

Ecohydrology of a Floodplain Forest: Relationships Between Evapotranspiration, Vegetation, and Topography at Congaree National Park, South Carolina

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ABSTRACT

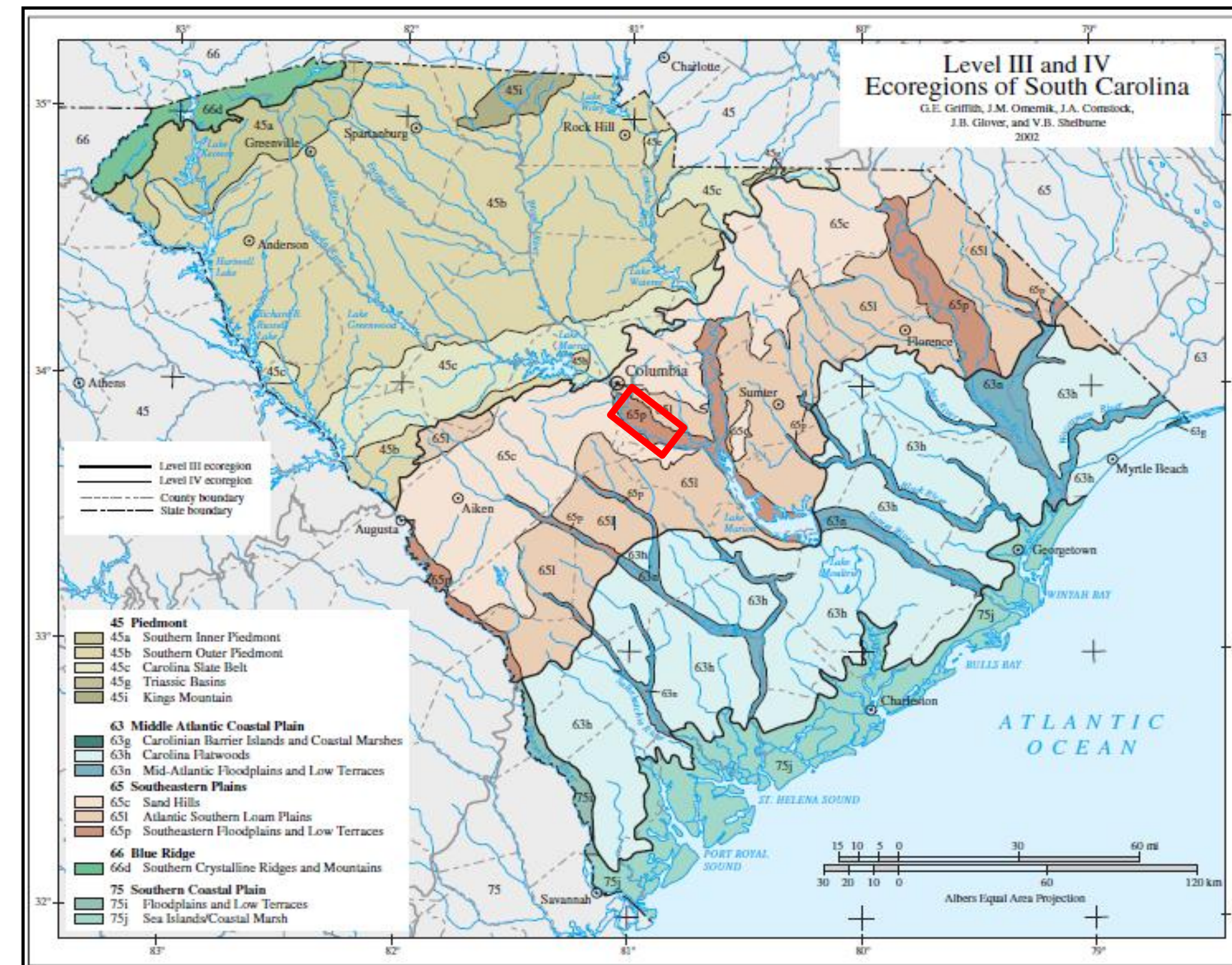
Congaree National Park supports high biodiversity and provides ecosystem services for the surrounding area in the floodplain wetland system, especially in the bottomland hardwood forests which contain some of the last remaining old-growth stands in the eastern U.S. Maintaining the hydraulic functions of this ecosystem is essential not only for the conservation of biodiversity, but also for the ecosystem services it provides, such as nitrification, denitrification, decomposition, removal of organic carbon, and phosphorous uptake and sorption. Because management practices of the park depend on understanding the area's hydrology, past research has been performed to analyze the flooding of Congaree River. However, not much has been done to better understand groundwater movement through the floodplain sediments in the Congaree River Valley. The goal of this project is to quantify interactions between the shallow unconfined aquifer and local vegetation surrounding eight piezometers in the Congaree Observation Well Network at Congaree National Park through calculating and comparing evapotranspiration rates, specific yield, vegetation diversity and basal area, and microtopography. Data on groundwater response to storm events, diurnal signals caused by evaporation and transpiration in the forest, vegetation community structure, and local topography were compared to better understand the role of these factors on vegetation water demand in this wetland-dominated system.

