Flow regime, floodplain inundation and floodplain waterbody connectivity at Congaree National Park

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South Carolina Applied Landscape Ecology (SCALE) Lab

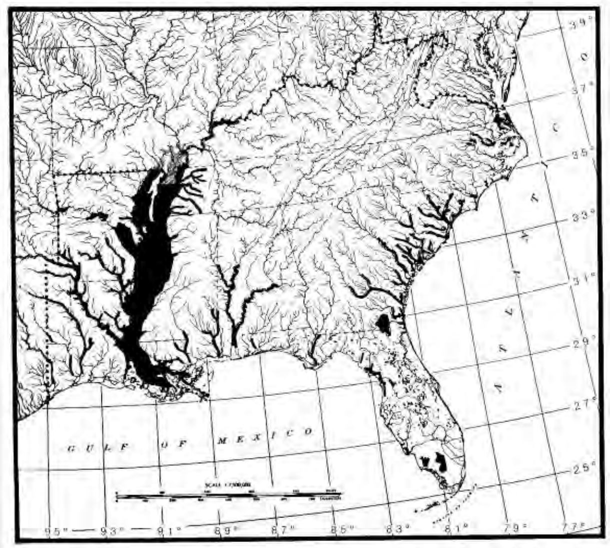
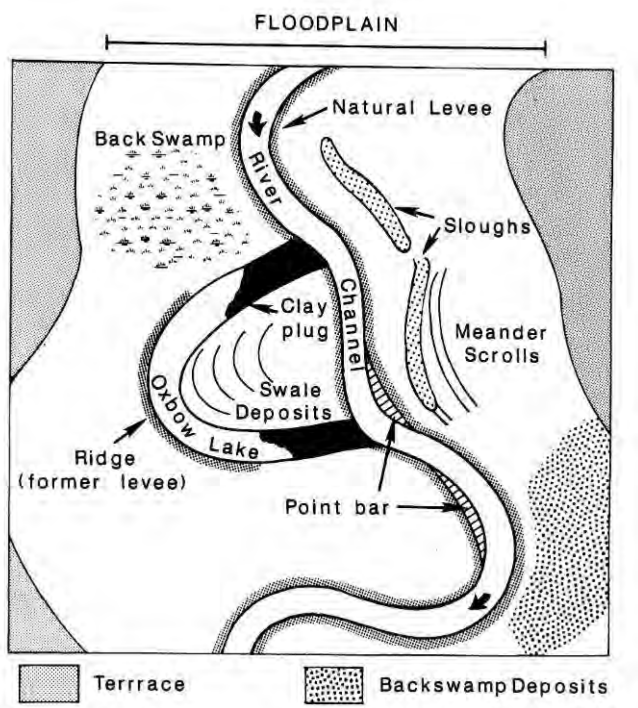


FIGURE 1. Potential natural distribution of floodplain forests of the United States (Küchler 1964). Type 113 (Southern Floodplain Forest) occurs along river and stream floodplains; Type 91 (Cypress Savanna) is found only in southwestern Florida.



Coastal Plain Floodplain Forests and Abandoned Channel Waterbodies (ACWBs)

Abandoned Channel Waterbodies (ACWBs): Oxbow lakes, sloughs and other floodplain depressions associated with former channel positions. ACWBs are critical elements of floodplain hydrology, geomorphology and ecology

Floodplain Connectivity and ACWBs

Lateral connectivity: the permanent and episodic links between the main course of a river and the waterbodies lying in the alluvial floodplain.

- Sources of connectivity
- Significance of connectivity
  - Storage / routing of high flows
  - Sediment fluxes
  - Habitat provision and access (e.g., floodplain spawners)
  - Metapopulation dynamics

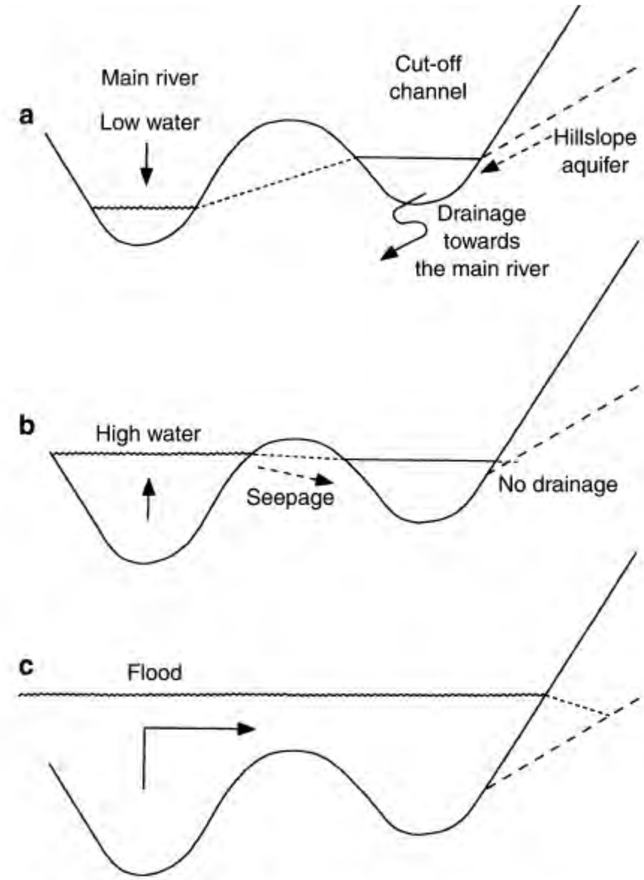


Fig. 3 Schematic illustration of the short-term dynamics of hydrological connectivity in relation to river stages: (a) (low-water stage), the floodplain waterbodies may be supplied by a hillslope aquifer; (b) (high-water stage), the floodplain waterbodies are supplied by river infiltration into the alluvial aquifer and possibly by river backflow through a downstream connection; (c) (flood), the floodplain waterbodies are supplied by overbank flow.

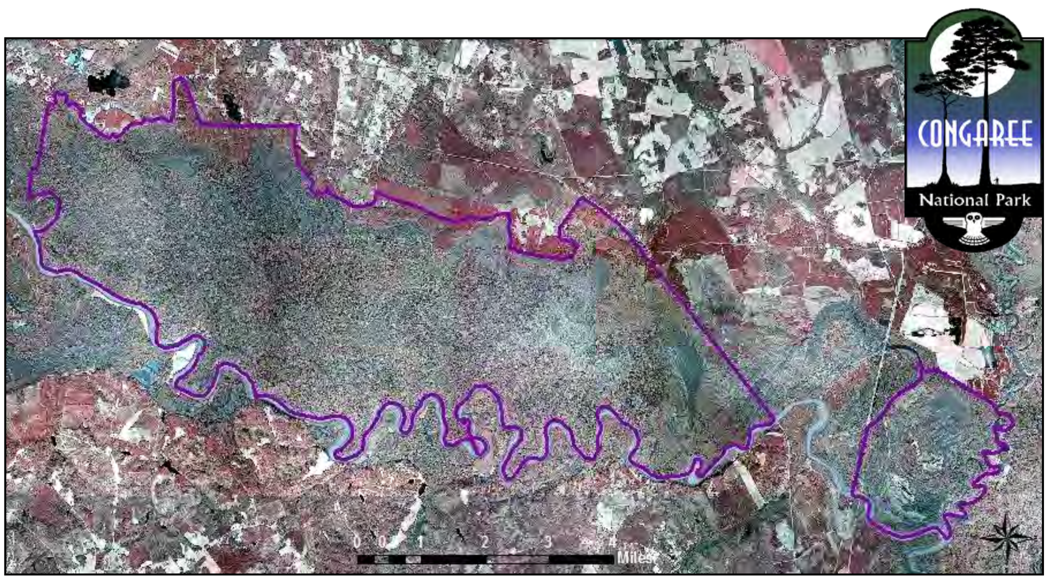
Amoros and Bornette (2002)

Study Objective

Objective: Examine how the <u>*surface connectivity*</u> of abandoned channel waterbodies along a major Coastal Plain river changes as a function of discharge and flood stage

