UNRBA Monitoring, Modeling, and Regulatory Support

Alix Matos - Cardno
Michelle Woolfolk – City of Durham, Stormwater Program

Modeling and Regulatory Kick-Off Meeting
September 28, 2016

Falls Lake Monitoring and Modeling

- Past efforts
  - DWR
  - UNRBA
- Current work
  - Monitoring
  - Planning for modeling
- Future activities
  - Continued monitoring
  - Modeling

Background Information on the Original Establishment of the Rules

Issues with Original Modeling Period

- Legislative mandate required that DWR collect monitoring data, develop and calibrate watershed and lake models, and draft rules within 3 years
- Most of the chorophyll *a* data from 2005 had to be rejected due to laboratory analysis issues
- Given time constraints, DWR proposed that the Nutrient Management Strategy would be based largely on 2006 data
- Technical Advisory Committee had concerns with 2006 as the baseline year, but no alternative available
- Overall the monitoring period (2005 through 2007) occurred in a severe drought when lake levels were often extremely low

Pictures of Falls Lake at I-85 Taken in 2007

Photo courtesy of City of Durham (October)

Photo courtesy of Southeast Regional Climate Center (November)

Rule Language Regarding Reexamination

- "**Recognizing the uncertainty** associated with model-based load reduction targets…a person may at any time during implementation of the Falls nutrient strategy develop and submit for Commission approval **supplemental nutrient response modeling**" requiring
  - Division review and approval of any monitoring study plan and description of the modeling framework
  - A minimum of three years of lake water quality data
  - Supplemental modeling is conducted in accordance with the quality assurance requirements of the Division

UNRBA Monitoring and Modeling and Regulatory Support to Support Reexamination

UNRBA Strategy for Reexamination (Past Work)

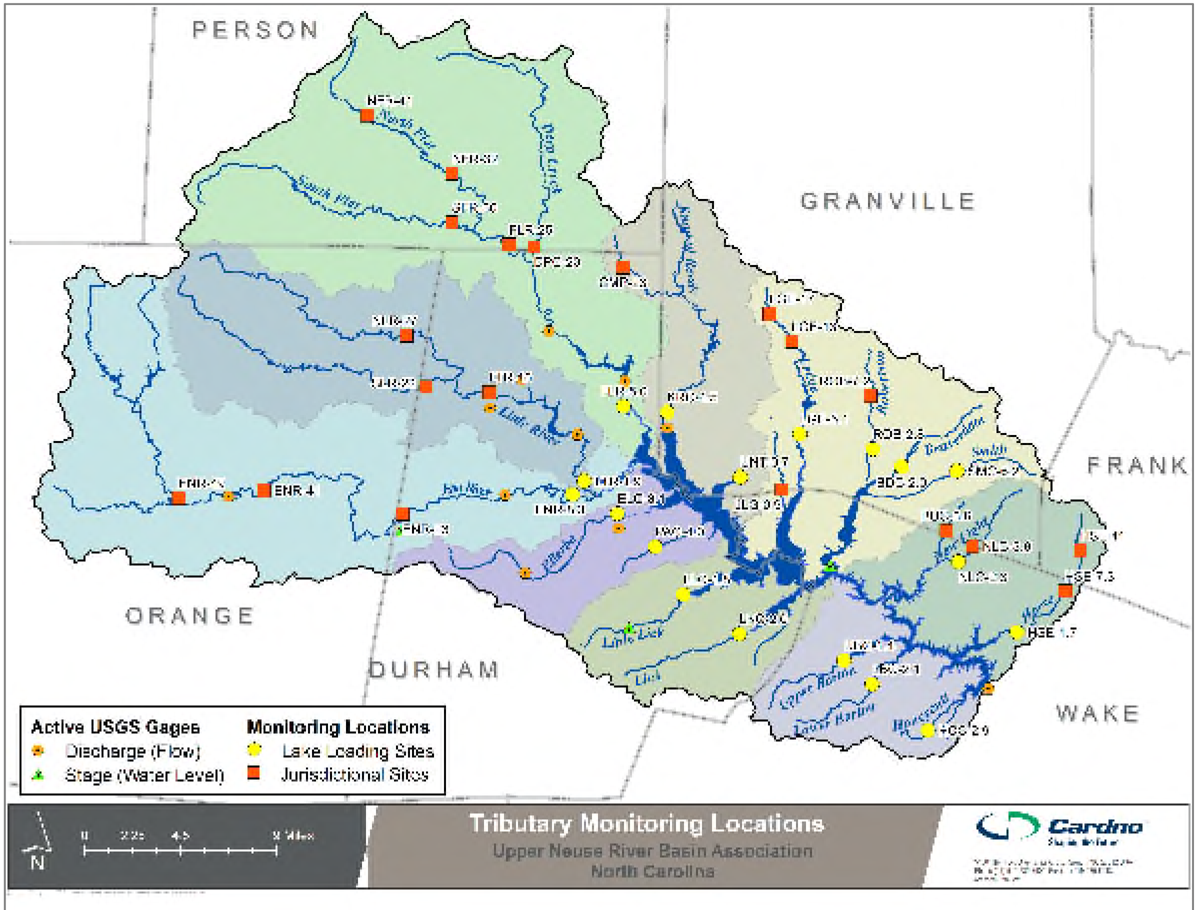
> In 2011, the UNRBA began planning for the reexamination using a measured, science-based approach and hired Cardno to
  - Review monitoring and modeling conducted by DWR
  - Evaluate data gaps and uncertainties
  - Develop a strategy for the reexamination (monitoring, modeling, and regulatory alternatives)
  - Develop and conduct an adaptive monitoring program to support
    - Revised lake response modeling
    - Load allocations to sources and jurisdictions
    - Regulatory options as needed

Examples of Data Gaps and Modeling Uncertainties

- Chlorophyll *a* and TOC were not sampled in tributaries
- Linear interpolation between grab samples was used to extrapolate tributary concentrations on days not sampled
- Lake processes such as nutrient flux were constant over the lake bottom (i.e., no spatial variability)
- Simulated nutrient loading to the lake was inconsistent between the watershed and lake response model
- Lake constrictions (bridge crossings are not represented) by the model grid

UNRBA Monitoring Program – Routine Monitoring

- 4-5 year program
- Began in August 2014
- Stations
  - 18 lake loading
  - 20 jurisdictional
  - 12 inlake (supplemental data)
- Sampled monthly

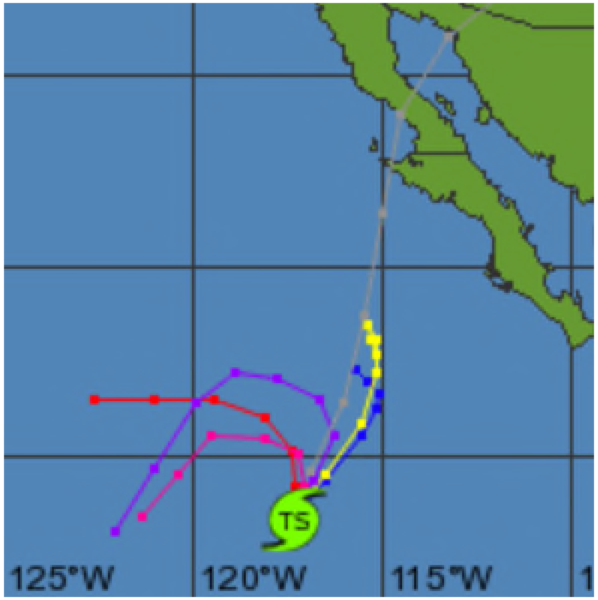


UNRBA Monitoring Program – Special Studies

- Special studies address specific questions
  - Storm event sampling (automated samplers)
  - High flow event sampling (grab samples)
  - Lake bathymetry study
  - Lake constriction point monitoring (velocities and water quality)
  - Lake sediment evaluations (cores, mapping depths of sediment)

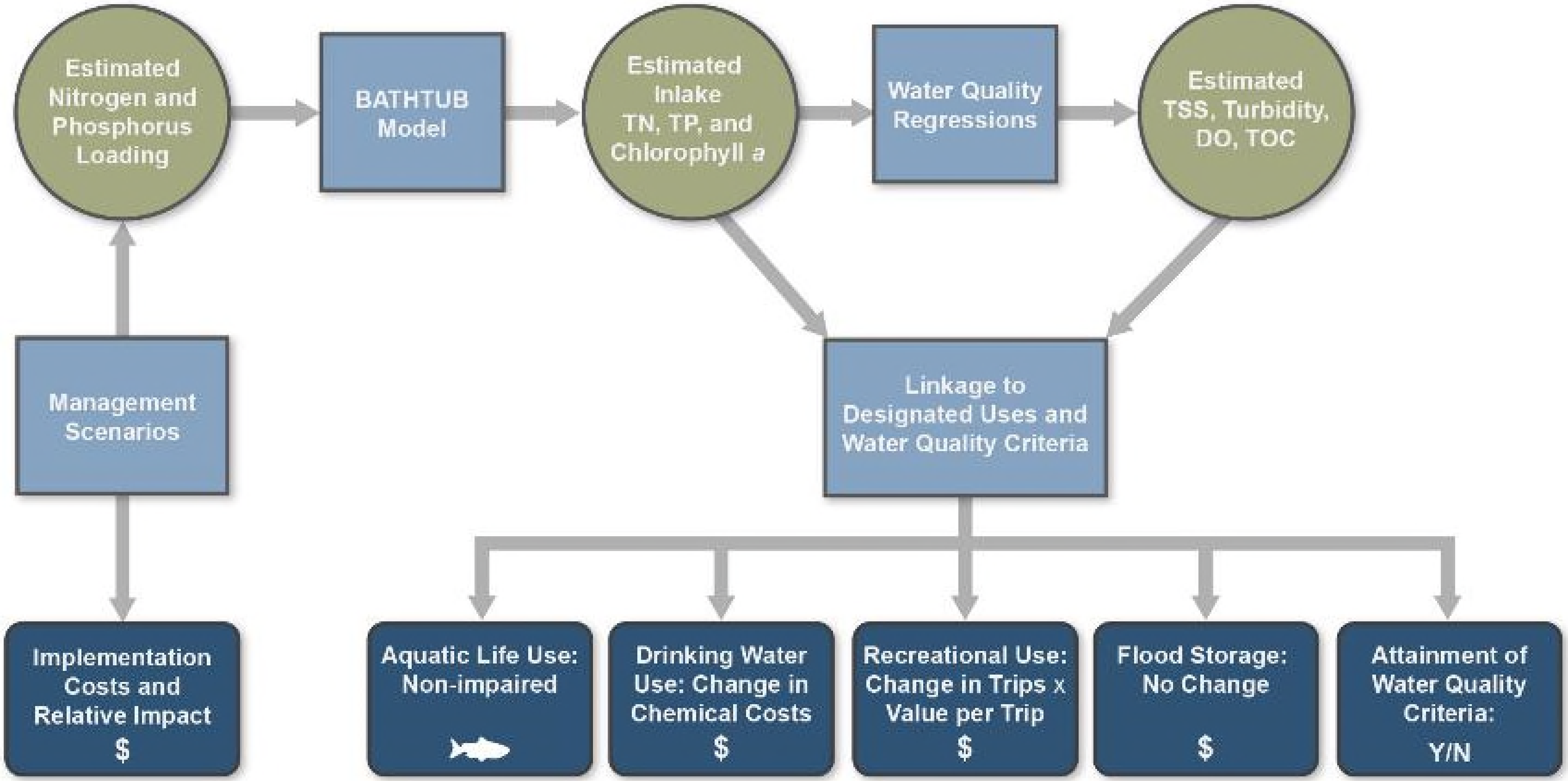
UNRBA Modeling Approach

- Use multiple models to corroborate results
- Test and optimize management strategies
- Make future predictions
- Test “What ifs”



UNRBA Modeling Approach, Continued

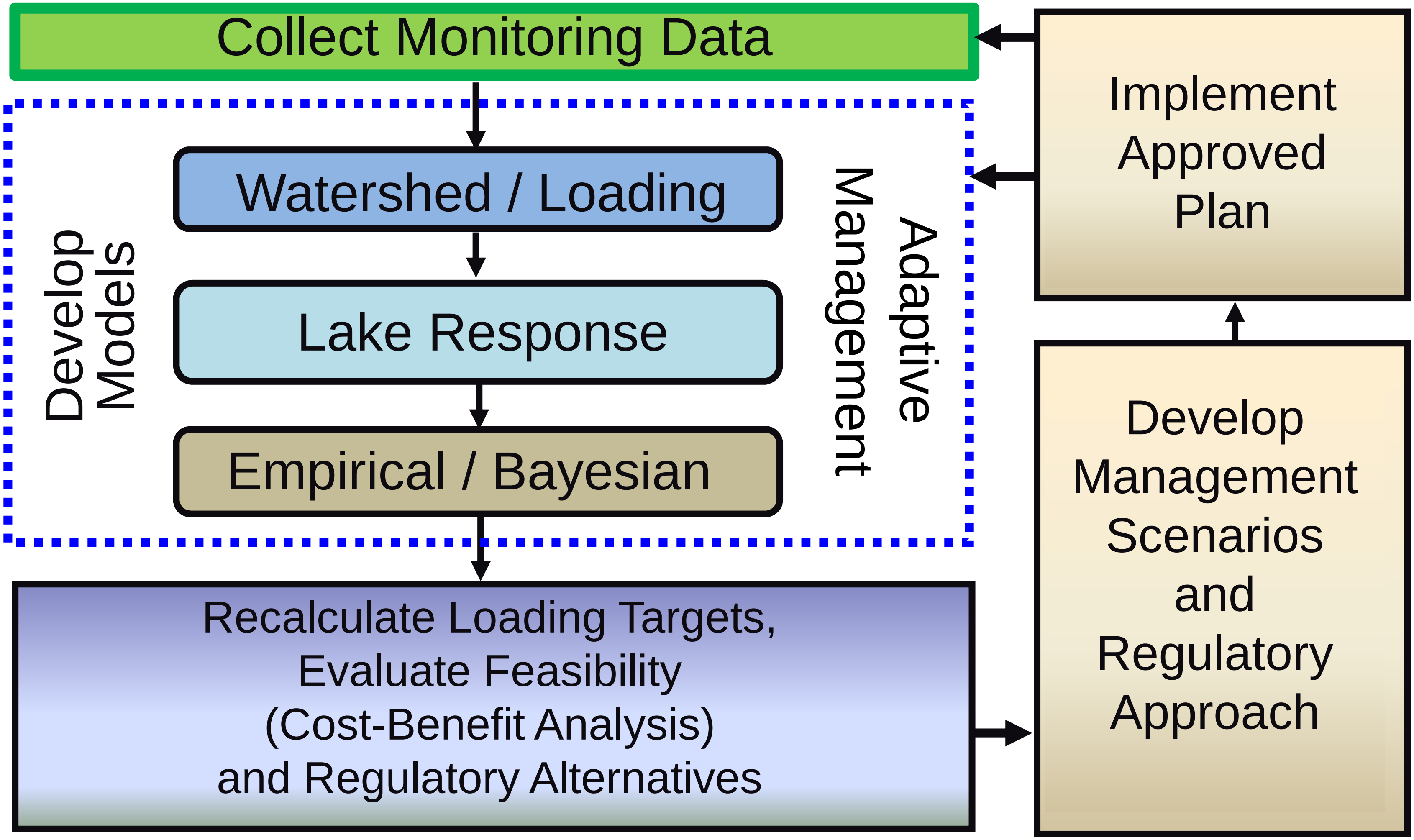
> Link water quality in the lake to designated uses



UNRBA Modeling Approach, Continued

- Follows required approval process described in the Falls Lake Nutrient Management Strategy (FLNMS)
  - UNRBA Description of the Modeling Framework was approved by the Division in June 2014
  - UNRBA Monitoring Plan and Monitoring QAPP were approved by the Division in July 2014
  - UNRBA Monitoring Program exceeds minimum 3-yr required
  - Supplemental modeling to be conducted in accordance with the quality assurance requirements of the Division

Linking the Components of the Reexamination



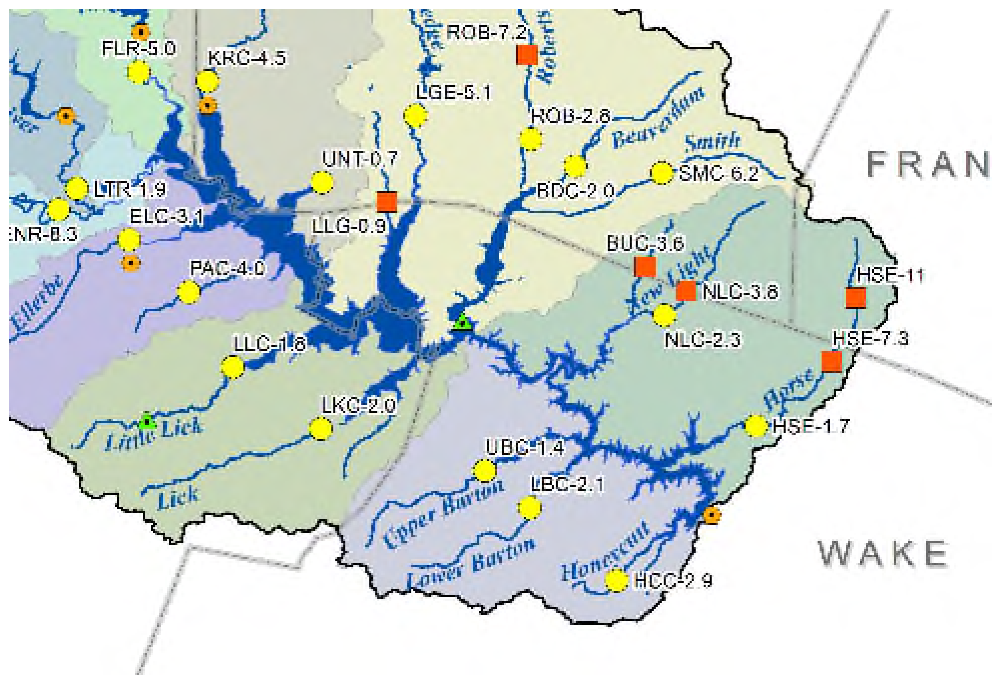
Year 1 Effort for the UNRBA Modeling and Regulatory Support

- Stakeholder kickoff meeting today to hear concerns and questions
- Evaluate and select watershed and lake models that best address modeling objectives
- Develop the conceptual plan for the multi-modeling approach
- Develop and obtain DEQ approval of the Modeling QAPP
- Develop of the two year work plan
  (October 2017 to September 2019)

Examples of how modeling goals link to the monitoring and modeling plans

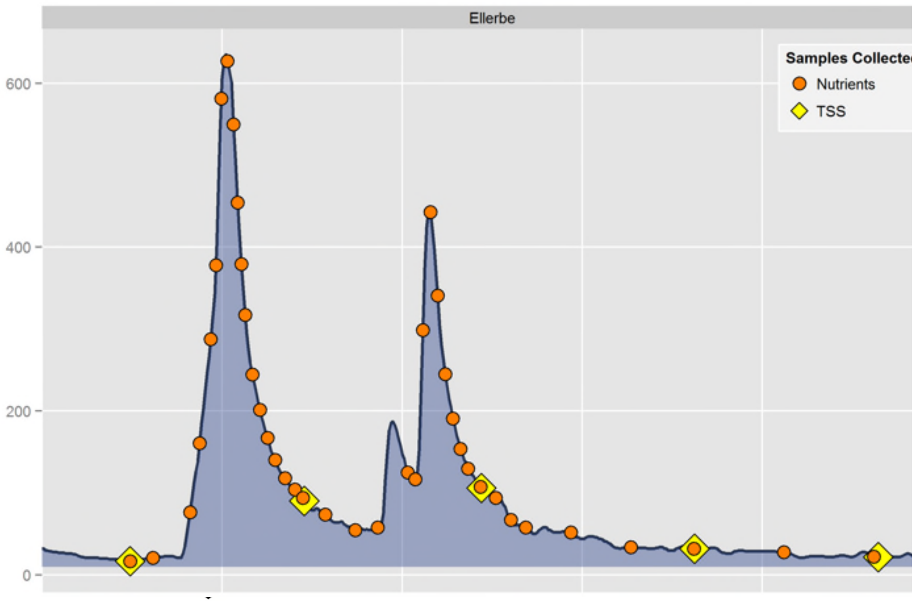
"What is entering the lake"? (chlorophyll a, nitrogen, phosphorus)

