NORTH CAROLINA SEDIMENTATION REVIEW

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STATEMENT OF PURPOSE

Reservoirs play a major role in North Carolina's water and energy supply. They are the storage sites of community drinking water, sources of hydroelectric power supply, and they serve as flood control structures and sediment storage depositories. Residential and commercial development, as well as agricultural and industrial growth, increases erosion and sedimentation into reservoirs by clearing forested landscapes and increasing surface-runoff. Increased sedimentation results in the decrease of reservoir capacity and threatens long-term water supply. The Nicholas Institute for Environmental Policy Solutions initiated a project to understand the extent of sedimentation and loss of capacity in North Carolina reservoirs.

The scope of the study included: a comprehensive review of federal, state, and local government surveys; management plans; private studies; academic reports; stakeholder interviews. Our research hoped to discover how current sedimentation rates in North Carolina affect water supply and reservoir management. This paper will review major study findings, including current data availability, sedimentation rates, and monitoring and sedimentation prevention practices. It will then provide a detailed report on the Catawba River basin.

SEDIMENTATION MONITORING AND FRESHWATER PROTECTION

Sedimentation monitoring[1] in North Carolina was conducted by the following entities:

Governmental agencies -

- U.S. Army Corps of Engineers
- U.S. Department of Agriculture
- NCDENR, Division of Water Resources
- Orange Water and Sewer Authority

Private businesses -

- Alcoa
- Duke Energy

Municipalities -

- Mecklenburg County
- City of Greensboro Water Resources
- Piedmont Triad Regional Water
- City of Durham

Academia and Community Organizations -

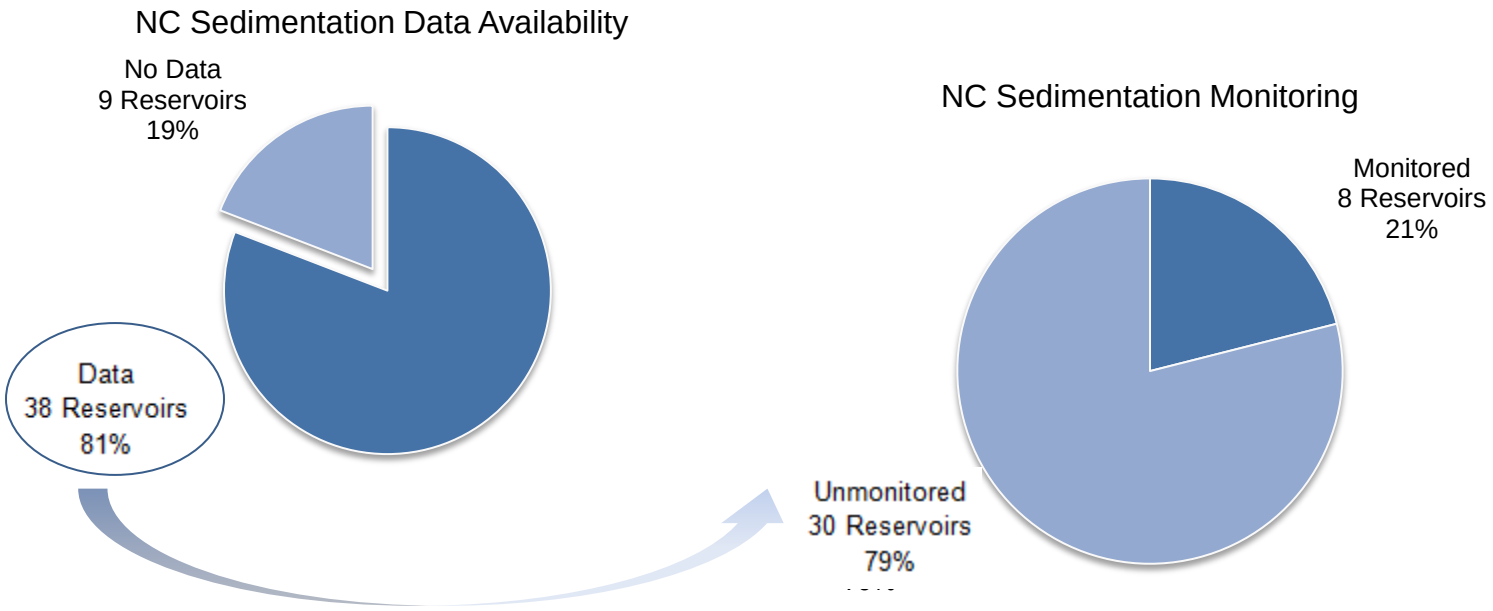
- Catawba Wateree Management Group
- Duke University
- University of North Carolina
- N.C. Urban Water Consortium

