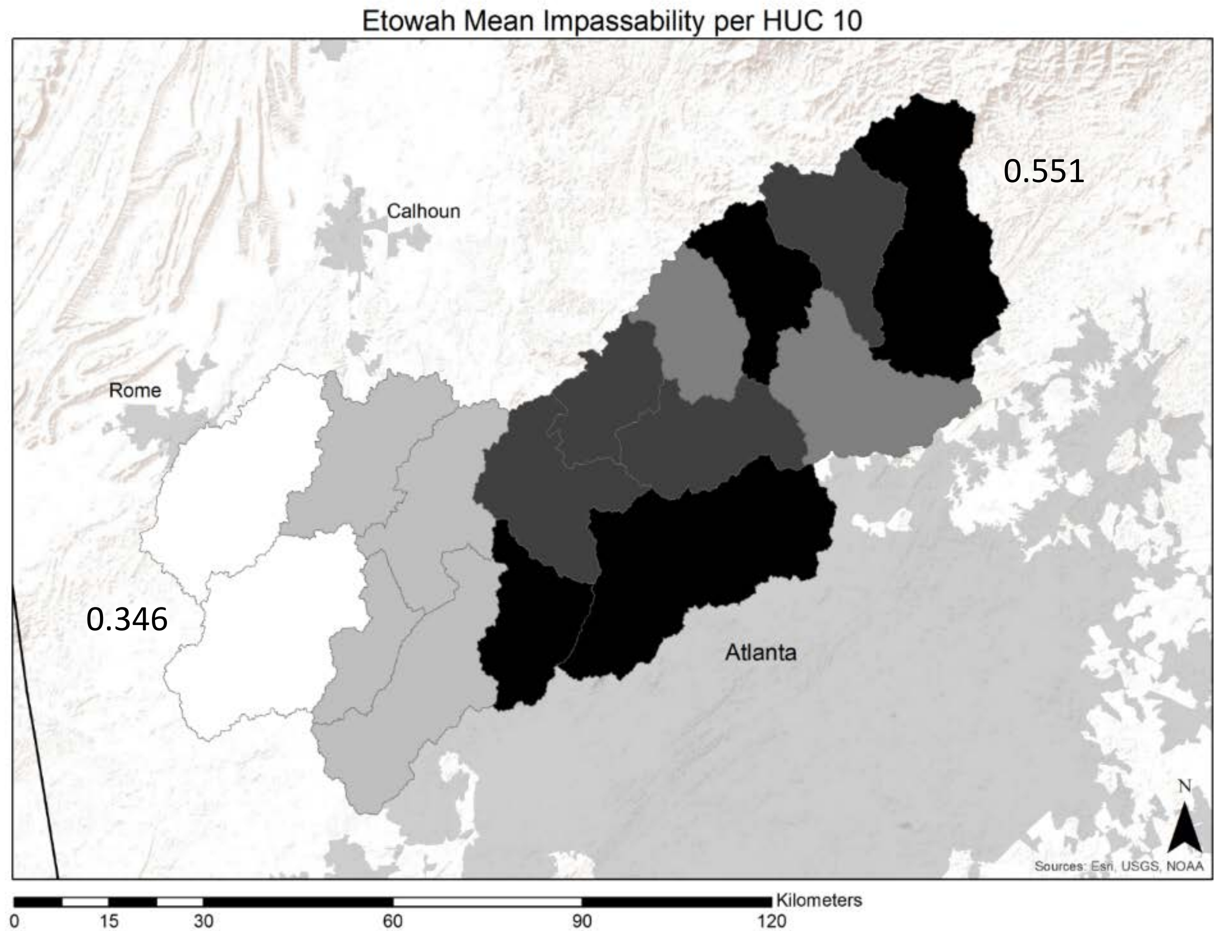
Family Specific Model	Parameters	AUC
Percidae	Mean Roughness (WS), % Impervious (WS), Stream Power, % Forest (WS), Mean Roughness (BF), Watershed Area, % Impervious (BF), % Shrub/Scrub (WS), % Grassland (WS), % Pasture (BF), % Woody Wetland (WS), % Cultivated Crops (WS), % Open Water (WS), % Herbaceous Wetland (WS)	0.614
Cyprinidae	Mean Roughness (WS), Mean Roughness (BF), Slope Position, CTI, % Forest (WS), Watershed Area, % Impervious (BF), Stream Gradient, % Pasture (WS), % Shrub/Scrub (WS), % Grassland (WS), % Woody Wetland (WS), % Cultivated Crops, Road Type (FCode), % Open Water (WS), % Shrub/Scrub (BF), % Herbaceous Wetland (BF)	0.642
Salmonidae	Slope Position, % Forest (WS), Watershed Area, Mean Roughness (BF), % Impervious (WS), % Impervious (BF), Mean Roughness (WS), Stream Gradient,), % Shrub/Scrub (WS), % Grassland (WS), % Pasture (BF), % Woody Wetland (WS), % Cultivated Crops, Watershed	0.655



Nolichucky Mean Impassability per HUC 10
0.510
Johnson City
Tennessee
0.588
North Carolina
N
Sources: Esri, USGS, NOAA
Kilometers
0
15
30
60
90
120

Chipola Mean Impassability per HUC 10



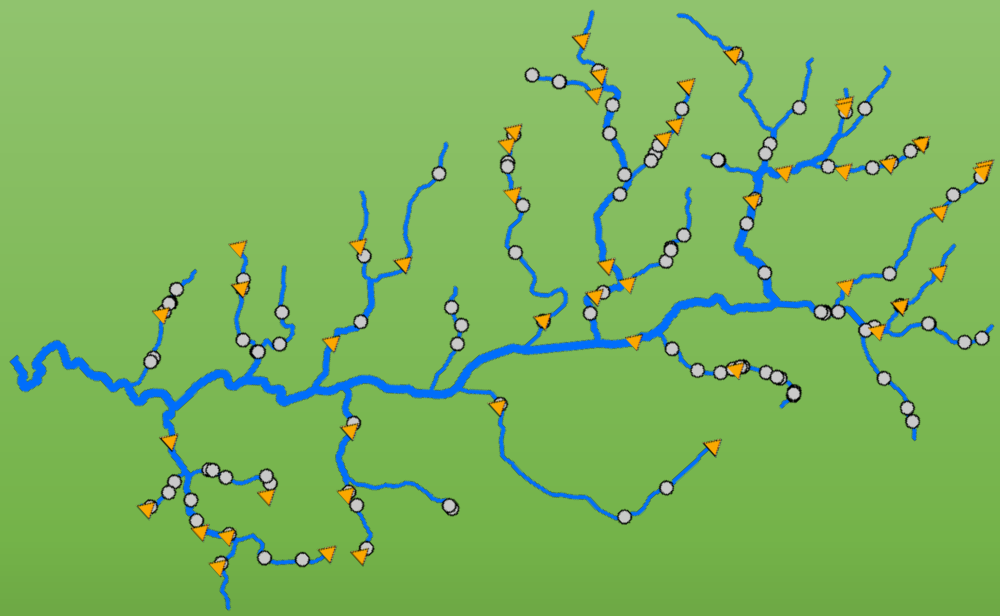

Etowah Mean Impassability per HUC 10
0.551
Calhoun
Rome
0.346
Atlanta
N
Sources: Esri, USGS, NOAA
Kilometers
0
15
30
60
90
120

