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Assessment of Water Resources and Watershed Conditions in Congaree National Park, South Carolina

Natural Resource Report NPS/SECN/NRR—2010/267

ON THE COVER
Researchers at Wise Lake, an oxbow within Congaree National Park
Photograph by: Michael Mallin

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Natural Resource Report NPS/SECN/NRR—2010/267

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Executive Summary

The purpose of this report was to locate and examine existing information pertaining to the water quality in and around Congaree National Park (CONG), assess the present and likely future water conditions of the park, and make recommendations to fill in existing information gaps. Water quality and quantity, habitat issues, potential for invasive species, and trends in park resource usage are addressed.

The body of this report details water quality issues impacting the rich aquatic resources within CONG. The most pressing issues are termed stressors, and are displayed below (Table 1) for each of the major water systems within or impacting humans, wildlife or the ecosystems within CONG. More detail explaining the table's conclusions is provided subsequently.

Water quality within CONG is generally good, but there are several current and potential problems that should be either noted or addressed and in some cases investigated further (Table 1). Upper Cedar Creek where it enters the park is generally considered to have excellent water quality. However, other research has shown lower Cedar Creek near Wise Lake to have elevated fecal bacteria counts; this is a human health concern. SCDHEC lists several areas adjoining the park as impaired for use. These include Toms Creek (impaired for high fecal coliform counts and, as previously noted, impaired biological community); the Congaree River at the west boundary of the park (impaired for high fecal coliform counts), and the Congaree River near the Bates Fork Tract at Highway 601 (impaired for high fecal coliform counts and elevated copper). Clearly, source tracking of fecal bacteria inputs are a major research need for CONG. In addition there is a fish consumption advisory for various species in the area due to mercury contamination. Various studies collectively indicate that there may be a problem with elevated metals in water and sediments of the park.

Table 1. Current and potential stressors that are affecting or may affect Congaree National Park habitats (reprinted from Table 29 within the text) [EP – existing problem, OK – low or no problem, PP – potential problem, ND – no data to make judgment].

Stressor	Cedar Creek	Toms Creek	Wellwater	Oxbows	Congaree River	Wateree River
Algal Blooms	OK	OK	OK	EP	OK	OK
Toxic Algae	OK	OK	OK	PP	OK	OK
Nutrient Loading	OK	OK	OK	PP	PP	PP
Excessive Nitrate	OK	OK	OK	OK	OK	OK
Hypoxia	OK	OK	OK	EP	OK	OK
Sedimentation	OK	OK	OK	OK	PP	PP
Turbidity	PP	OK	OK	OK	PP	PP
Erosion	PP	PP	OK	OK	OK	OK
Fecal Bacteria	PP	EP	OK	OK	EP	OK
Excessive Metals	PP	PP	OK	EP	EP	EP
Toxic Compounds	OK	PP	OK	ND	OK	ND
Invasive Species	EP	EP	OK	EP	OK	OK
Habitat Disruption	EP	EP	OK	EP	OK	OK

The Congaree and Wateree Rivers are subject to increases in turbidity after rainy periods. Recent NPS-generated data has shown that increases in turbidity also occur in Cedar Creek. Some of these appear to be linked to elevated stream discharge in Cedar Creek, the Congaree River, or both. As Cedar Creek has been designated as Outstanding National Resource Waters this turbidity issue bears further investigation.

The creeks contain low nutrient loads and do not suffer from low dissolved oxygen problems. However, data collected by USGS found periods of near-anoxia in some of the park's oxbow lakes. Additionally, these oxbows are subject to algal blooms, including blue-green algal (Cyanobacterial) blooms. Algal blooms can be a cause of low dissolved oxygen problems through creation of biochemical oxygen demand (BOD). Since flooding brings river-borne nutrients into the oxbows, these contributions to oxbow lake ecosystem function are of great importance, and limnological investigations of the oxbows are needed.

Operation of the Saluda River Dam upstream of the park impacts Congaree River gage heights and the periodicity and duration of floodplain flooding within CONG. The impacts on park ecosystems are incompletely understood; thus research on dam operational impacts on CONG are needed. This would be best accomplished within a stakeholder framework as discussed within.

Editors Note: *This assessment is based on the state of Congaree National Park in 2007. However, research on the natural resources of Congaree National Park is ongoing and the park has acquired additional lands since this report was initially prepared. Background information on the resources present (or thought to be present) within the park has been updated to reflect the most current data available, but in many cases (particulary with regard to park boundaries), we have presented information on the state of the park at the time the assessment was conducted.*

Acknowledgments

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Commonly Used Abbreviations

BOD – biological oxygen demand
BOD5 –five-day biological oxygen demand
CAFO – concentrated animal feeding operation
CFS – cubic feet per second
CFU – colony-forming units
CONG – Congaree National Park
DO – dissolved oxygen
EPA – United States Environmental Protection Agency
EPT Index – Ephemeroptera, Plecoptera and Trichoptera Index
GPD – gallons per day
ha – hectares
Kjeldahl nitrogen – the sum of organic nitrogen, ammonia (NH3), and ammonium (NH4+)
m – meter
MGD – million gallons per day
mg/L – milligrams per liter (= parts per million)
µg/L – micrograms per liter (= parts per billion)
N – nitrogen
North Carolina Biotic Index (BI)
NPS – National Park Service
NPDES – National Pollution Discharge Elimination System
NTU – Nephelometric turbidity units
ORW – Outstanding Resource Waters as designated by the state of South Carolina General Assembly
ONRW – Outstanding National Resource Waters as designated by the state of South Carolina General Assembly
P – Phosphorus
SAV – submersed aquatic vegetation
SC – South Carolina
SCDHEC – South Carolina Department of Health and Environmental Control
SCDNR – South Carolina Department of Natural Resources
STORET – short for STOrage and RETrieval Data Warehouse for water quality data
WWTP – Waste Water Treatment Plant

Introduction

Congaree National Park (CONG) preserves one of the largest intact stands of old-growth bottomland forest in the United States. CONG is known both nationally and internationally for its ecological uniqueness. As such, it has received a number of special designations attesting to its importance as a natural feature. The park contains approximately 24,230 acres (9,806 ha) of land, and is located in Richland County, on the South Carolina coastal plain, about 20 miles (32 km) southeast of the City of Columbia. There are two sections to the park currently owned by NPS, though both are included within a larger contiguous area authorized for acquisition. The main area where the Old-Growth Bottomland Forest Research and Education Center is located stretches along the Congaree River for approximately 10 miles and receives drainage from two major creek systems, Cedar Creek (designated as an Outstanding National Resource Water by the state of South Carolina) and Toms Creek. At the juncture of the Congaree and Wateree Rivers lies the Bates Fork Tract, added to the park in 2005. Much of the park is forested wetland that is flooded by the rivers to some degree several times a year, and the majority of the park is flooded on average about once per year. Besides the creek systems mentioned above, other water features in the park include oxbow lakes, ponds, guts and sloughs. The surface water bodies within CONG other than Cedar Creek have been designated Outstanding Resource Waters by the State of South Carolina. There is an upper aquifer with seeps forming wetlands in the northeast corner of the park, and a deeper aquifer from which drinking water is pumped 118 ft. (36 m) and chlorinated.

A diverse and unique flora characterizes CONG. The park is known for hosting champion trees, which are the largest individuals known for a species (25 species so noted at the time of preparation of this report). There are no Federally-listed Threatened or Endangered plant species currently within CONG. There are ten plant species that are listed as Species of Concern by the State of South Carolina. Based on park-certified data of vascular plant species at CONG, researchers have found 74 plant species that were either exotic (i.e. alien species not native to the U.S.) or invasive (alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health). They noted two species in particular that should be monitored for spreading: kudzu (*Pueraria lobata*) and Japanese climbing fern (*Lygodium japonicum*). There is no comprehensive information available on aquatic macrophyte or phytoplankton communities.

Some faunal groups within CONG have been well-characterized by researchers. Various research and monitoring efforts have found that the benthic macroinvertebrate community of upper Cedar Creek as it enters the park reflects excellent water quality, but lower Cedar Creek near Wise Lake is periodically degraded. The South Carolina Department of Health and Environmental Control (SCDHEC) has listed Toms Creek as impaired for the state of its biological community. The mussel community of the streams within CONG and the adjoining Congaree River contains several species that are listed as Federal or State species of concern, and one invasive species, the Asiatic clam (*Corbicula* sp.), is exotic. At least 56 fish species belonging to 17 families have been collected in CONG. A study by the United States Geological Survey (USGS) concluded that the fish community of most stations they sampled (with the exception of upper Cedar Creek) should be rated as poor. There is a high taxonomic richness of reptiles and amphibians within this park. Numerous birds (at least 191 species) have been observed at CONG, and it is listed as a Globally Important Bird Area by the American Bird

Conservatory. There is an extensive mammal list for the park; however, the feral hog *Sus scrofa* is abundant and causes considerable habitat damage in many areas of the park through its rooting activities. These animals may also be a source of fecal microbial contamination and suspended sediment to park waters.

The purpose of this report was to locate and examine existing information pertaining to the water quality in and around CONG, assess the present and likely future water conditions of the park, and make recommendations to fill in existing information gaps. Water quality and quantity, habitat issues, potential for invasive species, and trends in park resource usage are addressed.

Park Description

Background

Location, Size, and Boundaries

Congaree National Park preserves the largest intact stand of old growth bottomland forest in the southeastern United States (Plate 1). The park, which contains approximately 24,230 acres (9,806 ha) of land, including approximately 11,000 acres of old-growth, is located in Richland County, on the South Carolina coastal plain, about 20 miles (32 km) southeast of the City of Columbia (Figure 1). It is most easily accessed from Columbia via S.C. 48 or from the east by exiting U.S. 601 to S.C. 48, from which Old Bluff Road can be accessed either from the east or west. The National Park Service road is entered from Old Bluff Road. The main portion of the park is located along and just above the floodplain of the Congaree River, and a smaller, more recently added section is the Bates Fork Tract (2,395 acres, or 969 ha), on the Wateree River to the east. The main portion of the park runs along the north bank of the Congaree River for about 10 miles (16 km), and varies in width from the river bank inland between, 1.8 to 3.5 miles, or 2.5 to 5 km (Knowles et al. 1996), while the Bates Fork Tract runs along the Wateree River for about four miles (6.4 km), and borders the Congaree River where it joins the Wateree River. This National Park is under the jurisdiction of the U.S. National Park Service (NPS), and there is a Park Office on-site (http://www.nps.gov/cong). The coordinates of the Harry Hampton Visitor's Center parking lot are N33.83031°, W80.82343° (WSG 84 datum). Presently the NPS maintains the Harry Hampton Visitor's Center and museum, the Old-Growth Bottomland Forest Research and Education Center (the Learning Center), a Maintenance Facility and Fire Building and a lower and upper boardwalk trail totaling 2.4 miles, or 3.9 km (Plate 1), and five other trails in the wooded areas (NPS 2004; NPS undated); with approximately 20 miles (32 km) of trails in CONG.

Plate 1. Boardwalk within Congaree Park showing flooding high water mark. Photo by M. Mallin.

Figure 1. 2007 boundary of Congaree National Park, located east of Columbia, South Carolina.

History of the Park

In pre-European times the Congaree River and its floodplain were fished and hunted by the Congaree Indians, who were decimated by a smallpox epidemic apparently brought to the region along with European settlers in the 1700s (NPS undated). Subsequently some farming was attempted on the floodplain with poor success; livestock raising did better (Lockhart 2006). Since flooding by the river is relatively frequent, in the early to mid 1800s dikes (Plate 2) and raised areas called cattle mounts were built by slave labor on the floodplain to protect livestock during floods (Lockhart 2006). Six cattle mounts have been listed in the National Register of Historic Places (Lockhart 2006). Besides remnant cattle mounts and dikes, there is some evidence of past agricultural activities such as drainage ditches, fence rows and old road beds found within current old-growth forest areas (Jones 1997). During the period 1895 to 1905 the Congaree area was purchased by Francis Beidler, whose company, the Santee River Cypress Lumber company, began limited logging operations (NPS 2006). During this period bald cypress (*Taxodium distichum*) was extensively harvested (Jones 1997). Difficulties in logging the wetlands and a sense of conservationism led to Beidler's discontinuing logging operations in the Congaree floodplain around 1910-1915, and the area was mainly leased to hunting clubs for the next several decades (Lockhart 2006). A conservationist named Harry Hampton began a campaign to protect the Congaree floodplain's ecosystems in the 1950s. However, in 1969 logging, re-established by Francis Beidler II, again threatened the area due to increases in timber prices (NPS 2006; NPS undated).

Plate 2. Dike formerly used to protect cattle and agricultural areas from flooding. Such dikes and cattle mounts are found in several locations in Congaree National Park. Photo by M. Mallin.

Creation of the Park

Because of the logging threat to the area's giant trees in the early 1970s, a public campaign to save the trees led Congress to establish Congaree Swamp National Monument in 1976 through Public Law 94-545. With Public Law 108-108 Congress changed the park's name in 2003 to Congaree National Park and expanded the park's authorized boundary to 21,666 acres (8,768 ha). In 2005, 2,564 acres (1,038 ha) were purchased and added to the park (the Bates Fork Tract); this acreage being located along the Wateree River where it joins the Congaree River to the east of the main portion of the park (Figure 1). The present Harry Hampton Visitor's Center was completed in 2001, and the Old-Growth Bottomland Forest Research and Education Center was completed in 2004.

Special Designations of the Park

CONG is known both nationally and internationally for its ecological uniqueness. As such, it has received a number of special designations attesting to its importance as a natural feature.

- August 25, 1974: The area was designated a Natural National Landmark by the U.S. Secretary of the Interior.

- June 30, 1983: The monument was declared an International Biosphere Reserve by the United National Educational, Scientific and Cultural Organization (UNESCO).

- October 24, 1988: The monument was designated a Wilderness by the U.S. Congress.

- July 26, 2001: The monument was designated a Globally Important Bird Area by the American Bird Conservatory.

- May 31, 2006: The waters within Congaree were reclassified as "Outstanding Resource Waters" and portions of Cedar Creek were reclassified as "Outstanding National Resource Waters" by the South Carolina General Assembly (State Register Document No. 3025, Amendment of R.61-69). The Cedar Creek designation was the first such designation of its kind for South Carolina waters.

The Outstanding Resource Waters classification specifically includes the portions of water bodies beginning at the borders of CONG including Cedar Creek to Wise Lake, Dry Branch to Weston lake, McKenzie Creek to Toms Creek, Myers Creek to Cedar Creek, Running Lake Creek to Toms Creek, Toms Creek to Cedar Creek, entire Weston Lake, entire Wise Lake, entire Bates Old River (described in the regulation as Old Dead River) and unnamed creeks, ponds or lakes entirely within the park. The legislation denotes as ONRW the portion of Cedar Creek beginning at Wise Lake to its confluence with the Congaree River.

Hydrologic Information

Mean annual rainfall in Columbia is approximately 47 inches (127 cm), ranging between 34 and 53 inches, or 86 and 134 cm (Patterson et al. 1985). While rainfall is often highest in summer, evapotranspiration is also highest then and limits runoff into streams and the rivers.

Rivers

CONG lies within the Santee River Watershed, which at 7,020 miles^2 (18,182 km^2 – Knowles et al. 1996) is the largest watershed in South Carolina (Figure 2). It begins in North Carolina as the Catawba River, which becomes the Wateree River as it leaves Lake Wateree in South Carolina (Figure 2). Including the Lake Wateree system there are four hydroelectric facilities and one thermoelectric facility along the Catawba River (SCDHEC 2007). The 6th order Congaree River itself (Plate 3) begins in Columbia, where it is formed by the Saluda and Broad Rivers at the fall line (the Piedmont-Coastal Plain boundary). The Broad River upstream of Columbia is regulated to a degree by the presence of at least 10 hydroelectric facilities and two thermoelectric power plants (SCDHEC 2007). The Congaree joins the Wateree River about 80 km (50 miles) downstream to form the Santee River, which flows into Lakes Marion and Moultrie. Those reservoirs, respectively, are drained into the Atlantic Ocean by the Santee and Cooper Rivers.

Mean annual discharge rates for the Congaree and Wateree Rivers are 9,147 and 6,215 ft^3/s (259 and 176 m^3/s), respectively, while discharge for the Santee is approximately 11,618 ft^3/s or 329 m^3/s (Sexton 1999). Based on a common sinuosity index (channel length/downvalley length), the Congaree and Wateree Rivers, with index values of 1.75 and 1.73, respectively, are considered good examples of meandering rivers, while an index value of 1.37 makes the upper Santee more of a straight river (Sexton 1999). Meanders are common in lowland southeastern U.S. rivers, and important in that through erosion they remove and transport accreted sediment from floodplains downstream (Hupp 2000). Depths of the Congaree River range from 3-5 m (10-16 ft) whereas in the Wateree depth ranges from 2-3 m (6.5-10 ft) except for some deep areas that reach 6 m (20 ft); the Santee River is deeper than both, with the channel ranging from 5-7 m, or 16-23 ft (Sexton 1999).

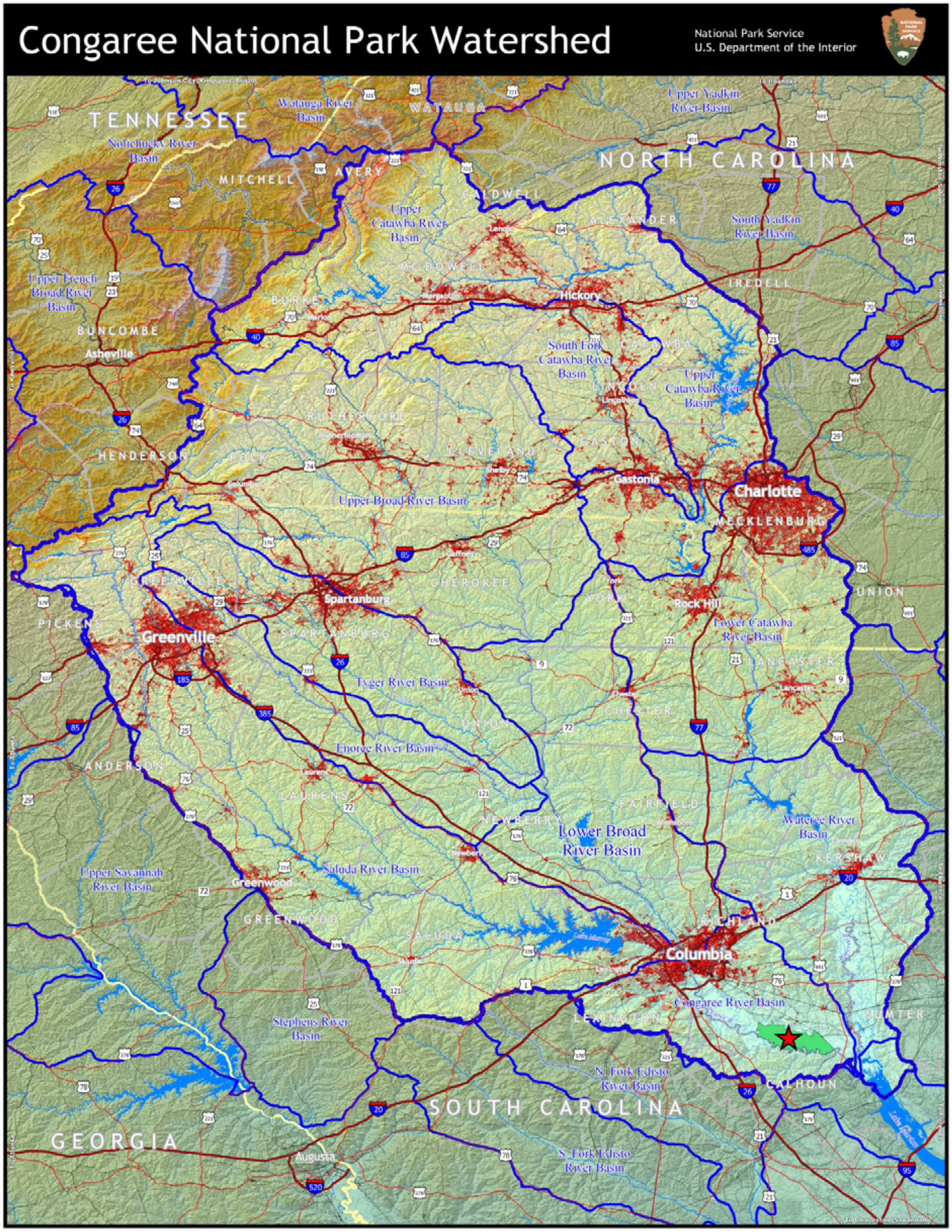


Figure 2. The Santee River Watershed and location of Congaree National Park.

Plate 3. The Congaree River at southwest corner of Congaree National Park. Photo by M. Mallin.

Creeks

The main section of CONG receives the inflow from several streams, including Cedar Creek, Dry Branch, Toms Creek and McKenzie Creek (Figure 3, Plate 4). Cedar Creek is the most prominent inflowing stream to the park, entering in the northwestern corner of the park. It is a 5^{th} order stream that averages about 23 ft (7 m) in width as it enters the park and for much of its length; however, near where it enters Wise Lake it broadens to about 125 ft (38 m) in width (Maluk and Abrahamsen 1999). As mentioned above, this creek has been reclassified as "Outstanding National Resource Waters" by the South Carolina General Assembly. Woody snags are an important habitat in this stream (Smock et al. 1985), with about 22-27% of the bottom containing such material (Maluk and Abrahamsen 1999). Before entering the park it drains a catchment of approximately 35 $miles^2$ (90 km^2); by the time it reaches Wise Lake in the middle of the park this drainage area increases to 71 $miles^2$ (184 km^2), or (Maluk and Abrahamsen 1999). Upstream of the park Cedar Creek is fed by several tributaries, 2^{nd} order Myers Creek, 3^{rd} order Cabin Branch (which joins Myers Creek), and 3^{rd} order Horsepen Branch (Table 2, Figure 3).

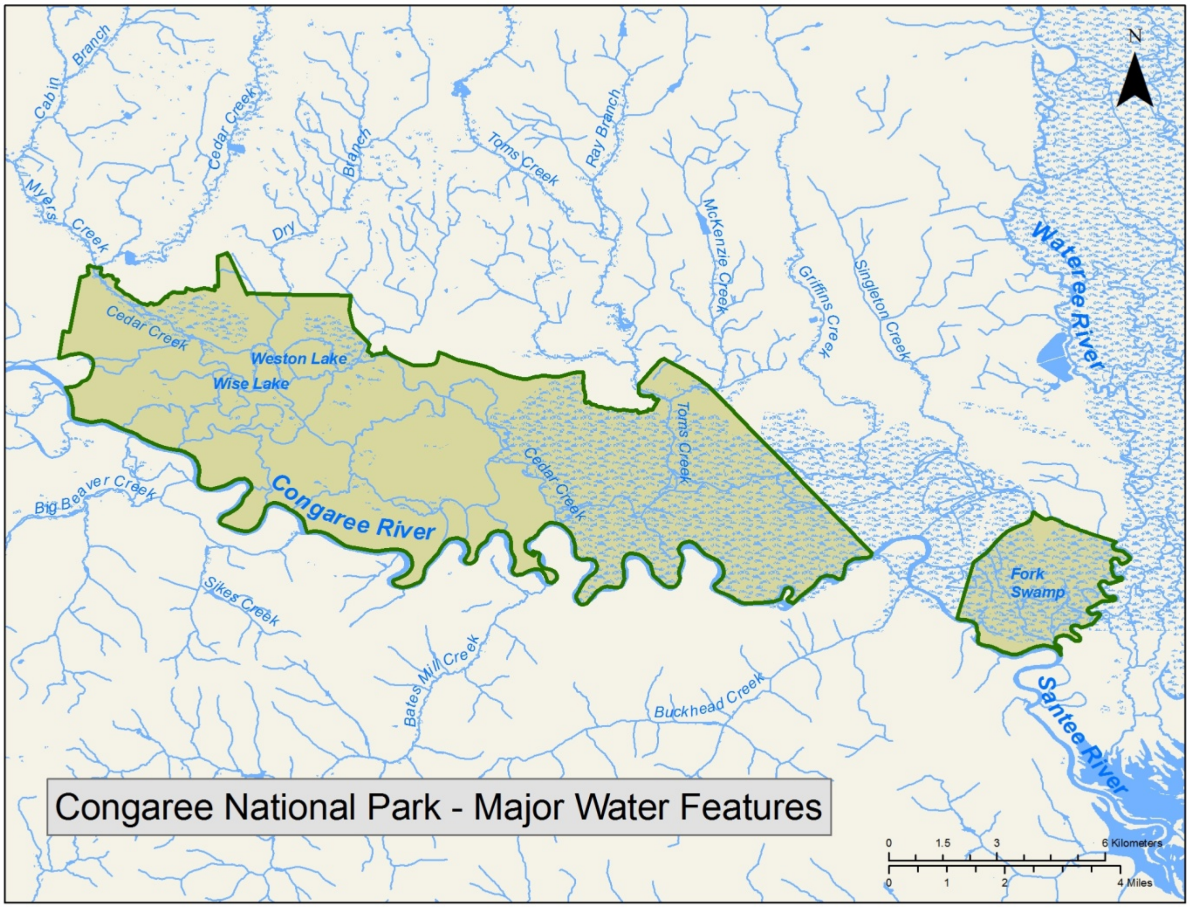


Figure 3. Streams, oxbow lakes, and other water features in and influencing Congaree National Park (note that the area referred to as Fork Swamp is now called the Bates Fork Tract).

Dry Branch, a 3rd order stream, enters the midsection of the park from the north (Figure 3). To the east of this creek, 4th order Toms Creek (Plate 4) enters the park, with its 3rd order tributary McKenzie Creek also entering the park to the east of Toms Creek. Another tributary to Toms Creek, 2nd order Ray Branch, joins Toms Creek before it enters the park (Figure 3). Near its entrance to the park Toms Creek is 20-23 ft wide (6-7 m) wide and about 2.6 ft (0.8 m) deep (Table 2). Toms Creek drains a catchment of approximately 39 mi2 (100 km2) (Maluk and Abrahamsen 1999). The floodplain area for both Cedar and Toms Creeks within the park extends beyond 50 m (164 ft) from the stream bank in either direction (Maluk and Abrahamsen 1999). Collectively, the creeks within the park meander considerably, joining and separating before entering the Congaree River (Figure 3). These are all blackwater creeks, which are characterized by darkly stained water from floodplain vegetation leachate, somewhat acidic waters, and elevated dissolved organic carbon content (Myer 1990). Just to the east of the main park is Running Creek/Running Lake (which enters present park lands and joins Toms Creek) and Griffins Creek and Singleton Creek lying in an area that may be a future park acquisition.


Plate 4. Cedar Creek (left) contains a canoe launch and trail and is designated an Outstanding National Resource Water by the State of South Carolina. Tom's Creek (right) is one of several creeks draining into the park from the northern border. It is listed as impaired waters by the SCDHEC for fecal coliform bacteria pollution and an impaired biological community.

Table 2. Geomorphologic and hydrologic characteristics of streams impacting Congaree National Park (modified from Knowles et al. (1996), and Maluk and Abrahamsen (1999).*

Stream or tributary (stream order) (Strahler system)	Total Length (miles)	Length in Park (miles)	Mean Depth (feet)	Mean Width (feet)
Cedar Creek (5)	25.8	14.0	5.0	22.3
Myers Creek (2)	6.3	0.0	3.0	30.5
Cabin Branch (3)	5.8	0.0		
Horsepen Branch (3)	0.9	0.0		
Goose Branch (2)	4.5	0.0		
Reeves Branch (1)	3.6	0.0		
Dry Branch (3)	10.8	0.4		
Toms Creek (4)	13.5	1.8	2.6	22.0
McKenzie Creek (3)	5.4	0.6		
Ray Branch (2)	2.7	0.0		

*Order and length from Knowles et al. (1996); mean depths and widths from stations sampled by Maluk and Abrahamsen (1999).

Major creeks do not impact the Bates Fork Tract. However, the northwest border of the tract is formed by Bates Old River (also referred to as Old Dead River in some maps), which is an abandoned Congaree River channel cutoff in 1852 (Dr. David Shelley, NPS, personal communication; Figure 4, Plate 5).

Plate 5. Bates Old River borders the Bates Fork Tract in Congaree National Park. Photo by M. Mallin.