[1] We define monitoring to include reservoirs where a sedimentation analysis has been conducted for more than one consecutive year *or* where a future resurvey is expected (dependent on funding).

CURRENT TRENDS IN NORTH CAROLINA RESERVOIRS

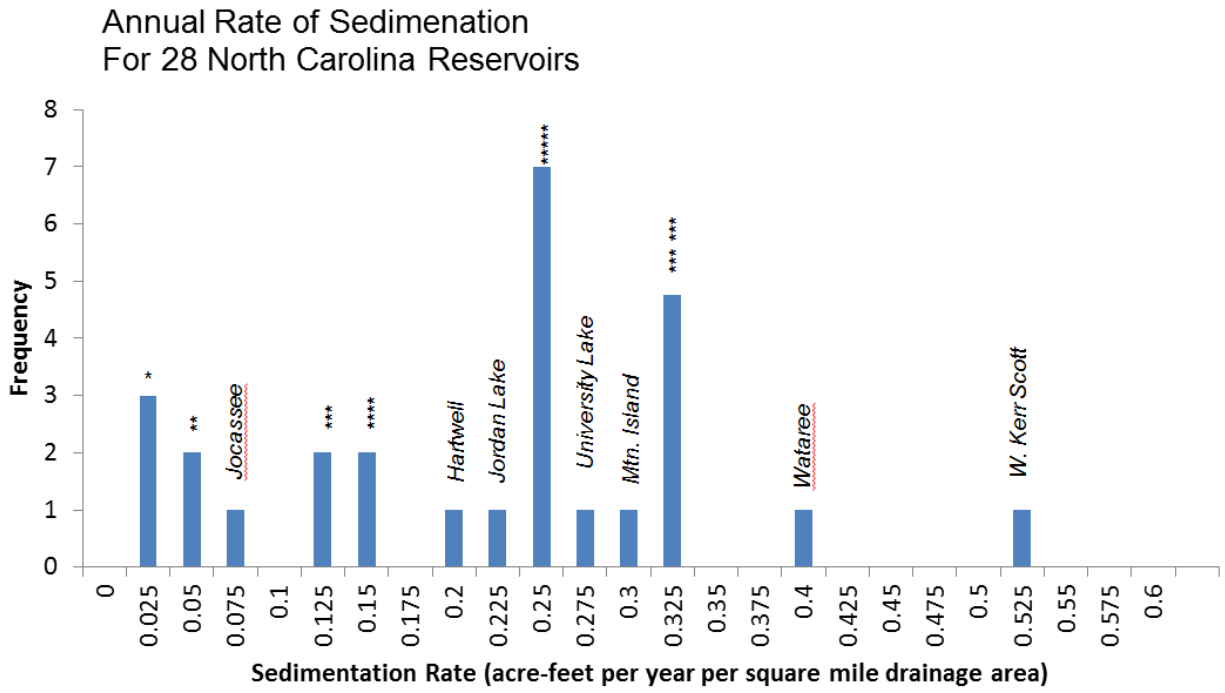
Our research spans 47 reservoirs. We found that entities initiated studies due to relicensing of hydroelectric projects, routine government surveys, and stakeholder and academic interest.