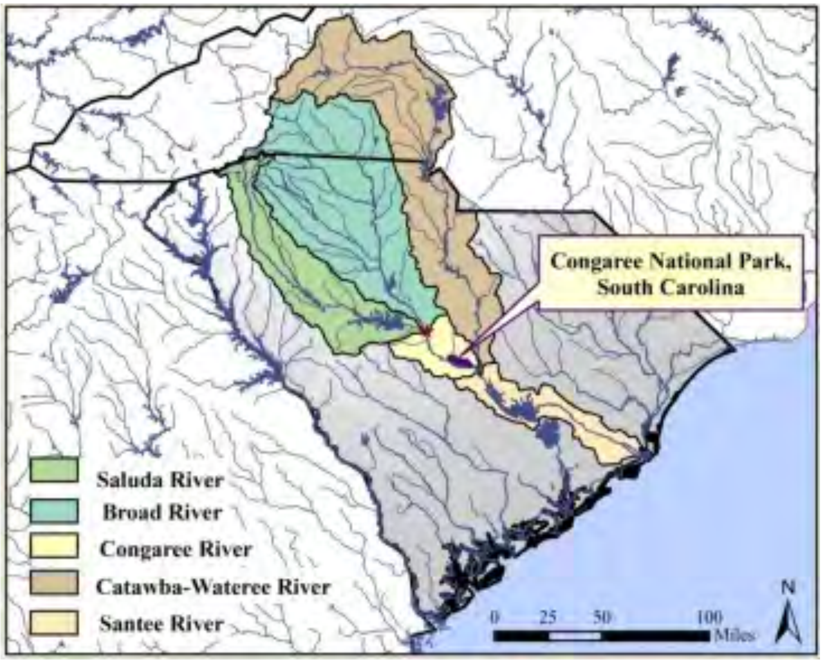
Congaree National Park

- Largest tract of remnant old-growth bottomland floodplain forest
- International Biosphere Reserve
- Globally Important Bird Area
- Ramsar Wetland of International Importance



Home of the last remaining ivory-billed woodpecker

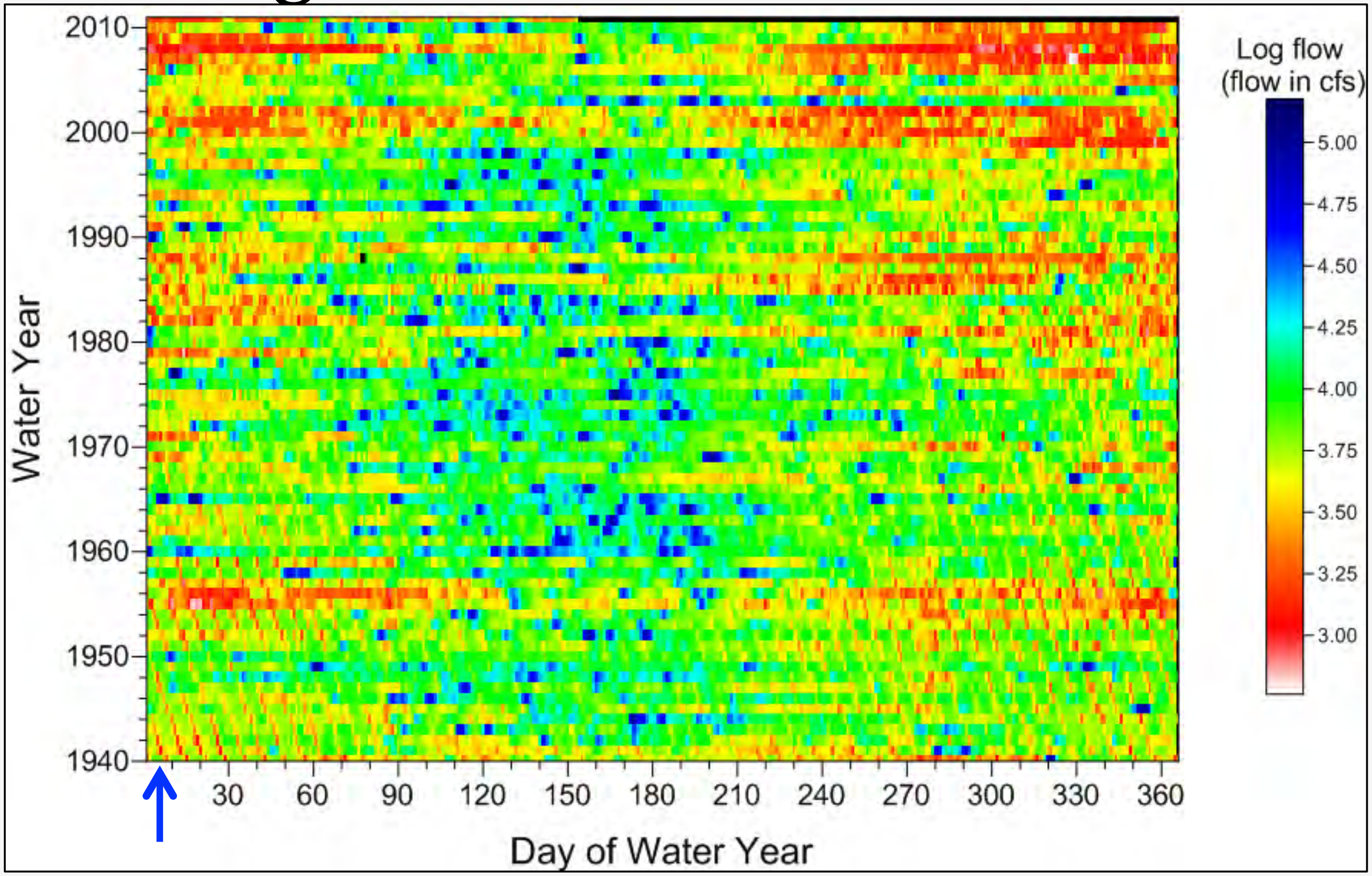
Congaree River Watershed



The Congaree and Wateree Rivers merge at the park's downstream boundary to form the Santee River

- The Congaree River is formed by the confluence of the Broad and Saluda Rivers, which originate in the Blue Ridge, flow through the Piedmont, and converge at the Fall Line
- Drainage Basin ~ 18,137 km^2
- Mean Annual Q and Range: ~ 254 m^3s^{-1} (~ 98 – 467 m^3s^{-1})
- Mean Daily Q Range: ~ 140 – 1400 m^3s^{-1}

Congaree River Flows: 1940-2010



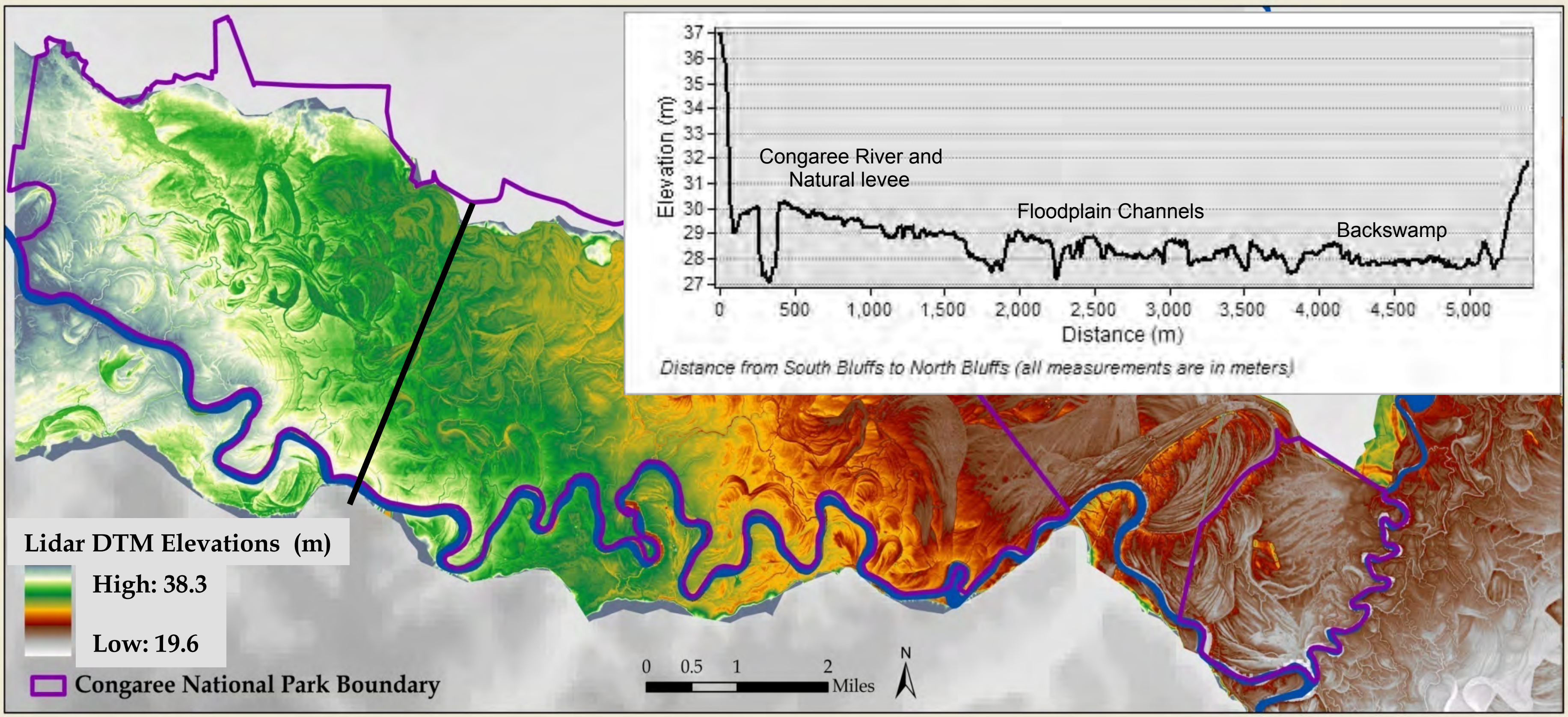
Hydrologic Water Year: October 1 – September 30th