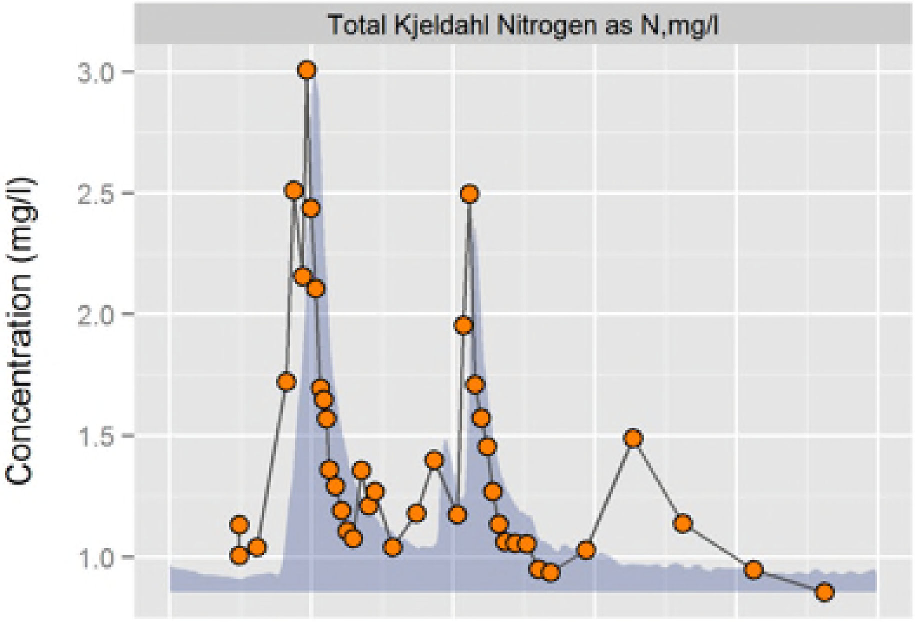
- UNRBA routine monitoring includes sampling these parameters at each lake loading station



"What is entering the lake"? (chlorophyll a, nitrogen, phosphorus)

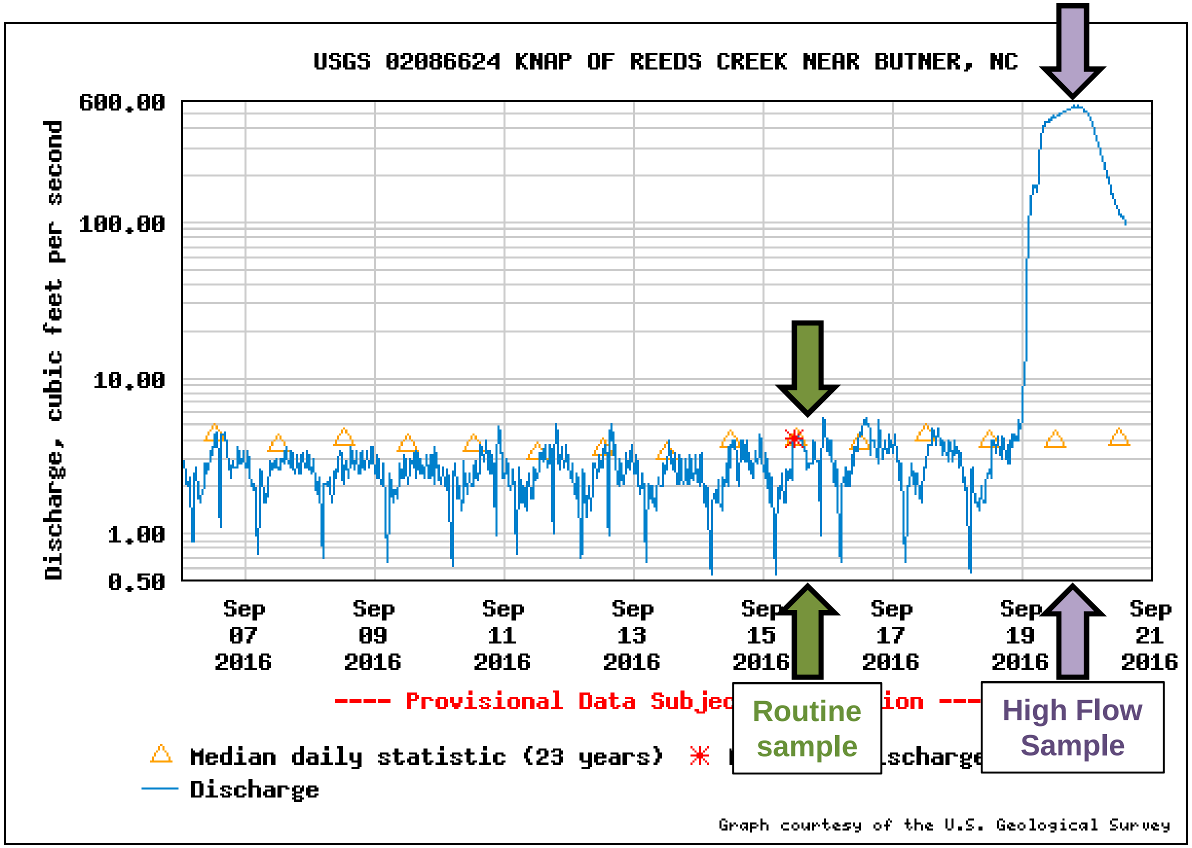
- Storm event sampling occurred during four storms on two tributaries to obtain "measured" loads entering the lake
- Auto samplers collect approximately 20 samples per storm to be paired with USGS 15-min flow data





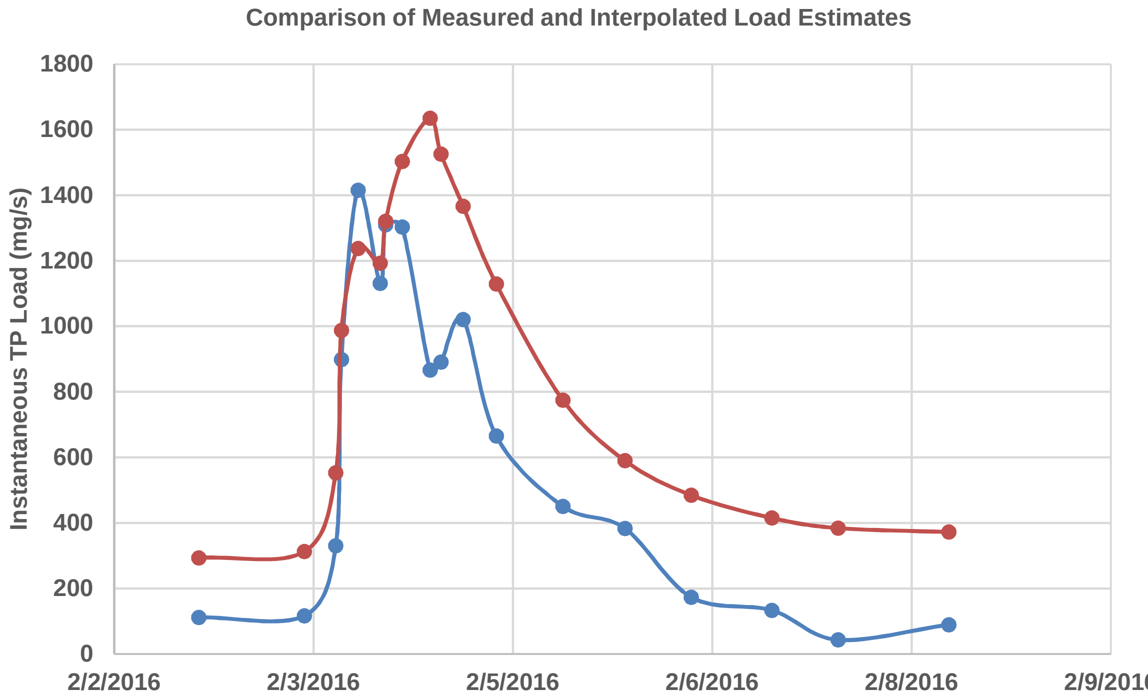
“What is entering the lake”? (chlorophyll a, nitrogen, phosphorus)

- High flow sampling to target conditions when loading to the lake is high



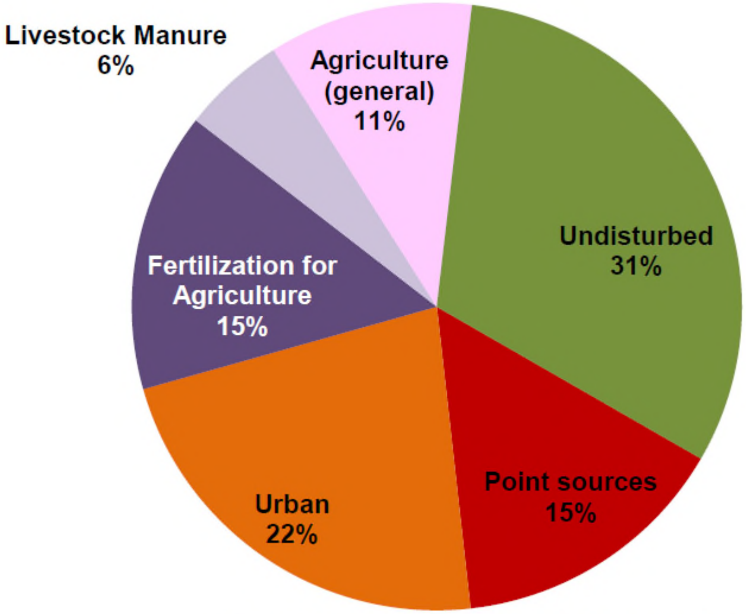
"What is entering the lake"? (chlorophyll a, nitrogen, phosphorus)

> Comparison of load estimation techniques to develop most accurate tributary input files for the lake response model



"What is entering the lake"? (chlorophyll a, nitrogen, phosphorus)

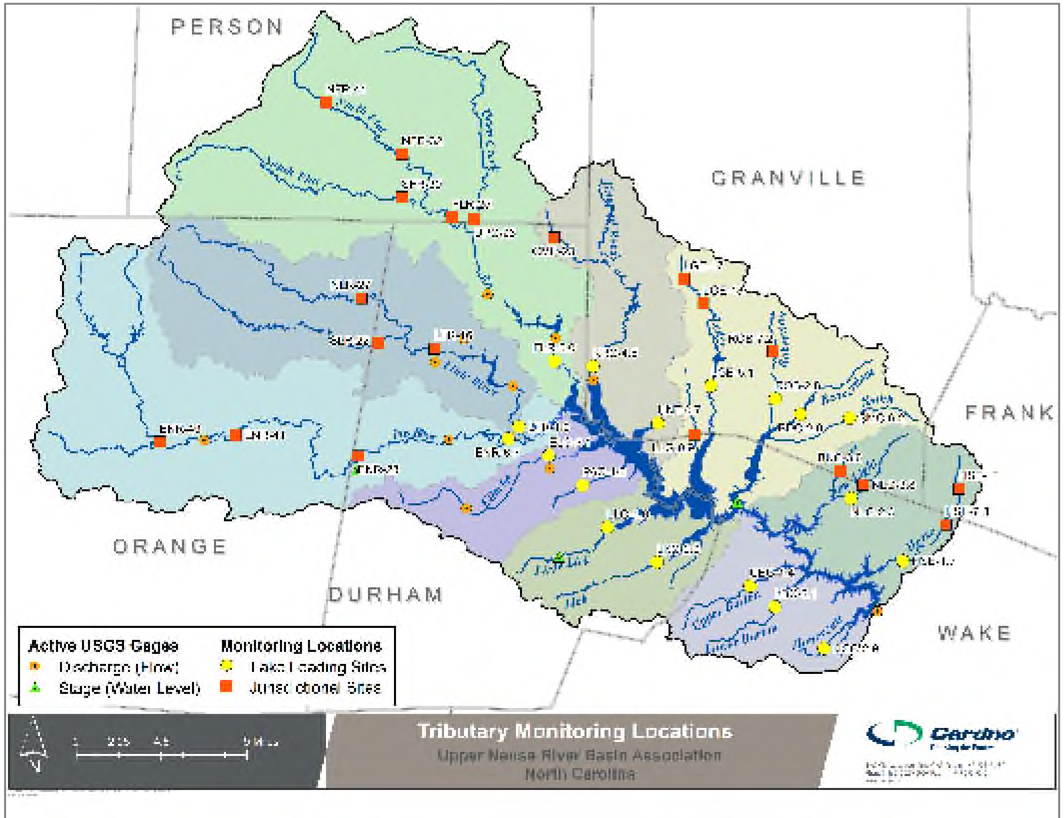
> Future development of a watershed model will help identify sources of nutrient and carbon loading



SPARROW Delivered TN = 1,041,250 lb/yr

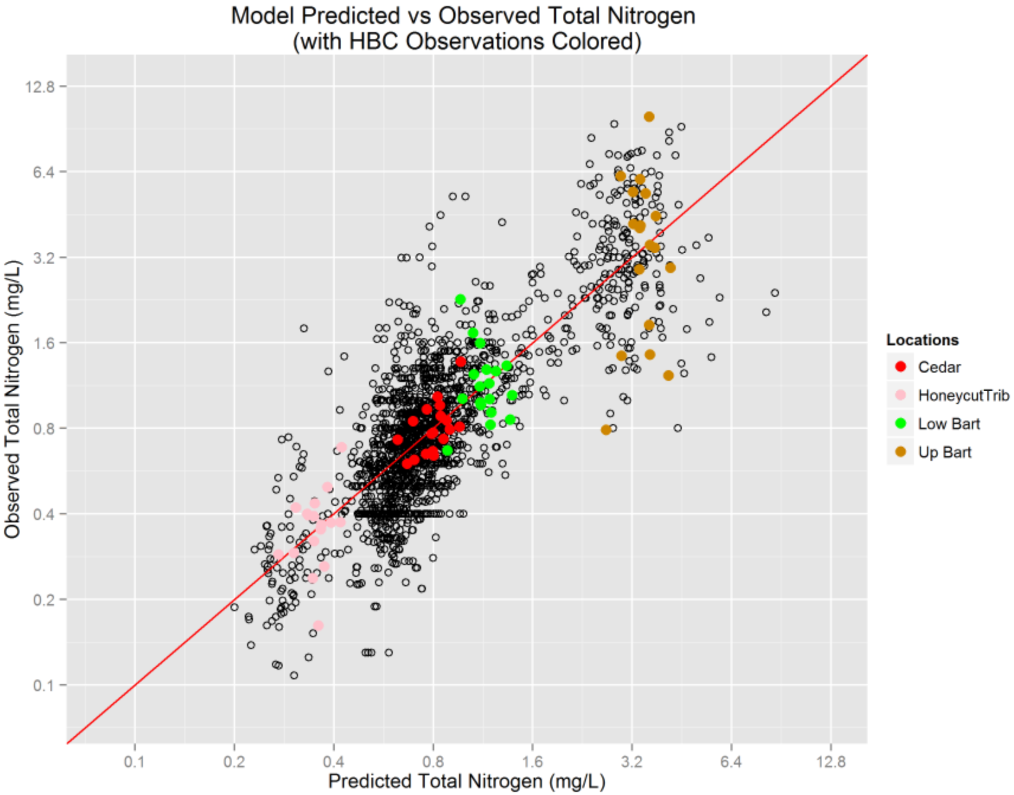
“What is the load distribution from subwatersheds and jurisdictions”?

> UNRBA routine monitoring includes sampling at 20 jurisdictional monitoring locations



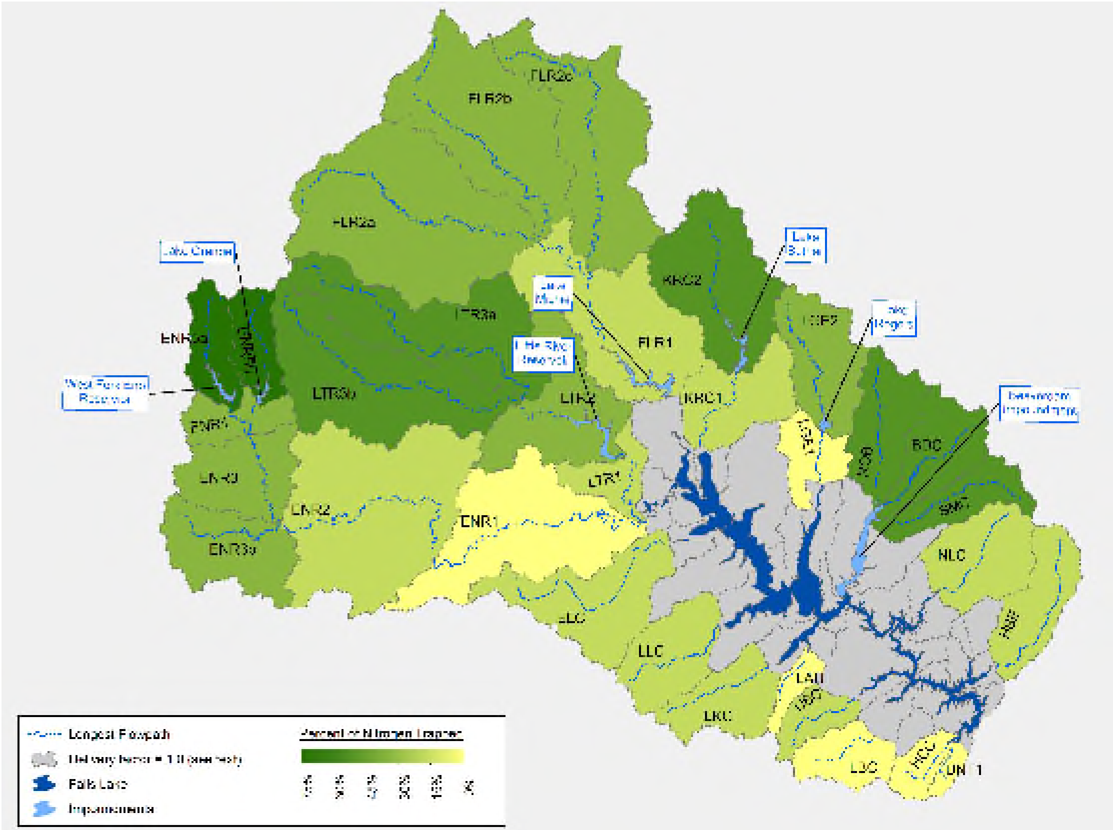
“What is the load distribution from subwatersheds and jurisdictions”?

> Previously developed statistical models test our ability to predict concentrations



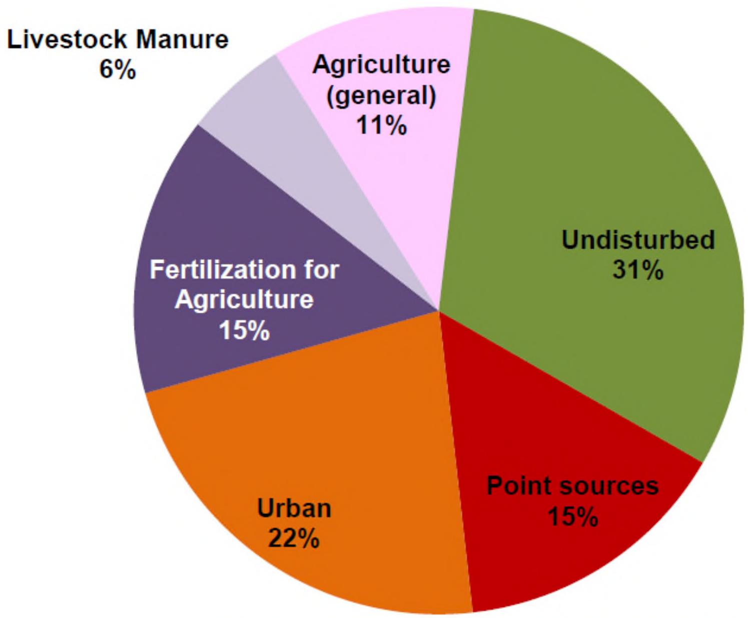
“What is the load distribution from subwatersheds and jurisdictions”?