Conclusions and Implications

- Passability can be predicted with landscape characteristics
- Predictive modelling can help us gain a better understanding of where problems may occur
- Predictions can be used to guide prioritizations

Prioritizing Aquatic Connectivity: Implementation and Applications

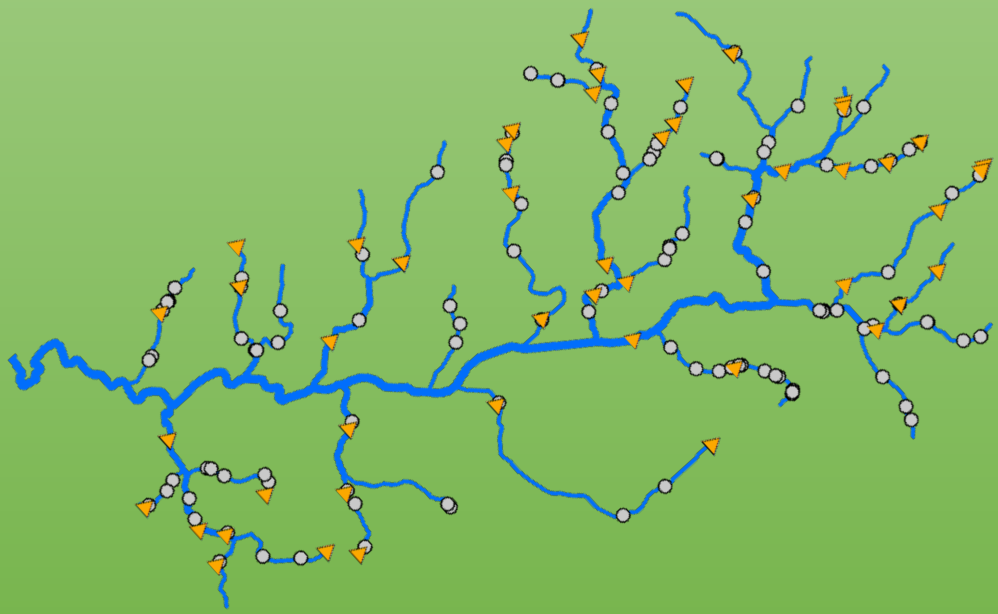
Thomas Prebyl, Duncan Elkins, Evan Collins, Nathan Nibbelink
University of Georgia Warnell School of Forestry and Natural Resources



Outline

1. Overview of prioritization problem
2. General workflow and ArcGIS toolbox
3. Application Examples
4. Ongoing work

Overview

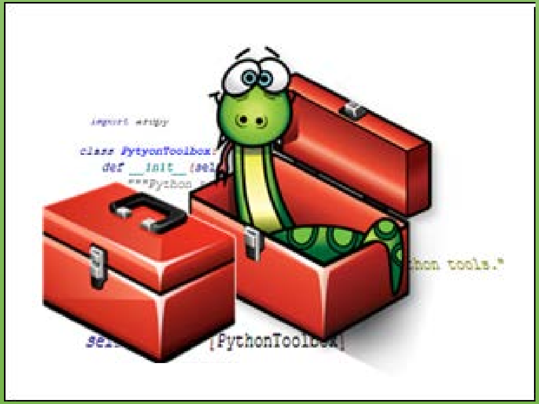


- How do dams and culverts influence connectivity?
- Which barriers (if removed) would most benefit connectivity.

Workflow

1. Data Sources
2. Data Preperation
3. Network Simplification
4. Prioritization Algorithms
5. Visualizing Results

Custom ArcGIS Toolbox
“Stream Network Tools”



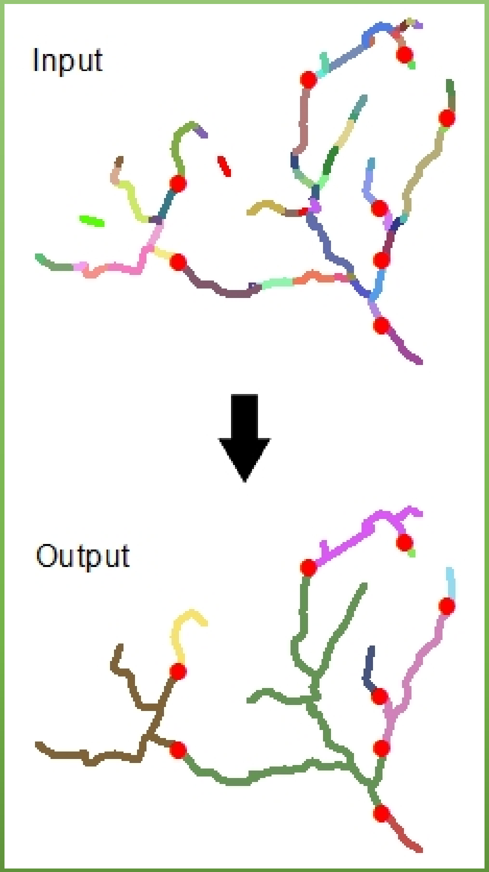
Workflow: Data Sources

- Streams
  - National Hydrology Dataset (USGS)
  - NHDPlus Version 2 (Horizon Systems)
    - 1:100K but many value added attributes
- Dams
  - National Inventory of Dams (NID): US Army Corps of Engineers
  - National Anthropogenic Barrier Dataset (NABD)
  - GeoFIN (USFWS)
  - NHD Dam Events (USGS)
  - Various regional and state datasets (e.g. SARP)
- Roads
  - TIGER/Line (US Census)
- Bridges
  - National Bridge Inventory (FHWA)