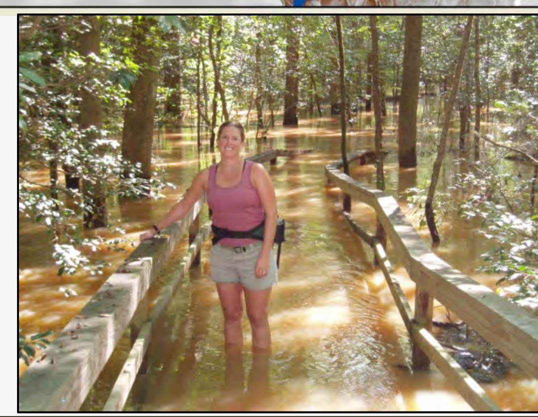


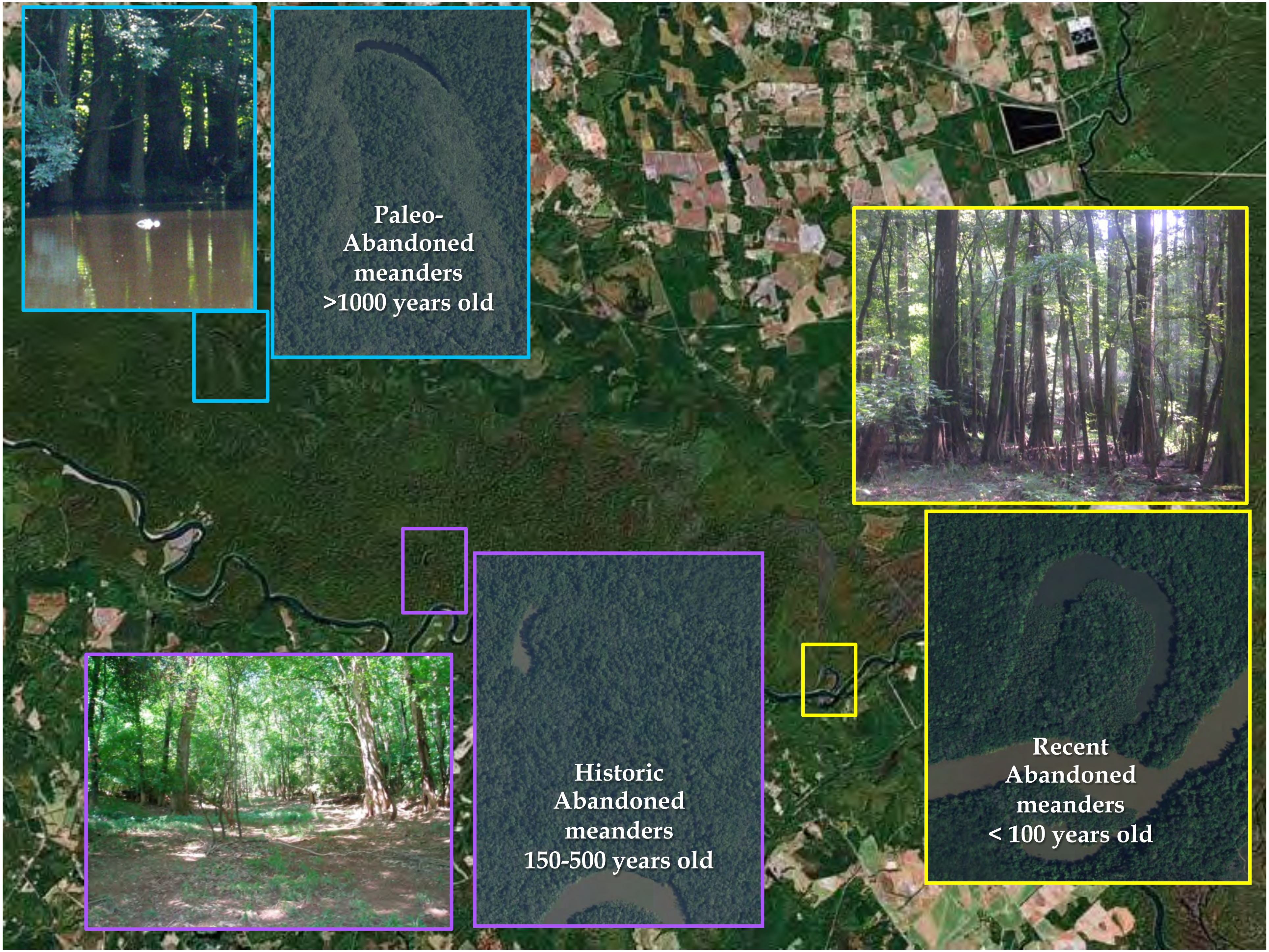




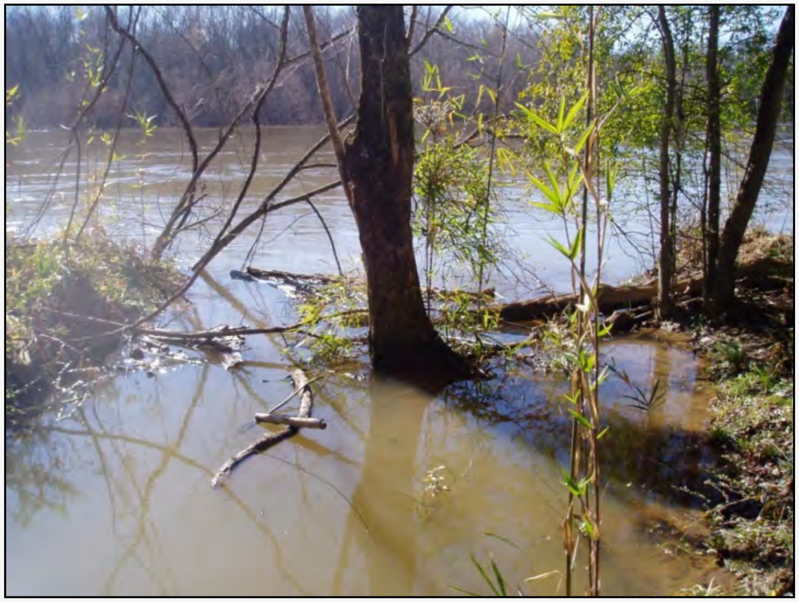
Floodplain Geomorphology and Hydrology






Paleo-
Abandoned
meanders
>1000 years old
Historic
Abandoned
meanders
150-500 years old
Recent
Abandoned
meanders
< 100 years old

Elements of Floodplain Connectivity



TUFLOW Hydrodynamic 2D Flood Model

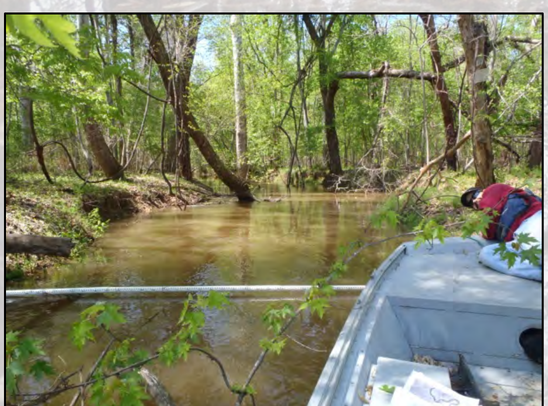
- Spatially-explicit flood simulation model developed for lowland floodplains and tidal systems
- Bi-directional/alternating flows routing through complex overland flow pathways
- Spatially distributed roughness parameters
- 2D models are more effective in lowland floodplain environments than 1D models