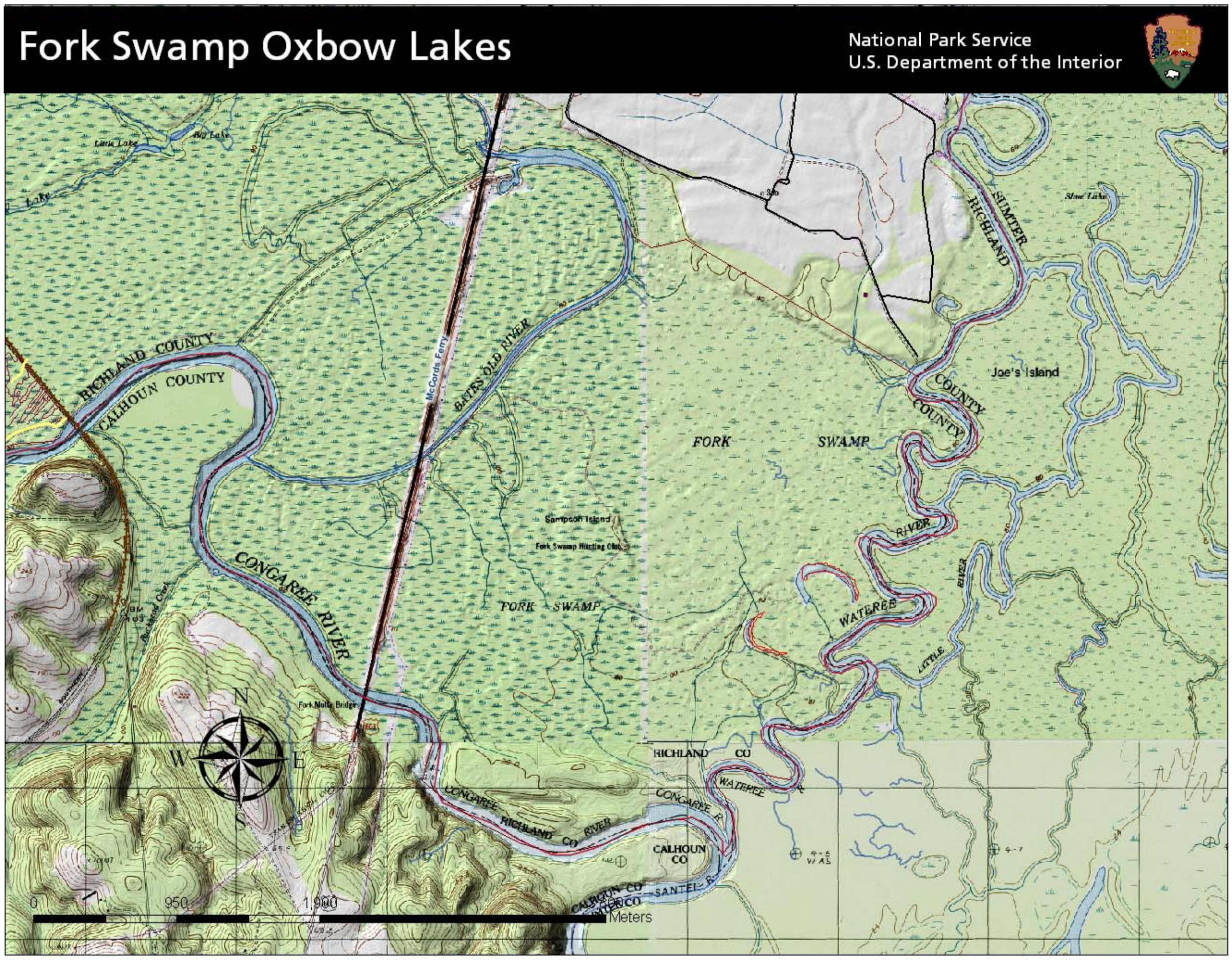


Figure 4. Bates Fork Tract (also called Fork Swamp) of Congaree National Park, with Bates Old River along the eastern border.

Lakes

Oxbow lakes are seen primarily in southeastern lowland areas of the U.S. They are formed when a meandering river channel loop is cut off. This straightens the channel and leaves behind an oxbow lake (Hupp 2000). There are two well known such lakes in the park, Wise and Weston Lakes, and other that are less accessible (Figures 3-5). Weston Lake is accessible to pedestrians via the raised boardwalk that extends from the Visitor's Center to the lake and returns to the Visitors Center (Figure 1). Wise Lake is accessible by a roadway (Sim's Trail) that becomes submerged during the periodic flooding that CONG experiences. Weston Lake is about 2.02 acres (0.82 ha) in size, whereas Wise Lake is about 5.54 acres (2.24 ha) in size (Ryan 2007). As are the creeks, these lakes are blackwater systems (Plate 6).

Plate 6. Weston Lake (left), accessible by the boardwalk, and Wise Lake (right) are two significant oxbow lakes within Congaree Park. Wise Lake is accessible via a road and trail.

There are numerous water bodies scattered throughout the park (Cely, 2004). Besides Wise and Weston Lakes there are seven other named lakes and 25 named ponds (Figure 5). There are also 14 named sloughs, which are swampy areas that hold water for a period after flooding subsides, and are additional wildlife habitat (Maliszewski 2005). Because of the poor accessibility to most of the water features, the majority of lentic biotic (fish and invertebrate) surveys have been limited to Wise and Weston Lakes. There are at least two oxbow lakes in the Bates Fork tract, neither of which is presently accessible by vehicle, as well as Bates Old River (Plate 5).

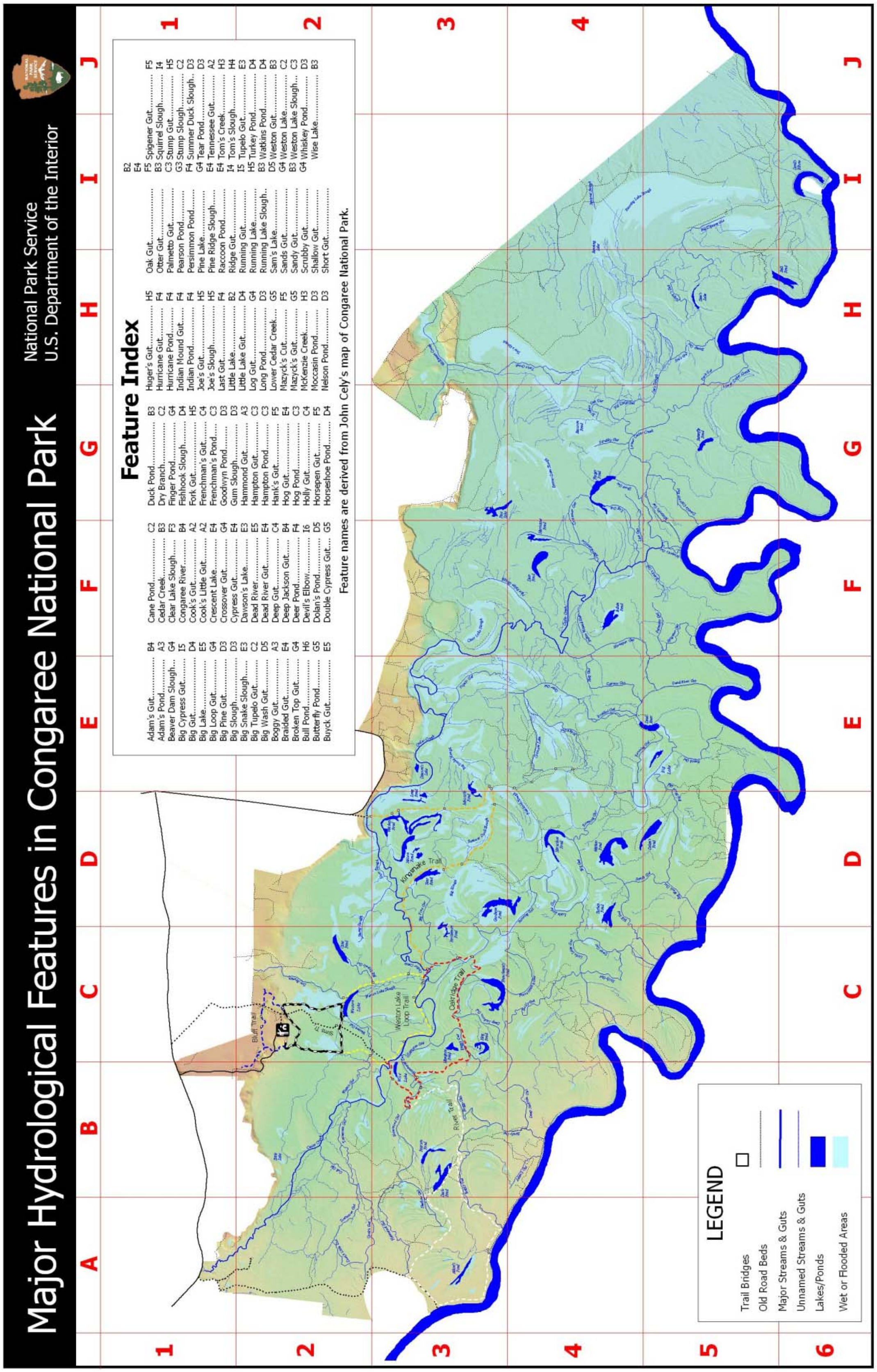


Figure 5. Oxbow lakes, ponds, and other named water features in a portion of Congaree National Park.

Wetlands

CONG consists largely of forested bottomland wetlands (Plates 1 and 7; Figures 3 and 4). Two estimates of total wetland coverage within the main portion of CONG include 20,269 acres (91.3% of the area) from the U.S. Fish and Wildlife Service National Wetlands Inventory, and 21,245 acres (95.7% of the area) from the U.S. Department of Agriculture Natural Resource Conservation Service (SCDNR 1995). The river surface and stream channels within the park are within the 90 and 100 ft (27.4 and 30.5 m) elevation contours. The park offices and visitor's center are located along a bluff at approximately the 120 ft (36.6 m) contour. Regular seasonal flooding typically reaches the 110 ft (33.5 m) contour (Plate 1). Approximately 90% of the main area of the park is flooded primarily from the Congaree River on average once per year, with lesser portions of the park flooded several times per year (Patterson et al. 1985). Besides the creeks, oxbow lakes and ponds mentioned above, other wet areas include guts, which are low areas usually containing standing water that become conduits for river water during flood periods (Plate 8). Sloughs, as mentioned, are swampy areas that hold water periodically. A complex web of various types of channels called scroll complex channels, batture channels, backswamp channels and crevasse channels distributes water and sediment throughout CONG; these have been classified by Shelly and Meitzen (2005) as cited in Shelly et al. (2008) with detailed information presented in Appendix A. In upland areas of the park there are seeps from the upper aquifer that create bog areas that support wetland vegetation, primarily an overstory of swamp tupelo *Nyssa biflora* and an understory of sedges dominated by *Carex* spp. (high species richness; 47 species within CONG), in non-flood periods (Gaddy et al. 2000).

Plate 7. Typical wetland area within Congaree National Park. Photo by M. Mallin.

Hydrology Affecting Congaree National Park.
The main portion of the CONG ecosystem is extensively influenced hydrologically, both from creeks entering CONG and water from the Congaree River (Figures 3 and 4). The degree of flooding within the main portion of CONG is controlled by Congaree River discharge (Table 3). Gage height for the Congaree River near CONG (Station 02169625) is accessible for the USGS at this website: http://waterdata.usgs.gov/nwis/uv?02169625. Along the north bank of the Congaree River is a natural levee, normally 8 to 10 ft (2.4 – 3 m) high, which is pierced at intervals by breaches known as guts (Plate 8). As the river discharge increases, river water begins to overflow into the floodplain through the guts and into the low areas of the floodplain (Table 3). Lower elevations fill first, and if discharge is great enough as much as 90% of the main portion of the park will become covered in water – on average this occurs approximately once per year (Patterson et al. 1985). The general movement of the water in the floodplain is, like the river itself, eastward toward the Wateree River. Flooding is most common in late winter and early spring, following the period of lowest evapotranspiration (Patterson et al. 1985; Knowles et al. 1996). The Bates Fork Tract is impacted by flooding from both the Congaree and Wateree Rivers. Impacts of flooding by the rivers on the Bates Fork Tract have not been studied and this should be an area of further research. Gage height data for the Wateree River is available for USGS Station 02148315.

Table 3. Impact of Congaree River discharge (as computed at Columbia, data 1973-1982) on flooding within the main body of Congaree National Park (revised from Patterson et al. 1985).

Discharge (cfs)	Percent of time equaled or exceeded	Average times per year equaled or exceeded
11,800	23.7	11
River water enters floodplain channels		
19,900	9.3	6
Guts overflow into low areas of floodplain; road to Wise Lake impassable		
25,500	5.8	5
Bakfull flow at USGS station 02169625 on Congaree River west of Wise Lake near Gadsen		
34,300	3.0	4
Water covers the ground at Wise Lake; most of swamp is flooded		
76,600	0.3	1
Entire Swamp Flooded		

Depending upon upstream rainfall, the Congaree River may contain large quantities of suspended sediments and be turbid at times (Plate 9). As will be discussed later in this report, at times this river-borne turbidity may impact the water quality of streams within CONG. During flooding events the larger sediment particles settle on the floodplain nearest the river, while the lighter particles are carried into the interior of the swamp (Patterson et al. 1985). This deposition provides fertile soil to the floodplain to enhance vegetation growth (as noted, this park contains many champion trees). Thus, the flooding is a natural and important part of the ecosystem function. However, if the sediments (and floodwaters) are bearing pollutants, the fauna of the parks streams and lakes could be impaired by the pollutants brought in from upstream in the Congaree Watershed and the Wateree Watershed. There is presently little information on vertical accretion rates of sediment within the different areas of the park, and on the contents of such suspended sediments (i.e. nutrients and toxicants). Historical increases in sediment load due to land use in the watershed, however, have likely significantly increased sedimentation rates and related process. Obtaining such information on a transect through the floodplain from the river to the uplands would provide important information related to the importance of river discharge to ecosystem fertility, and how upstream land use and stormwater runoff from such land use impacts park biotic communities, either positively through fertilization or negatively through import of potentially toxic materials in the floodwaters and suspended sediments.

Plate 8. Gut in Congaree National Park. Photo by M. Mallin.

Plate 9. Mid-channel view of the Congaree River. Photo by M. Mallin.

One of the two major tributaries of the Congaree River is the Saluda River, on which the Lake Murray Dam (Figure 2) was created in 1929 for hydroelectric power production and operated by the South Carolina Electric and Gas Company (SCDNR 1995). The other major tributary to the Congaree River is the Broad River, which as mentioned is regulated to some degree by the presence of at least 10 hydroelectric facilities (SCDHEC 2007), and joins the Saluda about 11 miles (18 km) below the Saluda Dam. The dam on the Saluda, located about 38 miles (60 km) upstream of Congaree Park controls about one third of the total flow to the Congaree River upstream of Columbia (Knowles et al. 1996). The damming of the Saluda River has not decreased the frequency of the one-year flooding, depicted in Table 3 (Patterson et al. 1985). However, it was thought to have reduced the frequency of the largest floods (for example, floods with a five-year recurrence interval were increased to a 25 year recurrence interval after 1929 – Patterson et al. 1985).

Authors of a later study (Conrads et al. 2007) took issue with the belief that the Saluda Dam led to fewer major floods in the park. By utilizing a combination of data mining, backcasting and statistical approaches these authors determined that the lack of large floods after 1930 was due to natural causes (more natural floods pre-construction), and the main impact of the dam was to cause lower river gage heights in the first half of the year (December to May) and higher gage heights in the second half of the year (June to November)). Another effect these authors determined was that the dam increased the 1, 3, 7, 30 and 90 day minimum gage heights by up to 23.9% and lowered the 1, 3, 7, 30 and 90 day maximum gage heights by up to 7.2% (Conrads et al. 2007). These authors speculated that dam operations may affect the levels of the surficial aquifer and may impact vegetative community structure, but provided no further detail on suspected ecological effects.

Regarding potential vegetation impacts, one report (Minchin and Sharitz 2007) suggested that a long-term change in forest composition was occurring toward a community less tolerant of flooded conditions, particularly in higher elevation sites >3 km from the river. The champion trees (and their tree rings) are a source of historical information, and an analysis of such "living records" could be a key endeavor in assessing long-term dam operation impacts on the ecosystem of CONG.

A stakeholder's group (NPS 2008) recently engaged in a multi-step process modeled after the Ecologically Sustainable Water Management Approach (ESWM) devised by the Nature Conservancy. This was designed to provide a process by which flows from the Saluda River Dam could be better managed to provide for multiple needs including power production, adequate recreation in Lake Murray, and appropriate timing, discharge and water levels for protection of a healthy native biological community in the Congaree and Saluda Rivers and floodplain of CONG. The process included a literature review, expert opinion on individual species, workshops and a production of a model. Several plant and animal species were noted as being or potentially being affected by flow management (addressed later in this report). The results of the process are detailed in NPS (2008) but are referred to by the authors as the naturalized flow scenario and in part recommend allowance of continuous downstream flows for a set period each spring that approximate natural inflows, and provide for intra-and-inter annual variability to meet the ecological needs of the Congaree River system. The report recommends establishment and funding of an adaptive management council consisting of experts and interested stakeholders that would meet twice annually to implement the plan and monitor key species using various metrics and make decisions to adjust the water management plan as needed. We recommend NPS follow through on this approach with the stakeholders as it provides for strong science-based management of water flows impacting CONG.

Groundwater Resources

There is a shallow aquifer underlying CONG that is variable, ranging from the surface in some areas to 55 ft (21 m) in other locations, underlain by a confining bed of approximately 70 ft (17 m) in thickness (Patterson et al. 1985). The shallow aquifer breaches the surface in areas where there is primarily sand at the surface, and is confined where the surface materials are more silty and clayey, such as in most of the floodplain (Patterson et al. 1985). Where it impinges on the surface there are ponds and lakes; additionally the groundwater sustains streamflow (base flow) during drought periods. Where the groundwater exits from hillsides rim swamps occur, which support diverse vegetation (Shelley et al. 2008). Below the confining layer supporting the upper aquifer there lies a deep aquifer made primarily of sand that lies at depths varying from 125 to 360 ft, or 38 to 110 m (Patterson et al. 1985). Recharge to the shallow aquifer occurs by local rainfall where surface sediments are highly permeable, and by leakage from the deep aquifer (Patterson et al. 1985). Some small streams in and near CONG receive flow only from the shallow aquifer and have poorly sustained low flows, including Griffin's Creek, Dry Branch and Tom's Creek (Patterson et al. 1985). More deeply incised streams such as Mill Creek and Cedar

Creek are recharged by the deep aquifer and are thus critical to the water needs of the floodplain when other sources are reduced, such as during drought (Patterson et al. 1985). Well water is used for drinking water in the park, but the well water is drawn from 118 ft. (36 m) depth and tested by SC DEHEC (two wells are on-site). The water is treated on-site by chlorination regardless. Crystalline bedrock is found 600-800 ft below the floodplain surface (Dr. David Shelley, NPS, personal communication).

Biological Resources

Because of the beauty and uniqueness of the habitats within CONG much of the flora and fauna have been well-studied by government, academic, and citizen researchers. In particular these include trees and other terrestrial species, invertebrates, reptiles and amphibians, mammals and stream fish communities, yet some major gaps remain in terms of phytoplankton and other algae, zooplankton, aquatic macrophytes and flood-period fish communities.

Algae

There have been no published studies of the phytoplankton or benthic microalgal communities within the park. In July 2007 Wise Lake experienced an algal bloom that SCDHEC personnel identified as *Oscillatoria* sp., a genus of blue-green algae, or cyanobacteria (Dr. Theresa Thom, NPS, personal communication). Since there is no nearby source of nutrients to stimulate such a bloom, it was either formed from a naturally occurring population within the lake or was perhaps seeded by flooding from the river that occurred in March of that year. A 1996-1997 USGS study found periodic high chlorophyll *a* concentrations in the water column in three oxbow lakes (see NPS 1998 and tables 22-24, this report), demonstrating their capability of algal bloom formation. Thus, a limnological sampling program involving algal sampling would be prudent for selected lakes, since they would be most susceptible to bloom formation.

Chlorophyll *a* data are available for the rivers impacting the park for the period 1989-1991. These data, collected by SCDHEC a few miles upstream of CONG, yielded mean chlorophyll *a* concentrations of 4.0 and 4.5 µg/L for the Congaree and Wateree Rivers, respectively (Lacy 1992). These values are comparable to that of the Cape Fear River in North Carolina, a moderately productive ecosystem that likewise receives turbidity pulses after extensive watershed rainfall (Mallin et al. 1999). There was very little seasonal difference in chlorophyll concentration for either the Congaree or Wateree River (Lacy 1992).

Aquatic Macrophytes

There has been no comprehensive survey of aquatic macrophytes in the creeks or lakes within the park. This is a major concern because many non-native and exotic aquatic macrophyte species can cause major ecological damage through physical habitat alteration, crowding out of native species, alteration of vertebrate or invertebrate feeding strategies, physical blockage of waterways and degradation of water quality through decreases in dissolved oxygen by biomass decay. In areas hard hit by aquatic “weed” invasions, monetary costs can be very high to protect ecosystem integrity. For instance, the U.S. spends $100 million per year to control non-native aquatic nuisance species (Pimentel et al. 2000). These invasive species can be easily transported by boats, fishing tackle, birds, and flowing water; thus a comprehensive survey of aquatic macrophytes throughout CONG would be prudent, and should be repeated at three year intervals (at least in key locations) to find out what is present, and to ensure future community integrity.

Terrestrial Vegetation

CONG contains the largest intact tract of old-growth bottomland forest in the southeastern United States, with the woody species dominated by bald cypress, tupelo, several oaks and loblolly pine. CONG contains one of the tallest broad-leaved forests in North America (Jones 1997), including trees that are 700 years old (NPS staff, personal communication). CONG contains many state champion trees, which are the largest known individual for their species in South Carolina (Plate 10). In a 1993-1995 survey Jones (1997) found 29 individuals representing 25 species that are state champions. In addition to the State champions, three individuals representing three species, including possumhaw (*Ilex deciduas*), persimmon (*Diospyros virginiana*), and water hickory (*Carya aquatic*) were large enough to quality as National champions (Jones 1997).

Gaddy et al. (2000) compiled the most comprehensive information available on the flora of CONG. These researchers listed over 500 vascular plant species from the park, including 80 native species of trees. Gaddy et al. (2000) described the park as having a very complex vegetation community, with one of the most diverse assemblages of forest communities in North America. Reviews of ecosystem effects of biodiversity indicate that in general greater plant diversity leads to greater productivity, greater nutrient retention in ecosystems, and greater ecosystem stability (McCann 2000; Tilman 2000). Gaddy et al. (2000) noted ten different vegetation cover types within CONG:

1. Upland pine (most of which have been planted except for a stand of loblolly and longleaf pine)

2. Upland pine-mixed hardwoods (relatively rare and along the northeast boundary, mainly oaks and sweet gum)

3. Upland mixed hardwood depressions (found in a two acre depression along the northeast boundary)

4. Bluff mixed hardwoods (on the bluffs in the northeast boundary)

5. Mixed bottomland hardwoods (the most extensive cover type; covering 50% of the floodplain)

6. Pine-mixed bottomland hardwoods (tall, old-growth loblolly pines mixed with an understory of mixed old-growth hardwoods)

7. Swamp tupelo (in swamps near the northeast boundary)

8. Bald cypress-water tupelo (covering over 15% of the floodplain in old oxbows, sloughs, guts and other low areas)

9. Open water-flowing water (free-floating aquatic macrophytes on the open water surface)

10. Open fields/disturbed areas (various habitats dominated by variable early successional weedy plants)

Plate 10. Congaree National Park is known for unusually tall trees of many species. Photo by M. Mallin.

It is notable that a stakeholder's group (NPS 2008) considered bald cypress *Taxodium distichum* to be a potentially at-risk species on the floodplain because of operations of the Saluda River dam. The report notes that when water heights are increased during naturally low water periods, the seedlings of this species experience prolonged inundation during a life stage that is highly intolerant to submersion.

Rare and Threatened Plant Species

There are no known Federally-listed Threatened or Endangered plant species currently documented as occurring within CONG. However, there are nine vascular plant species documented in the park that are listed as Species of Concern by the State of South Carolina (Table 4). Previous lists (Gaddy et al. 2000) have included the Winter grapefern (*Botrychium lunaroides*), however in 2005, additional surveys and carful examination of the vocher specimens showed that this species was originally misidentified and does not occur within CONG (Hauk 2005).

Invasive Plants

Gaddy et al. (2000) documented 18 species in CONG (Table 5) that were either exotic (i.e. not native to the U.S.) or invasive (not native to the local plant communities, but could be native to other U.S. areas). Additional plant surveys and research have documented 74 vascular plant species considered to be exotic and/or invasive in CONG (NPSpecies 2009). To date, no known surveys of aquatic invasive species have been conducted in CONG.

Table 4. Plant Species of Concern within Congaree National Park listed by the State of South Carolina (revised from Gaddy et al. 2000); main section of the park only.

Species	Habitat(s)
Cherokee sedge *Carex cherokeensis*	Mixed bottomland hardwoods
Crow's-foot sedge *Carex crus-corvi*	Mixed bottomland hardwoods
Social sedge *Carex socialis*	Mixed bottomland hardwoods
Swamp cucumber *Cayaponia boykinii*	Bald cypress-water tupelo
Walter's horsebalm *Collinsonia serotina*	Bluff mixed hardwoods
Toothed woodfern *Dryopteris carthusiana*	Mixed bottomland hardwoods
Sevice holly *Ilex amelanchier*	Upland mixed hardwood depressions/swamp tupelo
Bog mint *Macbridea caroliniana*	Swamp tupelo
Weak nettle *Urtica chamaedryoides*	Mixed bottomland hardwoods

Table 5. Partial exotic and/or invasive plant species found in Congaree National Park (revised from Gaddy et al. 2000).

Species	Exotic	Native to U.S. Invasive at Congaree
Mimosa *Albizzia julibrissin*	X	
Asiatic dayflower *Analeima keisak*	X	
Catalpa tree *Catalpa bignoniodes*		X
Lambsquarter *Chenopodium album*)		X
Silverberry *Eleagnus umbellata*		X
Japanese privet *Ligustrum japonicum*	X	
Chinese privet *Ligustrum sinensis*	X	
Monkey grass *Liriope* sp.	X	
Japanese honeysuckle *Lonicera japonica*	X	
Japanese climbing fern *Lygodium japonicum*	X	
Creeping charlie *Lysimachia nummumlaria*	X	
Japanese Hedge hyssop *Mazus japonicus*	X	
Chinaberry *Melia azedarach*	X	
Japanese shade grass *Microstegium vimneum*	X	
White mulberry *Morus alba*	X	
Kudzu *Pueraria lobata*	X	
Meadow buttercup *Ranunculus acris*	X	
Christmas cherry *Solanum psuedocapsicum*	X	

Zooplankton

Weekly zooplankton collections were carried out at a single station in each of the Congaree and Wateree Rivers during 1989-1991 at locations a few miles upstream of CONG (Lacy 1992). The zooplankton community was dominated by, in descending order, rotifers, copepods (particularly nauplii), and cladocerans, with some meroplankton present mainly as clam veligers (a planktonic larval stage). Average concentrations of the major groups for the Congaree River were (as no/m^3) were total zooplankton 6,530, rotifers 2,946, copepods 1,924 and cladocerans 362. Average concentrations for the Wateree River (as no/m^3) were total zooplankton 9,465, rotifers 6,591, copepods 1,853 and cladocerans 164. The major groups showed spring and fall peaks and summer minima (a negative response to elevated temperatures, which is normal in the southeasetern United States). The zooplankton abundances responded positively to increases in river discharge and corresponding increases in turbidity and suspended solids, particularly rotifers. Lacy (1992) found some evidence that rainfall had a positive effect on rotifer abundance and a negative effect on copepod abundance, although we found that evidence to be rather equivocal. We note that zooplankton in turbid reservoirs are capable of consuming and subsisting on turbidity particles, provided that nutritious organic matter is associated with such particles, such as through adsorption of dissolved organic matter (Marzolf 1990). In blackwater rivers chemical and physical reactions cause colloidal-sized particles to coalesce into "amorphous particulate matter", that has been evaluated and described as nutritious food for invertebrate consumers (Carlough 1994).

Benthic Macroinvertebrates

The benthic invertebrate community of CONG has been well studied. The species composition, species richness and species diversity were noted as reflecting excellent water quality for Cedar Creek (Smock and Gilinsky 1982). A later study of stations at nine sites in the park concluded that CONG contains relatively high aquatic insect diversity, particularly for aquatic beetles, caddisflies, and damselflies and dragonflies (Pescador et al. 2004). Pescador et al. (2004) focused on five insect orders, and in terms of species diversity ranked them is descending order as follows: Coleoptera (beetles), Trichoptera (caddisflies), Odonata (dragonflies and damselflies), Ephemeroptera (mayflies) and Plecoptera (stoneflies). Table 6 breaks down the various orders into number of families, genera, and species. While the lowest species richness is among mayflies and stoneflies, that is not surprising given the generally warm, slow moving waters and periodic low dissolved oxygen found in blackwater streams of the southeast United States – thus that does not reflect poor water quality. The richest collection locations for these taxonomic groups were Cedar Creek and Weston Lake, while the location with fewest species was Wise Lake (Table 7). The species list compiled by Pescador et al. (2004) is provided in Appendix B.

Table 6. Taxonomic richness by family, genus and species for five insect orders found in Congaree National Park, 2002-2003 (modified from Pescador et al. 2004).

Order	Common names	Families	Genera	Species
Coleoptera	beetles	47	152	302
Trichoptera	caddisflies	13	30	67
Odonata	dragon & damselflies	6	34	55
Ephemeroptera	mayflies	8	15	19
Plecoptera	stoneflies	4	7	8

Table 7. Benthic macroinvertebrate species richness by location as sampled by Pescador et al. (2004).

Habitat	Total Species
Cedar Creek at Bluff Rd. below bridge	141
Weston Lake	129
Cedar Creek at Dawson Lodge	123
Toms Creek	98
Cedar Creek at Service Rd.	83
Cedar Creek at Bluff Rd. above bridge	75
McKenzie Creek	73
Cedar Creek at jeep trail	67
Wise Lake	49

Various benthic habitats occur within the park, including woody material, plant material such as *Sparganium*), muddy banks, sandy sediments (Smock and Gilinsky 1982), presenting a variety of food resources for the invertebrate community. For three sites within Cedar Creek, Smock and Gilinsky (1982) determined that the dominant taxa were the mayfly *Stenonema modestum*, the caddisflies *Macronema carolina*, *Cheumatopsyche* spp. and *Oecetis* spp., the elmid beetle *Ancyronyx variegata*, the chironomids *Polypedilum illinoense*, *Tanytarsus* spp., *Rheotanytarsus* spp. and *Ablabesmyia parajanta*, as well as various tubificid oligochaetes. Smock et al. (1985) assessed benthic productivity and use of the various habitats. They found that the snags (woody tree parts within the stream) yielded the highest densities of individuals (21,000 individuals/m^2 of habitat) with highest annual mean biomass (2.14 g/m^2) on snags as well. Productivity on snags was twice that of any other habitat, and productivity on leaves of bur-reed (*Sparganium americanum*) was also high, while productivity in leaf packs was the lowest of any habitat. Smock et al. (1985) found that the hydropsychid caddisfly (*Macronema carolina*) yielded the highest production among individual taxa (4.90 g/m^2) while the chironomids *Rheotanytarsus* and *Tanytarsus* also had relatively high annual production. Productivity was highest in the creek upstream of the park, and decreased as the stream passed through the park. Overall this study found that the stream bottom yielded the highest invertebrate production (39-44% of the total production) due to the sediments being the largest habitat, while snags, with their far lower habitat area but much higher productivity yielded 28-35% of total invertebrate production.