MOTIVATION

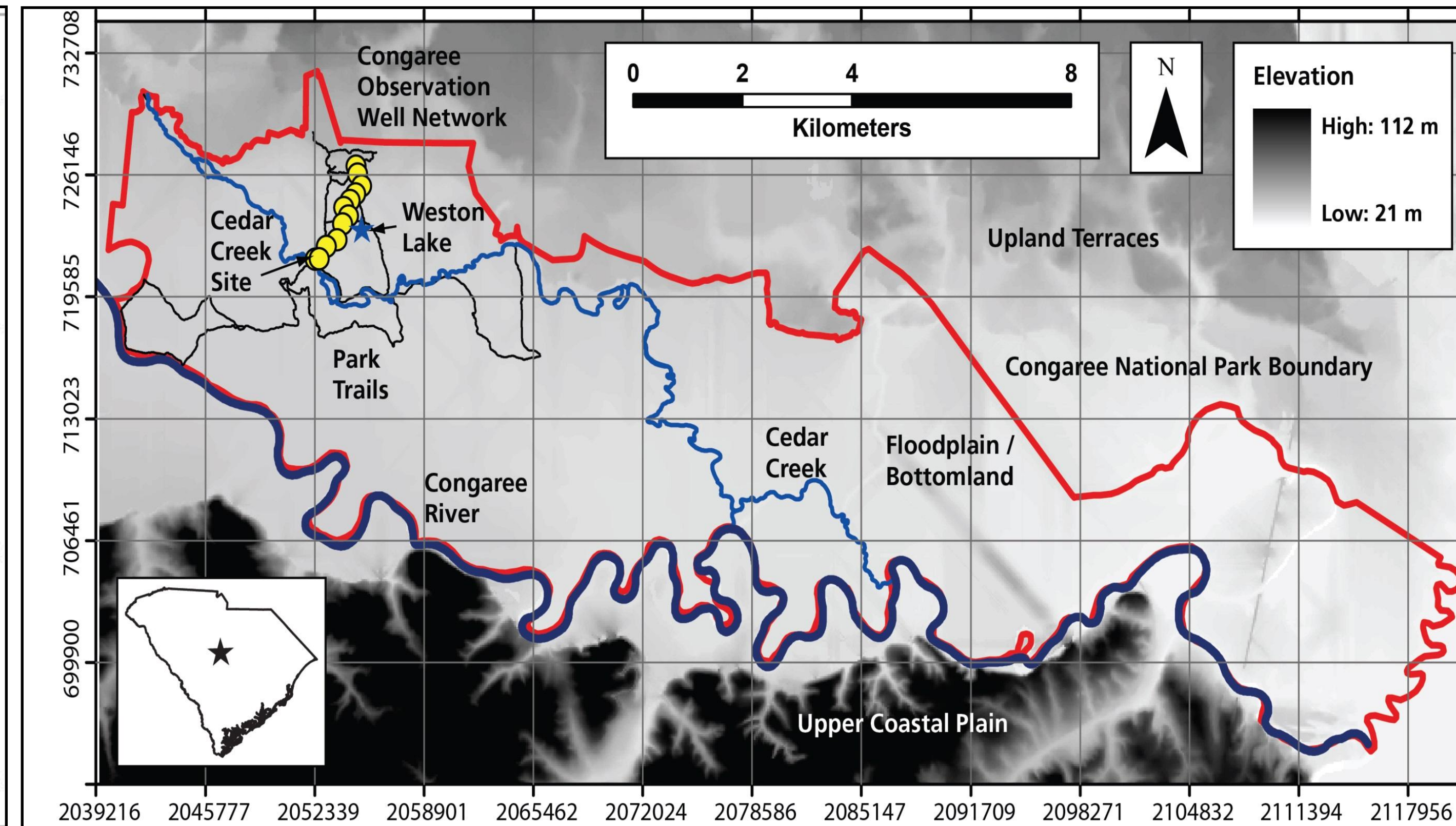
- Forested wetlands in the Southeast U.S. are productive ecosystems. Ecosystem services are carbon sequestration, flood mitigation, and wildlife habitat – very important in old-growth bottomland hardwood systems like Congaree National Park
- Ground water is the “hidden” resource that supports these forests. How does it work?

