Key Findings from Monitoring Data Collected in Falls Lake

Water quality data have been collected in Falls Lake since it was filled in the 1980s. Figure 1 shows the locations of the monitoring stations and organizations that collect data in Falls Lake.

Lake data summaries are provided in the following documents:

- 2019 UNRBA Annual Monitoring Report (comprehensive report)
- UNRBA Lake Modeling Report

Several key findings of the lake monitoring data were critical to the development of the UNRBA recommendations for a revised nutrient management strategy and Falls Lake Rules:

- Falls Lake is meetings its designated uses (fishing, swimming, aquatic life). Table 1 provides examples of input from the Technical Advisors Work Group and users of Falls Lake. Additional information is provided in the UNRBA Lake Modeling Report.
- Water quality in Falls Lake has improved since the 1980s and stabilized in the past two decades. The UNRBA has summarized the Falls Lake data for three parts of Falls Lake (Figure 2). The upper lake receives most of the nutrient loading from the watershed. This area of the lake is also wide and shallow. These two characteristics result in higher and more variable concentrations of nutrients and algal indicators compared to the middle and lower lake segments.
- Water quality in the upper lake has improved significantly due to reductions in nutrient loading from the watershed. Click here for a summary of the historic trends in nutrient loading to Falls Lake.
- Water quality in the lower lake has always been stable, even when nutrient loading to the lake was high (1980s). Table 2 shows the water quality trends since the 1980s for three parts of the lake. Figures show total nitrogen, total phosphorus, chlorophyll-a, and total organic carbon. Chlorophyll-a is a green pigment used as an indicator of algal growth. Chlorophyll-a is used as a water quality standard in North Carolina. The chlorophyll-a standard requires less than 40 micrograms per liter (40 µg/L) in water samples from Falls Lake. Data summaries for other parameters are provided in the UNRBA Lake Modeling Report.
- Falls Lake sediments accumulate and release nutrients slowly over time. This process delays how quickly the lake will respond to changes in nutrient loading. Nutrient releases from the lake sediments contribute to the stability of nutrients and chlorophyll-a in Falls Lake.
- Several organizations have collected data in, or studied, Falls Lake (Table 3). Monitoring locations for other organizations listed in Table 3 are provided in the linked reports. Each of these studies were integrated into the UNRBA Falls Lake models.

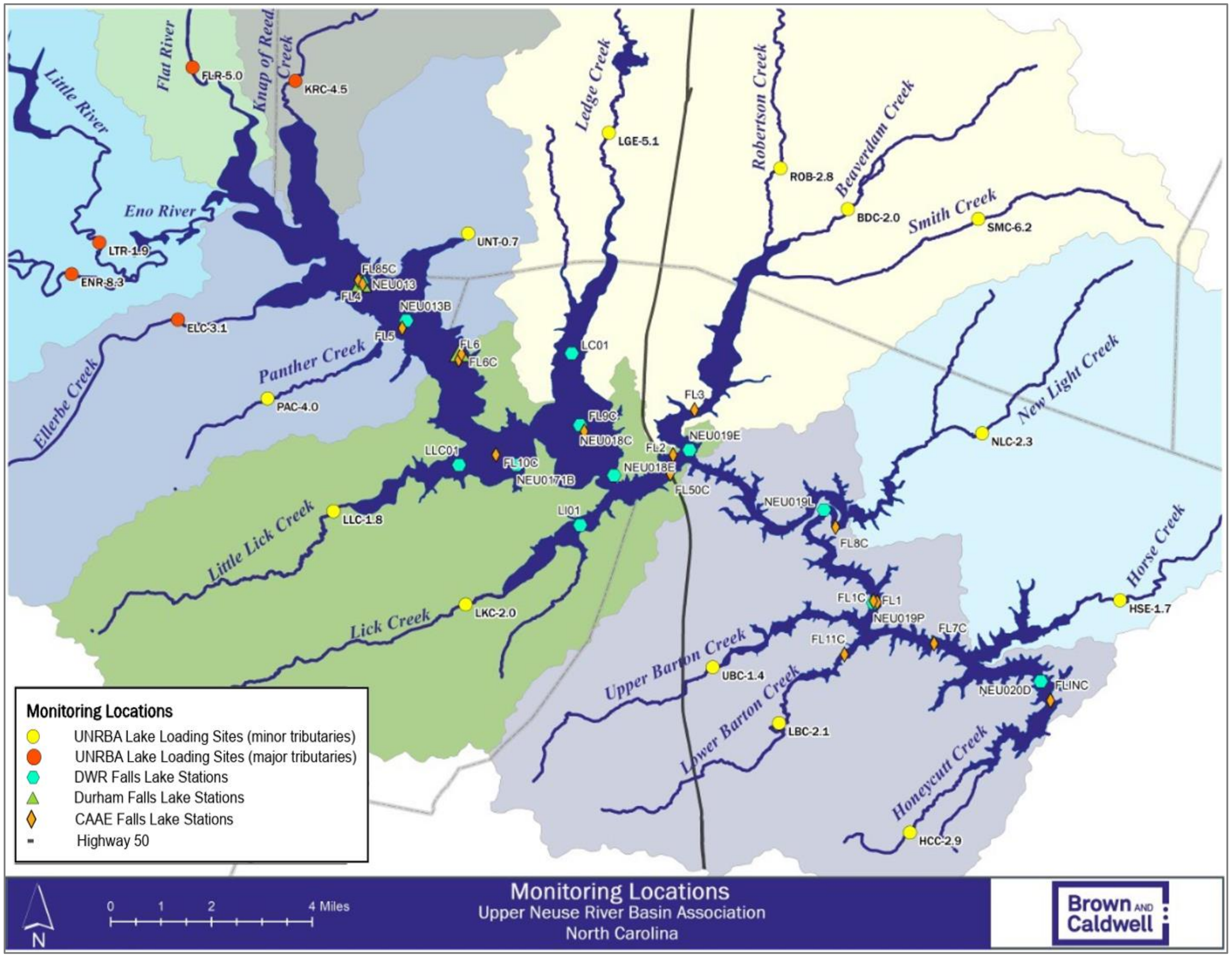


Figure 1. Location of Water Quality Monitoring Stations in Falls Lake

Table 1. Example Input from Representatives of Local Organizations Regarding the Designated Uses of Falls Lake