Smock and Roeding (1986) assessed what were the food sources supporting the invertebrate production in Cedar Creek. They found that fine particulate organic matter (FPOM) was the major food source, supporting 47-64% of total production, while algae (mainly filamentous algae and diatoms) supported 15-34% of production. This was surprising as previously held dogma assumed that algae were rather unimportant in blackwater stream systems. Animal material supported 16-26% of macroinvertebrate production while coarse particulate organic matter (CPOM) only supported 1-3% of total production. Smock and Roeding (1986) hypothesized that unlike upland streams, streams within the lowlands receive much previously-processed material from the floodplain, where shredders such as amphipods, isopods, amphibians and other terrestrial organisms convert the CPOM into FPOM, which then enters the streams in runoff or flooding events. These authors suggested that the floodplain provides a similar function for lowland blackwater stream systems that low order streams provide for streams in upland areas in terms of CPOM processing.

In 1995-1998 the U.S. Geological Survey performed an assessment of the benthic macroinvertebrates at six locations within Cedar Creek, Toms Creek, Myers Creek and the Congaree River (Maluk and Abrahamsen 1999), and applied various biotic indexes to the data. Compared with a reference stream outside of the park (the Coosawhatchie River), these researchers concluded that most of the sites were unimpaired with the exception of Cedar Creek near Wise Lake, which they described as slightly impaired. The elevated abundance of chironomids relative to their number of taxa at that location was the cause of the comparatively lower biotic score.

In 2002, March-October 2008, and March-August 2009 additional odonate surveys were conducted in various surface water features in the park (Worthen 2009). This effort documented 63 species, including 17 new county records and a new state record. When combined with the 2002 survey results, the total Odonate species found within CONG is 70 species, representing 45% of the 157 species now listed for the state of South Carolina. The new state record is *Gomphus (Hylogomphus) apomyius* (Banner Clubtail), captured on 30 March 2009 in a successional field adjacent to Wise Lake. The other new county records are: *Hetaerina titia* (Smoky Rubyspot), *Lestes australis* (Southern Spreadwing), *Lestes inaequalis* (Elegant Spreadwing), *Lestes vigilax* (Swamp Spreadwing), *Enallagma doubledayi* (Atlantic Bluet), *Enallagma dubium* (Burgundy Bluet), *Enallagma geminatum* (Skimming Bluet), *Enallagma traviatum* (Slender Bluet), *Enallagma vesperum* (Vesper Bluet), *Nehalennia integricollis* (Southern Sprite), *Helocordulia selysii* (Selys' Sundragon), *Somatochlora filosa* (Fine-lined Emerald), *Macromia alleghaniensis* (Allegheny River Cruiser), *Libellula axilena* (Bar-winged Skimmer), *Libellula luctuosa* (Widow Skimmer), and *Sympetrum ambiguum* (Blue-faced Meadowhawk). Voucher specimens for all but *L. luctuosa* (photo record) are maintained in the archives at Congaree National Park. Photos of all species can be seen at: http://eweb.furman.edu/~wworthen/dflies/cong/conlist2.htm.

Crayfish

In 2005 a crayfish survey was conducted utilizing multiple sampling techniques at 38 sites across six habitat types in CONG (Price 2005). Habitats sampled included oxbow lakes, gum ponds, sloughs, streams, guts and floodplains. Six species of crayfish were collected (Table 8), which the report author considered relatively high diversity compared with other protected areas in the region. Of the six species, *Procambarus chacei* is listed as a South Carolina Species of Concern due to the dearth of distribution information on it and because it appears to be endemic to South Carolina and eastern Georgia (Price 2005). This species was found only in streams habitats within the park. In general, research conducted in the park on crayfish suggest they are a key component of the detrital-based foodweb of the floodplain forest ecosystem.

Table 8. Crayfish species collected with Congaree National Park, January – December 2005 (collected by Price 2005).

Species	common name (if available)	status
Cambarus diogenes	the devil crayfish	common
C. reduncus		common
Procambarus acutus	the white river crayfish	common
P. troglodytes		common
P. chacei		SC Species of Concern
Fallicambarus fodiens		common

Mussels

There has been catastrophic loss of mussels in North American, especially so in the southeast, due to various anthropogenic activities in the past several decades (Neves et al. 1997). Due to lack of mobility they cannot escape when changes in their environment occur, such as flow changes by human alterations, sediment and other pollutant loading, or non-native bivalve introductions (competitors) occur. Thus, mussel presence (especially that of imperiled species) provides a useful bellwether of negative changes in stream or river water quality. It is of interest to note that South Carolina in the early 20th century had the lowest species richness (33) of the southeastern States; Alabama had the most with 175 species (Neves et al. 1997). A mussel survey of CONG was conducted in 2002 and 2004, with sampling conducted in the Congaree River along the southern boundary of the park, Cedar Creek, Toms Creek, McKenzie Creek, Myers Creek, Weston Lake and Wise Lake (Williams and Benson 2004). Several Federal or State Species of Concern were found (Table 9).

Table 9. Mussels collected within Congaree National Park by Williams and Benson (2004).

Common name	Scientific Name	Status
Carolina lance	*Elliptio angustata*	Federal Special Concern
Eastern elliptio	*E. complanata*	Stable
Variable spike	*E. icterina*	Stable
Atlantic spike	*E. producta*	Special Concern in SC
Yellow lampmussel	*Lampsilis cariosa*	Endangered in SC, Fed Sp. Con.
Eastern lampmussel	*L. radiata*	Threatened in SC
Eastern pondmussel	*Ligumia nasuta*	Endangered in SC
Eastern floater	*Pyganodon cataracta*	Stable
Florida pondhorn	*Uniomerus carolinianus*	Stable
Paper pondshell	*Utterbackia imbecillis*	Stable
Asian clam	*Corbicula fluminea*	Invasive

A survey of mussels outside of the park included collections at six locations in the Congaree River along the Lexington/Richland County line (Alderman 2006). Of the nine species collected in the Congaree River, five are considered species of concern. Carolina slabshell (*Elliptio congaraea*), Roanoke slabshell (*E. roanokensis*), Carolina lance (*E. angustata*), Yellow lampmussel (*Lampsilis cariosa*) and Rayed pink fatmucket (*L. splendid*) are all listed as Federal Species of Concern, with Roanoke slabshell considered at high risk of extinction and Yellow lampmussel and Rayed pink fatmucket considered at moderate risk of extinction (Alderman 2006). Additional mussel surveys were completed in 2008 using tactile surveys and SCUBA (Krueger 2009). At least 15 species of freshwater mussels were collected and identified across 18 survey points located in the Congaree and Wateree mainstem rivers, a large oxbow known as Bates' Lake (Griffin Creek), and an unnamed oxbow lake off the Wateree mainstem. *Elliptio complanata* and *E. icterina* were likely both present but no attempt was made to separate these two species (*E. complanata* and *E. icterina*), as they are common in many Atlantic drainages and are considered locally and globally secure. Considering both species as occurring would bring the total to 16 species. Species detected included all species represented in Williams and Benson (2004), as well as four additional species not previously detected: *Toxolasma pullus*, *Leptodea ochracea*, *Villosa delumbis*, and *Elliptio congaraea*. Also, *Elliptio roanokensis* was reported in this survey, but Williams and Benson (2004) declined to report this species due to morphological intergrading. The Savannah liliput (*Toxolasma pullus*) is considered to be highly imperiled, and is currently being considered as a candidate for federal listing status and proposed state listing as endangered (Krueger 2009, Bogan and Alderman 2008).

Because there are a number of imperiled species present, mussel surveys in CONG on a regular basis would be a prudent way to assess ecosystem changes. Also both inside and outside of the park in the Congaree and Wateree Rivers, as well as in some streams within the park, the Asiatic clam (*Corbicula fluminea*) has been collected in several locations (Williams and Benson 2004; Alderman 2006, Krueger 2009). This is an exotic invasive species introduced in the 1930s and well established in U.S. waters.

Fish

In 1995-1998 the U.S. Geological Survey collected and analyzed the CONG and nearby area fish communities from six locations within Myers Creek, Cedar Creek, Toms Creek and the Congaree River (Maluk and Abrahamsen 1999). They applied an Index of Biotic Integrity to the fish data, compared the index values with a reference stream outside of the park, and rated the fish community of upper Cedar Creek as Fair, but rated lower Cedar Creek near Wise Lake as Poor, and Myers Creek, Toms Creek, and the Congaree River as Poor. However, they noted that the low conductivity and deep water lowered catch efficiency of their electroshocker and likely compromised the results at the lower Cedar Creek site (Maluk and Abrahamsen 1999).

The Freshwater Fisheries Section of the South Carolina Department of Natural Resources (SCDNR), in cooperation with NPS, completed a total of 50 fishery surveys from 33 sites within Congaree Park from 1999-2002 (Rose 2002; Rose and Bulak 2004). The majority of the sampling sites were streams; however, in 2002 a number of collections were made from guts, sloughs, ponds and the two larger lakes, Weston and Wise. Stream sampling was completed by block-netting either end of a 100 m stretch of stream, and then using a backpack electroshocker to stun the fish. In Wise and Weston Lakes a boat electroshocker was used to collect around the entire circumference of the lake. All collections were performed in the main section of CONG (the Bates Fork Tract near the Wateree River has not been sampled for fish as of yet).

A total of 56 species belonging to 17 different families were collected within the (main section) park boundaries (Table 10). Cluster analyses (Rose and Bulak 2004) identified four community groups associated with differing habitat characteristics:

- Community group 1 indicator species were Flier (*Centrarchus macropterus*), Eastern mudminnow (*Umbra pygmaea*), Golden shiner (*Notemigonus crysoleucas*) and banded pygmy sunfish (*Elassoma zonatum*); this group's sites were characterized by relatively low flows and dissolved oxygen.

- Community group 2 indicator species were the Tesselated darter (*Etheostoma olmstedi*), Largemouth bass (*Micropterus salmoides*) and the Redear sunfish (*Lepomis microlophus*); this group's habitat was comprised of faster flowing, deeper streams such as Cedar Creek.

- Community group 3 were the Sailfin shiner (*Pteronotropis hypselopterus*), Dusky shiner (*Notropis cummingsae*), Spotted sunfish (*Lepomis punctatus*) and the Dollar sunfish (*Lepomis marginatus*); this group's sites were characterized by high flow and firm, sandy bottoms, and were located in the transition area between bluff and swamp.

- Community group 4 was a single outlier site that yielded only four species (compared to the average number of 16); Yellow bullhead (*Ameiurus natalis*), Largemouth bass (*Micropterus salmoides*), Pirate perch (*Aphredoderus sayanus*) and Mosquitofish (*Gambusia holbrooki*). It was located in McKenzie Creek, which had low dissolved oxygen and comparatively high conductivity and farming, grazing, and a poultry facility in its watershed. Rose and Bulak (2004) considered this creek a degraded stream and suggested further study of the creek.

Flooding of the park by the Congaree River alters taxonomic composition of the fish fauna. The composition of 11 pre-flood samples, collected in 2001-2002, were compared with eight post-flood samples taken in 2003 by Rose and Bulak (2007). These researchers found similar species richness between periods (38 species pre-flood and 37 species post-flood). However, seven taxa (blackbanded sunfish, channel catfish, flat bullhead, green sunfish, piedmont darter, snail bullhead and spotted sucker) were only collected in the pre-flood sampling while seven other taxa (bowfin, black crappie, carp, longnose gar, mud sunfish, pumpkinseed and redear sunfish) were only collected in the post-flood sampling (Rose and Bulak 2007).

Regarding the Congaree River fish community, it is notable that the shortnose sturgeon Acipenser brevirostrum is Federally listed as an Endangered species. There are no records of it in CONG, but a spawning site for this species is located in the Congaree River near Columbia (Collins et al. 2003). However, historical accounts preserved in local folktales indicate locals found large sturgeon in Weston Lake, an oxbow lake of the Congaree River (Cain et al. 2000).

Outside of CONG, a study of the fish community of the lower Saluda River downstream of the Lake Murray Dam and upstream of the Congaree River was performed by State of South Carolina biologists (Crane 1987). Sampling was conducted in three areas using a boat electroshocker and seining. The results consisted of 889 fish representing 29 species and 11 families collected, with the community described as typical of a lower piedmont/upper coastal plain community, with no exclusively cold water species collected (Crane 1987).

A recent report by a stakeholder's group (NPS 2008) made recommendations to continue a process that was begun in order to provide species-specific science in managing water flows from the Saluda River Dam that impact CONG and the Congaree River. Regarding area fish, improved water flow management was recommended to enhance spawning of shortnose sturgeon and American shad in early March and robust redhorse, sunfish and other spawners in late May (see NPS 2008 for more detail).

Table 10. Fish species collected in Congaree National Park between 1999 and 2002 and collection location, revised from Rose and Bulak (2004).

Family	Species	Stream	Lake
Lepisosteidae	Longnose gar (*Lepisosteus occeus*)	X	X
Amiidae	Bowfin (*Amia calva*)	X	X
Anguillidae	American eel (*Anguilla rostrata*)	X	
Clupeidae	Threadfin shad (*Dorosoma petenense*)	X	
	Gizzard shad (*Dorosoma cepedianum*)	X	
Umbridae	Eastern mudminnow (*Umbra pygmaea*)	X	X
Esocidae	Redfin pickerel (*Esox americanus*)	X	X
	Chain pickerel (*Esox niger*)	X	X
Cyprinidae	Greenfin shiner (*Cyprinella chloristius*)	X	X
	Whitefin shiner (*Cyprinella nivea*)	X	
	Common carp (*Cyprinus carpio*)		X
	Eastern silvery minnow (*Hybognathus regius*)	X	
	Bluehead chub (*Nocomis leptocephalus*)	X	
	Golden shiner (*Notemigonis crysoleucas*)	X	
	Dusky shiner (*Notropis cummingsae*)	X	
	Spottail shiner (*Notropis hudsonius*)	X	
	Taillight shiner (*Notropis maculates*)	X	X
	Coastal shiner (*Notropus petersoni*)	X	
	Sailfin shiner (*Pteronotropis hypselopterus*)	X	
Catostomidae	Creek chubsucker (*Erimyzon oblongus*)	X	X
	Spotted sucker (*Minytrema melanops*)	X	X
	Shorthead redhorse (*Moxostoma macrolepidotum*)	X	
Ictaluridae	Snail bullhead (*Ameiurus brunneus*)	X	
	Yellow bullhead (*Ameiurus natalis*)	X	
	Brown bullhead (*Ameiurus nebulosus*)	X	
	Flat bullhead (*Ameiurus platycephalus*)	X	
	Channel catfish (*Ictalurus punctatus*)	X	
	Tadpole madtom (*Noturus gyrinus*)	X	
	Margined madtom (*Noturus insignis*)	X	

Table 10. (Continued).

Family	Species	Stream	Lake
	Flathead catfish (*Pylodictis olivaris*)	X	
Amblyopsidae	Swampfish (*Chologaster cornuta*)	X	
Aphredoderidae	Pirate perch (*Aphredoderus sayanus*)	X	X
Cyprinodontidae	Lined topminnow (*Fundulus lineolatus*)	X	
Poeciliidae	Eastern mosquitofish (*Gambusia holbrooki*)	X	X
Atherinidae	Brook silverside (*Labidesthes sicculus*)	X	X
Percichthyidae	White perch (*Morone americana*)	X	
Centrarchidae	Mud sunfish (*Acantharcus pomotis*)	X	
	Flier (*Centrarchus macropterus*)	X	X
	Banded pygmy sunfish (*Elassoma zonatum*)	X	X
	Blackbanded sunfish (*Enneacanthus chaetodon*)	X	
	Bluespotted sunfish (*Enneacanthus gloriosis*)	X	X
	Redbreast sunfish (*Lepomis auritus*)	X	X
	Green sunfish (*Lepomis cyanellus*)	X	
	Pumpkinseed (*Lepomis gibbosus*)	X	X
	Warmouth (*Lepomis gulosus*)	X	X
	Bluegill (*Lepomis macrochirus*)	X	X
	Dollar sunfish (*Lepomis marginatus*)	X	X
	Redear sunfish (*Lepomis microlophus*)	X	X
	Spotted sunfish (*Lepomis punctatus*)	X	X
	Largemouth bass (*Micropterus salmoides*)	X	X
	Black crappie (*Pomoxis nigromaculatus*)	X	X
Percidae	Swamp darter (*Etheostomafusiforme*)	X	
	Tesselated darter (*Etheostoma olmstedi*)	X	
	Sawcheek darter (*Etheostoma serrifer*)	X	X
	Yellow perch (*Perca flavescens*)	X	X
	Piedmont darter (*Percina crassa*)	X	

Reptiles and Amphibians

A total of 61 native reptiles and amphibian species have been documented at CONG (Tables 11 and 12), of which none are introduced species (Tuberville et al. 2005). This park ranks third among the 16 Southeast Coast Network parks in terms of native species documented. There have been 32 species of reptiles noted, including one crocodilian (the American alligator *Alligator mississippiensis*), 19 snakes (three poisonous, the cottonmouth *Agkistrodon piscivorus*, the copperhead *A. contortrix*, and the timber rattlesnake *Crotalus horridus*), five lizards and seven turtles (Tuberville et al. 2005). Of the 28 total amphibian species found 20 were frogs and toads and eight were salamanders (Tuberville et al. 2005). Tuberville et al. (2005) noted that CONG contained a high taxa richness of amphibians and reptiles due to the size of the park and high diversity of habitat types. A broad variety of studies has indicated that increased diversity (plant and animal) is positively related to ecosystem stability (McCann 2000). It is important to note that these species in the Tuberville et al. (2005) study were catalogued from the main portion of the park only, and a survey of the Bates Fork Tract would be appropriate to form a baseline by which to compare with other parks and future surveys of CONG. The Marbled salamander *Ambystoma opacum* was noted by a stakeholder's group (NPS 2008) as a species that is potentially impacted by artificial river flows and flooding in CONG due to operations of the Saluda River Dam.

Table 11. Amphibian taxa verified from Congaree National Park (from Tuberville et al. 2005).

Species
Northern cricket frog (*Acris crepitans*)
Southern cricket frog (*Acris gryllus*)
Southern toad (*Bufo terrestris*)
Eastern narrowmouth toad (*Gastrophyne carolinensis*)
Gray treefrog (*Hyla chrysoscelis*)
Green treefrog (*Hyla cinerea*)
Pine woods treefrog (*Hyla femoralis*)
Barking treefrog (*Hyla gratiosa*)
Squirrel treefrog (*Hyla squirella*)
Brimley's chorus frog (*Pseudacris brimleyi*)
Spring peeper (*Pseudacris crucifer*)
Southern chorus frog (*Pseudacris nigrita*)
Ornate chorus frog (*Psuedacris ornate*)
American bullfrog (*Rana catesbeiana*)
Green frog (*Rana clamitans*)
Pickerel frog (*Rana palustris*)
River frog (*Rana heckcheri*)
Southern leopard frog (*Rana sphenocephala*)
Carpenter frog (*Rana virgatipes*)
Eastern spadefoot (*Scaphiopus holbrookii*)
Marbled salamander (*Ambystoma opacum*)
Mole salamander (*Ambystoma talpoideum*)
Southern dusky salamander (*Desmognathus auriculatus*)
Threelined salamander (*Eurycea guttolineata*)
Dwarf waterdog (*Necturus punctatus*)
Slimy salamander (*Plethodon glutinosus*)
Mud salamander (*Pseudotriton montanus*)
Greater siren (*Siren lacertian*)

Table 12. Reptile taxa verified from Congaree National Park (from Tuberville et al. 2005).

Species
American alligator (*Alligator mississippensis*)
Snapping turtle (*Chelydra serpentine*)
Spotted turtle (*Clemmys guttata*)
Eastern mud turtle (*Kinosternon subrubrum*)
River cooter (*Pseudemys concinna*)
Stinkpot (*Sternotherus odoratus*)
Eastern box turtle (*Terrapene carolina*)
Pond slider (*Trachymys scripta*)
Green anole (*Anolis carolinensis*)
Common fivelined skink (*Eumeces fasciatus*)
Southeastern fivelined skink (*Eumeces inexpectatus*)
Broadheaded skink (*Eumeces laticeps*)
Little brown skink (*Scincella lateralis*)
Copperhead (*Agkistrodon contortix*)
Cottonmouth (*Agkistrodon piscivorus*)
Eastern wormsnake (*Carphophis amoenus*)
Eastern racer (*Coluber constrictor*)
Timber rattlesnake (*Crotalus horridus*)
Ringnecked snake (*Diadophus punctatus*)
Eastern ratsnake (*Elaphe obsolete*)
Redbellied mudsnake (*Farancia abacura*)
Eastern hognosed snake (*Heterodon platirhinos*)
Common kingsnake (*Lampropeltis getula*)
Choachwhip (*Masticophis flagellum*)
Plainbellied watersnake (*Nerodia erythrogaster*)
Southern watersnake (*Nerodia fasciata*)
Brown watersnake (*Nerodia taxipilota*)
Rough greensnake (*Ophreodrys aestivus*)
Brownsnake (*Storeria dekayi*)
Redbellied snake (*Storeria occipitomaculata*)
Eastern ribbonsnake (*Thamnophis sauritus*)
Common gartersnake (*Thamnophis sirtalis*)

Mammals

Based on sampling conducted by Dr. David Webster of the University of North Carolina as a part of the Inventory and Monitoring Program and other records, 35 mammal species are known to be present at the park (Table 13). An additional three species are probably present or unconfirmed, and two species (black bear and red wolf) are thought to have been extirpated.

Of the non-native species, Webster (personnel communication) notes that feral cats are active predators on birdlife, reptiles and small mammals. Nationwide, it has been estimated that feral cats, together with outdoor cats, kill over 560 million birds per year in the United States (Pimentel et al. 2000). Webster also noted that feral hogs are an invasive species with clear destructive impacts to the park. Throughout the U.S., the 4,000,000 feral hogs are belived to cause approximately $800 million worth of crop damage per year, with considerably more costs due to environmental damage and disease spreading (Pimentel et al. 2000). The impacts of these large mammals to CONG alone merit a section and discussion (below).

Feral hogs

Feral hogs *Sus scrofa* were introduced as captive animals into America in 1539, and occur in approximately half of the states in the U.S. (Freibel 2007). There is a large and very active population of these animals within Congaree Park that has caused extensive damage through rooting and wallowing (Plate 11). The authors of this report saw evidence of rooting and wallowing in several areas of the park, including along the boardwalk trail to Weston Lake, in areas near Wise Lake, near water bodies along the eastern border road of the park, and especially within the Bates Fork Tract (Plate 11). In areas of heavy use the soil and vegetation is extensively turned over to depths of 4 to12 in (10 to 30 cm), with the patches as large as 6.5 by 33 ft (2 m by 10 m) easily visible near trails (Plate 11A and B). While conducting mussel surveys Williams and Benson (2004) noted that feral hogs had uprooted hundreds of meters of streambank to depths of 6 to 12 in (15 to 30 cm) in search of food, killing vegetation and enhancing the potential for streambank erosion. Williams and Benson (2004) also found evidence that feral hogs fed on mussels along streams. We saw evidence that feral hog activity along water bodies (where clay was present) contributed to significantly elevated turbidity in the water (Plate 11C). A study by Freibel (2007) indicated that individuals maintained comparatively compact home ranges and spatial fidelity, suggesting an abundant resource base in CONG. While recording feral hogs within all types of habitats studies within the park, Freibel (2007) found evidence that the hogs particularly selected habitats for availability of oak mast, and suggested its prevalence within the park may be critical to hogs. A study of hog disturbance of plots within various habitats (performed primarily during drought conditions) found that average total disturbance in individual plots was 19% in cypress-tupelo forest, 9% in mixed bottomland hardwoods, 9% in seepage forest and <1% in uplands, showing a preference for wetter areas (USGS 2005). However, the study found that once widespread flooding recurred, differences in disturbance between uplands and wetlands were no longer statistically significant. Regarding long-term impacts, that report noted that severe rooting in the seepage forest plots remained visible for months to even years (USGS 2005). Presently, USDA is conducting disease research through a permit from NPS in CONG (Plate 11D). Feral hogs are trapped, euthanized, and tested for zoonotic diseases.

As mentioned, the feral hog community within CONG is responsible for considerable habitat alteration and destruction, with potential implications to plant and invertebrate species of concern. The USGS (2005) study demonstrated that during drought periods these animals will concentrate their activities in wetland areas. The Williams and Benson (2004) study, along with our own observations, show that feral hog activities can degrade stream bank habitat and water quality. Additionally, we note that these large mammals produce feces that can contain bacteria, viruses, and protozoans that are pathogenic to humans (Hinton and Bale 1991) and their presence may be contributing to microbial water pollution within the park (see subsequent section titled *Human Health Issues*). Thus, NPS needs to continue and enhance programs designed to reduce the population of feral hogs within CONG. As noted by Freibel (2007), because these animals move freely across park borders management programs will need to involve neighboring property owners.

Plate 11. A – hog wallow, B – feral hog rooting area, C – feral hog rooting causes stream turbidity increases, D – USDA feral hog research program utilizes traps in Bates Fork Tract.

Table 13. Mammals certified or considered to be probably present at Congaree National Park (NPSpecies, 2010).

Common Name	Scientific Name	Status in Park
A. Mammals present in park		
Virginia opossum	*Didelphis virginiana*	Common
Southeastern shrew	*Sorex longirostris*	Uncommon
Star-nosed mole	*Condylura cristata*	Status Unknown
Northern short-tailed shrew	*Blarina brevicauda*	Status Unknown
Southern short-tailed shrew	*Blarina carolinensis*	Common
Least shrew	*Cryptotis parva*	Common
Eastern mole	*Scalopus aquaticus*	Common
Southeastern myotis	*Myotis austroriparius*	Status Unknown
Big brown bat	*Eptesicus fuscus*	Status Unknown
Eastern red bat	*Lasiurus borealis*	Status Unknown
Evening bat	*Nycticeius humeralis*	Status Unknown
Eastern pipistrelle bat	*Pipistrellus subflavus*	Status Unknown
Eastern cottontail	*Sylvilagus floridanus*	Uncommon
Southern flying squirrel	*Glaucomys volans*	Status Unknown
Fox squirrel	*Sciurus niger*	Uncommon
Eastern gray squirrel	*Sciurus carolinensis*	Common
Beaver	*Castor canadensis*	Uncommon
White-footed mouse	*Peromyscus leucopus*	Status Unknown
Cotton mouse	*Peromyscus gossypinus*	Common
Marsh rice rat	*Oryzomys palustris*	Status Unknown
Eastern harvest mouse	*Reithrodontomys humulis*	Common
Hispid cotton rat	*Sigmodon hispidus*	Common
Eastern woodrat	*Neotoma floridana*	Uncommon
River otter	*Lontra canadensis*	Uncommon
American mink	*Mustela vison*	Common
Striped skunk	*Mephitis mephitis*	Rare
Raccoon	*Procyon lotor*	Common
Bobcat	*Lynx rufus*	Uncommon
Coyote	*Canis latrans*	Uncommon
Gray fox	*Urocyon cinereoargenteus*	Common
White-tailed deer	*Odocoileus virginianus*	Common
Feral hog	*Sus scrofa*	Abundant
Cat	*Felis catus*	Uncommon
Dog	*Canis familiaris*	Uncommon
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*	Status Unknown

Table 13. (Continued).

Common Name	Scientific Name	Status in Park
B. Mammals probably present but not verified		
Marsh Rabbit	*Sylvilagus palustris palustris*	Status Unknown
Red Fox	*Vulpes vulpes*	Status Unknown
Muskrat	*Ondatra zibethicus*	Status Unknown
C. Mammals extirpated from area		
Black Bear	*Ursus americanus americanus*	Absent / Historic

Birds

At least 191 species of birds have been observed at CONG (Carter 2005). Several groups are represented that are often or occasionally associated with aquatic habitats including Grebes, Pelicans, Herons and Egrets, Ibises and Storks, and Geese and Ducks, and Shorebirds. However, these birds are all listed by Carter (2000) as uncommon (50% chance of encounter), occasional (20% chance of encounter), or rare (<5% chance of encounter). Those listed as uncommon include the Anhinga *Anhinga anhinga*, Great Blue Heron *Ardea herodias*, Night Heron *Nycticorax nycticorax* and Wood Duck *Aix sponsa*; occasionals include the Great Egret *Casmerodius albus*, Green Heron *Butoides virescens*, Wood Stork *Mycteria amaericana* and American Woodcock *Scolopax minor*. The Bald Eagle *Haliaeetus leucocephalus* is rare and nests in the park; other rarely-seen raptors that utilize the park's aquatic resources are Swallow-tail Kite *Elanoides forficatus* and Osprey *Pandion haliaetus*. The Rusty Blackbird *Euphagus carolinus* breeds in forested wetlands and is seen in fall and winter in CONG. As mentioned, this park is considered a Globally Important Bird Area by the American Bird Conservatory. It is important to note that Prothonotary Warblers *Protonotaria citrea* and other migratory birds utilize the floodplain forest habitats in Congaree National Park. The breeding success of Prothonotary Warblers *Protonotaria citrea* is considered by a stakeholder's group (NPS 2008) to be dependent at least in part by proper flow management of the Congaree River and flooding of CONG through Saluda River Dam operations.

Rare and Threatened Animal Species

There are no known terrestrial mammals found to occur in CONG that are listed as Species of Concern by the U.S. Fish and Wildlife Service. The State of South Carolina lists both the star-nosed mole and the eastern fox squirrel as Special Concern. The American alligator Alligator mississippiensis (Federally listed as Threatened) has been documented from CONG (Tuberville et al. 2005). It is not State listed and there is a controlled hunt in South Carolina for alligator since 2008 (not within CONG however). The shortnose sturgeon Acipenser brevirostrum, which is a Federally-listed Endangered Species has been tracked via radio transmitter in the Congaree River and a spawning site was verified in the river near Columbia (Collins et al. 2003).