> Developed watershed trapping factors as part of the UNRBA Nutrient Credits Project



“What is the load distribution from subwatersheds and jurisdictions”?

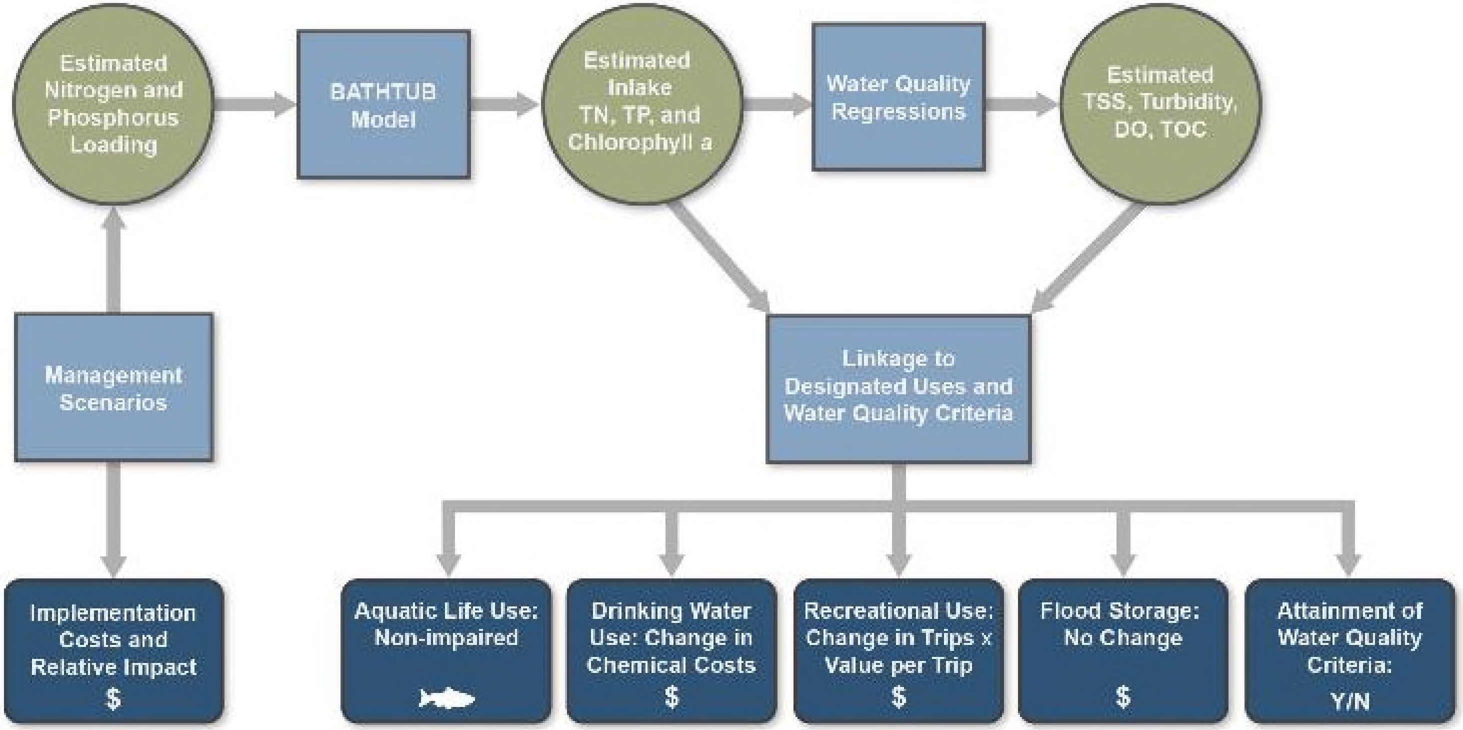
> Future watershed modeling to provide estimates of loading from various sources and locations in the watershed



SPARROW Delivered TN = 1,041,250 lb/yr

“Evaluate how well the lake meets existing uses”

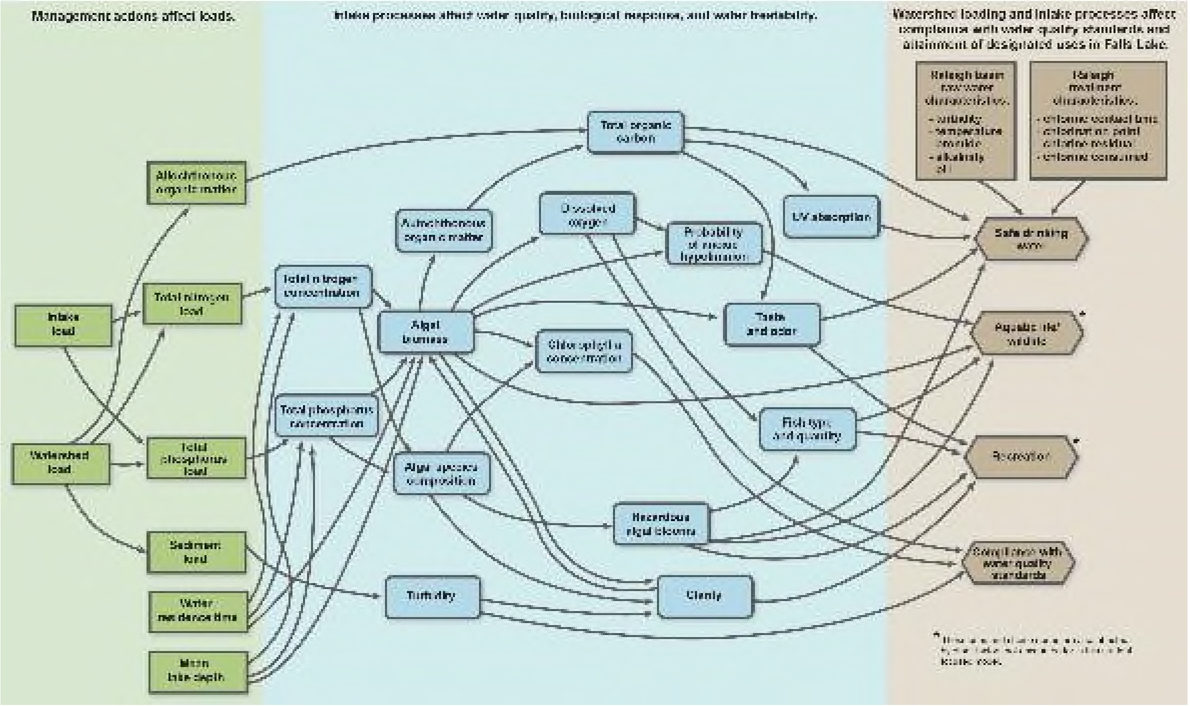
> UNRBA developed the Falls Lake Framework Tool as a preliminary empirical model to link water quality to designated uses



“Evaluate how well the lake meets existing uses”

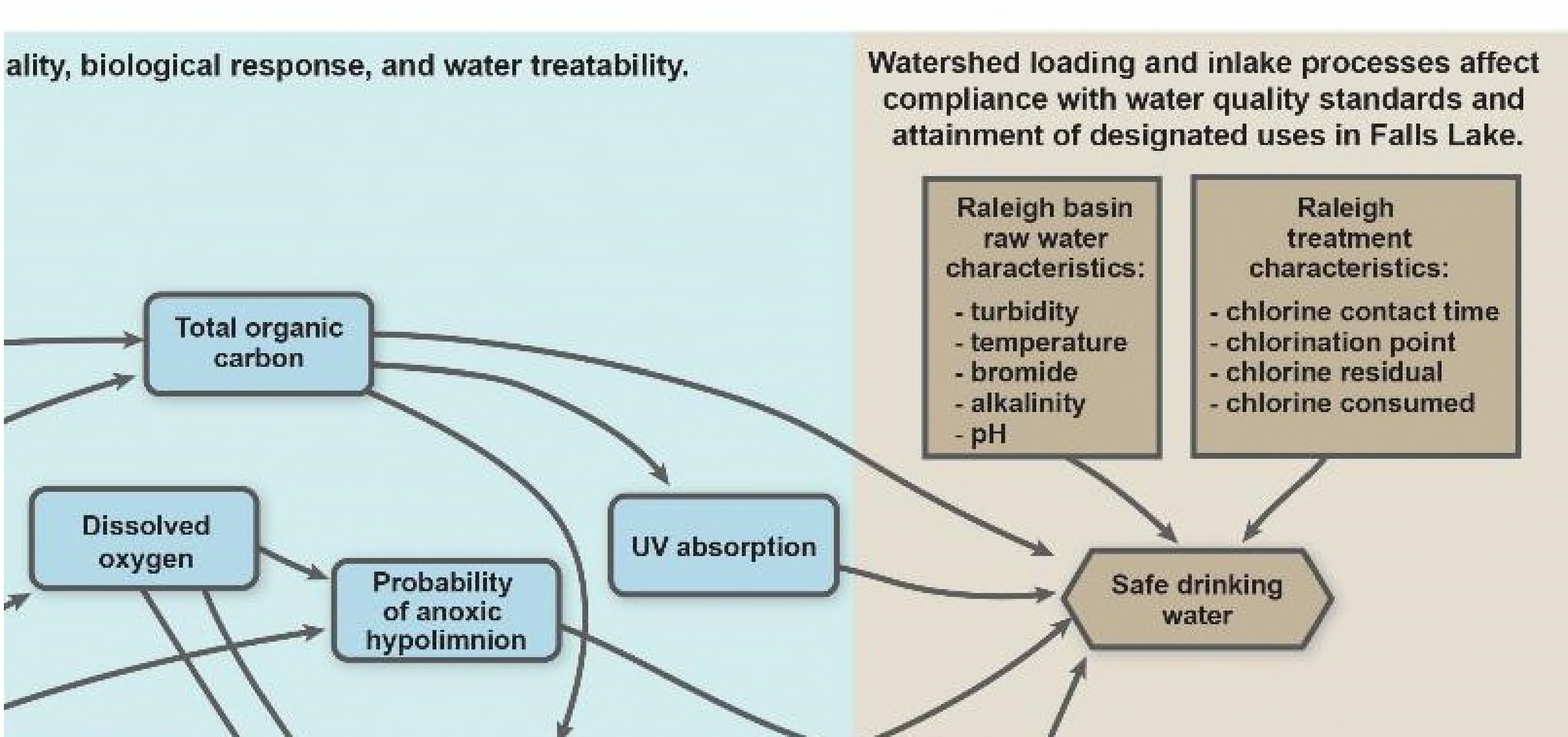
> Multi-modeling approach includes an empirical model to be developed to link nutrient loading to lake water quality and designated uses (drinking water, aquatic life, and recreation)

Framework to Link Management Strategies and Lake Water Quality to Designated Uses in Falls Lake



“Evaluate how well the lake meets existing uses”

> Monitoring Program includes analysis of additional lake water quality parameters to understand the sources of carbon in the lake and the treatability of drinking water



Goals and Objectives, 2010

Falls Lake Monitoring and Modeling Goals and Objectives
Stakeholder Meeting: September 7, 2010. Facilitator: Vickie Atkinson, City of Durham

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

MUST DO

Falls Lake

- Evaluate Past, Present and Future Uses of the Lake
  - Determine if existing water quality standards support existing uses. Are they too restrictive, too loose, or missing?
  - Evaluate how well the lake meets existing uses. Water supply, aquatic life propagation, recreation (boating, swimming, fishing)
  - Evaluate the degree to which the lake has, is, or can support all it's authorized uses.
  - Understand current condition of the lake
  - Supports UAA (Use Attainability Assessment) or change in use (water quality standard) for upper Falls Lake
- Lake Response Timeline
  - Given high internal loading in the lake, how will the lake respond to changes in the load?
  - Data and analysis that can be used to forecast or "backcast" conditions
- Water Treatment Concerns
  - Relationship between TOC and chlorophyll a
- Account for lake operations in model
- Fix short-comings of the existing model
- Capability to develop our own model
- Account for atmospheric deposition
- Lake Boundary Conditions
  - What is entering the lake? Chlorophyll a, other tributaries N, P and chlorophyll a
  - Are loads to the lake declining? (N, P and chlorophyll a)
  - Where is the best location (stable) to monitor inputs to the lake?

Falls Lake Watershed

- Characterize the distribution of loads
  - Load distribution (at jurisdictional boundaries)
  - What loads come from each jurisdiction
  - What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
  - Know loads by jurisdiction & tributary
  - Nutrient loading by jurisdiction and by subwatershed (2006 base and ongoing, current as of date certain)
  - Better unit loading rates that may vary by geography and by land use
- Tell us whether management efforts are succeeding (a vigorous effort)
  - Understand how management practices are affecting loads (individual and cumulative)
- Monitor Rainfall
  - Given that the model used rain data from RDU, would local monitoring of rainfall improve hydrologic calibration?
- Nutrient Mapping
- Sources Mapping
- Unknowns: Fertilizer, septic, sediment-attached P, atmospheric deposition
- Know the value of EACH individual management strategy (e.g., septic, ag). Do the BMPs work?
- Watershed Characterization
  - Distinguish sources of different types of nitrogen
  - Understand loads from forest and atmospheric deposition
  - Atmospheric deposition—coordinate with energy & air quality efforts with regard to nutrients
  - Forest is the largest component of the watershed. What are the actual nutrient loads from forests in the Triassic basin?

MUST DO

Goals and Objectives, 2012

Upper Neuse Water Quality Monitoring Plan

Potential Objectives

Table 1. Objectives for a water quality monitoring plan as grouped into headings.

Sources/Dynamics of Nutrient Loading

- What is entering the lake? Chlorophyll a, other tributaries N, P and Chlorophyll *a*
- Are loads to the lake declining? (N, P and chlorophyll a)
- What is entering the lake? (Chlorophyll a, other tributaries (N, P, Chl a)
- Where is the best location (stable) to monitor inputs to the lake?
- Sources Mapping
- Unknowns: Fertilizer, septic, sediment-attached P, atmospheric deposition
- What are the impervious cover characteristics of the watershed? (Where is IC and how is it distributed?)
- Understand (soils for) onsite wastewater attenuation rates
- What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
- What loads come from each jurisdiction?
- Characterize internal lake load
- What is approximate nutrient loading into Falls Lake watershed from groundwater?
- Nutrient loads from groundwater discharge
- Lake boundary conditions (are loads to the lake declining (N, P, Chl a))?
- Understand how loads from agriculture (equine) differ from others (flow, composition, urban/suburban)
- Where is the best location (stable N, P, Chlorophyll a) to monitor inputs to the lake?
- Nutrient loading by source type. Base, ongoing, and current as of date

Round Table Discussions for Breakout Session

- What concerns do you have about what you have heard today?
- What advice do you have for the UNRBA and their contractors as they move forward with the project?
- What are we doing right? What are we not considering?
- Is the list of goals provided in the pre-meeting material appropriate? What are we missing?
- What are your concerns about the project? What could we do to address them?

Nothing Compares
NORTH CAROLINA

Falls Lake Rules

Upper Neuse River Basin Association

Modeling Kickoff Meeting – Sept 28, 2016

Department of Environmental Quality

Overview

- Falls Nutrient Strategy Rule Requirements
- Implementation Status
- Recent Legislation / Impact on Rules Readoption

Falls Lake Rules

15A NCAC 2B

- Strategy in place to address lake Chl-a impairment
- Rules Effective January 15, 2011
- Falls Rules

.0275 Purpose & Scope (Goals)
.0276 Definitions
.0277 Stormwater – New Development
.0278 Stormwater – Existing Development
.0279 Wastewater Discharges
.0280 Agriculture
.0281 Stormwater – State & Federal Entities
.0282 Trading

Purpose & Scope

15A NCAC 2B .0275

- Establishes Framework for Rules
  - Adaptive Management & Staged Implementation
- Stage I *(2011- 2021)*
  - Initial reductions watershed wide (20% TN & 40% TP)
  - Achieve standards in lower lake
- Stage II *(2021 – 2036)*
  - Overall reduction objectives (40% TN 77% TP)
  - Achieve standards throughout lake by 2041
- Division required to report to EMC every 5 years
  - First report provided January 2016
  - 2025 Report – "Relook"

- Post-construction runoff meet N & P rate targets
  - 2.2 lbs/ac/yr TN .33 lbs/ac/yr TP
- Implemented by Local Governments Programs
- Land Disturbance Thresholds & Nutrient Offset Option
- Implementation Status
  - Local government implemented local programs - July 2012

- Load Reducing Activities on Existing Developed Land

- Implemented by Local Governments in Two Stages
  - Stage I: Back to 2006 baseline by 2020
  - Stage II: 40% TN & 77% TP – Update plans every 5 years

- Implementation Status
  - LGs submitted inventories in 2013
  - Model Program Presented to EMC July 2013
  - Implementation delayed to add additional credit measures

- Expanding credit measures toolbox - Ongoing
  - Division and UNRBA working together to add measures

Wastewater Discharge

15A NCAC 2B .0279

- Reductions from Wastewater Dischargers
- Establishes Nutrient Allocations
  - Stage I: 20% TN & 40% TP reductions by 2016
  - Stage II: 40% / 77% reductions by 2036
- Implementation Status
  - Reductions of 20% TN and 67% TP achieved as of 2014
  - Two of the three plants have invested in upgrades
  - Reductions also achieved through improved management of current technology
- Dischargers evaluating Stage II technologies

Agriculture

15A NCAC 2B .0280

- Reductions from Agriculture Operations
  - Applies to Row Crops & Pasture
- Stage Collective Compliance Approach
  - Stage I: 20% TN & 40% TP by 2020
  - Stage II: 40% TN & 77% TP by 2036
- Implementation Status
  - Watershed Oversight Committee Formed - Implementation & AR
  - Estimated 46% N loss reduction in crop year 2014
  - No increase in phosphorus loss risk
- Next annual report due to EMC in November

State & Federal

15A NCAC 2B .0281

- Stormwater requirement for State & Fed lands
  - Similar to requirements for local governments

- NCDOT requirements
  - New Development
    - New DOT road projects meet buffer requirements
  - Existing Development
    - Minimum of at least 6 stormwater retrofits per year

- Implementation Status
  - New Development req implemented in 2011 / 2014
  - NCDOT implementing existing development in 2014.