Organization	Input
Recreation (Fishing, Swimming, Etc.)	
NC State Parks	No known record keeping of complaints; most complaints relate to "too crowded" or negative personal interactions, or trash/facility needs; more related to guest experience than water quality concerns. State Parks data indicates that visitation to Falls Lake increased from 1 million in 2020 to nearly 1.5 million in 2021.
Wake County	Wake County manages some of the recreational areas on Falls Lake including swim beaches. The County has a response plan that includes coordination with DEQ, signage, etc. if DEQ confirms toxin exposure has led to an adverse event. Algal toxin levels have never resulted in a beach closure at Falls Lake.
Triangle Fly Fishers	Triangle Fly Fishers are frequently on Falls Lake and have extensive knowledge of fish species, fish movement, and trends on Falls Lake. Triangle Fly Fishers does not track algal toxin data in Falls Lake because toxins are consistently low. The group is not concerned about environmental or consumptive exposure to algal toxins on Falls Lake. If a fish kill was noticed, they would notify their members and DWR, but the group has not seen fish kills on Falls Lake.
City of Durham	Food web accumulation is a potential exposure pathway to subsistence fishers. Currently there is no data from Falls Lake to include in the model (potential future study).
Center for Disease Control (CDC)	The CDC launched a national database in 2016 called the One Health Harmful Algal Bloom System (OHHABS). The database includes voluntary reporting by States of toxic bloom events. The amount of information included for each event varies but may include environmental conditions, water quality and algae monitoring data, human health effects, and animal effects. OHHABS was used for comparison to Falls Lake algal toxin data and to provide a reference for algal toxin levels that cause human or animal adverse effects. Toxin levels in Falls Lake are relatively low compared to those in the OHHABS data and adverse effects from algal toxins in Falls Lake have not been documented by the State.
Aquatic Life	
NC Wildlife Resources Commission (WRC)	Staff noted the quality of fisheries in Falls Lake is generally above average for the Piedmont and not highly variable. Crappie fluctuates more than largemouth bass, but this is probably more a natural, ecological cycle than a response to specific lake conditions. Noted if we want to see problems, we'd probably have to expand our fisheries data beyond Falls Lake. Noted fisheries benefit from being eutrophic (more food) to a degree. There is a "sweet spot" level of eutrophication to provide a great fishery without detrimental impacts to the fishery or other uses. The 2015 WRC Overview of the Falls Lake Largemouth Bass Fishery (2007–2015) states that "Falls Lake supports an excellent Largemouth Bass fishery and is being appropriately regulated" and "survey results indicate that the abundance of Largemouth Bass and the size structure of the fishery has been relatively stable."
North Carolina Department of Environmental Quality (NCDEQ)	NCDEQ maintains a statewide database of reported fish kills. DEQ provided reported events for Falls Lake, and this information was used to assess nutrient-related impacts to the aquatic life designated use. Falls Lake records extend back to 1986. Nutrient or algae-related fish kills have not been reported since 1988 relatively soon after the lake was filled. Recreational use of the lake has increased over time, allowing for more potential observers if a fish kill occurred. NCDEQ created a phone application in 2018 for users to report fish kills making it easier to report events.
Triangle Fly Fishers	Triangle Fly Fishers are frequently on Falls Lake. If a fish kill was noticed, they would notify their members and DWR, but the group has not seen fish kills on Falls Lake.
Dr. Nathan Hall	In 2021, EPA issued proposed models to calculate site-specific chlorophyll-a standards based on the relationship between phytoplankton (algae) and zooplankton (small organisms that eat algae and are in turn eaten by small fish). Hall and Piehler (2021) evaluated this relationship for Falls Lake and other southeastern reservoirs. He found the approach was not appropriate Falls Lake and that chlorophyll-a in Falls Lake is about half the average of other southeast reservoirs.
Drinking Water Supply	

City of Raleigh	The City of Raleigh has monitored water quality in Falls Lake for the past two decades. Over this period, the type and timing of algal blooms has become more stable. Drought/flood cycle tends to increase total organic carbon in the lake. Staff are hopeful that research studies will increase the knowledge about how the lake bottom serves as a nutrient and sediment trap and whether dam releases stir up these materials. Noted manganese is the most difficult and expensive to treat. Manganese concentrations can become high in Falls Lake when bottom material is stirred up. City of Raleigh drinking water staff track algal toxin levels. Monitoring to date has not shown a concern in Falls Lake. Results show consistently low levels. Diatoms can clog filters at the drinking water plant. The City has two terminal ponds between Falls Lake and the treatment plant that are used for treatment of diatoms when needed. The City noted that they have had only one issue several years ago that required treatment in the terminal ponds. The City does not have issues with taste and odor or disinfection byproducts at Falls Lake. In 2023, the American Water Works Association ranked the City of Raleigh 3rd in its international "'Best of the Best' Water Taste Test"