As to invertebrates, the crayfish *Procambarus chacei* is listed as a South Carolina Species of Concern, and is found in streams within CONG (Price 2005). A number of mussel species within CONG are species of concern (see Table 9) Carolina lance (*Elliptio angustata*) and Yellow lampmussel (*Lampsilis cariosa*) are Federally listed Species of Concern, while Atlantic spike (*Elliptio product*) is a South Carolina Species of Concern, Eastern lampmussel (*Lampsilis radiate*) is threatened in South Carolina, and Eastern pondmussel (*Lignumia nasuta*) is endangered in South Carolina (Williams and Benson 2004). Outside of but near the park in the Congaree River several mussels, Carolina slabshell (*Elliptio congaraea*), Roanoke slabshell (*E. roanokensis*), Carolina lance (*E. angustata*), Yellow lampmussel and Rayed pink fatmucket (*L. splendid*) are all listed as Federal Species of Concern, with Roanoke slabshell considered at high risk of extinction and Yellow lampmussel and Rayed pink fatmucket considered at moderate risk of extinction (Alderman 2006). Additionally, Bogan and Alderman (2008) provide proposed status updates of several species above (to list as either state endangered, state threatened, or state listed species of special concern) based on fieldwork, including the Savannah liliput *Toxolasma pullus*, which is considered to be highly imperiled, and is currently being considered as a candidate for federal listing status (Krueger 2009).

Invasive Animal Species

According to CONG personnel, with the exception of feral hogs and the Asian clam, other exotic invasive animal species (terrestrial or aquatic), have not been documented in the park. Black rats, Norway rats, and house mice are not native to the area and their impact of local vegetation has not been adequately assessed (W.D. Webster, personal communication). As mentioned earlier, former domesticated and now feral pigs and cats may have significant impacts on the wildlife and flora. Feral dogs are relatively uncommon in the park.

In the Congaree River in and near the park the Asian clam (*Corbicula fluminea*) has been collected in several locations (Alderman 2006). This is an exotic invasive long established in U.S. waters that causes fouling problems in water intake pipes for power plants and water treatment facilities. Its impact in terms of competitive exclusion with native bivalves is equivocal (Neves et al. 1997).

Assessment of Park Water Resources

Sources of Pollutants

Congaree National Park and USGS/SCDHEC Watersheds Designation

CONG is divided within several watersheds as designated by the United States Geological Survey (USGS) and utilized as such by the South Carolina Department of Health and Environmental Control (SCDHEC). The hydrologic units used by SCDHEC are from the 1999 USGS Hydrologic Unit code for South Carolina. The Congaree River Watershed is an 8-digit hydrologic unit designated 03050110. It drains 668 mi^2 (1730 km^2), and it's land use consists primarily of forested lands, agricultural lands, forested wetlands and urban land (Figure 6; see also SCDHEC 2004a). The subwatersheds within the Congaree Watershed are 11-digit hydrologic units. These include the Congaree River Watershed (03050110-010) which extends from the confluence of the Saluda River and the Broad River in Columbia along the river southeast until the Congaree River joins the Wateree River; thus the portions of the park adjoining the Congaree River lie within this subwatershed. The largest portion of the park lies within the Cedar Creek Watershed, represented by the 11 digit hydrologic unit 03050110-050. This watershed drains Cedar Creek and its main tributaries Myers Creek and Dry Branch (SCDHEC 2004a). The easternmost edge of the main portion of the park is in the Toms Creek Watershed, designated as 11-digit hydrologic unit 03050110-060. The Bates Fork Tract is officially within the lower Congaree River Watershed 03050110-070, but is also strongly influenced by flooding from the Wateree River Watershed, 03050104-030 (SCDHEC 2005).

Point Source Pollution

Point source discharges are waste waters containing various degrees and types of pollutants, and discharged by a pipe of some sort from municipal, industrial or commercial facilities into surface waters. Such discharges are regulated by the U.S. National Pollutant Discharge Elimination System (NPDES) administered by the U.S. Environmental Protection Agency (EPA). The EPA generally cedes this regulation of this program to a regulatory agency within the individual states, in the case of South Carolina it is SCDHEC. Floodwaters entering CONG from the two rivers, as well as stream water entering the park from the creeks can be impacted by many NPDES dischargers (Figure 7). Five major NPDES dischargers are located along the Congaree River upstream of the park, including some within the City of Columbia. These facilities discharge a combined permitted flow of > 212 MGD, in addition to an additional 12 facilities that discharge a combined permitted flow of < 0.9 MGD into tributaries. The five major dischargers are (SCDHEC 2004a):

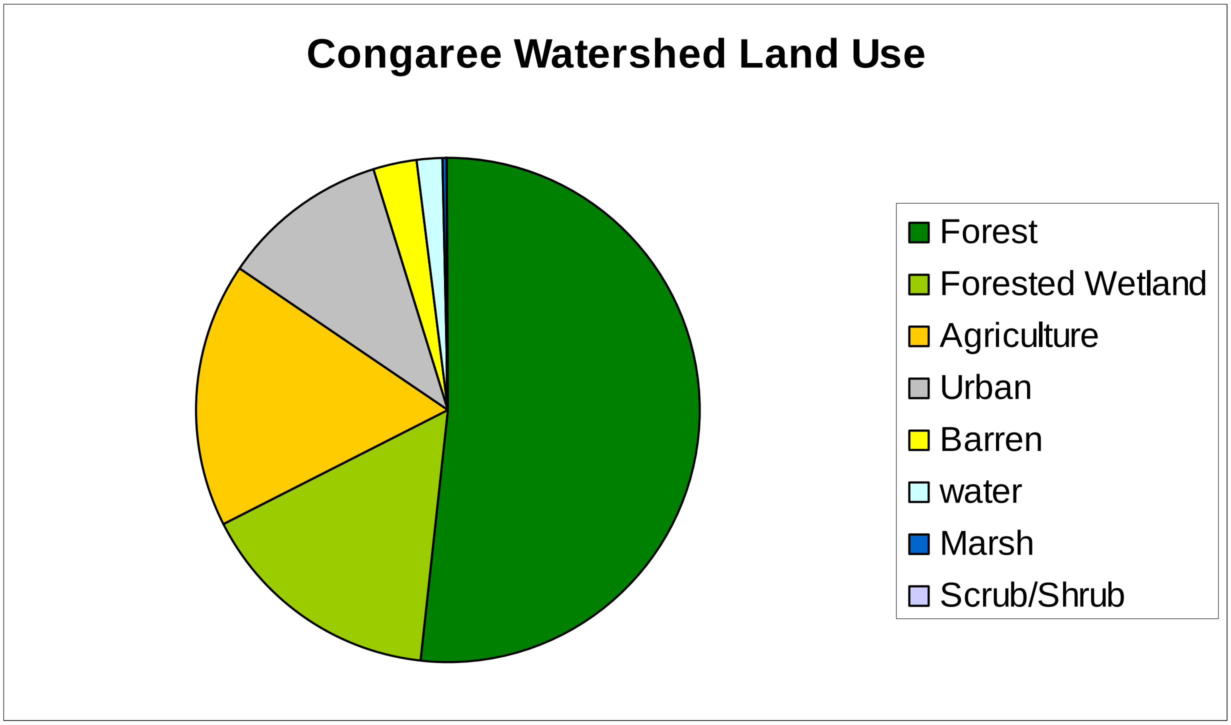
- Voridian plant at 100.82 MGD, major industrial (NPDES# SC0001333)
- City of Columbia Metro WWTP at 60 MGD, major domestic (NPDES# SC0020940)
- Westinghouse Electric Plant at 0.13 MGD, major industrial (NPDES# SC0001848)
- City of Cayce WWTP at 12 MGD, major domestic (NPDES# SC0024147) – note an additional 40 MGD are proposed for this discharger.

- East Richland Co. PSD/Gills Creek Plant at 39.5 MGD, major domestic (NPDES# SC0038865)

The Cedar Creek watershed contains seven minor NPDES dischargers totaling about 0.15 MGD, while the Toms Creek Watershed and the lower Congaree Watershed (03050110-070) contain no NPDES dischargers (SCDHEC 2004a). The Wateree River Watershed contains seven major NPDES dischargers that discharge into the Wateree River proper totaling about 490 MGD and 14 minor NPDES facilities discharging either into the river or tributary streams with permits totaling less than 4.1 MGD. Major NPDES dischargers licensed to discharge into the Wateree River are as follows (from SCDHEC 2005);

- South Carolina Electric and Gas (SCE&G) Wateree Station, at 490 MGD, major industrial (NPDES# SC0002038)
- Invista Sarl/Camden at 4.2 MGD, major industrial (NPDES# SC0002585)
- Clariant LSM (America) at 0.8 MGD, major industrial (NPDES# SC0002682)
- City of Camden WWTP at 2.4 MGD, major domestic (NPDES# SC0021032) – note this plant has an additional 3.0 MGD proposed.
- International Paper/Eastover, major industrial (NPDES# SC0038121)
- Kawashima Textile USA, major industrial (NPDES# SC0023264)
- City of Sumter at 9.0 MGD (proposed), major domestic (NPDES# SC0027707)

Other information on point source dischargers can be found in Knowles et al. (1996) and Maliszewski (2005), as well as SCDHEC (2004a and 2005).



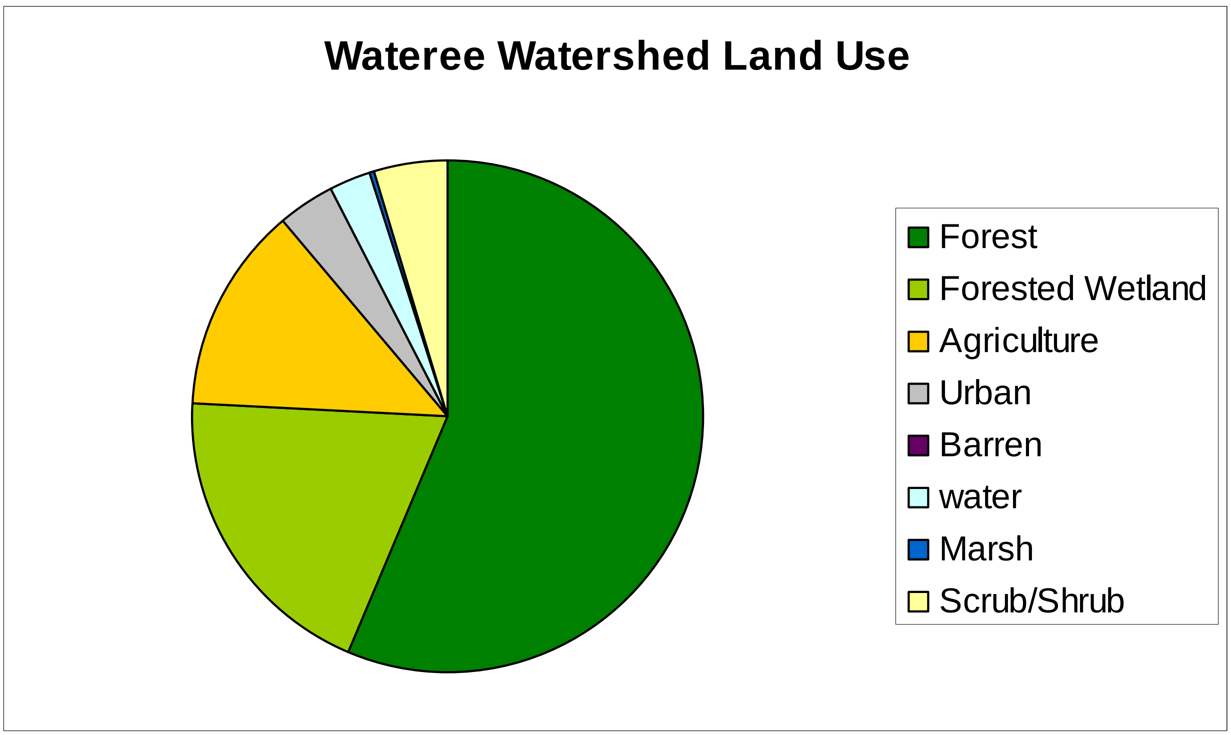


Figure 6. Land use within the Congaree and Wateree River Watersheds (SCDHEC 2004a; 2005).

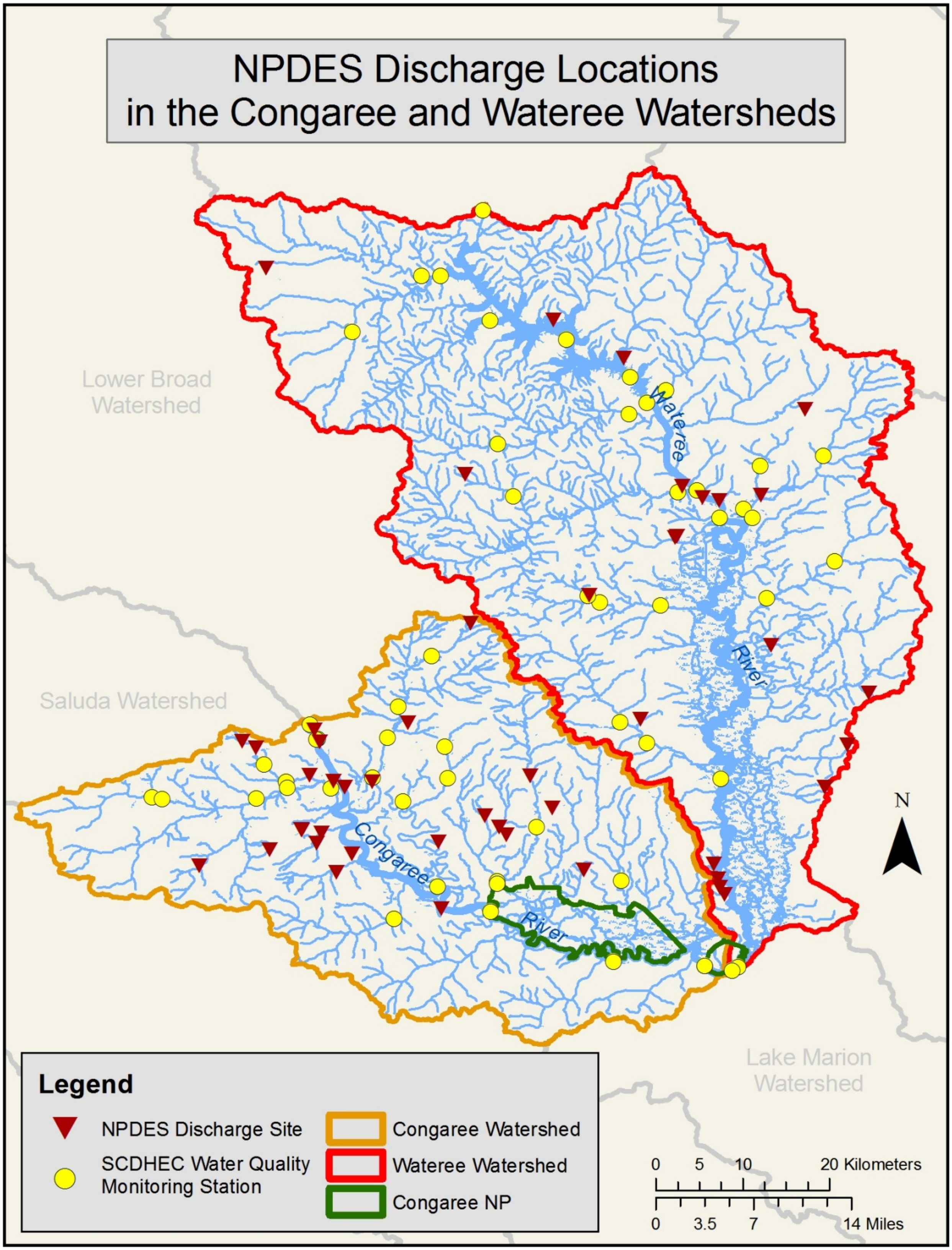


Figure 7. Location of NPDES dischargers and SCDHEC water sampling sites within or near Congaree National Park, SC.

Non-point Source Pollution

Non-point source pollution consists of pollutants that are not piped off-site, but are diffused upon the landscape and subject to movement off site by stormwater runoff. Concentrated animal feeding operations (CAFOs) are large-scale livestock production facilities where dozens to hundreds (horse or cattle) or hundreds to thousands (swine) to hundreds of thousands and even millions (chicken and turkey) of animals are raised in close quarters and produce large amounts of manure. In these systems animal manure is spread out diffusely over the landscape either as liquid spray (swine waste) or dry litter (poultry waste), or semi-solid waste (cattle and hoses), this becoming non-point source pollution threats and subject to stormwater runoff carrying it into the nearest body of water. Thus, livestock waste runoff in some areas is a major water quality issue (Mallin 2000; Burkholder et al. 2007). There are several active permitted livestock facilities (located in the Congaree River, Wateree River, and Toms Creek watersheds (Figure 8). In Congaree hydrological subunit 03050110-010 none of these facilities are near the river or park and are likely not an issue, and no such facilities are located in the Cedar Creek watershed 03050110-050 (Figure 8). In Toms Creek hydrologic subunit 03050110-060 there is a stable facility (ND0086428) maintaining up to 100 horses. Runoff from such an area where horses defecate can pollute a stream with potentially pathogenic microbes. In Congaree River hydrological subunit 03050110-070 there are two poultry CAFOs (ND0080543 and ND0068268) holding between 80,000 and 100,000 birds each (Figure 8), and runoff from such facilities may be able to impact the easternmost portions of the park with fecal microbial or nutrient pollution. The Wateree River hydrological subunit 03050104-030 contains a number of permitted animal facilities, but only one is near the river itself (ND0080519) a poultry facility permitted for 80,000 birds. See Appendix C for information on all permitted CAFOs in the watersheds impinging on CONG.

Cultivated cropland produces non-point source pollution primarily in the form of nutrients from fertilizers that are then subject to rural stormwater runoff entering streams and rivers. However, the amounts of cultivated land in the Congaree River watersheds and the Wateree River watershed are not large in the area compared with forested land and forested wetland (Table 14). In contrast, the Toms Creek watershed has significant agricultural land use that may contribute to downstream pollution (Table 14). There is a large aquaculture facility (Southland Fisheries, Inc.) located near Cedar Creek near Old Bluff Road; Knowles et al. (1996) noted that the impacts of potential discharges or flooding from this facility on the creek is unknown. However, an examination of the existing water quality data from sampling sites on Cedar Creek downstream of this facility show no unusual or negative impacts in regards to nutrient inputs or dissolved oxygen (see section Water Quality in Cedar Creek). It is hoped that SCDHEC will continue sampling at the creek where it enters CONG to continue monitoring any potential inputs of pollutants. If discharges do occur from this facility the in-situ instrumentation in Cedar Creek, along with regular SCDHEC sampling, should reflect this. Regardless, NPS should seek an agreement with Southland Fisheries to alert the park staff if a pond drainage or other water release is planned.

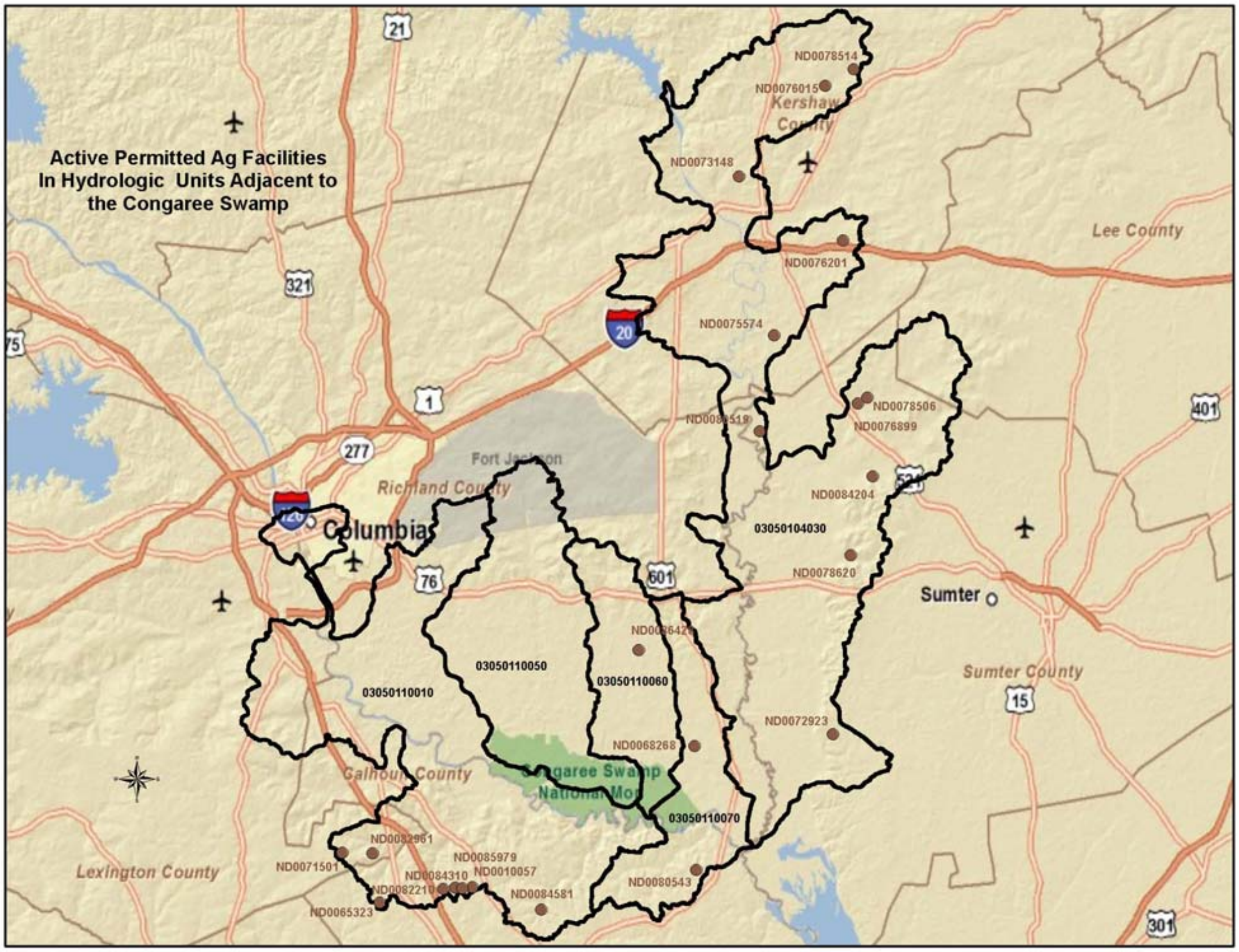


Figure 8. Location of permitted livestock production facilities (CAFOs) in watersheds impinging upon Congaree National Park (see Appendix C for map details).

Table 14. Land use by percent coverage in the watersheds impacting Congaree National Park (from SCDHEC 2004a and SCDHEC 2005).

Watershed	Hydrologic Unit	Urban	Agricultural	Forested	Forested Wetland	Barren
Congaree River	03050110-010	7.4%	11.9%	54.2%	21.8%	2.0%
Congaree River	03050110-070	0.6%	21.9%	48.0%	24.9%	2.2%
Cedar Creek	03050110-050	3.8%	23.5%	44.0%	23.3%	4.1%
Toms Creek	03050110-060	1.4%	32.2%	51.4%	13.4%	0.2%
Wateree River	03050104-030	3.6%	13.0%	56.5%	19.4%	0.1%

Impervious surface coverage (roads, sidewalks, parking lots, rooftops), which concentrates pollutants and increases stormwater runoff pollution, is presently very low in CONG. There are the parking areas near the Visitors Center and the entrance road; and the roofs of the park buildings are impervious surfaces. All of these surfaces are well away from Cedar Creek or any of the other surface water bodies and thus immediate runoff within the park is not a potential problem to park water quality.

Impervious surface coverage in general in watersheds is largely a product of urban land. Of the area watersheds only Congaree River 03050110-010 has notable urban coverage (Table 14), draining much of the Columbia metropolitan area, and undoubtedly the river receives non-point source loads of fecal bacteria, nutrients, suspended sediments, metals and toxic chemicals.

Toxic waste sites with the potential to contaminate groundwater and/or nearby surface water are called Superfund sites; i.e. falling under the U.S. EPA's Superfund Program. While coming from a known industrial site, pollutants in groundwater move as a plume and cannot be controlled as a point source, but require removal of large amounts of contaminated soils – thus are functional underground non-point source discharges. The great majority of Superfund sites in South Carolina are local urban sites with little potential for contaminating downstream areas. However, the EPA maintains a National Priorities List (NPL), which are sites that the EPA has determined present a "significant risk to human health or the environment". South Carolina has 26 such sites that are active, and three that have been remediated sufficiently to be deleted from the listing.

In the Congaree Watershed or nearby watersheds there are five such NPL sites (Figure 9):

1) The most relevant one to CONG is SCRDI Bluff Road, an abandoned petroleum and chemical disposal and recycling plant located across Bluff Road (Highway 48 – see Figure 9) from the Westinghouse facility four miles away from the park (EPA ID: SCD000622787, Site ID 0403212; Lat/Long 33.885410, -080.908750). The facility had a polluted underground plume, but has been remediated to "no contaminated groundwater migration" and is considered by EPA as "construction complete". This means that this is a site "where all immediate threats are eliminated and all long-term threats are under control"

2) The Townsend Saw Chain Company is an NPL site located well away from CONG, north of Ft. Jackson and near I20 (EPA ID: SCD980558050; Site ID: 0403363; Lat/Long 34.106250, -080.834160). This site is also listed as "construction complete", but contaminated groundwater migration is not considered under control yet.

3) In the Congaree Watershed near Columbia (Figure 9) is SCRDI Dixiana, an NPL site (EPA ID: SCD980711394; Site ID: 0403402; Lat/Long 33.904450, -081.063880). This site is also considered "construction complete', with no contaminated groundwater migration.

4) Located close to SCRDI Dixiana is the Lexington County Landfill Area (Figure 9), an NPL site (EPA ID: SCD980558043, Site ID: 0403362, Lat/Long 33.919580, -081.074160). This is also considered "construction complete": with no contaminated groundwater migration.

5) The final NPL site in the area is Palmetto Recycling company, located in the Congaree Watershed in suburbs of Columbia (EPA ID: SCD037398120, Site ID: 0403274; Lat/Long 34.122800, -081.011700). This site is listed as deleted from the Superfund lists, which is the final step beyond "construction complete". This information was obtained from two useful websites that also contain further information on these and

other Superfund sites, one is called Wasting Away – The Center for Public Integrity http://projects.publicintegrity.org/Superfund. The other website is the EPA Superfund site http://www.epa.gov/superfund/sites/index.htm.

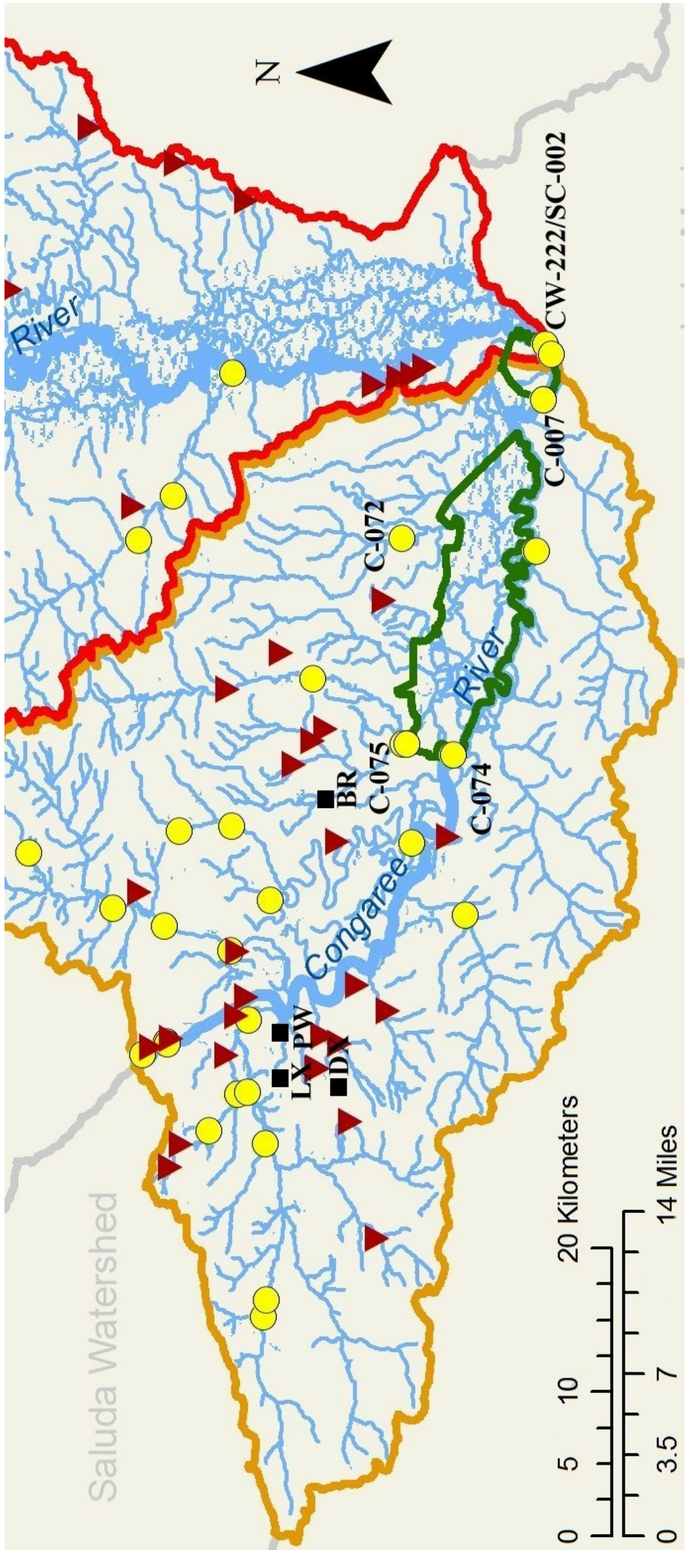


Figure 9. Location of SCDHEC active sampling sites near CONG (green border) that have data detailed on various Tables in this report, and Superfund sites that are on the EPA National Priorities List (black boxes). BR = SCRDI Bluff Road, DX = SCRDI Dixiana, LX = Lexington Landfill area, PW = Palmetto Recycling. As in Figure 7, yellow circles are SCDHEC sample sites and red triangles are NPDES locations.