Data was not readily available for all reservoirs. Table 1 in the appendix shows a breakdown of reservoirs that were studied and monitored by river basin. Thirty-eight reservoirs, or approximately 81%, had data available. Amongst reservoirs with available data, only eight are monitored, which represents 21% of the total.



The histogram on the following page displays the range of sedimentation rates in North Carolina, with a minimum of 0.003 for Falls Lake (in the Yadkin – Pee Dee River Basin) to a maximum of 0.52 for W. Kerr Scott. Sedimentation rates are measured in acre-feet per year per square mile drainage area. The median state-wide rate is 0.23, while the median range in the histogram is 0.25 – 0.275.

Reservoirs in the Catawba Wateree River Basin were all in the median range or higher. With the exception of W. Kerr Scott, all reservoirs in the Yadkin Pee-Dee River Basin were in the median range or lower. All reservoirs in the Savannah River Basin fall below the median range. Results were variable in the Cape Fear and Neuse River Basins. Of note, Falls Lake in the Neuse River Basin is omitted in the histogram. Data for Falls Lake was collected by the U.S. Geological Survey (1976) and the U.S. Army Corps of Engineers (1972 and 1997). However, results showed capacity in the lake increasing with a sedimentation rate equal to -0.95 acre-feet per sq. mi. drainage area per year. This is an unlikely result and stands out as an extreme outlier.



*	*Falls (Yadkin Pee Dee); Tiller; Blewett*
**	*Badin (Narrows) ; Tuckertown*
***	*Keowee; J. Strom Thurman*
****	*Richard B. Russell; Stony Creek*
*****	*Bridgewater; Fishing Creek; Great Falls & Dearborn, Rocky Creek and Cedar Creek; High Rock; Lake Michie; Little River*
*** ***	*Rhodiss; Oxford (Lake Hickory) ; Lookout; C. Ford (Lake Norman), Wylie*

In most cases, only a single study has been completed for a reservoir, so that one number represents the sedimentation rate over time. In selected cases, multiple studies show a changing rate. In reality, a variable rate is more likely, which emphasizes the difficulty in understanding state-wide trends and interpreting the effects of sedimentation on reservoirs. Where variable rates were available, some instances show sedimentation rates decreasing. Possible sources of variability in sedimentation rates may include changing landscape, better land management practices, liability and corporate reputation, and increased preventative measures. The examples below highlight how liability and reputation have influenced reservoir management by companies operating in North Carolina. Another example describes how a North Carolina municipality was able to successfully implement a project to reduce reservoir sedimentation.

- *Liability*:
  Corporations that operate dams for hydroelectric power are facing greater scrutiny from regulators and the communities which they impact. For example, Alcoa Power Generating Inc.'s Yadkin Hydroelectric project, particularly High Rock Dam, has faced significant

scrutiny from community advocacy groups and surrounding cities. Complaints vary from unrestrained water use during drought periods, to illegal discharge of contaminants, to excessive amounts of sedimentation. [1][2][3]

At the same time, the regulatory process has contributed to initiation of one of the most effective sedimentation monitoring programs discovered by this study. More specifically, in 2006, Duke Energy applied to the Federal Energy Regulatory Commission (FERC) to relicense the company's hydroelectric operations in the Catawba River Basin. [4] This process included participation from community stakeholders interested in long-term management issues in the river basin, including the impacts of sedimentation on Catawba-Wateree reservoirs. The result of the relicensing effort was the formation of the Catawba Wateree Management Group that is currently overseeing a five-year field study on sedimentation. The purpose of the study is to ensure that actual field measurements match sedimentation models that were utilized during the relicensing process. [5]

- *Prevention efforts:*
  An example of preventative measures taken to reduce loss of capacity due to sedimentation can be found in the City of Burlington. When a new reservoir was impounded in 1961 to supply the city with water, twenty-six sedimentation ponds were installed to intercept runoff and catch sediment. As a result of their effectiveness, the city has invested in maintaining the basins outside of their original lifespan. [6] Recently, the city budgeted $55,000 for maintenance of the basins. [7]

The best studied river basins consist of reservoirs managed by private companies. Possible explanations for this may include greater financial resources, government regulation, and increased importance on public reputation. Government agencies have also conducted thorough analyses of reservoir capacity, but are inconsistent in administering resurveys and are limited by funding. We observe that reservoirs managed by municipalities have the fewest amounts of resources to conduct studies and frequently rely on academia for detailed reports. This may be attributed to a lack of resources and pressing water quality concerns.