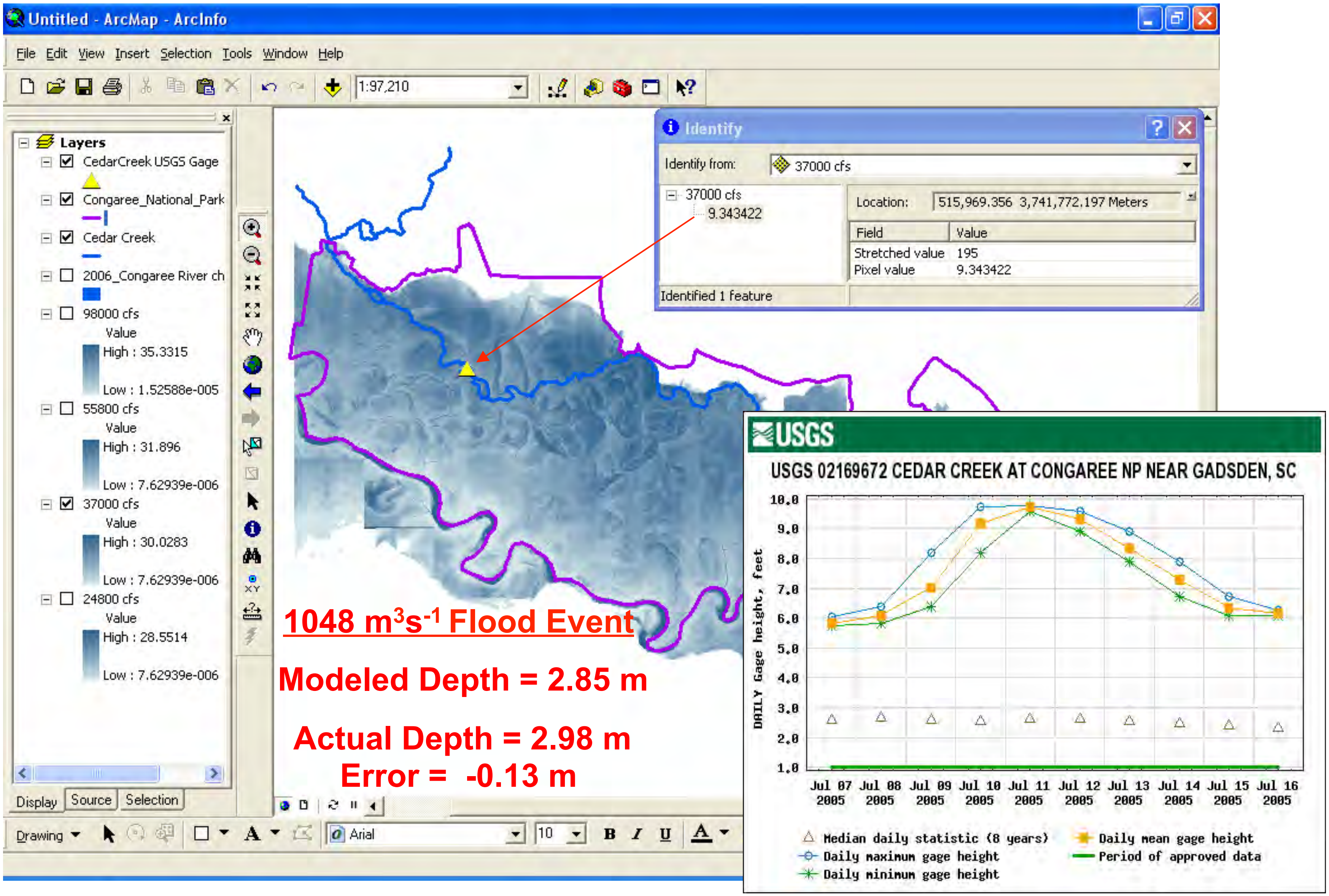
2D Flood Modeling Data Input

- Hydrology
  - USGS stream flow gages
    - Discharge
    - Stage
    - Water Surface Elevations
- Elevation
  - LiDAR-derived DTM:
    5 m horiz., 12-15 cm vert.
  - 1:24k Hypsography
  - Congaree River Bathymetry
- Manning's Roughness *n*
  - Spatially distributed values
    - Hydrologic features, forest structure, roads, etc…

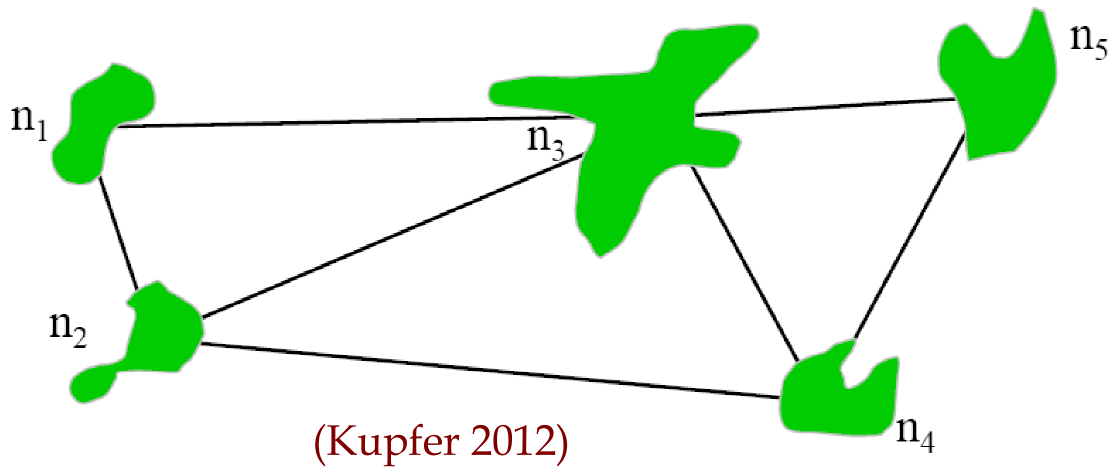
Flood Simulation Model: 1 Year Flood



Model Validation with Cedar Creek Stage



ACWBs and Landscape Graphs



(Kupfer 2012)

A landscape is represented as a set of nodes that are connected by links

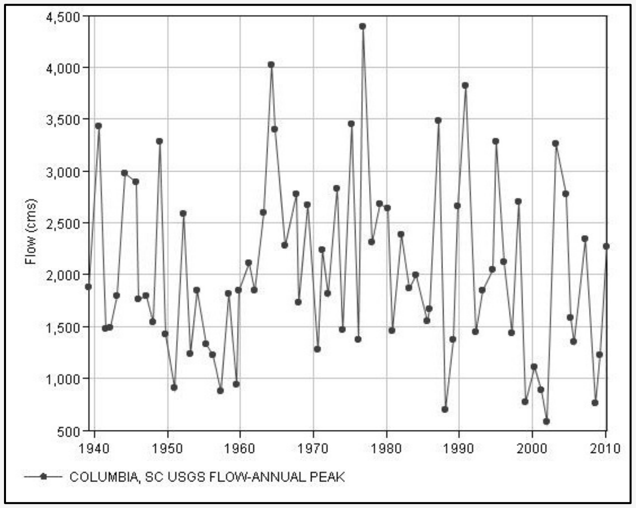
Nodes → Focal habitat patches

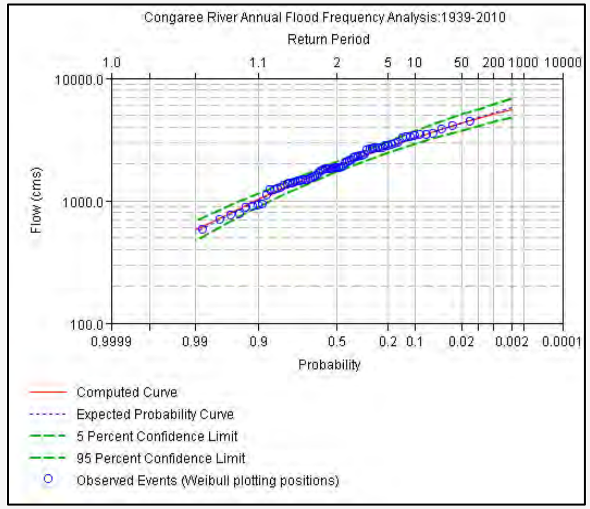
Links → Graph elements used to represent connectivity between patches