Trading
15A NCAC 2B .0282

- Provides option to sell/buy reductions across sources
- Includes requirements for parties buying / selling credits
- Sets Geographic limitations
  - Impacts in lower ws – offset anywhere in ws
  - Impacts in upper ws – offset must be in upper ws

- S.L. 2016-94: Nutrient Framework Section 14.13.(a)
  - UNC Evaluation of F/J Management Strategies
  - Calls for Several Studies by Department
  - Revises Dates for EMC Readoption of Falls Rules

- Impact on Falls Rules Readoption
  - Sets Falls & Jordan on own Readoption Timeline
  - EMC to Convene Stakeholder Working Group Dec 2016
  - Directs EMC to begin rule readoption process by March 2019
  - Prevents readoption of Falls Rules until October 2022

Timeline Summary

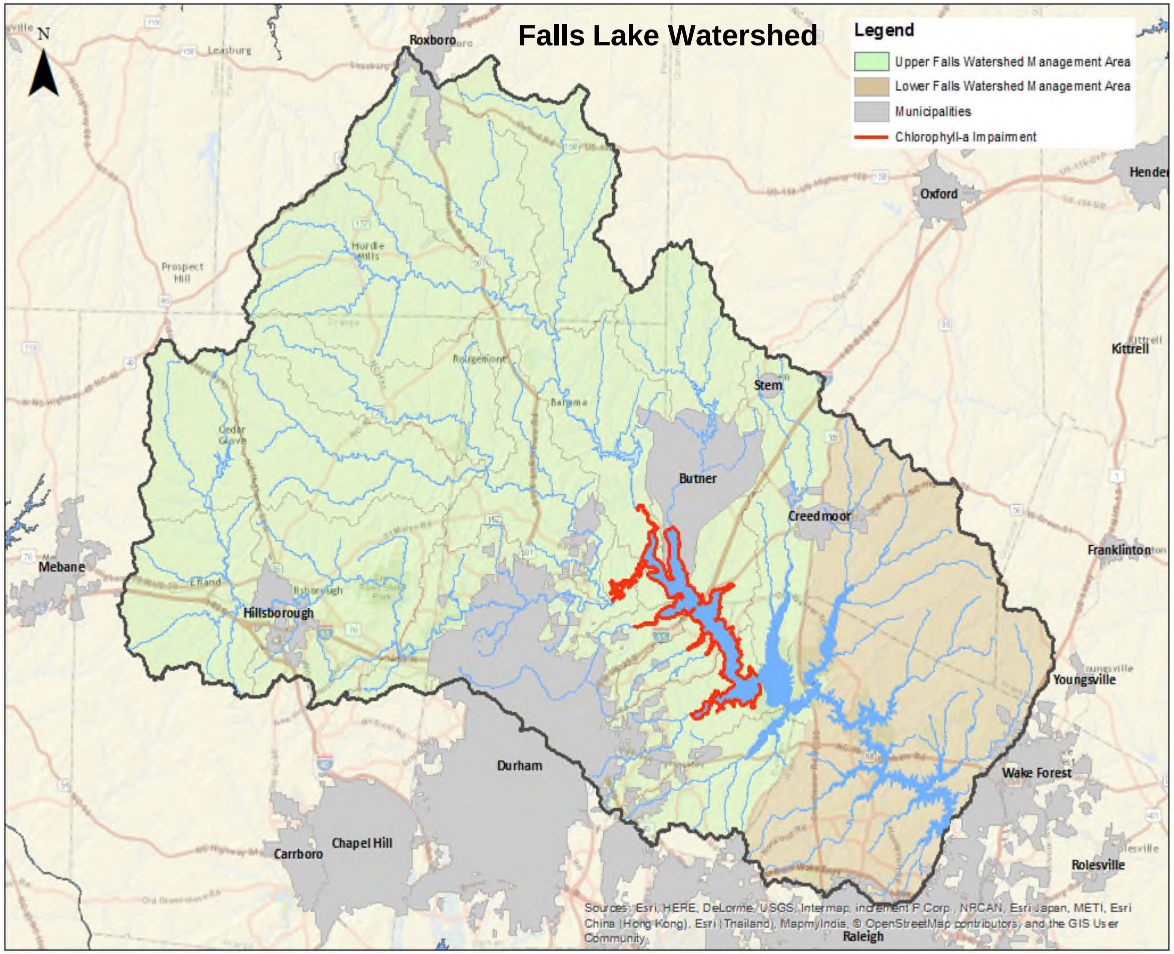
S.L. 2014-94

Task	Reporting Date	Responsible Party
Nutrient Offsets Study	December 1, 2016	DMS / DWR
CBP Stormwater BMP Values	December 1, 2016	DEMLR
Convene Stakeholder Working Group	December 31, 2016 (EMC Approval of Working Group in November)	EMC
In Situ Study	March 1, 2018 (Interim Report March 1, 2017)	DWR
UNC Evaluation of Falls & Jordan Nutrient Management Strategies	**Jordan:** December 31, 2018 (Interim 2016 / 2017) **Falls:** December 31, 2021 (Interim Reports 2019 / 2020)	UNC
Begin Falls / Jordan Rules Readoption	March 2019	EMC

QUESTIONS?

Department of Environmental Quality

Slides in Reserve



770 sq/mi watershed located in upper Neuse River Basin

Falls Lake Local Governments

Municipalities

Butner
Creedmoor
Durham
Hillsborough
Raleigh
Roxboro
Stem
Wake Forest

Counties

Durham
Franklin
Granville
Orange
Person
Wake

- Strategy in place to address lake Chl-a impairment
- Rules effective January 2011
  - Require reductions from both point & nonpoint
  - Staged adaptive implementation
- Stage I (2011 – 2021)
  - Initial reductions watershed wide
  - Achieve standards in lower lake
- Stage II (2021 – 2036)
  - Additional reeducations in upper watershed
  - 40% TN and 77% TP reductions
  - Achieve standards throughout lake by 2041

- Division required to report to the EMC every 5 years

- Purpose
  - Provide update on strategy implementation
  - Evaluate changes in loading & lake water quality progress
  - Review advancements in science & control technology

- Information provided by multiple Divisions & stakeholders

Overview of Draft Falls Lake 2016 Report

Report Organization

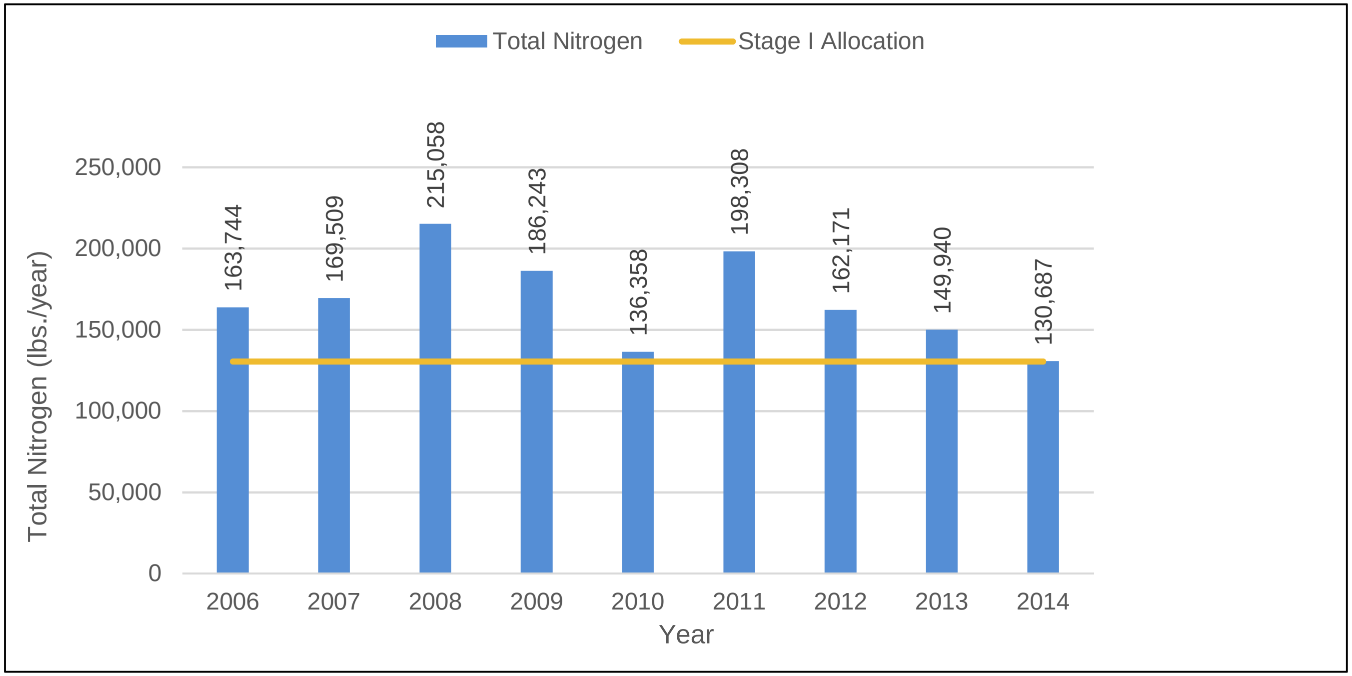
- Background & History
- Implementation & Water Quality Progress
  - Strategy Progress
  - Changes in Loading to Lake
  - Lake Improvement
- Advances in Science & Control Technology
  - Wastewater & Stormwater Treatment Technology
  - Current & Projected use of Reuse & Land Application
  - Programmatic Measures
  - Updates to Accounting Tools
  - Utilization of Nutrient Offsets
  - Changes in Atmospheric Deposition
  - Summary of Groundwater, DSF, and Septic Studies

Falls Lake Stage I Rule Requirements

Source	Stage I Reduction Requirements
Wastewater	• 20% TN & 40% TP Reductions by 2016
Agriculture	• 20% TN & 40% TP Reductions by 2021
New Development Stormwater	• Development meet rate targets: • 2.2 lbs/ac/yr TN and 0.33 lbs/ac/yr TP
Existing Development Stormwater	• Local Governments Conduct Inventories • Reduce loads back to 2006 baseline
State & Federal Stormwater	• Similar to LG requirements • NCDOT implements 6 retrofits per year

Falls Strategy Implementation Progress

Wastewater Nitrogen Reductions

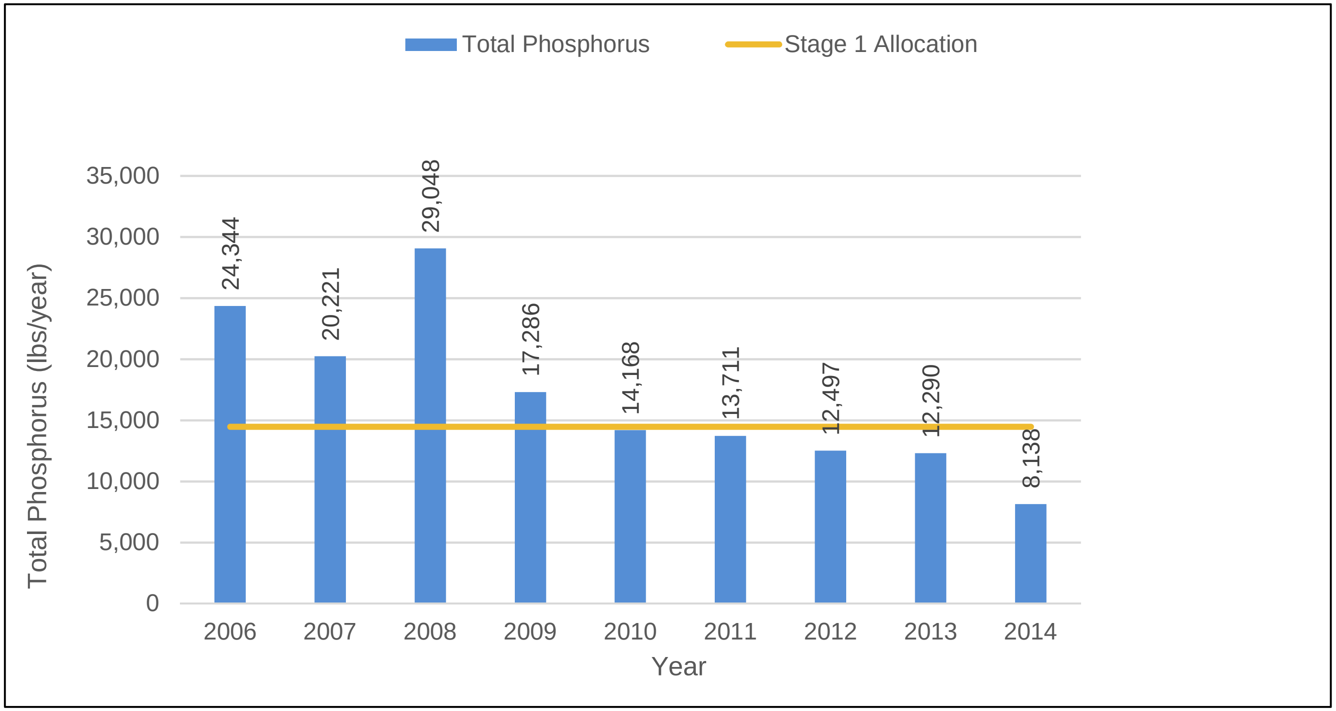


- 3 major dischargers in upper watershed
- Wastewater has achieved a 20% TN reduction as of 2014

Department of Environmental Quality

Falls Strategy Implementation Progress

Wastewater Phosphorus Reductions

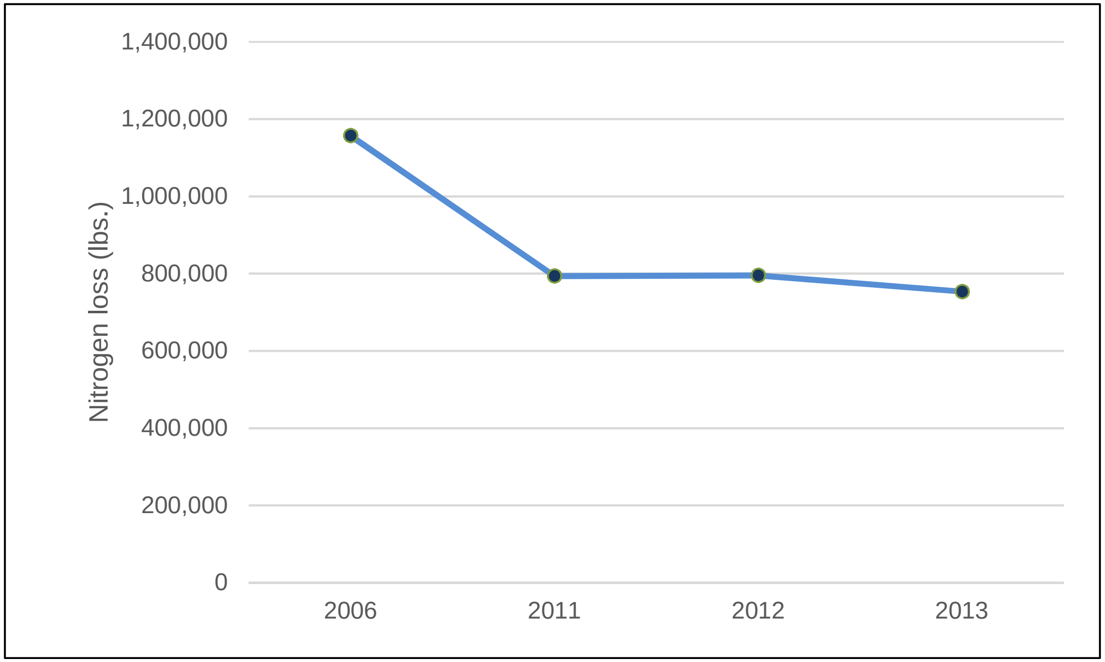


- Wastewater has achieved a 67% TP reduction as of 2014

- Two of the three plants have invested in upgrades
- Stage I reductions also achieved through improved management of current technology
- As flows increase more advanced technology needed to maintain Stage I limits
- Two of the three plants have invested in upgrades
- Stage I reductions also achieved through improved management of current technology
    - Reverse Osmosis
    - Increased Wastewater Reuse
    - Anammox bacteria

Falls Strategy Implementation

Agriculture Estimated N Loss Reductions



- Agriculture estimates 35% N loss reduction as of 2013
- No increase in phosphorus loss risk

Department of Environmental Quality

Rule Implementation Status

New Development Stormwater

- LG's began implementing programs July 2012.
- State & Federal entities also implementing New D
- Nutrient Offset Payments as of June of 2015
  - 50,766 lbs. of nitrogen
  - 3,645 lbs. of phosphorus

	Nitrogen	Phosphorus
Total transactions	107	68
Total Credits (lbs)	50,766	3,645
Total Acres Mitigation	22.34	24.99

Rule Implementation Status

Existing Development

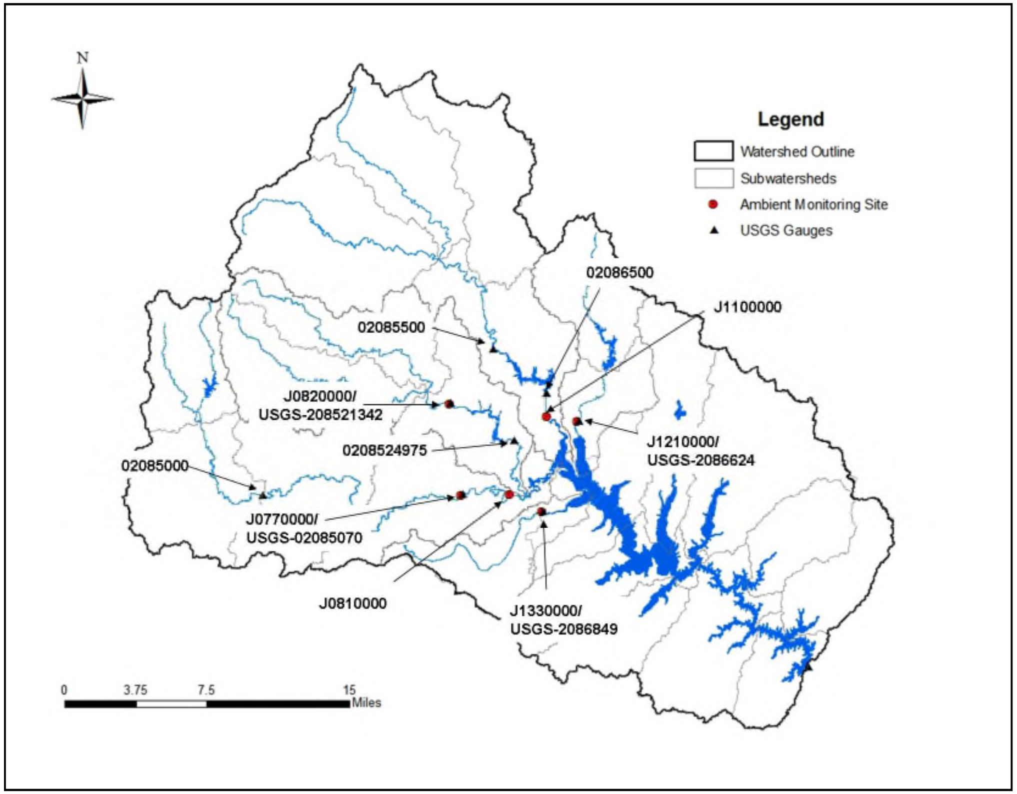
- Existing Development
  - LGs submitted inventories in 2013
  - Implementation delayed to add additional credit measures
- Expanding credit measures toolbox
  - Division and UNRBA working together
  - Expect to add 16 additional creditable practices
  - Improving accounting tools
- Division to bring model program to EMC in two years
  - Proposed extending Stage I to 2025 in rule revisions

Trends in Atmospheric Deposition Reductions

- Report includes deposition data and modeling results
- 15% decline N deposition estimated since 2006
  - Due primarily to downward trend in nitrate deposition
- Reductions likely due to state & federal air quality initiatives
  - Clean Smokestacks Act
  - Reductions in motor vehicle emissions
- Additional reductions expected

Changes in Lake Loading

Loading from Upper Watershed



- DWR estimated annual nutrient loads
- Used Ambient Monitoring Stations and USGS Flow Stations
- Upper 5 major tributaries
  - Eno River
  - Little River
  - Flat River
  - Knap of Reeds
  - Ellerbe Creek

Department of Environmental Quality

Changes in Loading to the Lake

2006-2014

Combined Nutrient Load from the Five Major Tributaries	Phosphorus (lbs/year)	Nitrogen (lbs/year)
2006	107,915	819,854
2007	82,283	691,397
2008	104,612	935,335
2013	56,223	925,732
2014	48,413	991,186

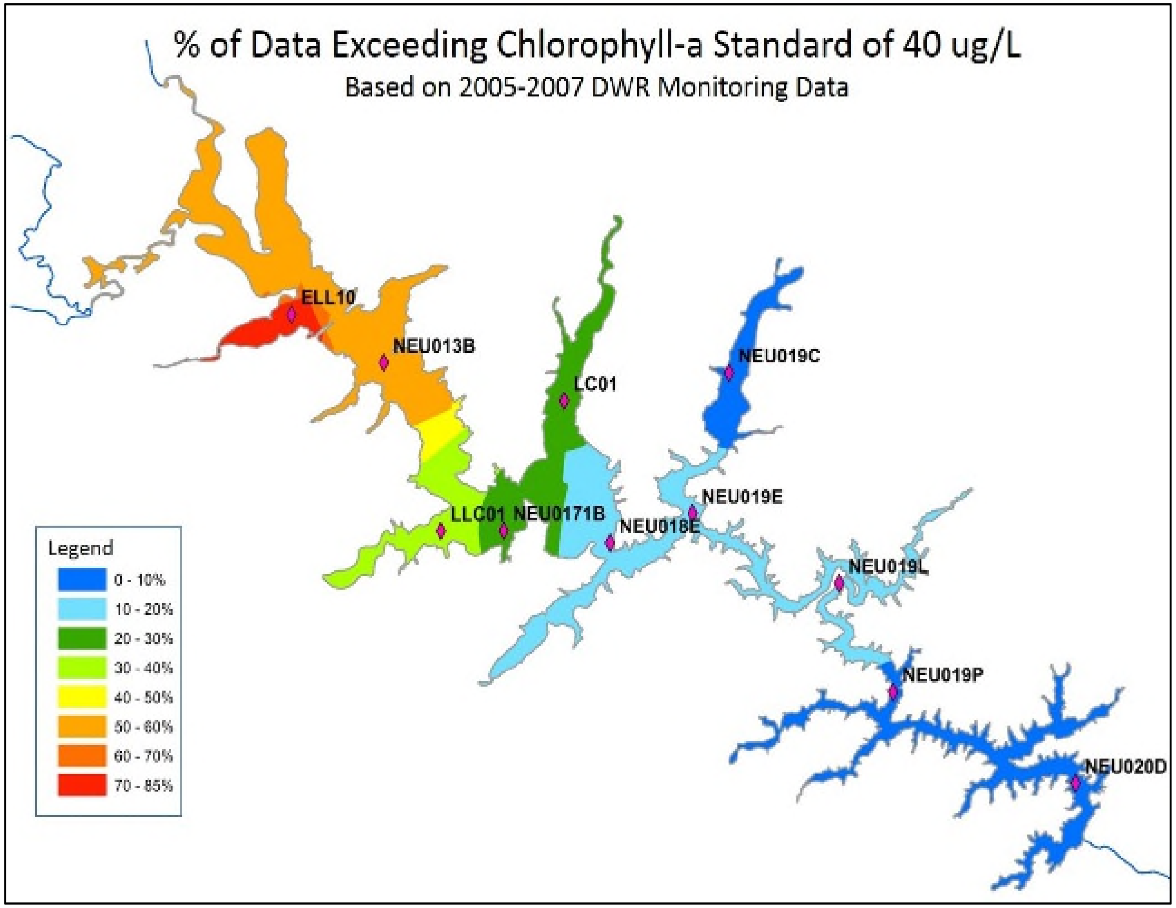
-Nitrogen load up 20% since baseline
-Phosphorus load down 55% since baseline

- 2014 was wet year with flows up 60 percent since baseline

Note: Load estimates are not available from 2009 to 2012 as budget constraints resulted in an insufficient number of sampling events to allow load estimation.