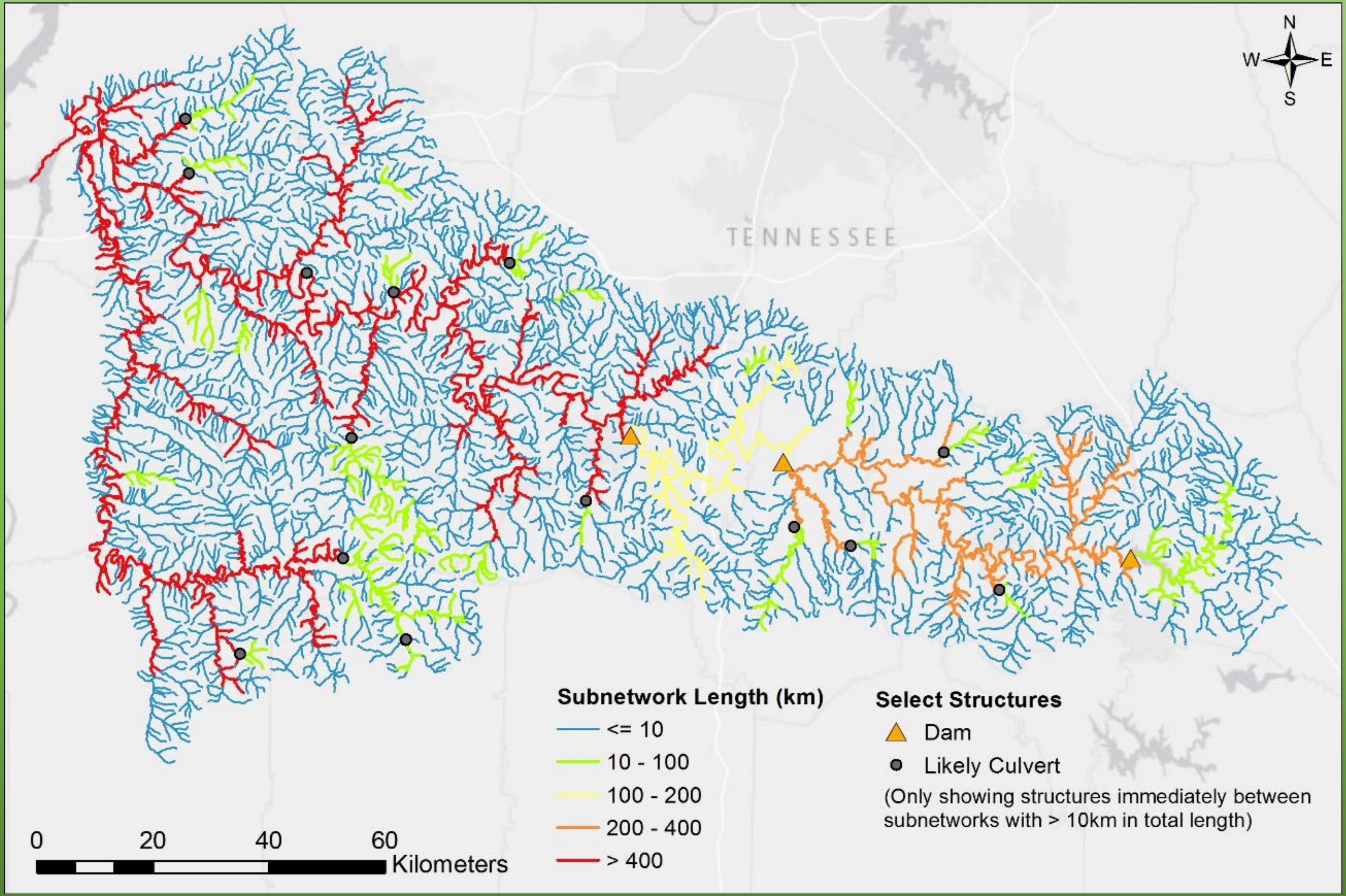
Workflow: Data Preperation

- Intersect roads and streams to identify likely culverts
- Remove known bridges
  - NBI and drainage area
- Snap dams to stream network
- Identify disjunct stream segments (tool)

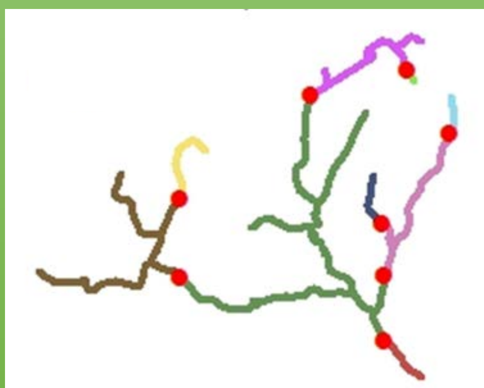
Workflow: Network Simplification



Workflow: Network Simplification



Workflow: Extract Adjacency



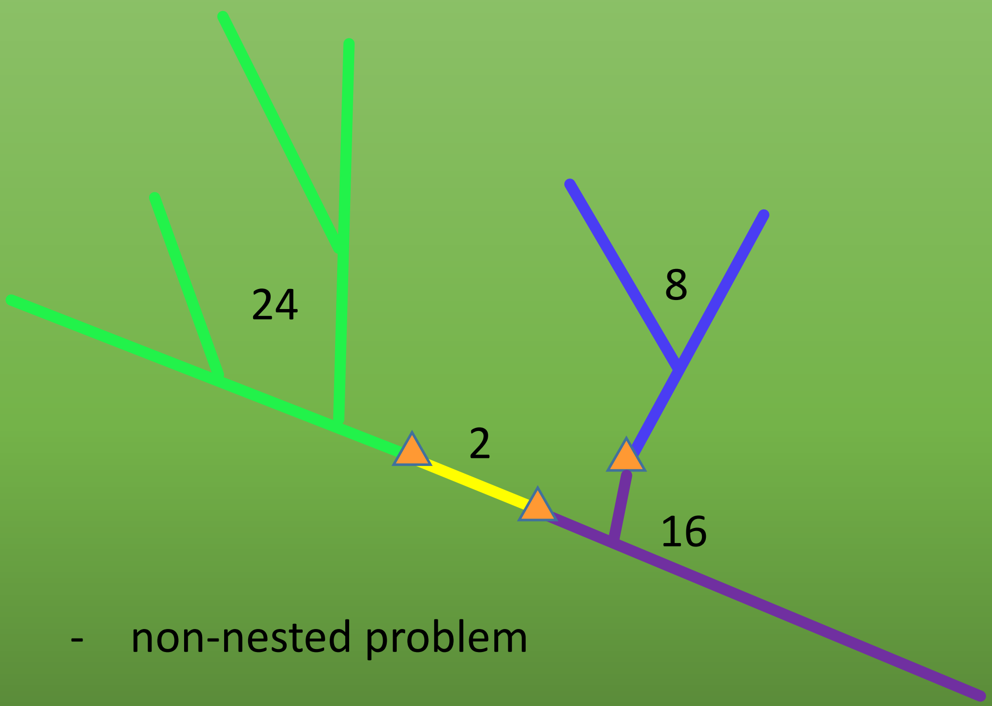
Table

ex_adjtab.csv

seg1ID	seg2ID	barID	seg1W	seg2W	barPu	barPd	barRm
71	174	39	1836.470883	23.509404	0.9	0.5	1
202	203	8	141.03846	44.506855	0.9	0.5	1
108	251	257	554.917253	148.747485	0.9	0.5	1
99	109	204	2134.815816	153.00352	0.9	0.5	1
156	157	19	131.54525	62.336899	0.9	0.5	1
83	100	7	453.348025	323.895175	0.9	0.5	1
5	231	66	1504.809058	1076.929365	0.9	0.5	1
99	171	184	2134.815816	295.056823	0.9	0.5	1
200	202	228	27.832415	141.03846	0.9	0.5	1
168	169	174	68.729391	1348.778721	0.9	0.5	1
28	237	193	3600.811391	597.026747	0.9	0.5	1
18	19	259	613.646816	412.419993	0.9	0.5	1
38	86	182	1014.243672	2814.161663	0.9	0.5	1

Workflow: Prioritize Removal

How to prioritize barriers for removal?