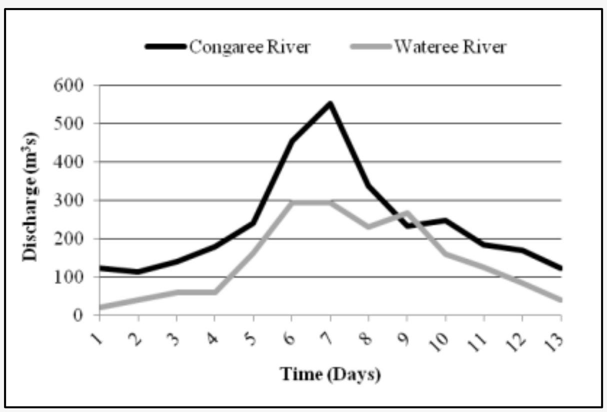
Here, the nodes are 22 floodplain waterbodies and the links are surface water connections between them

Flood Frequency Analysis

Congaree River at Columbia, USGS 02169500







1 Year Recurrence Flood

<u>Ten Discharge Levels flood events:</u>

150 m^3s^{-1} (Multiple events per year)

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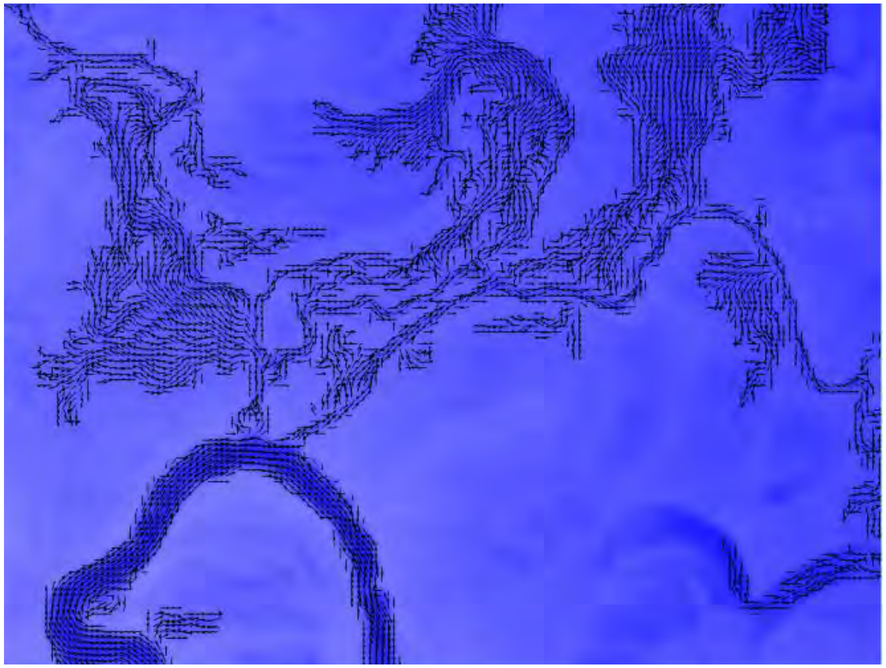
850 m^3s^{-1} (1-2 yr recurrence flood)

Results

1. Connectivity during frequent, lower Q events (150-235 m^3s^{-1}) increases slowly and is initiated via back-flooding of Cedar Creek, Old Dead River, and breaches in the main channel banks



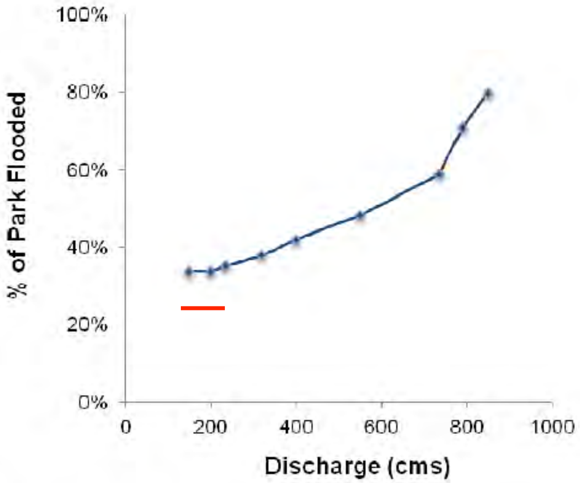
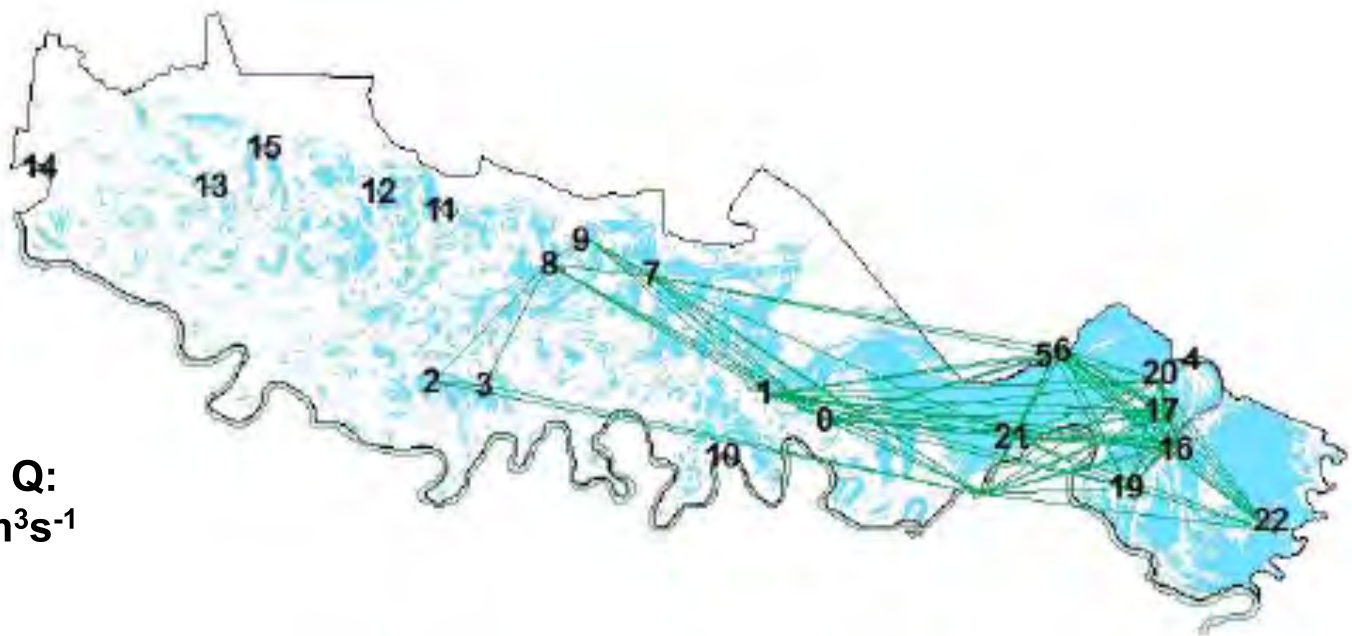


Figure 1. Percentage of the area within Congaree NP flooded as a function of Congaree River discharge.

Results

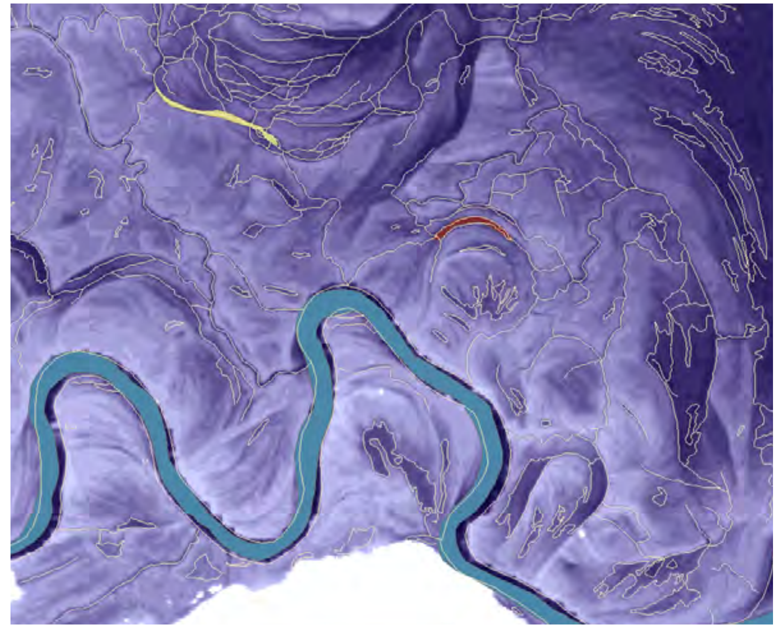
This initial flooding links a number of wetlands to each other and the mainstem river through short distance routes and flooding through crevasses and distributary channels. Greatest connectivity is in two areas:



River Q:
160 $m^3 s^{-1}$

Results

2. As Q increases (320-735 m^3s^{-1}), flooding is still driven by flow through crevasses and backflooding, and the area inundated increases steadily as more floodplain features are activated.