LOOKING TO THE FUTURE

Selected trends show that sedimentation has decreased in some instances (e.g. Jordan Lake) since the early 20th century. While this is a positive finding, future economic and population growth have the ability to reverse this trend. The North Carolina Office of State Budget and Management projects that the state population will grow by 11.5% from 2010 – 2020, and an additional 10.2% from 2020 – 2030. Over the next two decades, counties expected to have the fastest pace of growth include Durham, Orange, Wake, and Chatham in the Cape Fear and Neuse River Basins, as well as Cabarrus and Mecklenburg in the Catawba and Yadkin River Basins. [8] Increased growth has the potential to lead to higher sedimentation through construction and urban landscapes that augment sediment runoff. In combination with climate change predictions, reservoir capacity may decline rapidly.

The need to consider climatic changes in water resource planning was made apparent in North Carolina most recently during the 2007-2008 drought. In fact, the North Carolina Division of Water Resources reported that the drought "was the worst in the 112-year recorded rainfall history." [9] In conditions of minimal rainfall, communities can be impacted through mandatory rationing of water use, importation of water, purchasing from surrounding communities, and increased water

prices. [9] Long-term response measures include impounding a reservoir or removing sediments through dredging.

Certainly, increasing our understanding of these issues is critical, as the alternatives are costly. A review of local dredging companies shows that costs may be as high as $100 per cubic yard. Moreover, dredged sediments include toxins that can be costly and hazardous to dispose of. In the long run, prevention measures may be more economically feasible. Examples of prevention measures include installation of sediment retention ponds, implementation of riparian buffers and setting aside land for conservation.

This one-year study has shown that the level of awareness and concern regarding sedimentation in North Carolina reservoirs varies based on geographic region, community awareness, reservoir use, and management. In a few communities, sedimentation has caused enough concern to stimulate monitoring groups or municipal dredging plans. However, a lack of understanding of this topic for most reservoirs prevents continuous monitoring activities. As a preliminary step, entities managing reservoirs should include sedimentation research in their management plans and seek dedicated financing to this issue. Academically, further research should be conducted to compare sedimentation rates in other Piedmont states, to better understand how rates compare nationally, and to define specific forces that influence sedimentation rates in North Carolina.

FOCUS ON CATAWBA WATEREE

The Catawba-Wateree River headwaters are located in the Blue Ridge Mountains in North Carolina and flow nearly 200 miles into Lake Wateree, South Carolina. [10] Beginning in 1904, a series of eleven reservoirs was constructed along the Catawba and Wateree Rivers to meet increased demand for water and electric supply as a result of population growth and industrial development. [11] The most recent reservoir was constructed in 1963 at Lake Norman. [12] Today, the reservoirs continue to provide a variety of benefits to communities in North and South Carolina, including highly valued services such as water and energy supply.

Duke Energy manages the reservoirs and operates them for hydropower purposes. Duke Energy cites that, "more than 1.3 million people depend on the river for energy production, drinking water, industrial uses, cultural resources and recreational amenities." [13]

Six of the eleven Catawba-Wateree reservoirs are a source of drinking water for the following communities:

North Carolina -

- Granite Falls
- Lenoir
- Morgantown
- Valdese
- Huntersville
- Eastern Lincoln County
- Mooresville
- Davidson
- Cornelius
- Northern Charlotte
- Belmont

South Carolina –

- Rock Hill
- Chester County
- Lugoff
- Camden

Several reservoirs are also sites of electric generating stations of various types, including hydroelectric, nuclear, water-turbine, and coal-fired. Additionally, the lakes support recreational activities including public boating and fishing. [14]

