Task 1: Framework for a Re-examination of Stage II of the Falls Nutrient Strategy

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ES.1 Introduction

Falls Lake was constructed by the US Army Corps of Engineers in the late 1970s. The Congressionally authorized uses of the project were flood control, water supply, recreation, fish and wildlife enhancement, and augmentation of low flows for purposes of pollution abatement and water-quality control in the Neuse River Basin. P.L. 89-298 (Oct. 27, 1965). The NCDWQ designated uses of Falls Lake under the Clean Water Act are drinking water supply, recreation, fishing, aquatic life including propagation and survival, and wildlife.

The North Carolina General Assembly's 2005 "Clean Lakes Act" (S.L. 2005-190) generated intensive data collection in water supply reservoirs across the State, including Falls Lake. Based on water quality monitoring conducted primarily in 2006, a portion of Falls Lake, from the confluence of the Eno and Flat River arms to the Interstate 85 Bridge (I-85), was identified as impaired due to exceedances of the turbidity and chlorophyll *a* water quality criteria (NCDENR 2012a). Another portion of Falls Lake, from the I-85 Bridge downstream to the dam also exceeds the chlorophyll *a* water quality criterion (NCDENR 2012a). The water quality criteria for chlorophyll *a* and turbidity are 40 µg/L and 25 nephelometric turbidity units (NTU), respectively. Under the Use Support guidance employed for the referenced review period, NCDWQ identified waterbodies as impaired if ten percent or more of the data (minimum of ten samples) exceeded the water quality criteria. The impairment determinations for Falls Lake were based on data collected between 2002 and 2006. Based on feedback from the Upper Neuse River Basin Association (UNRBA), the Association is, in addition to the specific re-examination process for Falls Lake, evaluating the State's chlorophyll *a* standard and is planning on entering into discussions with the Division of Water Quality (NCDWQ) and the Environmental Management Commission (EMC) to review the State's interpretation and application of the chlorophyll *a* standard. As reflected in UNRBA discussions, there are a number of alternatives relative to the standard including the standard value itself, application of the standard over the growing season as an average, and the use of several trophic measurements rather than one to define eutrophication level.

Table ES-1 summarizes the impairments for Falls Lake segments. The impairment status is specified by assessment unit number, which is a unique identifier that NCDENR uses to define specific segments of a waterbody. The UNRBA may recommend revisions to this segmentation in the future based on collection of additional data or to pursue specific regulatory options. The designated use associated with these water quality standards violations is the Aquatic Life use. However, there is no existing biological evidence to support an impaired status for this use; i.e., the lake does not have issues with fish kills due to eutrophication or low DO and supports a healthy sports fishery, etc. Although a fish kill occurred in 2008 near Highway 50, it was limited primarily to one species, channel catfish, and water quality measurements, total algal counts, and algal speciation during the event were within normal ranges (NCDWQ 2008). A North Carolina Wildlife Resources commission representative considered it a natural event likely "caused by a combination of spawning activities and high water temperature which may have allowed a bacterial infection to sicken weakened fish" (NCDWQ 2008). However, the lake is considered impaired by NCDWQ because it is does not meet all of the applicable water quality criteria assigned to the aquatic life use.