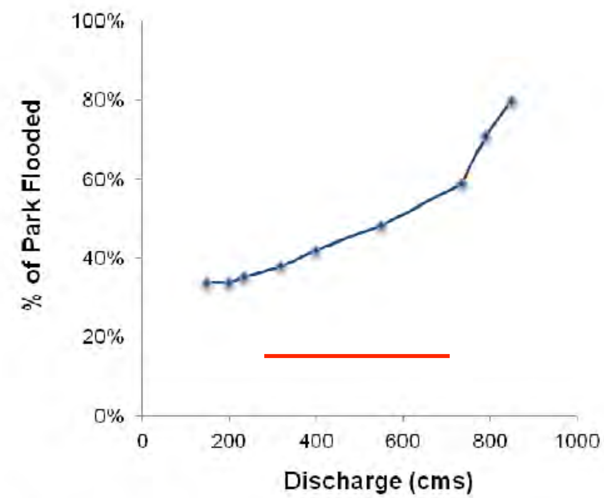
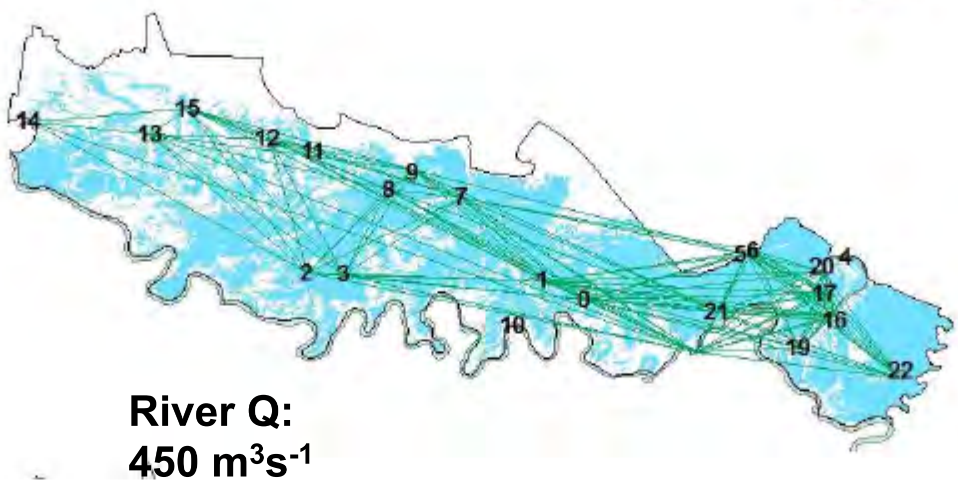


Figure 1. Percentage of the area within Congaree NP flooded as a function of Congaree River discharge.

Results

ACWBs are better connected, and the distance to the mainstem river begins to stabilize.



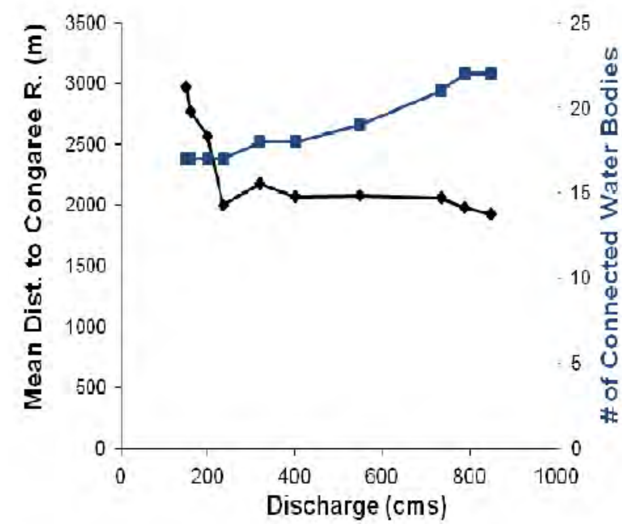
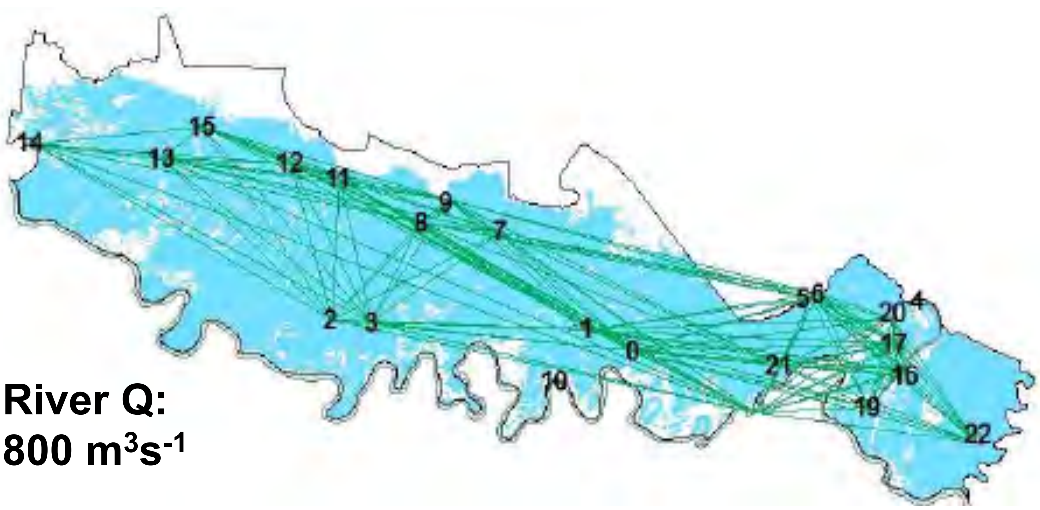


Figure 2. Number of abandoned channel waterbodies connected to the mainstem Congaree River, and the average minimum connection distance.

Results

3. Connectivity during less frequent, higher Q events > 735 m^3s^{-1}), shifts to overbank and cross-floodplain movements, linking wetlands to each other and the mainstem river. The nature of these linkages is different, though.



River Q:
800 m^3s^{-1}

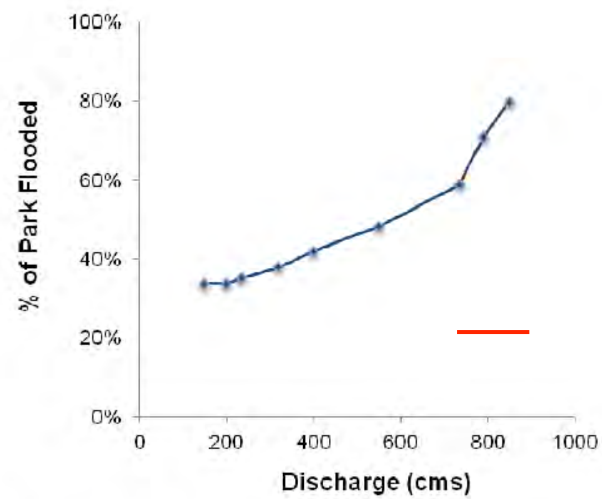


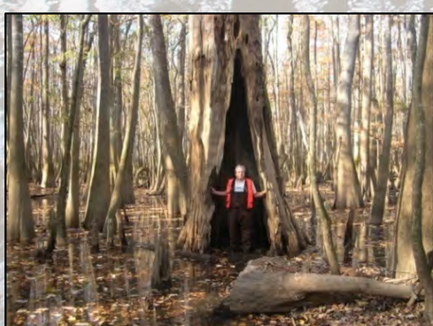
Figure 1. Percentage of the area within Congaree NP flooded as a function of Congaree River discharge.