Lake Improvements: Water Quality in the Lake

2005-2007 (Before Rule Implementation)

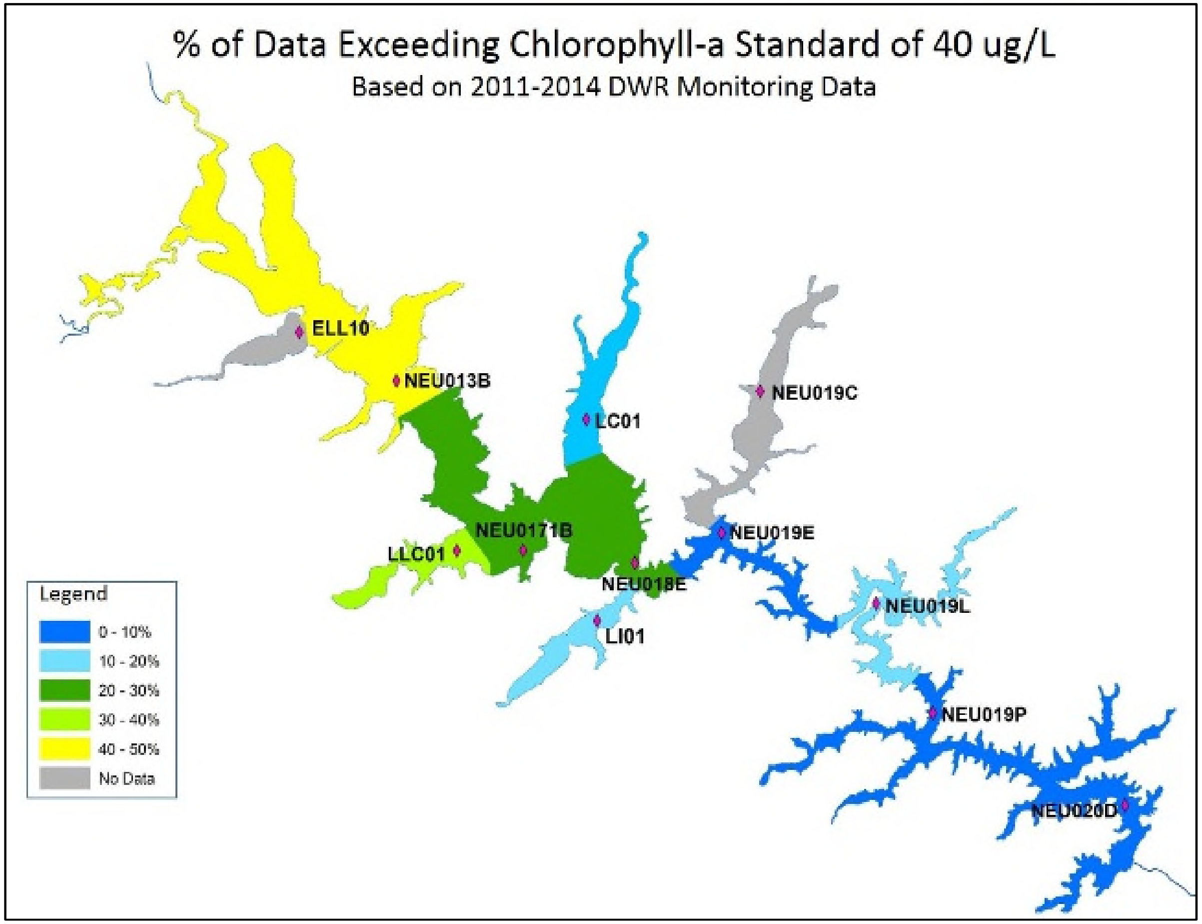


- Ten in lake stations monitored monthly by the Division

Department of Environmental Quality

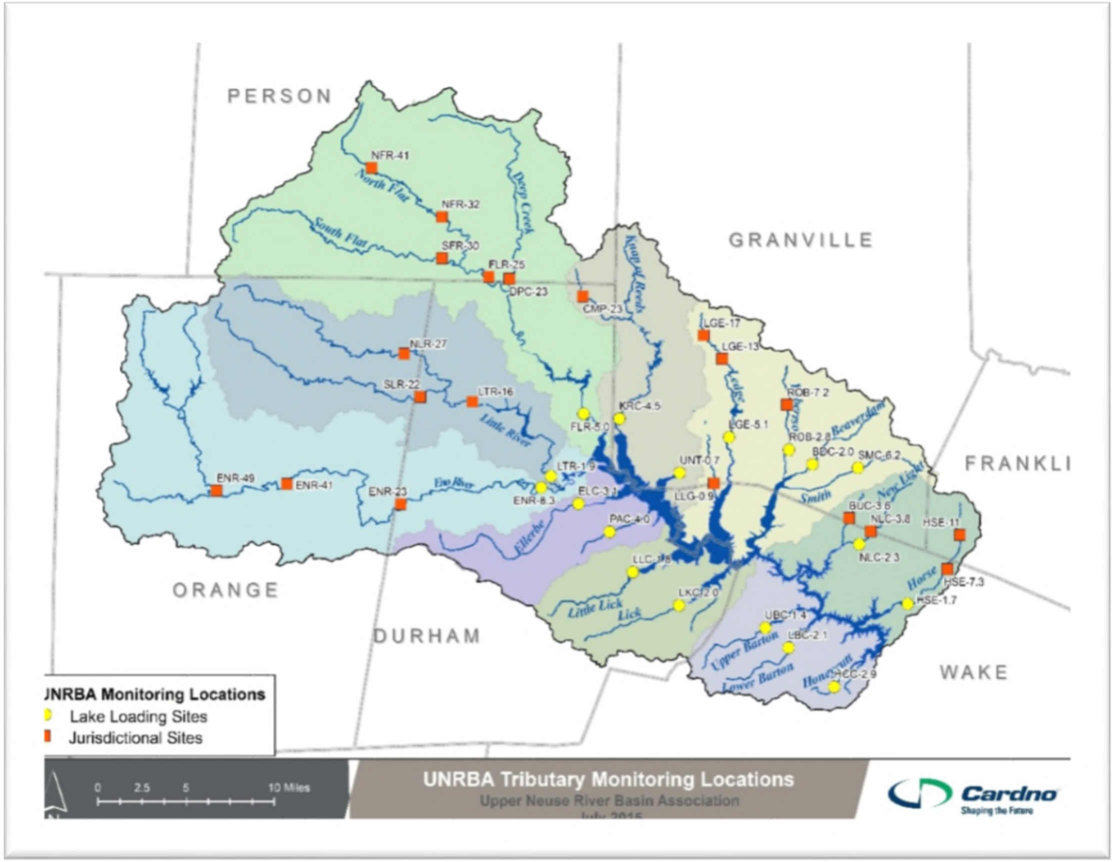
Water Quality in the Lake

2011-2014 (Post Rule Implementation)



- % exceedance of chl-a standard has improved since 2011

Department of Environmental Quality



UNRBA has implemented supplemental monitoring:

- Address uncertainty of original modeling
- Fill data gaps and support supplemental lake model
- Support UNRBA's reexamination of Stage II rules

Summary

- Implementation proceeding in timely fashion
- Sources on track to meet Stage I reduction goals
- Nutrient loading & water quality generally improving
- Regulated community working constructively & collaboratively with the Division

Next Steps

- Rules Readoption Process Ongoing
- Continue Credit Measures Work w/ UNRBA
  - Establish credit for additional 16 measures
- Complete Existing Development Model Program
  - Including load reduction assignments
  - Bring Model Program to EMC within next two years
- Next 5-year Report in 2021

Delay of Further Implementation - Jordan

S.L. 2016-94

Rule	Implementation Dates Pre-S.L. 2016-94	Date w/ Repeal of 3 Year Delay (SL 2015-241)	Post-S.L. 2016-94 Implementation Dates
New Development	August 2020	August 2017	Readoption
Existing Development Notification	UNH – March 2020 LNH & Haw – March 2023	UNH – March 2017 LNH & Haw – March 2020	UNH - Readoption LNH & Haw – March 2020
Point Sources	Compliance by 2022 / 2024	2019 / 2021	Readoption / 2021
Agriculture	Compliance by 2021 /2024	2018	Readoption
State & Federal New D	NCDOT 2013 / Non-DOT 2012	Already Implemented	Already Implemented
State & Federal ED	UNH – March 2020 LNH & Haw – March 2023	UNH – March 2017 LNH & Haw – March 2020	UNH - Readoption LNH & Haw – March 2020
Buffers	March 2011	Already Implemented	Already Implemented
Nutrient Management	2010 / 2012	Already Implemented	Already Implemented

Delay of Further Implementation - Falls

S.L. 2016-94

Rule	Implementation Dates Pre-S.L. 2016-94	Implementation Dates Post-S.L. 2016-94
New Development	Implemented 2012	Implemented 2012
Existing Development	Once Final Model Program Approved ~ 2017	Readoption
Point Sources	Stage I: Implemented 2016 Stage II Compliance: 2036	Stage I: Implemented 2016 Stage II: 2036
Agriculture	Stage I: Implemented 2013 Stage II Compliance 2036	Stage I: Implemented 2013 Stage II: 2036
State & Federal New D	NCDOT & Non-DOT: Implemented 2011	Implemented 2011
State & Federal ED	Once Final Model Program Approved ~ 2017	Readoption
Buffers	Already Implemented *(Neuse NMS)*	Already Implemented
Nutrient Management	Already Implemented *(Neuse NMS)*	Already Implemented

Department of Environmental Quality

WATER QUALITY MODELING AND REGULATORY SUPPORT

Exhibit A- Scope of Work, September 21, 2016 through September 30, 2017

Introduction

The Upper Neuse River Basin Association (UNRBA) has selected Cardno, Inc., and their team of partners, to provide water quality modeling, cost benefit analysis, and regulatory support as described in its Request for Qualifications - Water Quality Modeling and Regulatory Support issued in April 2016 (Exhibit C).

The primary purposes of this Scope of Services under the contract resulting from the RFQ is to develop a Quality Assurance Project Plan (QAPP) that includes the lake and watershed models and to develop a two year work plan (for approximately October 2017 to September 2019) for the modeling, cost benefit analysis, and regulatory support project. Significant input on this Scope of Work has been provided by the Path Forward Committee's (PFC), Modeling and Regulatory Support Workgroup (MRSW), the PFC, the UNRBA Executive Director, and technical advisors. Separate scopes of work will be developed with the UNRBA for each fiscal year of the overall project.

Phase 1: Develop a QAPP for the Falls Lake Response Models and the Falls Lake Watershed Model(s)

The goal of Phase 1 of the project is to develop the lake and watershed Modeling QAPP that will guide development of the models used to support the UNRBA reexamination of Stage II of the Falls Lake Nutrient Management Strategy. The Modeling QAPP will include both the lake and watershed models. While the main deliverable associated with Phase 1 is the modeling QAPP, several preliminary activities are needed to define the specific objectives of each type of model and select the best models to meet the chosen objectives. A conceptual modeling plan will be developed to summarize the modeling objectives and identify the models the UNRBA has selected for the lake modeling, watershed modeling, and empirical/probabilistic/Bayesian modeling. Elements of this conceptual plan will be incorporated into the Modeling QAPP. Depending on the selected models and the QAPP, the previously submitted, DWR-approved Description of the Model Framework may need to be revised for consistency relevant to the lake modeling and the watershed modeling approach.

Cardno and its teaming partners (the Team) will develop in consultation with the UNRBA a conceptual plan for conducting the lake and watershed modeling using a multi-modeling approach. Development of the conceptual plan will include the following tasks:

- Discussion of the UNRBA goals for the lake modeling effort during a Kickoff Meeting expected to be held in conjunction with the September 28, 2016 PFC meeting. This meeting will include additional watershed stakeholders including DWR, DOT, Neuse River Keeper, land conservation trusts, environmental groups, WOC, Health and Human Services Onsite Wastewater (county reps also), watershed associations, soil and water conservation. This meeting will be an extension of the PFC meeting and will occur in the afternoon following the meeting.

- Review and evaluation of potential lake model packages (e.g., EFDC, BATHTUB, CE-QUAL-W2, WASP, WARMF-lake, WARMF-CE-QUAL-W2, and stochastic modeling; addressing 1D/2D/3D models and capabilities) that will support a recommendation to the UNRBA of the modeling packages or combination of packages that will provide accurate and appropriate simulation of nutrients, algae, and total organic carbon to support the UNRBA's Falls Lake Nutrient Management Strategy reexamination. Comparison of models will be provided in tabular format with preliminary recommendations in the form of a slide presentation developed by the Team for discussion with the MRSW and PFC. A brief description of why each model was selected will be included in the QAPP.
- Review and evaluation of potential watershed model packages (e.g., WARMF, SWAT, SPARROW, PC-SWMM, RHYSS, and stochastic modeling) with the MRSW and PFC to develop a recommendation on the package or combination of packages can provide accurate and appropriate simulation of watershed nutrient and total organic carbon loading given the monitoring data and modeling objectives defined by the UNRBA to support reexamination of the Falls Lake Nutrient Management Strategy. Comparison of models will be provided in tabular format with preliminary recommendations in the form of a slide presentation developed by the Team for discussion with the MRSW and PFC. A brief description of why each model was selected will be included in the QAPP.
- Development of supporting materials that describe the conceptual modeling plan. These materials will be distributed prior to the UNRBA PFC meeting or meetings that will discuss and make decisions on the conceptual modeling plan. These supporting materials may include slides, handouts, figures, and tables. Relevant information from these materials will be incorporated into the Modeling QAPP and its appendices.

The conceptual model plan and evaluation of models will be used to develop the Modeling QAPP. Decisions regarding the model selection and conceptual model plan will be documented in the form of meeting notes during MRSW and PFC meetings by Cardno. The Team will develop the Modeling QAPP in accordance with the Falls Lake Rules (15A NCAC 02B .0275 (5) (f)) and will use EPA's (2002) Guidance for Quality Assurance Project Plans for Modeling (QA/G-5M) EPA/240/R-02/007.

A draft of the Modeling QAPP will be provided iteratively to the UNRBA MRSW and PFC for review and editing, and then to the NC Division of Water Resources (DWR) for review prior to formal submittal. The Team will be responsible for finalizing the QAPP for submittal to the agency and assisting the UNRBA in responding to any agency comments or issues.

Communications

The Team will coordinate communications throughout the project with the Executive Director, the MRSW and the PFC through a series of meetings, calls, or webinars. The UNRBA Board will be briefed and updated as appropriate based on guidance from the PFC.

The scope of work for the development of the lake and watershed modeling QAPP assumes the following communications (additional communications are included in Phase 5):

- Twice per year in person meetings between active modeling task leads and the UNRBA. It is anticipated that these meetings will coincide with PFC meetings and may extend beyond the regularly scheduled meeting time. The first meeting is planned for September 28, 2016 to kickoff Phase 1.
- Bi-monthly calls (every other month) with the MRSW beginning in November or December. An agenda will be developed for these calls and the sessions will last approximately 1.5 hour, providing sufficient opportunity to discuss status and technical issues for the project.

Phase 1, First Year Deliverables:

The schedule for deliverables associated with Phase 1 is presented in Figure 1. This prospective schedule is based on meeting the UNRBA objectives and time frames for this project. Based on review and input by the MRSW, PFC, UNRBA, and DWR, this schedule may need to be revised.

1. Slides and handout materials (electronic copies in native format) to facilitate discussion of a) model evaluation and selection and b) development of the conceptual modeling plan. Key elements of these materials will be included in the Modeling QAPP to formally document why specific models were selected and how multiple models may be used to support the reexamination.

2. Draft and final Falls Lake nutrient response and watershed Modeling QAPP.

3. Presentations to the UNRBA Path Forward committee or UNRBA Board of Directors as appropriate and needed (see Phase 5), and

4. Revisions to the previously submitted Description of the Model Framework that was approved by DWR for consistency with the revised modeling QAPP.

Phase 2: Develop the Two-Year Work Plan

The Team will develop, in consultation with the UNRBA, a two-year work plan (approximately October 2017 to September 2019) for the modeling project including implementation of the watershed and lake modeling conceptual plans from Phase 1 and the development of the cost-benefit model that effectively supports the UNRBA's goal of providing a successful reexamination of the Falls Lake Nutrient Management Strategy, including additional regulatory options. The work plan will include detailed task breakdown structures and cost estimates for the two year period based on the local government fiscal year. The Team will seek input and direction from the MRSW and Path Forward Committee regarding the development of the work plan.

Communications

Throughout this project, the Team will coordinate with the Executive Director, the MRSW and the PFC through a series of meetings, calls, or webinars. The UNRBA Board will be briefed and updated as appropriate based on guidance from the PFC. The scope of work for the development of the two year work plan assumes the following communications continued from Phase 1 (additional communications are included in Phase 5):

- Twice per year in person meetings between active modeling task leads and the UNRBA. It is anticipated that these meetings will coincide with PFC meetings and may extend beyond the regularly scheduled meeting time. The second meeting is planned for March 22, 2017 to kickoff Phase 2.
- Continued bi-monthly calls (every other month) with the MRSW. An agenda will be developed for these calls and the sessions will last approximately 1.5 hour, providing sufficient opportunity to discuss status and technical issues for the project.

Phase 2, First Year Deliverables:

The schedule for deliverables associated with Phase 2 is presented in Figure 1. These include:

1. Draft and final, two-year work plan (approximately October 2017 to September 2019) with a cost estimate for each year. A draft of the work plan will be presented to the PFC at its June 2017 meeting.
2. Draft and final scope of work and budget for Modeling and Regulatory Support for October 2017 to September 2018 will be presented to the PFC at its August 2017 meeting for requested approval by the UNRBA Board of Directors during the September BOD meeting.
2. Status presentation and discussion of this phase with the UNRBA Path Forward Committee (see Phase 5).

Phase 3: Cost Benefit Analysis

There are no first-year deliverables anticipated for this component of the Modeling and Regulatory Support effort. A majority of this work will be conducted in subsequent years and will be described in the two-year work plan (See Task 2). The Team is prepared to adapt the schedule and budget to initiate work on this phase earlier than anticipated, if requested by the UNRBA.