METHODS

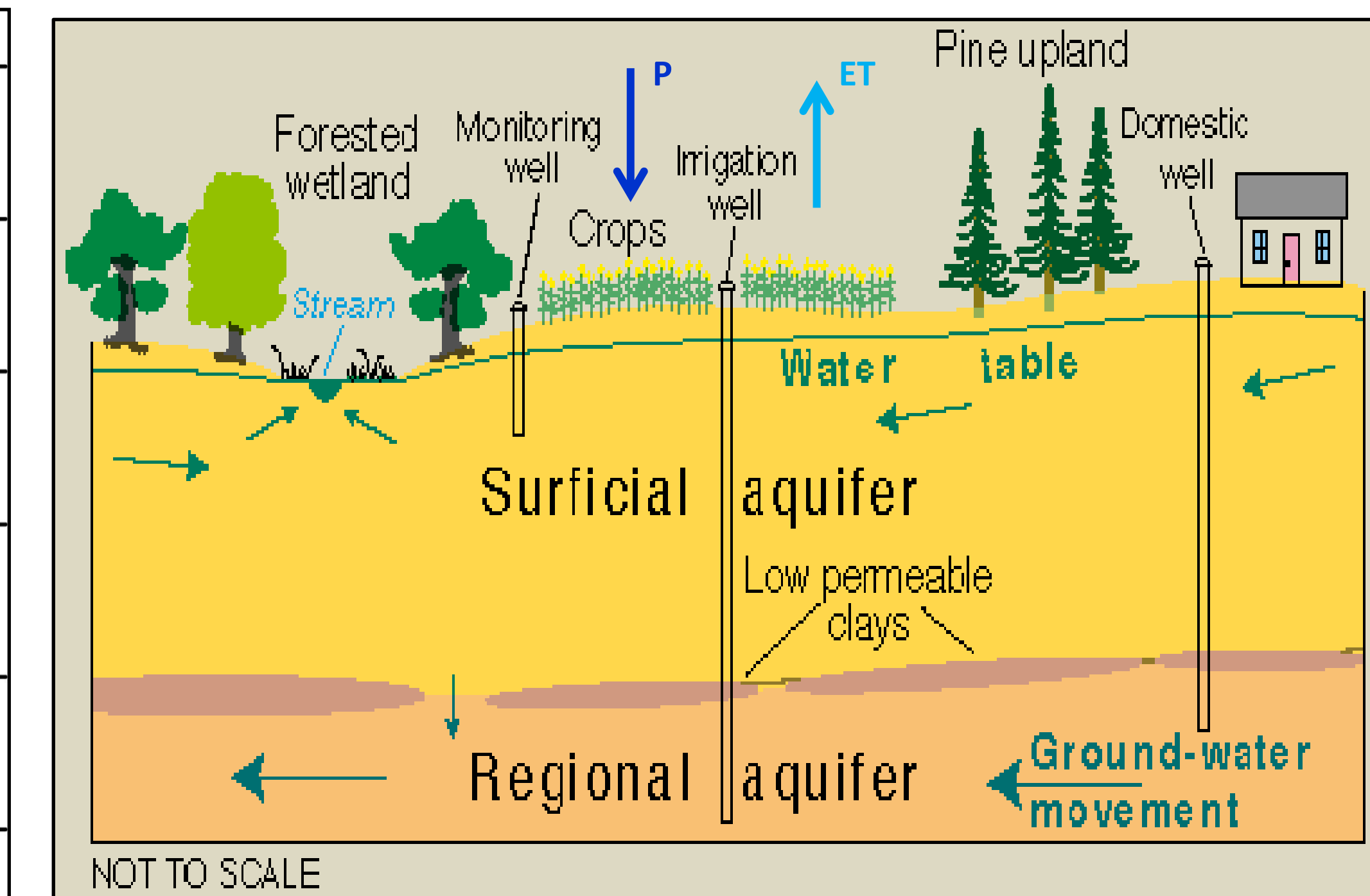
- Hourly water levels collected at 10 locations in the shallow unconfined aquifer using the piezometer transect. For this study data were analyzed from S-1 through S-8.
- A water balance model (White 1932) was used to estimate evapotranspiration [ET] in the forested floodplain (Figure 1):
$$ET [mm/day] = S_y (h/t + s/t) * (24hr/day)$$
- S_y is the specific yield (water uptake/release potential) of sediments, h is the rate of water level recovery from midnight to 5:00 am, s is the water level change from 2:00 am on one day to 2:00 am on the next, and t is time (5 hr or 24 hr).
- Average specific yield was estimated (Harder et al. 2007) by inspecting storm-induced water-level responses (Figure 2):
$$S_y = \frac{P}{dh}$$
 P_i is the total storm amount and dh is the corresponding rise in water level (both in mm)
- A vegetation survey of woody stems at each piezometer site was conducted in March 2014. In circular plots of 400 m² diameter at breast height [DBH] of woody stems (approx. 1.4 m) was recorded and each stem identified to species (Peet et al. 1998).
- Basal Area [BA] was calculated from DBH (in) using the following equation (Walsh 2010):
$$BA [sq m] = [0.005454 \times (DBH)^2] * 0.092903$$
- Wetland indicator status was used to determine the ‘wetness score’ of each site based on species composition (Table 3).