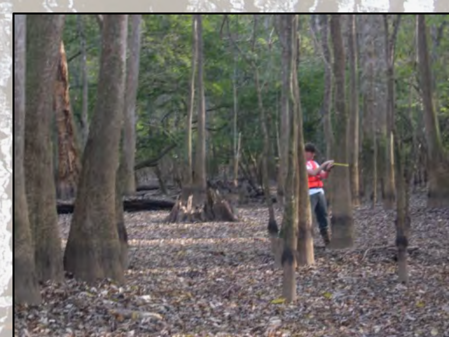
Climate change-induced changes in flow regime, floodplain inundation and species habitats at Congaree National Park

1. *Climatic downscaling*: develop an ensemble of climate change simulations for the region.
2. *River flow:* project changes in river discharge due to climate and river management
3. *Floodplain inundation:* model new flood regimes under future flow conditions
4. *Bioindicator species analysis*: predict effects on flood-sensitive species

Acknowledgments

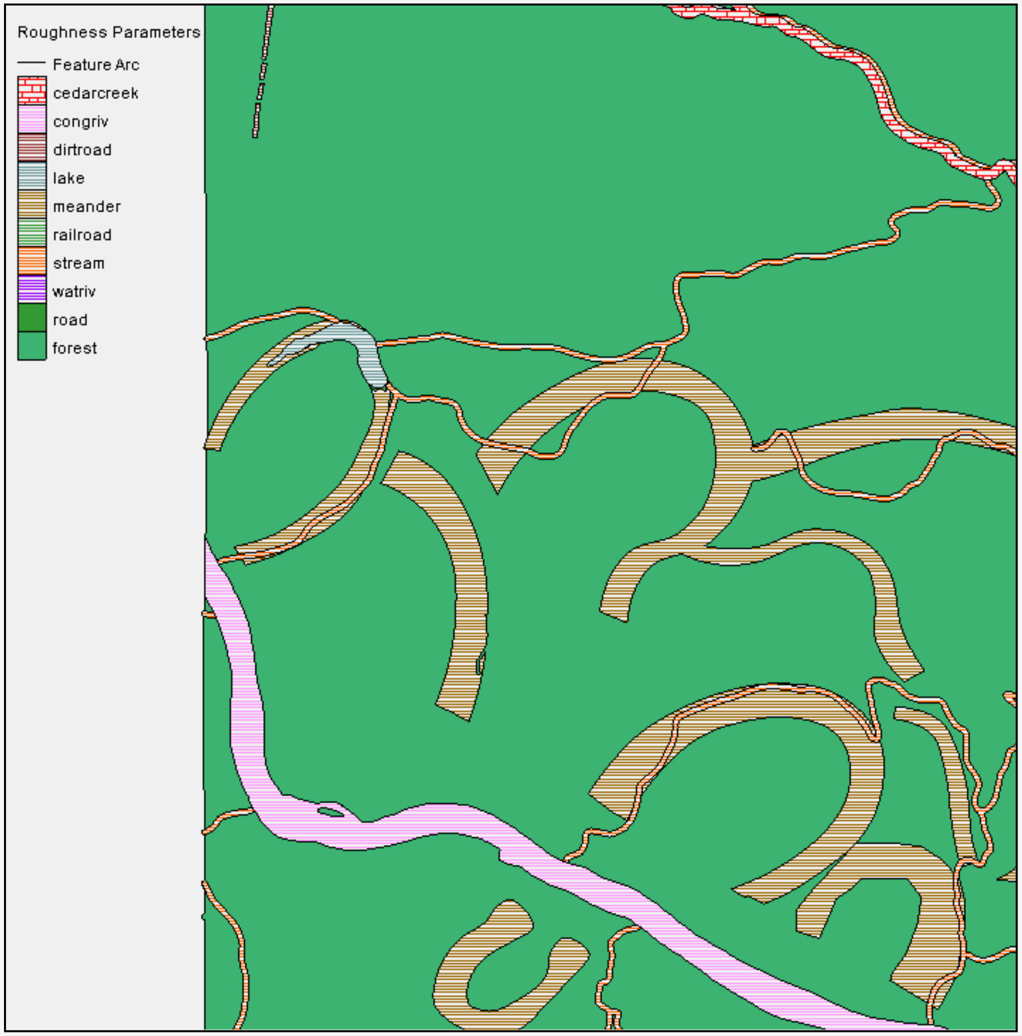
- Funding from the National Park Service and Department of Interior
- Friends of Congaree Swamp, Biogeography Specialty Group
- TUFLOW and SMS User Forums and Bill Syme