Phase 4: Regulatory Options Support

There are no first-year deliverables within this service area. A majority of this work will be conducted in subsequent years and will be addressed in the two-year work plan (See Task 2). The Team is prepared to adapt the schedule and budget to initiate work on this phase earlier than anticipated, if requested by the UNRBA.

Phase 5: Project Management and General Meetings

Cardno will provide general program management for these efforts and will generate monthly invoices and supporting documentation for submittal to the UNRBA.

Cardno will facilitate scope and contract development for subsequent fiscal years.

Cardno will participate in the routine general UNRBA meetings with the Path Forward Committee (PFC) and Board of Directors (BOD) with the following assumptions:

- The Cardno Project Manager will provide status reports at BOD meetings.
- The Cardno Project Manager will provide status reports at the monthly PFC meetings beginning in October. The Cardno Project Manager will participate in these monthly meetings, with modeling leads participating remotely on an as needed basis.
- The Cardno Project Manager will participate in weekly status calls with the Executive Director.

Project Schedule

The prospective project schedule is provided in Figure 1.

UNRBA Modeling Project - September 2016 to September 2017

ACTIVITY	PLAN START	PLAN DURATION	Sep 16 1	Oct 16 2	Nov 16 3	Dec 16 4	Jan 17 5	Feb 17 6	Mar 17 7	Apr 17 8	May 17 9	Jun 17 10	Jul 17 11	Aug 17 12	Sep 17 13
Phase 1 - Modeling QAPP	1	10													
Kickoff Phase 1 meeting (9/28/2016)	1	1													
Model evaluation/recommendation and discussion with MRSW (11/15/2016)	2	2													
Discuss modeling evaluation and recommendation with the PFC (11/23/2016)	3	1													
Draft Conceptual Model Plan to MRSW (1/15/2017)	4	2													
Present Conceptual Model Plan to PFC (1/25/2017)	5	1													
Present Conceptual Model Plan to BOD (3/15/2017)	7	1													
Draft QAPP to MRSW (3/22/2017)	6	2													
Draft QAPP to PFC with presentation (4/26/2017)	8	1													
Draft QAPP to DWR (5/31/2017)	9	1													
Finalize QAPP (6/30/2017)	10	1													
Revise Description of the Model Framework (7/31/2017)	11	1													
Phase 2 - Two Year Work Plan (October 2017 to September 2019)	7	7													
Kickoff Phase 2 meeting (3/22/2016)	7	1													
Draft Two Year Work Plan to MRSW (5/31/2017)	8	2													
Draft Two Year Work Plan to PFC with presentation (6/28/2017)	9	1													
Finalize Two Year Work Plan (7/14/2017)	10	1													
Draft Scope of Work to Forrest for Oct 2017-Sep 2018 (7/28/2017)	11	1													
Discuss Oct 2017-Sep 2018 Scope of Work with MRSW (8/9/2017)	12	1													
Present Oct 2017-Sep 2018 Scope of Work to PFC (8/23/2017)	12	1													
Finalize Oct 2017-Sep 2018 Scope of Work for Board Approval Contract (9/20/2017)	13	1													

Figure 1. Schedule for September 2016 to September 2017 of the UNRBA Modeling Project (This prospective schedule is based on meeting the UNRBA objectives and time frames for this project. Based on review and input by the MRSW, PFC, UNRBA, and DWR, this schedule may need to be revised.)

UNRBA Meeting Attendees

Workgroup: Modeling Kick off Meeting

Date: 9/28/2016

Name	Representing
Ryan Eaves	Durham County
David Harris	Durham Soil & Water
Jenn Fitts	Butner, Creedmoor, Person, Granville, Stem
Jessica Gladwin	Butner
Carolyn Bachl	City of Raleigh
George Matthis	River Guardian Foundation
Michael Orbon	Wake County
Christopher Wallen	Dynamic Solutions, LLC
Jennifer Dean	WakeUP Wake County
John Cox	Retiree
Keith Larick	NC Farm Bureau
Katie van Werkhoven	Dynamic Solutions LLC
Anne Coan	NC Farm Bureau Federation
Joey Hester	Division of Soil & Water Conservation
Liz Weisbrot	City of Raleigh
PAUL LEONARD	CARDNO, INC.
Doug Durbin	for Cardno
Tom Davis	Orange County
John Huisman	NCDENR - DWR
Dan McLawhorn	City of Raleigh
Ken Reckhow	Duke Univ.
Reggie Hicks	City of Durham
Pam Behm	DWR
Carrie Ruhlman	NCWRC
TERRY HACKETT	TOWN OF HILLSBOROUGH
BRIAN JACOBSON	AECOM
Andy McDaniel	NCDOT
Lance Fontaine	City of Durham
Matthew Van de Bogert	Cardno
Barb Oslund	FallsWOC/NC Horse Council
Blair Hinkle	City of Raleigh
Ben Brown	City of Raleigh
Don O'Toole	City of Durham
Jonathan Baker	" " "

UNRBA Meeting Attendees

Workgroup: Modeling Kick off Meeting

Date: 9/28/2016

Name	Representing
Kenneth Waldroup	City of Raleigh
Kristin Waldroup	Self :)
Sandi Wilbur	City of Durham
Emily Rhode	City of Durham
Vann Stancil	NC Wildlife Res. Comm.
Barry Baker	Granville County
Michael Cimello	PERSON County
Katie Cromwell	Butner, Stem, Creedmoor, Granville Co, Person Co.
Melissa Hodges	Town of Butner
Michelle Woolfolk	City of Durham
Lindsay Mize	SGWASA
Rich Gannon	NCDWR
JAY SAUBER	Consultant
FORREST WESTALL	UNRBA
Andy Sachs	
Haywood Phthisic	UNRBA

Reference Material for the UNRBA Modeling and Regulatory Support Kickoff Meeting – September 28, 2016

In 2010, the Environmental Management Commission passed the Falls Lake Nutrient Management Strategy, requiring two stages of nutrient reductions for Falls Lake. The Strategy was developed on a compressed schedule with only three years to collect data, develop watershed and lake models, and adopt the rules. Because of the uncertainty associated with the model-based load reductions, the Strategy allowed for a reexamination of the required nutrient load reductions (http://portal.ncdenr.org/web/fallslake/home). Due to this uncertainty and because the Strategy is estimated to cost over $1 billion, the Upper Neuse River Basin Association (UNRBA) began planning for a reexamination in 2011. As described below, the UNRBA has been collecting water quality data in the watershed and the lake since August 2014 and has begun planning for the modeling component of the reexamination.

The UNRBA is pleased to host its kickoff meeting for the Modeling and Regulatory Support component of the UNRBA Reexamination Project on September 28, 2016. Due to the compact agenda for the kickoff meeting, this reference material is being distributed beforehand to provide an overview of the work of the UNRBA and other organizations. Additional information is available on the UNRBA website (www.unrba.org). In an effort to conserve paper, a limited number of copies of this reference material will be available at the kickoff meeting (one per table). It is recommended that meeting participants print this document if they would like a hard copy. This reference material includes the following types of information:

- A summary of the goals and objectives established in 2010 for the original Falls Lake Nutrient Response Modeling and a summary of the monitoring goals established by the Triangle J Council of Governments in 2012. As part of the kickoff meeting, stakeholders will be asked to discuss the past goals and objectives and provide input on necessary revisions to address current issues and concerns.

- An overview of the UNRBA Monitoring Program that began in August 2014. The locations, parameters, and frequencies of the routine monitoring as well as brief descriptions of special studies are provided. During the kickoff meeting, we will provide a few examples of how the UNRBA Monitoring Program address questions from the original goals and objectives. We will not review each element of the Monitoring Program in detail during the kickoff meeting. The monitoring tab on the UNRBA website contains links to the monitoring database and summary reports that describe the data.

- A description of the types of modeling packages that will be evaluated to support the Modeling and Regulatory Support contract and a summary of the scope of work for Year 1 which includes the kickoff meeting, evaluation and selection of modeling packages to support the reexamination, and development of a Modeling Quality Assurance Project Plan. Input from the kickoff meeting will be used to inform the model evaluation and selection criteria.

The UNRBA is comprised of many watershed stakeholders, including the City of Raleigh which withdraws a large portion of its drinking water from Falls Lake. A key objective of the UNRBA is to conduct the reexamination using a measured, scientific approach with the best available information. Figure 1 provides a graphical depiction of how the monitoring and modeling projects support the reexamination of the Falls Lake Nutrient Management Strategy.

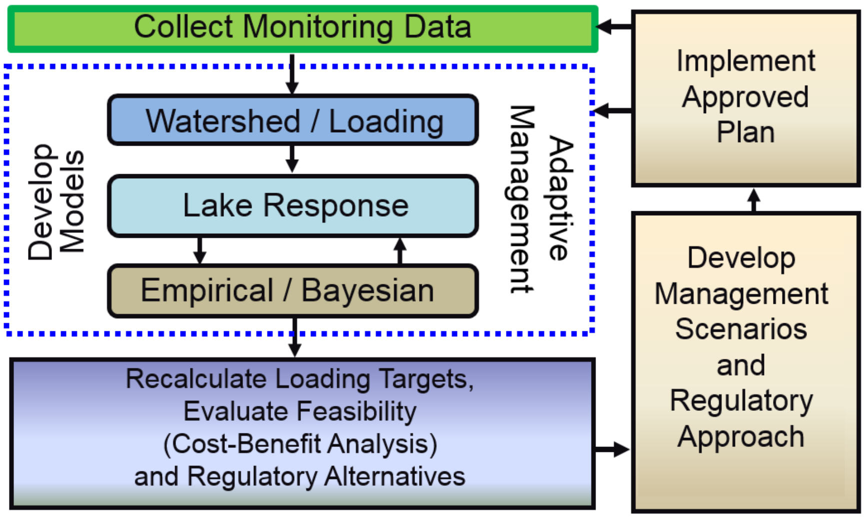


Figure 1. Adaptive Implementation of Monitoring and Modeling Efforts

Falls Lake Monitoring and Modeling Goals and Objectives
Stakeholder Meeting: September 7, 2010. Facilitator: Vickie Atkinson, City of Durham

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

MUST DO

Falls Lake

- Evaluate Past, Present and Future Uses of the Lake
  - Determine if existing water quality standards support existing uses. Are they too restrictive, too loose, or missing?
  - Evaluate how well the lake meets existing uses. Water supply, aquatic life propagation, recreation (boating, swimming, fishing)
  - Evaluate the degree to which the lake has, is, or can support all it's authorized uses.
  - Understand current condition of the lake
  - Supports UAA (Use Attainability Assessment) or change in use (water quality standard) for upper Falls Lake
- Lake Response Timeline
  - Given high internal loading in the lake, how will the lake respond to changes in the load?
  - Data and analysis that can be used to forecast or "backcast" conditions
- Water Treatment Concerns
  - Relationship between TOC and chlorophyll a
- Account for lake operations in model
- Fix short-comings of the existing model
- Capability to develop our own model
- Account for atmospheric deposition
- Lake Boundary Conditions
  - What is entering the lake? Chlorophyll a, other tributaries N, P and chlorophyll a
  - Are loads to the lake declining? (N, P and chlorophyll a)
  - Where is the best location (stable) to monitor inputs to the lake?

Falls Lake Watershed

- Characterize the distribution of loads
  - Load distribution (at jurisdictional boundaries)
  - What loads come from each jurisdiction
  - What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
  - Know loads by jurisdiction & tributary
  - Nutrient loading by jurisdiction and by subwatershed (2006 base and ongoing, current as of date certain)
  - Better unit loading rates that may vary by geography and by land use
- Tell us whether management efforts are succeeding (a vigorous effort)
  - Understand how management practices are affecting loads (individual and cumulative)
- Monitor Rainfall
  - Given that the model used rain data from RDU, would local monitoring of rainfall improve hydrologic calibration?
- Nutrient Mapping
- Sources Mapping
- Unknowns: Fertilizer, septic, sediment-attached P, atmospheric deposition
- Know the value of EACH individual management strategy (e.g., septic, ag). Do the BMPs work?
- Watershed Characterization
  - Distinguish sources of different types of nitrogen
  - Understand loads from forest and atmospheric deposition
  - Atmospheric deposition—coordinate with energy & air quality efforts with regard to nutrients
  - Forest is the largest component of the watershed. What are the actual nutrient loads from forests in the Triassic basin?

MUST DO

Falls Lake Monitoring and Modeling Goals and Objectives (September 7, 2010 Stakeholder Meeting)

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

	Falls Lake	Falls Lake Watershed	
MUST DO		○ Measured load from forests (slate vs. Triassic) ○ Nutrient loading by source type, 2006 base and ongoing ○ What are the impervious cover characteristics of the watershed? (where is IC and how is it distributed?) ○ Which streams do not have intact riparian buffers?	MUST DO
NICE TO DO	• Consider emerging pollutants (endocrine disruptors, personal care products, cyanotoxins) • How much does water level fluctuation contribute to internal loading in the lake? • Alternatives to chlorophyll a as an indicator • Learn about fish populations and biota in upper and lower lake relative to chlorophyll a and turbidity (impairment)	• Understand (soils for) onsite wastewater attenuation rates • Nutrient trading tool (USDA, lbs N, lbs P, reductions)	NICE TO DO
NOT NOW	Nothing was placed in this category for the lake or watershed.		NOT NOW

Falls Lake Monitoring and Modeling Goals and Objectives (September 7, 2010 Stakeholder Meeting)

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

MUST DO

Combined, Both or In-Between Goals and Objectives

- TRUST
- Work together, Do Good Things
  - One testing program accepted by all stakeholders and DWQ
  - Negotiate MOA or program with DWQ for entire monitoring program
  - Neutral & unbiased monitoring, management and oversight
- Stable Funding (no gaps in data collection) (timing longitudinal)
- Analyze process needs. Get Association
  - What does good long-term lake & watershed management look like? (account for droughts, pool re-allocation, hurricanes)
  - Ask Corps of Engineers to do research evaluating lake operations on water quality
  - Get Association together and let them determine accounting tools (instead of the Jordan Lake stakeholders)
- Clear system of water quality benchmarks. Relevant to decision-makers and the public.
- Understand current monitoring efforts
- Standardized methods, consistent and state approved.
- EPA & DWQ agreement on using correct & cost-effective study methods
- Translate/compare data collected using different methods (if possible)
- Know by 2017 (at least) where we are vis-à-vis Stage I.
- Gather new data for remodeling in 2018 (means we need to know which model will be used)
- Cost-effective, well-coordinated with other efforts
- Data is accepted by DWQ
- Define minimum data requirements
- Address data gaps
- Assess data being collected (current monitoring plans)
- Better definition of how data will be used to modify NMS
- Make sure our data can support decisions at a high level of certainty within regulatory time frame.

MUST DO

NICE TO DO

- Determine if modeling is as accurate as possible given state of science.
- Propose a new model(s) to address any identified deficiencies. Make sure flexible enough to incorporate new learning.

NICE TO DO

NOT NOW

Nothing was placed in this category.

NOT NOW

Upper Neuse Water Quality Monitoring Plan

Potential Objectives

Table 1. Objectives for a water quality monitoring plan as grouped into headings.

Sources/Dynamics of Nutrient Loading

- What is entering the lake? Chlorophyll a, other tributaries N, P and Chlorophyll *a*
- Are loads to the lake declining? (N, P and chlorophyll a)
- What is entering the lake? (Chlorophyll a, other tributaries (N, P, Chl a)
- Where is the best location (stable) to monitor inputs to the lake?
- Sources Mapping
- Unknowns: Fertilizer, septic, sediment-attached P, atmospheric deposition
- What are the impervious cover characteristics of the watershed? (Where is IC and how is it distributed?)
- Understand (soils for) onsite wastewater attenuation rates
- What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
- What loads come from each jurisdiction?
- Characterize internal lake load
- What is approximate nutrient loading into Falls Lake watershed from groundwater?
- Nutrient loads from groundwater discharge
- Lake boundary conditions (are loads to the lake declining (N, P, Chl a))?
- Understand how loads from agriculture (equine) differ from others (flow, composition, urban/suburban)
- Where is the best location (stable N, P, Chlorophyll a) to monitor inputs to the lake?
- Nutrient loading by source type. Base, ongoing, and current as of date.
- Distinguishing sources of different types of Nitrogen (i.e. residential, fertilizer vs. onsite wastewater)
- Watershed characterization
- Characterize sources better
- Measured load from forests (slate vs. Triassic)
- Nutrient loading by source type, 2006 base and ongoing

Nutrient Mapping

- Characterize the distribution of loads
- Load distribution (at jurisdictional boundaries)
- What loads come from each jurisdiction?
- What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
- Know loads by jurisdiction & tributary
- Nutrient loading by jurisdiction and by subwatershed (2006 base and ongoing, current as of date certain)
- Better unit loading rates that may vary by geography and by land use
- Nutrient trading tool (USDA, lbs N, lbs P, reductions)

Lake Response Timeline

- Given high internal loading in the lake, how will the lake respond to changes in the load?
- Data and analysis that can be used to forecast or “backcast” conditions
- What contribution of P (maybe N) does re-suspension have on the total nutrient load to be managed in the lake?

Lake Characterization

- Understand current condition of the lake
- Lake Boundary Conditions (are loads to the lake declining (N, P, Chl a)
- How much does water level fluctuation contribute to internal loading in the lake?
- Forest is the largest component of the watershed. What are the actual nutrient loads from forests in the Triassic basin?
- Understand loads from forest and atmospheric deposition
- Ask Corps of Engineers to do research evaluating lake operations on water quality
- Which streams do not have intact riparian buffers?
- Atmospheric deposition—coordinate with energy & air quality efforts with regard to nutrients
- Account for atmospheric deposition

Modeling Concerns

- Monitor Rainfall
- Given that the model used rain data from RDU, would local monitoring of rainfall improve hydrologic calibration?
- Determine if modeling is as accurate as possible given state of science.
- Propose a new model(s) to address any identified deficiencies. Make sure flexible enough to incorporate new learning
- Account for lake operations in model
- Fix short-comings of the existing model
- Capability to develop our own model
- Account for atmospheric deposition
- Gather new data for remodeling in 2018 (means we need to know which model will be used)
- What does good long-term lake & watershed management look like? (account for droughts, pool re-allocation, hurricanes)
- Better definition of how data will be used to modify NMS
- What are the least number of sites that would allow a remodel and use support assessment
- Data and analysis that can be used to forecast or "backcast" conditions
- New models needed
- Better unit loading rates that may vary by geography/use

Institutional Oversight

- Analyze process needs. Get Association
- Get Association together and let them determine accounting tools (instead of the Jordan Lake stakeholders)
- Define minimum data requirements
- One testing program accepted by all stakeholders and DWQ
- Know how DWQ is going to assess nutrient reductions for BMPs. Need to know requirements before assessing in projects (site specific before/after modeling?)