Table ES-1 Falls Lake Water Quality Attainment and Impairment Status

Listing Year	Water Body	Assessment Unit Number	Cause of Impairment	Use Support Category	Use Support Rating
2008	Flat River (incl. Flat R. Arm of Falls Lake)	27-3-(9)	Low Dissolved Oxygen	Aquatic Life	Impaired
	Neuse River (From Source to I-85 Bridge)	27-(1)	Turbidity; Chlorophyll a	Aquatic Life	Impaired
	Neuse River (From I-85 Bridge to Dam)	27-(5.5)	Chlorophyll a	Aquatic Life	Impaired
2010	Flat River (incl. Flat R. Arm of Falls Lake)	27-3-(9)	Low Dissolved Oxygen	Aquatic Life	Impaired
	Neuse River (From Source to I-85 Bridge)	27-(1)	Turbidity; Chlorophyll a	Aquatic Life	Impaired
	Neuse River (From I-85 Bridge to Panther Creek)	27-(5.5)a	Turbidity; Chlorophyll a	Aquatic Life	Impaired
	Neuse River (From Panther Creek to Falls Dam)	27-(5.5)b	Chlorophyll a	Aquatic Life	Impaired
2012	Flat River (incl. Flat R. Arm of Falls Lake)	27-3-(9)	Low Dissolved Oxygen	Aquatic Life	Impaired
	Neuse River (From Source to I-85 Bridge)	27-(1)	Turbidity[1]	Aquatic Life	Impaired
	Neuse River (From I-85 Bridge to Panther Creek)	27-(5.5)a	Turbidity[1]	Aquatic Life	Impaired

In 2010 the Environmental Management Commission (EMC) passed the Falls Lake Nutrient Management Strategy, requiring two stages of nutrient reductions (N.C. Rules Review Commission 2010). The Rules establish a Nutrient Management Strategy for Falls of the Neuse Reservoir aimed at attaining:

> "…the classified uses of Falls of the Neuse Reservoir set out in 15A NCAC 02B .0211 from current impaired conditions related to excess nutrient inputs; protect its classified uses as set out in 15A NCAC 02B .0216, including use as a source of water supply for drinking water; and maintain and enhance protections currently implemented by local governments in existing water supply watersheds encompassed by the watershed of Falls of the Neuse Reservoir." (15NCAC 02B .0275)

Stage I of the Nutrient Management Strategy requires "intermediate or currently achievable controls throughout the Falls watershed with the objective of reducing nitrogen and phosphorus loading, and attaining nutrient-related water quality standards in the Lower Falls Reservoir as soon as possible but no later than January 15, 2021, while also improving water quality in the Upper Falls Reservoir…." (15NCAC 02B .0275 (4) (a)). Based on modeling and evaluation by the NC Division of Water Quality (NCDWQ), Stage I will require a 20 percent and 40 percent reduction in total nitrogen and total phosphorus loading, respectively, for point sources and agriculture. For development based sources, the rules require that loading be reduced to the levels of the baseline year (2006) established by NCDWQ. Stage I requires local jurisdictions to establish requirements to control nutrient input from new development sources.

Stage II requires that all areas of Falls Lake achieve the nutrient-related water quality standards. Based on NCDWQ modeling and evaluation, the additional loading reductions required to achieve this goal are

40 percent and 77 percent for total nitrogen and total phosphorus, respectively, relative to the baseline year. NCDWQ reservoir monitoring data will be used to assess compliance with the goals of the Strategy and determine if additional load reductions to a particular lake segment are needed. As stated in the Rules:

> "Stage II requires implementation of additional controls in the Upper Falls Watershed beginning no later than January 15, 2021 to achieve nutrient-related water quality standards throughout Falls Reservoir by 2041 to the maximum extent technically and economically feasible…." (15NCAC 02B .0275 (4) (b))

The NCDWQ believes that the Stage II nutrient reductions are needed for all of Falls Reservoir to achieve compliance with water quality standards. The rules identify the parties (municipalities, counties, agriculture, and state and federal entities) responsible for implementing the nutrient reductions. The nutrient reductions are to be achieved by requiring stormwater controls and implementation of best management practices (BMPs) for new and existing development, point source discharges, and agricultural non-point sources.

The Consensus Principles were adopted in February 2010 to guide the Falls Lake Nutrient Management Strategy. The Consensus Principles call for a review of the attainability of the designated uses for the Upper Lake, and the feasibility of achieving Stage II reduction goals and meeting the water quality standard for chlorophyll *a*. The principles also propose an examination of whether existing uses of the Upper Lake can be protected with alternative water quality standards.

Cardno ENTRIX is assisting the Upper Neuse River Basin Association (UNRBA) in determining the best approach to address the nutrient management rule requirements and the Consensus Principles regarding the re-examination of Stage II of the Falls Lake Nutrient Management Strategy. The re-examination should consider existing data, models, nutrient management strategies, the Consensus Principles, water quality standards (including designated uses and water quality criteria), implementation costs, and regulatory flexibility (Figure ES-1).