Assessment of Biological Resources with Respect to Water Quality (Both Surface and Groundwater)

Water Quality Standards

The South Carolina Department of Health and Environmental Control is required to develop a priority list of water bodies pursuant to Section 303(d) of the Federal Clean Water Act and Federal regulation 40 CFR 130.7. The listing identifies S.C. water bodies that do not currently meet State water quality standards for its designated use. The ratings for a water body are based on chemical water quality standards and biological assessments, if available, based on benthic macroinvertebrate community structure (see Lenat (1993) and NCDENR (2006)). For water bodies not meeting State standards, a TMDL (total maximum daily load) may be required. A TMDL is a calculation of the maximum amount of a specific pollutant that a water body can receive and still meet water quality standards. For impaired water bodies the TMDL document specifies the level of pollutant reductions needed and how much from what sources.

The State of South Carolina has freshwater quality standards (SCDHEC 2004b) for common water quality parameters including:

- Dissolved oxygen (5 mg/L, with a low of 4 mg/L)
- Turbidity (50 NTU for most freshwater, 25 NTU for lakes)
- Chlorophyll *a* of 40 µg/L (for lakes >40 acres).

Microbiological water quality and S.C. standards are discussed in a subsequent section (*Human Health Issues*). South Carolina also has standards for metals and various toxic compounds, and standards for total phosphorus and total nitrogen for lakes, depending on ecoregion (SCDHEC 2004b); there are also narrative standards. Standards can be accessed at this website: http://www.scdhec.net/environment/water/regs/r61-68.pdf. Additionally, there is an Environmental Protection Agency standard of 10 mg/L for nitrate-N for drinking water, to protect infants from potentially fatal methemoglobinemia (blue-baby syndrome)

Surface Water Quality

No active SCDHEC ambient water quality monitoring stations are located within the park boundaries; however, there are a number of such sites near the borders of the park (Figure 7 and Figure 9). Upstream in West Columbia where the Saluda and Broad Rivers join to form the Congaree, SCDHEC maintains two sampling stations, CSB-001L and CSB-001R; a third station (C-074) is located in the Congaree River at the west boundary of the park (Figure 9), and a fourth station (C-007: see Figure 9) in the lower river at Highway 601 (SCDHEC 2004a). Cedar Creek has three SCDHEC stations: C-069 upstream in the creek at S-40-66, C-071 farther downstream at S-40-734 and C-075 (Figure 9) south of S-40-734 at the old USGS gauging platform (SCDHEC 2004a). Myers Creek hosts one station, C-578 at SR 734, and Toms Creek is host to two stations, C-072 at SC 48 (Figure 9) and C-579 at the power line and railroad track (SCDHEC 2004a). There is also a station on the Wateree River 2.5 km upstream of its confluence with the Congaree River (CW-222/SC-002: see Figure 9). Besides SCDHEC, a number of special water quality studies have carried out in and near the park by USGS and NPS personnel. Thus, there is an abundance of water quality data from a few river and stream stations near the park. There is some historical data from sites within the park, but it is limited. Historical and recent data at the stations located either within the park or closest to the park are provided in the tables below. NPS is currently collecting sonde-based continuous water quality data from Cedar Creek, which will be discussed subsequently in this report.

Water Quality in the Congaree River. SCDHEC (2004a) sampling has indicated mixed water quality in the upper Congaree River in Columbia. CSB-001L is rated as fully supportive of aquatic life, but recreational uses are only partially supportive due to elevated fecal coliform bacteria and copper, while downstream near CONG the Congaree River is impaired by fecal coliform bacteria, copper and mercury (Impairment information is listed in a subsequent section in Table 28).

In the Congaree River at the western boundary of the park (Station C-074: Figure 9), a brief historical data set was provided in NPS (1998). These results showed unremarkable conditions in terms of turbidity and generally high dissolved oxygen concentrations (Table 15). Excessive levels of nutrients and fecal coliform bacteria were not found, and five-day biochemical oxygen demand (BOD5) concentrations were at levels normal for coastal plain rivers (Mallin et al. 2006).

SCDHEC (2004a) provided summary information for Station C-074 in the Congaree River at the western boundary of CONG (Figure 9) from 1987-2001. Only 2% of the dissolved oxygen samples violated the standard, although there was a significant decreasing trend during that period. Turbidity showed 6% violations and no trend, as did 6% of the copper measurements (SCDHEC 2004a). During 1987-2001 9% of the fecal coliform bacteria samples exceeded the human contact standard, and there was a significant downward trend (SCDHEC 2004a). SCDHEC data for this site representing 2005-2006 were obtained from the EPA STORET system. Eleven of 30, or 37% of the samples had fecal coliform counts exceeding 200 CFU/100 mL, the state standard for human contact, indicating that fecal bacteria problems may be increasing for the Congaree River near CONG. Recent SCDHEC data showed that dissolved oxygen and turbidity were no problem, and nutrient concentrations were unremarkable.

Farther downstream where the Congaree River is crossed by Highway 601 near the Bates Fork Tract (Station C-007: Figure 9) a robust historical data set was presented in NPS (1998). Turbidity data show that there are periodic excursions above the state standard, although mean and median levels were well below it (Table 16). For the period 1987-2001 SCDHEC (2004a) noted only 3% of samples exceeded the standard and there was a decreasing trend in turbidity. Dissolved oxygen concentrations were not problematic, and chlorophyll *a* measurements were all below the South Carolina algal bloom standard for lakes. Nutrient concentrations were not excessive compared with other southeastern Coastal Plain rivers (Meyer 1992; Mallin et al. 1999; Burkholder et al. 2006), and SCDHEC (2004a) noted a significant decreasing trend in total phosphorus concentrations. Fecal coliform bacteria counts (Table 16) indicated that excursions above the human contact standard can be a continuing problem, although SCDHEC (2004a) found a decreasing trend in fecal coliforms between 1987 and 2001.

Table 15. Congaree River water quality, collected at the west edge of Congaree National Park; SCDHEC Station C-074. Data presented as mean ± standard deviation / range / median. Sample size (n) = 30 for all data unless otherwise noted.

	11/1996 - 06/1997 SCDHEC data in NPS (1998)			1/2005 - 12/2006 Most Recent STORET data		
Parameter	**Mean**	**Range**	**Median**	**Mean**	**Range**	**Median**
Turbidity (NTU)	11.6±5.7 [a]	4.7-22.0 [a]	10 [a]	18.9±19.0	3.0-90.0	12
Dissolved oxygen (mg/L)	9.6±1.6 [a]	2.9-13.2 [a]	9.9 [a]	7.9±1.6	5.8-10.9	7.7
BOD5 (mg/L)	1.0±0.7 [b]	0.5-2.8 [b]	0.8 [b]	--	--	--
Nitrate-N (mg-N/L)	0.428±0.030 [b]	0.390-0.470 [b]	0.425 [b]	0.520±0.160	0.310-0.900	0.59
Ammonium-N (mg-N/L)	0.067±0.041 [b]	0.025-0.120 [b]	0.06 [b]	0.270±0.120	0.110-0.560	0.26
Total Kjeldahl nitrogen (mg-N/L)	0.345±0.138 [b]	0.200-0.620 [b]	0.33 [b]	0.440±0.150	0.050-0.710	0.46
Total phosphorus (mg-P/L)	0.060±0.011 [b]	0.040-0.070 [b]	0.06 [b]	0.060±0.020	0.010-0.100	0.06
Fecal coliform bacteria (CFU/100 mL)	74±44 [a]	31-150 [a]	74 [a, c]	177±369	5-1800	65

[a] n=7 samples, [b] n=8 samples, [c] geometric mean

Summary information provided in SCDHEC (2004a) for Station C-007 at Highway 601 showed no major problems with dissolved oxygen, turbidity, nutrients, or fecal coliform bacteria during the period 1987-2001, and significant downward trends during that period for turbidity, phosphorus and fecal coliform bacteria. STORET data for 2005-2006 (Table 14) showed 13% of the fecal coliform bacteria samples exceeding 200 CFU/100 mL during that period, while 2007 data from DHEC showed 8% exceeding that standard. The 2005-2006 data showed no problems for dissolved oxygen, but excessive turbidity on occasion (maximum of 90 NTU). Nutrients were low to moderate compared with other regional systems (Meyer 1992; Mallin et al. 1999; Burkholder et al. 2006). Thus, water in the Congaree River at Station C-007 at Highway 601 showed that excessive fecal coliform bacteria counts are a continuing problem, and turbidity is on occasion.

Water Quality in Cedar Creek. The National Park Service began collecting regular automated water quality data in Cedar Creek beginning in August 2006. The data sonde deployed at this location is a YSI 6600 EDS Multi-Parameter Water Quality Logger with "wiped" Rapid Pulse D.O. probe. The water quality station is designated “CONGccbr”, a fixed site water monitoring station located in CONG on the downstream side of the metal Cedar Creek bridge (ccbr) located at the junction of Sims Trail, Weston Lake Loop and the start of the Oakridge Trail. The metal bridge is labeled as “B” on trail maps. Walking from the Old-Growth Bottomland Forest Research and Education Center down Sims Trail to the data sonde takes between 30 minutes to an hour. This site was chosen as a long-term fixed water quality monitoring site for several reasons. Cedar Creek is one of the main blackwater tributary streams that traverse the forested floodplain within CONG. Cedar Creek supports diverse aquatic communities, and provides recreational opportunities (mainly canoeing and fishing) for park visitors. In addition, this section of Cedar Creek is designated as Outstanding National Resource Waters for South Carolina. CONG staff also manage two additional YSI data sondes for use in various projects and for future water quality work.

Table 16. Congaree River water quality, 3/74 – 6/97, collected at Highway 601; SCDHEC Station C-007. Data presented as mean ± standard deviation / range / median. Sample size (n) = 23 for all data unless otherwise noted.

	03/1974 – 06/1997 SC Pollution Control Authority (NPS 1998)			**1/2005 - 12/2006 Most Recent STORET data**		
Parameter	**Mean**	**Range**	**Median**	**Mean**	**Range**	**Median**
Turbidity (NTU)	22.5±24.1 [a]	0.6-210 [a]	15 [a]	18.0±19.0	Mar-90	12
Dissolved oxygen (mg/L)	8.2±1.7 [b]	2.9-13.2 [b]	7.8 [b]	7.9±1.6	5.8-10.9	7.7
Chlorophyl *a* (µg/L)	4.0±2.3 [c]	1.3-13.6 [c]	3.4 [c]	--	--	--
Nitrate-N (mg-N/L)	0.373±0.122 [d]	0.030-1.140 [d]	0.37 [d]	0.520±0.160	0.310-0.900	0.47
Ammonium-N (mg-N/L)	0.139±0.312 [e]	0.010-2.700 [e]	0.06 [e]	0.160±0.070	0.030-0.360	0.11
Total Kjeldahl nitrogen (mg-N/L)	0.748 [f]	0.050-32.000 [f]	0.41 [f]	0.320±0.150	0.050-0.640	0.33
Total phosphorus (mg-P/L)	0.120±0.285 [g]	0.010-4.400 [g]	0.08 [g]	0.060±0.020	0.030-0.120	0.05
Fecal coliform bacteria (CFU/100 mL)	830+2551 [h]	8-24,000 [h]	179 [h, i]	177±369	5-1,800	65

[a] n=271 samples, [b] n=346 samples, [c] n=102 samples, [d] n=289 samples, [e] n=256 samples, [f] n=252 samples, [g] n=253 samples, [h] n=224 samples, [i] geometric mean

The operation of CONGccbr has proved to be a useful endeavor. The data (Table 17) indicate this stretch of Cedar Creek as being a low conductivity stream with good dissolved oxygen concentrations and pH values normal for blackwater streams. However, the sonde has also recorded periods where turbidity values well exceed South Carolina freshwater standards (Table 17).

Table 17. Cedar Creek water quality as recorded by NPS-operated in-situ instrumentation CONGccbr, August 9, 2006 – August 15, 2008, 30 minute intervals (missing data from February 19 – May 14, 2008). Data presented as mean ± standard deviation / range / median.

Parameter	**Mean**	**Range**	**Median**
Temperature (oC)	18.83+7.14	3.74-31.37	20.37
Specific Conductance (mmho)	0.03+0.01	0.02-0.07	0.03
pH	5.84+0.25	5.20-6.91	5.86
Turbidity (NTU)	51.8+182.1	1.0-1,935.8	9.2
Dissolved Oxygen (mg/L)	7.5+1.8	4.5-12.1	6.8
DO % Saturation	77.6+7.9	55.2-95.8	76.7

There are numerous occasions when turbidity jumps to levels exceeding 1,000 NTU for brief periods of 30 minutes to a couple of hours; these excursions are likely a result of particulate matter becoming briefly lodged in the sensor, or possibly a stream disturbance in the immediate area such as hogs, researchers, or canoers. What is particularly striking are the extended periods (several days) when turbidity remains elevated to concentrations well exceeding SC standards. The USGS maintains water level meters in Cedar Creek (USGS Station 02169672) and the Congaree River near CONG (USGS Station 02169625). On some occasions elevated water levels driven by upstream rainfall coincided with the turbidity excursions. For example, in late

July and early August 2008 turbidity in Cedar Creek as measured by CONGccbr coincided strongly with elevated stream height in Cedar Creek as recorded by USGS, but much less so with Congaree River height. We obtained data from the NPS sonde CONGccbr as well as SC USGS for the period July 18 – August 14, 2008, and produced a scatter plot showing the positive relationship (Figure 10), and produced a highly significant ($p < 0.001$) and strong ($r^2 = 0.80$) predictive linear regression equation:

$$\text{Cedar Creek turbidity} = 307.5 \text{ (gage height in ft. Cedar Creek)} - 597.8$$

Substituting Congaree River gage height produced a significant ($p = 0.01$) but weak regression equation ($r^2 = 0.22$), thus in this instance runoff-related discharge in Cedar Creek likely led to the elevated turbidity values.

$$\text{Cedar Creek turbidity} = 222.6 \text{ (gage height in ft. Congaree River)} + 26.9$$

However, elevated turbidity in Cedar Creek in May and early June 2007 was not significantly related to gage height in either stream ($p > 0.05$). Thus, at times elevated discharge in either Cedar Creek or the Congaree River may increase Cedar Creek turbidity to high concentrations. We note that these elevated turbidity measurements well exceed those seen in blackwater streams in southeastern North Carolina except during pollution incidents (Ensign and Mallin 2001; Mallin et al. 2006).

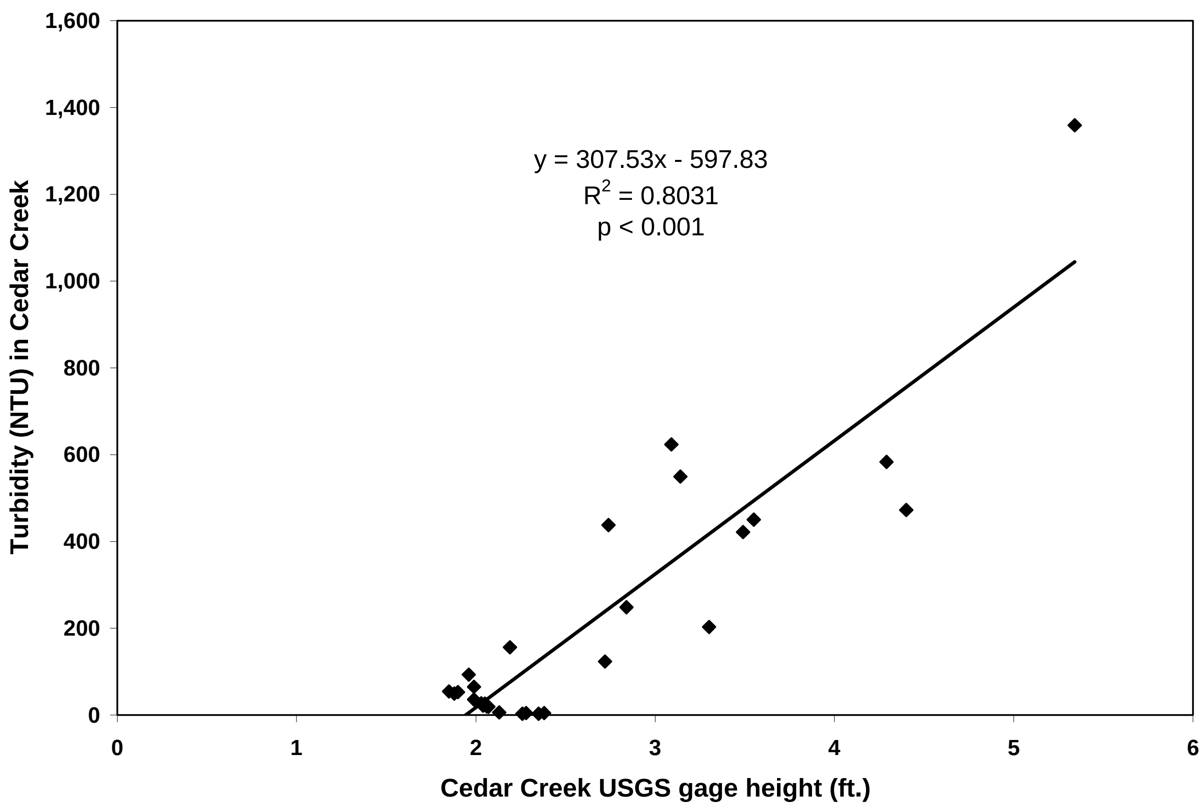


Figure 10. Regression equation predicting Cedar Creek turbidity at CONGccbr site using USGS-generated stream gage height in Cedar Creek Station 02169672, July 18 – August 14, 2008.

Because Cedar Creek has been designated by the State as Outstanding National Resource Waters (ONRW) from Wise Lake to the Congaree River, this issue needs further attention. We recommend that CONG perform a study to determine the sources of the turbidity in Cedar Creek. This can take the form of a rainfall/runoff study; i.e. when heavy or persistent rain events are detected in the Cedar Creek watershed CONG staff can spot sample (daily) by truck various bridge or other locations upstream of CONG to measure turbidity to compare with data from CONGccbr. To test for turbidity coming into CONG from the Congaree River a similar series of samples can be obtained, although boat use would be required. Additionally, in either case sampling the creek by canoe within CONG would enhance the strength of the study. If results show a strong statistical relationship between turbidity within CONG and runoff from either the Cedar Creek or Congaree watersheds then these data can be used by NPS to push SCDHEC to force mitigative measures (Best Management Practices) on upstream areas to reduce stormwater runoff inputs to protect these designated protected park areas from pollution. In addition to field measurements, gage height data generated by USGS in both Cedar Creek and the Congaree River can be correlated to turbidity concentrations as in Figure 10 from CONGccbr to provide further analysis, and presumably, justification for runoff mitigative measures outside of the park boundaries.

Sampling by SCDHEC (2004a) has indicated that Cedar Creek upstream of the park is fully supportive of aquatic life at all three sites sampled. The portion of Cedar Creek within CONG is designated as Outstanding Resources Waters (ORW), except, as mentioned, the portion of this creek from Wise Lake to the Congaree River, reclassified as ONRW by the South Carolina General Assembly (the Cedar Creek designation was the first such designation of its kind for South Carolina waters). ONRW is the highest level of protection the State can offer. As such, there is no discharge permitted from domestic, industrial, agricultural or aquaculture facilities, and no open water dredged soil disposal. There is also no non-point source discharge permitted, including from agriculture, aquaculture, or concentrated animal feeding operations, and no dumping of trash or refuse. The USGS maintains a station (02169672) monitoring stream height.

A limited SCDHEC data set was presented in NPS (1998) for Cedar Creek just before it enters the park from Station C-075 (Table 18). None of the physical, chemical, or biological parameters showed excessive values in that data set. The United States Geological Survey (USGS) performed an intensive study on several Cedar Creek locations in and near CONG, sampling a broad variety of physical, chemical and biological parameters, some of which was reported in Maluk and Abrahamsen (1985). NPS (1998) provided summary data from that study for a Cedar Creek location just upstream of the park (Table 19). The data indicated that pH of the stream was low, as can be expected of a blackwater coastal Plain stream (Meyer 1990). There were no evident problems with low dissolved oxygen, in contrast to many blackwater streams in general (Meyer 1990; Mallin et al. 2004). Inorganic nutrients and chlorophyll *a* were low, characteristic of canopied blackwater streams not impacted by large nutrient sources, point or non-point (Mallin et al. 2004); the planktonic chlorophyll *a* would place this stream in the oligotrophic (low productivity, no algal bloom problems) category, based on an analysis of hundreds of temperate stream sites (Dodds et al. 1998). Thus, the historical data show Cedar Creek to maintain excellent water quality just upstream of the park.

Summary information provided in SCDHEC (2004a) for Station C-075 just upstream of the park showed no problems with dissolved oxygen, turbidity, nutrients or fecal coliform bacteria, and decreasing trends from 1987-2001 in turbidity and BOD5. There was an increasing trend for pH as well (SCDHEC 2004a). However, the STORET fecal coliform data for 2005-2006 showed some bacteria problems, with 21% of samples exceeding 200 CFU/100 mL (Table 18). Subsequent 2007 showed no samples exceeding the standard. The 2005-2006 data (Table 18) showed no problems with dissolved oxygen or turbidity, and nutrient concentrations were typical of wooded blackwater streams (Ensign and Mallin 2001; Mallin et al. 2004).

At the Cedar Creek site C-069 well upstream of the park SCDHEC (2004a) has rated this site as partially supportive for recreational uses based on fecal coliforms. However, the lower station C-075 (Figure 9) nearest the park is rated as fully supportive of recreational uses.

Table 18. Cedar Creek water quality collected at USGS gauging platform near S-40-734; SCDHEC Station C-075. Data presented as mean ± standard deviation / range / median. Sample size (n) = 24 for all data unless otherwise noted.

	11/1996 - 06/1997 SCDHEC data in NPS (1998)			**1/2005 - 12/2006 Most Recent STORET data**		
Parameter	**Mean**	**Range**	**Median**	**Mean**	**Range**	**Median**
Turbidity (NTU)	3.7+2.2 [a]	1.1-7.1 [a]	2.8 [a]	4.0+3.0	2.0-17.0	2
Dissolved oxygen (mg/L)	9.0+1.5 [b]	7.4-11.3 [b]	8.7 [b]	7.5+1.3	4.6-9.8	7.3
BOD5 (mg/L)	1.7+0.48 [a]	1.0-2.3 [a]	1.8 [a]			
Nitrate-N (mg-N/L)	0.106+0.093 [a]	0.040-0.340 [a]	0.09 [a]	0.050+0.030	0.010-0.110	0.04
Ammonium-N (mg-N/L)	0.038+0.027 [c]	0.025-0.090 [b]	0.025 [b]	0.120+0.060	0.030-0.290	0.01
Total Kjeldahl nitrogen (mg-N/L)	0.567+0.229 [a]	0.250-0.960 [a]	0.5 [a]	0.540+0.210	0.240-0.980	0.05
Total phosphorus (mg-P/L)	0.026+0.010 [a]	0.010-0.040 [a]	0.03 [a]	0.020+0.010	0.010-0.050	0.02
Fecal coliform bacteria (CFU/100 mL)	152+105 [d]	23-280 [d]	113 [d, e]	171+392	9-2,000	70 [e]

[a] n=9 samples, [b] n=8 samples, [c] n<9 samples, [d] n=8 samples, [e] geometric mean

Table 19. Cedar Creek water quality, 1/96 – 3/97, collected 500 ft. downstream from junction of Reeves and Myers Creeks with Cedar Creek (near SCDHEC Station C-075). Data presented as mean ± standard deviation / range / median (USGS data summarized in NPS 1998).

Parameter	**Sample Size**	**Mean**	**Range**	**Median**
pH	55	5.8+0.7	4.5-7.8	5.7
Dissolved Oxygen (mg/L)	423	8.9+1.8	6.1-14.8	8.7
Chlorophyll a (µg/L)	113	1.8+1.4	0.3-8.2	1.4
Nitrate-N (mg-N/L)	82	0.092+0.089	0.020-0.400	0.060
Ammonium-N (mg-N/L)	82	0.039+0.020	0.015-0.096	0.032
Orthophosphate (mg-P/L)	82	0.028+0.043	0.001-0.150	0.007

Water Quality in Toms Creek. Toms Creek within CONG is designated as ORW by the State. However, Toms Creek in the vicinity of SC 48 (Station C-072) at and Red Bluff Road is considered by SCDHEC to be impaired by elevated fecal coliform bacteria, and at Red Bluff Road and near the power lines considered to have an impaired biological community (see Table 24). Summary information provided in SCDHEC (2004a) for 1987-2001 showed no dissolved oxygen, nutrient or turbidity problems at this site in Toms Creek just upstream of the park, and significant decreasing turbidity and BOD5 trends (and an increasing pH trend). From 1987-2001 23% of the samples collected exceeded the fecal coliform bacteria standard (SCDHEC 2004a). STORET data for 2005-2006 (Table 20) showed continuing bacterial problems with 29% of samples exceeding 200 CFU/100 mL, while 2007 data from SCDHEC showed 42% of samples exceeding the standard. Dissolved oxygen, turbidity, and nutrients were non-problematic for 2005-2006 (Table 20). A set of samples collected in 1996-1997 by USGS and summarized in NPS (1998) near SCDHEC Station C-579 found no problems with dissolved oxygen and low chlorophyll a and nutrients (Table 19). SCDHEC rates this site as partially supportive of aquatic life based on benthic macroinvertebrtate community data.

A set of samples was collected In Toms Creek just upstream of the park during 1988-1990 by the NPS consisting primarily of physical measurements and metals. Dissolved oxygen was suitable for stream life on all occasions sampled (Rikard 1991). However, concentrations of aluminum in the water column were considered to be at levels that could harm aquatic life (Rikard 1991 – also see subsequent section *Ecosystem Effects*).

Table 20. Toms Creek water quality, 1/96 – 3/97. Data presented as mean ± standard deviation / range / median. Left panel is USGS data collected from bridge over Toms Creek 1.5 mi NW of Kingville near SCDHEC Station C-579 summarized in NPS (1998), variable n, right panel is SCDHEC data collected at Station C-072. Sample size (n) = 24 for all data unless otherwise noted.

	1/1996 - 03/1997			1/2005 - 12/2006		
Parameter	**Mean**	**Range**	**Median**	**Mean**	**Range**	**Median**
pH	5.6±0.5 [a]	4.3-6.6 [a]	5.5 [a]	6.0±0.5	5.5-7.4	5.8
Turbidity (NTU)	--	--	--	3.0±1.0	2.0-4.0	3
Dissolved oxygen (mg/L)	8.1±1.8 [b]	5.0-12.9 [b]	8 [b]	7.3±1.4	4.2-9.8	7.1
Chlorophyll *a* (µg/L)	0.8±0.9 [c]	0.0-7.7 [c]	0.5 [c]	--	--	--
Nitrate-N (mg-N/L)	0.171±0.103 [d]	0.020-0.400 [d]	0.1 [d]	0.220±0.100	0.050-0.430	0.22
Ammonium-N (mg-N/L)	0.034±0.017 [d]	0.013-0.087 [d]	0.03 [d]	0.130±0.070	0.030-0.360	0.11
Orthophosphate (mg-P/L)	0.034±0.073 [d]	0.001-0.570 [d]	0.009 [d]	0.020±0.010 [e]	0.010-0.050 [e]	0.01 [e]
Fecal coliform bacteria (CFU/100 mL)	--	--	--	344±861	40-4,400	143 [f]

[a] n=55 samples, [b] n=383 samples, [c] n=112 samples, [d] n=80 samples, [e] measured as total phosphorus, [f] geometric mean

In lower Toms Creek, after it is joined by Cedar Creek and just before it enters the Congaree River USGS also conducted an intensive study of several water quality parameters, including physical parameters, dissolved nutrients and chlorophyll *a*, summarized in NPS (1998). Interestingly, pH was higher within CONG than upstream of it (Table 21), possibly a result of inputs from oxbow lakes, sloughs, or groundwater as the stream meanders through the park. Dissolved oxygen concentrations were not problematic (Table 21), nitrate concentrations were somewhat higher than they were upstream of CONG, but chlorophyll *a* concentrations were low, likely due to the closed canopy and subsequent reduced sunlight availability in the forest. Chlorophyll *a* concentrations were within the oligotrophic category as defined by Dodds et al. (1993).

Table 21. Lower Toms Creek water quality, 2/96 – 11/97, collected in creek just before it enters the Congaree River within Congaree National Park. Data presented as mean ± standard deviation / range / median (USGS data summarized in NPS 1998).

Parameter	Sample Size	Mean	Range	Median
pH	48	6.5±0.4	5.3-7.5	6.5
Dissolved Oxygen (mg/L)	840	8.1±2.4	4.5-20.0	7.9
Chlorophyll a (µg/L)	97	1.1±0.8	0.0-4.2	0.8
Nitrate-N (mg-N/L)	72	0.300±0.171	0.020-0.600	0.3
Ammonium-N (mg-N/L)	72	0.052±0.020	0.024-0.111	0.051
Orthophosphate (mg-P/L)	80	0.030±0.033	0.004-0.150	0.02

Water Quality in Congaree Park Oxbow Lakes. Oxbows within CONG are classified as ORW by South Carolina; however, these lakes are not sampled by SCDHEC. An analysis by USGS in 1996-1997 provided data on three oxbow lakes: Weston Lake, Wise Lake, and Bates Old River, which was outside of the park at the time of study but now forms the border of the Bates Fork Tract - Figure 4; Plate 5). In contrast to the lotic systems discussed above, these lakes are subject to periodic low dissolved oxygen problems, especially Wise Lake (Tables 22-24). Also in contrast to the rivers and streams these lakes host algal blooms, sometimes of considerable magnitude (see chlorophyll a concentrations in Tables 22-24). We reiterate that Wise Lake hosted a large blue-green algal bloom in 2007, according to SCDHEC. For lakes exceeding 40 acres in size the State of South Carolina uses a chlorophyll a standard of 40 µg/L as a measure of waters impaired by nutrient loading. The oxbows are of course much smaller than 40 acres, but these values can serve as a guide at least. Based on a broad variety of lakes and reservoirs (Wetzel 2001, Tables 15-20) the mean chlorophyll a concentrations in Weston Lake and Bates Old River are characteristic of eutrophic systems (high productivity, with frequent algal blooms) while those of Wise Lake are characteristic of mesotrophic systems, which are moderately productive with occasional algal blooms. The analysis by Dodds et al. (1993) places all three lakes in the mesotrophic range.