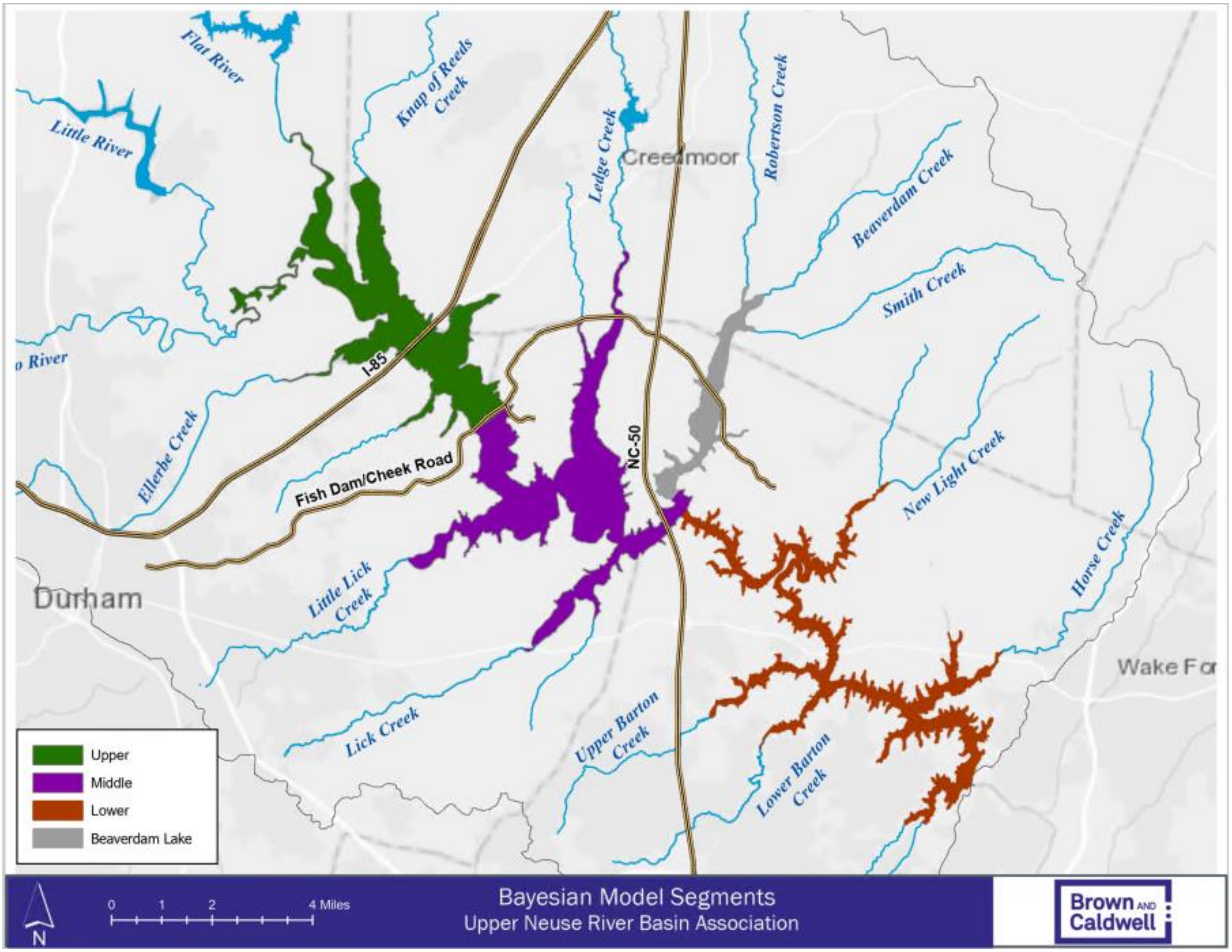
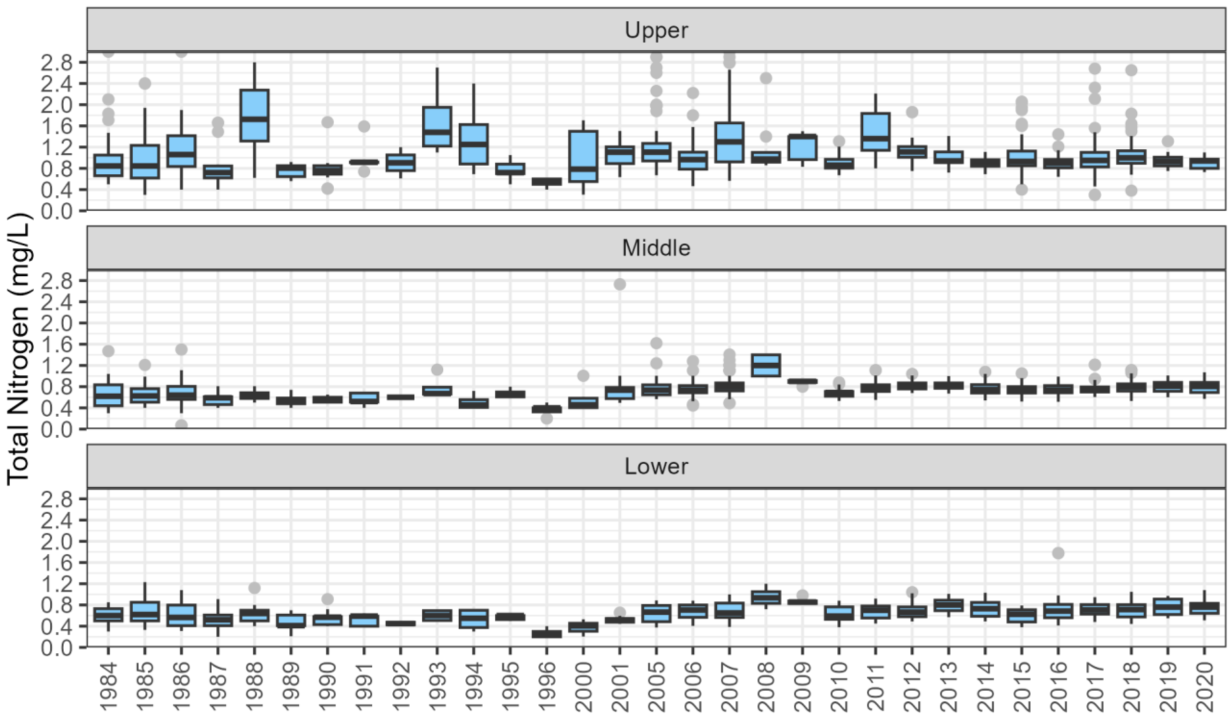


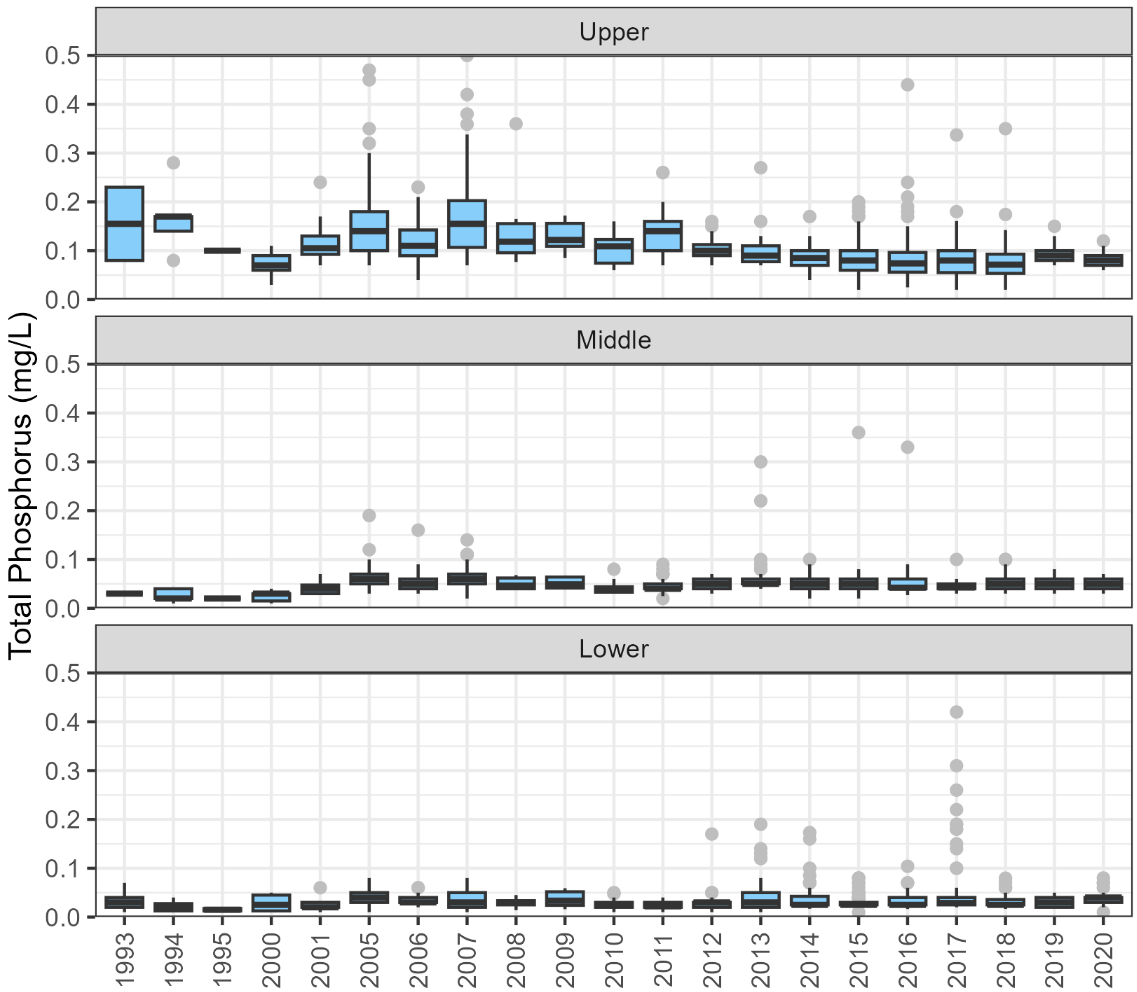
Figure 2. Segments of Falls Lake for Water Quality Data Summaries and Bayesian Modeling