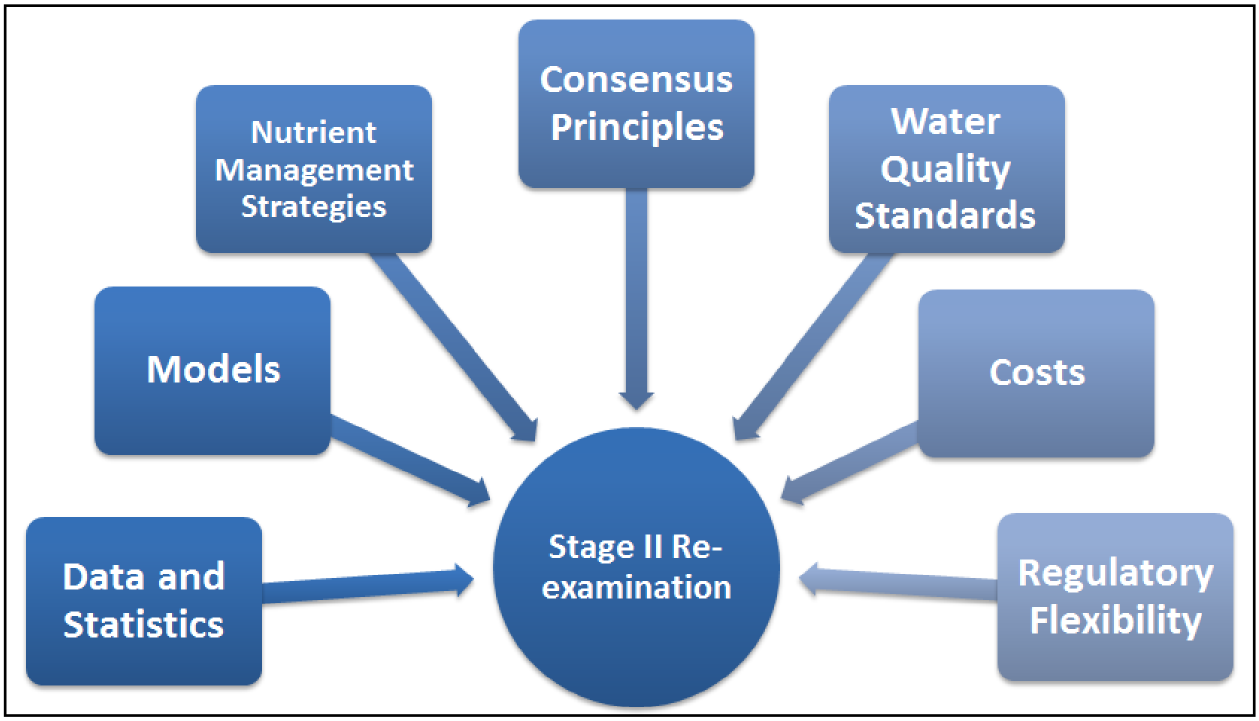


Figure ES- 1 Stage II Re-examination Components

Four project tasks were designed to provide the UNRBA with the information needed to make informed decisions regarding the next steps to implementation of the re-examination and to develop jurisdictional loads for regulatory and program implementation purposes:

> Task 1. Develop a Framework for a Re-examination of Stage II of the Falls Lake Nutrient Management Strategy (described in this TM)

> Task 2. Review Existing Data and Reports to Summarize Knowledge of Falls Lake and the Falls Lake Watershed (Cardno ENTRIX 2012)

> Task 3. Review Methods for Delivered and Jurisdictional Nutrient Loads (Cardno ENTRIX 2013a)

> Task 4. Recommend Future Monitoring and Modeling (Cardno ENTRIX 2013b)

The objective of Task 1 is to integrate the findings from Tasks 2, 3, and 4 into a recommended path forward for the re-examination of the Stage II rules. This task also includes development of a spreadsheet tool that predicts the impacts of various nutrient reduction scenarios on lake water quality. The Falls Lake Framework Tool has been set up using existing information and models to link water quality to designated uses. The output of the Tool is intended to provide planning level information with the understanding that the results of future monitoring and modeling studies will be used to refine the Tool when necessary.