Ecoregions Map of South Carolina



Location and Topographic Map Congaree National Park



The Ground Water Cycle

RESULTS

- ET signals were apparent year-round but more pronounced in the summer months (Figure 3).
- Specific yield of the sediments were similar and in the expected ranges for fluvial sediments (Table 2).
- ET was variable across sites and did not compare to BA, possibly due to microtopographic differences (Table 2).
- Vegetation was reflective of bottomland hardwood forest type, however the wetness score differed by site (Table 1).

Location	Wetness Score	Prominent Species by Basal Area		
		Common name	Latin name	photo
S-1	3.78	Tupelo	<i>Nyssa sp.</i>	
S-2	2.85	American beech	<i>Fagus grandifolia</i>	
S-3	3.22	Sweetgum	<i>Liquidambar styraciflua</i>	
S-4	4.05	Bald cypress	<i>Taxodium distichum</i>	
S-5	3.40	Loblolly pine	<i>Pinus taeda</i>	
S-6	4.64	Tupelo, bald cypress	<i>Nyssa sp., Taxodium distichum</i>	
S-7	3.17	Sweetgum	<i>Liquidambar styraciflua</i>	
S-8	3.94	Swamp laurel oak	<i>Quercus laurifolia</i>	

Table 1: Prominent tree species by basal area (m²) for each piezometer site with wetness score (range 1-5). Scores closer to 1 indicated more upland species, while scores closer to 5 indicated more facultative or obligate wetland species.