Table 2. Historic Water Quality Trends for Total Nitrogen, Total Phosphorus, Chlorophyll-a, and Total Organic Carbon in the Three Segments of Falls Lake

Data Visualization	Notes
Total Nitrogen Photic Zone Composite Samples	
	Total Nitrogen by Year and Segment (y-axis cropped at 3 mg-N/L): • Higher values and higher variability in upper lake with conditions stabilizing • Lower lake generally stable distribution through time • Middle lake is less variable to upper and more variable that lower • No clear time pattern regarding median or mean, but variance is lower in more recent years • 13 samples were above 3 mg-N/L; these are not displayed on this figure • Values above 3 mg/L (clipped from figure) occurred post filling, mid-1990s, and 2007 (historic drought) • Gray circles are outliers that represent 5 percent of the data

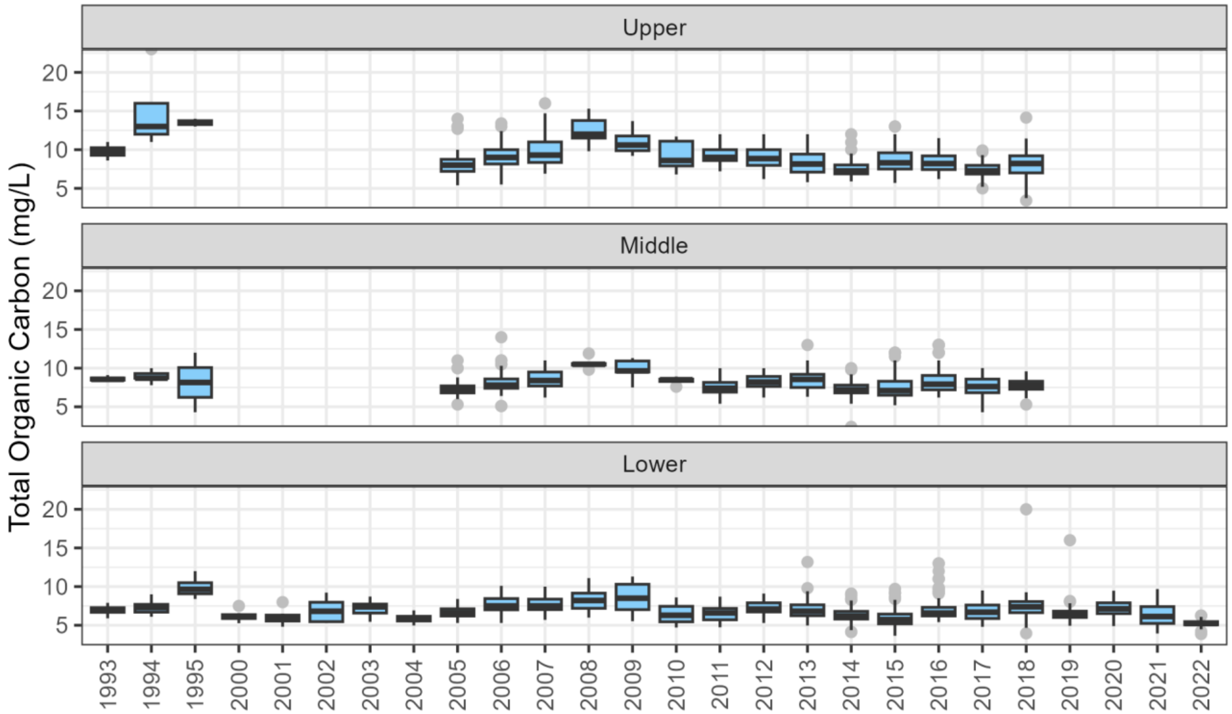
Data Visualization	Notes

<u>Total Phosphorus Photic Zone Composite Samples</u>



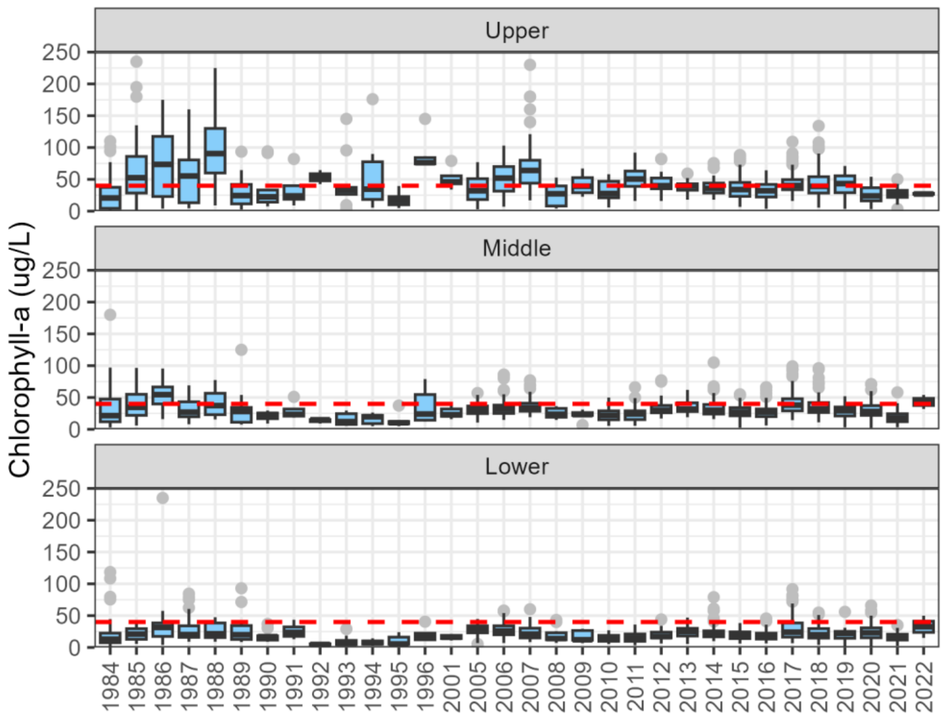
Total Phosphorus by Year and Segment (y-axis cropped at 0.5 mg-P/L):

- Data gaps in upper lake
- Decrease through time in upper
- Middle and lower lake has been relatively stable through time
- 9 samples were above 0.5 mg-P/L; these are not displayed on this figure
- Gray circles are outliers that represent 5 percent of the data