Like many river systems in the Southeast United States, the quality and quantity of water available in the Catawba Wateree has been threatened. Lake Norman, Lake Wylie, and Mountain Island Lake all host Duke Energy's coal-ash ponds. [15] Coal ash is the byproduct of burning coal for power generation and may contain hazardous materials. [16] In fact, the EPA has cited that "two of the 44 highest hazard coal ash ponds in the United States are located at the coal-fired Riverbend Station." [17]

At the same time, population growth, severe drought events, and out-of-basin water transfers have threatened water supply to Catawba Wateree communities. The water quality and quantity issues facing the Catawba Wateree have received regional and national attention. In 2008, American Rivers named the Catawba-Wateree as the number one "most endangered river in the United States" and the river made the Southern Environmental Law Centers list of Top 10 Endangered Places in 2012. [18][19]

The water supply issues threatening the Catawba Wateree reached a climax with a 2007 approval to transfer water out of the river basin after droughts had reduced lake levels. [20] At the same time, Duke Energy was in the process of relicensing the company's hydropower project. The relicensing process became a mechanism to address certain water supply issues through the formation of a stakeholder management group. The resulting Catawba Wateree Management group was formed to:

> …identify, fund and manage projects that help extend and enhance the capacity of the Catawba-Wateree River to meet human water needs while maintaining the ecological health of the waterway. [21]

In the scope of their work, the Catawba Wateree Management Group has initiated a project to monitor loss of capacity through sedimentation in the lakes of the Catawba Wateree. More specifically, the project involves a contract with HDR Engineering to conduct a five-year verification study to ensure that sedimentation modeling conducted by Duke Energy in the relicensing process was accurate. The study focuses on six reservoirs in the system, in which the highest rates of sedimentation are believed to be occurring. [22]

Baseline data was collected in November 2010 and published in an August 2011 report. The Year 2 study was conducted in November 2011 and published in a December 2012 report. Highlights of the preliminary surveys show little sediment deposition occurring. Out of the six reservoirs, notable sediment deposition has only been documented at selected transects in Lake James, the most upstream of the reservoirs. However, the report explains that weather conditions in the most recent years have not been representative of average rainfall, which has prevented historical sediment accumulation in the reservoirs. Future reports will be informative for understanding long-term sedimentation rates. [23]

In short, Duke Energy's relicensing efforts and the initiative of the Catawba Wateree Management Group ensure that these reservoirs have comprehensive data on sedimentation and loss of reservoir volume. Moreover, this project represents the only consistent monitoring of lakes among the 47 studied by the Nicholas Institute. This partnership is instructive for a successful model of cooperation between conservation interests, residents, government, and the business community, and should be considered for application in other river basins in North Carolina.

References Cited

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[3] Ken Otterbourg, "Alcoa and the great North Carolina power grab," *CNN Money,* November 30, 2010, Availablt at: http://features.blogs.fortune.cnn.com/2010/11/30/alcoa-and-the-great-north-carolina-power-grab/

[4] Duke Energy, "Catawba-Wateree Relicensing Overview." Last accessed May 15, 2013. Available at: http://www.duke-energy.com/catawba-wateree-relicensing/process-overview.asp

[5] Catawba Wateree Management Group, "Sedimentation Monitoring Project." Last accessed May 15, 2013. Available at: http://www.catawbawatereewmg.org/projects.html

[6] NC DENR, Public Water Supply Section, "Capturing Sediment." Last accessed May 9, 2013. Available at: http://www.ncwater.org/pws/swap/pages/burlingtonsedshort.htm

[7] City of Burlington, personal communication, December 05, 2012

[8] North Carolina Office of State Budget and Management, "County/State Population Projections." Last updated April 18, 2013, Available at: http://www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/county_projections.shtm

