



The South Carolina Stream Conservation Planning Tool

Mark Scott, Ph.D.

South Carolina Dept. of Natural Resources

Freshwater Fisheries Research

Clemson, SC



Life's Better OUTDOORS

dnr.sc.gov

DNR

The vision for the application is to implement a mountains-to-the-sea framework for proactive aquatic conservation

Framework is data-driven, informed by ongoing resource assessments

Identify key drivers maintaining resource integrity

Geographic Information System interfaces data and analytical results over the web, allows users to run alternate scenarios for planning



- State Wildlife Grants - federal monies appropriated by Congress to the states for the purpose of “keeping common species common”
- State Wildlife Action Plan (2005, 2015)
 - proactive plan to help conserve wildlife and vital natural areas before they become too rare and costly to protect
- 125 aquatic-dependent species listed as of priority conservation concern (~ 40% of total list)



Troy Cribb



Troy Cribb



Kevin Kubach

Aquatic ecosystem management = watershed management

Freshwater ecosystem

- Hydrologic cycle driven by climate and geology/topography
- Mediated by soils and vegetation
- Transport and storage of water, sediment, and organic material
- Biogeochemical cycling of dissolved and suspended carbon and nutrients
- **Watershed** (aka. catchment, drainage basin) as the basic ecosystem unit
- Entire landmass can be organized into watersheds



Eastern United States Forested landscapes

- Stable hydrology
- Low rates of sedimentation
- Stable channels
- Moderate temperature
- Coarse substrates (uplands)
- Allochthonous energy for trophic system (OM)
- Wood also important habitat



Human-dominated landscapes have consequences for aquatic habitats

- Unstable hydrology
- Rates of sedimentation
- Finer substrates
- Unstable channels
- Temperature regime, variability
- Organic matter inputs
- Dissolved nutrients
- Contaminants
- Fragmented stream networks due to barriers



South Carolina Stream Assessment (SCSA)

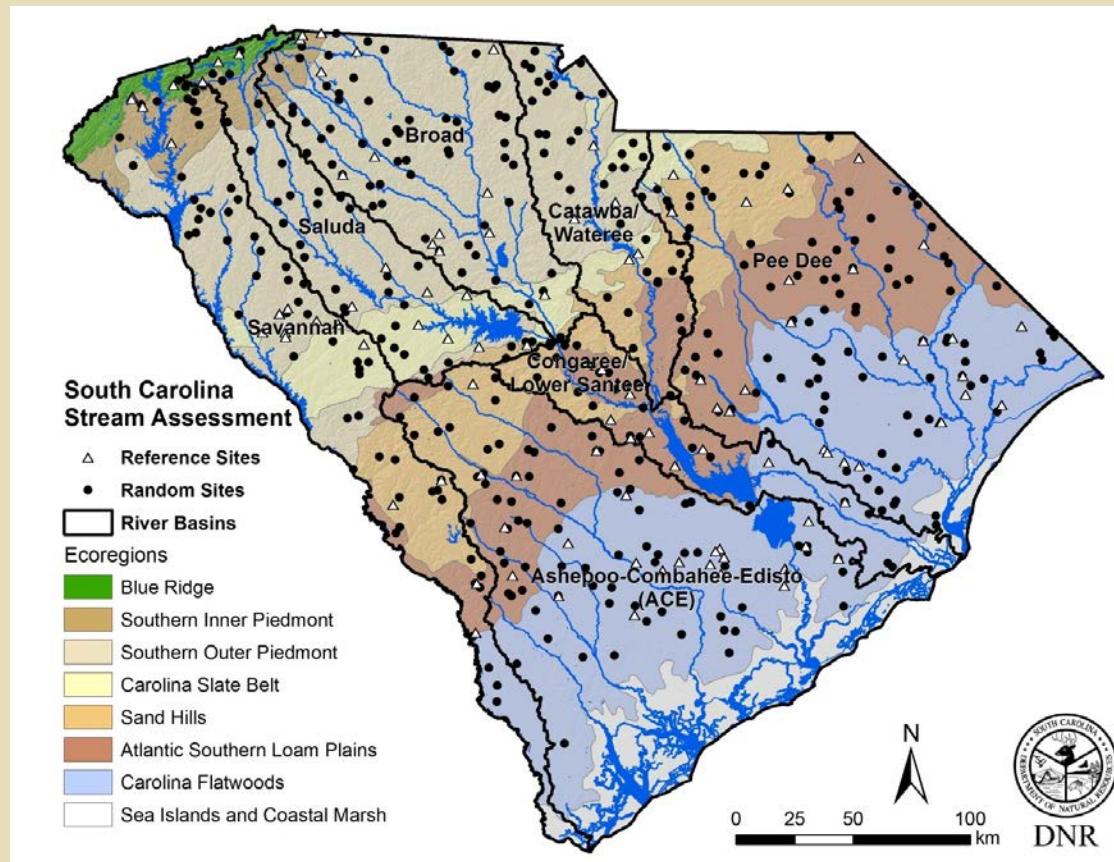
- Initiated in 2005 by South Carolina Department of Natural Resources through a State Wildlife Grant from USFWS
- Collaboration with Clemson University faculty and students
- Field surveys of wadeable streams commenced 2006, completed in 2011
- Project objectives were to
 - Characterize current resource status statewide
 - Establish baseline conditions for future trends analysis
 - Identify factors with greatest influence on resources
 - Use results for synthesis and forecasting



SCSA fish collection

SCSA

- Nearly 500 streams sampled
- 4-150 km² watersheds
- 85 reference streams sites
- Stratified random sampling design
- Biological, chemical, & physical data collected



SC Stream Assessment sampling locations

SCSA Data Collected Each Site

Table 1. Suite of measurements corresponding to each stream sample site (n=450) in the SC Stream Assessment.

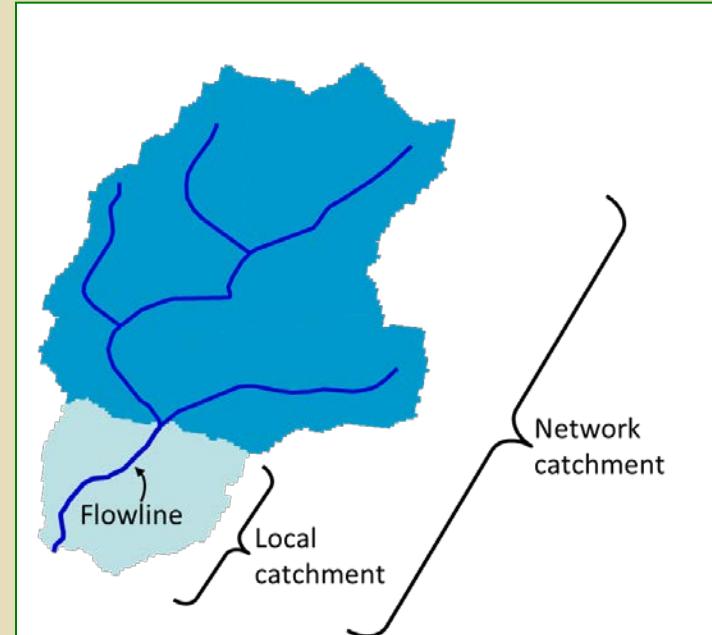
Variables associated with each stream site (units)	
Stream reach ID	Drainage area of watershed (km ²)
Longitude (decimal degrees)	Elevation (m above mean sea level)
Latitude (decimal degrees)	Channel gradient (percent slope)
<u>Water quality/chemistry</u>	
Dissolved oxygen (mg/L)	Nitrogen (mg/L): nitrate, nitrite, TN
Conductivity (μ S/cm)	Phosphorus (mg/L): ORP, TP
pH	Metals (water & sediment; μ g/L and mg/kg respectively): Ag, Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se, Tl, Zn
Hardness	
Turbidity (NTU)	Organic compounds (μ g/L): selected polycyclic aromatic hydrocarbons, nonylphenols, estrogens, caffeine, triclosan, & atrazine
Total suspended solids (mg/L)	
Total dissolved solids (anions, cations; mg/L)	
<u>Physical/Geomorphological</u>	
Water temperature (°C) continuous hourly logging	Mean wetted width (m)
Channel dimensions: ratios of width to depth, bank height/angle, cross sectional area	Mean and standard deviation (STD) water depth (m)
Channel substrate particle size distribution	Mean and STD water velocity (m/sec)
	Percent occurrence of organic debris and wood in stream channel
<u>Biological</u>	
Biomarkers indicating exposure to pollutants in sunfish individuals: EROD activity, bile fluorescence, and induction of metallothionein and vitellogenin	Biological Community Structure:
Indicators of fish health: hepatosomatic index, gonadosomatic index and splenosomatic index	aquatic insects crayfishes mussels fishes reptiles & amphibians (herpetofauna)

Linking Streams to Landscape

Evaluate cumulative effects of landscape variables on aquatic resources and species composition

Spatial predictor data from the National Fish Habitat Action Plan (NFHAP)
 (Wang et al. 2011)

- 1:100K NHD+ Catchments (Version 1)
- Natural and human disturbance variables



Local catchment versus network catchment spatial scales. Figure from Esselman et al. (2011)

	Landscape variables	
Type	Physical	Human Disturbance
Example	Elevation, Slope	Dam density, forest cover

Predictive Models

- Random Forest classifications generated using response variables from SCSA data and NFHAP spatial predictor data.
- Tree-based machine learning method handles noisy data, high-order interactions, and nonlinear effects



Source: Cathy Marion, SCDNR

SC model regions



Source: Cathy Marion, SCDNR

Example response variables:

Conservation Priority Species Richness (Upstate)
Shiner Sucker Darter Richness (Upstate)
Darter Richness (Upstate)
Centrarchid Density (Upstate)
Taxonomic Groups (Coastal Plain)

Stream Conservation Planning Tool

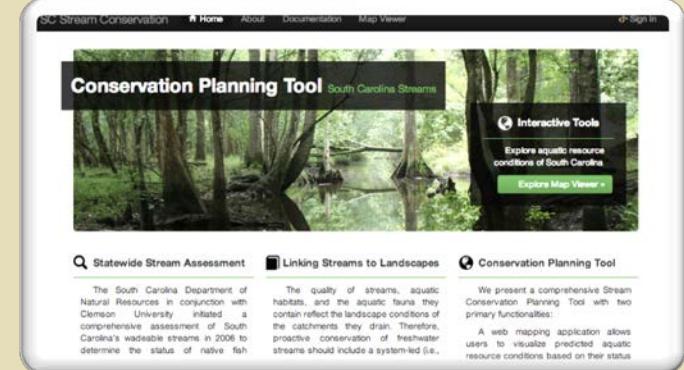
Purpose:

1. Aquatic Resource Condition Map Viewer

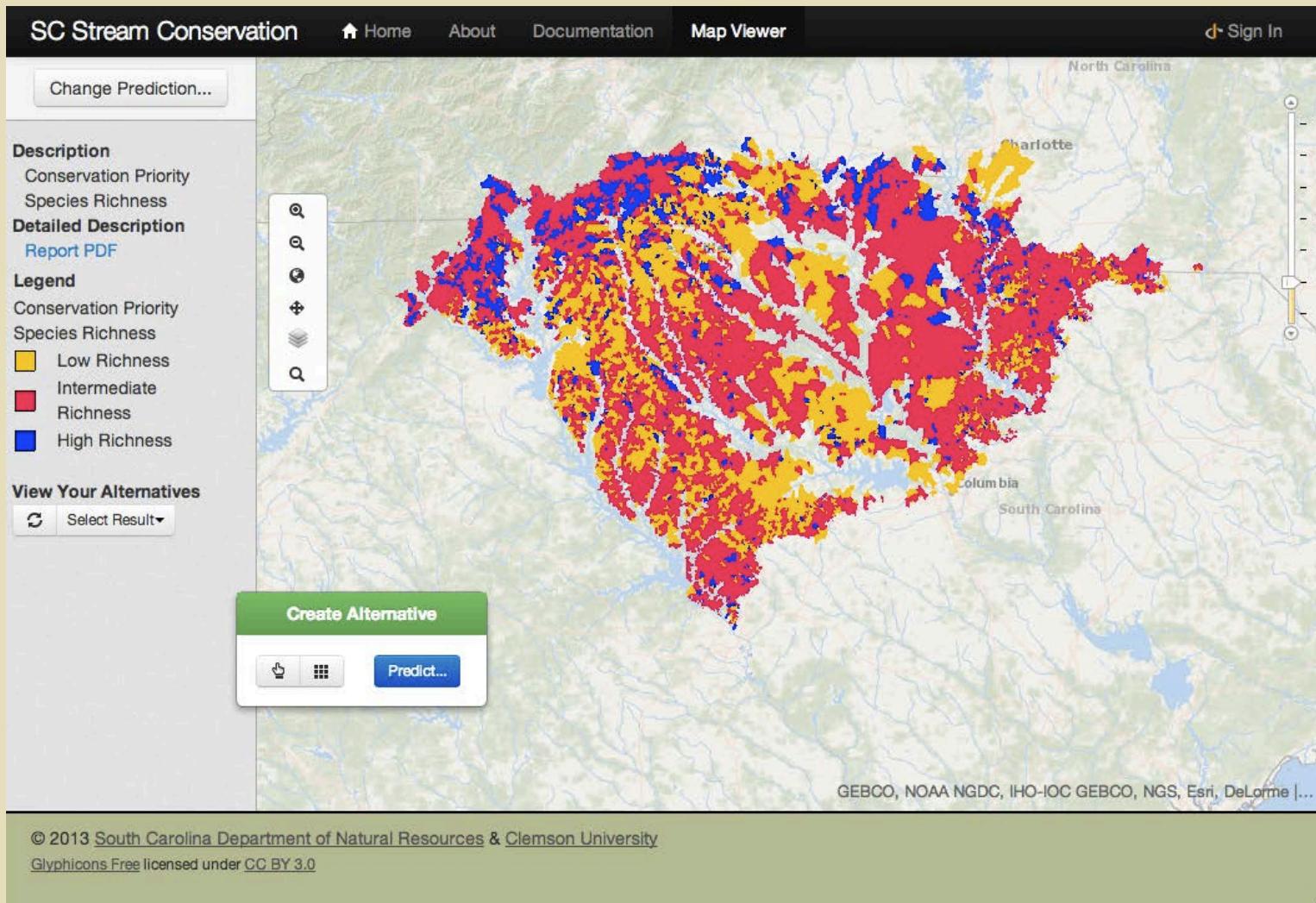
Visualize expected aquatic resource conditions based on Random Forest predictions.

2. Interactive landscape modification

Allow user to modify human disturbance variables and visualize the effect of modifications on aquatic resource conditions.



Stream Conservation Planning Tool



Communicate model findings:
Current aquatic resource conditions

Random Forest Results

SC Stream Conservation

Home About Documentation Map Viewer

Change Prediction...

Description
Taxonomic Groups
Detailed Description
Report PDF

Legend

Coastal Plain Taxonomic Groups

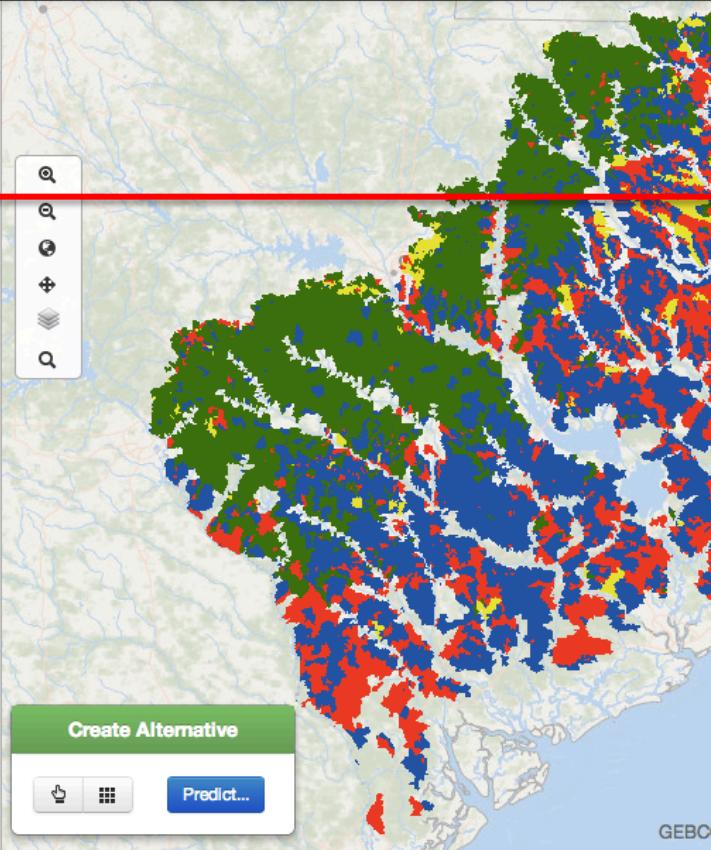
- Fluvial
- Eastern mudminnow
- Centrarchid
- Non-fluvial

View Your Alternatives

Select Result

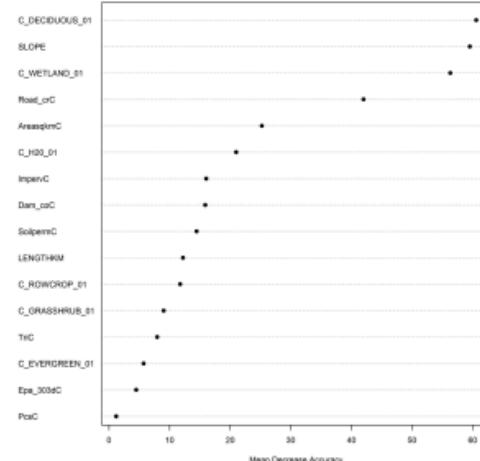
Create Alternative

Predict...



GEOGRAPHIC INFORMATION SYSTEM (GIS)

8. Variable Importance Plot



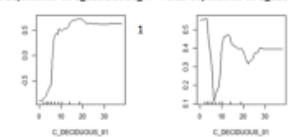
Variable	Mean Decrease Accuracy
C_DECIDUOUS_B1	~85
SLOPE	~80
C_WETLAND_B1	~75
Rose_lorC	~70
AnassimicC	~65
C_H2O_B1	~60
ImpenC	~55
Dari_cocC	~50
SolpercC	~45
LENGTH_KM	~40
C_ROWDROP_B1	~35
C_GRASSHRUB_B1	~30
THC	~25
C_EVERGREEN_B1	~20
Epa_300dC	~15
PerG	~10

Figure 1. Top ranked variables from random forests classification for predicting South Carolina Coastal Plain Taxonomic Groups.

9. Partial Dependence Plots

Partial dependence plots isolate and examine the relationships between top ranked predictors and Coastal Plain Taxonomic Groups (1=fluvial, 2=Eastern mudminnow, 3=centrarchid, 4=non-fluvial) while holding the effect of all other predictive variables constant.