Data Visualization	Notes
Total Organic Carbon Photic Zone Composite Samples	
	Total Organic Carbon by Year and Segment: • Data gaps in upper and middle lake (x-axis is not continuous) • Shorter time series comparison • No strong trends apparent • Gray circles are outliers that represent 5 percent of the data

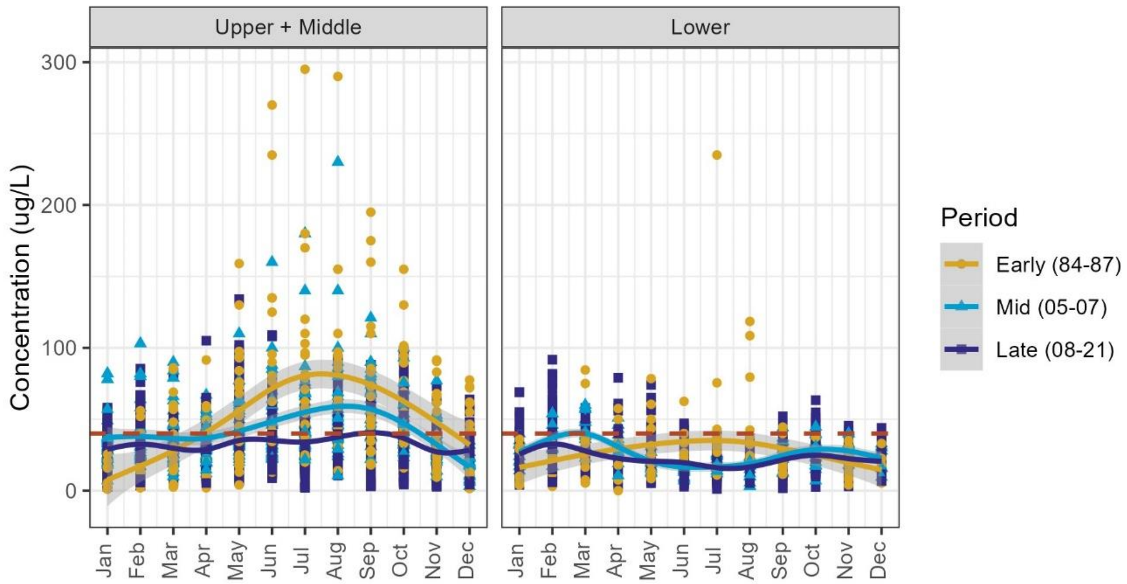
Data Visualization | **Notes**

<u>Chlorophyll-a Photic Zone Composite Samples</u>

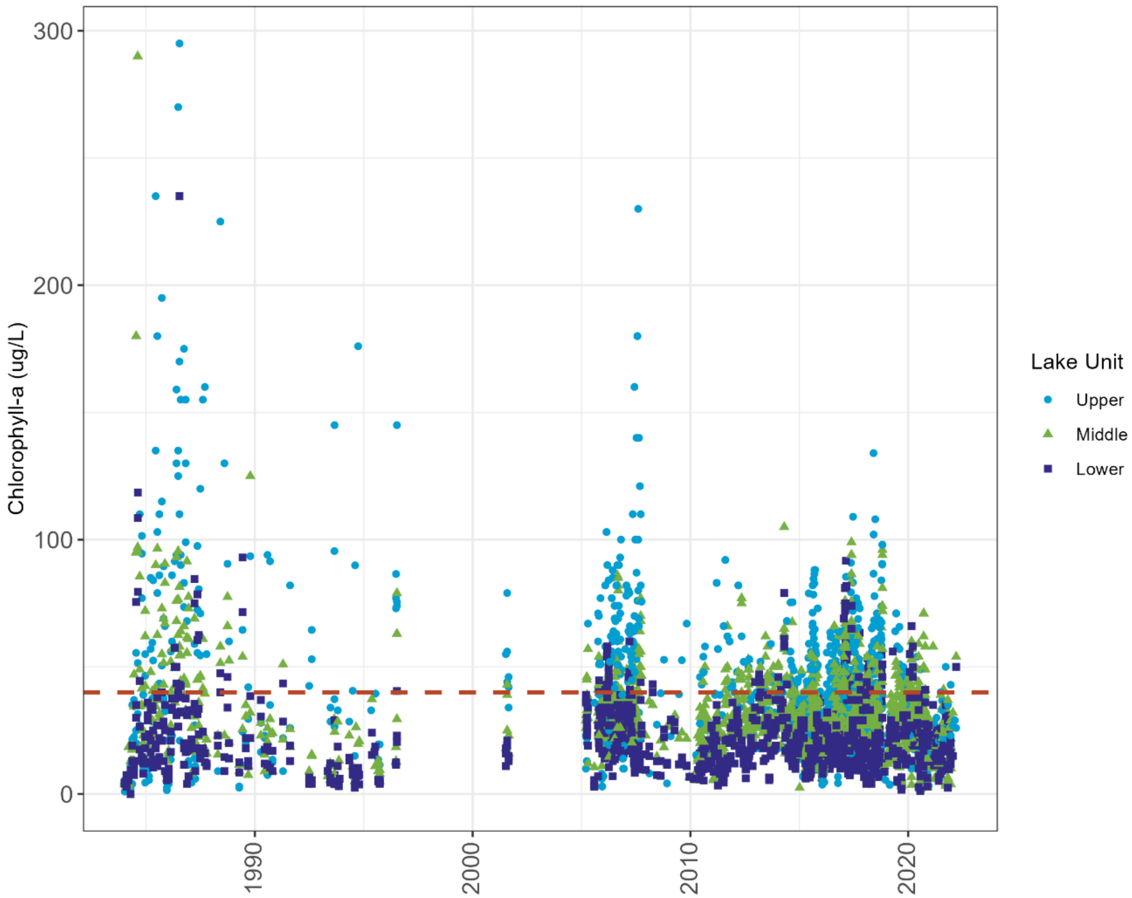


Distribution of Chlorophyll-a by Year and Segment:

- Red dashed line is the 40 µg/L NC chlorophyll-a standard
- Variance is highest in upper segment before 2012; less variability in upper segment after 2012; higher values in upper segment from 1988-2001 may be an artifact of sample bias (absence of winter data); high values in 2007 are due to the historic drought when the upper lake dried considerably
- Variance is relatively high in the middle segment in the mid-1980s after reservoir filling and in 1996 (Hurricane Fran); after 2001 variance is relatively low and majority of chlorophyll-a samples are below 40 µg/L
- Outliers were more common in the lower segment after reservoir filling; variance has been relatively stable across the period of record; majority of chlorophyll-a samples are below 40 µg/L
- Gray circles are outliers that represent 5 percent of the data