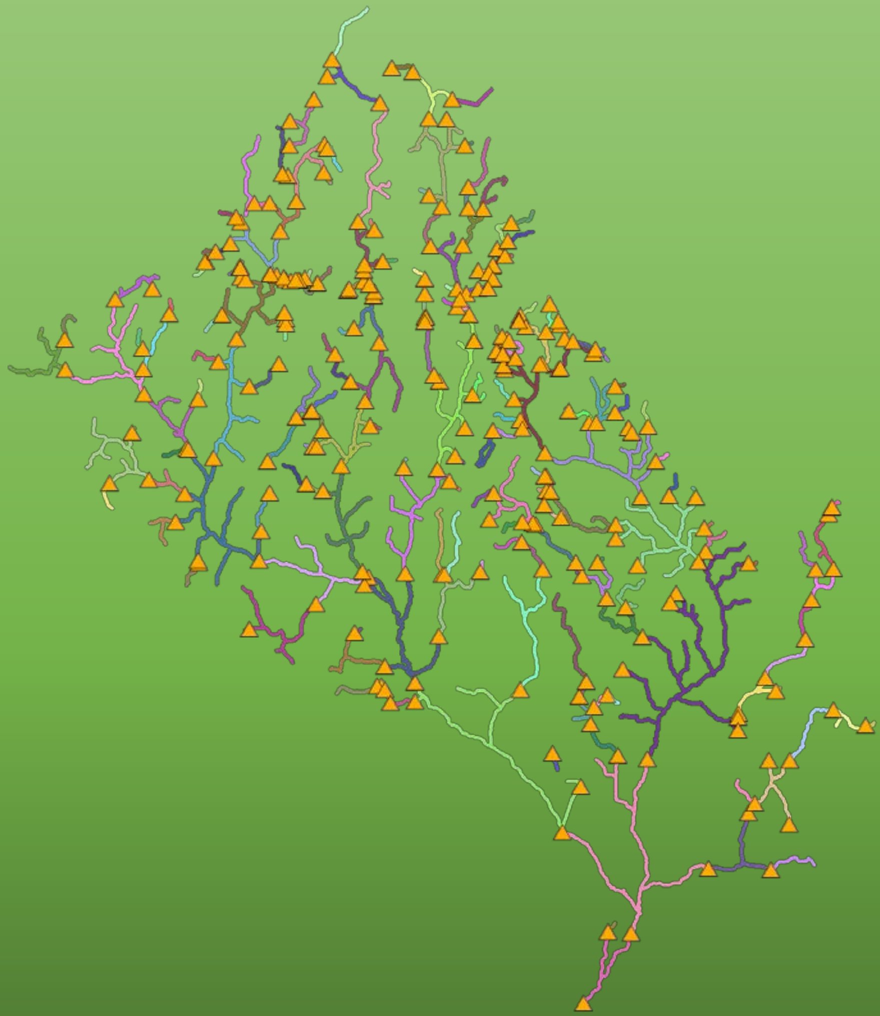
DCI: Cote et al 2009

$$\mathrm{DCI_P} = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\frac{l_i}{L}\frac{l_j}{L} * 100.$$

$$c_{ij} = \prod_{m=1}^{M} p_m^u p_m^d$$

- non-nested problem

Workflow: Prioritize Removal



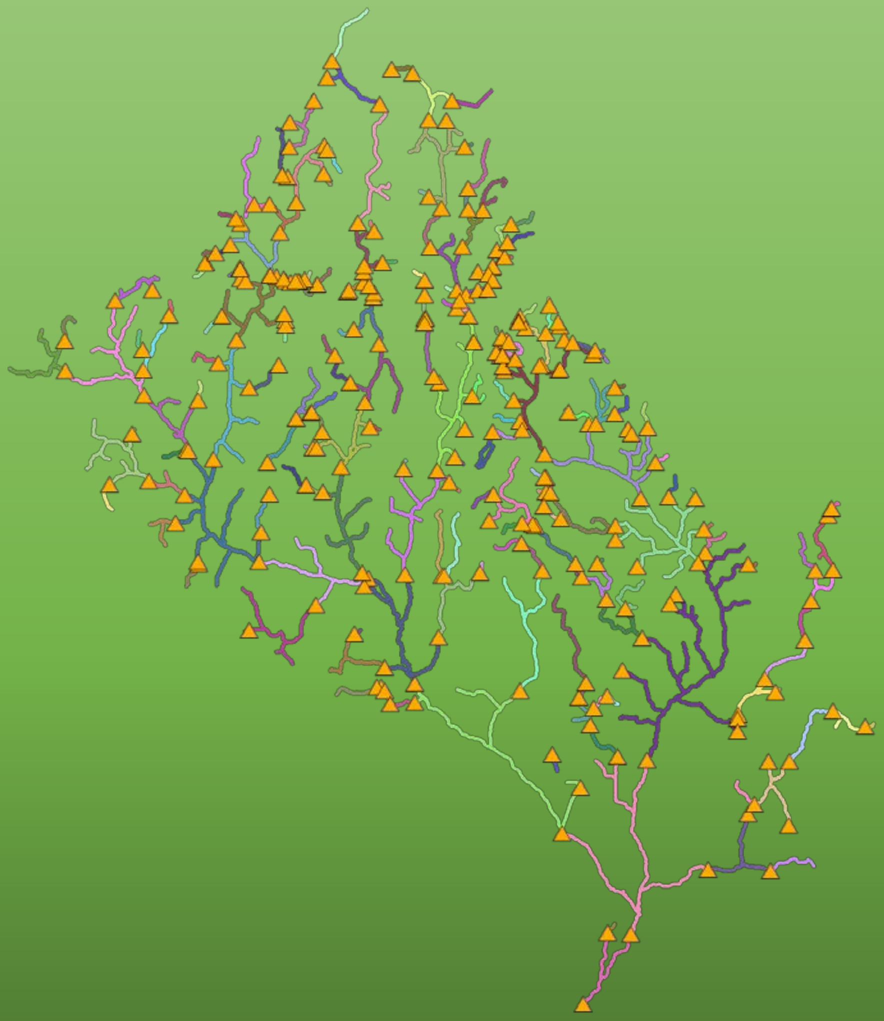
Computation Size:

n = total # of barriers
b = # to remove

b	n = 300
1	300
2	44,850
3	4,455,100
4	330,791,175
5	1.95×10^{10}

$$\frac{n!}{b!(n-b)!}$$

Workflow: Prioritize Removal



Computation Size:

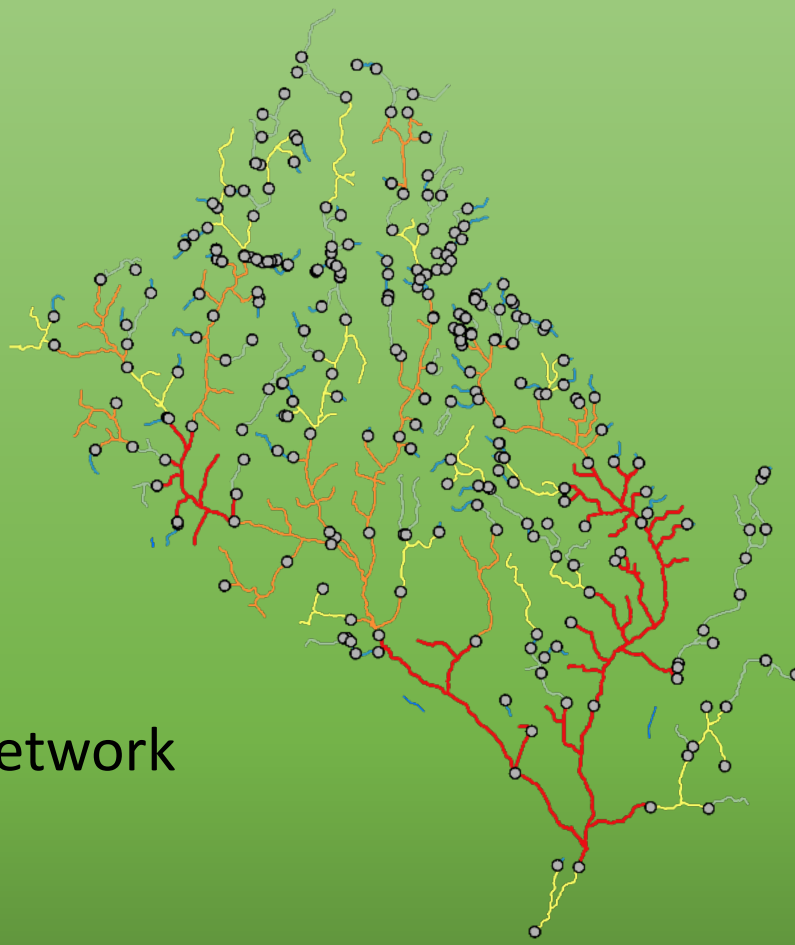
n = total # of barriers
b = # to remove

b	n = 300	n = 10000
1	300	10000
2	44,850	49,995,000
3	4,455,100	1.66 x 10^{10}
4	330,791,175	4.16 x 10^{13}
5	1.95 x 10^{10}	8.35 x 10^{13}

$$\frac{n!}{b!(n-b)!}$$

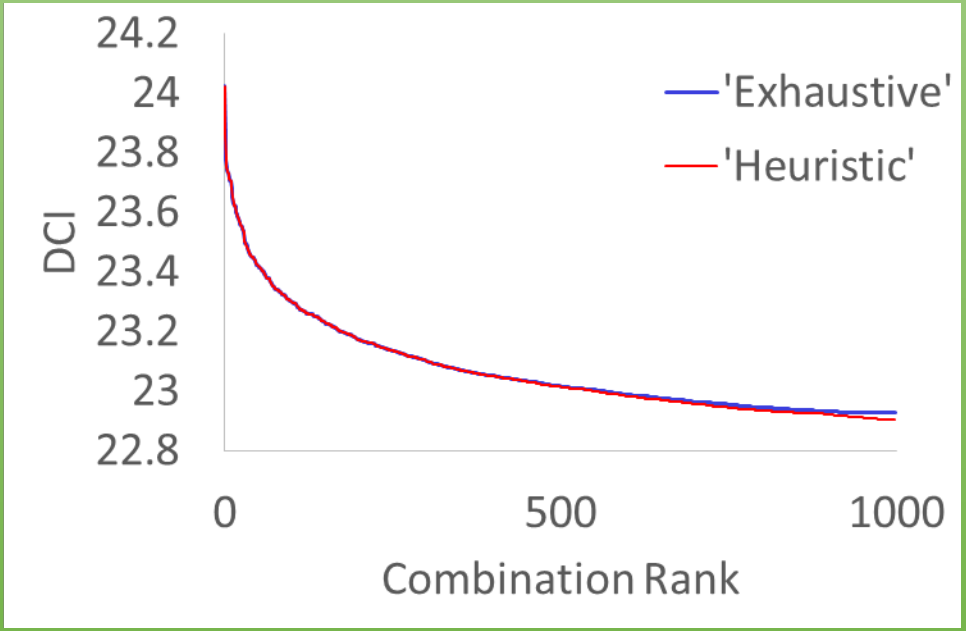
Workflow: Prioritize Removal

- Use heuristics to limit search
  - Connect high-weight streams
  - Identify paths where a large cumulative improvement to passability is possible
  - Progressively expand search
    - Path, Neighborhood, Full Network



Workflow: Prioritize Removal

- Evaluation
  - Compared to exhaustive searches
  - 300 node network
  - Removing 3 barriers
  - > 4 million possible combinations