A series of experiments on blackwater streams in southeastern North Carolina have demonstrated that, contrary to previous dogma, shallow blackwater streams can and do host algal blooms provided nutrients and sufficient light are available (Mallin et al. 2001; 2004). The North Carolina experiments demonstrated that phytoplankton growth was stimulated by nitrogen, but not phosphorus additions. When we computed inorganic N/P molar ratios for the CONG oxbows (Tables 22-24), mean values ranged from 4.3 (Weston Lake) to 6.8 (Bates Old River) and median ratios ranged from 6.2 (Weston Lake) to 9.8 (Wise Lake). These ratios are well below the Redfield Ratio of 16; values considerably greater than the Redfield Ratio are considered to be indicative of systems in which phytoplankton growth is phosphorus limited, while lakes with ratios well below the Redfield Ratio are generally considered to be nitrogen limited. Thus, phytoplankton production in these oxbows appears to be limited by nitrogen in general. These oxbows likely obtain nutrients from periodic flooding (and possibly groundwater inputs), and the canopy is open above the majority of the lake surface area, which would set the stage for algal blooms. Based on the mean and maximum chlorophyll a values and the occasional severe hypoxia, eutrophication is a periodic problem in the oxbow lakes of CONG.

Table 22. Weston Lake water quality, 1/96 – 3/97, collected within Congaree National Park. Data presented as mean ± standard deviation / range / median / n (USGS data summarized in NPS 1998). Bolded value exceeds the SC chlorophyll *a* standard for large lakes (no standard as such for small lakes).

Parameter	Sample Size	Mean	Range	Median
pH	57	6.1±0.6	6.0-7.5	6.7
Dissolved Oxygen (mg/L)	648	6.0±2.7	0.1-12.4	5.9
Chlorophyll a (µg/L)	116	8.2±8.0	0.1-40.1	5.3
Nitrate-N (mg-N/L)	81	0.037±0.074	0.002-0.400	0.01
Ammonium-N (mg-N/L)	81	0.023±0.017	0.006-0.108	0.018
Orthophosphate (mg-P/L)	81	0.031±0.041	0.010-0.150	0.01
Inorganic N/P	--	4.3	--	6.2

Table 23. Wise Lake water quality, 1/96 – 3/97, collected within Congaree National Park. Data presented as mean ± standard deviation / range / median / n (USGS data summarized in NPS 1998). Bolded value exceeds the SC chlorophyll *a* standard for large lakes (no standard as such for small lakes).

Parameter	Sample Size	Mean	Range	Median
pH	51	5.8±0.5	4.1-6.8	5.9
Dissolved Oxygen (mg/L)	503	4.7±2.5	0.1-10.0	4.6
Chlorophyll a (µg/L)	104	18.4±21.4	0.4-115.4	8.4
Nitrate-N (mg-N/L)	74	0.033±0.040	0.001-0.200	0.02
Ammonium-N (mg-N/L)	74	0.029±0.035	0.009-0.305	0.022
Orthophosphate (mg-P/L)	74	0.022±0.032	0.001-0.140	0.01
Inorganic N/P	--	6.2	--	9.4

Table 24. Bates Old River water quality, 1/96 – 3/97, collected within Congaree National Park. Data presented as mean ± standard deviation / range / median / n (USGS data summarized in NPS 1998). Bolded value exceeds the SC chlorophyll *a* standard for large lakes (no standard as such for small lakes).

Parameter	Sample Size	Mean	Range	Median
pH	12	6.7±0.4	4.8-7.1	6.1
Dissolved Oxygen (mg/L)	95	7.5±3.0	2.9-11.6	7.2
Chlorophyll a (µg/L)	24	18.2±32.9	1.0-164.0	10.7
Nitrate-N (mg-N/L)	17	0.090±0.016	0.002-0.300	0.04
Ammonium-N (mg-N/L)	17	0.060±0.060	0.010-0.180	0.037
Orthophosphate (mg-P/L)	17	0.049±0.074	0.005-0.290	0.02
Inorganic N/P	--	6.8	--	8.5

<u>Water Quality in the Wateree River.</u> Much of the Wateree River downstream of Lake Wateree is impaired for fish consumption by mercury. In addition, SCDHEC considers the Wateree River well upstream of the park at I20 impaired by low dissolved oxygen (see Table 28). At the SCDHEC station nearest the park, CW-222/SC-002, summary information provided in SCDHEC (2005) found no problems with dissolved oxygen, turbidity, nutrients or fecal coliform bacteria, and found significant decreasing trends in turbidity and fecal coliform bacteria from 1988-2002. STORET data from 2005-2006 showed only one of 23 fecal coliform samples exceeding the standard of 200 CFU/100 mL, while SCDHEC data for 2007 showed all samples to be less than 200 CFU/100 mL. Data from 2005-2006 showed dissolved oxygen reflecting good conditions, while turbidity on rare occasions will exceed the standard (Table 25), while 1984-1996 data showed generally good dissolved oxygen, low average BOD5 and turbidity that was elevated on occasion (Table 25). Nutrients in the Wateree River were low to moderate compared with other regional riverine systems (Meyer 1992; Mallin et al. 1999; Burkholder et al. 2006).

Table 25. Wateree River water quality collected 2.5 km upstream of confluence with the Congaree River; SCDHEC Station CW-222/SC-002. Data presented as mean $\pm$ standard deviation / range / median.

	02/1984 - 12/1996 SCDHEC data in NPS (1998)			**1/2005 - 12/2006 Most Recent SCDHEC STORET data**		
Parameter	**Mean**	**Range**	**Median**	**Mean**	**Range**	**Median**
Turbidity (NTU)	17.6+10.2 [a]	1.4-80.0 [a]	16.1 [a]	21.0+13.0	5.0-56.0	18
Dissolved oxygen (mg/L)	8.0+1.8 [b]	4.7-13.2 [b]	7.8 [b]	8.0+1.6	5.7-11.0	7.8
BOD5 (mg/L)	1.1+1.7 [c]	0.1-17.0 [c]	0.9 [c]	--	--	--
Nitrate-N (mg-N/L)	0.386+0.189 [d]	0.010-1.15 [d]	0.37 [d]	0.460+0.110	0.200-0.640	0.47
Ammonium-N (mg-N/L)	0.083+0.083 [e]	0.010-0.500 [e]	0.06 [e]	0.150+0.080	0.030-0.390	0.12
Total Kjeldahl nitrogen (mg-N/L)	0.524+0.605 [d]	0.050-6.640 [d]	0.605 [d]	0.400+0.140	0.110-0.670	0.39
Total phosphorus (mg-P/L)	0.088+0.06 [f]	0.010-0.600 [f]	0.08 [f]	0.070+0.020	0.030-0.100	0.07
Fecal coliform bacteria (CFU/100 mL)	--	--	--	716+855	5-2,100	36 [g]

[a] n=166 samples, [b] n=126 samples, [c] n=99 samples, [d] n=122 samples, [e] n=121 samples, [f] n=123 samples,
[g] geometric mean

Groundwater Quality

Groundwater quality in terms of nutrients or toxins is not sampled within the park. USGS monitors water levels only. There are two wells for drinking water in the park, located at the Harry Hampton Visitors Center and Old-Growth Bottomland Forest Research and Education Center that are screened at different depths. As mentioned, well water is drawn from 36 m (118 ft), chlorinated and monitored for fecal bacteria by DHEC. There are at least two old supply wells in the park that are non-potable and no longer in use located near Wise Lake and Dawson's Cabin. In addition, the Old-Growth Bottomland Forest Research and Education Center at CONG maintains a groundwater well network along Sims Trail that consists of 10 shallow groundwater wells up to 7 meters deep. Data loggers measure water height and temperature every 30 minutes. Data are downloaded periodically. These wells are maintained by CONG staff through a partnership with College of Charleston and Furman University (Shelley et al. 2008).

Ecosystem Effects

Water quality issues that could affect the flora and fauna of park waters include natural or anthropogenically caused hypoxia, excessive nutrient loading leading to eutrophic conditions (and subsequent hypoxia) and toxic compounds in the surface or groundwaters that could affect survival or growth.

Hypoxia and Anoxia. Blackwater streams in coastal lowland areas are often afflicted with hypoxia (< 4.0 mg/L DO) during summer. This is because these streams have abundant sediment bacteria populations, are fed by drainage from swamp water already low in dissolved oxygen, and have high organic carbon (principally dissolved) loads that exert a biochemical oxygen demand on the water (Meyer 1992). Because these streams already have low summer DO levels, they are especially sensitive to additional anthropogenic inputs of BOD that can drive DO concentrations even further to stressful levels (Mallin et al. 2004). However, the Congaree River, the lower Wateree River, Cedar Creek and Toms Creek do not appear to have low dissolved oxygen problems. As mentioned, the Wateree River upstream is impaired by low DO but that problem is not an issue downstream near the park.

The dissolved oxygen data on the oxbow lakes are not long term and not recent, but the existing data (Tables 22-24) shows that DO mimima can reach near-anoxic conditions, and a set of over 500 samples showed Wise Lake to have mean and median DO concentrations below 5.0 mg/L. Thus, these oxbows are subject to this ecosystem problem at times. Such hypoxia and anoxia issues can be exacerbated by eutrophication. This problem can be exacerbated by inputs of either nitrogen or phosphorus, or both together. As mentioned above, blackwater systems can and do host algal blooms provided nutrients and sufficient light are available, and experiments demonstrated that phytoplankton growth was stimulated by nitrogen, but not phosphorus additions, and that bacterial growth was stimulated by phosphorus, especially organic phosphorus (Mallin et al. 2001; 2004). In the experiments significantly increased BOD occurred due to the indirect photosynthetic pathway of nitrogen inputs stimulating algal growth, which in turn dies and becomes organic matter, stimulating bacterial growth and BOD. Phosphorus inputs increased BOD by directly stimulating bacterial growth (heterotrophs). In a variety of rivers, lakes and streams in southeastern North Carolina (Mallin et al. 2006) have shown strong correlations between chlorophyll *a* concentrations and BOD. Since the oxbow lakes within Congaree Park have been shown to host periodic algal blooms, and are likely limited by nitrogen they may be subject to periods of hypoxia following nitrogen-induced blooms through floodwater inputs. Likewise, inputs of phosphorus may stimulate bacterial growth and BOD. Thus, a limnologically based research program focused on the oxbow lakes is a desirable goal.

Fish kill information is accumulated by SCDHEC (J.R. Rice, personal communication) in data files but is presently in the process of reorganization. The available information showed that fish kills have not been reported from CONG specifically, but a number (<20) fish kills have been reported in the Congaree and Wateree Rivers and their tributaries since 1985 over the years for various reasons, including temperature changes, low dissolved oxygen, and turbine blades. Species affected were generally sunfish and shad, with the number affected ranging from less than 10 to 2,000 individuals.

Water Column Toxicity. Exposure to toxicants including pesticides, PCBs, PAHs, metals and other compounds can affect organism reproduction and community health. There is a fish consumption advisory mainly for mercury in several fish species in the Congaree area; this is discussed further below. In terms of fish reproduction, experiments run using water from the Congaree, Wateree and Santee Rivers found that striped bass *Morone saxatilis* larvae had high mortality when exposed to Wateree River water, whereas water from the other two rivers was not toxic but the larvae swam lethargically compared with control water (Finger and Bulak 1988). The specific cause of toxicity was not determined, although elevated concentrations of the phenolic compound pentachloroanisole (PCA) were found in the Wateree. This compound, along with possibly other phenolic compounds was suspected in playing a role in the low larval survival in the Wateree (Finger and Bulak 1988).

An NPS study (Rikard 1991) found concentrations of aluminum in the water column of Myers, Toms and Reeves Creeks that were considered to be at levels that could harm aquatic life (>0.25 mg/L). A USGS study (Maluk and Abrahamsen 1999) found the presence of 12 pesticides in park stream waters. However, all concentrations were below criteria for the protection of aquatic life or human health. A USGS/SCDNR study on mercury in organisms and sediments in CONG found generally low levels of Hg in sediments (May et al. 2005). However, the authors found that approximately 10% of the whole fish samples analyzed exceeded the USEPA consumption advisory standard; the authors noted that most of the fish analyzed were small, and suspected that larger fish would have even greater body burdens. The impacted fish were widespread throughout CONG, collected at locations in Cedar Creek, Toms Creek, Dry Branch, Weston Lake and various tributaries.

Sediment Toxicity and Quality. Exposure to toxicants such as metals, pesticides and other organic contaminants can cause toxicity to benthic organisms and adversely impact living habitat of invertebrates and fish. Researchers have compiled sediment concentration data and consequent effects on benthic macroinvertebrates from multiple studies to produce a set of consensus-based guidelines for metals and organic contaminants for freshwater systems (MacDonald et al. 2000). While these are not Federal legal standards they provide helpful guidelines for researchers and natural resource managers freshwater as well (Table 26).

Table 26. Freshwater guideline values for sediment metals and organic pollutant concentrations (ppm, or μg/g, dry wt.) potentially harmful to aquatic life, based on consensus (MacDonald et al. 2000). TEC = (Threshold effect concentration). Concentrations below the TEC are those in which harmful effects on aquatic communities are not expected to occur. PEC = (Probable effect concentration). Concentrations above the PEC are those in which adverse effects are expected to occur more often than not. Concentrations between the TEC and PEC are those in which harmful effects occasionally occur.

Metal	TEC	PEC
Arsenic (As)	9.79	33
Cadmium (Cd)	0.99	4.98
Chromium (Cr)	43.4	111
Copper (Cu)	31.6	149
Lead (Pb)	35.8	128
Mercury (Hg)	0.18	1.06
Nickel (Ni)	22.7	48.6
Zinc (Zn)	121	459
Total PCBs	0.0598	0.676
Total PAHs	1.61	22.8
Total DDT	0.0058	0.572
Chlordane	0.00324	0.0176
Dieldrin	0.0019	0.0618

Table 27. Locations near or in Congaree Park where sediment metals have been found in potentially toxic concentrations according to estuarine guidelines (revised from Maluk and Abrahamsen 1999). Bolded indicates concentrations exceeding the TEC; none of the concentrations exceeded the PEC (MacDonald et al. 2000).

	Cr	Cu	Pb	Ni	Total DDT
Congaree R. Columbia Left Bank	**74**	46	**68**	**28**	**0.0093**
Congaree R. Columbia Right Bank	**85**	50	**36**	**35**	**0.0084**
Congaree R. at Hwy 601	**92**	**39**	**55**	**35**	0.0038
Myers Creek	**70**	18	**76**	**27**	**0.0147**
Cedar Creek before park	**70**	20	**49**	**22**	0.0002
Cedar Creek near Wise Lake	**92**	**37**	**54**	**35**	0.0042
Toms Creek	**68**	13	**50**	20	0.0051

A study by USGS (Maluk and Abrahamsen 1999) collected sediment metals data from the Congaree River, Cedar Creek and Toms Creek. Metals found in potentially harmful concentrations included chromium, copper, lead and nickel (Table 27). We note that these collections did not find metals levels that were likely to produce adverse effects (i.e. >PECs) but many concentrations exceeded the TECs (those below where adverse effects were unlikely to occur). The mercury study performed by May et al (2005) likewise found all sediment Hg samples to contain less than the TEC. Thus, there are potential metals toxicity problems in sediments in and near CONG; however, the concentrations found are not associated with the strong likelihood of sediment toxicity (Table 26). Several organochlorine pesticides were also sampled from the sediments in the Maluk and Abrahamsen (1999) study. Of these, only total

DDT exceeded the TEC in three locations, the Congaree River at Columbia and Myers Creek (Tables 26, 27).

Groundwater Toxicity. There are no known underground storage tanks within the park, however groundwater contamination is of concern from CERCLA sites, underground storage tanks, and landfills within the watershed. The Water Resources Management Plan for Congaree National Park (Knowles et al. 1996) specifically addresses an EPA-NPL site located approximately 4 miles from the northeast boundary of the park. This site includes a groundwater contaminant plume and soil contamination from various containerized toxic and hazardous materials. Underground storage tanks are also mentioned (Knowles et al. 1996), which includes 2 sites in Eastover, SC that may border the Tom's Creek watershed that present the possibility of groundwater contamination in the park from petroleum. As of 1996, there were eleven permitted solid waste landfills in Richland County, and their potential to contaminate groundwater in the park is addressed (see Knowles et al. 1996 p. 75). Testing and monitoring groundwater within the park for xenobiotic compounds remains an need.

Human Health Issues

Waterborne factors potentially influencing human health can be assessed by several metrics. These metrics include water contact safety in terms of either fecal coliform bacterial, *Enterococci* or *E. coli* counts, and water contact or aerosol safety in terms of toxic algal blooms, and finfish or shellfish toxicant body burdens. Human contact with toxic or otherwise dangerous chemicals in surface or groundwaters is another potential issue.

Microbial Pathogens and Human Contact: Humans can contract illness through contact with microbially contaminated waters while swimming, wading, or working in contaminated water if pathogenic viruses, bacteria or protozoans enter the individual through the mouth, nose, eyes, or open wounds. The South Carolina freshwater standard for human contact is not to exceed a geometric mean of 200 CFU/100 ml of fecal coliform bacteria based on five samples during a 30 day period, nor shall more than 10% of the total samples during a 30 day period exceed 400 CFU/100 mL (SCDHEC 2004a).

At Station C-074 in the Congaree River at the west edge of the park (Figure 9), fecal coliform data collected by SCDHEC and placed into STORET showed few problems at this site historically but 2005-2006 data showed a recent upswing in fecal coliform bacteria counts. Farther downstream at C-007 near Highway 601 there were minor fecal coliform problems according to the most recent data. Cedar Creek as it enters the park (Station C-075) had historically good quality water in terms of fecal coliform bacteria, but had some problems in 2005-2006, with a return to excellent conditions in 2007. As indicated in Table 28, Toms Creek is considered by SCDHEC to be impaired by excessive fecal coliform counts. Historical and recent SCDHEC data from Toms Creek show poor bacteriological water quality (SCDHEC 2004a; Table 18). The sources may be agriculture, animal waste, or land disturbing activity upstream of the park, or septic system failures upstream of the park. All dwellings in this watershed are utilizing septic systems (Maliszewski 2005). The Wateree River near CONG continues to manifest good water quality in terms of fecal bacteria.

Montebello (2008) performed a study of *Enterococcus* and *Escherichia coli* abundance at several stations located in Cedar Creek, Toms Creek, Wise Lake and Weston Lake (as a high school project for the state science fair). Based on EPA criteria, the stations in upper Cedar Creek at the canoe launch, Wise Lake, and Weston Lake maintained safe water quality at all times for these two fecal bacteria indicators. However, lower Cedar Creek near Wise Lake and farther downstream at the canoe landing, as well as two stations on Toms Creek, often did not meet the EPA criteria (Montebello 2008). A limited number of samples were sent to a contracting laboratory to determine if human DNA markers were present. The samples were negative for human presence except for one sample from Toms Creek, which showed a human gene biomarker based on a fecal *Bacteroides* test (Montebello 2008). As mentioned earlier, we saw evidence of feral hog rooting activity near lower Cedar Creek in the vicinity of Wise Lake, and we also spotted a feral hog in the vicinity of the lake. Thus, we suspect that these large mammals may be contributing at times to fecal water pollution within the park.

Wastewater within the park is treated by septic systems, which are potential sources of fecal pathogens. However, all are well away from Cedar Creek and other water bodies and have posed no problems technically, and thus should pose no threat to the park surface water quality. Since the drinking well water is drawn from over 118 ft (36 m) depth in the lower aquifer these septic systems pose no threat to the well water (which is chlorinated and tested regardless).

Exposure to Toxic Algae: Humans can also be adversely affected by skin contact with water containing toxic algae or breathing aerosols containing toxins from such algae. In freshwater systems, a number of cyanobacterial (blue-green algal) species contain toxins injurious to humans (Burkholder 2002). There is presently no information available on the presence or absence of toxic algal blooms in the waters of CONG. There was a documented blue-green algal bloom in Wise Lake in 2007 that was identified to genus *Oscillatoria* (T. Thom, NPS, personal communication). However, no fish kill was noted and there was no other information on potential toxicity of this bloom. Additionally, the oxbow lakes are subject to period excessive chlorophyll *a* concentrations (Tables 22-24). This, the occurrence of a toxic blue-green algal bloom within the park is possible but would probably be rare.

Fish Toxicant Body Burdens: Eating fish with body burdens high in contaminants can be a human health hazard. Several fish species in this region have high mercury body burdens and consuming more than four meals per month of these fish is considered hazardous. In the Congaree River from Columbia to the Santee River the consumption of bowfin, largemouth bass, and chain pickerel is restricted to one meal per week, and in the Wateree River from Lake Wateree to the Congaree River consumption of bowfin and flathead catfish is restricted to one meal per week. Fish advisory information can be found at this website: http://www.scdhec.net/environment/water/fish/index.htm. Fishing is permitted in all waters of the park except for Weston Lake, so toxicant body burdens are a concern.

List of impairments (State and Federal listings)

South Carolina DHEC determines if the water quality of the water bodies of the state meet their intended use classifications, or if they are impaired. To make these determinations they utilize water quality data, benthic macroinvertebrate data, and/or fish and shellfish consumption advisories based on fecal bacteria pollution or toxicant body burden data. Briefly, for parameters such as dissolved oxygen, pH, turbidity, phosphorus, nitrogen, and chlorophyll *a*, when the state standard is exceeded in more than 25% of samples collected the criterion for that particular measure is not supported. Benthic macroinvertebrate community impairment is determined

utilizing the already-mentioned EPT Index and the North Carolina Biotic Index (BI). Stream stations can be rated for either Recreation or Aquatic Life, or both, depending upon classification and what is measured at any given site. Water bodies are rated at point locations; however, the impairment is considered to extend for some distance upstream and downstream of the listed point location (SCDHEC 2004a; 2004b). There are several water bodies outside of but upstream of and within reasonable proximity of the park that are listed on the 2008 South Carolina 303(D) list as Impaired Waters, located in Richland, Fairfield, Sumter and Kershaw Counties. These waters will require a TMDL (total maximum daily load) to bring them into water quality compliance (South Carolina Department of Health and Environmental Control records). These water bodies are listed in Table 28; further information on determination of impairment is available at the following website:
http://www.scdhec.net/environment/water/tmdl/docs/tmdl_08_303d.pdf.

List of Water Bodies with Undocumented Conditions/ Status

Most rivers and streams immediately adjacent to or impacting the park have ratings for designated uses (SCDHEC 2004a; SCDHEC 2005, Table 28), with the exception of McKenzie Creek, Dry Branch, Griffins Creek, Singleton Creek and Running Creek/Running Lake. DHEC only provides use support ratings to water bodies that have DHEC monitoring sites. These streams have no SCDHEC monitoring sites on them and are thus not rated (simply designated as FW), except for portions lying within CONG, which are rated ORW as noted earlier. To reiterate, all waters within CONG are rated ORW except for the portion of Cedar Creek from Wise Lake to the Congaree River, which is rated ONRW. The Congaree River itself is not rated ORW, although it adjoins the park.

Table 28. Water bodies located upstream and near Congaree National Park that are considered impaired and are on the South Carolina 303(d) list, including the reason and target date for completed TMDL. Locations are limited to the areas on the Broad, Saluda and Congaree Rivers near and downstream of Columbia, creeks directly entering Congaree Park, and on the Wateree River downstream of Lake Wateree. We note that a number of locations in Lake Wateree are impaired for phosphorus, dissolved oxygen and pH. Also, areas in Lake Murray are impaired for chlorophyll *a*, phosphorus, copper and pH.

Basin	Water body and location	Reason	TMDL target date
Broad	Broad River at SO. RR trestle, 0.5 mi DS of SC 213	Cu	2018
Broad	Broad River at US 176 (Broad River Rd.) in Columbia	Cu	2018
Broad	Smith Branch at N. Main St. (US 21) in Cola	biological community	2013
Broad	Crane Creek at US 321	biological community	2013
Broad	Crane Creek at S-40-43 under I-20 in Cola	dissolved oxygen	2021
Saluda	Saluda just below Lake Murray Dam	Hg	2017
Saluda	Broad River diversion canal at Cola Water Plant	fecal coliforms	2009
Saluda	Congaree River at Barney Jordan Ramp	Hg	2017
Saluda	Congaree River at State Highway 378	Hg	2017
Saluda	Congaree River at Blossom St.	fecal coliforms	2011
Saluda	Congaree River at west boundary of Congaree Park	fecal coliforms	2011
Saluda	Congaree River at Devro-Teepak discharge outfall	Cu	2011
Saluda	Congaree River at US 601	Cu, fecal coliforms, Hg	2011, 2017
Saluda	Cedar Creek at S-40-734	biological community	2015
Saluda	Toms Creek at SC 48	fecal coliforms	2008
Saluda	Toms Creek at power line and railroad track	biological community	2013
Saluda	Toms Creek at Red Bluff Rd.	biological community	2013
Saluda	Toms Creek at Red Bluff Rd.	fecal coliforms	2013
Catawba	Wateree River below Lake Wateree Dam	Hg	2017
Catawba	Wateree River at I-20	Hg, dissolved oxygen	2010, 2017
Catawba	Wateree River at US 378/76	Hg	2017

Other Areas of Concern

Development Trends

Land Use

Land use affecting CONG includes both the immediate area within the park, and the watershed upstream that drains into it. As mentioned earlier (Figure 6), the Congaree River Basin drains 668 mi^2 (1730 km^2), and it's land use consists of 51.7% forested land, 16.9% agricultural land, 15.8% is forested wetland, 10.8% is urban land, 2.8% is barren land, 1.6% is water and 0.4% is marsh (SCDHEC 2004a). The Bates Fork Tract is officially within the lower Congaree River Watershed, but is also strongly influenced by flooding from the Wateree River Watershed (SCDHEC 2005). Land use within the Wateree 11-digit hydrologic unit (Figure 6) consists of 56.5% forested land, 19.4% forested wetland, 13.0% agricultural land, 4.7% scrub/shrub land, and 3.6% urban land, 2.4% water, 0.3% marsh and 0.1% barren land (SCDHEC 2005). Thus, of the watersheds immediately impacting CONG, approximately 70% of the Congaree and 76% of the Wateree watersheds are either forested or wetland of various types. This is good in that these forest and wetlands serve as buffers to reduce overland runoff pollution to the creeks and rivers impacting the park. The challenge is to keep the wetlands from being drained and developed (which may impact groundwater levels within CONG by incising Cedar or Toms Creeks (see Shelley et al. 2008), and keep clearcutting of forests to a minimum to reduce runoff impacts.

Congaree Park Land Use Issues: One potential concern is stormwater runoff from impervious surfaces, leading to increased loading of pollutants into waterways. Pollutants that are often associated with stormwater runoff include fecal coliform bacteria, nutrients, BOD, PAHs and airborne pollutants. The parking lot near the Visitors Center (Figure 1) is situated well away from any of the creek channels passing through the park. Therefore, thus rain events and not likely to cause runoff within the park that will impact the water features and associated biota. Presently there are two septic systems used to treat human sewage in Congaree National Park. But as mentioned, their location appears to pose no threat to the creek or drinking well water.

Watershed Land Use Issues: SCDHEC (2004a) notes that the Congaree River Watershed 03050110-010 has a high potential for growth, especially in various areas of the City of Columbia and its metropolitan area, and they note in particular that the Bluff Road area of Columbia should experience heavy growth. Heavy urban growth will increase the amount of watershed impervious surface area and subsequent pollution runoff into the streams and river. Along Bluff Road west of CONG several clearcut areas are visible from the road. Clearcuts increase the amount of pollutant loading to nearby creeks, including suspended sediments, nutrients, and fecal bacteria, and can lead to algal blooms and low dissolved oxygen problems as well (Ensign and Mallin 2001). The Cedar Creek Watershed is considered by SCDHEC (2004a) to have low to moderate growth potential. This watershed contains part of the City of Columbia, and part of Bluff Road, which was mentioned above. The upper portion of the watershed drains Fort Jackson Army Base. There are no listed major NPDES dischargers in the fort, but chemical spills from military activities on the base could impact the park. CONG personnel have indicated that it would be desirable to have agreements between the base and park in which the park will be immediately notified if a pollutant spill occurs on the base that impacts Cedar Creek or its tributaries. Toms Creek is described as having low potential for growth by SCDHEC (2004a). It is largely rural and agricultural. As mentioned, this creek is impaired by fecal bacteria and has an impaired biological community. Sources of fecal pollution including septic systems and the horse farm bear investigation, and potentially one of the afore-mentioned poultry farms (ND0068268). The lower Congaree River Watershed 03050110-070 is described by SCDHEC (2004a) as having low growth potential. The Wateree River Watershed is described by SCDHEC (2005) as having a high growth potential. The upper portions of the watershed contain the City of Camden, the Town of Lugoff, and military bases. Along with the increased runoff potential from more impervious surface coverage, expansion of wastewater discharges is planned. All of this will increase pressure on the water quality of the lower Wateree River that impacts (through flooding) the Bates Fork Tract of the park.

Surface and Groundwater Withdrawals

Whereas the Mountains and Piedmont provinces utilize mostly surface waters for human use, the Sandhills and Coastal Plain have several aquifers presently in use, including the Florida Aquifer system, Black Mingo Aquifer, Pee Dee Aquifer, Black Creek Aquifer, Middendorf Aquifer and Cape Fear Aquifer (SCDHEC 2007). SCDHEC has some relevant available information on water use in the watersheds impacting CONG, including specific information on the Catawba/Wateree basin facilities for 2004 (SCDHEC 2006), and a summary report on South Carolina water usage by county for 2006 (SCDHEC 2007). Only withdrawals exceeding three million gallons/month are required to report water use to the State. In the counties upstream of CONG, the major water use is hydroelectric power (flow-through) followed by thermoelectric power, which is primarily cooling water for fossil fuel and nuclear power plants (SCDHEC 2007). Industrial and municipal water supply are distant third and fourth uses, while golf course and crop irrigation consume far less water (SCDHEC 2007). In general groundwater usage comprises only a small percentage compared with surface water use.