Data Visualization	Notes
	Change in Seasonal Trends Over Time • Red dashed line is the 40 µg/L NC chlorophyll-a standard • Early, post-filling years (1984-1987) are represented by orange circles (samples) and orange line (default LOESS fit with 95 percent confidence interval. LOESS is locally estimated scatterplot smoothing) • Mid years (2005 to 2007) correspond to the baseline monitoring period for the Rules during a historic drought. Samples are represented by light blue triangles. The light blue line is the default LOESS fit with 95 percent confidence interval. • Late years (2008-2021) are represented by dark blue squares (samples) and dark blue line (default LOESS fit with 95 percent confidence interval) • In the early years, chlorophyll-a has a strong seasonal pattern with the highest values in the warm months • Over time, seasonal changes are less extreme, and the maximum values are lower

Data Visualization



Notes

Chlorophyll-a Samples by Segment:

- Red dashed line is the 40 µg/L NC chlorophyll-a standard
- Upper lake samples are in light blue, middle lake in green, and lower lake in dark blue
- Maximum values of chlorophyll-a have decreased since the post-filling period (1980s); values over 200 µg/L were observed in all three segments
- Historic drought (2005 to 2007) had elevated values especially in the upper lake
- Extreme high values not documented since 2007 (historic drought)

Table 3. Summary of Falls Lake Data and Evaluations

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
WATERSHED STUDIES, TRIBUTARY AND LAKE DATA, AND TRIBUTARY LOADING EVALUATIONS TO FALLS LAKE				
Compilation of watershed and lake data to support planning for the reexamination	1999 to 2012 Watershed and Falls Lake	DWR, USGS, Local Governments,	UNRBA review of water quality data for Falls Lake and the Watershed by organization, sampling depth, month, year, etc. (Task 2 Report)	While this evaluation period does not overlap with the UNRBA Study Period, previous DWR sampling included water quality sampling at deeper depths in the water column. Distributions of past water quality summarized by depth provide a reasonableness check on EFDC and WARMF Lake simulations relative to predicted water quality in the bottom layers.
Measurement of nutrient, TSS, and total organic carbon from forested areas	2008 to 2013, forested headwater catchments in the Falls Lake watershed	US Forest Service	Measured loading rates from forested areas and comparison to simulated loading rates under varying rainfall conditions is provided in the UNRBA WARMF Watershed Modeling Report. Published data are available in Boggs et al. (2012).	While this evaluation period does not overlap with the UNRBA Study Period, these studies were used to provide a reasonableness check on WARMF-simulated loading rates for forested areas. When WARMF was evaluated for similar rainfall conditions to the Forest Service monitoring studies conducted in the Falls Lake watershed, simulated rates were similar to measured rates (baseflow and storm event runoff).
Tributary water quality monitoring to support UNRBA watershed model development	Aug. 2014 to Oct. 2018, Watershed and Falls Lake	UNRBA Routine Monitoring	Data summarized in the UNRBA 2019 Annual Report Raw data are available on the UNRBA data portal available in the UNRBA Resource Library.	Watershed data was used to calibrate the WARMF watershed model which provides stream flow and water quality concentrations delivered to Falls Lake for both WARMF Lake and EFDC.
Tributary high flow sampling to support UNRBA watershed model development	Grab sampling targeting precipitation events on largest 5 tributaries or corresponding with routine monitoring events, Aug 2014 to Dec. 2018	UNRBA Special Study	Distribution of concentrations by flow percentile in the 2019 Annual Report in Section 3.4.1; and partial results summarized in a different format in Results summarized in the 2016 Annual Report, Section 4.2	Watershed data was used to calibrate the WARMF watershed model which provides stream flow and water quality concentrations delivered to Falls Lake for both WARMF Lake and EFDC.

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Tributary storm event sampling to support UNRBA watershed model development	Automated samplers deployed April, September, and October 2015 on Ellerbe Creek and Eno River capturing four or more distinct storm peaks for each tributary.	UNRBA Special Study	Results summarized in the 2016 Annual Report, Section 4.1	Watershed data was used to calibrate the WARMF watershed model which provides stream flow and water quality concentrations delivered to Falls Lake for both WARMF Lake and EFDC.
Sediment and carbon inputs to Falls Lake	Flat River, Eno River, Little River, and Ellerbe Creek August 2019 to March 2020	NC Collaboratory	Results summarized in McKee et al. (2023)	This study concludes that most of the particulate organic matter entering Falls Lake originates from soil organic matter, freshwater algae (likely from upstream impoundments) and fertilizer. The cores from Falls Lake only indicate soil organic matter in the carbon signature. Average sedimentation rates in Falls Lake from 0.7 cm/yr to 1 cm/yr. The study concludes that ". If other reservoirs are similar in nature to Falls Lake, then the organic carbon accumulating in reservoirs (to offset growing CO2 concentrations in the atmosphere) is primarily from the carbon from reservoir watersheds which are better preserved and stored in reservoir bottom sediments. This conclusion is contrary to the idea that the source of the sedimentary carbon in bottom sediments results from the input of excess nutrients to reservoirs that results in large seasonal algae blooms and low oxygen waters." **For Falls Lake, the dominant source of carbon is from the watershed, and that is comprised mostly of soil organic matter.**
Empirical estimates of loading to Falls Lake	1980's to present at four tributaries with historic data (Flat River, Eno River, Knap of Reeds, and Ellerbe Creek	DWR water quality data and USGS stream flow data	See UNRBA Lake Modeling Report	Provides historic loading (total nitrogen and total phosphorus) to the UNRBA Statistical/Bayesian model

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Historic water quality measurements.	Several locations in Falls Lake and the watershed	DWR and USGS data	EPA Water Quality Portal	Historic lake data used to evaluate long-term trends in Falls Lake. Historic water quality data from the watershed used to develop annual average ratios of total organic carbon to total nitrogen to develop historic loading estimates of total organic carbon from the GAM models for total nitrogen described in the previous row.
WARMF simulated loading to Falls Lake	2014 to 2018 for seventeen tributary inputs	UNRBA Watershed Model	Summarized in the UNRBA Watershed Modeling Report	Simulated stream flows and water quality concentrations provide input to EFDC, WARMF Lake, and the UNRBA Statistical/Bayesian model
CBOD5 in lake loading in lake samples	August 2014 to December 2015 for seventeen tributary inputs	UNRBA Routine Monitoring	Data summary provided in the UNRBA 2016 Annual Report, Section 3.2 (parameter discontinued the following year) Data portal available in the UNRBA Resource Library.	Approximately 95 percent of the organic material entering Falls Lake is in the dissolved form; see description of development of labile and refractory constituents for EFDC model in Appendix A
Falls Lake profile data	2014 to 2018	DWR, CAAE, City of Durham	DO summarized in the 2019 Annual Report in Section 5.1.7.4;	Profile data used in EFDC and WARMF Lake for model calibration to ensure appropriate simulation of thermal stratification
Falls Lake UV254 and absorbance data	August 2014 to -October 2018	UNRBA Routine Monitoring	Included each year with 2014 to 2018 summarized in the 2019 Annual Report in Section 3.3.2	Provides additional lake data to support the evaluation of disinfection byproduct formation simulated in the UNRBA Falls Lake Statistical/Bayesian model
LAKE BATHYMETRY, LAKE SEDIMENT EVALUATIONS, INTERNAL LOADING FROM LAKE SEDIMENTS, and ATMOSPHERIC DEPOSITION TO SURFACE OF FALLS LAKE				