Partial Dependence on C_DECIDUOUS_B1 Partial Dependence on C_DECIDUOUS_B1



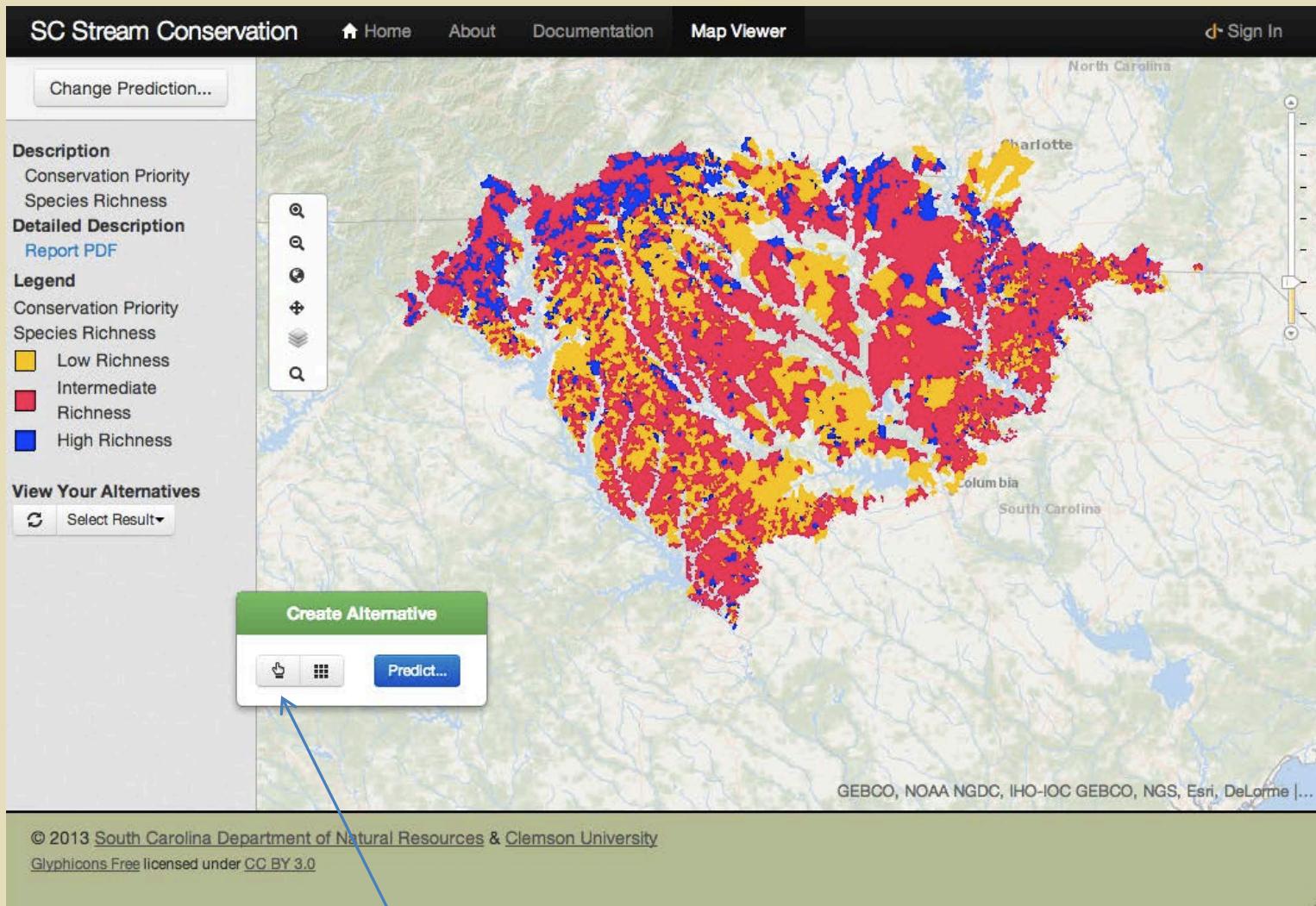
Partial Dependence on C_DECIDUOUS_B1 Partial Dependence on C_DECIDUOUS_B1



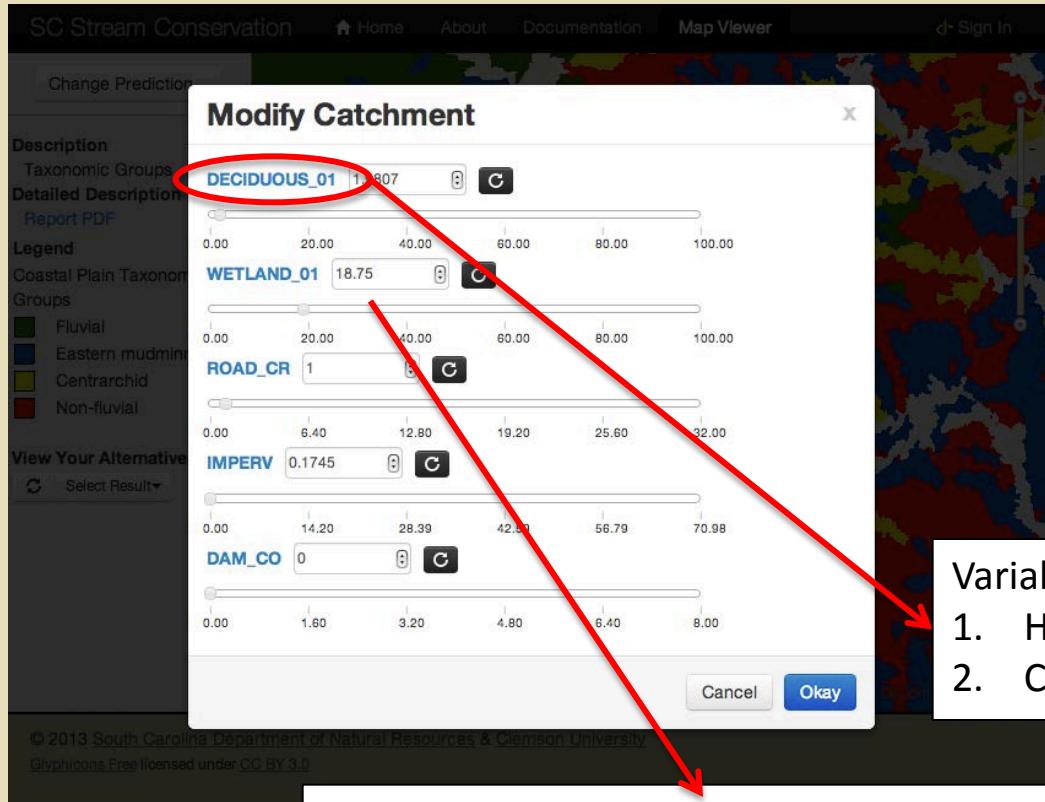
© 2013 South Carolina Department of Natural Resources & Clemson University

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Stream Conservation Planning Tool



Interactive Conservation Planning



Modifications are made at the catchment spatial scale (1:100K).

Any number of catchments may be modified.

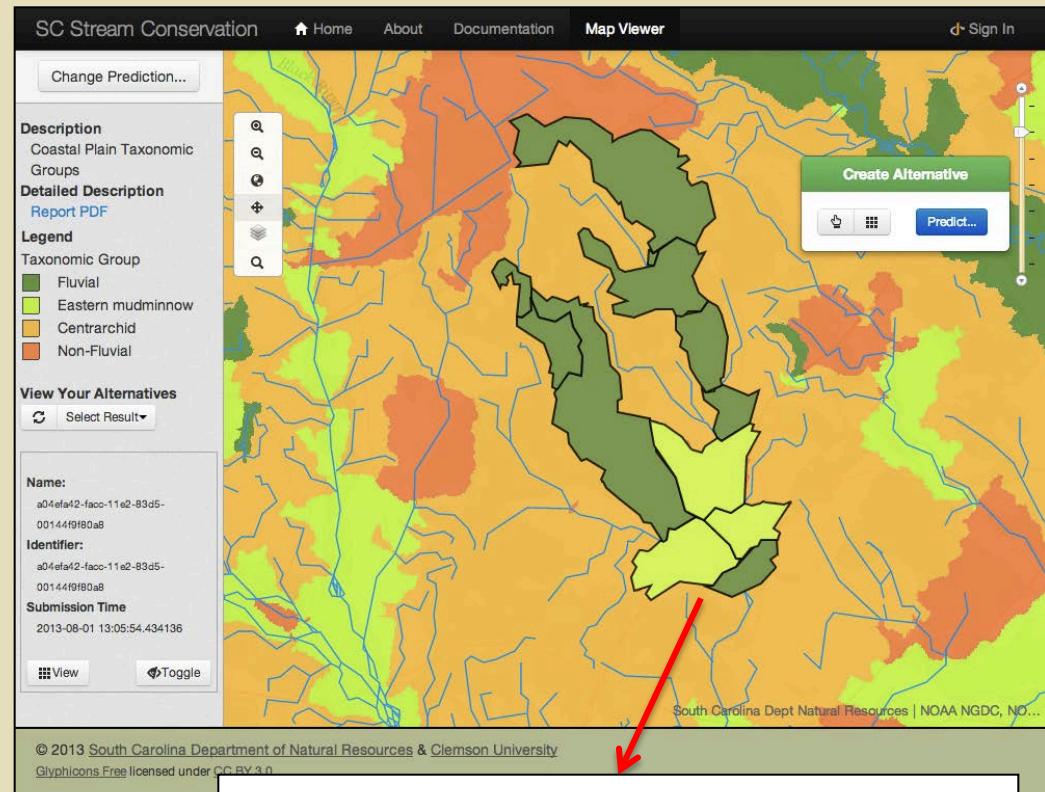
Variables are presented based on:

1. Human Disturbance Variable
2. Contribution to model outcome

Users adjust variable value with slider or text box. Existing, minimum, and maximum values are obtained from the dataset.

Interactive Conservation Planning

- Results are sent to a server process via an HTTP API.
- Server process dynamically executes a random forest prediction inside an R statistical computing environment
- Results are returned and displayed in the map viewer.
- Typically occurs in ~1s

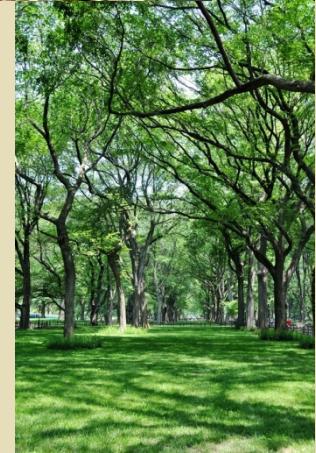


Downstream cumulative effects are automatically calculated and incorporated into prediction.

Interactive Conservation Planning

Three scenarios of landuse change:

1. The county/municipal planning commission has proposed enacting a growth plan; What are the expected consequences for my stream?
2. My agency has \$X available to be put toward installing greenspace in a basin; What spatial configuration would give the most conservation bang for the buck?
3. A large project is planned and approved but requires mitigation of anticipated impacts; How much mitigation is necessary and where should it be placed to offset impacts to the larger system?



Urban growth plan 10%-20%-30%



[Change Prediction...](#)**Description**

Centrarchid Density

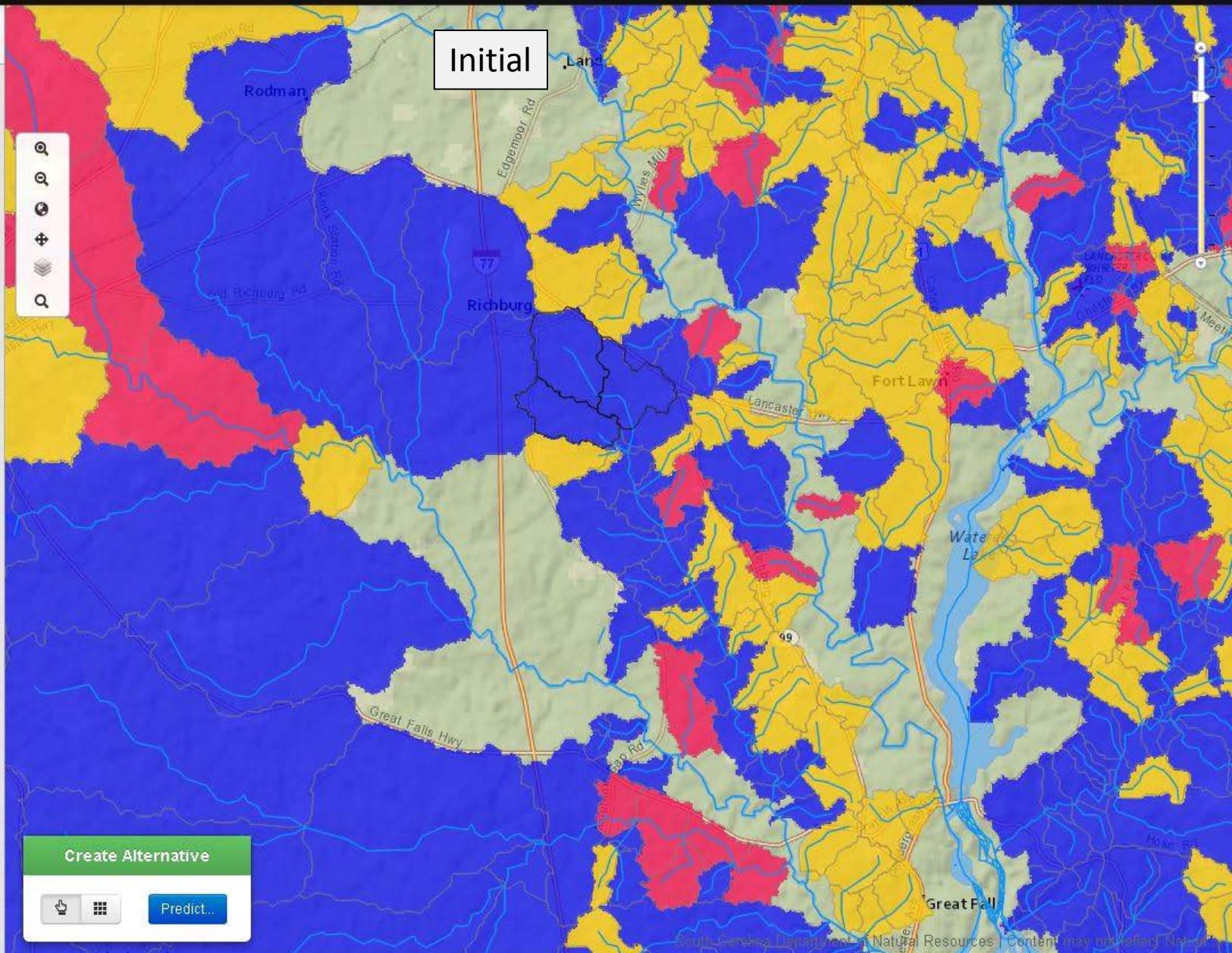
Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

High Density

Intermediate Density

Low Density

View Your Alternatives[Select Result▼](#)**Initial**

[Change Prediction...](#)**Description**

Centrarchid Density

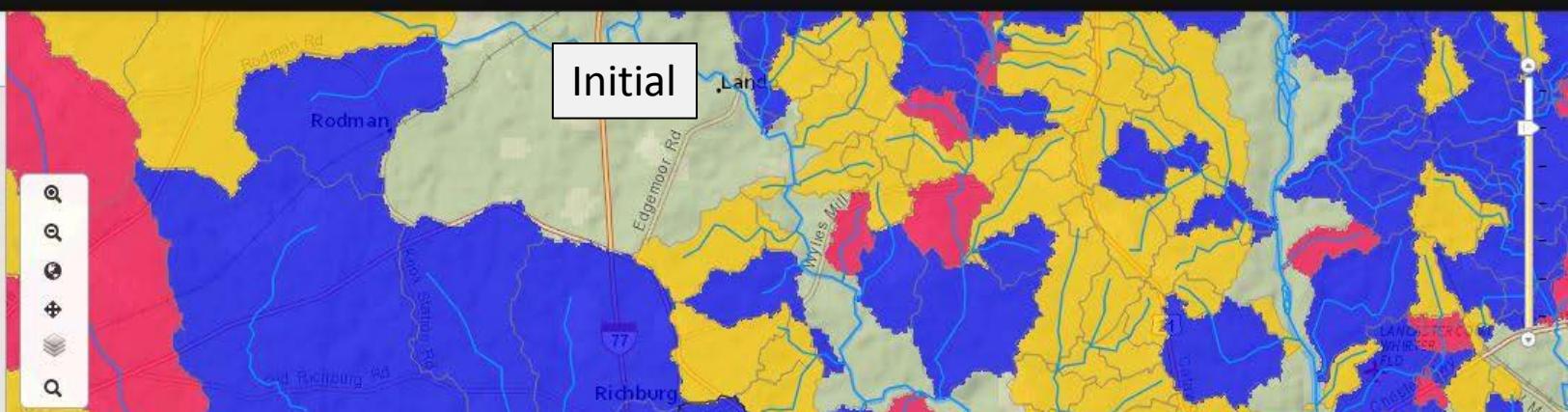
Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

High Density

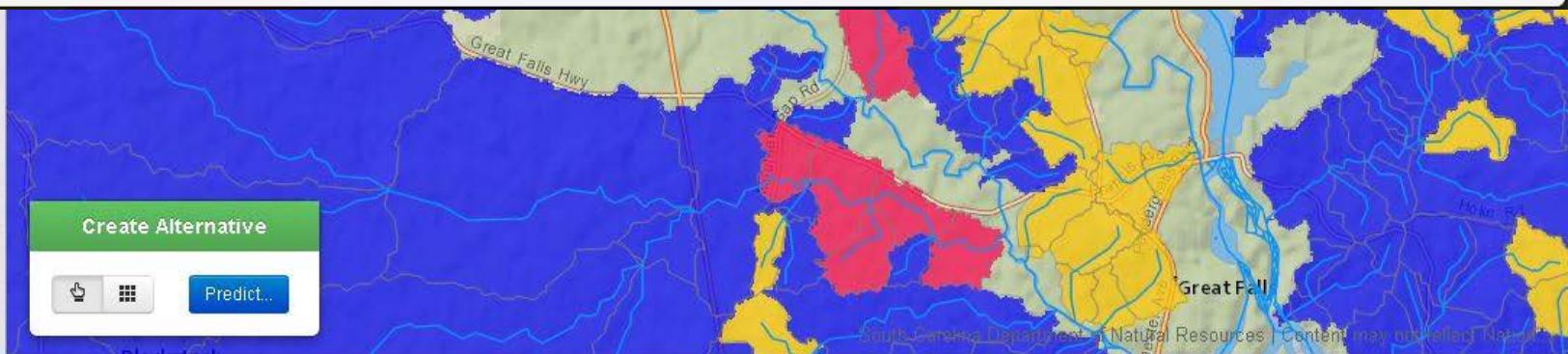
Intermediate Density

Low Density



Selected Catchments

Zoom	Edit	Remove	COMID	L_FOREST_01	L_URBAN_01	TRI	L_AGRICULTURE_01	ROAD_LEN
			9734964	72.1839	4.0035	0	16.2832	4149.48
			9734982	85.4205	2.2157	0	6.4225	2420.16
			9737066	54.1164	9.8797	1	19.8486	7722.81

[Okay](#)

[Change Prediction...](#)**Description**

Centrarchid Density

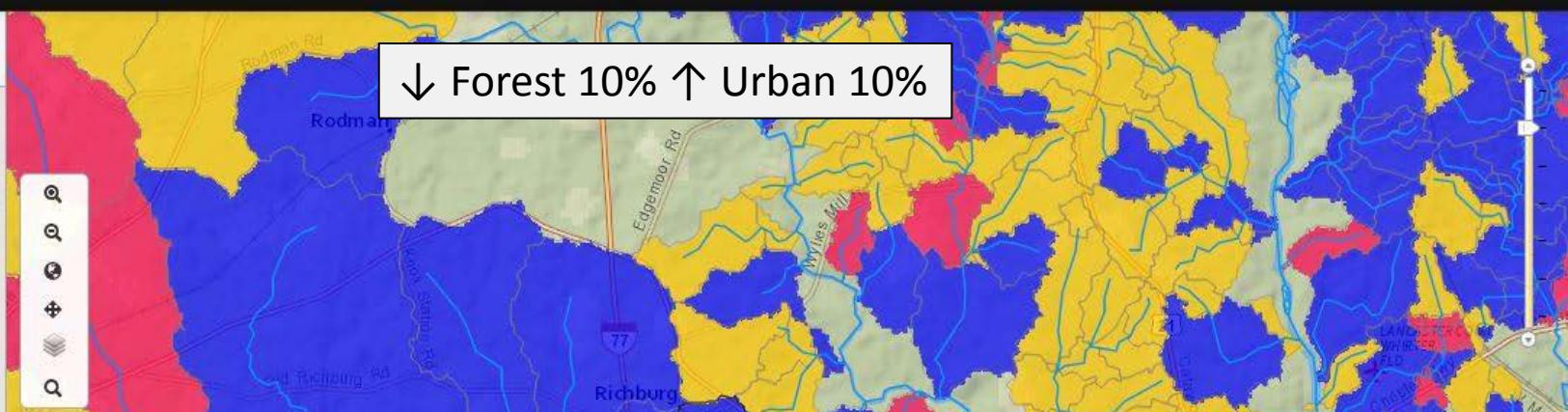
Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