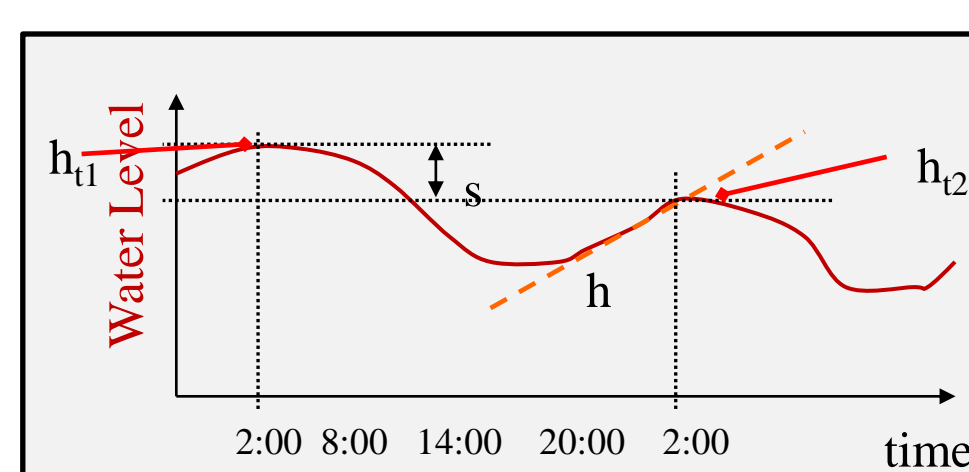


Figure 1: Groundwater hydrograph analysis, adapted from White (1932).

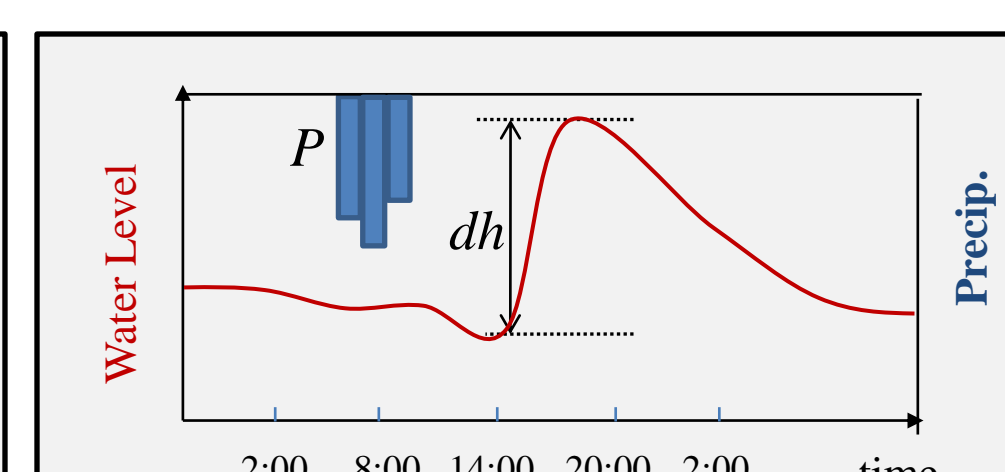


Figure 2: Calculating specific yield from storm-induced groundwater change (Harder et al., 2007).

Site	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8
Topographic features	hummock	hollow	hollow	hollow	hollow	hollow	hummock	hummock
Soil type	sand/clay	sand/clay	sand/clay/silt	sand/clay/silt	sand	sand/clay	clay/sand	clay/sand
Specific yield	0.14 ± 0.05	0.19 ± 0.13	0.16 ± 0.10	0.16 ± 0.10	0.19 ± 0.09	0.15 ± 0.10	0.14 ± 0.06	0.19 ± 0.08
ET (mm/day)	10.09	7.5 ± 8	0.85	2.03	5.7 ± 4	4.42 ± 3	10.0 ± 7	1.0 ± 0.3
Basal Area (sq m)	3.83	1.64	2.55	1.76	3.76	4.67	2.60	1.97

Table 2: Topographic features and summary of soil type, ET, specific yield, and basal area for each piezometer site. Topographic features are defined as either a hummock or hollow. Soil type described during installation of piezometers.