ES.2 Summary of the Physical, Chemical, and Biological Conditions of Falls Lake

Cardno ENTRIX compiled existing data and reports on Falls Lake and its watershed from 1999 to 2011. The resulting database was used to summarize spatial and temporal trends in lake water quality and to identify gaps in monitoring data (Cardno ENTRIX 2012). Figure ES-2 is a map of the monitoring stations in the watershed along with the jurisdictional boundaries. Summary statistics and box plots were used to assess spatial and temporal trends in water quality data.

The water quality database was also used to calculate tributary nutrient loading to the lake and to describe how data gaps may affect watershed and lake response modeling results (Cardno ENTRIX 2013a). Cardno ENTRIX recommended future monitoring and modeling studies to fill monitoring gaps and reduce the uncertainty associated with the watershed and lake response modeling conducted by the State (Cardno ENTRIX 2013b).

Section 2 of this TM provides a brief summary of the findings from these reports. Several key points are noted here in the executive summary:

> The data summaries (Cardno ENTRIX 2012) confirm the trends reported by NCDENR and other researchers. In particular, several studies demonstrate that water quality improves in the lake from the upstream end to the downstream end near the dam.

> The highest levels of chlorophyll *a* occur in the upstream segments of the lake, with stepwise improvements occurring downstream toward the dam. As described in Section 2.1.2.2, this longitudinal improvement in water quality was predicted in the studies that preceded construction of the dam (State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources 1973, USACE 1974).

> The chlorophyll *a* criteria of 40 µg/L is exceeded in each of the three lake segments upstream of Highway 50.

> The turbidity criteria of 25 NTU is exceeded in the upper lake.

> Other than the Flat River arm, the lake is not impaired for dissolved oxygen or pH.

> Water quality in the tributaries was relatively poor during the baseline year of 2006.

> Chlorophyll *a* concentrations in the lake increased from 2003 to 2006. Since 2006, concentrations have generally leveled off in the Upper Lake and declined in the Lower Lake.

> The Lower Lake has not exceeded the chlorophyll *a* standard in 10 percent or more of samples since 2009. None of the samples collected in the Lower Lake by NCDWQ exceeded the chlorophyll *a* criteria in 2010, 2011, or 2012 except for Station NEU019L where 8 percent of the samples exceeded the criteria in 2012 (Figure ES-3, NCDENR 2012b). NCDWQ may remove the Lower Lake from the list of impaired waters following attainment of water quality standards for two consecutive use support assessments, which occur every two years based on the previous five years of data.

> The total organic carbon (TOC) concentrations in the Upper Lake were highest in 2008 and 2009 relative to the other six years monitored (2005 through 2012). The TOC concentrations in the Lower Lake fluctuate from year to year with the highest concentrations observed in 2002 and 2003. Concentrations decreased in 2004 followed by an increasing trend in 2005 and 2006, stable concentrations from 2006 to 2008, and a decreasing trend from 2008 to 2010.

> Data gaps in the existing monitoring programs are a source of uncertainty in the lake response modeling conducted by NCDWQ. A specific concern with the existing modeling is that since chlorophyll *a* data was not collected in the tributaries upstream of Falls Lake, there was no data available to build the model input for this parameter. To fill this gap, NCDWQ assumed that tributary chlorophyll *a* concentrations were the same as those observed at nearby lake stations. This approach was also used to build the model inputs for TOC. Cardno ENTRIX (2013b) recommends collection of additional monitoring data to reduce uncertainty associated with these parameters.