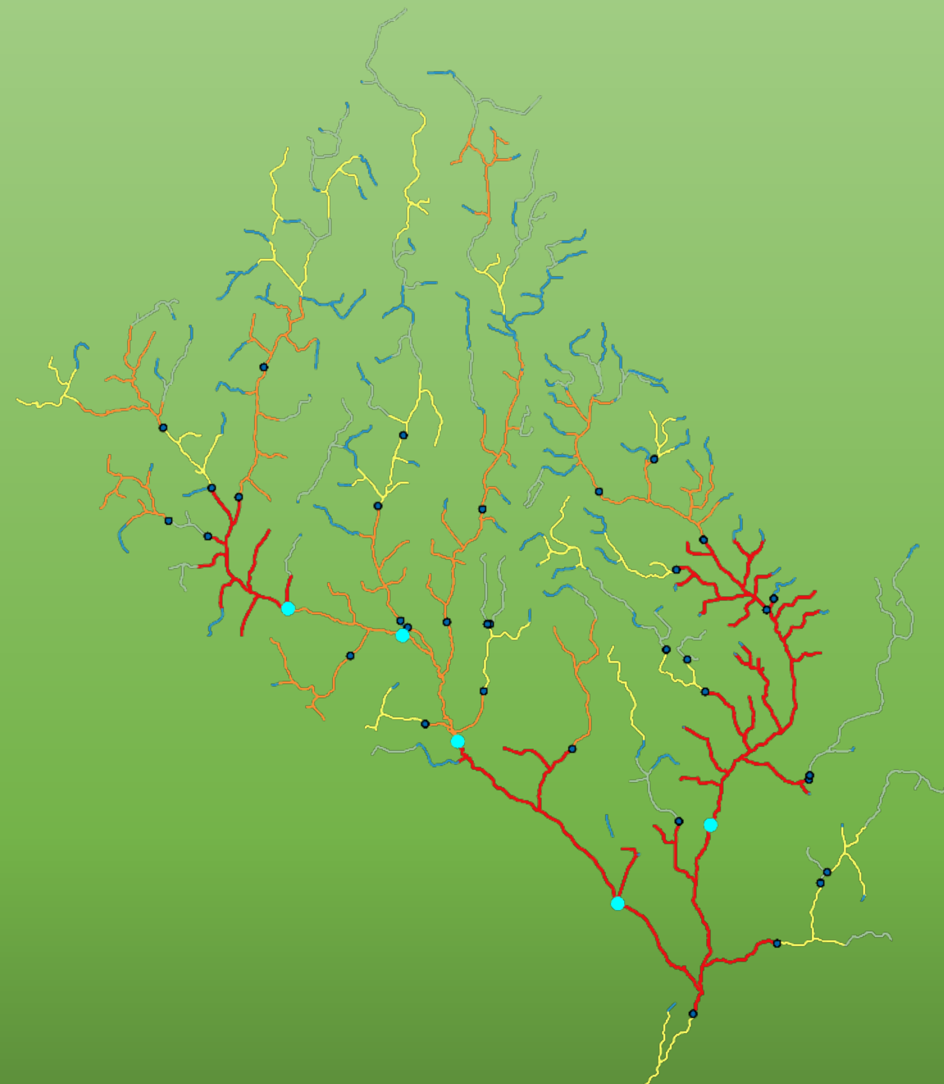


Workflow: Visualizing Results

Table

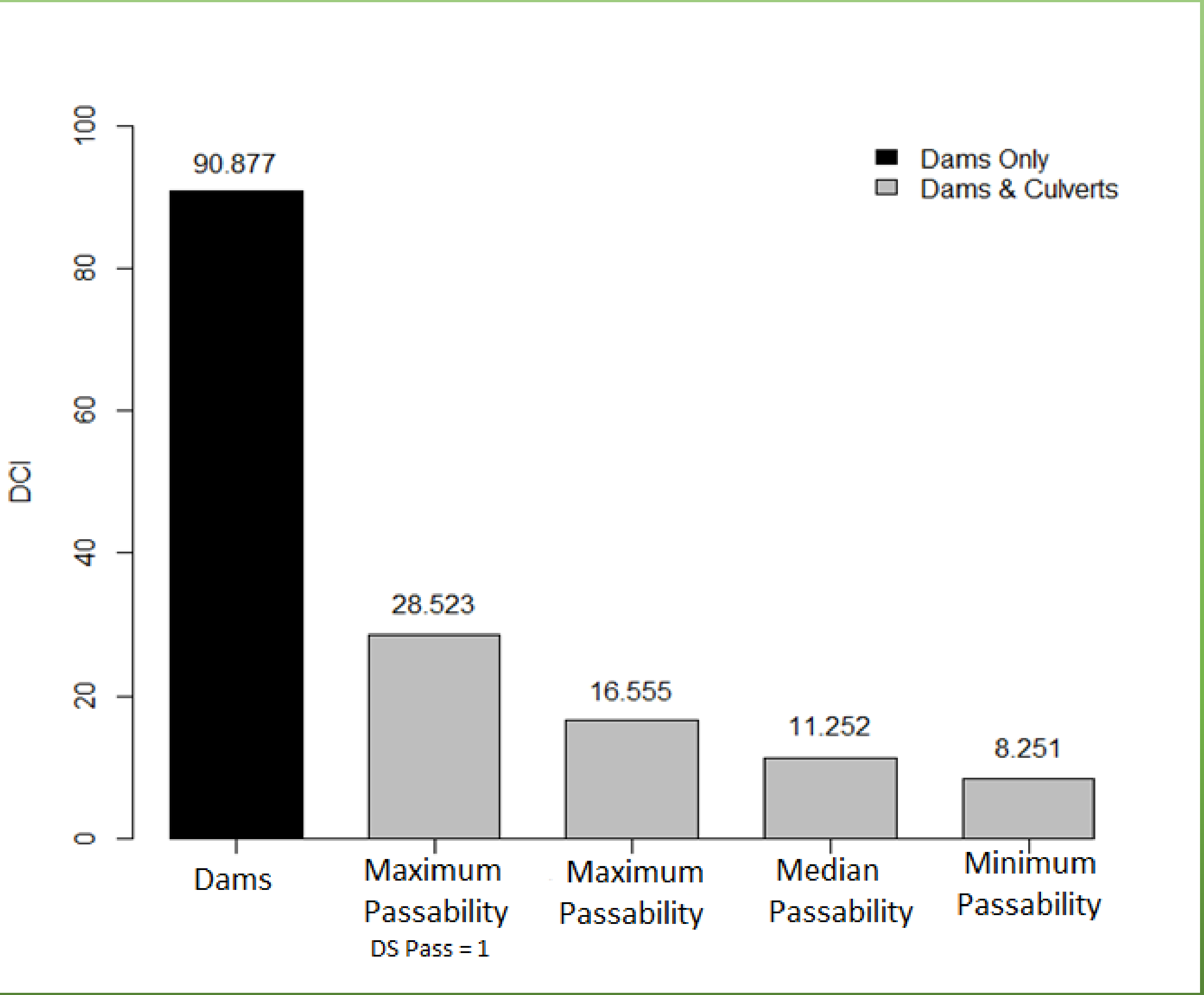
outdci5

	bar1	bar2	bar3	bar4	bar5	DCI
▸	12	29	61	103	213	11.81718
	12	29	103	113	213	11.661645
	12	18	29	113	213	11.389526
	12	29	113	213	245	11.198436
	12	29	61	113	213	11.186259
	12	29	103	213	245	11.059671
	12	29	30	113	213	10.751206
	12	29	113	212	213	10.691535
	12	29	113	213	252	10.682282
	12	29	102	113	213	10.681341
	12	29	113	178	213	10.663293
	12	29	113	213	242	10.660706
	12	29	113	114	213	10.625846
	12	29	30	103	213	10.617544
	12	29	113	213	235	10.603748
	12	29	113	213	237	10.593374
	12	29	113	213	244	10.591586