High Density

Intermediate Density

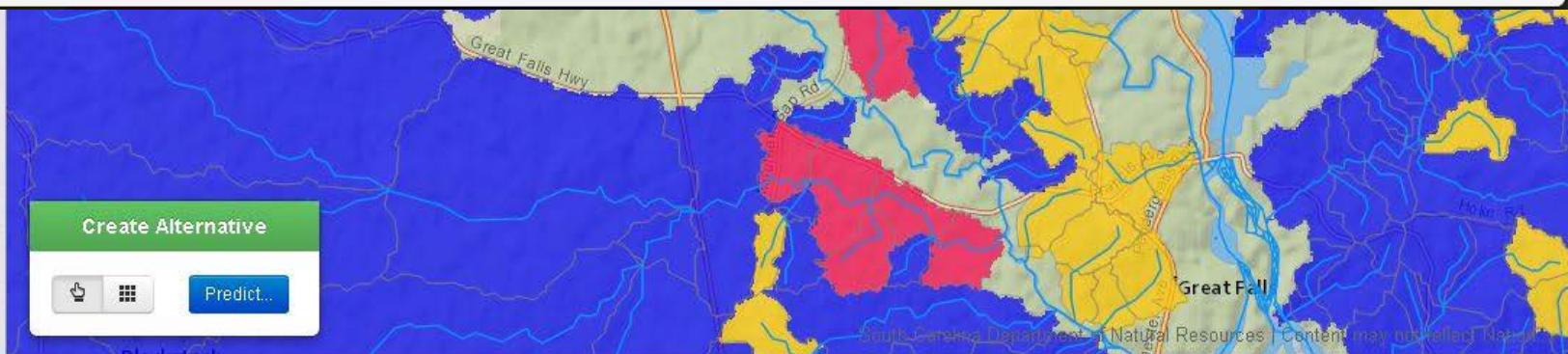
Low Density

**Selected Catchments**

X

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			9734982	75.4205	12.2157	0	6.4225	2420.16
			9737066	44.1164	19.8797	1	19.8486	7722.81

Okay



[Change Prediction...](#)**Description**

Centrarchid Density

Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

High Density

Intermediate Density

Low Density

View Your Alternatives[Select Result](#) ▾**Name:**

10% Urban Increase

Identifier:

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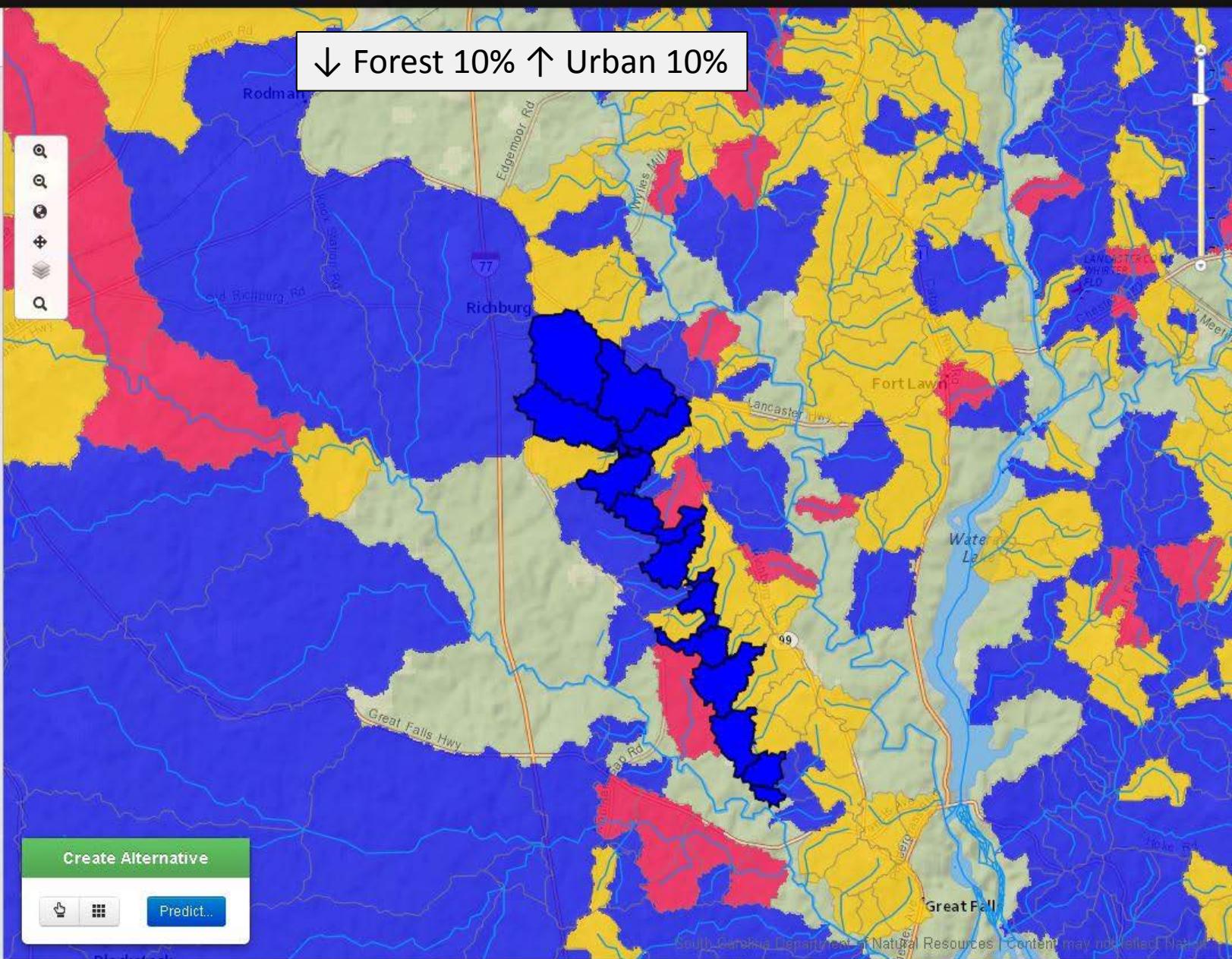
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[View](#)[Toggle](#)[Create Alternative](#)[Predict...](#)

↓ Forest 10% ↑ Urban 10%



[Change Prediction...](#)**Description**

Centrarchid Density

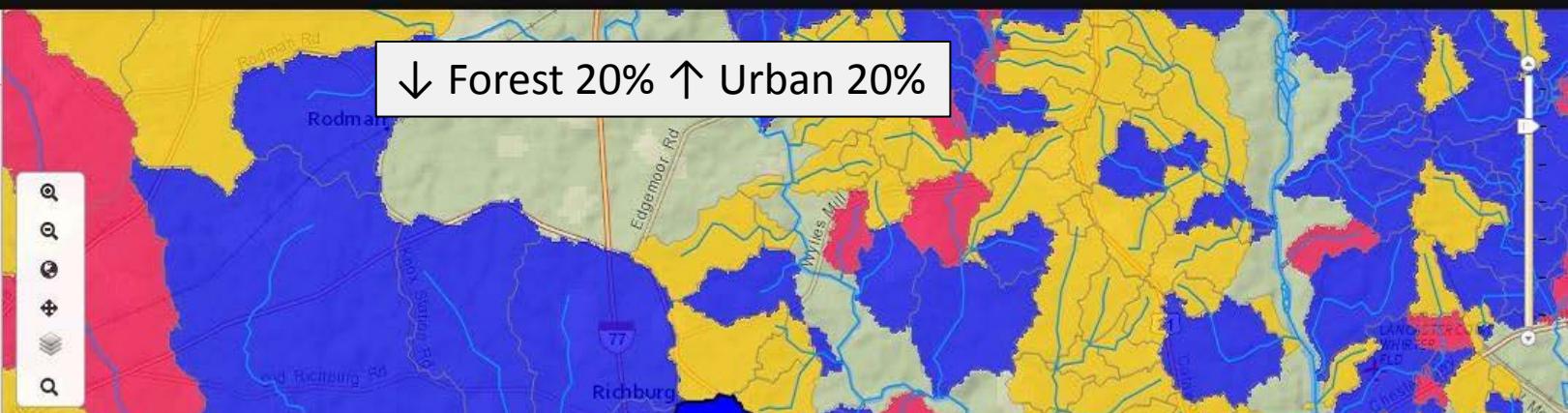
Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

High Density

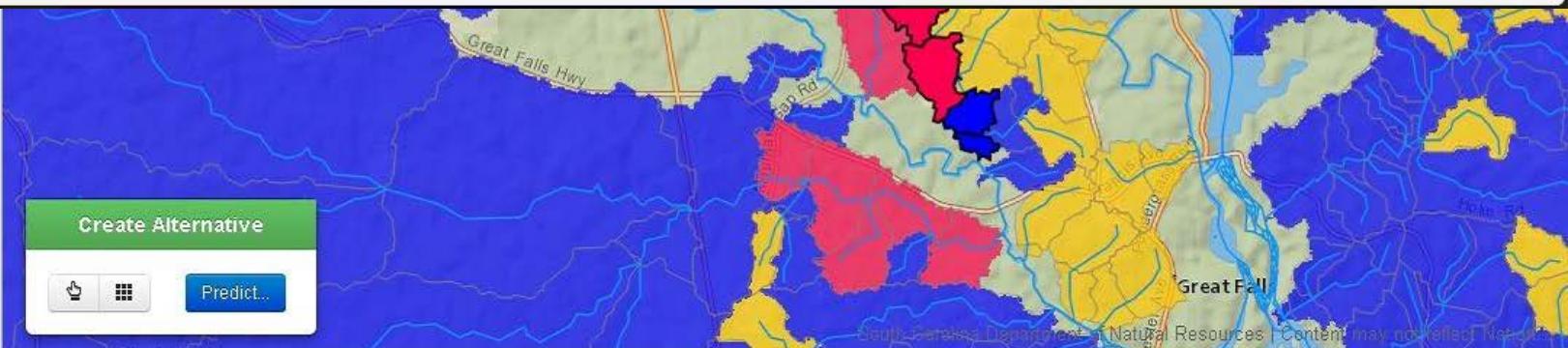
Intermediate Density

Low Density

**Selected Catchments**

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			9734982	65.4205	22.2157	0	6.4225	2420.16
			9737066	34.1164	29.8797	1	19.8486	7722.81

[Okay](#)

[Change Prediction...](#)**Description**

Centrarchid Density

Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

High Density

Intermediate Density

Low Density

View Your Alternatives[Select Result](#) ▾**Name:**

20% Urban Increase

Identifier:

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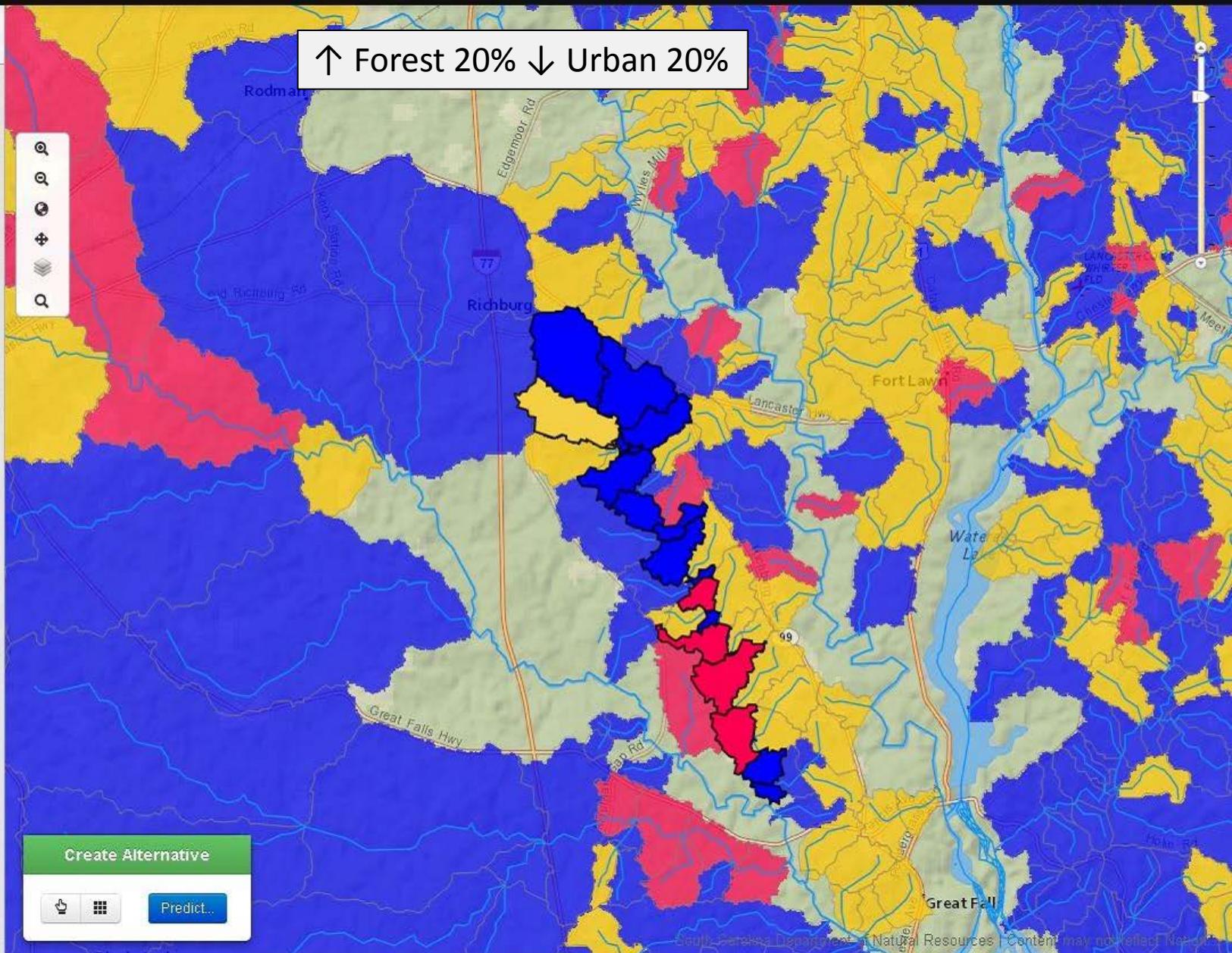
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[View](#)[Toggle](#)[Create Alternative](#)[Predict...](#)

↑ Forest 20% ↓ Urban 20%



[Change Prediction...](#)**Description**

Centrarchid Density

Detailed Description[Report PDF](#)**Legend**

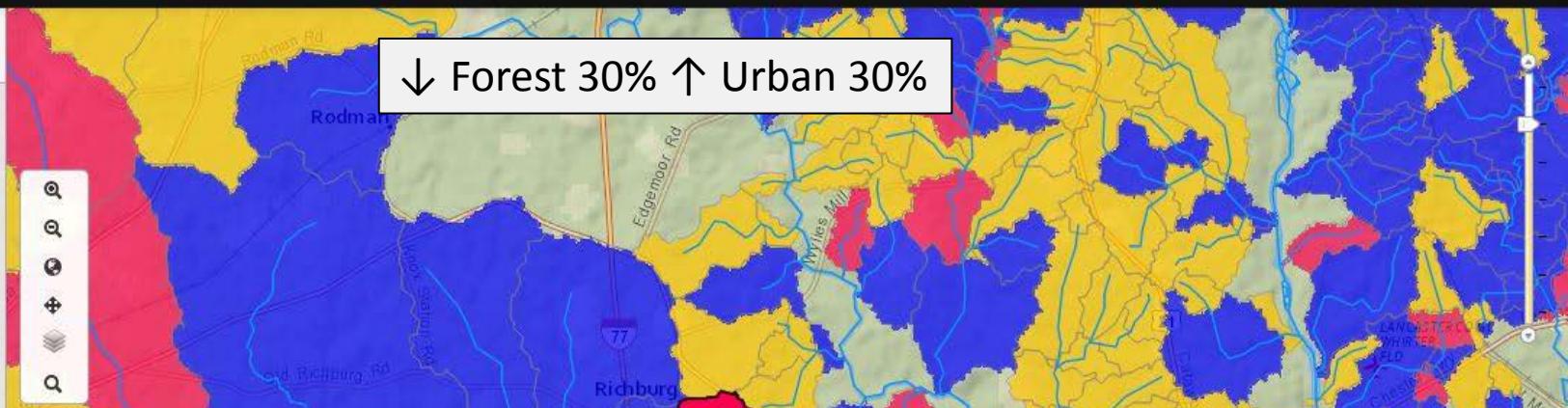
Centrarchid Density

Yellow: High Density

Pink: Intermediate Density

Blue: Low Density

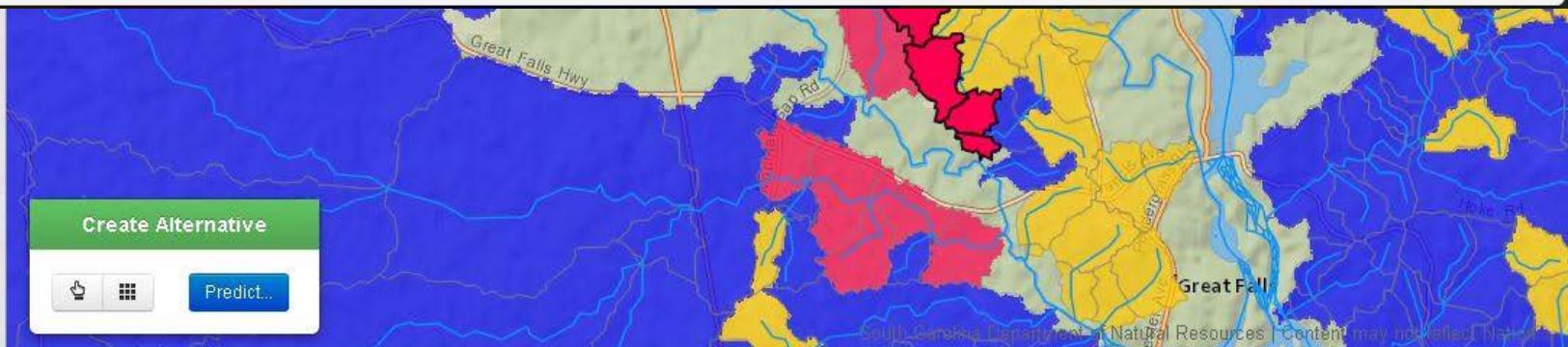
↓ Forest 30% ↑ Urban 30%



Selected Catchments

X

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			9734964	42.1839	34.0035	0	16.2832	4149.48
			9734982	55.4205	32.2157	0	6.4225	2420.16
			9737066	24.1164	39.8797	1	19.8486	7722.81

[Okay](#)

[Change Prediction...](#)**Description**

Centrarchid Density

Detailed Description[Report PDF](#)**Legend**

Centrarchid Density

Yellow: High Density

Red: Intermediate Density

Blue: Low Density

View Your Alternatives[Select Result](#) ▾**Name:**

30% Urban Increase

Identifier:

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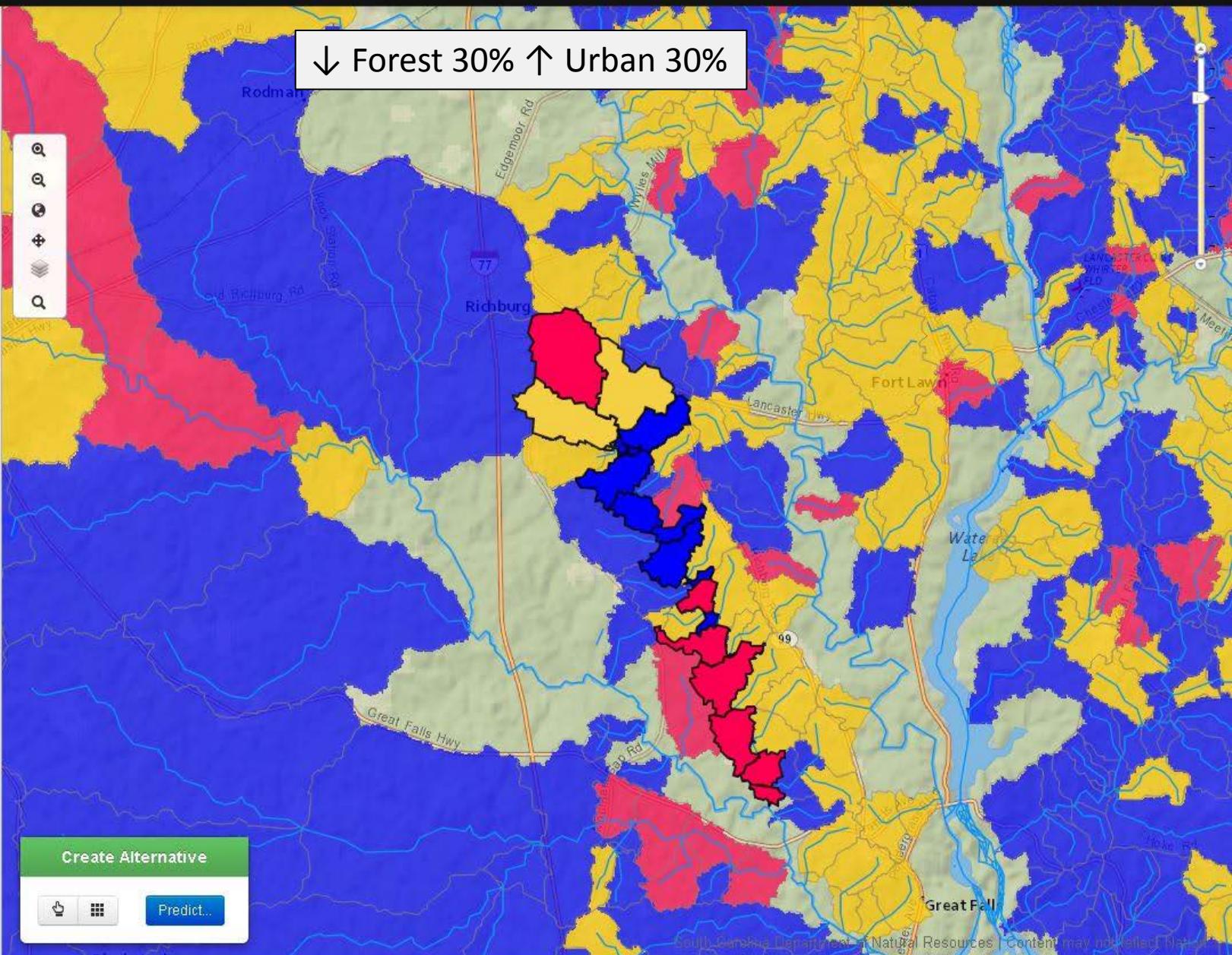
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Submission Time

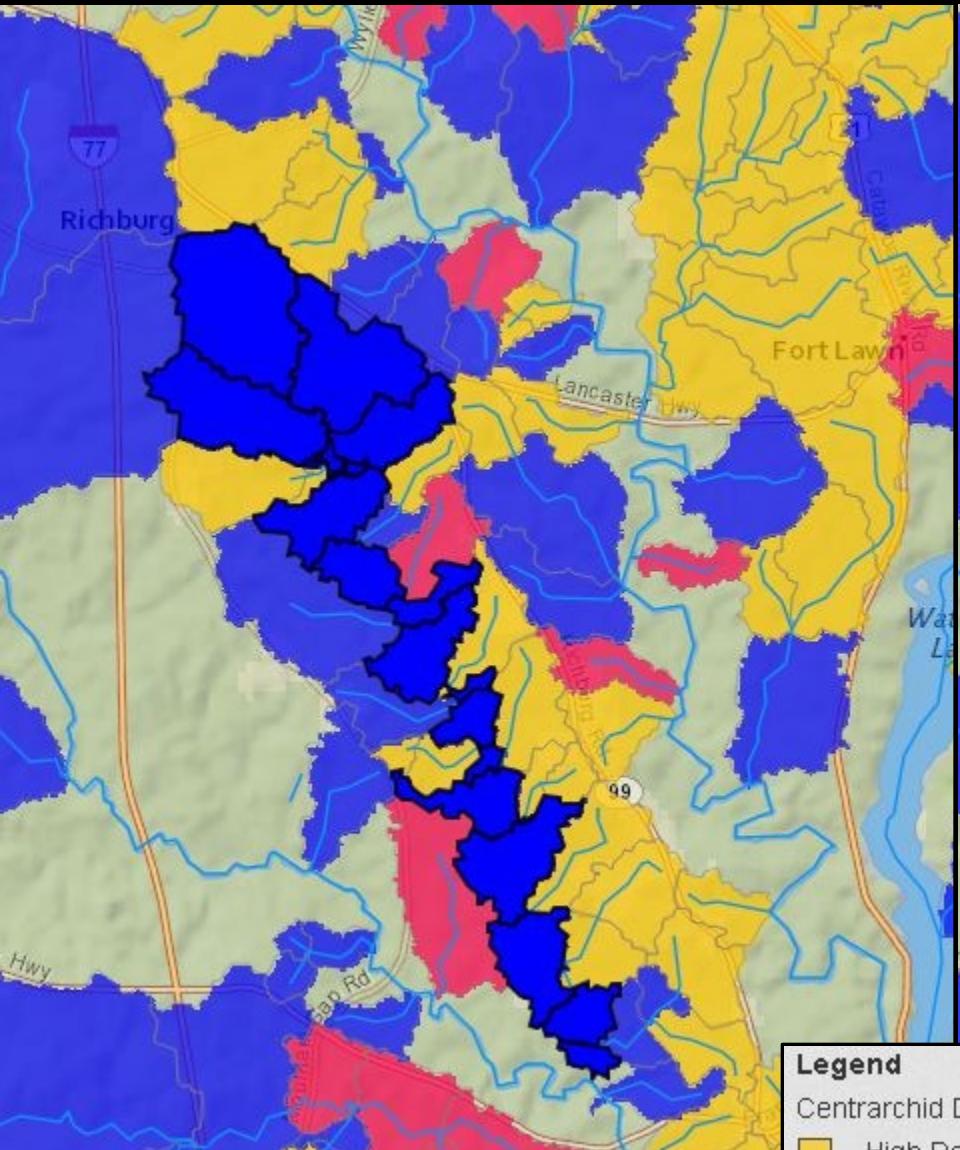
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[View](#)[Toggle](#)[Create Alternative](#)[Predict...](#)

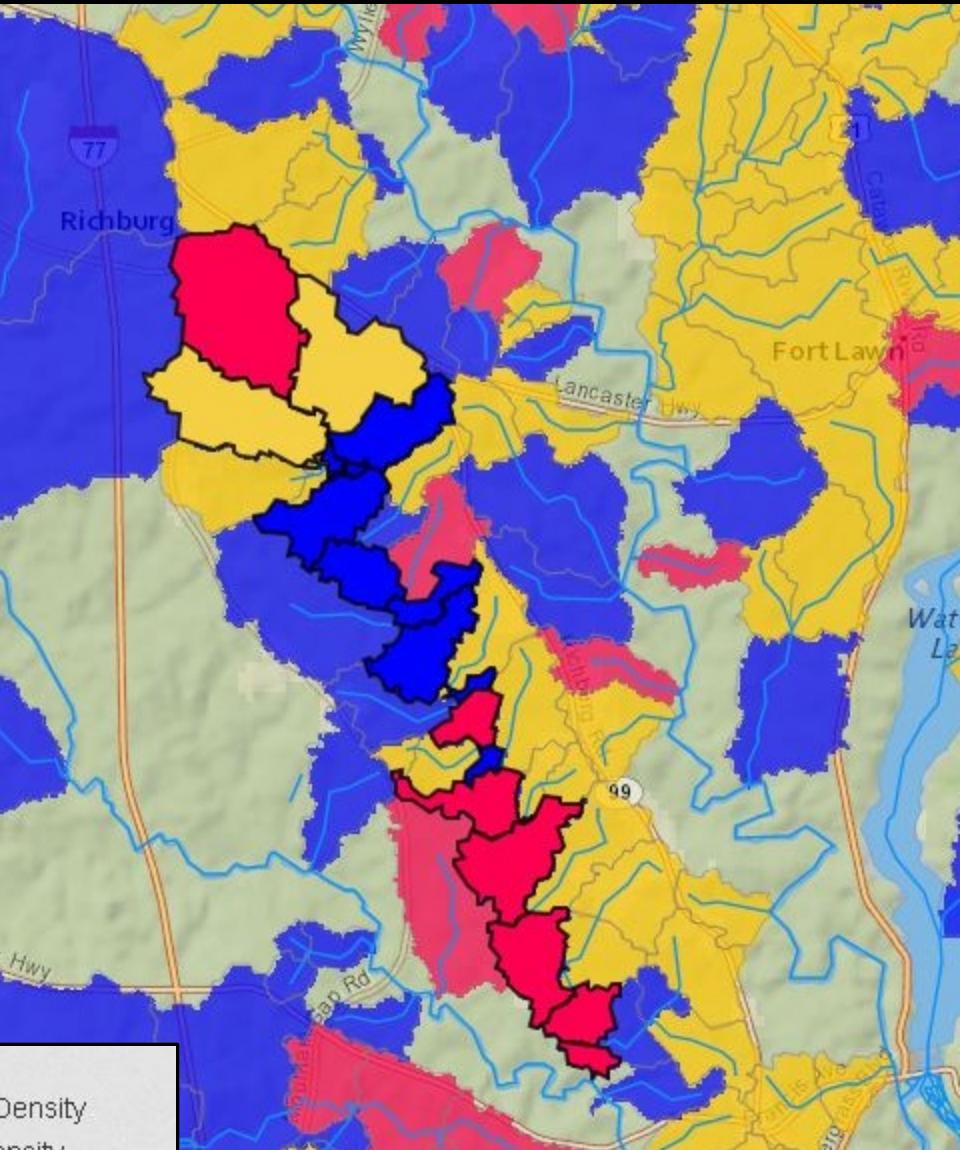
↓ Forest 30% ↑ Urban 30%



Initial



↓ Forest 30% ↑ Urban 30%

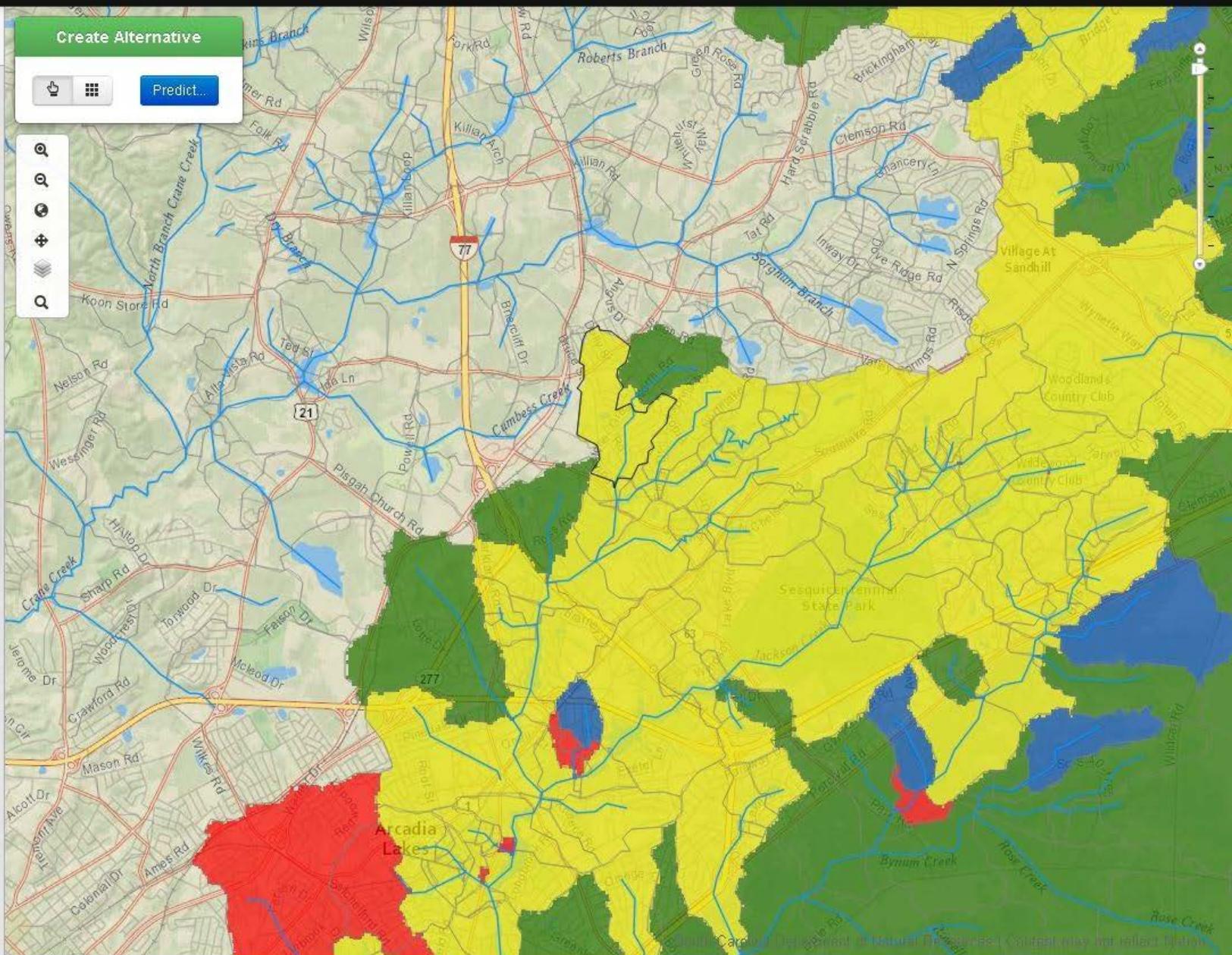


Legend

- Centrarchid Density
- High Density (Yellow)
- Intermediate Density (Pink)
- Low Density (Blue)

Evaluating Spatial Configuration for Placement of Greenspace - Single catchment changes



[Change Prediction...](#)**Create Alternative**[Predict...](#)**Description**

Taxonomic Groups

Detailed Description[Report PDF](#)**Legend**

Coastal Plain Taxonomic Groups

Fluvial

Eastern mudminnow

Centrarchid

Non-fluvial

View Your Alternatives[Select Result▼](#)

None

5% Change complete10% Change complete15% Change complete

Change Prediction...

Description

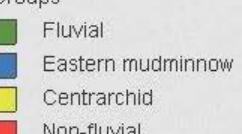
Taxonomic Groups

Detailed Description

[Report PDF](#)

Legend

Coastal Plain Taxonomic Groups



View Your Alternatives

 Select Result

None

5% Change complete

10% Change **complete**

15% Change **complete**

Create Alternative
Predict...

Modify Catchment

X

DECIDUOUS_01 C

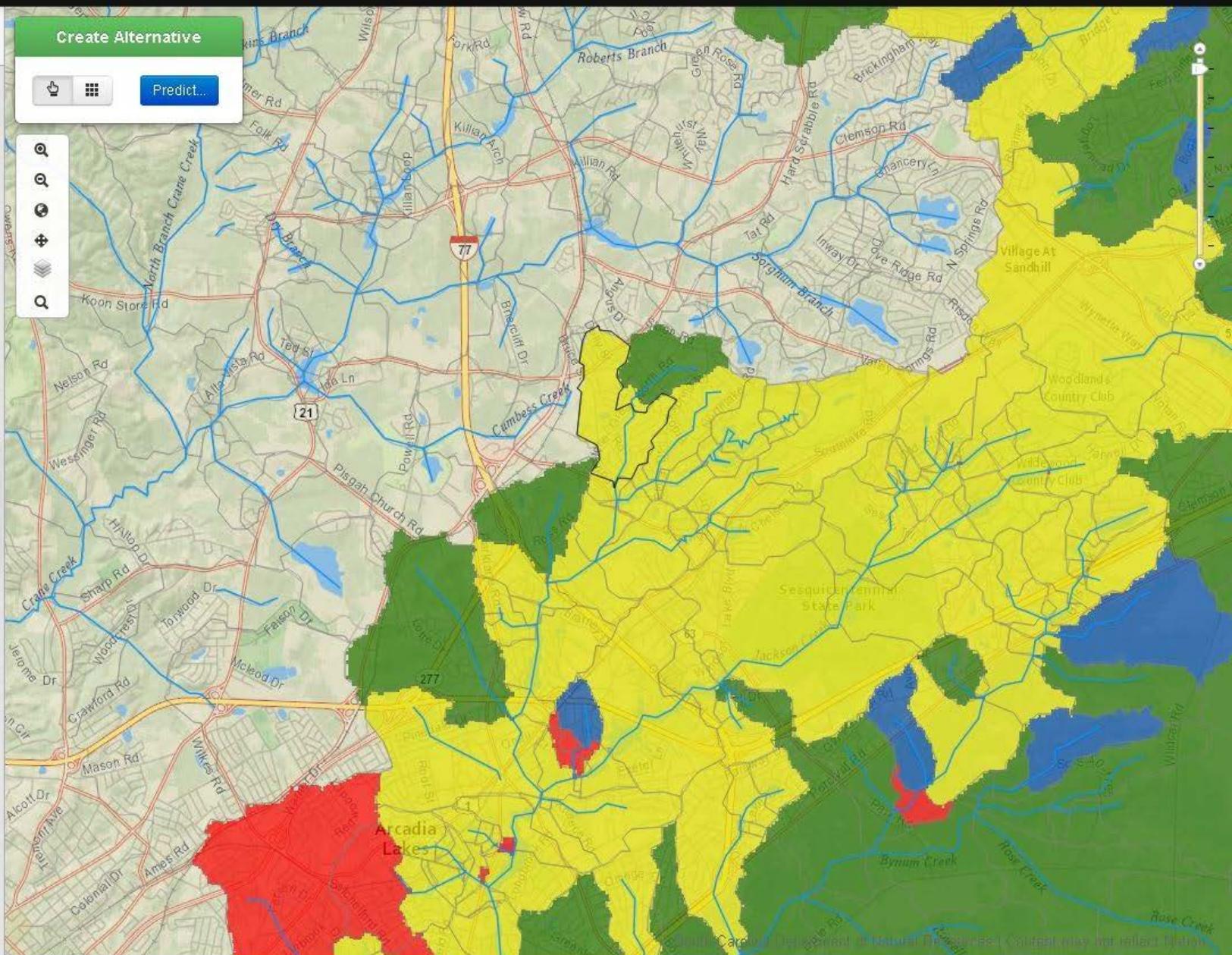
WETLAND_01 C

ROAD_CR C

IMPERV C

DAM_CO C

Cancel
Okay

[Change Prediction...](#)**Create Alternative**[Predict...](#)**Description**

Taxonomic Groups

Detailed Description[Report PDF](#)**Legend**

Coastal Plain Taxonomic Groups

Fluvial

Eastern mudminnow

Centrarchid

Non-fluvial

View Your Alternatives[Select Result▼](#)

None

5% Change complete10% Change complete15% Change complete

[Change Prediction...](#)**Create Alternative**[Predict...](#)

↑ Forest 05% ↓ Urban 05%

Description

Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

[View Your Alternatives](#)[Select Result](#)**Name:**

5% Change

Identifier:

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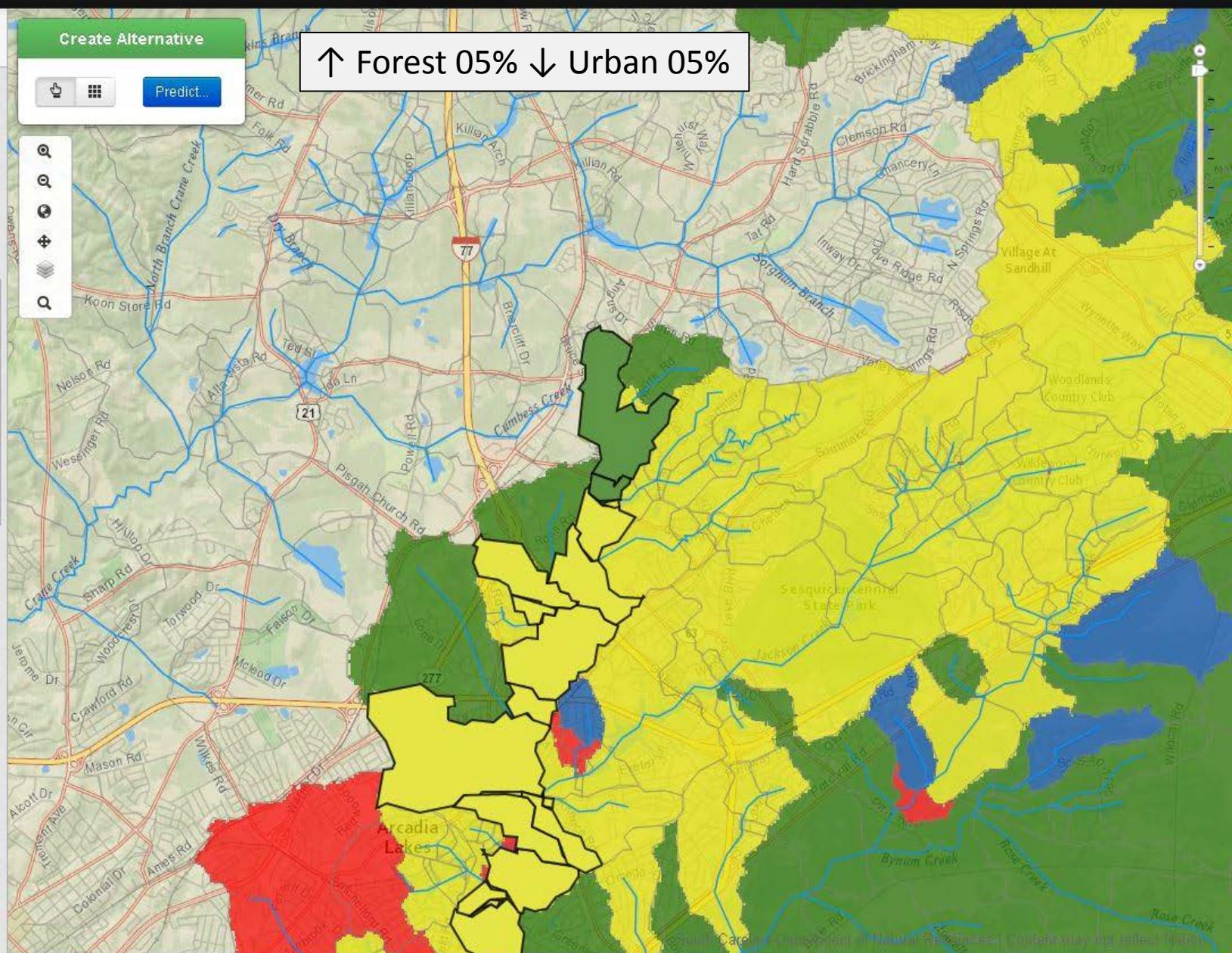
Submission Time

2015-01-22 18:40:51.339218

[View](#)[Toggle](#)**Legend**

Coastal Plain Taxonomic Groups

- █ Fluvial
- █ Eastern mudminnow
- █ Centrarchid
- █ Non-fluvial



[Change Prediction...](#)**Create Alternative**[Predict...](#)

↑ Forest 10% ↓ Urban 10%

**Description**

Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

View Your Alternatives[Select Result...](#)**Name:**

10% Change

Identifier:

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Submission Time

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[View](#)[Toggle](#)**Legend**

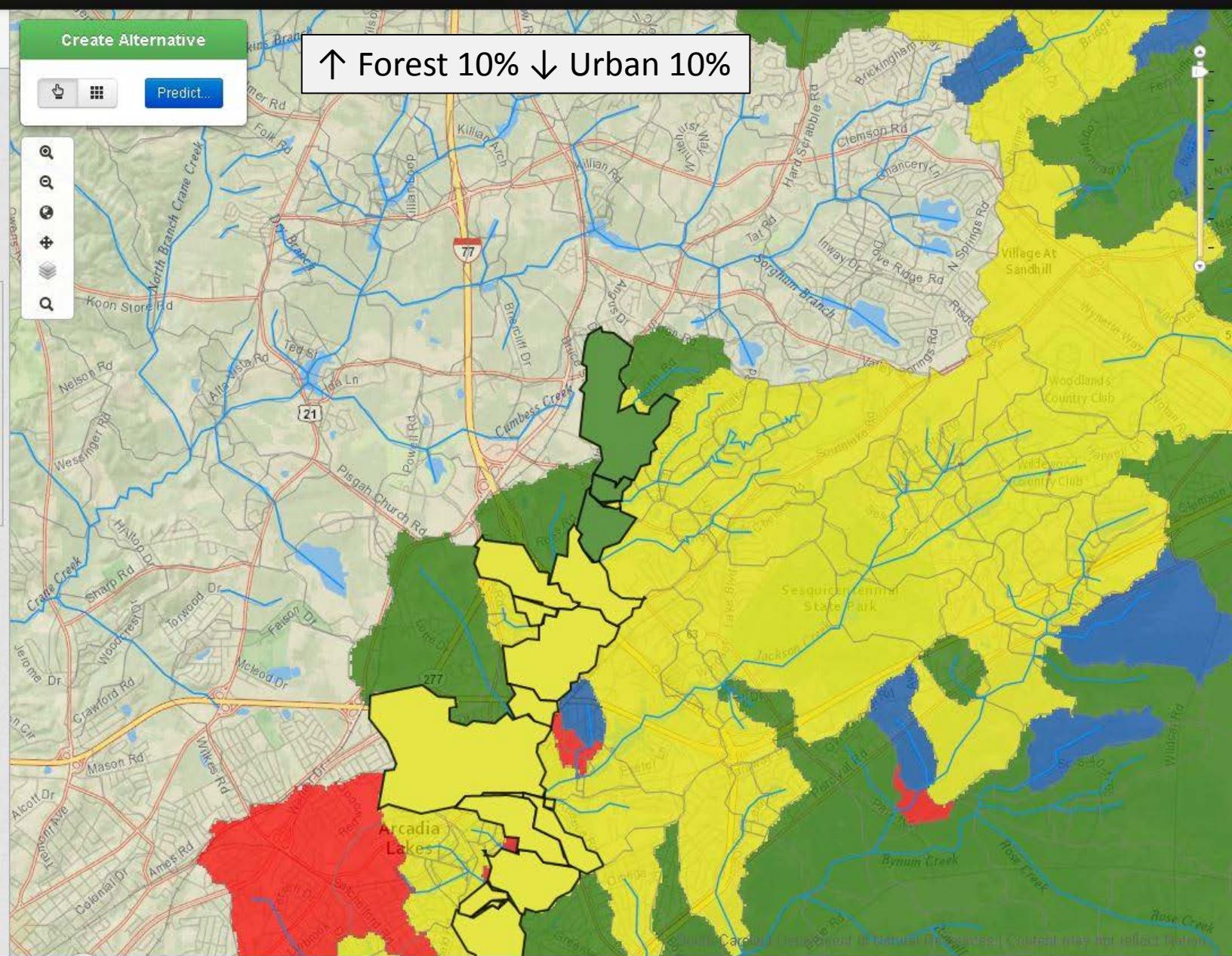
Coastal Plain Taxonomic Groups

Fluvial

Eastern mudminnow

Centrarchid

Non-fluvial



[Change Prediction...](#)**Create Alternative**[Predict...](#)

↑ Forest 15% ↓ Urban 15%

**Description**

Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

View Your Alternatives[Select Result▼](#)**Name:**

15% Change

Identifier:

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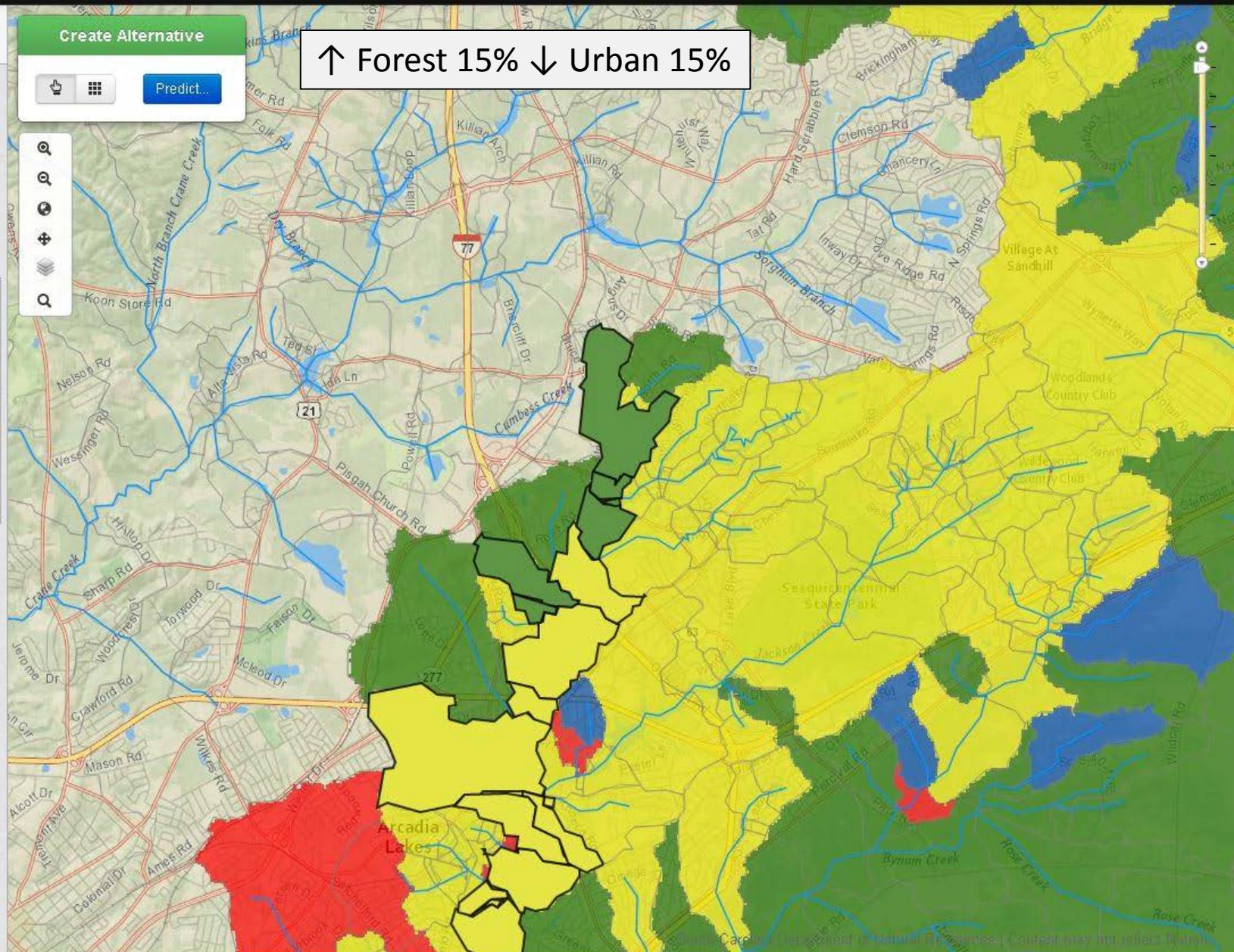
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2015-01-22 18:35:50.533252

[View](#)[Toggle](#)**Legend**

Coastal Plain Taxonomic Groups

- █ Fluvial
- █ Eastern mudminnow
- █ Centrarchid
- █ Non-fluvial



Evaluating Spatial Configuration for Placement of Greenspace - spatially distributed across multiple catchment changes



[Change Prediction...](#)**Description**

Taxonomic Groups

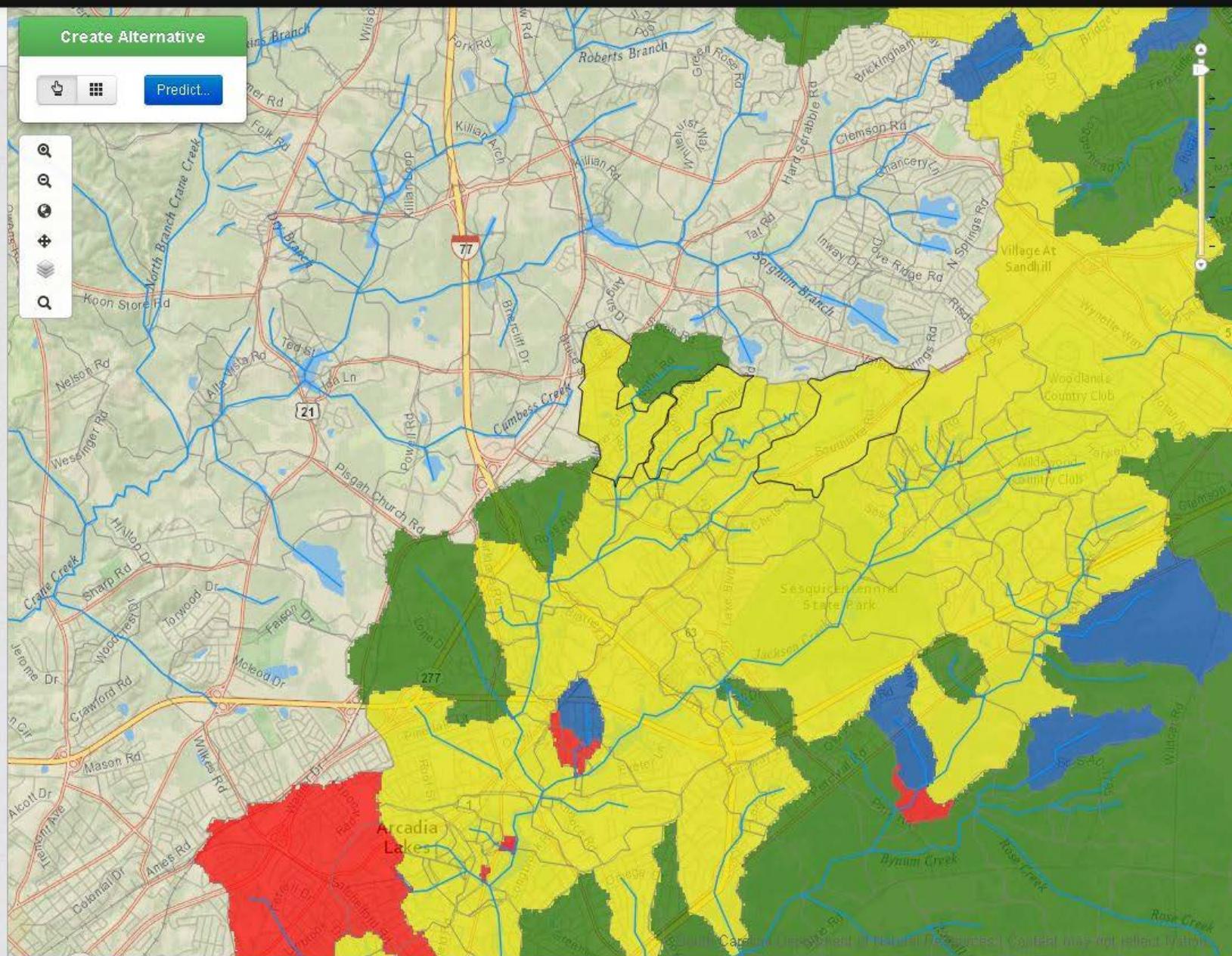
Detailed Description[Report PDF](#)

No legend

[View Your Alternatives](#)[Select Result▼](#)**Legend**

Coastal Plain Taxonomic Groups

- █ Fluvial
- █ Eastern mudminnow
- █ Centrarchid
- █ Non-fluvial



[Change Prediction...](#)**Description**

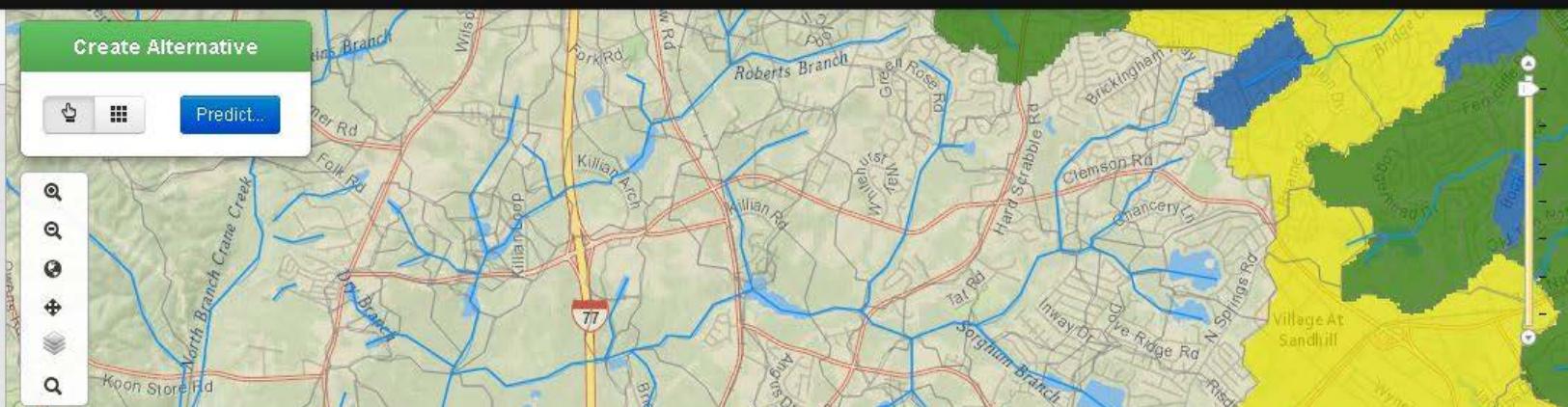
Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

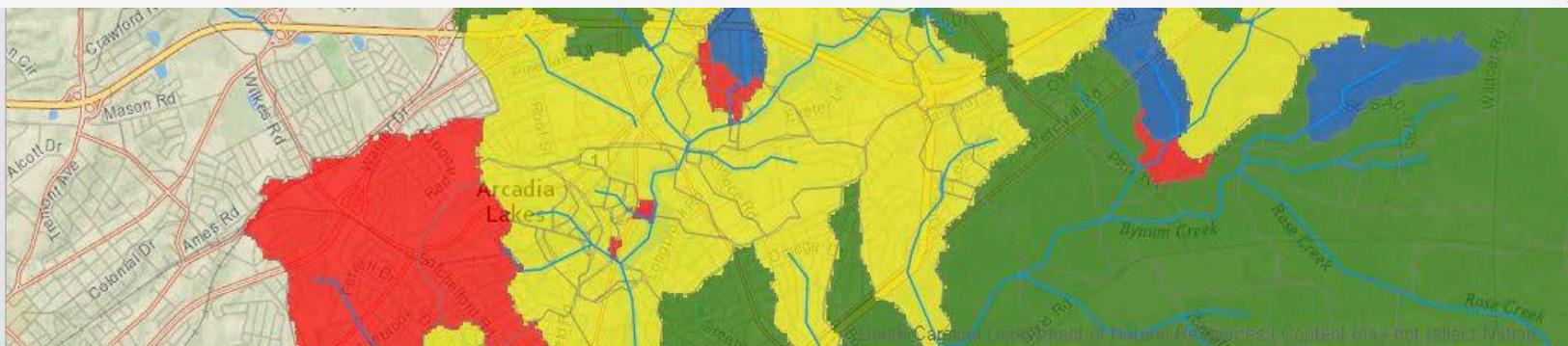
[View Your Alternatives](#)[Select Result](#)**Legend**

Coastal Plain Taxonomic

**Selected Catchments**

X

Zoom	Edit	Remove	COMID	L_DECIDUOUS_01	L_WETLAND_01	ROAD_CR	IMPERV	DAM_CO
			9676810	1.0743	3.0438	7	16.0259	0
			9676816	3.2855	0.7168	6	23.4414	0
			9677670	0.426	0.8947	0	31.3617	0



[Change Prediction...](#)**Description**

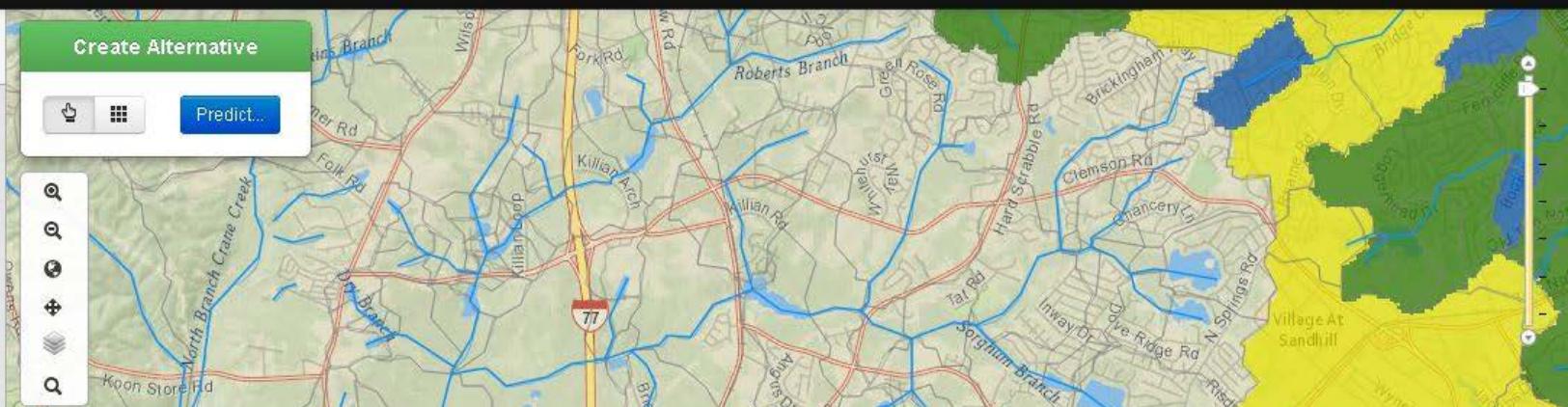
Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