> The NCDWQ relied on a single year to set the nutrient load allocations, and this year (2006) was impacted by a large tropical storm. Because the UNRBA has identified the need for a more complete evaluation of Falls Lake beneficial uses and the effect of the Stage II requirements on the practical impact to established and classified uses, the ability to effectively and accurately simulate Falls Lake

water quality over a wider range of conditions is needed. In addition, there needs to be a mechanism that directly links lake water quality with attainment of designated uses.

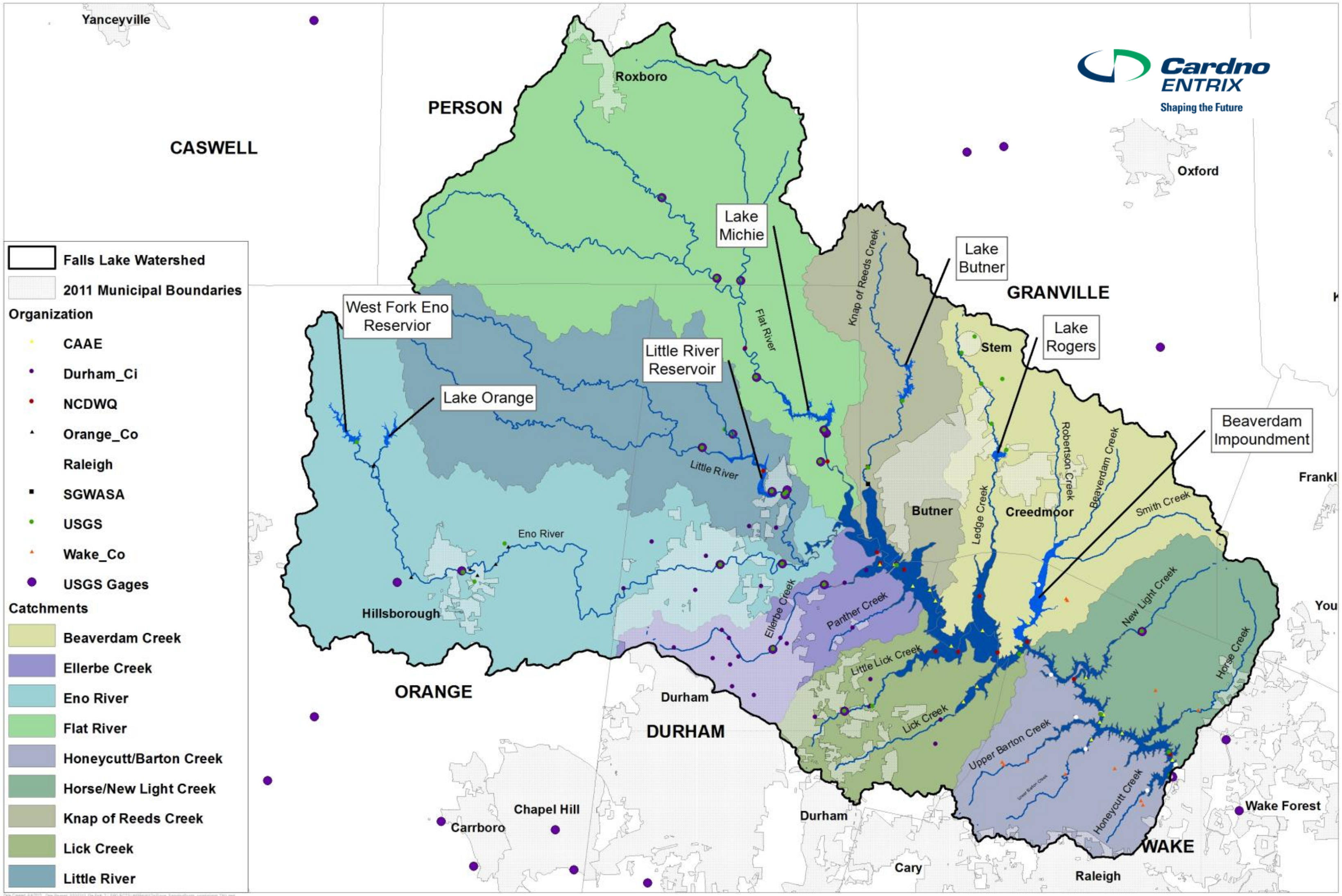
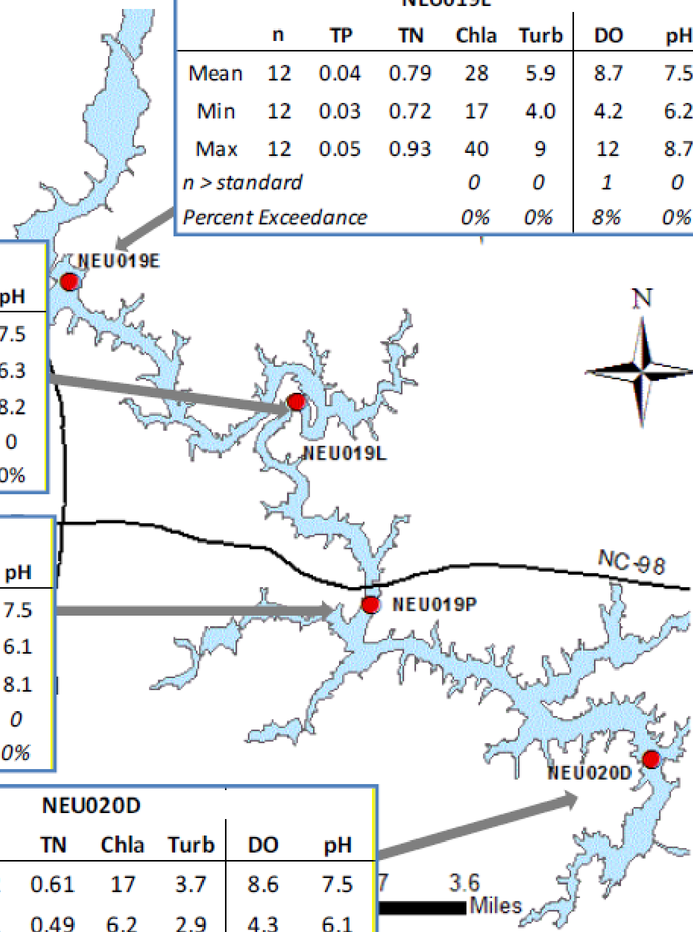