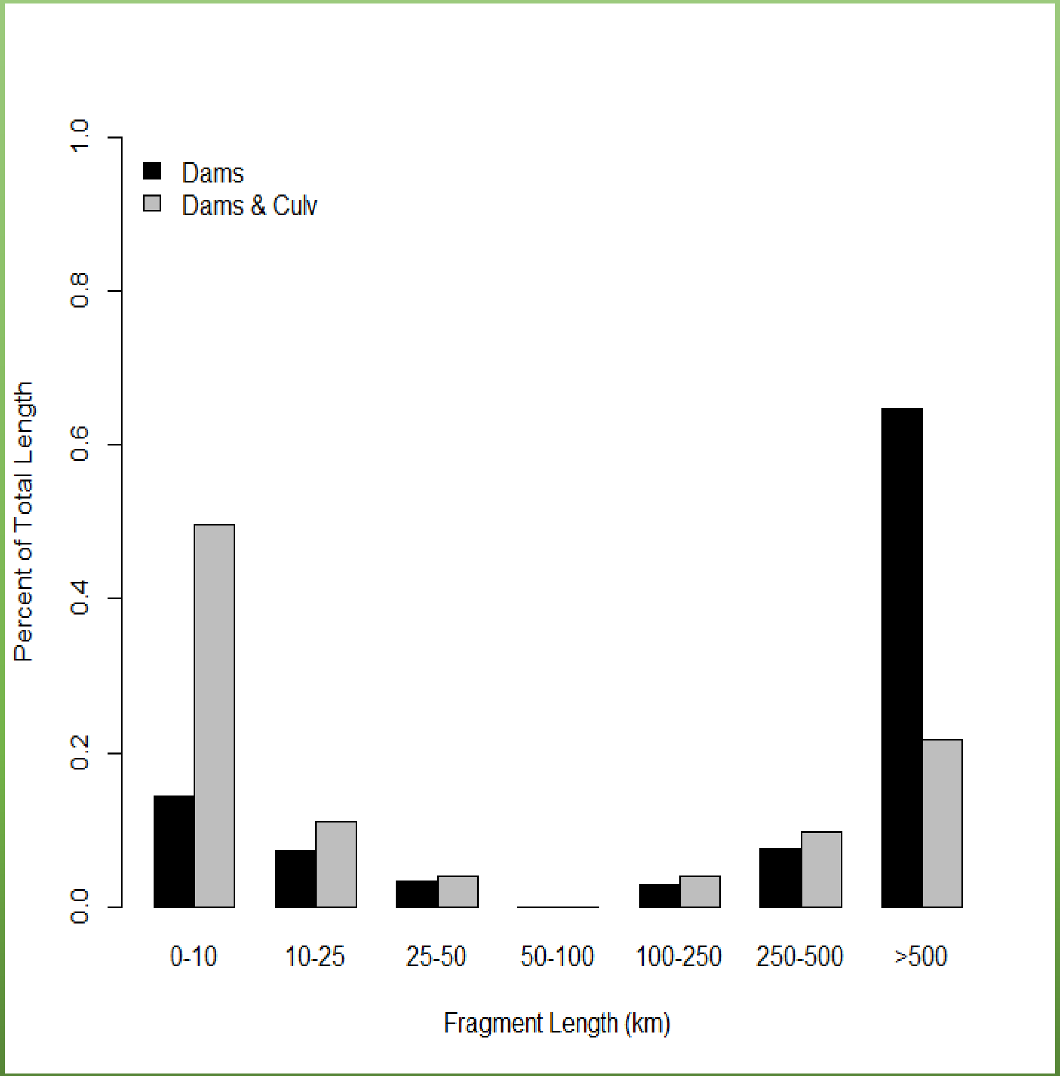
Applications

DCI in the Etowah River Watershed



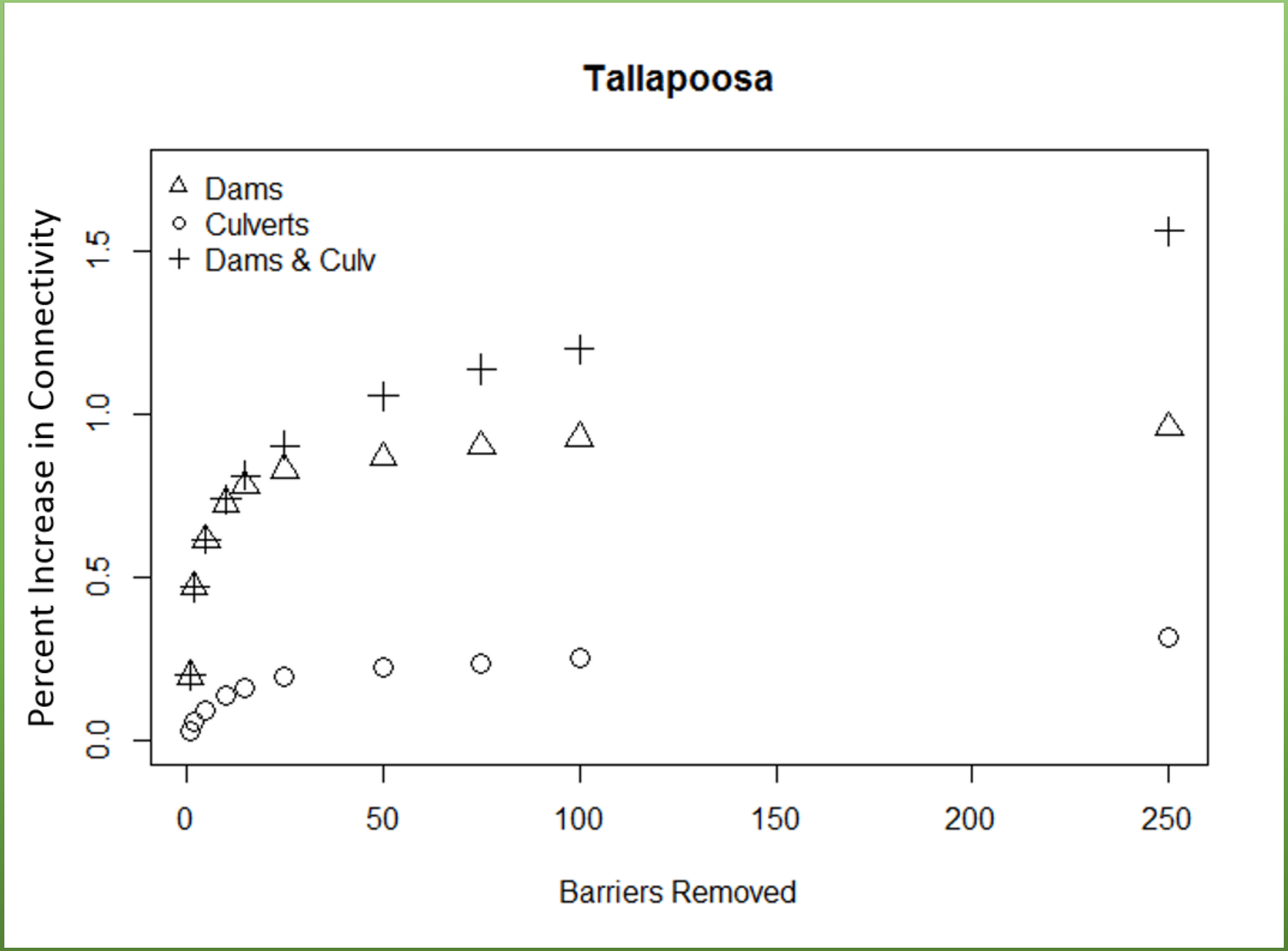
Applications

Distribution of Fragment Lengths in the Etowah River Watershed



Applications

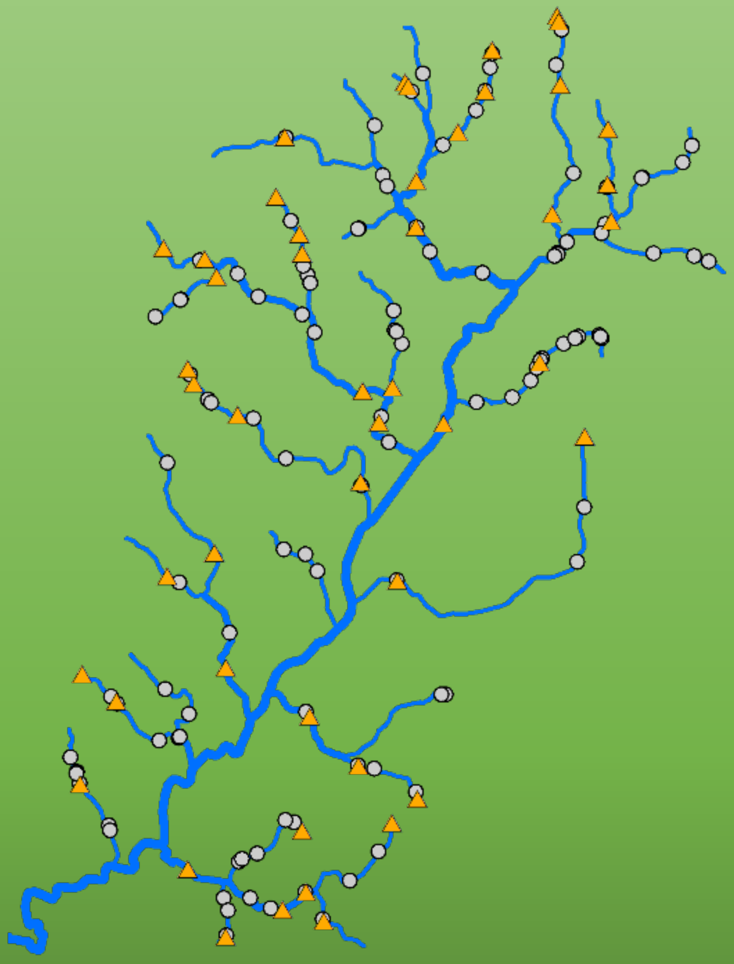
Evaluating Alternatives



Applications

Compare scenarios

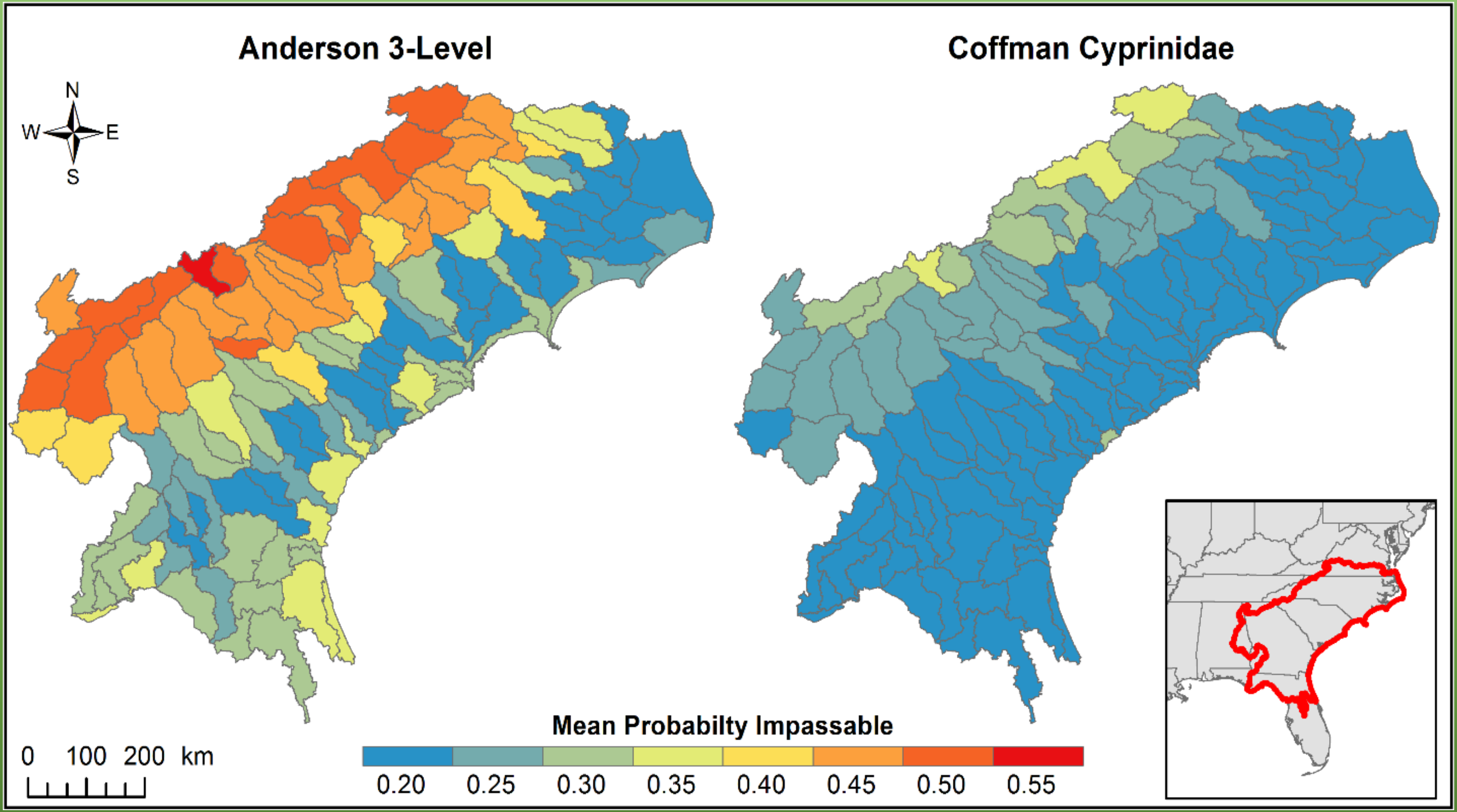
- Add Barriers
- Make barriers ‘un-removable’
- Alter passability assumptions
- Alter stream weight (habitat quality)



Ongoing Work

South Atlantic LCC Report

- Assessing the influence of road-stream crossings



Ongoing Work

Web-application of aquatic connectivity tools

- Partnership with CSU, UGA, UMASS, & Army COE

eRAMS *Share your geographic perspective ...*

How Aquatic Connectivity tool fits into Eco-Logical

STEP 1 Build and strengthen collaborative partnerships and vision

- Shared understanding of issues surrounding aquatic connectivity

STEP 2 Characterize resource status and integrate natural environment plans

- Compile data and identify current conditions “such as stream crossings”

STEP 3 Create a regional ecosystem framework (conservation strategy + transportation plan)

- Inform scenarios to help define footprint for proposed projects

How Aquatic Connectivity tool fits into Eco-Logical