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
UNRBA Falls Lake bathymetry and sediment depth study (Water Cube)	Falls Lake, 2016	UNRBA Special Study	Results summarized in the UNRBA 2019 Annual Report in Section 5.4	Data used to establish the EFDC model grid and the WARMF Lake segments and to estimate the thickness of sediment across the bottom of Falls Lake
Quantifying sediment nutrient processing in Falls Lake (Dr. Michael Piehler)	Between July 2019 and August 2022, a series of sampling campaigns were conducted along a transect of 6 main channel stations and at 10 creek arm sites to measure N2 fixation and the biological, physical, and chemical characteristics at each site.	NC Collaboratory	Results summarized in final report (NC Collaboratory 2023), Piehler (2020), and Smiley et al. (2023). Researchers conclude that 1) policies aimed at reducing anthropogenic nitrogen inputs could mitigate water quality degradation to some extent but will likely not prevent algal blooms completely and that 2) excess nitrogen may be a characteristic of urban reservoir systems, and water quality standards should reflect that.	Data informs simulation of nutrient processing in the EFDC and WARMF Lake models for Falls Lake. Research confirmed that nitrogen fixation was an insignificant component of the Falls Lake nitrogen balance (~1 percent) and omission of this source from the Falls Lake models would not introduce significant uncertainty. Researchers indicated that most of the nitrogen and phosphorus within Falls Lake are bound up in plankton biomass and that neither nitrogen nor phosphorus is available in great excess. The three lake models for Falls Lake developed by the UNRBA also indicate that nutrient concentrations are relatively low.
Falls Lake sediment nutrient release (DWR)	June 2006	DWR	Results summarized in the 2019 Annual Report	Similar results to more recent sediment flux evaluations conducted by DWR and UNRBA when adjusted for temperature
Falls Lake sediment quality and nutrient release study (Dr. Marc Alperin)	June 8 and 10, 2015; 27 locations in Falls Lake	UNRBA Special Study	Alperin (2018) summarized in the 2019 Annual Report in Section 5.5.	Data provides initial conditions of lakebed sediments for simulation in the EFDC and WARMF Lake models for Falls Lake; nutrient release estimates provide a reasonableness check on model simulations
Falls Lake sediment nutrient release	June 2018	EPA	Flexner (2019) summarized in the 2019 Annual Report in Section 5.5.	Nutrient release estimates provide a reasonableness check on model simulations

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Atmospheric deposition to the lake surface for the UNRBA Study Period	2014 to 2018 for nitrogen, phosphorus, and total organic carbon	UNRBA based on data from CASTNET, NADP, and NC State Climate Office	Summarized in the UNRBA Watershed Modeling Report	Provides estimates of wet and dry deposition for WARMF Lake and EFDC models. See Section **Error! Reference source not found.** for long-term estimates used for the UNRBA statistical/Bayesian model.
WATER BALANCE AND WATER MOVEMENT IN FALLS LAKE				
Flow and water quality at two Falls Lake constrictions	January 2016; Oct./Nov. 2016	UNRBA Special Study	January 2016 event, 2016 Annual Report, Section 4.5 Oct/Nov 2016 event, 2017 Annual Report, Section 4.2	Provides water movement and water quality data for comparison to simulated values during high flow conditions
In situ observational study of falls lake	ADCPs were deployed at 4 locations: I-85, Fish Dam/Cheek Road, Hwy 50, Hwy 98; Nov 2019 to Dec 2020 Temperature profilers deployed at 3 downstream locations; also collected PAR data and YSI measurements at deployment/ redeployment 11/2019 and 6/2020	NC Collaboratory	Results summarized by Luettich et al. (2023). The researchers report that residence time in Falls Lake can be as short as weeks and as long as 5 years. Residence times in the side arms due to the exchange flow vary between 4.6 to 16.4 days, with the shorter residence times more common during the summer months.	EFDC modelers compared simulated water movement and velocities for 2015 to 2018 to those measured by Dr. Luettich in 2019 and 2020 to confirm the general patterns, directions, and magnitudes of flow were consistent with observations.
Evaluation of Falls Lake residence time	2014 to 2018	UNRBA	2014 to 2018 data summarized in the 2019 Annual Report in Section 5.8	Provides reasonableness check for EFDC and WARMF Lake and provides inputs to UNRBA Statistical/Bayesian model.
Precipitation, UNRBA study period	2015 to 2018 6-hour rainfall	NC State Climate Office	Summarized in the UNRBA Watershed Modeling Report	Provides 6-hour rainfall at 78 locations in the watershed for the watershed and lake models

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Precipitation, historic record	1990 to 2020 at 60 stations with variable periods of collection	National Oceanic and Atmospheric Administration (NOAA)	Global Historical Climatology Network	Used to evaluate rainfall trends over time (rainfall depth, number of days of rain, wet and dry periods, identification of extreme events) for the UNRBA Statistical/Bayesian model.
Falls Lake water supply withdrawals	2005-2007, 2014-2018	City of Raleigh	Daily data provided by City of Raleigh	Used to develop daily time series of withdrawals for EFDC and WARMF Lake
Falls Lake water level	1991 to 2022, gages located at Beaverdam Dam and Falls Lake Dam	USGS	Beaverdam Creek at Dam Near Creedmoor, NC – 0208706575 Falls Lake Above Dam NR Falls, NC - 02087182	Both gages were used for hydrodynamic calibration of the EFDC model for the UNRBA Study Period (2015 to 2018); the Falls Lake gage was used for hydrologic calibration of WARMF Lake for the UNRBA Study Period. The long-term record at the Falls Lake Dam was used by the UNRBA Statistical/Bayesian model to generate daily average, annual average, monthly variation, 30-day rolling average, and daily change in water level data inputs.
Falls Lake dam releases	1983 to 2023	USGS	Neuse River Near Falls, NC - 02087183	Used to specify the discharge from Falls Lake to the Neuse River for the WARMF Lake and EFDC models
LIGHT EVALUATION AND PHOTOSYNTHESIS				
Light attenuation and Secchi depth data collected within Falls Lake	Mid 1980s to early 1990s and 3 locations in Falls Lake, October 2015	DWR	Results summarized in the 2016 Annual Report, Section 4.7; Light Attenuation Falls of the Neuse Reservoir 10-2015.pdf; Model Evaluation Report, Section 3.1.3	Confirms assumption that the photic zone can be reasonably approximated as twice the Secchi depth; provides information on background light extinction in Falls Lake for EFDC and WARMF Lake
Jordan Lake - Effects of nutrient and light limitation on phytoplankton dynamics	Jordan Lake, July 2017 to June 2018	NC Collaboratory	Results summarized by Paerl and Hall (2019)	While this study was not conducted on Falls Lake, this evaluation of photosynthesis rates, light saturation, and shade adaption provides a reasonable starting point for calibration of these rates for the Falls Lake EFDC and WARMF Lake models.