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[11] Catawba Riverkeeper, "Lake Wylie Page." Last accessed May 28, 2013. Available at: http://www.catawbariverkeeper.org/our-work/covekeepers/lakes-of-the-catawba/lake-wylie-page

[12] Catawba Riverkeeper, "Lake Norman Page." Last accessed May 28, 2013. Available at: http://www.catawbariverkeeper.org/our-work/covekeepers/lake-norman-page

[13] Duke Energy. "A Partnership with the Catawba-Wateree River." Duke Energy, December 2006. Available at: http://www.duke-energy.com/pdfs/relicensing/cw-brochure.pdf

[14] Catawba Riverkeeper, "Lakes of the Catawba." Last accessed May 28, 2013. Available at: http://www.catawbariverkeeper.org/our-work/covekeepers/lakes-of-the-catawba

[15] Catawba Riverkeeper, "Lakes of the Catawba." Last accessed May 28, 2013. Available at: http://www.catawbariverkeeper.org/our-work/covekeepers/lakes-of-the-catawba

[16] United States Environmental Protection Agency, "Coal Ash." Last accessed May 28, 2013. Available at: http://www.epa.gov/radiation/tenorm/coalandcoalash.html

[17] Catawba Riverkeeper, "Mountain Island Lake Page." Last accessed May 28, 2013. Available at: http://www.catawbariverkeeper.org/our-work/covekeepers/mountain-island-lake-page

[18] Hamilton, Heather and Kober, Amy and Hewes, Will. "America's Most Endangered Rivers," Washington D.C.: *American Rivers*, 2008. Available at: http://www.americanrivers.org/assets/pdfs/mer-past-reports/MER_Report2008optb969.pdf

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[22] Catawba-Wateree Hydroelectric Project Sedimentation Monitoring Report Year 1 Baseline Data. Prepared for: Duke Energy Carolinas, LLC. Charlotte, NC. Prepared by: HDR Engineering, Inc. of the Carolinas. August 2011 http://catawbawatereewmg.com/2011/Catawba-Wateree_Sediment_Report_Year_1_Final_2011.pdf

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APPENDIX

Table 1. Available Data in Selected River Basins

River Basin	Reservoirs in Study[1]	Reservoirs w/ Available Data[2]	Reservoirs Monitored[3]	Entities with Studies on Sedimentation
CAPE FEAR	13	7	1	U.S. Army Corps; USDA; N.C. Urban Water Consortium; City of Greensboro; UNC w/ funding from OWASA
NEUSE RIVER	5	3	1	U.S. Army Corps; City of Durham;City of Raleigh
YADKIN PEE DEE	11	11	0	U.S. Dept. of Agriculture; United States Geological Survey; Alcoa; Army Corps; Duke University
CATAWBA WATEREE	12*	12	6	Duke Energy; Catawba Wateree Management Group
SAVANNAH	5	5	0	Duke Energy
ROANOKE	1	0	1	U.S. Army Corps

*Catawba Wateree River Basin consists of eleven reservoirs. However, we include Brown's Cove (part of Lake Wylie) as a separate entity in Table 1. This is due to focused sedimentation research conducted specifically on Brown's Cove. Moreover, it is the only entity in the study that had a draft dredging plan and provided a concrete estimate on the cost of sediment removal.

[1] *Reservoirs in Study*: Scope of reservoirs studied is not a comprehensive review of all river basins in North Carolina. Reservoirs within each river basin were selected by data availability and significance.

[2] *Reservoirs w/ Available Data*: Studies have been completed where data regarding capacity loss and sedimentation were not made publicly available. Alternatively, sedimentation was not a concern of entity performing study.

[3] *Reservoirs Monitored*: In this category, we include reservoirs where sedimentation is being monitored for more than one consecutive year or where a future resurvey is expected (dependent on funding).

Table 2. Selected capacity loss and sedimentation rates; highlights largest and smallest volume change per river basin studied.