- Help create a regional-scale picture of potential and cumulative impacts
- Scenarios can help identify and quantify mitigation needs

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- Tool can help prioritize conservation / restoration actions
- Spatial location and type of impacts can help identify potential lead agencies

How Aquatic Connectivity tool fits into Eco-Logical

STEP 4 Assess effects on conservation objectives

- Help create a regional-scale picture of potential and cumulative impacts
- Scenarios can help identify and quantify mitigation needs

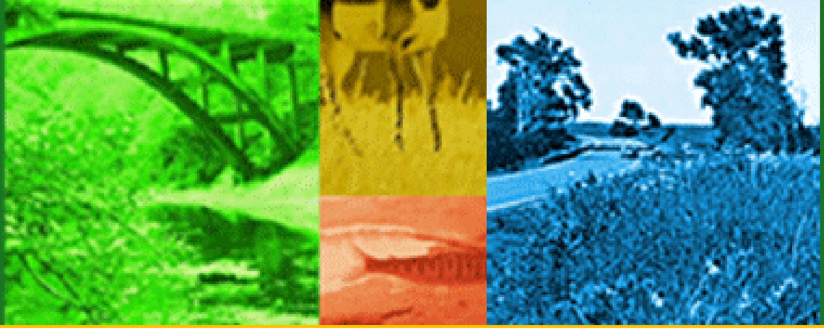
STEP 5 Establish and prioritize ecological actions

- Tool can help prioritize conservation / restoration actions
- Spatial location and type of impacts can help identify potential lead agencies

STEP 6 Develop crediting strategy

- Identify measurements for mitigation goals – e.g. connectivity indices
- Help establish off site mitigation opportunities

Eco-Logical
Webinar Series



Q & A

Presenters

Mike Ruth, Federal Highway Administration, Office of Project Development and Environmental Review
Duncan Elkins, University of Georgia
Evan Collins, U.S. Fish and Wildlife Service
Thomas Prebyl, University of Georgia
Nate Nibbelink, University of Georgia

Learn more about Eco-Logical at the FHWA website