[View Your Alternatives](#)[Select Result](#) ▾**Legend**

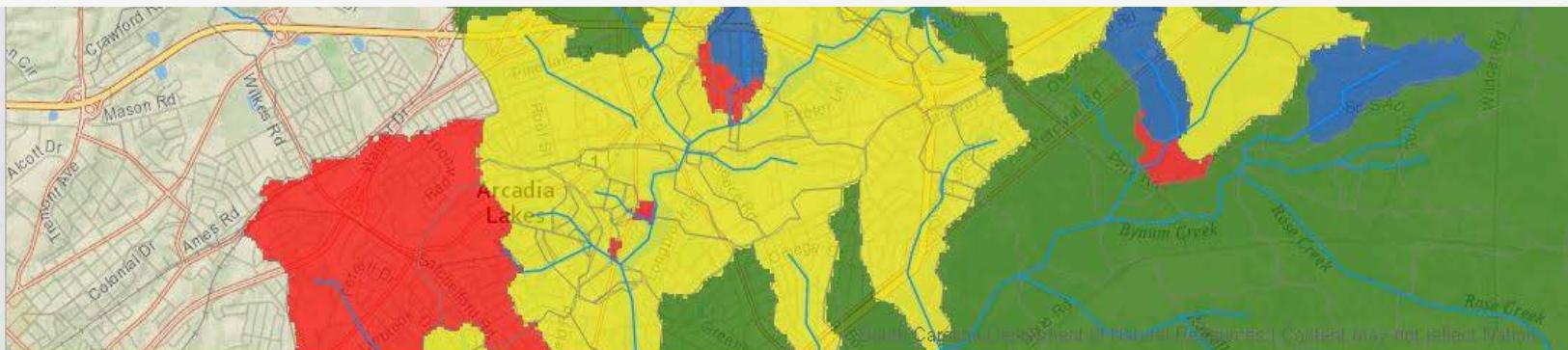
Coastal Plain Taxonomic



Selected Catchments

X

Zoom	Edit	Remove	COMID	L_DECIDUOUS_01	L_WETLAND_01	ROAD_CR	IMPERV	DAM_CO
			9676810	6.0743	3.0438	7	11.0259	0
			9676816	8.2855	0.7168	6	18.4414	0
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[Change Prediction...](#)**Description**

Taxonomic Groups

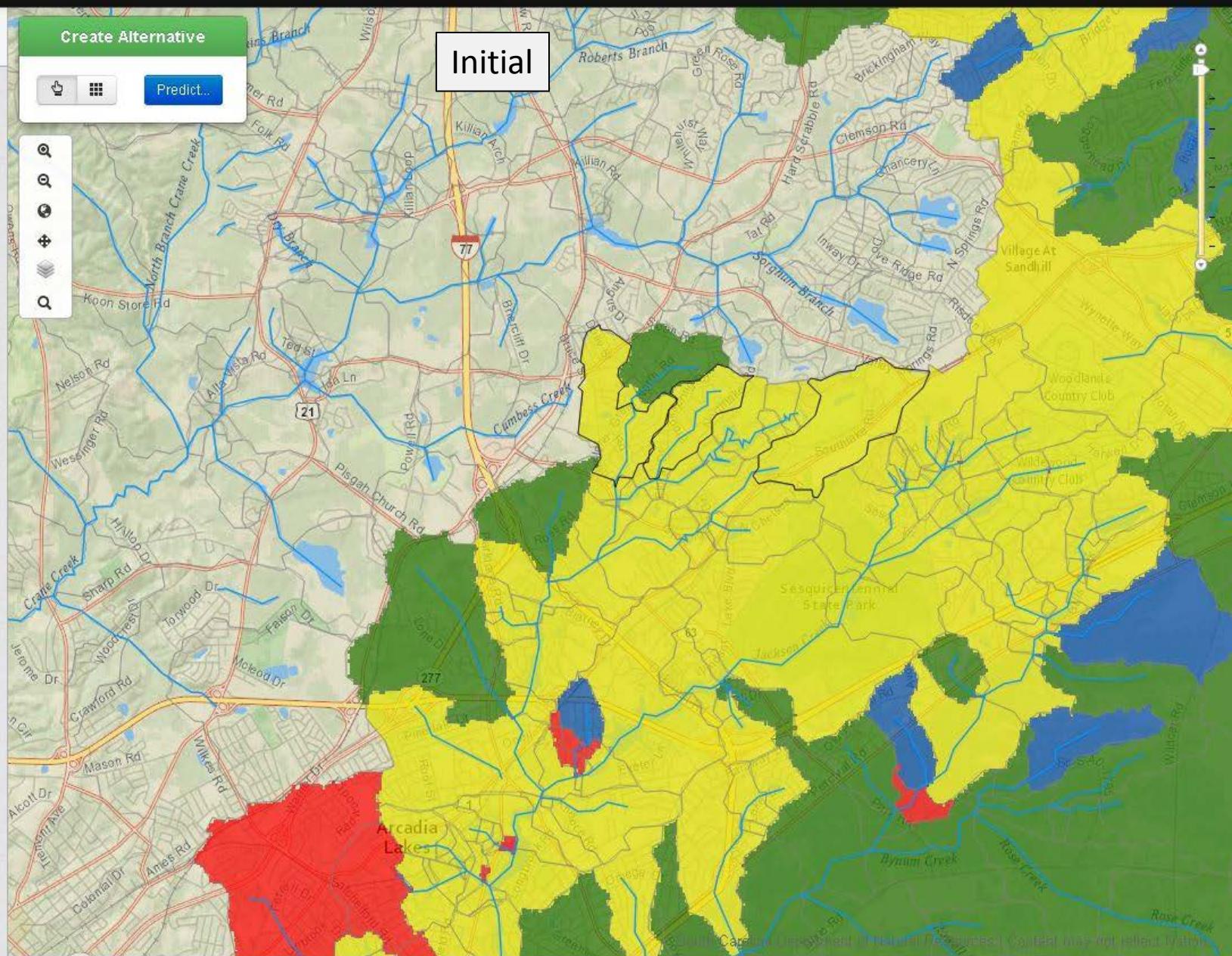
Detailed Description[Report PDF](#)

No legend

[View Your Alternatives](#)[Select Result▼](#)**Legend**

Coastal Plain Taxonomic Groups

- █ Fluvial
- █ Eastern mudminnow
- █ Centrarchid
- █ Non-fluvial



[Change Prediction...](#)**Description**

Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

View Your Alternatives[Select Result▼](#)**Name:**

Multi Catchment 5%

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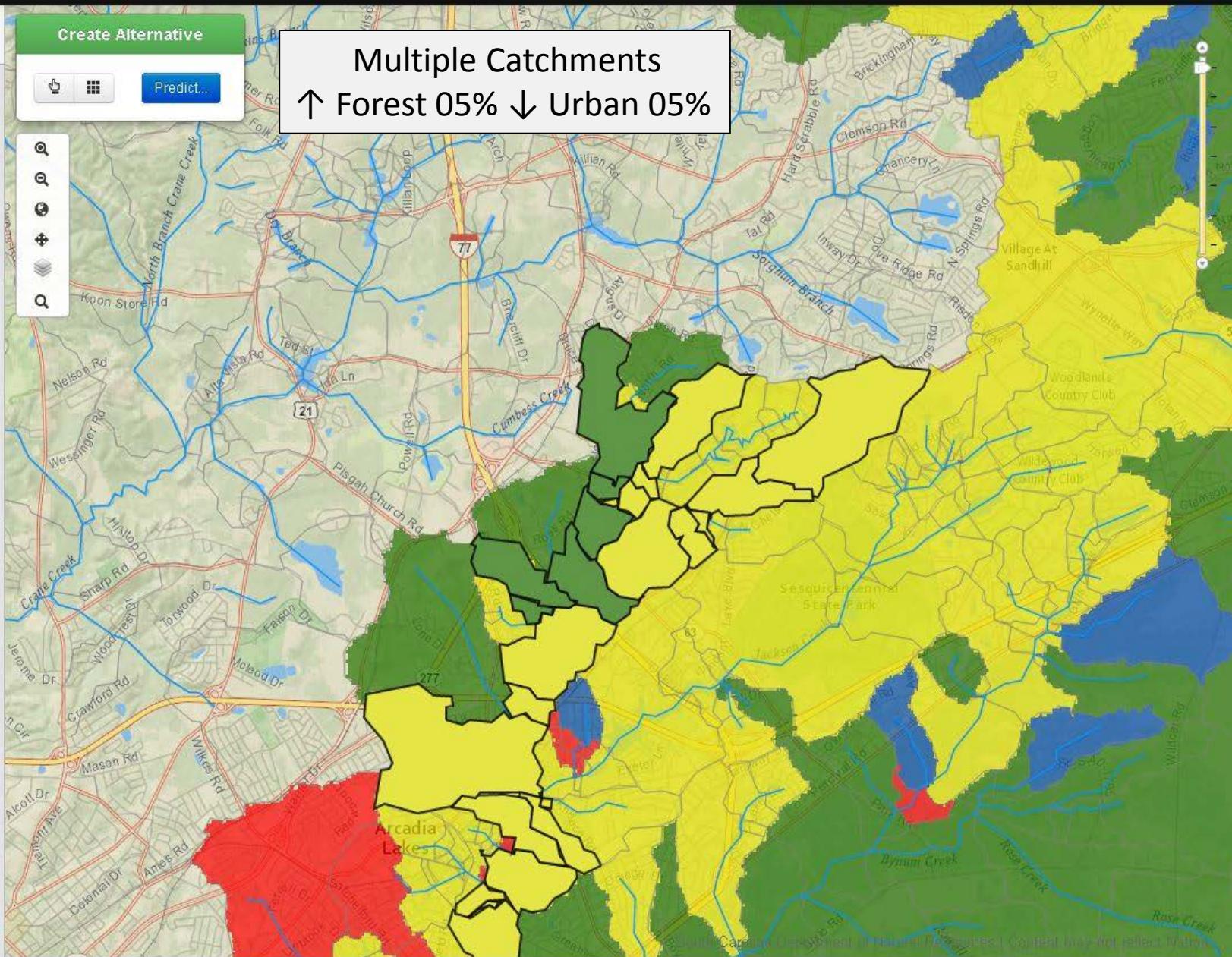
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Submission Time

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[View](#)[Toggle](#)**Legend**

Coastal Plain Taxonomic Groups

 Fluvial Eastern mudminnow Centrarchid Non-fluvial

[Change Prediction...](#)**Create Alternative**[Predict...](#)

Single Catchment
↑ Forest 15% ↓ Urban 15%

Description

Taxonomic Groups

Detailed Description[Report PDF](#)

No legend

View Your Alternatives[Select Result▼](#)**Name:**

15% Change

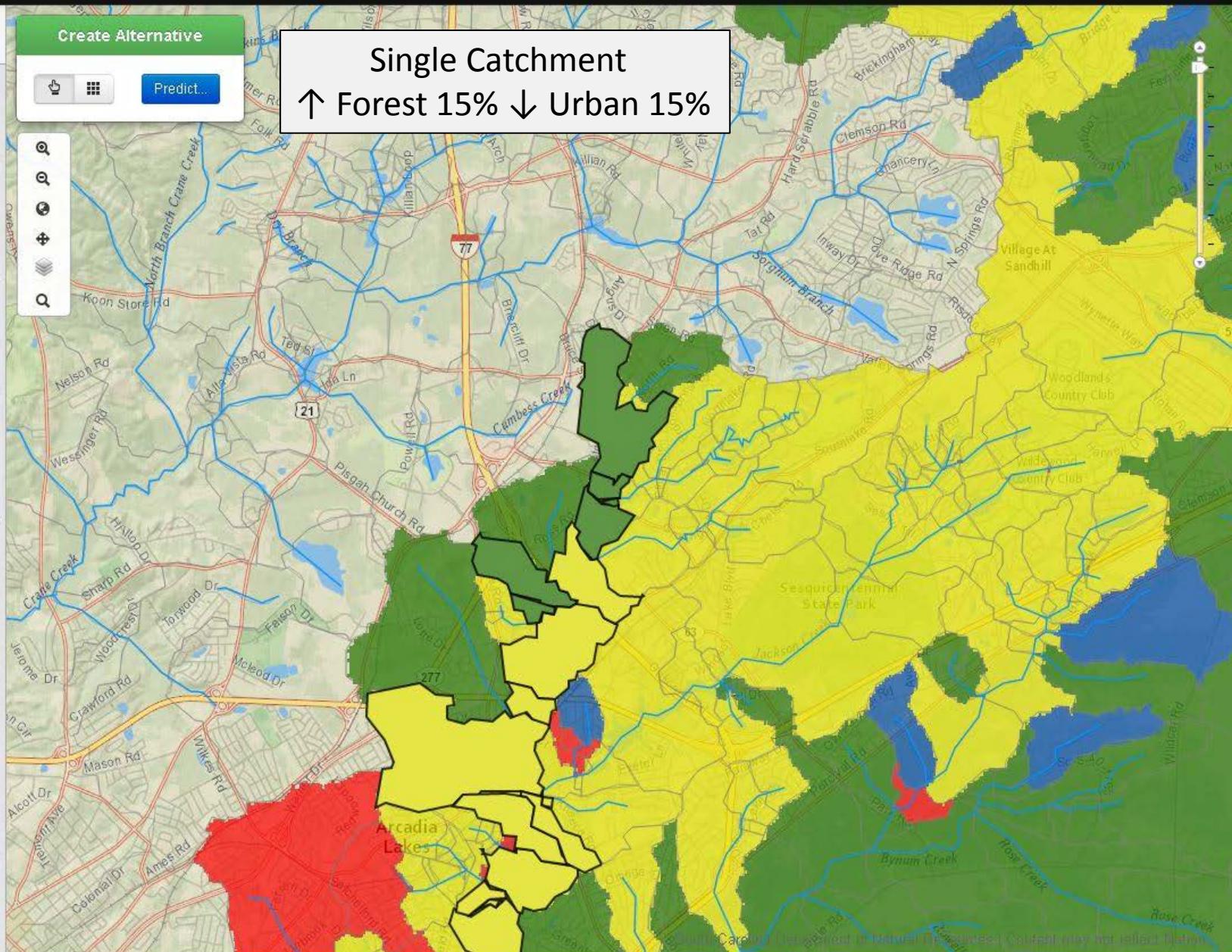
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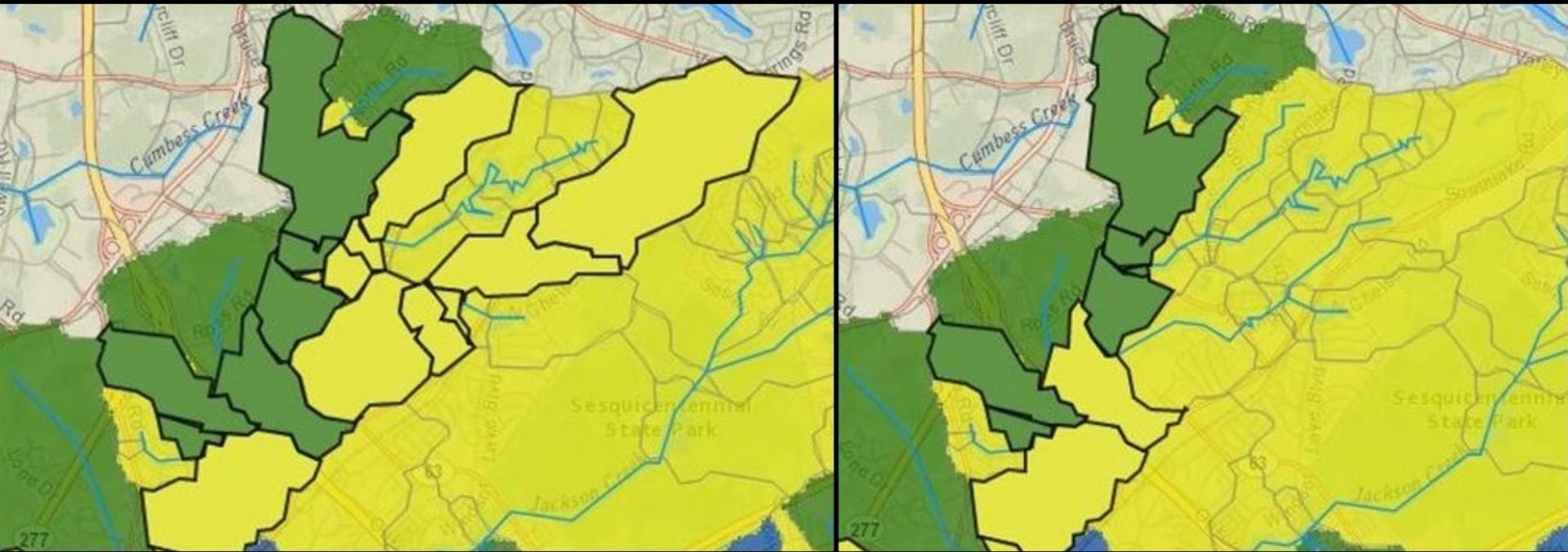
Coastal Plain Taxonomic Groups

- █ Fluvial
- █ Eastern mudminnow
- █ Centrarchid
- █ Non-fluvial



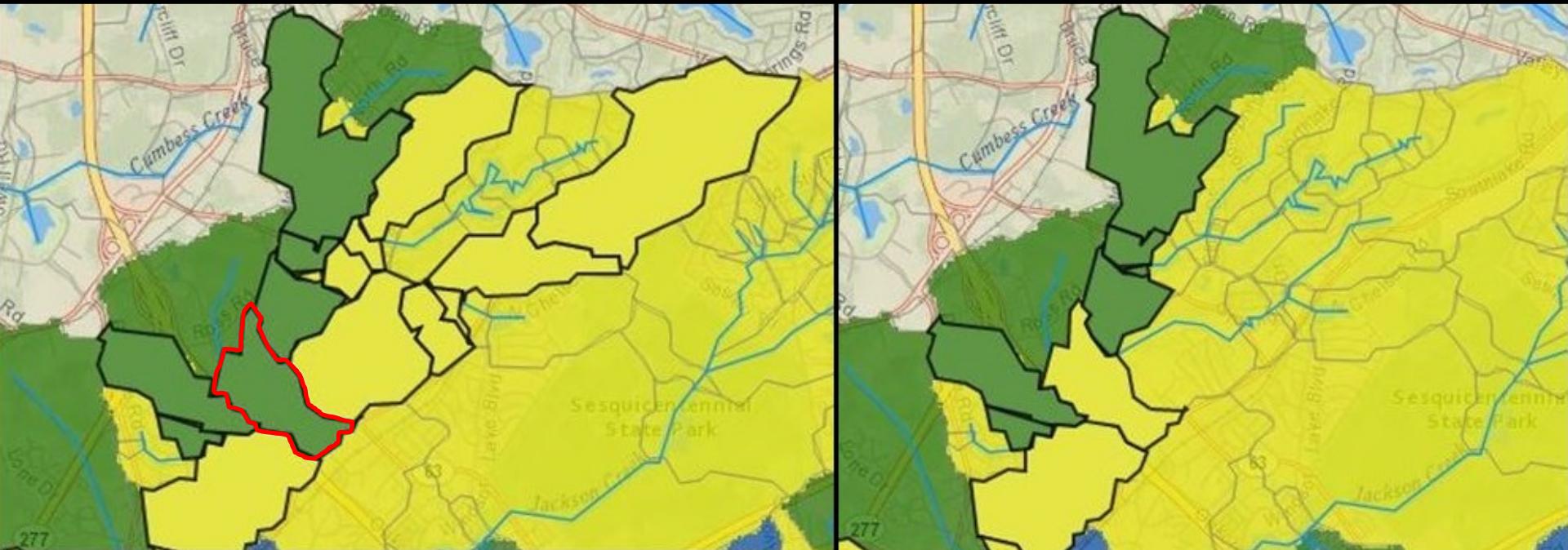
Multiple Catchments
↑ Forest 05% ↓ Urban 05%