River Basin	Years of Study	Loss of Capacity	**Sedimentation Rate** (acre-feet per sq. mile drainage area per year)
CAPE FEAR			
University Lake	1932-1990	**Total Loss: 20%**	0.26
Jordan Lake	*1979-1990*	*6410 acre-feet*	0.34
	1990-1997	*310 acre-feet*	0.02
		Total Loss: 6720 acre-feet	Average Rate: 0.22
NEUSE RIVER			
Lake Michie/ Little River	1926-1992	Loss: 2,541 acre-feet	0.23
Falls Lake	1976		0.07
	1982-1997	(-) 728 acre-feet (-) 2.89%	(-) 0.95
YADKIN PEE DEE			
High Rock Lake		Annually: 0.36%	0.23
Badin (Narrows)		Annually: 0.05%	0.03
CATAWBA WATEREE			
Rhodiss	1925-2006	Total Loss: 37.2%	0.31
Bridgewater (Lake James)	1923-2006	Total Loss: 3.9%	0.23
KEOWEE/SAVANNAH			
Keowee	1971-2010	Total Loss: 6.553%	0.13
Richard B. Russell	1983-2010	Total Loss: 0.049%	0.18
ROANOKE			
Kerr Lake		n/a	n/a

Table 3. References Cited - Reservoir Sedimentation Data

Reservoir	Sedimentation Sources
CAPE FEAR RIVER BASIN	
Brandt	United States Department of Agriculture, *Reservoir Sedimentation Data Summary: Greensboro (Lake Brandt)*, October 1950, Available at: http://ida.water.usgs.gov/ressed/datasheets/6-3.pdf
	City of Greensboro Water Resources, personal communication, 2012.
Burlington	Bob Patterson, City of Burlington, e-mail correspondence, December 5, 2012.
	North Carolina Department of Environment and Natural Resources, Public Water Supply Section, *Capturing Sediment: Burlington, North Carolina,* Available at: http://www.ncwater.org/pws/swap/pages/moreburlingtonsed.htm
	United States Department of Agriculture, *Reservoir Sedimentation Data Summary: Burlington Municipal Reservoir*, September 27, 1950, Available at: http://ida.water.usgs.gov/ressed/datasheets/6-9.pdf
Cammack	see Burlington
Cane Creek	Edward Holland, Orange Water and Sewer Authority, personal communication, November 16, 2012.
City Lake	see Stony/Stoney
Graham-Mebane	Sedimentation information unavailable
Higgins	City of Greensboro Water Resources, personal communication, 2012.
Jeanette	Stow, Craig A and Wintergreen, James W., and Cason, Rebecca D. (November 2002). "Sedimentation and Water Quality in Lake Jeanette, Greensboro, NC" The research on which this report is based was funded by the City of Greensboro, NC, through the N.C. Urban Water Consortium. Project No. 50241 UNC-WRRI-SRS-22
Jordan	US Army Corps of Engineers, Wilmington District "Report of Sedimentation Resurvey" B. Everett Jordan Dam and Lake, Cape Fear River Basin, North Carolina August 1997
Makintosh	Sedimentation information unavailable
Randleman	Sedimentation information unavailable
Reidsville	Sedimentation information unavailable