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
LAKE PROCESSES, ALGAL SPECIES, AND ALGAL GROWTH				
Cyanobacterial N2 fixation and denitrification in Falls Lake	July 2019 and early July 2020: Profiles of temperature, conductivity, dissolved oxygen, pH; Photosynthetically active radiation (PAR); Photic zone composite nutrient and silicate samples; chlorophyll-a, taxa, POC and PON	NC Collaboratory	Results summarized by Hall and Paerl (2023): "Based on the mass balance and direct core measurements of denitrification it appears that denitrification exceeds N2 fixation and that the balance of these microbial processes result in a net loss of N from Falls Lake. Net loss of N could help maintain N limited phytoplankton which is consistent with N limited growth observed in nutrient addition experiments conducted in spring and summer 2021. Most of the N and P within Falls Lake are bound up in plankton biomass. P is not available in great excess and appeared to be an important constraint on N2 fixation. This situation of N limitation but with the potential for stimulation of N2 fixation by P suggests that dual management of N and P is warranted for preventing undesirable levels of phytoplankton biomass in Falls Lake.	Provides information to set initial reaction rates in WARMF Lake and EFDC pertaining to nitrogen reactions
Evaluation of nutrient limitation	Using UNRBA routine monitoring data (2014 to 2018)	UNRBA	Data summarized in the 2019 Annual Report in Section 5.9	Provides context for evaluating simulations by WARMF Lake and EFDC along with NC Collaboratory research studies

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Evaluation of DWR EFDC model sensitivity to lability	The lability of POC was an assumed parameter for DWR's 2006 EFDC model, along with the assumption that 50 percent of all incoming carbon was delivered in particulate form (as POC). Assumptions used by DWR to build their Falls Lake EFDC model and relevant data to consider	UNRBA evaluation of DWR model	Model Evaluation Report, Section 3.1.2	Provides information regarding previous EFDC model. UNRBA routine Monitoring has since shown that POC accounts for only about 5 percent of the organic carbon entering Falls Lake.
Algal species data	Three locations in Falls Lake monthly	DWR	2014 to 2018 data summarized in the 2019 Annual Report in Section 3.3.2; historic data summarized in Appendix D	Provides algal cell densities and biovolumes to determine seasonal trends in algal groups and support calibration of WARMF Lake and EFDC.
Assessment of Zooplankton-Phytoplankton Relationships in Falls Lake	Zooplankton data from Falls Lake were provided by Dr. Sandra Cooke. Zooplankton samples were collected at ten CAAE monitoring stations approximate monthly from 2009 to 2012. Chlorophyll-a was measured by CAAE using fluorometry.	NC Collaboratory	Results summarized by Hall and Piehler (2023)	In 2021, EPA issued proposed models to calculate site-specific chlorophyll-a standards based on the relationship between phytoplankton (algae) and zooplankton (small organisms that eat algae and are eaten by small fish). The UNRBA had requested the raw zooplankton data for incorporation into the statistical/Bayesian model but was not able to obtain the data. Dr. Nathan Hall was able to obtain the data and evaluated the relationship proposed by EPA for Falls Lake and other southeastern reservoirs. He found the approach was not appropriate Falls Lake. For this reason, the statistical modeling team did not further pursue the raw zooplankton data.
ALGAL TOXIN DATA				
Falls Lake algal toxin data	Six locations, three toxins, 2007-2012, raw intake measurements; Monthly data collected at multiple stations from 2016 to 2018	City of Raleigh	2016 to 2018 data summarized in the 2019 Annual Report in Section 5.10	Provides data for the Statistical/Bayesian model regarding conditions in Falls Lake and concentrations of algal toxins

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Cyanotoxin presence and year-round dynamics in Falls Lake	2019-2021 (toxin adsorption to SPATTs, toxin concentrations, field parameters)	NC Collaboratory	Results summarized by Schnetzer and Pierce (2023): "Maximal toxin concentrations from monthly collections did not exceed regulatory thresholds established by the World Health Organization. However, accumulated dissolved toxins were detected by the passive in situ samplers. Algal biomass alone is not a reliable indicator of cyanotoxin exposure risk in Falls Lake."	Provides data for the Statistical/Bayesian model regarding conditions in Falls Lake and levels of algal toxins
One Health Harmful Algal Bloom System	Voluntary reporting by States, launched in 2016; data through 2020	Center for Disease Control (CDC)	Provides data on reported events in terms of environmental conditions, water quality and algae monitoring data, human health, and animal effects	Provides data for the Statistical/Bayesian model regarding conditions in other states that have reported human health events or animal incidents associated with harmful algal blooms and environmental conditions during the event
ADDITIONAL DESIGNATED USE DATA AND EVALUATIONS				
Reported fish kills	1986 to 2020, statewide database	NCDEQ	See additional description in Section **Error! Reference source not found.**	Used in the UNRBA Statistical/Bayesian model to understand water quality conditions when fish kills have been reported and to evaluate the aquatic life designated use
In lake fish type and quantity	Black crappie and largemouth bass every other year, alternating spring and fall depending on the species; primarily in deeper part of lake	Wildlife Resource Commission (WRC)	Data provided to Ashton Drew via personal communication (K. Rundle, November 2021)	Data are collected every other year for each species, so not directly included in the UNRBA Statistical/Bayesian model which has been developed with monthly data. This data provides context when evaluating output from the UNRBA Statistical/Bayesian model.

Study	Date Range and Location	Organization	Summary of Results or Link to Data	Applicability
Additional raw water characteristics (turbidity, manganese, pH, temperature)	2013 to 2018	City of Raleigh	Data discussed with E. Buchan on May 2022; originally acquired by UNRBA for 2019 Annual Report	Used in the UNRBA Statistical/Bayesian model to understand how water quality conditions affect drinking water treatment.
Boat ramp study	2000; Falls, Jordan, and Kerr Lakes	Colorado State University	The purposes included documenting current use of the lake, determining boater perceptions of their visits, and identifying the nature and magnitude of boating conflicts (2013 USACE Falls Lake Master Plan)	The study found that boater experiences were being negatively impacted at peak periods of use by the high level of motorboat traffic on the reservoir. Provides context and background to the statistical/Bayesian model; not directly applied given it is a single survey.
Falls Lake recreational use assessment	2005 to 2015	UNRBA	Trips and trip types (2005 to 2015), facility limitations, summarized in the 2016 Annual Report, Section 4.9; Different data are summarized in the 2019 Annual Report in Section 5.11	Data are summarized annually, so not directly included in the UNRBA Statistical/Bayesian model which has been developed with monthly data. This data provides context when evaluating output from the UNRBA Statistical/Bayesian model.