For the Catawba/Wateree basin, there are 25 facilities withdrawing surface water and 13 withdrawing groundwater, and 11 with dual withdrawal (SCDHEC 2006). Total water withdrawal for 2004 in the basin was 5,714,252.22 million gallons, of which 95.4% was flow-through hydroelectric power generation. Of the non-hydroelectric use, groundwater withdrawals comprised only 1,647.55 million gallons, or less than one percent. For the total 2004 surface withdrawals, besides hydroelectric power production there was 207,486.20 million gallons used for thermoelectric generation, 34,933.37 used for industrial purposes, 15,768.62 million gallons for water supply, 394.30 million gallons for crop irrigation and 218.18 million gallons used for golf course irrigation. Of the total 2004 groundwater withdrawals, 803.28 million gallons were for industrial purposes, 610.78 million gallons were for water supply, 125.57 million gallons for golf course irrigation, 94.93 million gallons for crop irrigation and 13.00 million gallons for mining. Permitted transfers out of the basin accounted for 17.79 million gallons per day while permitted transfers into the basin totaled 4.5 million gallons per day, for a net transfer out of the basin of 13.29 million gallons per day.

Within CONG proper, surface waters are not utilized for drinking purposes. Well water is used for drinking, drawn up from a 36 m (118 ft depth - the deep aquifer). Patterson et al. (1985) noted that ground water pumping at current rates has had little effect on water levels in CONG, and only a major increase in pumpage near CONG would be likely to affect water levels in the shallow aquifer. Patterson et al. (1985) also emphasized that the deep aquifer, from where water is presently drawn, is largely isolated from the shallow aquifer (and the park plant root zone) by a confining layer. As noted previously, shallow groundwater within CONG is largely fed by rainfall and from groundwater moving into CONG from outside the park, and it reaches the surface in seeps in upper areas of the park.

Nuisance and Invasive Species

Non-native aquatic organisms such as fish, nuisance bivalves, or other food web-altering organisms would most likely enter CONG through the Congaree River when it floods, or the Wateree River (for the new tract). There are also (more rare) introduction possibilities such as deliberate release by humans, introduction via fishing bait or on tackle, and brought in by birds. As of now, invasives and non-natives have been confined to either terrestrial mammals including feral hogs, the Asian clam *Corbicula* or terrestrial plants, although the status of aquatic macrophytes within the park is presently unknown.

Physical Impacts

Physical changes to the landscape may impact water quality. Disturbances such as hurricanes and floods are natural phenomenon that impact flora and fauna. Hurricane Hugo caused a considerable amount of tree damage within CONG, particularly in mixed bottomland forests (Putz and Sharitz 1991). However, water quality degradation by hurricanes is most often a function of impacts to upstream human infrastructure and pollution sources (Mallin and Corbett 2006). A severe hurricane impacting Columbia would likely bring polluted water into the park during flooding.

Continuous Land Impacts

Within CONG there are nature trails used by the public, which need to be surveyed periodically to see if overuse and degradation of the resource occurs. There are three designated camping areas in the park, which can lead to some land disturbance. Upstream of the park are areas where powerlines cross streams that later enter the park. Spraying of herbicides may potentially lead to runoff of such chemicals entering the streams; likewise cutting/bush-hogging/mowing in these areas can enhance runoff. A railroad runs through the park and crosses streams and the river. Maintenance activities by the railroad can potentially impact the water locally. Active construction/expansion along the railroad is expected to begin in 2011, and active construction is currently occurring along the 601 Highway bridge corridor on the Congaree River.. The major physical impacts caused by feral hogs within the park are continuous, as mentioned earlier.

Acute Land Impacts in the Park

There is presently no construction activity ongoing within the park that can impact water quality. Land clearing or watershed construction activity upstream of the park has the potential to impact the creeks entering CONG, especially in terms of suspended sediments, turbidity and possibly fecal bacteria.

Stressors to Congaree National Park Water Bodies

The body of this report details water quality issues impacting the rich aquatic resources within CONG. The most pressing issues are termed stressors, and are displayed below (Table 29) for each of the major water systems within or impacting humans, wildlife or the ecosystems within CONG. More detail explaining the table’s conclusions is provided subsequently.

Table 29. Current and potential stressors that are affecting or may affect Congaree National Park habitats. [EP – existing problem, OK – low or no problem, PP – potential problem, ND – no data to make judgment].

Stressor	Cedar Creek	Toms Creek	Wellwater	Oxbows	Congaree River	Wateree River
Algal Blooms	OK	OK	OK	EP	OK	OK
Toxic Algae	OK	OK	OK	PP	OK	OK
Nutrient Loading	OK	OK	OK	PP	PP	PP
Excessive Nitrate	OK	OK	OK	OK	OK	OK
Hypoxia	OK	OK	OK	EP	OK	OK
Sedimentation	OK	OK	OK	OK	PP	PP
Turbidity	PP	OK	OK	OK	PP	PP
Erosion	PP	PP	OK	OK	OK	OK
Fecal Bacteria	PP	EP	OK	OK	EP	OK
Excessive Metals	PP	PP	OK	EP	EP[1, 2]	EP[1]
Toxic Compounds	OK	PP	OK	ND	OK	ND
Invasive Species	EP	EP	OK	EP	OK	OK
Habitat Disruption	EP[e]	EP[e]	OK	EP[e]	OK	OK

[1] Fish tissue mercury consumption advisory by SCDHEC
[2] Excessive copper in water
[3] Feral hogs
[4] Feral hog streambank and inland damage from rooting

Explanation of Stressors

Cedar Creek

This creek, where it enters the park, is not presently impaired by excessive fecal bacteria, low dissolved oxygen, nor is it experiencing algal blooms. However, there are data from one study that indicate elevated fecal bacteria in the creek near Wise Lake – which may be due to feral hog manure. There are also potential problems in the park with erosion of stream banks due to visible habitat damage by feral swine rooting; thus, feral hogs in particular may be causing a number of problems within the park. Within the park there is some evidence of elevated metals in sediments, which should be investigated further. That same USGS study (Maluk and Abrahamsen 1999) also found a substandard fish community in the creek near Wise Lake, although sampling problems may have contributed to that assessment. This stream has been designated as Outstanding National Resource Waters and has some protections outside of the park as such, but visible clearcutting along Bluff Road west of the park is cause for concern as well as urbanization moving eastward from Columbia. Automated water quality instrumentation operated by NPS and located within Cedar Creek has detected elevated turbidity pulses that can be quite severe, potentially linked to elevated stream discharge in both Cedar Creek and the Congaree River. To protect this important stream we recommend NPS initiate a study of the relationship between these turbidity pulses and rainfall/runoff episodes in the watersheds of both these streams.

Toms Creek

Toms Creek where it enters the park is considered impaired by SCDHEC due to an impaired biological community as well as elevated fecal coliform bacteria. As this is largely a rural/agricultural area the fecal coliform impairment is potentially due to poorly functioning septic systems and/or domesticated animal wastes. Metals pollution is potentially an issue for this creek system, and possibly toxic compounds that may contribute to impairment of the biological community. As with Cedar Creek, within the park rooting by feral hogs causes habitat destruction.

Drinking Water Wells

Drinking water is chlorinated and is thus not at risk from fecal bacteria. Furthermore, septic contamination, nitrate loading, or toxin contamination of drinking water is not likely due to the depth (118 ft) of the well supplying the Visitor Center, and the well (134 ft) supplying the Old-Growth Bottomland Forest Research and Education Center and associated buildings.

Oxbow Lakes

Limited existing data from a USGS project showed periodic algal blooms in which chlorophyll *a* well exceeded the state water quality standard, and average chlorophyll *a* concentrations put these oxbows in the mesotrophic and eutrophic ranges for freshwater lakes in general. It seems likely that nutrients periodically enter the oxbows from river flooding; the systems are poorly flushed, and there is an open canopy to provide plenty of sunlight for photosynthesis. There are periodic low dissolved oxygen problems as well, which can be caused in part by algal blooms. There is visible habitat damage near some of these oxbows from feral hog rooting.

Congaree River

Congaree River water quality is an issue from the constituents the floodwaters carry into the park aquatic habitats. There is a fish consumption advisory due to high mercury levels, and excessive copper concentrations are also listed as a cause for impaired waters by SCDHEC. The Congaree River well upstream of the park in Columbia, as well as in the reaches bordering the park is impaired by excessive fecal coliform bacteria. We reiterate that floodwaters bring pollutants into the park, and this would include fecal bacteria and metals. While not impaired for turbidity, this river clearly can become very turbid after significant rain events (Plate 9). Turbidity is often correlated with various pollutants so flooding with high turbidity (i.e. suspended sediments) will deposit pollutants in the park. While nutrients are not continually excessive in the river water, both nitrogen and phosphorus can reach very high concentrations at times. These nutrients are subject to movement into the oxbow lakes in the park, which support algal blooms.

Wateree River

The lower Wateree River near the park is not impaired except for fish consumption by mercury. This river does flood the portion of the park known as the Bates Fork Tract, and some of the same cautionary material described above for the Congaree River bears repeating here. Floodwaters bring pollutants into the park; while not impaired for turbidity, this river can become turbid after significant rain events. Turbidity is often significantly correlated with various pollutants so flooding with high turbidity (i.e. suspended sediments) will deposit pollutants in the park. While nutrients are not normally excessive in the river water, both nitrogen and phosphorus can reach high concentrations at times. These nutrients are subject to movement into the oxbow lakes in the park, which in turn support algal blooms.

Recommendations for Addressing Impairments, Potential Impacts and Undocumented Water Bodies

Human Health Issues

- We recommend that CONG, possibly in cooperation with SCDHEC, sponsor a bacterial source tracking project to investigate the fecal bacterial contamination impacting Toms Creek and portions of Cedar Creek within the park near Wise Lake. An approach utilizing molecular/PCR based methods may be most appropriate, with capability to detect fecal contamination from human sources (i.e. septic systems) as well as feral swine signatures (a problem within the park) and ruminant signatures (for example, a 100 unit horse farm in the watershed upstream of the park may be a contributor).

Monitoring Needs

- Various sources point toward a potential problem of excessive metals within park stream sediments. We recommend sampling of sediments in Cedar Creek within and upstream of the park, Toms Creek within and upstream of the park, and at least three oxbow lakes in the park, Wise Lake, Weston Lake, and Bates Old River. Other potential toxic compounds such as PCBs, pesticides, and PAHs should be sampled as well. These data can be compared with academically-derived published benthic community impairment standards. Where feasible, fish and clam body burdens for metals and toxicants should be sampled as well, and compared with Federal and State consumption advisory standards. Performing such sampling following a dry period and then following a large flooding event would provide useful information on resident toxicity status and that of sediments deposited by flooding events.

- We recommend that the park sponsor benthic macroinvertebrate community assessments within park streams and selected oxbows lakes on a three-year basis if feasible. SCDHEC performs such surveys outside of the park as part of its watershed assessments, and the same methodology should be applied within the park. The increased urbanization in the Congaree, Wateree, and Cedar Creek watersheds are likely to have ecosystem level impacts on the park biological communities and benthic community assessments are a useful tool for monitoring such impacts.

Research Needs

- We recommend the park have a limnological investigation performed on three oxbow lakes; Wise, Weston, and Bates Old River. These lakes are systems that host algal blooms and have periodic low dissolved oxygen problems, and at least one of these lakes is open to fishing. The study should run one to two years with monthly collections. Parameters should include water temperature, dissolved oxygen, pH, turbidity, conductivity (as vertical profiles), nitrate, ammonium, TN, orthophosphate, TP, chlorophyll *a*, BOD5, and fecal coliform bacteria. Basic lake morphology characteristics should also be obtained (i.e. lake bottom mapping). Phytoplankton and zooplankton collections should also be made. Lake conditions prior to and following large flooding events would especially be of interest, such as change in chemical parameters and biological communities. Because of the potential for groundwater inputs, bottom-water nutrient samples should be included as well in the collection scheme.

- A survey should be completed for inventorying aquatic macrophytes within park water bodies, in particular the streams and oxbow lakes, as well as selected sloughs and guts. This will provide baseline survey data for the park and network; additionally, it will allow the park to determine if invasive species are impacting local aquatic plant communities.

- We recommend NPS perform a Cedar Creek turbidity source study. This would require manual sampling of upper Cedar Creek and the Congaree River outside of the park during periods of elevated discharge to determine if stormwater runoff from outside of CONG causes elevated turbidity as recorded by NPS instrumentation within Cedar Creek. Statistical correlation of gage heights and creek turbidity measures would add further strength to such a study. If a relationship between watershed runoff outside of CONG and turbidity within CONG proves to be the case, these data can be used by NPS to provide evidence to SCDHEC that Best Management Practices and other mitigative measures need to be enacted to protect water quality within CONG.

- Perform a hydrological study (perhaps in partnership with USGS) on the relationship between groundwater and Cedar Creek, especially in reference to how upstream swamp drainage contributes to incising of Cedar Creek and potential draining of CONG wetlands.

- Perform a hydrological study determining how various flood stages of the Wateree River impacts flooding in the Bates Fork Tract of Congaree National Park. This is useful both for scientific purposes and those of public safety. A similar study was done for the main section of the park by Patterson et al. (1985).

- We also suggest that this park presents an excellent opportunity to study the movement of fishes onto a lowland floodplain and their uses of such a floodplain for breeding and/or feeding. This is important for basic science and applied science both, as the Saluda Dam releases affect flooding of park areas adjoining the Congaree River and the reproductive health of the native fisheries may be impacted by operations.

- Vertical accretion rates of sediment within the park have not been studied, and a program should be designed to do so (including pollutant composition of accreting sediments). Such a program would provide needed information related to river discharge and upstream land use and stormwater runoff interactions on park biotic communities.

- The Bates Fork Tract presents new habitats; thus a survey of the Bates Fork Tract reptiles and amphibians would be appropriate to form a baseline by which to compare with other parks and future surveys of CONG.

- Outside of the present park but between the two present tracts are several creeks (McKenzie Creek, Dry Branch, Griffins Creek, Singleton Creek, and Running Creek/Running Lake). These water bodies are not assessed by SCDHEC and it would be wise for NPS to begin gathering water quality data such as dissolved oxygen, turbidity, nutrients, fecal bacteria, etc., at least monthly from key locations (bridges or road accesses as close to the potential new park boundaries as possible). Also, any survey data of flora and fauna within the potential new tract would be useful.

Ecosystem Health Needs

- Proper river discharge and water level management on the CONG floodplain are critical to success of various key species of plants and animals. A stakeholder's group (detailed in NPS 2008) utilized a multifaceted approach called the Ecologically Sustainable Water Management Process (ESWM) to provide science-based recommendations for discharge management from the Saluda River Dam so as to protect and enhance natural biological processes in the Congaree River and the floodplain within CONG. This approach called for funding and devising a monitoring program of key species using various metrics overseen by an Adaptive Management Council of experts and other stakeholders. We recommend that NPS pursue these goals in collaboration with state and federal regulatory agencies. Actual monitoring could be carried out by university researchers, consultancies, or State personnel. This approach has been pioneered in North Carolina previously in the Cape Fear River system, and funding may have to come from private stakeholders as is done for the Lower Cape Fear River Program, see details of organization, funding, and products at: http://www.uncw.edu/cmsr/aquaticecology/Laboratory/LCFRP/index.htm.

- As a companion effort to the stakeholder approach above, long-term monitoring of vegetation on the floodplain should be carried out with emphasis on impacts of water level changes due to Saluda Dam operations or natural floods and droughts. Tree ring analysis should play a role in such monitoring to obtain information on tree growth variability as a response to water quantity changes (i.e. use of "living records".

- We understand that the National Park Service is pursuing a feral swine control program. Due to the visibly obvious habitat damage (Plate 11) and the potential for waterborne fecal microbial contamination we reiterate that such a program be pursued with vigor.

- CONG should commission high resolution maps of tributary watersheds that break out sub-basins in detail, to better assess or predict potential or realized pollution or flooding events.

Community Relations/Cooperation Needs

- Park personnel have expressed a need for formal cooperative agreements with upstream entities that have the potential to pollute the park's waters. Such agreements (with for instance major municipal wastewater treatment plants and military bases) would be designed so that the park is immediately alerted when a pollutant spill or unusual discharge event occurs upstream either in the Congaree or Wateree Rivers, or Cedar or Toms Creeks.

- Southland Fisheries operates a series of aquaculture ponds upstream of Cedar Creek. We recommend that the owners be asked to alert CONG whenever a pond drainage is planned or flooding occurs.

- SCDHEC should be communicated with and urged to continue regular water quality sampling at points around CONG (especially Cedar Creek). In times of tight budgets such programs often fall by the wayside for state agencies.

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Carlough, L. A. 1994. Origins, structure, and trophic significance of amorphous seston in a blackwater river. Freshwater Biology 31:227-237. (This paper describes how nutritious particulate matter is formed by physical and chemical means in blackwater rivers, and used for food by invertebrate consumers).

Carter, R. 2000. Birds of Congaree National Park. Checklist available at Congaree Park Visitors Center. List maintained by the Columbia Audubon Society, P.O. Box 5923, Columbia, S.C. 29250 (Checklist divides birds into various broad phylogenetic groups and ranks the individuals according to chance of encounter within the park).

Carter, Robin M. 2005. An Annotated Checklist of the Birds of Congaree National Park. The Chat, v. 69, #1, Raleigh, NC, Carolina Bird Club, pp 1-28. (Notes that 191 species have been seen within, and provides some detail on sightings of the more rare species/sightings).

Cely, J. E. 2004. Map of Congaree National Park, v. 3.8, 1:12,000: Columbia, SC, Friends of Congaree Swamp, 1 Plate. (This is a hand-drawn map of the original sections of Congaree National Park that includes navigational features such as guts, bridges, and large trees).

Collins, M. R., D. Cooke, B. Post, J. Crane, J. Bulak, T. I. J. Smith, T.W. Greig and J.M. Quattro. 2003. Shortnose sturgeon in the Santee-Cooper reservoir system, South Carolina. Transactions of the American Fisheries society 132:1244-1250. (This paper discusses the movements and habitat of shortnose sturgeon above and below Lakes Marion and Moultrie, as well as noting the presence of and spawning of this endangered species in the Congaree River).

Conrads, P. A., T. D. Feaster, and E. A. Roehl, Jr., 2007. Separating anthropogenic influences on hydrology using data mining techniques – A case study of Congaree National Park, South Carolina, Water Environment Federation Technical Exhibition Conference 2007, San Diego, California, October 2007. (This paper takes issue with previously held belief that the Saluda Dam led to fewer major floods in the park. By utilizing a selection of data mining and statistical approaches these authors determined that the lack of large floods after 1930 was due to natural causes, and the main impact of the dam was to cause lower river gauge heights in the first half of the year (December to May) and higher gauge heights in the second half of the year (June to November).

Crane, J. 1987. Lower Saluda River Fishery Study, Preliminary Report. South Carolina Wildlife and Marine Resources Department, Wateree-Congaree Project. (This report presents data from SC state biologists in which the lower Saluda river below the Lake Murray Dam was sampled for fish by electroshocking and seining. The results consisted of 889 fish representing 29 species and 11 families collected, with the community described as typical of a lower piedmont/upper coastal plain community, with no exclusively cold water species collected).

Dodds, W. K., J. R. Jones and E. B. Welch. 1998. Suggested classification of stream trophic state: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. Water Research 32:1455-1462. (The authors statistically analyze hundreds of temperate stream sites to determine oligotrophic,, mesotrophic and eutrophic categories based on benthic chlorophyll, sestonic chlorophyll, TN and TP; reanalysis of much lake and reservoir is also done to provide such categories).

Ensign, S. E. and M. A. Mallin. 2001. Stream water quality following timber harvest in a Coastal Plain swamp forest. Water Research 35:3381-3390. (This paper provides a before and after clearcut analysis of water quality in Goshen Swamp, a third order stream in the Northeast Cape fear river basin. The clearcut led to high nutrient and suspended sediment inputs, low dissolved oxygen, and algal blooms, including blue-green algae).

Finger, S. E. and J. S. Bulak. 1988. Toxicity of water from three South Carolina rivers to larval striped bass. Transactions of the American Fisheries Society 117:521-528. (In this paper experiments run using water from the Congaree, Wateree and Santee Rivers found that striped bass *Morone saxatilis* larvae had high mortality when exposed to Wateree River water, whereas water from the other two rivers was not toxic but the larvae swam lethargically compared with control water. The specific cause of toxicity was not determined, although the elevated concentrations of the phenolic compound pentachloroanisole (PCA) were found in the Wateree. This compound, along with possibly other phenolic compounds was suspected in playing a role in the low larval survival in the Wateree).

Friebel, B. A. 2007. Home range and habitat use of feral hogs (*Sus scrofa*) in Congaree National Park. M.S. Thesis, Wildlife and Fisheries Biology, Clemson University. (This thesis involved radio collaring and tracking feral hogs in Congaree Park in 2005 and 2006 and indicated that individuals maintained comparatively compact home ranges and spatial fidelity, suggesting an abundant resource base in Congaree. While recording feral hogs within all types of habitats studies within the park, the author found evidence that the hogs particularly selected habitats for availability of oak mast, and suggested its prevalence within the park may be critical to hogs).

Gaddy, L. L., J. B. Nelson and A. B. Pittman. 2000. Endangered, threatened, and rare plants of Congaree Swamp national Monument, Richland County, South Carolina. Report prepared for Congaree swamp National Monument, 200 Caroline Sims Road, Hopkins, SC 29061. Contract Numbers 1443PX524097009 and 144CA509097009. (The authors found 18 species that were either exotic (i.e. not native to the U.S.) or invasive (not native to the local plant communities, but could be native to other U.S. areas). These authors noted two species in particular that should be monitored for spreading; *Pueraria lobata* (kudzu) and *Lygodium japonicum* (Japanese climbing fern).

Hauk, W. 2005. An Analysis of Genetic Variation in the Prostrate Grapefern (Botrychium lunarioides) at Congaree National Park. Investigator Annual Report Number: 33046 for Permit Number: COSW-2005-SCI-0001 December 08, 2005. (Investigator Annual Report work included surveys of the park, and examiniation of voucher specimens at CONG and USC; https://science.nature.nps.gov/research/ac/search/iars/pdf/IAR.pdf?reportId=33046)

Hinton, M. and M. J. Bale. 1991. Bacterial pathogens in domesticated animals and their environment. Journal of Applied Bacteriology Symposium Supplement 70:81S-90S. (This paper lists various pathogenic bacteria, what animals that harbor them, their survival in the environment, and information on their spread and containment).

Hupp, C. R. 2000. Hydrology, geomorphology and vegetation of Coastal Plain rivers in the south-eastern USA. Hydrological Processes 14:2991-3010. (this review article explains have rivers are formed, maintained and changed by rainfall, erode materials and create meanders, deposit sediment on floodplains and how vegetation slows flow and helps the deposition of sediments).

Jones, R. H. 1997. Status and habitat of big trees in Congaree Swamp National Monument. Castanea 62:22-31. (Jones found 29 individuals representing 25 species that are state champions. In addition to the state champions, three species, including possumhaw *Ilex decidua*, persimmon *Diospyros virginiana*, and water hickory *Carya aquatica* were large enough to quality as national champions).

Knowles, D. B., M. M. Brinson, R. A. Clark and M. D. Flora. 1996. Water Resources Management Plan. Congaree Swamp National Monument. National Park Service, U.S. Department of the Interior. (This document provides much basic information on park history, hydrology, geology, pollutant sources and water quality, and also provides some proposed projects for increasing park water quality and management knowledge).

Krueger, E. A. 2009. Freshwater Mussels (Family Unionidae) of the Congaree National Park, 2008. Final Report to the Congaree National Park. March 27, 2009. (Report summarizing research conducted with TNC, the SC Aquarium, and NPS along the Congaree and Wateree rivers, and selected oxbow lakes in newly acquired park property).

Lacy, C. M. 1992. Assessment of zooplankton in response to nonpoint source loadings to the Santee-Cooper lake system. Technical Report SCP 002-92, South Carolina Department of Health and Environmental Control. (This report is the result of a two-year study of zooplankton in the Congaree and Wateree Rivers near Congaree Park. Zooplankton community composition in both rivers was dominated by rotifers, copepods (particularly nauplii) and much fewer cladocerans, with spring and fall peaks and summer minima. Chlorophyll *a* concentrations were moderate with no evident seasonality, and zooplankton responded positively to elevated river discharge, turbidity and TSS rather than chlorophyll).

Lenat, D. R. 1993. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. Journal of the North American Benthological Society 1:279-290 (This paper describes how the NC Biotic Index was derived as a companion to the EPT index in order to rate NC streams segments on water quality in terms of supporting aquatic life. It is based on analysis of 2,000 macroinvertebrate samples from various ecoegions).

Lockhart, M. 2006. The trouble with wilderness education in the National Park Service: the case of the lost cattle mounts of Congaree. The Public Historian 28:11-30. (This article provides a history of Congaree National Park and the slave-built cattle mounts within the park. It also discusses how current wilderness regulations prohibit some valuable cultural educational opportunities by denying reasonable access to the mounts and dikes and prohibiting educational signage).

MacDonald, D. D., C. G. Ingersol and T. A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31. (This paper presents a consensus based set of standards for freshwater sediments for metals and various toxicants, and describes the process of deriving these standards. It also supplies standards developed by other researchers).

Maliszewski, L. M. 2005. Assessment of contaminant sources and pathways affecting Congaree National Park, South Carolina. M.S. Thesis, Department of Civil and Environmental Engineering, University of South Carolina, Columbia, S.C. (This thesis provides a literature review on water quality of the park, including sources, government sampling efforts and stations, and pollutant sources, and develops a water quality data base for use in Microsoft Access. It also presents proposals on assessing heavy metals pollution, source tracking of fecal bacteria, and educational outreach).

Mallin, M. A. 2000. Impacts of industrial-scale swine and poultry production on rivers and estuaries. American Scientist 88:26-37. (This paper provides an introduction to concentrated animal feeding operations (CAFOs); their history, operations, and waste-generating capabilities, and provides data on pollutants released through spills, floods and leaks and how these incidents have polluted downstream waters).

Mallin, M. A. and C. A. Corbett. 2006. Multiple hurricanes and different coastal systems: How hurricane attributes determine the extent of environmental impacts. Estuaries and Coasts 29:1046-1061. (This paper summarizes various water quality effects caused by hurricanes in Florida, North Carolina and South Carolina, and what meteorological and anthropogenic factors exacerbate those impacts).

Mallin, M. A., L. B. Cahoon, M. R. McIver, D. C. Parsons and G. C. Shank. 1999. Alternation of factors limiting phytoplankton production in the Cape Fear Estuary. Estuaries 22:985-996. (This paper provides nutrient and physical parameter data along the axis of the Cape Fear River estuary and results of experiments determining limiting nutrients).

Mallin, M. A., L. B. Cahoon, D. C. Parsons and S. H. Ensign. 2001. Effect of nitrogen and phosphorus loading on plankton in Coastal Plain blackwater streams. Journal of Freshwater Ecology 16:455-466. (This paper provides results of nutrient addition experiments to water from the Black and Northeast Cape Fear Rivers. Ammonium and urea inputs stimulated phytoplankton growth, while orthophosphate and glycerophosphate stimulated ATP but not phytoplankton).

Mallin, M. A., M. R. McIver, S. H. Ensign and L. B. Cahoon. 2004. Photosynthetic and heterotrophic impacts of nutrient loading to blackwater streams. Ecological Applications 14:823-838. (This paper summarizes nutrient addition experiments on water from several blackwater streams in the Cape Fear basin. Collectively, nitrate, ammonium, and urea additions stimulated phytoplankton growth and increased BOD. Phosphorus, particularly organic P additions stimulated bacteria growth, ATP, and BOD).

Mallin, M. A., V. L. Johnson, S. H. Ensign and T. A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. Limnology and Oceanography 51:690-701. (This paper draws on extensive BOD and water quality data collected in southeastern North Carolina. BOD was strongly related to chlorophyll a in the Cape Fear River, several tidal creeks, and two urban lakes. In blackwater streams BOD was significantly related mainly to phosphorus and fecal coliform bacteria, and to urban runoff in an urban stream).

Maluk, T. L. and T. A. Abrahamsen. 1999. Results of Water-Quality Sampling and Ecological Characterization of Streams in Congaree Swamp, South Carolina, 1995-98. Water-Resources Investigations Report 99-4121, U.S. Geological Survey, Columbia, South Carolina. (Shows excessive metals in sediments in some park locations, also provides indices showing poor macroinvertebrate and fish community structure in a few areas in and near the park. Most water column data for common pollutant parameters are not remarkable).

Marzolf, R. 1990. Reservoirs as environments for zooplankton. Pgs. 195-208 in Thornton, K. W., B. L. Kimmel and F. E. Payne, (Eds.) Reservoir Limnology: Ecological Perspectives. Wiley-Interscience, New York. (This book chapter deals primarily with how zooplankton get nutrition in reservoirs, especially under turbid situations, and how the differences between natural lakes and reservoirs influence zooplankton).

May, T., W. Brumbaugh, M. Walther, B. Poulton and L. Rose. 2005. Concentrations of Total Mercury in Sediment, Invertebrates, and Fish from Congaree National Park, S.C. Final Report CERC-8335-FY05-32-11, U.S. Geological Survey, U.S. Department of the Interior, Columbia, MO. (This report found that approximately 10% of fish samples in CONG had Hg levels exceeding the USEPA consumption advisory. Also, Hg levels in invertebrates were elevated compared with reference specimens, while sediment concentrations were relatively low, with a different spatial distribution than the wildlife. They recommend further monitoring on a three year basis due to continuing airborne emissions).

McCann, K. S. 2000. The diversity-stability debate. Nature 405:228-233. (This paper discusses how early research lead to the conclusion that increased diversity led to more ecosystem stability, but some recent papers have found exceptions to this. The author concludes that within a given ecosystem diversity is positively correlated with stability, but this correlation does not extend to population-level stability).

Meyer, J. L. 1990. A blackwater perspective on riverine ecosystems. BioScience 40:643-651. (This is a summary article explaining how blackwater streams differ from clearwater streams, especially in terms of their organic carbon loads and intense heterotrophic activity).