Regulatory Acceptance/QACC/QAPP

- One testing program accepted by all stakeholders and DWQ
- Negotiate MOA or program with DWQ for entire monitoring program
- Neutral & unbiased monitoring, management and oversight
- Data is accepted by DWQ
- Standardized methods, consistent and state approved.
- EPA & DWQ agreement on using correct & cost-effective study methods
- Implementable (fundable) plan that DWQ will accept

Management Effectiveness

- Tell us whether management efforts are succeeding (a vigorous effort)
- Understand how management practices are affecting loads (individual and cumulative)
- Know by 2017 (at least) where we are vis-à-vis Stage I.
- Know the value of EACH individual management strategy (e.g., septic, ag). Do the BMPs work?
- Tell us whether management efforts are succeeding; track success of NMS by source (agriculture, existing development, etc)
- Determine if BMPS are effective
- Focused sub-basin monitoring designed to isolate impacts from individual sources and improvements after BMPs implemented (to use to calibrate for basin future modeling efforts)
- Monitor BMPs

Emerging Contaminates

- Consider pollutants other than just nutrients (i.e. those that pose health risks to users of water)
- Consider emerging pollutants (endocrine disruptors, personal care products, cyanotoxins)
- Need to know levels of endocrine-disrupting chemicals, pharmaceuticals, and personal care products. Will help determine/reflect sources of input to the lake and watershed

Use Support Analysis

- Evaluate how well the land (public) meets needs (recreation) in watershed
- Evaluate Past, Present and Future Uses of the Lake
- Determine if existing water quality standards support existing uses. Are they too restrictive, too loose, or missing?
- Evaluate how well the lake meets existing uses. Water supply, aquatic life propagation, recreation (boating, swimming, fishing)
- Evaluate the degree to which the lake has, is, or can support all its authorized uses.
- Supports UAA (Use Attainability Assessment) or change in use (water quality standard) for upper Falls Lake

Public Education and Outreach

- Designation of Actions/Behaviors that residents, volunteers, and non-profits can do that won't cost taxpayers money
- Expand/Improve/Increase public awareness and participation in annual big sweep events; track totals
- Subsidize or incentivize residential composting; track # participants

Drinking Water

- Understand relationship between TOC, nutrients, and Chlorophyll a

Wildlife Management

- Learn about fish populations and biota in upper and lower lake relative to chlorophyll a and turbidity (impairment)
- Map urban stream syndrome (deeply incised streams)

Data Consolidation

- Make sure our data can support decisions at a high level of certainty within regulatory time frame.
- Translate/compare data collected using different methods (if possible)
- Stable Funding (no gaps in data collection) (timing longitudinal)
- Understand current monitoring efforts
- Cost-effective, well-coordinated with other efforts
- Address data gaps
- Assess data being collected (current monitoring plans)
- Develop data standards for monitoring data and tools; convert current monitoring from various sources

into a more common format
- Clear system of water quality benchmarks, relevant to decision-makers and public

Table 2. Questions for a water quality monitoring plan generated with heading names.

Sources and Dynamics of Nutrient Loading/Nutrient Mapping
- Identify sources of nutrients within and outside our combined regulatory purview.
- For nutrients within regulatory purview, identify sources of nutrients by use and by jurisdiction.
- For modeling, accounting for transport/attenuation/uptake as they relate to streams, for different media (i.e. groundwater, types of streams).
- How might different land uses inform efficient monitoring regimes?
- Better understanding of poorly quantified nutrient sources (sources not regulated); can we trust nutrient trading tools?

Lake Response
- What short-term changes in phytoplankton and chlorophyll-a community composition occur with measured load reductions from watershed?
- How important is internal nutrient loading vs. allocthonous loading in the lake?
- What are the major influences on watershed and lake hydrology?
- What are influences of hydrology on nutrient expression in lake?

Lake Characterization
- Where are the nutrient source loads originating from within the lake and watershed?
- How does nitrogen get processed in lake?
- What level of nutrients can the lake process?
- Differentiate mass loads from different sources in watershed.

Modeling Concerns
- What type/quantity of monitoring data to use?
- What models are needed/appropriate?
- Who develops the model?
- What is the goal of the model?
- Frequency of review and recalibration?
- Who interprets data and model output?
- What is appropriate time for sampling?

Institutional Oversight and Regulatory Acceptance
- What are standards that would be acceptable to DWQ and local governments?
- Who will develop the standards?
- What organization will have oversight and will this be by consensus?

Management Effectiveness
- Perform targeted evaluations of BMP assumptions.
- Are there things we can do to evaluate model effectiveness?
- Is management effectiveness a core goal of water quality monitoring process?
- Can data on management effectiveness help feed data for compliance?
- Question of degree to which evaluating the management effectiveness a core goal?
- Different levels of evaluation.
- Are loads to lake declining?

- Goals discussed at this table:
    - Understand relationship between TOC and chlorophyll-*a*.
    - Gather data on chlorophyll-*a* and other parameters such that model can be run to determine whether Stage II is appropriate.
    - Gather data for a use attainability analysis.
    - Targeted evaluations of established BMP assumptions.

Emerging Contaminants

- Are there measurable levels of emerging contaminants? At wastewater treatment plant effluent? In Falls Lake? In drinking water?
- If so, what are the concentrations compared to other research?

Drinking Water

- Is there a correlation between TOC, nutrients, and chlorophyll-*a*?

Use Support

- What type of monitoring should be performed to determine use support?
- Can existing data generate answers for use support questions?
- What are existing uses or classes and what type of land uses help determine use, land use focus on monitoring?

Public Outreach and Education

- Can monitoring generate increased participation in public outreach?
- Can monitoring determine effectiveness of public outreach involvement efforts?
- What are the priorities for public education?
- Do grassroots efforts such as residential composting produce reductions in nutrients? Is this too small a piece to measure?

Data Consolidation

- Is standardizing a test method a good way to achieve data consolidation?
- Is standardizing a test method a good way to achieve collection methods?
- Can permit regulations be modified to allow data consolidation?
- Can data consolidation be used to reduce duplication of effort and reduce overall cost?
- Can data consolidation be used to address existing data gaps?
- Can data consolidation help ensure the right data are being collected at an acceptable frequency?

Overview of the UNRBA Monitoring Program

Table 1 UNRBA Monitoring Program Objectives

Number	Objective
1	Support lake response modeling
2	Support alternative regulatory options
3	Understand source allocation and jurisdictional loading

Table 2 UNRBA Monitoring Program Components

Monitoring Program Component	Data Use	UNRBA Objectives[1] Supported
Routine Monitoring		
Lake Loading at 18 stations	> Quantify lake loading inputs to the models	1
20 Jurisdictional boundary stations	> Demonstrate water quality at multiple locations for all UNRBA member organizations > Provide additional water quality observations in upper reaches of the watershed which may be used in the future to develop watershed loading models	3
Special Studies [Fiscal Year, July through June]		
Storm event sampling (SS.LR.1) [FY2015, FY2016]	> Provide additional monitoring data for comparing multiple methods for estimating loads to the model(s) and to assist in the selection of best method for estimating loads to Falls Lake > Provide additional water quality observations which may be used in the future to develop watershed loading models	1
Lake sediment evaluation (SS.LR.2) [FY2016]	> Collect lake bottom sediment cores to characterize nutrient flux rates for use in revised lake models > Update sediment nutrient flux rates in the model(s) > Understand lag times associated with watershed implementation and lake response > Support regulatory options	1
High flow sampling (SS.LR.3) [FY2015, FY2016, FY2017]	> Sample tributaries during storm events to characterize water quality data when loading to the lake is high > Provide a better understanding of the water quality conditions in stagnant areas and wetland complexes during high flow events > Refine loading estimates to the model(s) > Provide additional data for the development of a watershed model	1
Special Lake Studies (SS.LR.5) [FY2016 and FY2017]	**Water quality / velocity measurements at representative lake constriction points [FY2016]** > Provide data at a refined temporal scale for EFDC model calibration > Provide estimates of flux through the major lake segments for EFDC, BATHTUB, and empirical models > Provide data to support regulatory options that may include site specific criteria or use attainability analyses for specific lake segments **Bathymetry and Sediment Mapping [FY2017]** > Collect lake bathymetry data to define the model domain and support revisions to the lake model grid	1

Monitoring Program Component	Data Use	UNRBA Objectives[1] Supported
	> Characterize the depths of unconsolidated sediments along the lake bottom for comparison to sediment core data and estimated nutrient fluxes from the Lake Sediment Evaluation (SS.LR.2)	
Obtain light extinction data (SS.LR.7a and b) [FY2016]	> Provide a better understanding of the quality of the relationship between light extinction and Secchi depth in Falls Lake > Provide data to develop and calibrate EFDC and BATHTUB models	1
Basic evaluation of model performance (SS.LR.8) [FY2016]	> Use the existing EFDC and BATHUB models and Falls Lake Framework Tool to support future revisions to the Monitoring Program > Compare tributary load estimation methods to storm event data to support future model revisions > Develop a framework and preliminary network connections for the empirical model > Assess data needs for the empirical model	1
Tracking BMP Implementation, Inspections, and Repairs (SS.SA.1) [ongoing by each jurisdiction]	> Track information regarding description of each BMP, geographic position, parcel square footage, square footage by land use draining to the BMP, and BMP inspections and maintenance performed to document compliance with the rules and changes in watershed loading > May be used to inform future watershed modeling in terms of practices implemented	3
Obtain CAAE platform data (SS.RO.1) [FY2016 and FY2017]	> Provide additional data for the EFDC model calibration and development of the empirical model > Support potential development of alternative regulatory approach	2
Obtain fish monitoring data (SS.RO.2) [FY2015, FY2016, FY2017]	> Correlate water quality with fish population data collected by Wildlife Resources Commission > Assess the need for supplemental data needed in this area of "alternative regulatory approaches" as we move through this monitoring program (i.e. if WRC data isn't appropriate and we can't secure additional data from them (get them to do a special study), the UNRBA will generate the data needed (coordinated with WRC). > Provide data for the development of the empirical model > Support potential development of alternative regulatory approach	2
Obtain drinking water quality data (SS.RO.3) [FY2015, FY2016, FY2017]	> Provide estimate of forms of carbon throughout the lake for Falls Lake EFDC model refinement > Provide additional data for City of Raleigh regarding fluctuations in TOC concentrations > Determine whether TOC is generated primarily within Falls Lake or in the watershed > Support development of the empirical model by linking lake water quality to finished water quality and the drinking water designated use	1,2,3
Recreational Uses Assessment (SS.RO.4a and b) [FY2016 (4a)]	> Demonstrate that Falls Lake is supporting recreational uses and correlate use with fluctuations in water quality within Falls Lake > Provide data for the development of the empirical model > Support potential development of alternative regulatory approach	2
Preparation for and meetings with state and federal regulators (SS.RO.5) [FY2015, FY2016, FY2017]	> Legal support and Cardno participation in meetings with DWR and EPA to better understand agency requirements associated with special studies that will be used to support alternative regulatory options and development of the empirical model	2

Table 3 Anticipated Schedule and Sampling Frequencies for UNRBA Monitoring Program

Monitoring Program Component	FY2015 August 2014 - June 2015	FY2016 July 2015 - June 2016	FY2017 July 2016 - June 2017	FY2018 July 2017 - June 2018	FY2019 July 2018 - June 2019
Routine Monitoring					
Lake Loading at 18 stations	**Twice a month** for Ellerbe, Eno, Little, Flat, and Knap of Reeds; **Monthly** for all other locations.		**Monthly** for all locations	Frequency to be determined	
20 jurisdictional boundary stations	**Monthly** monitoring for all locations			Frequency to be determined	
Special Studies	**FY2015**	**FY2016**	**FY2017**	**FY2018**	**FY2019**
Storm event sampling	x	x			
Lake Sediment Evaluation[1]		x			
High flow event sampling	x	x	x	x	x
Water quality / velocity measurements at representative lake constriction points		x			
Bathymetry and sediment mapping			x		
Analyze historic light extinction data		x			
Collect light extinction data		x			
Basic evaluation of model performance		x			
Tracking BMP implementation, inspections, and repairs	x	x	x	x	x
Obtain CAAE platform data	x	x	x	x	x
Obtain fish monitoring data	x	x	x	x	x
Obtain drinking water quality data	x	x	x	x	x
Recreational uses assessment		x			
Preparation for and meetings with state and federal regulators		x	x	x	x

[1]This table reflects the schedule for the UNRBA Lake Sediment Evaluation. USEPA may conduct benthic chamber measurements of nutrient flux from the lake sediment during any or none of these monitoring years.

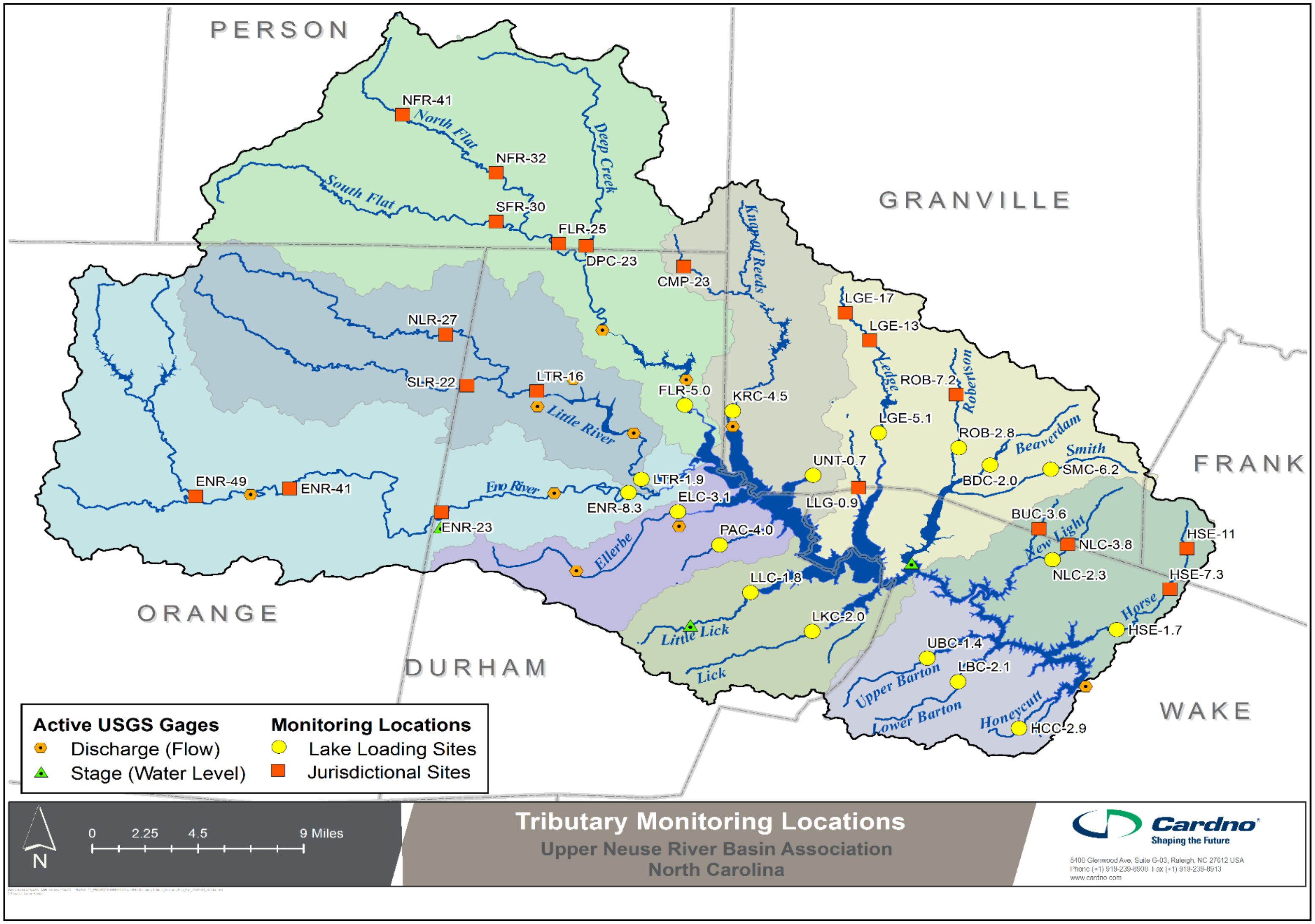


Figure 2 UNRBA Lake Loading and Jurisdictional Boundary Monitoring locations and Existing USGS Gages

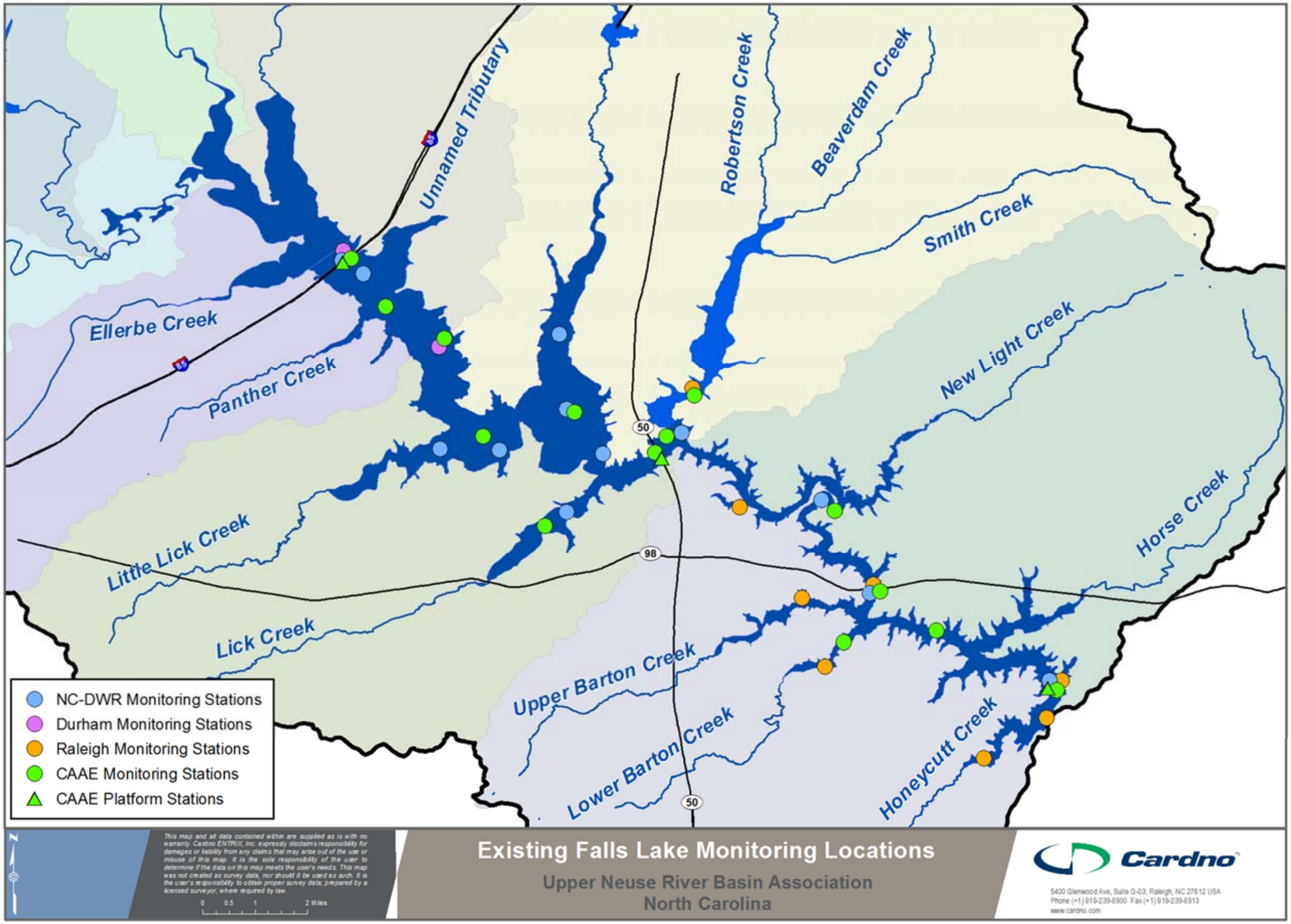


Figure 3 **Falls Lake DWR, CAAE, City of Raleigh, and City of Durham Monitoring Locations**

Table 4 Lake Loading Monitoring Locations

Name[1]	Waterbody	Road Crossing	Latitude	Longitude	Drainage Area (mi^2)
FLR-5.0	Flat River	at Old Oxford Highway	36.1319	-78.8280	169
ENR-8.3	Eno River	at Old Oxford Highway	36.0726	-78.8627	149
LTR-1.9	Little River	at Old Oxford Road	36.0817	-78.8547	104
KRC-4.5	Knap of Reeds Creek	at SGWASA WWTP	36.1280	-78.7985	41.9
ELC-3.1	Ellerbe Creek	at Glenn Road	36.0596	-78.8322	21.9
LGE-5.1	Ledge Creek	at Highway 15	36.1131	-78.7085	20.3
LLC-1.8	Little Lick Creek	at Patterson Road	36.0046	-78.7875	13.8
BDC-2.0	Beaverdam Creek	at Horseshoe Road	36.0913	-78.6399	12.7
NLC-2.3	New Light Creek	at Mangum Dairy Road	36.0270	-78.6013	12.3
ROB-2.8	Robertson Creek	at Brassfield Road	36.1030	-78.6592	12.0
HSE-1.7	Horse Creek	at Thompson Mill Road	35.9791	-78.5617	11.9
LKC-2.0	Lick Creek	at Southview Rd south of Hwy 98	35.9779	-78.7496	10.8
LBC-2.1	Lower Barton Creek	at State Road 1834 (Norwood Road)	35.9439	-78.6596	10.4
UBC-1.4	Upper Barton Creek	at Mt Vernon Church Road	35.9599	-78.6786	8.26
SMC-6.2	Smith Creek	at Lawrence Road	36.0884	-78.6024	6.30
UNT-0.7	Unnamed Tributary	at Northside Road	36.0843	-78.7489	3.43
PAC-4.0	Panther Creek	at end of Cooksbury Drive	36.0370	-78.8064	3.24
HCC-2.9	Honeycutt Creek	at Honeycutt Road	35.9126	-78.6221	2.76

[1]Name combines an abbreviation for the waterbody with an approximation of the distance upstream from Falls Lake (km).