Figure ES-2 Water Quality and Flow Monitoring Stations in Falls Lake Watershed



NEU019E

	n	TP	TN	Chla	Turb	DO	pH
Mean	12	0.04	0.79	28	5.9	8.7	7.5
Min	12	0.03	0.72	17	4.0	4.2	6.2
Max	12	0.05	0.93	40	9	12	8.7
n > standard				*0*	*0*	*1*	*0*
Percent Exceedance				*0%*	*0%*	*8%*	*0%*

NEU019L

	n	TP	TN	Chla	Turb	DO	pH
Mean	12	0.03	0.71	22	4.3	8.6	7.5
Min	12	0.02	0.52	9.7	3.1	5.3	6.3
Max	12	0.05	1.01	44	6.2	12	8.2
n > standard				1	0	0	0
Percent Exceedance				8%	0%	0%	0%

NEU019P

	n	TP	TN	Chla	Turb	DO	pH
Mean	12	0.04	0.72	20	4.2	8.5	7.5
Min	12	0.02	0.53	9.8	2.9	4.4	6.1
Max	12	0.17	1.04	34	7.1	12	8.1
n > standard				*0*	*0*	*1*	*0*
Percent Exceedance				*0%*	*0%*	*8%*	*0%*

NEU020D

	n	TP	TN	Chla	Turb	DO	pH
Mean	11	0.02	0.61	17	3.7	8.6	7.5
Min	11	0.01	0.49	6.2	2.9	4.3	6.1
Max	11	0.03	0.82	29	5.4	12	8.1
n > standard				*0*	*0*	*1*	*0*
Percent Exceedance				*0%*	*0%*	*9%*	*0%*