Single Catchment
↑ Forest 15% ↓ Urban 15%



Multiple Catchments
↑ Forest 05% ↓ Urban 05%

Single Catchment
↑ Forest 15% ↓ Urban 15%



Legend
Coastal Plain Taxonomic Groups

Fluvial
Eastern mudminnow
Centrarchid
Non-fluvial

Evaluating Spatial Configuration for Project Mitigation

[Change Prediction...](#)

Project catchment

Description

Conservation Priority

Species Richness

Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

Yellow: Low Richness

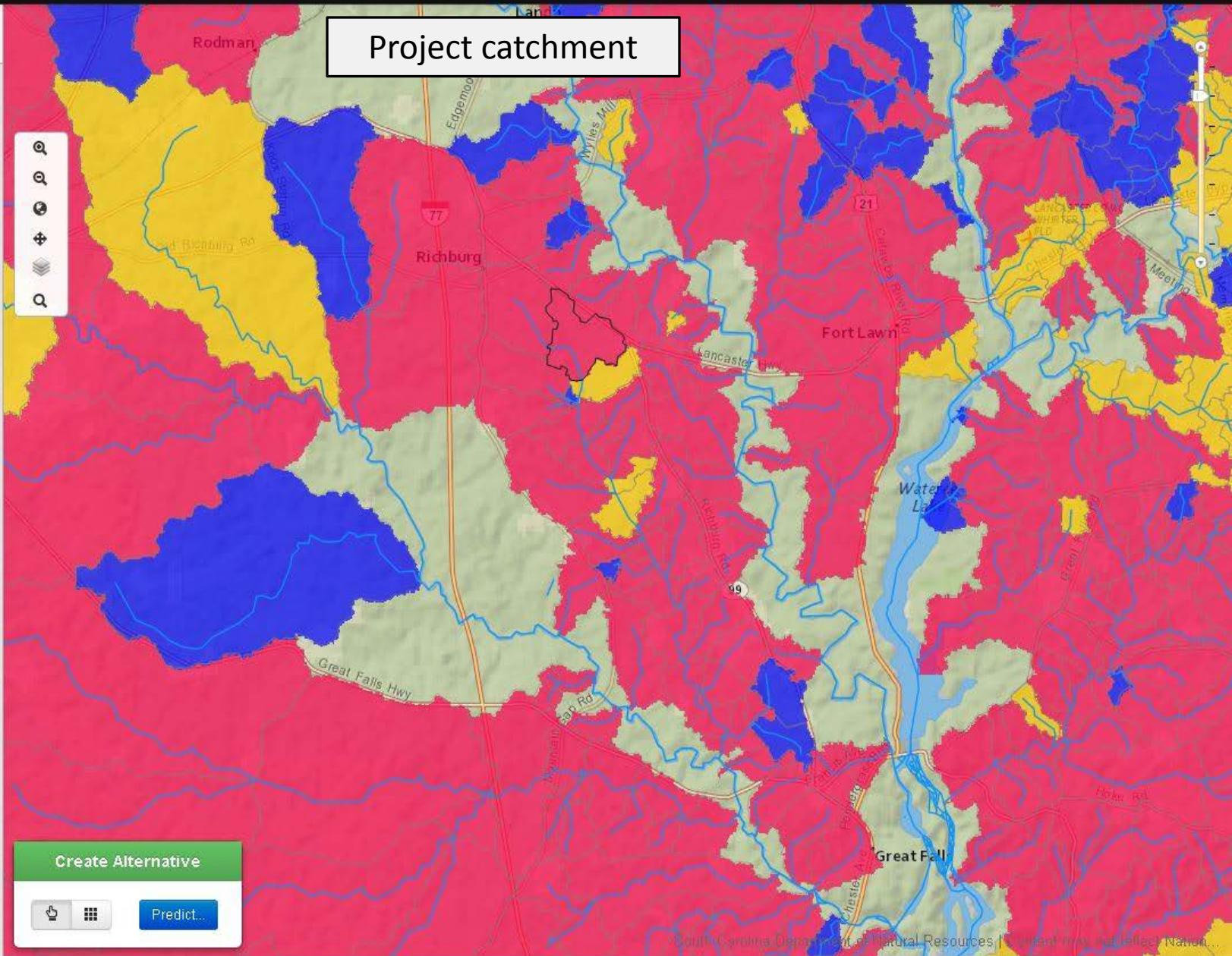
Red: Intermediate

Blue: High Richness

View Your Alternatives[Select Result▼](#)

Create Alternative

[Predict...](#)



[Change Prediction...](#)**Description**

Conservation Priority

Species Richness

Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

Low Richness

Intermediate

Richness

High Richness

View Your Alternatives [Select Result](#)

Modify Catchment

WETLAND_01

1.4341



FOREST_01

72.1839



DAM_CO

0



URBAN_01

4.0035

[Cancel](#)[Okay](#)[Create Alternative](#)[Predict...](#)

[Change Prediction...](#)**Description**

Conservation Priority

Species Richness

Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

Low Richness

Intermediate

Richness

High Richness

View Your Alternatives [Select Result](#)

Modify Catchment

WETLAND_01

1.4341



FOREST_01

52.1839



DAM_CO

0



URBAN_01

24.0035

[Create Alternative](#)[Predict...](#)[Cancel](#)[Okay](#)

[Change Prediction...](#)

Consequences of Project

Description

Conservation Priority

Species Richness

Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

Low Richness

Intermediate

Richness

High Richness

View Your Alternatives[Select Result▼](#)**Name:**

Urbanized Catchment

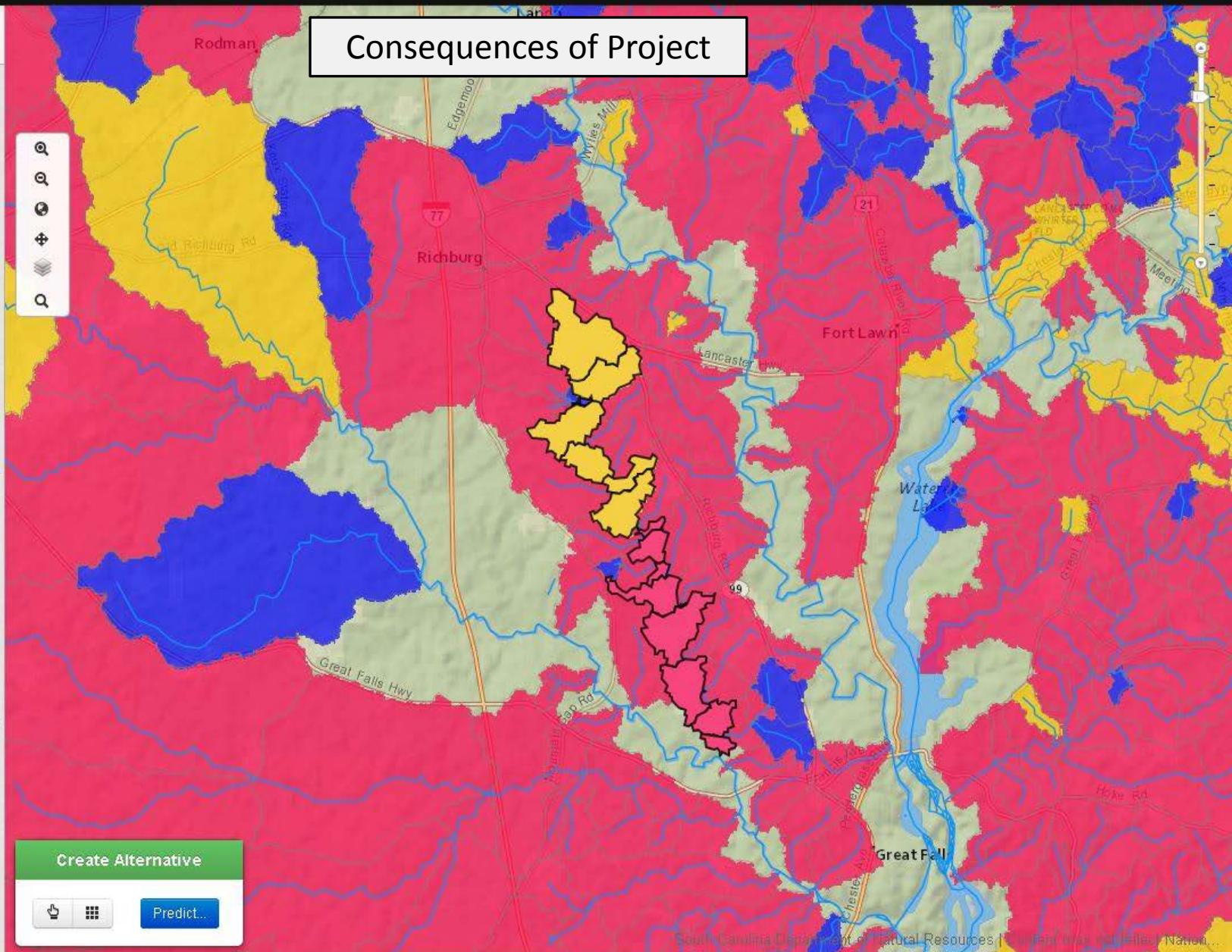
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[View](#)[Toggle](#)[Create Alternative](#)[Predict...](#)

[Change Prediction...](#)

Mitigated catchments

Description

Conservation Priority

Species Richness

Detailed Description[Report PDF](#)**Legend**

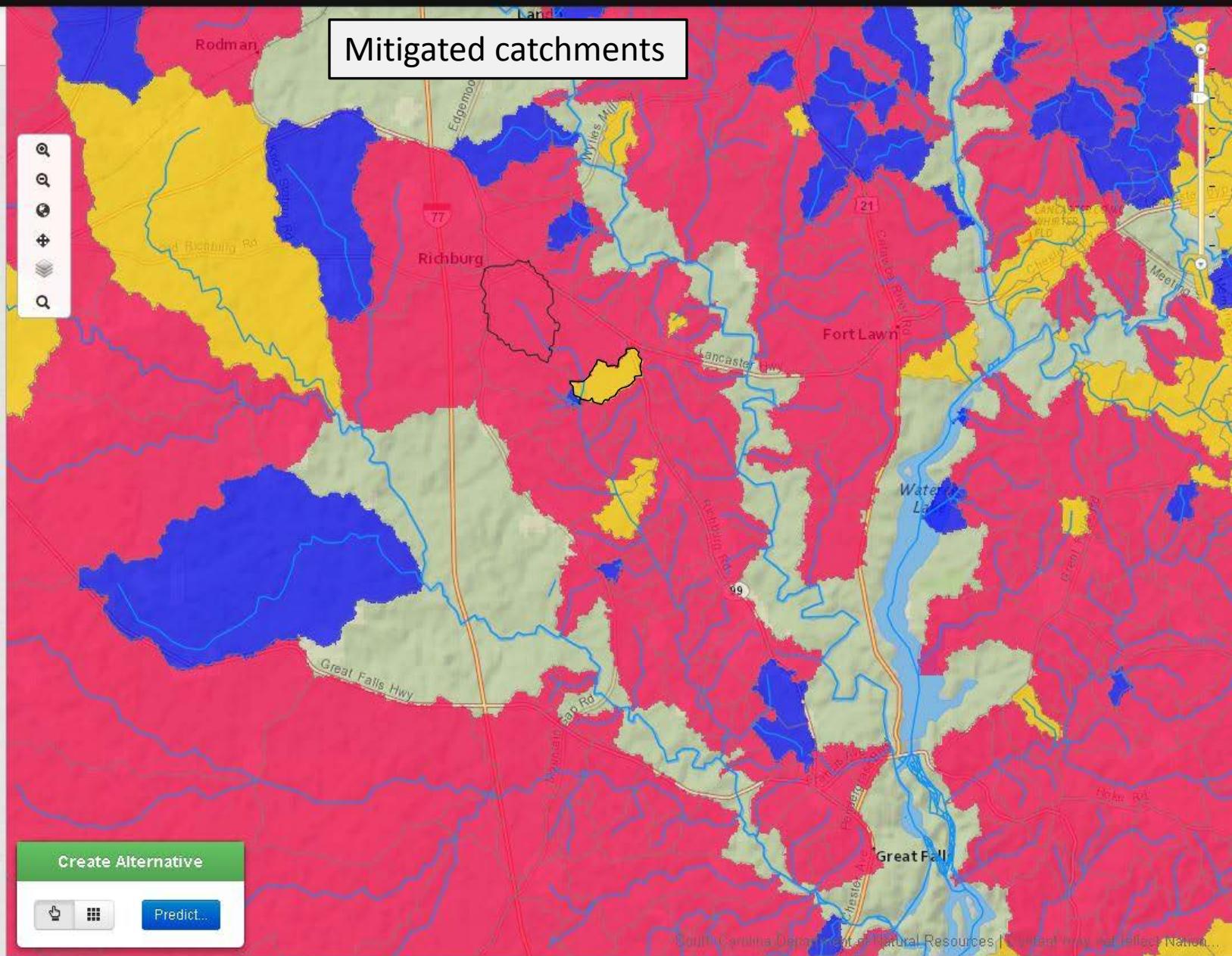
Conservation Priority

Species Richness

Yellow: Low Richness

Red: Intermediate

Blue: High Richness

View Your Alternatives[Select Result▼](#)[Create Alternative](#)[Predict...](#)

South Carolina Department of Natural Resources | Landscapes and Ecosystems

[Change Prediction...](#)**Description**

Conservation Priority

Species Richness

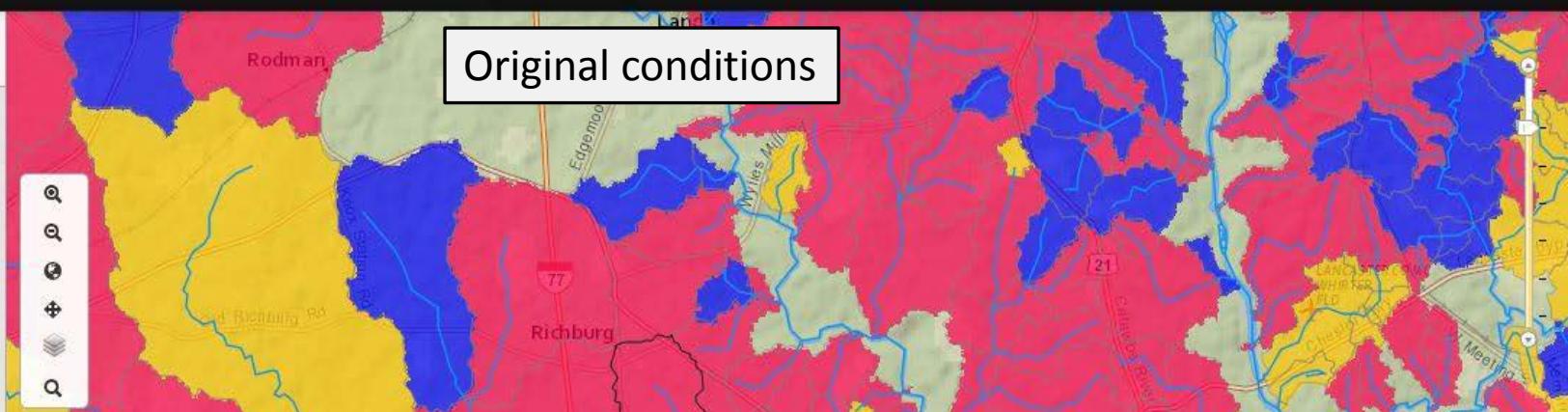
Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

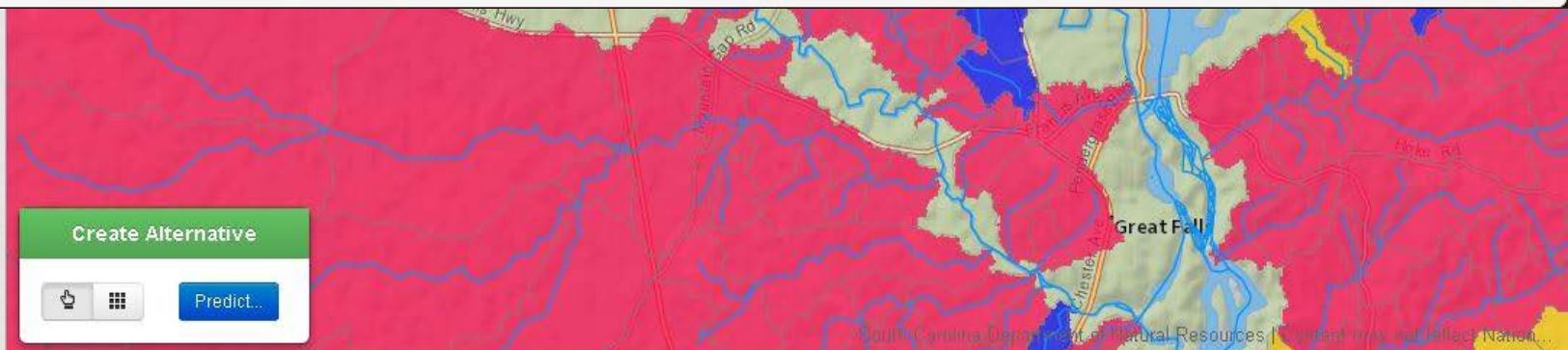
Yellow: Low Richness

Grey: Intermediate

**Selected Catchments**

X

Zoom	Edit	Remove	COMID	L_WETLAND_01	L_FOREST_01	DAM_CO	L_URBAN_01
			9734964	1.4341	72.1839	0	4.0035
			9736564	0.2988	70.9502	0	3.1678
			9737066	0.6675	54.1164	0	9.8797

[Okay](#)

South Carolina Department of Natural Resources | Land Use and Ecosystem...