Table 5 Parameters Measured Monthly at Lake Loading Sites

Parameter	Start Date	End Date
Field Measurements:		
Air temperature	Aug 2014	Aug 2015
Water temperature	Aug 2014	Ongoing
Specific conductance	Aug 2014	Ongoing
Dissolved Oxygen	Aug 2014	Ongoing
pH	Aug 2014	Ongoing
Reference-point tape-down	Jan 2015	Ongoing
Dye velocity	Jan 2015	Ongoing
Laboratory Analyses:		
Total Kjeldahl nitrogen	Aug 2014	Ongoing
Soluble Kjeldahl nitrogen	Aug 2014	Ongoing
Nitrate + nitrite	Aug 2014	Ongoing
Ammonia	Aug 2014	Ongoing
Total phosphorus	Aug 2014	Ongoing
Total soluble phosphorus	Aug 2014	Ongoing
Orthophosphate	Aug 2014	Ongoing
Total organic carbon	Aug 2014	Ongoing
Dissolved organic carbon	Aug 2014	Jun 2016
Chlorophyll *a*	Aug 2014	Ongoing
Total suspended solids	Aug 2014	Ongoing
Volatile suspended solids	Jul 2015	Ongoing
Color (platinum cobalt)	Aug 2014	Jun 2016
Visible absorbance at 440nm	Aug 2014	Ongoing
UV absorbance at 254nm	Aug 2014	Ongoing
5-day carbonaceous biochemical oxygen demand	Aug 2014	Jun 2016

Table 6 **Current Lake Sampling by DWR, Cities of Durham and Raleigh, and CAAE[1]**
Frequencies are provided in parentheses: M-monthly, W-weekly, D-subdaily.

Samples	DWR	City of Durham[2]	City of Raleigh	CAAE
TOC	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
DOC	Photic Zone Composite (M)[5]	-	-	-
$CBOD_5$	Photic Zone Composite (M)[5]	-	-	-
Color	Photic Zone Composite (M)[5]	-	-	-
Chlorophyll a	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Hwy 85, Hwy 50, and Raleigh Intake 1-2 meters, 2x/month Variable sampling frequency at other locations
TN	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
TKN	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
NO2 + NO3	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
NH3	Photic Zone Composite (M)	Photic Zone Composite (W)	-	Variable
TP	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]

Samples	DWR	City of Durham[2]	City of Raleigh	CAAE
Orthophosphorus	-	Photic Zone Composite (W)	-	-
Ultraviolet Absorbance (UVA) at 254 nm	Photic Zone Composite (M)[5] (Analyzed by UNRBA contract laboratory)	-	-	-
Turbidity	Photic Zone Composite (M)	-	Surface (M)	-
TSS	Photic Zone Composite (M)[5]	-	-	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
VSS	Photic Zone Composite (M)[6]			
pH	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Conductivity	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Dissolved oxygen	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Temperature	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Algal groups	Photic Zone Composite at three stations (M)	-	-	-

[1] Each program is responsible for their own quality assurance practices.

[2] The City of Durham monitors its Falls Lake stations during the months of April through October of each year. Sites are not monitored from November through March.

[3] Data are available for a number of CAAE sites which are either no longer sampled, are sampled only in summer months or have variable sampling frequency for these parameters.

[4] At the three platform sites, these data are collected at multiple depths several times per day. At other sites these are typically collected monthly.

[5] At UNRBA's request, DWR added this parameter to their monthly sampling starting in October 2014.

[6] At UNRBA's request DWR added this parameter to their monthly sampling starting in September 2015.

Table 7 Jurisdictional Boundary Monitoring Locations

Name	Waterbody and Location	Boundary	Latitude	Longitude	Drainage Area (mi^2)
ENR-49	Eno River at Dimmocks Mill Road	upstream of Hillsborough	36.0701	-79.1295	60.5
ENR-41	Eno River at Hwy 70 and Riverside Drive	downstream of Hillsborough	36.0754	-79.0716	73.2
ENR-23	Eno River at Cole Mill Road	downstream of Orange County	36.0593	-78.9780	121
NLR-27	North Fork Little River at New Sharon Church Road	between Orange and Durham Counties	36.1802	-78.9754	21.9
SLR-22	South Fork Little River at Guess Road (Hwy 157)	between Orange and Durham Counties	36.1455	-78.9622	37.4
LTR-16	Little River at Johnson Mill Road	upstream of City of Durham	36.1416	-78.9193	78.3
NFR-41[1]	North Flat River at North Flat River Church Road	downstream of Roxboro	36.3295	-79.0020	12.7
NFR-37[2]	North Flat River at US 501	downstream of Roxboro	36.3106	-78.9694	15.8
NFR-32	North Flat River at Helena-Moriah Road	Person Co. before confluence with South Flat	36.2890	-78.9429	32.8
SFR-30	South Flat River at US 501 / NC 57	Person Co. before confluence with North Flat River	36.2568	-78.9443	54.4
FLR-25	Flat River at Moores Mill Rd	downstream of Person county	36.2419	-78.9058	102
DPC-23	Deep Creek at Smith Road	downstream of Person County	36.2403	-78.8889	32.1
CMP-23	Camp Creek at Camp Butner	between Durham and Granville Counties	36.2095	-78.8053	4.99
LLG-0.9	Little Ledge Creek at Old Weaver Trail	downstream of Granville	36.0759	-78.7210	3.74
LGE-17	Ledge Creek at Old Rte 75	downstream of Stem	36.1949	-78.7292	1.79
LGE-13	Ledge Creek at W Lyon Station Road	upstream of Butner	36.1761	-78.7141	3.49
ROB-7.2	Robertson Creek at Sam Moss Hayes Road	upstream of Creedmoor	36.1392	-78.6608	4.43
BUC-3.6	Buckhorn Creek at Buckhorn Lane	between Granville and Wake Counties	36.0481	-78.6097	1.21
NLC-3.8	New Light Creek at Bold Run Hill Road	between Granville and Wake Counties	36.0375	-78.5921	9.90
HSE-5.7[3]	Horse Creek at Jenkins Rd	downstream of Franklin County	35.9947	-78.5371	9.61
HSE-7.3	Horse Creek at Purnell Rd	upstream of Wake Forest	36.0071	-78.5291	7.11
HSE-11	Horse Creek at Green Rd	downstream of Franklin County	36.0345	-78.5186	3.88

[1] NFR-41 was added in July 2015 to replace NFR-37.

[2] NRF-37 was suspended after June 2015 due to safety and accessibility concerns.

[3] HSE-5.7 was sampled temporarily in May and June of 2015 while HSE-7.3 was inaccessible due to construction.

Table 8 Parameters Measured Monthly at Jurisdictional Boundary Sampling Locations

Field Measurements	Laboratory Analyses
Water temperature	Total Kjeldahl nitrogen
Air temperature (*suspended Aug 2015*)	Nitrate + nitrite
Specific conductance	Ammonia
Dissolved oxygen	Total phosphorus
pH	Total organic carbon[1]
Reference-point tape-down *(added Jan 2015)*	Total suspended solids
Dye velocity *(added Jan 2015)*	

[1]As of July 2016, TOC is analyzed quarterly at the jurisdictional stations; all other parameters continue to be analyzed monthly.

Table 9 Special Studies and Data Use, Importance, and Timing of Study Implementation

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration[1]
Lake Response Modeling (Loading Estimation)			
SS.LR.1	Storm event sampling and comparison of loading methods	Compare the accuracy of tributary load estimation methods (e.g., various LOADEST options or WQ statistical model) to loads measured during storm event sampling. The TN and TP load estimate doubles depending on the method used as shown in the Model Sensitivity TM. Estimating lake loads based on the most accurate method will result in substantially more accurate model predictions and increased confidence in resulting Stage II targets.	2 - 4 storms per year, each at one site. Sites will vary for each storm. This study was conducted in FY2015 and FY2016 and will not be continued in FY2017.
SS.LR.2	Evaluate lake sediment quality, estimate and measure internal loading from lake sediments and measure other inlake processes	Improve accuracy and calibration of lake models. Cardno is currently working with Dr. Marc Alperin at UNC on a sediment core sampling program at up to 20 sites in Falls Lake. The analysis of porewater and sediment concentrations will allow for the estimation of sediment flux of ammonia and phosphate. In addition, the UNRBA has petitioned EPA to conduct SOD and nutrient flux chamber measurements at three locations in Falls Lake, which is expected to occur in monitoring year 3, 4, or 5. These studies will provide data to support lake modeling.	Evaluate lake sediment quality and estimate benthic flux in FY2015 and FY2016 in cooperation with UNC. UNRBA and DWR have cooperatively petitioned EPA to conduct in situ measures for Falls Lake (benthic chamber work and inlake processes). This study could occur during the summer months of any monitoring year.
SS.LR.3	High flow event sampling	High flow event sampling at tributaries will provide characterization of water quality when loading to the lake is high. The purpose of the high flow monitoring is to determine influence of storm flows on water quality concentrations at the largest tributaries and wetland influenced lake loading sites and select major lake loading stations. The data will be used to determine a likely "range" in nutrient concentrations and loading associated with storm flows.	FY2015, FY2016, FY2017, FY2018, FY2019 (optional)

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration[1]
SS.LR.5	Special Lake Studies: Water quality / velocity measurements at representative lake constriction points And Bathymetry and sediment mapping	Provide data at a refined temporal scale to constrain model calibration that will occur in the future and provide estimates of flux through the major lake segments. And Collect lake bathymetry data to define the model domain and support revisions to the lake model grid Characterize the depths of unconsolidated sediments along the lake bottom for comparison to sediment core data and estimated nutrient fluxes from the Lake Sediment Evaluation (SS.LR.2).	FY2016 And FY2017
SS.LR.7a	Analyze historic light extinction data	Light is an important limiting factor for algal growth, and the lake models can be sensitive to light availability in terms of predicting algal growth. Analyze historic data (if available) to determine adequacy of using Secchi depth as a surrogate for light extinction.	FY2016
SS.LR.7b	Collect light extinction data	If historic data are not available, or the data indicates such variability that additional data collection is warranted, collect light extinction data in Falls Lake at each lake monitoring location.	FY2016 (data collected by DWR)
SS.LR.8	Basic evaluation of model performance	Use the existing EFDC and BATHTUB models and Falls Lake Framework Tool to support revisions to the Monitoring Program for FY2017. Compare tributary load estimation methods to storm event data. Develop a framework and preliminary network connections for the empirical model.	FY2016
Source Allocation: Determining Loading from Different Watershed Sources			
SS.SA.1	Tracking BMP Implementation, Inspections and Repairs	The following information should be collected: description of each BMP, geographic position, parcel square footage, square footage by land use draining to the BMP, and BMP inspections and maintenance performed. The Nutrient Scientific Advisory Board (NSAB) is currently establishing guidance regarding data collection efforts for BMPs that will be needed to calculate credits. To continue receiving nutrient loading credits from BMPs, local governments should inspect and repair BMPs on an annual basis.	This information should be tracked annually by member jurisdictions.

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration[1]
Support of Regulatory Options - Linkage of Water Quality with Designated Uses			
SS.RO.1	Obtain profile data from three Center for Applied Aquatic Ecology (CAAE) monitoring stations (I-85, Highway 50, and Raleigh Intake).	Supports regulatory options and structural equation/ Bayesian modeling, and lake model calibration. Provides data needed to support development of site-specific water quality criteria or a sub-classification use attainability analysis.	FY2015, FY2016, FY2017, FY2018, FY2019
SS.RO.2	Obtain fish monitoring data collected by WRC at DWR Lake monitoring stations (or at the three CAAE locations)	Support regulatory options and structural equation/ Bayesian modeling. Correlates fish population, size and length with water quality conditions in the three main segments of the lake.	FY2015, FY2016, FY2017, FY2018, FY2019
SS.RO.3	Obtain drinking water quality data from the City of Raleigh to correlate water quality (nutrients, chlorophyll *a*, TOC, DOC, SUVA, and color) at the intake to finished water quality testing performed by Underwriters Laboratories (UL) (taste and odor and DBPs)	Support regulatory options and structural equation/Bayesian modeling. Provides data to identify how water quality at the intake is linked with disinfection byproduct formation and taste and odor issues in the finished water.	FY2015, FY2016, FY2017, FY2018, FY2019
SS.RO.4a	Recreational Uses Assessment	Support regulatory options and structural equation/Bayesian modeling to correlate lake water quality with recreational use: conduct initial research to inform discussions with regulators and develop survey protocols.	FY2016
SS.RO.5	Coordination with regulatory agencies in the design and implementation of studies associated with regulatory options.	Preparation of a strategy and presentation of materials for meetings and discussions with EPA Headquarters, EPA Region 4 and DWR in order to discuss agency positions concerning alternate regulatory approaches and to help identify the kinds of data that may be needed to support such approaches. These meetings and discussions will help identify and define future studies needed to develop the data for supporting alternate regulatory submissions by the UNRBA.	FY2015, FY2016, FY2017, FY2018, FY2019

[1] FY indicates the UNRBA's Fiscal Year, which runs from July through June. FY2015, for instance, included July 2014 through June 2015.

Overview of the Modeling Program (Year 1)

Table 10 Scope of Work for Year 1 of the Modeling and Regulatory Support Contract

Component
1. Kickoff meeting with watershed stakeholders and agency staff
2. Evaluation and selection of lake and watershed modeling packages
3. Development of conceptual plan for the multi-modeling approach
4. Develop the Modeling QAPP
5. Develop the two-year work plan (October 2017 through September 2019)
6. Revise the Description of Modeling Framework (previously approved by DWR)

Types of Modeling Packages Being Considered

- Watershed loading models predict the amount of pollutant generated from nonpoint sources (land uses, atmospheric deposition, onsite wastewater treatment, fertilizer application, etc.) and point sources (permitted dischargers such as wastewater treatment plants). These models may be empirical (data driven) or mechanistic (process based). Watershed loading models are often linked to downstream water quality models that predict the water quality in a receiving waterbody such as a river or lake. The UNRBA will evaluate approximately ten watershed modeling packages and select one or two models to support the reexamination effort.
- Lake nutrient response models predict water quality in a lake or reservoir in response to loading from the watershed, atmosphere, and point sources. Like watershed models, they may be either empirical or mechanistic. Lake response models should account for hydrologic inputs (tributary inflows, precipitation to the lake surface, point source discharges) and outputs (flow over the dam or through outlet structures, evaporation from the lake surface, and water withdrawals). Lake nutrient response models predict the growth of algae by simulating nutrient concentrations, light availability, and hydrologic residence time. Some lake nutrient response models account for internal nutrient loading from the lake bottom sediments. The UNRBA will evaluate approximately seven lake nutrient response modeling packages and select two or three models to support the reexamination effort.
- While watershed loading and lake nutrient responses models are often developed to predict nutrient loads and changes in water quality parameters, they typically do not address attainment of designated uses or key questions of concern from the public: Is the water safe to swim in? Will the lake support a healthy fish population? The UNRBA reexamination strategy includes an empirical/probabilistic/Bayesian model to link lake water quality to designated uses. Figure 4 shows the conceptual framework for this model and demonstrates how various water quality monitoring parameters and other information about the lake and water treatment plant characteristics may be used to evaluate compliance with the Safe Drinking Water Act, impacts to the recreational and aquatic life/wildlife designated uses, and compliance with water quality criteria. Because some of the information to populate this model may be difficult or costly to measure, expert opinion is often incorporated in the model. The UNRBA has identified subject matter experts in the fields of water chemistry, lake processes, drinking water treatability, and evaluation of impacts to recreational uses to support this component of the reexamination.

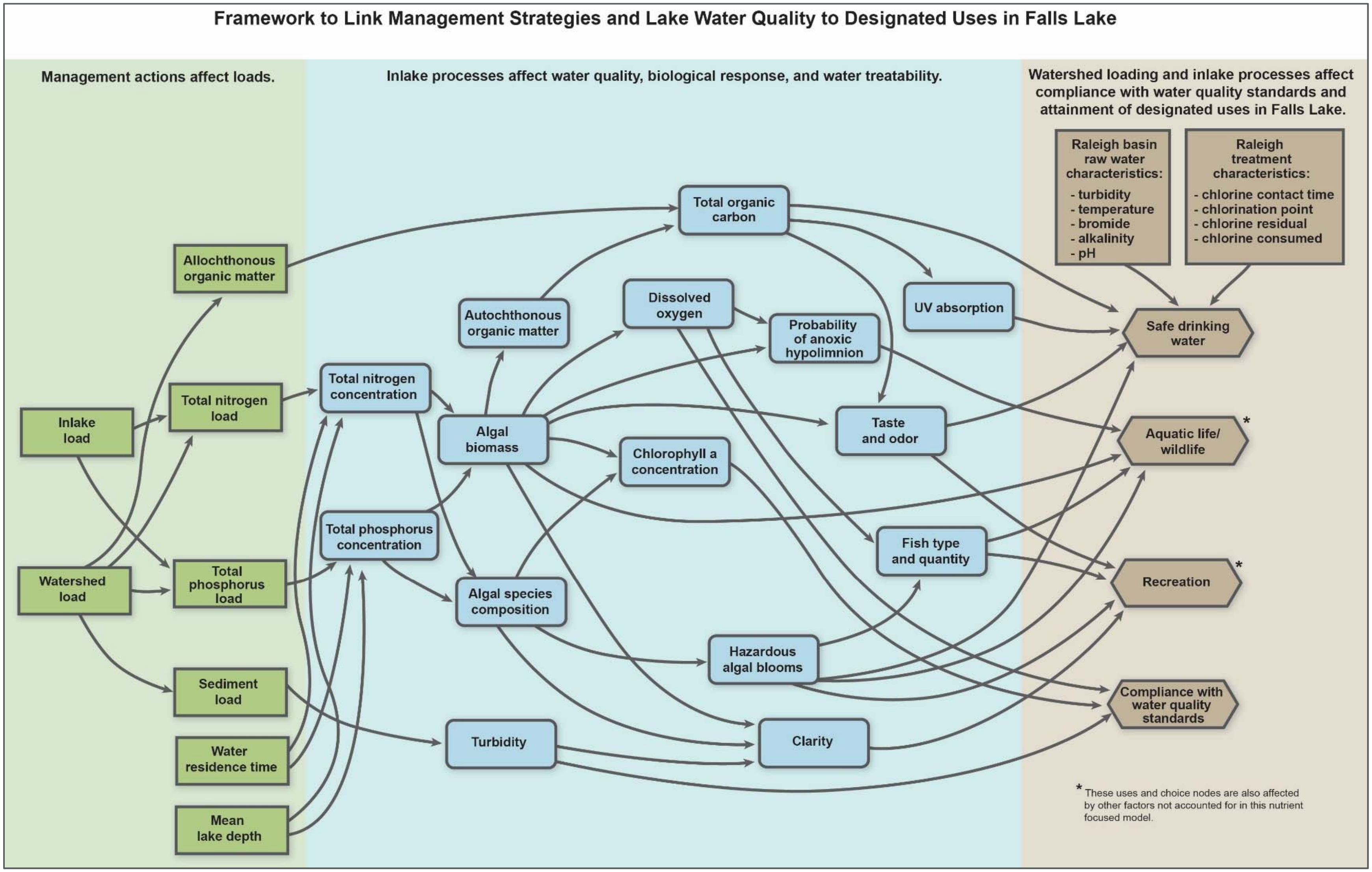


Figure 4 **Conceptual Diagram for the Empirical/Bayesian Falls Lake Model to Link Water Quality to Designated Uses**