Stony (Stoney)	City of Burlington, e-mail correspondence, December 5, 2012.
Townsend	City of Greensboro Water Resources, personal communication, 2012.
Troublesome Creek	see Lake Reidsville
University	Bises, James A. and Paull, Charles K. "Sedimentation in University Lake, Orange County, North Carolina," University of North Carolina Geology Department, March 1994, A report prepared with the sponsorship and funding of the Orange Water and Sewer Authority, Orange County, North Carolina.
CATAWBA – WATEREE RIVER BASIN	
Bridgewater	Catawba-Wateree Hydroelectric Project Sedimentation Monitoring Report Year 1 Baseline Data. Prepared for: Duke Energy Carolinas, LLC. Charlotte, NC. Prepared by: HDR Engineering, Inc. of the Carolinas. August 2011 http://www.duke-energy.com/catawba-wateree-relicensing/process-overview.asp Catawba Wateree Water Management Group, Sediment Monitoring Project (2013) Available at: http://www.catawbawatereewmg.org/projects.html CHEOPSTM hydro electric system simulation model Operations/Verification Report Appendix B: "Estimating Sediment Deposition and Volume Reduction in the Catawba-Wateree Resrvoirs (12 November 2004) http://www.duke-energy.com/pdfs/CWCVReport_08_01_06a_.pdf
C. Ford (Lake Norman)	
Fishing Creek	
Great Falls and Dearborn (GF-DEAR)	
Lookout	
Mountain Island	
Oxford (Lake Hickory)	
Rhodhiss	
Rocky Creek and Cedar Creek (RC-CC)	
Wateree	
Wylie	
Wylie: Brown's Cove	DIEMER, J. (05/01/2011). "Sedimentation in a Piedmont Reservoir: Evidence from Brown's Cove, Lake Wylie, North Carolina". Environmental & engineering geoscience (1078-7275), 17 (2), p. 123.

	Mecklenburg County Water Quality Program, personal communication, November 2012.
SAVANNAH RIVER BASIN	
Hartwell	Duke Energy Carolinas, 2012, "Keowee-Toxaway Hydroelectric Project (FERC No. 2503) Study Progress Report." Electronic Filing. June 15, 2012. FromDuke Energy Keowee-Toxaway Online Library. Available at: http://www.duke-energy.com/pdfs/KT_Progress_Report_2012_06.pdf
Jocassee	
J. Strom Thurmond (JST)	
Keowee	
Richard B. Russell (RBR)	
NEUSE	
Benson	Sedimentation information unavailable
Falls	US Army Corps of Engineers, Wilmington District "Report of Sedimentation Resurvey" Falls Lake Project, Neuse River Basin, North Carolina, July 1997.
Little River	Weaver, J.C., 1994, Sediment characteristics and sedimentation rates in Lake Michie, Durham County, North Carolina, 1990-92: U.S. Geological Survey Water-Resources Investigations Report 94-4123, 34 p. Hazen and Sawyer, 2010, "Technical Memorandum: City of Durham Dam Regulatory Compliance Study, Task 5: Reservoir Yield Evaluations." Prepared by Hazen and Sawyer for City of Durham. Aug 9 2010.
Michie	
Wheeler	Sedimentation information unavailable
ROANOKE RIVER BASIN	
Kerr Lake	United States Department of Army Corps of Engineers, *Reservoir Sedimentation Data Summary: John H. Kerr*, March 1961, Available at: http://ida.water.usgs.gov/ressed/datasheets/6-11.pdf
YADKIN- PEE DEE	

RIVER BASIN	
Badin (Narrows)	Yadkin-Pee Dee River Basin Plan, "Chapter 3: Causes of Impairment and Sources of Water Pollution," Available at: http://www.docstoc.com/docs/107023876/Yadkin-Pee-Dee-River-Basin-Plan-Chapter-3 Normandeau Associates, Inc. and PB Power , 2004, "Sediment Fate and Transport Draft Report: Alcoa Power Generating Inc. Yadkin Division, Yadkin Project Relicensing (FERC No. 2197)." Prepared by Normandeau Associates, Inc. and PB Power. December 2004. Available at: http://www.savehighrocklake.org/Proj2197/IAG/WQ/FinalDraftSedimentReport120904.pdf U.S. Department of Agriculture (USDA) 1979. Special Report: Erosion and Sediment Inventory, Yadkin – Pee Dee River Basin, North Carolina and South Carolina. USDA Economics, Statistics and Cooperative Services, Forest Service and Soil Conservation Service cooperating with the North Carolina Department of Natural Resources and Community Development and the South Carolina Water Resources Commission.
Blewett	
Falls	
High Rock	
Rockingham	
Rocky River	
S. Yadkin Gage	
Tillery	
Tuckertown	
Yadkin College Gage	
W. Kerr Scott	U.S. Army Corps of Engineers, personal communication, 2012.