[Change Prediction...](#)

Mitigation conditions

Description

Conservation Priority

Species Richness

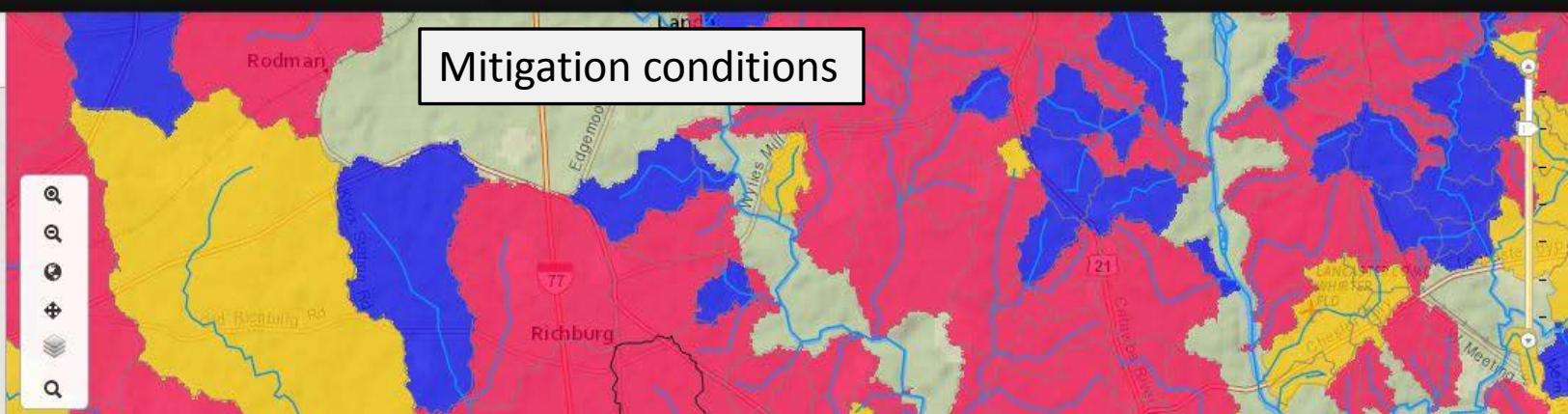
Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

Yellow: Low Richness

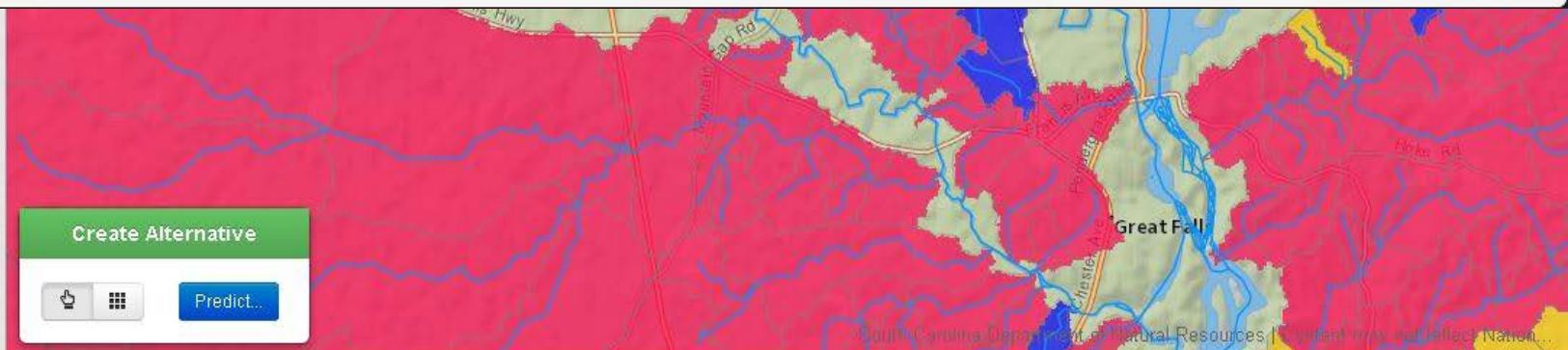
Grey: Intermediate



Selected Catchments

X

Zoom	Edit	Remove	COMID	L_WETLAND_01	L_FOREST_01	DAM_CO	L_URBAN_01
			9734964	1.4341	52.1839 20%	0	24.0035 20%
			9736564	0.2988	90.9502 30%	0	3.1678
			9737066	0.6675	84.1164 20%	0	9.8797

[Okay](#)

[Change Prediction...](#)

Mitigation results

Description

Conservation Priority

Species Richness

Detailed Description[Report PDF](#)**Legend**

Conservation Priority

Species Richness

Low Richness

Intermediate

Richness

High Richness

View Your Alternatives[Select Result](#) ▾**Name:**

Mitigation results

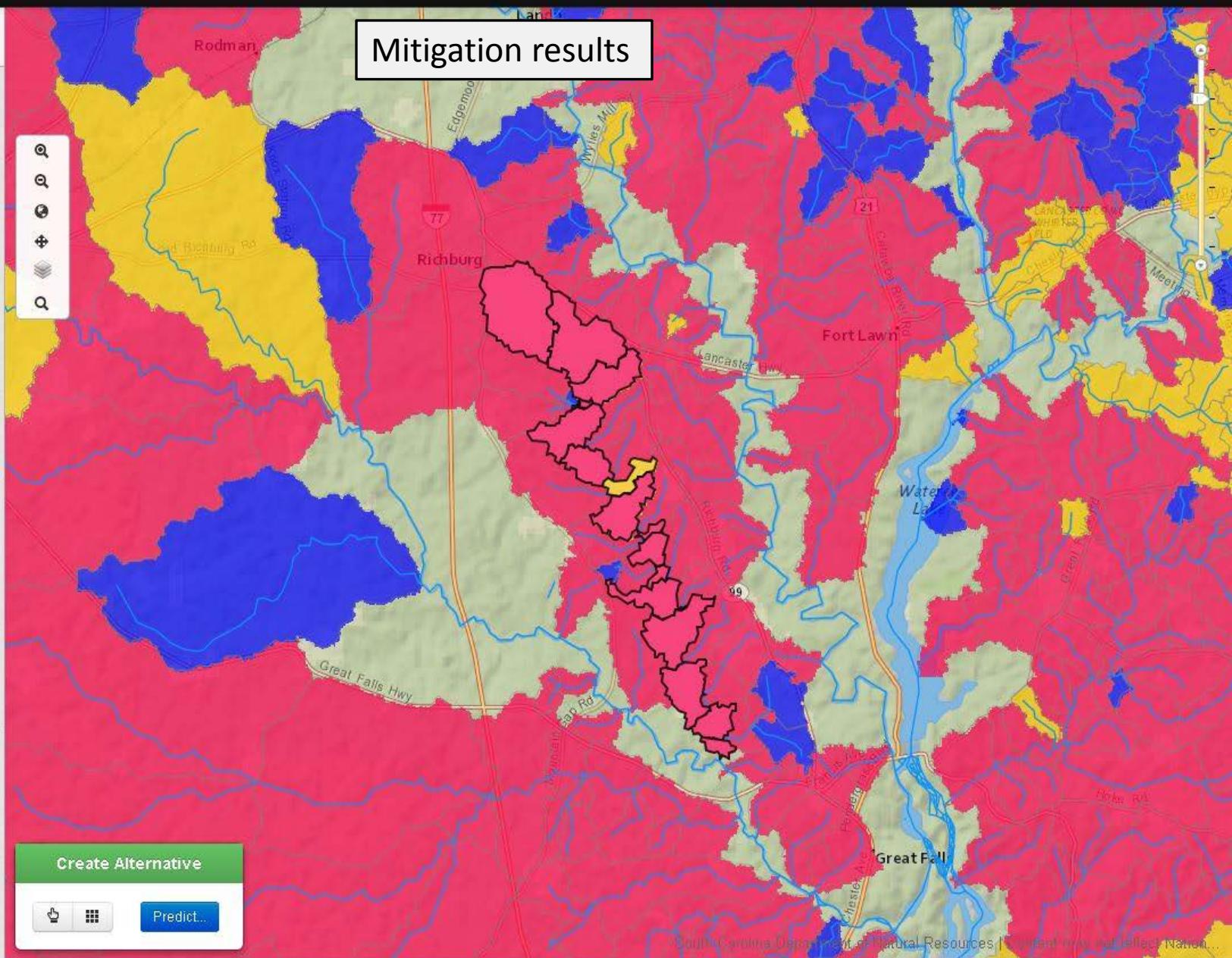
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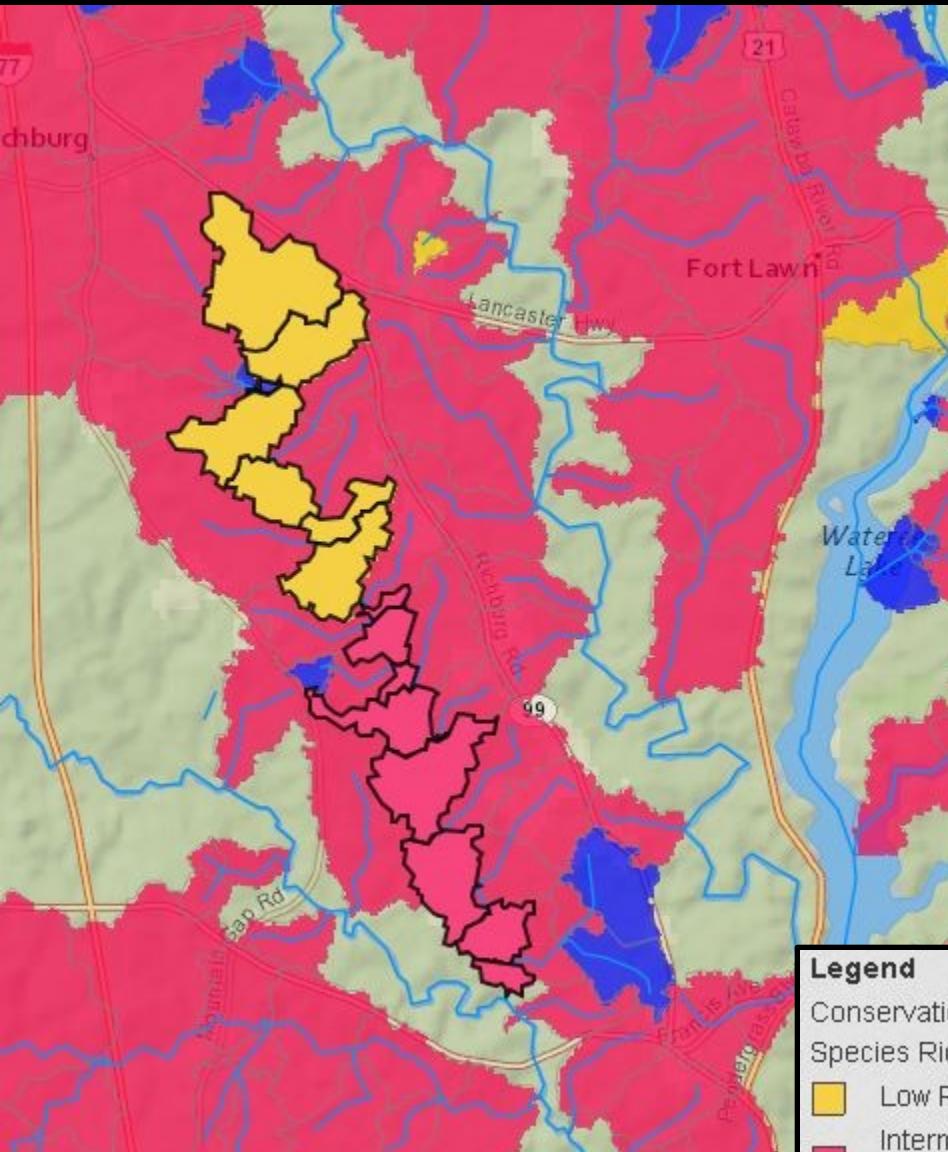
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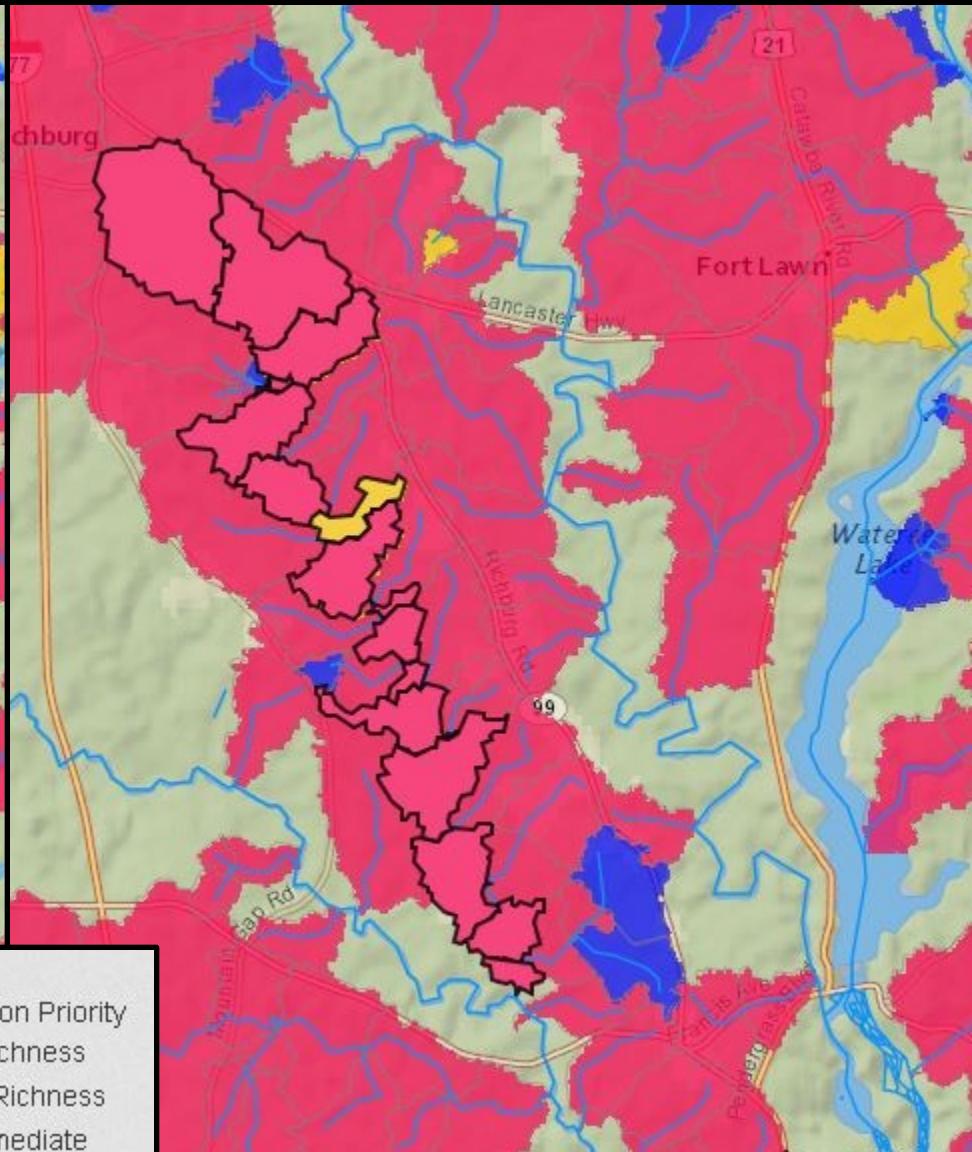
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[View](#)[Toggle](#)[Create Alternative](#)[Predict...](#)

Project results



Mitigation results

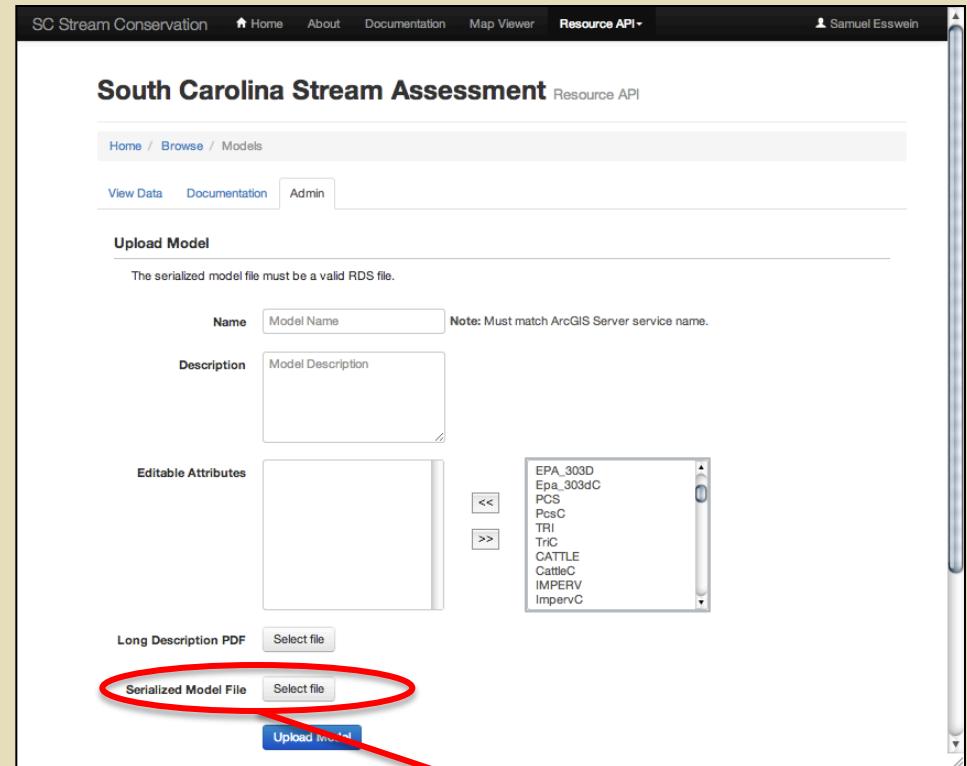


Legend

- Conservation Priority Species Richness
- Yellow: Low Richness
 - Pink: Intermediate
 - Blue: High Richness

Data Management

- A web client is provided to manage predictor data and predictive models
- Add new predictive models through a web interface
- Any geography in U.S. available



Uses the native “RDS” serialization format of R. Supports R objects including formulas (e.g., RandomForest models)

Information-driven stream conservation

- Application allows user to investigate questions such as:
 - How much alteration (restoration) will produce a shift in the resource?
 - Where will restoration do the most good (bang-for-buck)?
 - What will be the consequences of proposed plans?
- Robust data collection and statistical analyses support science-based conservation recommendations.
- The SCSA Conservation Planning Tool provides access to these analyses in a less technical format.

Target Audience:

- Municipal & county governments land planning and permitting.
- State & Federal agency permitting, land acquisition and natural resource management activities
- NGO's with land management and/or advocacy responsibilities

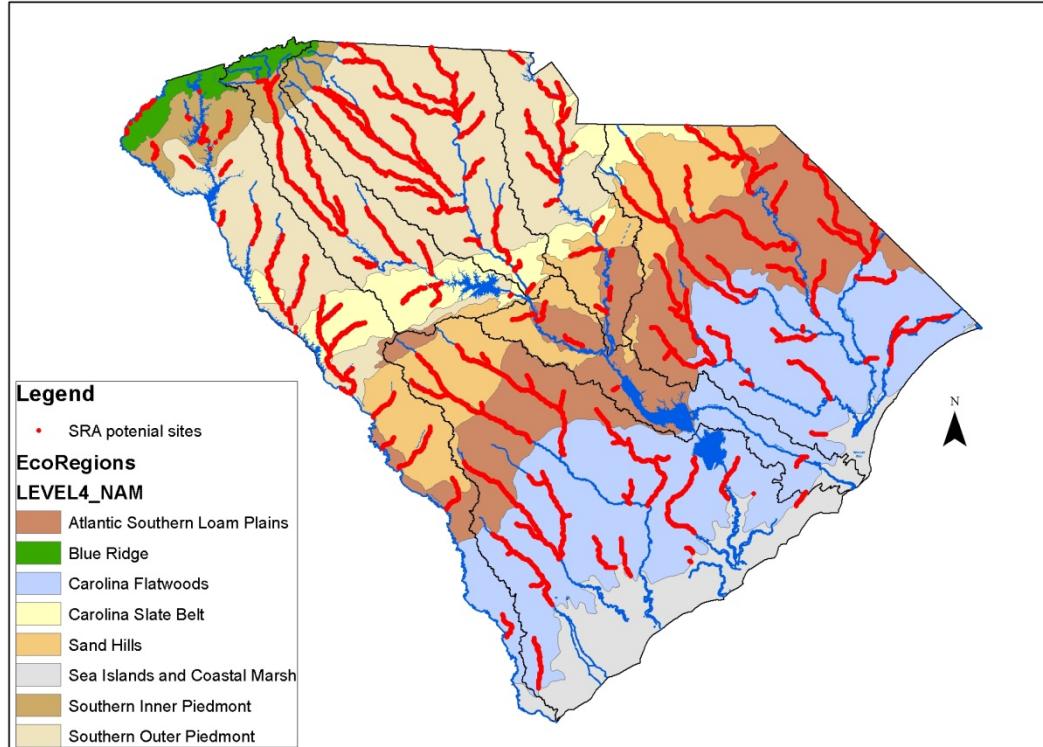
Next steps – scale up

Small Rivers Assessment

New project building on the streams work to fill in next spatial level

Ultimate goal is to connect mountains/headwaters to large reservoirs and coastal ecosystems

Quantify importance of source waters to receiving



Conclusions

- **Conservation Planning Tool:**
 - Communicate findings of aquatic resource assessments
 - Engage a broad audience in science-based decision-making
 - Facilitate proactive planning for aquatic conservation
- **Future Work:**
 - Include Small Rivers Assessment results
 - Expand library of predictive models
 - Add (and refine) spatial predictor variables

Public Deployment occurred in November 2013
<http://54.204.4.5/scsa>

Stream Assessment and Decision Tool Collaborators



Stream Team

Kevin Kubach
Cathy Marion
Drew Gelder
Bill Poly
Troy Cribb
Annemarieke de Vlaming
Jace Johnston
Greg Satterfield
Cory Guinn

Information Technology

Jason McBrayer
Dr. Jim Scurry
Richard Lacy



Clemson University

Dr. Sam Esswein
Dr. Rockie English
Dr. Peter van den Hurk
Dr. Steve Klaine

Dr. Chris Post
Jeremy Pike
Dr. Beth Carraway