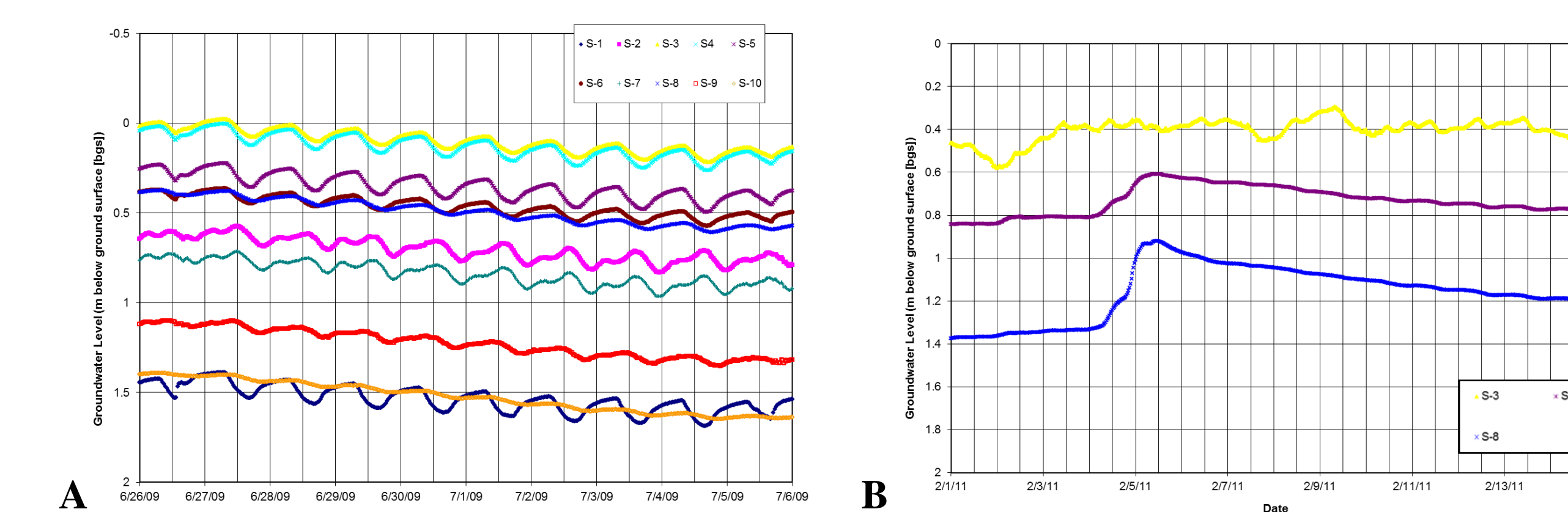


Figure 3: Two-week snapshots of water levels in the shallow aquifer for each piezometer. (A) shows diurnal fluctuations in summer. (B) shows these patterns muted in winter. Both graphs have the same color codes.

Indicator Status	Wetness score	Definition
Obligate wetland (OBL)	5	almost always occur in wetlands
Facultative wetland (FACW)	4	usually occur in wetlands, may occur in non-wetlands
Facultative (FAC)	3	occur in both wetlands and non-wetlands
Facultative upland (FACU)	2	usually occur in non-wetlands, may occur in wetlands
Upland (UPL)	1	almost never occur in wetlands

Table 3: Definitions of wetland indicator status and wetness score (USDA, 2014).

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DISCUSSION

- Basal area did not correlate with evapotranspiration at most sites. S-2 had lower basal area but higher ET rate possibly due to the vegetation composition at this location. Wetness score of 2.85 indicates the presence of a larger number of facultative upland species. S-2 also exists in a hollow so microtopographic differences, such as root tip-ups, may allow FACU species to survive.
- S-5 had the third highest basal area of the study, at 3.76 m². High basal area for this site can be contributed to two trees: one *Pinus taeda* (loblolly pine) at 1.64 m² and one *Quercus laurifolia* (laurel oak) at 1.14 m². Wetness score of this site (3.40) was most likely brought lower by the large *Pinus taeda* (FAC species with a score of 3).
- S-6 had the highest basal area and wetness score of all sites, due to its location within a creek bed, Moccasin Alley. Soils here remained saturated for longer periods than other piezometer locations, and provided habitat for wetland species such as *Nyssa* sp. and *Taxodium distichum*.
- S-7 and S-8 often displayed no change in water level after rain events, possibly due to clay soils in the upper 2 meters surrounding each well. Although this clay layer did not appear significant enough to alter vertical groundwater movement (Figure 3), a sudden influx of storm water most likely flowed over the clay instead of percolating through (Johnson 1967).
- The results of this study contribute to the base of knowledge that has been gathered at South Carolina's only national park, Congaree National Park (CNP), and by extension informs on wetland ecohydrology in floodplain forests.
- It is now known which tree species exist and the total basal area for those species across a nearly 2-km long transect terminating near Cedar Creek, an important sector of CNP that sees the majority of visitor traffic at the site.
- The results of this study provide baseline data for future research along with information that could help develop management guides for CNP staff and for managers of similar sites.

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