Meyer, J. L. 1992. Seasonal patterns of water quality in blackwater rivers of the coastal plain, southeastern United States. In Becker, C.D. and D.A. Neitzel (eds.) Water Quality in North American River Systems. Batelle Press, Columbus. (This article provides water quality information on the Ogeechee and Satilla Rivers in Georgia, and discusses various characteristics of blackwater streams).

Minchin, P. R. and R. R. Sharitz. 2007. Age Structure and Potential long-Term Dynamics of the Floodplain Forests of Congaree National Park. A report for the Park, submitted August 31, 2007. (This report notes that in area >3 km from the river there has been a change in vegetation composition to one that is less water tolerant, attributed to the operation of the Saluda Dam reducing the major flood height and persistence).

Montebello, S. 2008. an analysis of the concentrations of *Enterococci* and *Escherichia coli* in Cedar Creek, Toms Creek, Wise Lake and Weston Lake in Congaree National Park. Artefix Academy, Cayce, South Carolina. (This is a very helpful student paper in which the author measured fecal indicator abundances in several locations in Congaree Park's waterways over a six month period in 2007. She found generally good microbial conditions in Wise and Weston Lakes and upper Cedar Creek, but frequent violations of EPA criteria in lower Cedar Creek and Toms Creek; genetic testing by a contract lab detected a human source present at one station in Toms Creek).

Neves, R. J., A. E. Bogan, J. D. Williams, S. A. Ahlstedt and P. W. Hartfield. 1997. Status of mollusks in the Southeastern United States: a downward spiral of diversity. Chapter 3 in (Benz, G.W. and D.E. Collins, Eds.) Aquatic Fauna in Peril: the Southeastern Perspective. Special Publication 1, southeast Aquatic research institute, Lenz Design and communication, Decatur, GA. 554 pp. (Provides listings and statuses of snails and bivalves in the U.S. southeast, discusses them by State, and provides information on anthropogenic forces leading to their losses, including dam building, pollution, and species introductions).

NCDENR. 2006. Standard Operating Procedures for Benthic Macroinvertebrates, Biological Assessment Unit. North Carolina Department of Environment and Natural Resources, Division of Water Quality, Environmental Sciences Section, Raleigh, N.C. (This manual presents the methods for monitoring benthos in various areas of North Carolina, the differing indices used to assess community health, and the key indicator organisms. Swamp water on the Coastal Plain is assessed differently than the Piedmont, and Mountains).

NPS. 1998. Baseline Water quality data inventory and analysis, Congaree Swamp National Monument. Technical Report, Volume I. NPS/NRWRD/NRTR-98/148, National Park Service, Water Resources Division, Fort Collins, CO. (this is a report by the Park Service that collects any official on-line water quality data (i.e. STORET) for stations within 3 miles upstream and one mile downstream of the Park. Data are presented for Congaree National Park for many sites providing basic statistics and graphs, and relation to State or federal water quality standards. An ecological analysis is not provided).

NPS. Undated. Congaree National Park History. (Brochure explaining the park's history; contains a timeline of relevant events, and is available at the park office).

NPS. 2004. Resource Management Plan: Congaree National Park. December 1, 2004. (This 63 page management plan provides an update to the 1990 resource management plan for Congaree National Park, covering present status, baseline information, and an overview of current program needs, goals and objectives for park natural and cultural resources).

NPS. 2006. Congaree. GPO:2006-320-369/00476. (NPS brochure providing a park map and discussing the park's ecosystem, providing some historical background as well).

NPS. 2008. Final Report and Recommendations of the Saluda/Congaree Ecologically Sustainable Water Management Process; a cooperative effort led by the National Park Service, American Rivers, The Nature Conservancy, the U.S. Fish and Wildlife Service and the Carolina Coastal Conservation League. (This report represent findings of a group of stakeholders with interest in allocation of water in Lake Murray, the lower Saluda River and the Congaree River, specifically regarding operations of the Saluda Dam. It results from a literature review, meetings, expert opinions on plant and animal species water needs, and a model, and lays out a proposed future process designed to promote and protect the native wildlife and flora in CONG and the rivers).

Patterson, G. G., G. K. Sperry and B. J. Whetstone. 1985. Hydrology and its effects on distribution of vegetation in Congaree Swamp National Monument, South Carolina. U.S. Geological Survey Water-Resources Investigations Report 85-4256. Columbia, S.C. (This report provides very useful information on groundwater aquifers, river and floodplain flow patters, impacts of the Lake Murray dam, impacts of Congaree River discharge on flooding within Congaree Park).

Pescador, M. L., B. A. Richard and A. K. Rasmussen. 2004. An Aquatic Invertebrate Study for the Congaree Swamp National Park, Richland County, South Carolina. (Prepared for Congaree Swamp National Park; Task Order Number one (1): J5240 01 0555 Modification No. 1. Entomology/Center for Water Quality, Division of Agricultural Sciences, Florida A&M University, Tallahassee, Fl. (Report concluded that Congaree contains relatively high aquatic insect diversity, particularly for aquatic beetles, caddisflies, and damselflies and dragonflies. It focused on five insect orders, and in terms of species diversity ranked them is descending order as follows: Coleoptera (beetles), Trichoptera (caddisflies), Odonata (dragonflies and damselflies), Ephemeroptera (mayflies) and Plecoptera (stoneflies)).

Pimentel, D., A. L. Lach, R. Zuniga and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50:53-64. (This paper examines both plant and animal nonindigenous invasions and puts monetary costs on the damage that they cause in terms of crops losses, veterinary bills, waterway cleanups, infrastructure damage, pest control, etc. It also describes how natural communities are degraded with consequent effects on ecosystem stability and function).

Price, J. 2005. Species diversity and habitat partitioning of the crayfish community in Congaree National Park. Study completion Report, F-63. Division of Wildlife and Freshwater Fisheries, South Carolina Department of Natural Resources. (Habitats sampled included oxbow lakes, gum ponds, sloughs, streams, guts and floodplains. Six species of crayfish were collected, which the report author considered relatively high diversity compared with other protected areas in the region).

Putz, F. E. and R. R. Sharitz. 1991. Hurricane damage to old growth forest in the Congaree Swamp National Monument, South Carolina, USA. Canadian Journal of Forest Research 21:1765-1770. (This paper discusses impacts of Hurricane Hugo on the forest, and notes most damage was due to crown breakage and defoliation, while severe damage was most common in mixed bottomland forest and sloughs).

Rikard, M. 1991. A Water Quality Study at the Congaree Swamp National Monument of Myers Creek, Reeves Creek and Toms Creek. Unpublished manuscript, National Park Service, Cape Lookout National Seashore, Morehead City, North Carolina (This paper presents physical and chemical water quality (mainly metals) data collected in 1989 and 1990 from three creeks impacting the park. Most parameters were unremarkable with the exception of aluminum, which was at concentration considered to be harmful to aquatic life).

Rose, L. 2002. Species diversity and condition of the fish community of Congaree Swamp National Monument. Annual Report, CA No. H5240-00-0290, South Carolina Department of Natural Resources and National Park Service. (SCDNR completed a total of 50 fishery surveys from 33 sites within CONG from 1999-2002 sampling mainly streams but in 2002 a number of collections were made from guts, sloughs, ponds and the two larger lakes, Weston and Wise. A total of 56 species belonging to 17 different families were collected within the (main section) park boundaries).

Rose, L. and J. Bulak. 2004. Species diversity and condition of the fish community during a drought in Congaree National Park. South Carolina Department of Natural Resources, Freshwater Fisheries, Eastover, South Carolina. (These researchers used cluster analyses and identified four community groups associated with differing habitat characteristics. Community group 1 indicator species were characterized by relatively low flows and dissolved oxygen. Community group 2 's habitat was comprised of faster flowing, deeper streams such as Cedar Creek. Community group 3's sites were characterized by high flow and firm, sandy bottoms, and were located in the transition area between bluff and swamp. Community group 4 was a single outlier site located in McKenzie Creek, which had low dissolved oxygen and comparatively high conductivity and farming, grazing, and a poultry facility in its watershed. They considered this creek a degraded stream and suggested further study of the creek and its drainage).

Rose, L. and J. Bulak. 2007. Flood mediated change of the fish community in Congaree National Park streams. Final Report, South Carolina Department of Natural Resources, Freshwater Fisheries, Eastover, South Carolina.(These researchers found similar species richness between periods (38 species pre-flood and 37 species post-flood). However, seven taxa (blackbanded sunfish, channel catfish, flat bullhead, green sunfish, piedmont darter, snail bullhead and spotted sucker) were only collected in the pre-flood sampling while seven other taxa (bowfin, black crappie, carp, longnose gar, mud sunfish, pumpkinseed and redear sunfish) were only collected in the post-flood sampling).

Ryan, T. S. 2007. Congaree National Park: the potential for eutrophication of Wise and Weston lakes. MS Thesis, School of the Environment, University of South Carolina, Columbia. (This thesis attempts to predict potential oxbow lake eutrophication through phosphorus loading changes in Cedar and Toms Creeks by a model (EUTROMOD) that was not based on blackwater systems. This approach is flawed in that N rather than P is likely the limiting nutrient in these oxbows, and inputs from the rivers are ignored).

SCDHEC. 2004a. Saluda River Basin Watershed Water Quality Assessment, South Carolina Department of Health and Environmental Control. (This report provides detailed information on the watersheds within the Saluda Basin, including water quality data summaries, lists of impaired waters, NPDES discharges, land use, issues, and strategies).

SCDHEC. 2004b. Water Classifications and Standards, Regulation 61-68, South Carolina Department of Health and Environmental Control, Bureau of Water. (Regulation presenting chemical standards and narrative detail for evaluating water quality for various types of water classifications).

SCDHEC. 2005. Catawba River Basin Watershed Water Quality Assessment, South Carolina Department of Health and Environmental Control. (This report provides detailed information on the watersheds within the Catawba Basin, including water quality data summaries, lists of impaired waters, NPDES discharges, land use, issues, and strategies).

SCDHEC. 2006. South Carolina Catawba/Wateree River Basin Facilities Water Withdrawal Report 2004. South Carolina Department of Health and Environmental Control, Technical Report 014-05. (This report describes the various types of water use (including agriculture, golf course, industrial, water supply, thermoelectric and hydroelectric), and the amounts used in the Catawba/Wateree watersheds broken down by category and county for 2004).

SCDHEC. 2007. South Carolina Water Use Report 2006 Annual Summary. South Carolina Department of Health and Environmental Control. (this report provides a summary of surface and groundwater use in South Carolina for 2004 as broken down by county and use; also includes some information on aquifers and watersheds).

SCDNR. 1995. Wetland resource characterization of the Congaree Swamp National Monument, South Carolina. Final Project Report for the United States Department of the Interior, National Park Service. South Carolina Department of Natural Resources, Land Resources and Conservation Districts Division. (report representing an effort to incorporate several data bases for use in geographic information systems (GIS); primarily methodology with some maps; no details provided on amounts or coverage of wetlands area for the park, however.).

Sexton, W. J. 1999. Alluvial valleys of the middle Coastal Plain of South Carolina. Southeastern Geology 39:1-15. (This paper provides geological and hydrological information on the Congaree, Wateree and Santee Rivers, with information on discharge, depth, meanders, and sediments).

Shelley, D. C., A. D. Cohen and T. A. Thom. 2008. Floodplain geomorphology and depositional environments of Congaree national Park. Congaree Geology Field Guide Version 1.0. Geological Society of America, Southeastern Section Meeting, Filed trip #4, Congaree National Park, 53 pp. (This field guide provides background and exercises for students and professionals interested in the geology and hydrology of Congaree Park, including rim swamps, Cedar Creek and an alluvial fan).

Shelley, D. C., T. A. Thom, M. French, and B. Dolphin. 2008, Piezometers as Tools for Floodplain Hydrology Monitoring, Research, and Education Programs at Congaree National Park [abs.]: Floodplain Ecosystem Symposium: Integrating Science into the Restoration and Management of Floodplain Ecosystems of the Southeast. March 4-6, 2008, Little Rock, AR. (This abstract relates to the Congaree Observation Well Network, which is starting to yield some groundwater hydrology/chemistry results)

Smock, L. A. and E. Gilinsky. 1982. Benthic macroinvertebrate communities of a floodplain creek in the Congaree Swamp Monument. Contact No. CX5000-0-0946. Department of Biology, Virginia Commonwealth University, Richmond, VA. (These authors determined that benthic species composition, species richness and species diversity reflected excellent water quality for Cedar Creek).

Smock, L. A. and C. E. Roeding. 1986. The trophic basis of production of the macroinvertebrate community of a southeastern U.S.A. blackwater stream. Holarctic Ecology 9:165-174. (Smock and Roeding assessed what were the food sources supporting the invertebrate production in Cedar Creek and found that fine particulate organic matter (FPOM) was the major food source, supporting 47-64% of total production, while algae (mainly filamentous algae and diatoms) supported 15-34% of production. Animal material supported 16-26% of macroinvertebrate production while coarse particulate organic matter (CPOM) only supported 1-3% of total production. These authors suggested that the floodplain provides a similar function for lowland blackwater stream systems that low order streams provide for streams in upland areas in terms of CPOM processing).

Smock, L. A., E. Gilinsky and D. L. Stoneburner. 1985. Macroinvertebrate production in a southeastern United States blackwater stream. Ecology 66:1491-1503. (These researchers found that the caddisfly *Macronema carolina* yielded the highest production among individual taxa (4.90 g/m2) while the chironomids *Rheotanytarsus* and *Tanytarsus* also had relatively high annual production. Productivity was highest in the Cedar Creek upstream of the swamp, and decreased as the stream passed through the swamp. Overall this study found that the stream bottom yielded the highest invertebrate production (39-44% of the total production) due to the sediments being the largest habitat, while snags, with their far lower habitat area but much higher productivity yielded 28-35% of total invertebrate production).

Tilman, D. 2000. Causes, consequences and ethics of biodiversity. Nature 405:208-211. (This paper presents an overview of biodiversity (primarily plant biodiversity) and explains how diversity leads to stability via reducing variability as a whole and generally increasing community abundance. He notes how loss of biodiversity diminishes the capacity of ecosystems to supply society with sustainable goods and services, but realizes that many actions that harm biodiversity provide societal benefits.).

Tuberville, T. D., J. D. Wilson, M. E. Dorcas and J. W. Gibbons. 2005. Herpetofaunal species richness of southeastern national parks. Southeastern Naturalist 4: 537-569. (This paper provides a series of lists of reptile and amphibian species found at 16 southeastern national parks, broken down by taxa, with introduced species noted. There was a significant correlation between park area and species richness.)

USGS. 2005. Feral hog impact monitoring, management plan development, and initial management for Congaree National Park. Final Report. COSW-N-XX.XXX. United States Geological Survey/National Park Service/Clemson University. (This is one section of a larger report that contains a draft management plan. This section discusses feral hog disturbance monitoring, and found that average total disturbance in individual plots was 19% in cypress-tupelo forest, 9% in mixed bottomland hardwoods, 9% in seepage forest and <1% in uplands, showing a preference for wetter areas. However, the study found that once widespread flooding recurred, differences in disturbance between uplands and wetlands were no longer statistically significant. That report noted that severe rooting in the seepage forest plots remained visible for months to even years).

Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems, 3rd Ed. Academic Press, San Diego. (This is the most comprehensive textbook/reference volume on all aspects of the limnology of lakes, reservoirs, and running water; it also provides detailed information on the trophic classification of water bodies).

Williams, J. D. and A. J. Benson. 2004. Freshwater mussels (Family Unionidae) of the Congaree Swamp National Park. Final Report to the Congaree Swamp National Park. U.S. Geological Survey, Gainesville, Florida. (Sampling was conducted in the Congaree River along the southern boundary of the park, Cedar Creek, Toms Creek, McKenzie Creek, Myers Creek, Weston Lake and Wise Lake. Several Federal or State Species of concern were found).

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Appendix A. Individuals Providing Information Through Interviews During the Preparation of this Report

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Appendix B. Channel Types within Congaree National Park

As a tributary creek, Cedar Creek is only one of six types of channels classified by Shelley and Meitzen (2005).

Table B-1. Channel types found within Congaree National Park.

Tributary Creeks	The main tributary on the floodplain is Cedar Creek, but other tributaries include Tom's Creek, Griffin's Creek and Dry Branch. These channels conduct overland flow from the adjacent uplands. Tributary creeks are the largest and most significant channel type in terms of discharge and resulting geomorphic signature.
Scroll Complex Channels	These are small channels organized within the ridge-swale complexes. Typically they are characterized by swale-parallel channels that are connected by small cuts through the intervening ridges. These systems often empty into larger batture channels.
Batture Channels	These channels, termed batture channels by Saucier (1994), are those dominant drainages that follow the courses of well-defined abandoned channels. Cely (2001) refers to many of these as "guts." They are often associated with ox-bow lakes. In many cases, they have been captured by larger tributary systems, such as Cedar Creek, and integrated into the floodplain stream network outside of the abandoned channel. Tributaries that flow within abandoned channel may locally be recognized as batture channels.
Backswamp Channels	These are small, relatively unorganized networks of sinuous channels in low-lying areas of the floodplain. They do not appear to be influenced by any relict channel features such as abandoned channels, scrolls, or levees. In many cases these networks appear to be deranged, semi-closed, and connected with larger streams only at high water levels.
Crevasse Channels	These fairly linear channels, which are incised up to 2m into the levee deposits, connect the main channel to the low lying backswamp areas. Cely (2001) refers to many of these as "guts." Paleocurrent indicators and clear association of levees indicate the importance of back-flooding in these areas. These channels are likely the conduits for incorporation of channel-derived coarse grained sediments to the floodplain
Artificial Cuts	There is one significant cut, known as Mazycks cut, that connects the main river channel to Cedar Creek. This channel was constructed to aid in the export of logged timber. It cuts through the levees adjacent to the channel, and is similar to a crevasse channel. There are some other minor ditches on the floodplain as well, which are often associated with the construction of nearby roads, dikes, and cattlemounds (artificially raised areas for livestock).

Appendix C. Aquatic Benthic Macroinvertebrate Species at Congaree National Park

Table C-1. Species list of aquatic benthic macroinvertebrates from five insect orders in Congaree National Park (modified from Pescador et al. 2004; consult for more detail).

Order	Family	Species
Coleoptera (beetles)	Carabidae	*Clivina Americana*
		C. dentipes
		Semiardistomis viridis
	Chelonarium	*Chelonarium lecontei*
	Curculionidae	*Bagonus transversus*
		Listronotus porcellus
		Stenopelmus rufiansus
		Tanysphyrus lemnae
		Tyloderma aerea
		T. capitale
	Dryopidae	*Helichus lithophilus*
	Dytiscidae	*Acilius fraternus*
		Agabus gagates
		Anodocheilus exiguous
		Bidessonotus inconspicuous
		B. longovalis
		B. pulicarius
		Celina angustata
		C. contiger
		C. slossoni
		Copelatus caelatipennis princes
		C. lenticus
		C. loticus
		C. venustus
		Desmopachria convexa
		Dytiscus carolinus
		Hoperius planatus
		Hydaticus bimarginatus
		Hydroporus rufilabris
		H. signatus youngi
		Laccophilus fasciatus rufus
		L. proximus
		Lioporeus triangularis
		Neobidessus pullus

Table C-1. (Continued).

Order	Family	Species
Coleoptera (beetles)	Dytiscidae	*Neoprus aulicus*
		N. carolinus
		N. cimicoides
		N. clypealis
		N. effeminatus
		N. hybridus
		N. lobatus
		N. shermani
		N. undulates
		N. venustus
		N. vittatipennis
		Rhantus calidus
		Thermonectus basillaris bacillaris
		Uvarus falli
		U. granarius
		U. lacustris
	Elmidae	*Ancyronyx variegate*
		Dubiraphia vittata
		Macronychus glabratus
		Microcylloepus pusillus pusillus
		Stenelmis bicarinata
		S. convexula
		S. decorata
		S. fuscata
		S. lignicola
		S. sinuate
		Stenelmis spp.
	Gyrinidae	*Dineutus americanus*
		D. carolinus
		D. ciliatus
		D. discolor
		D. emarginatus
		D. serrulatus serrulatus
		Gyrinus analis
		G. gibber
		G. sayi
	Haliplidae	*Haliplus fasciatus*
		H. leopardus

Table C-1. (Continued).

Order	Family	Species
Coleoptera (beetles)	Haliplidae	*H. pantherinus*
		H.puctatus
		H. triopsis
		Peltodytes bradleyi
		P. dunavani
		P. floridensis
		P. muticus
		P. oppositus
		P. sexmaculatus
		P. shermani
	Heteroceridae	*Heterocerus fatuus*
		H. mollinus
		H. tenuis
		H. texanus
		Tropicus pusillus
	Hydraenidae	*Hydraena marginicollis*
	Hydrophilidae	*Berosus aculeatus*
		B. corrini
		B. exiguous
		B. infuscatus
		B. ordinatus
		B. pantherinus
		B. peregrinus
		B. pugnax
		B. striatus
		Cymbiodyta blanchardi
		C. chamberlaini
		C. vindicata
		Enochrus blatchleyi
		E. cinctus
		E. consors
		E. consortus
		E. interuptus
		E. ochraceus
		E. perplexus
		E. pygmaeus
		E. sayi
		E. sublongus
		Helocombus bifidus

Table C-1. (Continued).

Order	Family	Species
Coleoptera (beetles)	Hydrophilidae	*Helophorus marginicollis*
		Hydrobius melaenus
		Hydrochara soror
		Hydrochus excavatus
		H. inaequalis
		H. rufipes
		H. simplex
		H. subcupreus
		Hydrochus spp.
		Hydrophilus ovatus
		Paracymus disperses
		P. reductus
		P. subcupreus
		Phaenonotum exstriatum
		Sperchopsis tessellata
		Tropisternus blatchleyi blatchleyi
		T. collaris
		T. lateralis nimbatus
	Limnichidae	*Eulimnichus ater*
		E. nitidulus
		Noteridae
		Hydrocanhtus atripennis
		Suphisellus pucticollis
		Ptilodactylidae
		Ptilodactyla acuta
		P. angustata
		P. carinata
		P. serricollis
		Ptilodactyla spp.
	Scirtidae	*Cyphon americanus*
		C. padi
		C. perplexus
		C. variabilis
		Elodes pulchella
		Prionocyphon discoideus
		Scirtes tibalis
	Staphylinidae	*Anotylus insignitus*
		Bledius punctatissimus
		B. semiferrugineus

Table C-1. (Continued).

Order	Family	Species
Coleoptera (beetles)	Staphylinidae	*B. wudus*
		Bledius sp.
		Carpelimus dentiger
		Carpelimus sp.
		Thinodromus arcifer
		T. corvinus
Ephemeroptera (mayflies)	Baetidae	*Acerpenna pygmaea*
		Callibaetis pretiosus
		Heterocloeon sp.
		Procloeon viridoculare
		Procloen sp.
		Psuedocloeon ephippiatum
		P. frondale
	Caenidae	*Brachycercus maculates*
		Caenis macafferti
		Caenis sp.
	Ephemerellidae	*Eurylophella doris*
	Ephemeridae	*Hexagenia bilineata*
		H. limbata
	Heptageniidae	*Stenacron interpunctatum*
		Stenonema lenati
		S. modestum
	Isonychiidae	*Isonychia arida*
		Isonychia sp.
	Leptophlebiidae	*Leptophlebia bradleyi*
		L. intermedia
		Paraleptophlebia volitans
		Paraleptophlebia sp.
	Metretopodidae	*Siphloplecton* sp.
Odonata (dragonflies and damselflies)	Aeshnidae	*Anax junius*
		Basiaeschna junata
		Boyeria vinosa
		Epiaeschna heros
		Gomphaeschna antilope
		Nasiaeschna pentacantha
	Cordulegastridae	*Cordulegaster oblique*
	Gomphidae	*Dromogomphus armatus*
		D. spinsus
		Erpetogomphus designatus

Table C-1. (Continued).

Order	Family	Species
Odonata (dragonflies and damselflies)	Gomphidae	*Gomphus abbreviates*
		G. exilis
		G. hybridus
		G. lividus
		G. parvidens
		Gomphus sp.
		Hagenus bevistylus
		Progomphus obscurus
		Stylurus ivae
	Libellulidae	*Celithemis elisa*
		C. fasciata
		C. ornate
		C. verna
		Didymops transversa
		Epicordulia pinceps
		Erythemis simplicicollis
		Erythrodiplax minuscule
		Ladona deplanata
		Libellula auripennis
		L. cyanea
		L. incesta
		L. semifasciata
		L. vibrans
		Macromia illinoiensis
		Macromia sp.
		Neurocordulia alabamensis
		N. obseleta
		Orthemis ferruginea
		Pachydiplax longipennis
		Pantala flavescens
		Perithemis tenera
		Plathemis lydia
		Tetragoneuria costalis
		T. cynosure
		T. semiaquea
		T. spinosa
		Tetragoneuria sp.
		Tramea carolina
	Coenagrionidae	*Argia bipunctulata*

Table C-1. (Continued).

Order	Family	Species
Odonata (dragonflies and damselflies)	Coenagrionidae	*A. fumipennis*
		A. moesta
		A. tibialis
		Argia sp.
		Chomagrion conditum
		Enallagma divagans
		E. basidens
		Enallagma sp.
		Ischnura posita
	Calopterygidae	*Calopteryx dimidiate*
		C. maculate
		Calopteryx sp.
Plecoptera (stoneflies)	Nemouridae	*Amphinemura* sp.
		Prostoia sp.
	Perlidae	*Neoperla carlsoni*
		N. clymene
		Perlesta shubuta
		Perlesta sp.
		Perlinella sp.
	Perlodidae	*Helopicus bogaloosa*
	Taeniopterygidae	*Taeniopteryx lonicera*
		Taeniopteryx sp.
Trichoptera (caddisflies)	Brachycentridae	*Brachycentrus chelatus*
		Brachycentrus sp.
	Calamoceratidae	*Anisocentropus pyraloides*
		Heteroplecton americanum
	Dipsuedopsidae	*Phylocentropus placidus*
		Phylocentropus sp.
	Hydopsychidae	*Cheumatopsyche pasella*
		C. pettiti
		C. pinaca
		Cheumatopsyche sp.
		Hydropsyche alvata
		H. incommode
		H. rossi
		Hydropsyche sp.
		Macrostemum carolina
		Macrostemum sp.
	Hydroptilidae	*Hydroptila armata*

Table C-1. (Continued).

Order	Family	Species
Trichoptera (caddisflies)	Hydroptilidae	*H. delineate*
		H. molsonae
		H. novicola
		H. quinola
		H. remita
		H. scheiringi
		H. waubesiana
		Neotrichia vibrans
		Ochrotrichia tarsalis
		O. aegerfasciella
		Oxythira grisea
		O. janella
		O. lumosa
		O. novastota
		O. pallida
		O. pescadori
	Leptoceridae	*Ceraclea cancellata*
		C. diluta
		C. maculate
		C. ophioderus
		C. protonepha
		C. tarsipunctata
		C. transversa
		Leptocerus americanus
		Nectopsyche candida
		N. candita/equisita
		N. pavida
		Oecetis cinerascens
		O. ditissa
		O. georgia
		O. inconspicua complex
		O. nocturna
		O. osteni
		O. persimilis
		O. scala
		Triaenodes helo
		T. igitus
		T. perna
	Limnephilidae	*Ironoquia* sp.

Table C-1. (Continued).

Order	Family	Species
Trichoptera (caddisflies)	Limnephilidae	*Pycnopsyche* sp.
	Molannidae	*Molanna tryphena*
		M. ulmerina
	Philopotamidae	*Chimarra florida*
		Chimarra sp.
	Phryganeidae	*Agrypnia vestita*
		Ptilostomis ocellifera
		Ptilopstomis sp.
	Polycentropodidae	*Cernotina calcea*
		C. spicata
		Cyrnellus fraternus
		Neureclipsis crepuscularis
		N. melco
		Nyctiophylax affinis
		N. serratus
		Nyctiophylax sp.
		Polycentropus sp.
	Psychomyiidae	*Lype diversa*
	Sericostomatidae	*Agarodes libalis*

Appendix D. Permitted Animal Production Facilities

Table D-1. List of permitted animal production facilities in the five 11-digit hydrologic units surrounding Congaree National Park, with facility name underneath descriptors (data courtesy of Dr. J. Eidson, SCDHEC, Bureau of Water, Information Services).

Facility	NPDES Designation	Operation Type	Designated Count	CAFO size
Kaigler Swine Farm	ND0065323	swine	60	small
Shealy Broiler Farm	ND0080543	poultry (broilers)	98,000	medium
Beaver Creek Poultry Farm	ND0082961	poultry (broilers)	47,000	medium
Hoffman Broiler Facility	ND0071501	poultry (broilers)	57,000	medium
Woodward Vale Broiler Facility	ND0068268	poultry (broilers)	83,000	medium
Walker Poultry	ND0072923	poultry (broilers)	176,000	large
Sans Souci Farm	ND0078620	pigeons	4,400	N/A
Sumter Lodge and Farm LLC	ND0084204	poultry (broilers)	135,000	large
Wateree Corr. Institute – Layer Farm	ND0080519	poultry (layers)	80,000	medium
Bennett Turkey Growout Facility	ND0076899	turkey	22,500	medium
Dennis Growout Turkey Facility	ND0078506	turkey	45,000	medium
Red Level Farm Turkey Facility	ND0075574	poultry (broilers)	25,000	small
Frost Brooder Turkey Facility	ND0076201	turkey	25,000	medium
Cover Story Farms	ND0073148	horse	10	small
Denton Farms Inc.	ND0076015	turkey	25,000	medium
RR & B #38	ND0078514	turkey	25,000	medium
Drake Farms	ND0082210	poultry (broilers)	200,000	large
Ponderosa Farms	ND0084310	poultry (broilers)	135,000	large
Sunnyview Farms	ND0010057	poultry (broilers)	104,000	medium
Hamilton Stables	ND0086428	horse	100	small
Ziegler Poultry Farm	ND0085979	poultry (broilers)	99,000	large
Prickett Poultry Farm	ND0084581	poultry (breeders)	75,000	medium

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