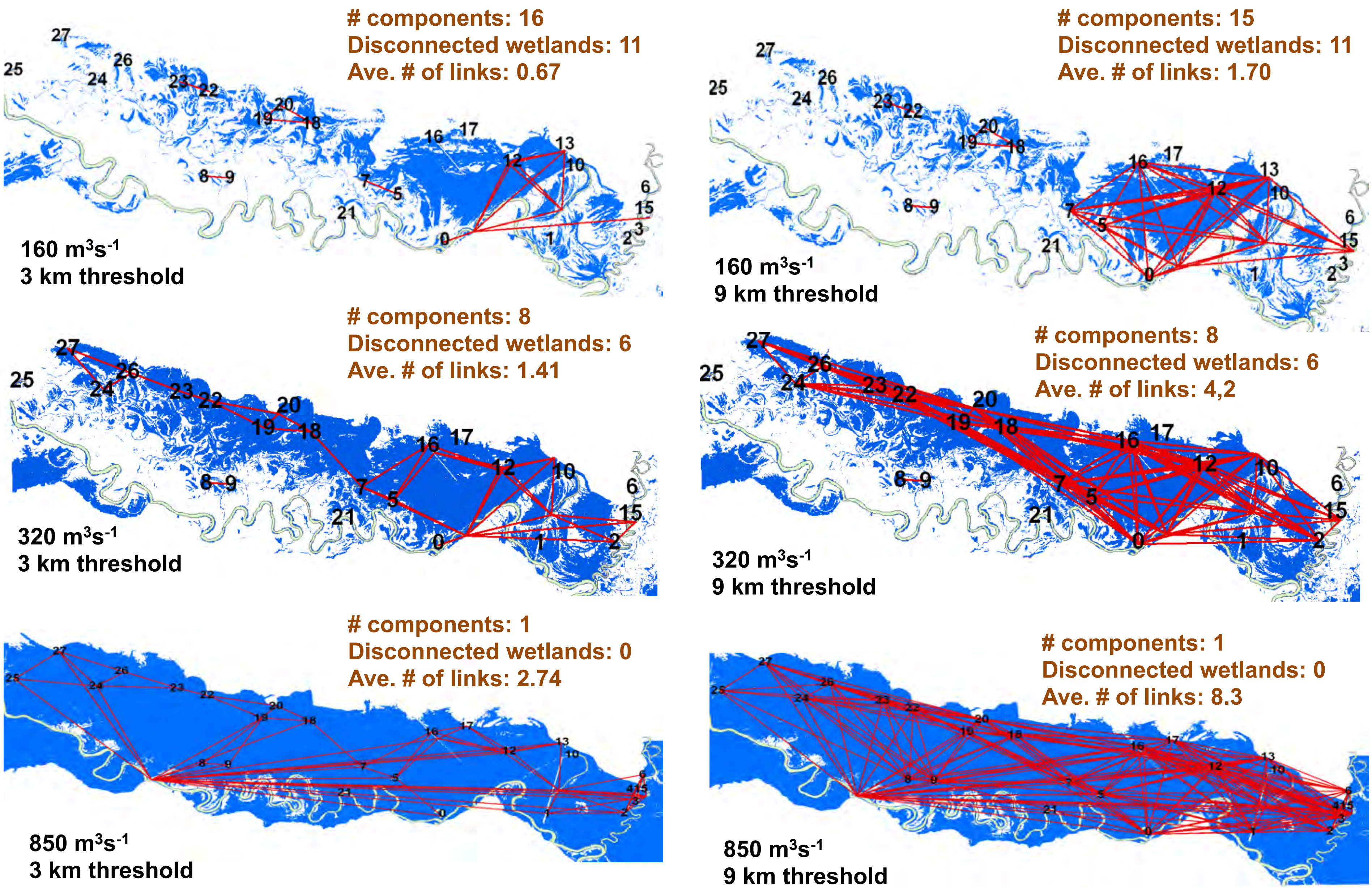



Spatially Distributed Manning's *n*

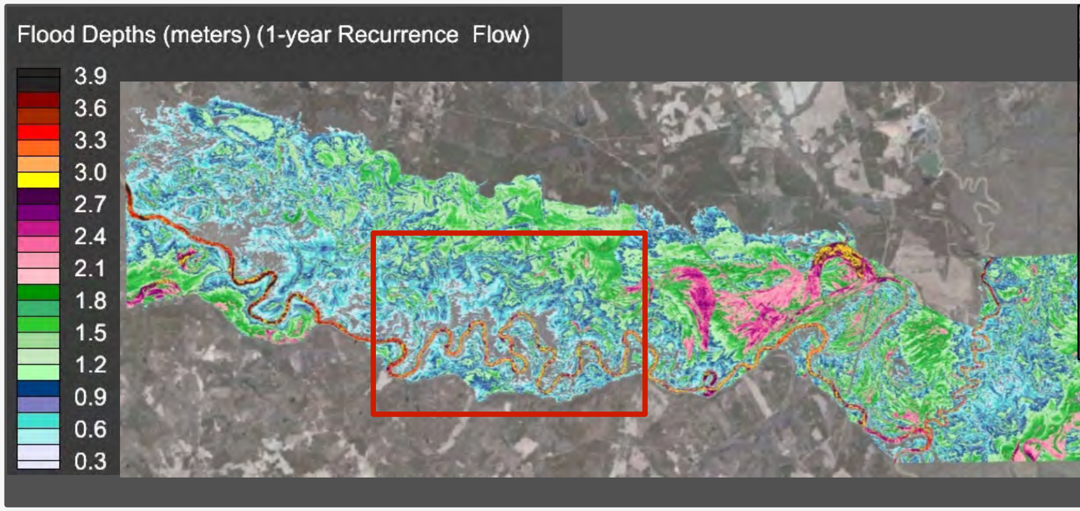
Feature	Roughness Coefficient
Congaree and Wateree Rivers	0.02
Floodplain streams	0.05
Floodplain lakes	0.03
Abandoned meanders	0.08
Floodplain surface	0.30
Gravel/dirt road	0.05
Railroad causeway	1.00

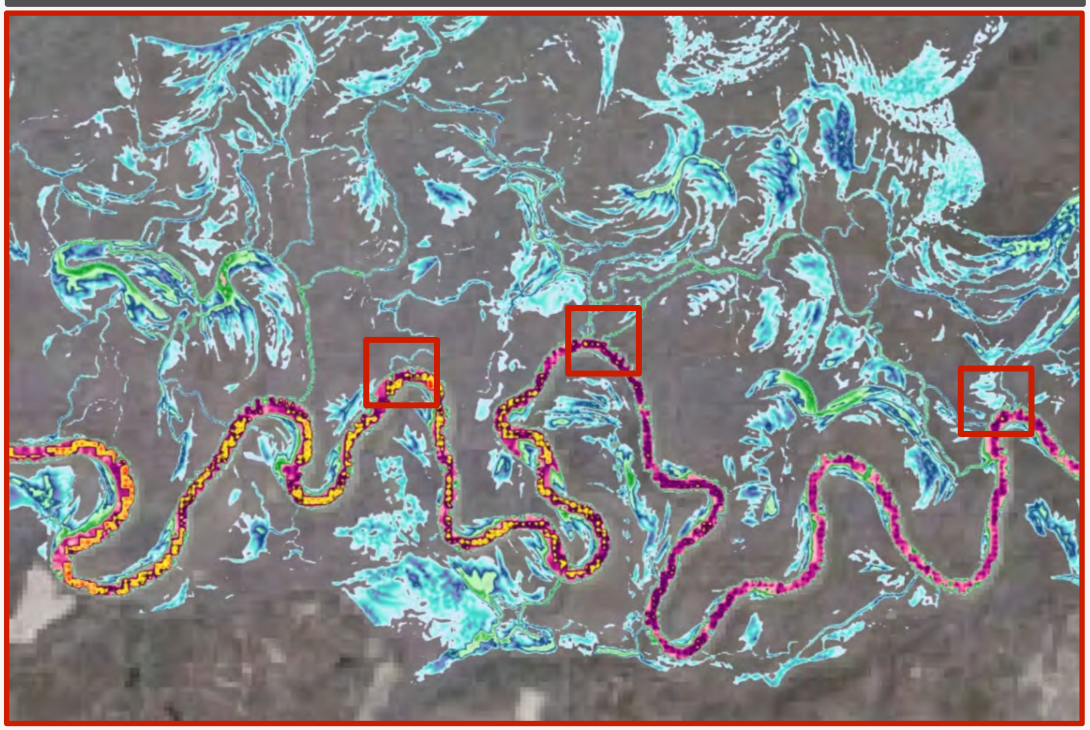


Flooding and Waterbody Connectivity



Crevasse Validation

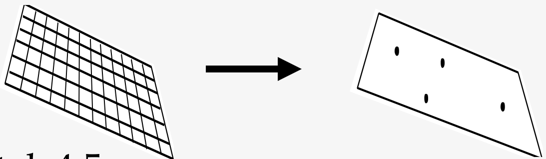




Site	Actual (m)	Model (m)	Error (m)
1	2.70	2.51	0.19
2	0.30	1.21	-0.91 ←
3	2.65	2.76	-0.11
4	1.65	1.77	-0.12
5	1.10	1.32	-0.22
6	0.30	0.52	-0.22
7	4.00	2.60	1.40 ←
8	1.85	2.29	-0.44
9	0.35	0.46	-0.11
10	1.40	1.01	0.39
11	1.45	1.73	-0.28
12	3.85	2.50	1.35 ←
13	1.38	1.31	0.08
	Mean Difference:		0.45

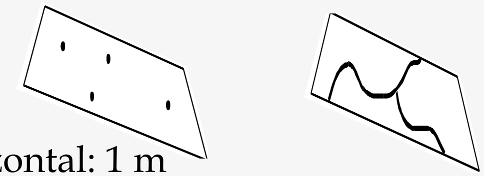
Digital Terrain Model

1. LiDAR Terrain Data from Ascii Elevation Grids converted to Points



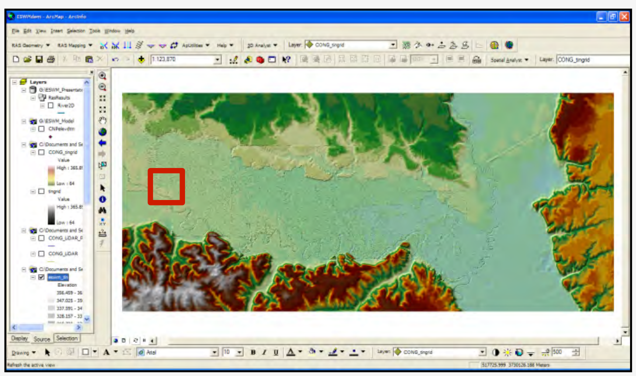
Horizontal: 4.5 m
Vertical: 12.5 -20 cm

2. Merged with Hydrographic Survey Data and hydrologic feature break lines



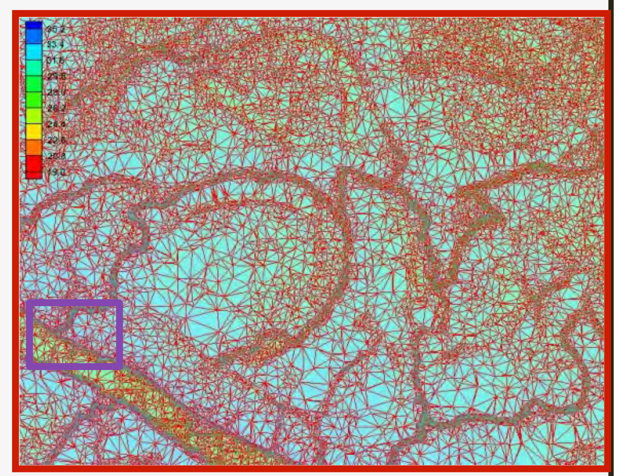
Horizontal: 1 m
Vertical: 4 cm

3. Build TIN Elevation Model



4. Extract 3D TIN Elements and import them into SMS

3D Points
3D Polygons (triangle faces)
3D Break lines



5. SMS 3D Mesh

Horizontal: 5 m
Vertical: 20 cm

6. TUFLOW 2D Grid