Figure ES-3 Results of NCDWQ 2012 Water Quality Sampling in the Lower Lake (NCDENR 2012b)

ES.3 Cost Assessment for Stage II

In 2010, NCDWQ published the fiscal analysis of the Falls Lake Nutrient Management Strategy which includes capital, permitting, operation, and maintenance costs (NCDWQ 2010). The report concluded that Stage I of the Strategy would cost approximately $604 million ($2010) in implementation costs and Stage II would cost approximately $946 million ($2010). Cardno ENTRIX reviewed the feasibility and cost estimates for the Stage II implementation based on the NCDWQ assumptions as well as additional sources of information. Based on the Cardno ENTRIX review, the Stage II loading targets are not technically, logistically, or financial feasible:

> The Stage II phosphorus reduction goal of 77 percent is beyond the limits of current technology. Meeting the Stage II nitrogen reduction goal of 40 percent will require treating nearly every acre of existing development. Given site specific constraints (topography, soil type, etc.) treating every acre of existing development is not technically feasible. In addition, these percent reductions rely heavily on a limited number of BMPs.

> Approximately 1,000 BMPs will need to be installed during each year to achieve compliance with Stage II nitrogen targets. Designing, permitting, and installing this number of BMPs in the watershed is not logistically feasible. Implementing this number of BMPs each year will likely cost more than the $551 million projected in the fiscal analysis due to the high percent reduction requirements and site specific constraints.

> Local studies conducted in North Carolina indicate that watersheds relying on retrofitting existing development to meet nutrient reduction goals will likely not be able to reduce nutrient loading by more than 20 percent for total nitrogen or 50 percent for total phosphorus. In an example watershed (Ellerbe Creek), cumulative nutrient reductions greater than 10 percent for nitrogen and 12 percent for phosphorus were not achievable given the constraints in the watershed including lack of space and high imperviousness (Hunt et al. 2012).

> NCDWQ does not currently have approved nutrient load accounting methods for three of the most cost effective BMPs identified by Hunt et al. (2012).

> The NCDWQ (2010) fiscal analysis acknowledges that cost effective practices for reducing nutrient loading from existing development may not be available today, but that new technologies and accounting procedures would likely be developed during the Stage I period that would help the local governments meet the Stage II requirements. If new technologies and credit accounting tools are not developed over the next several years, achieving the Stage II goals will not be technically feasible.

> While agriculture is estimated to contribute the largest percentages of baseline nutrient loads according to the modeling performed by NCDWQ, they have the lowest expected implementation costs of any sector. The NCDWQ (2010) fiscal analysis limits the amount of reductions achievable by agriculture by assuming only one BMP system will be applied to pasture lands. While the fiscal analysis indicates that the Stage II nitrogen targets are attainable for agriculture, there are not enough stream miles available for implementation to meet this goal.

> The NCDWQ (2010) fiscal analysis does not address the significant phosphorus reductions required of the agricultural community: "While the rule requires specific reductions in phosphorus as well, the current available accounting criteria are qualitative in nature and would not allow for meaningful cost estimation." Given that the stream protection BMPs on pastureland are not capable of achieving the Stage II nitrogen reductions, it is unlikely they will be able to achieve the Stage II phosphorus reductions which are nearly two times higher.

> In other parts of the country, the agricultural community is able to earn nutrient credits using BMPs that are generally more cost effective than those implemented on existing development. In North

Carolina, many of these BMPs do not have accounting measures in place to allow agriculture to earn nutrient credits. Increasing the number and type of BMPs that the agricultural community can use to earn credits may reduce overall implementation costs in the watershed through a nutrient trading program.

> The USEPA Municipal Preliminary Screener indicates that the Stage II loading targets will cause a "Large Impact" to the community in the Falls Lake watershed. The projected cost of $945 million ($2010) will require each household to contribute approximately $1,400 per year to reduce nutrient loading from existing development and wastewater treatment plants. This preliminary ranking indicates that additional studies are needed to confirm that the rules are not financially feasible.

In summary, a review of the available information indicates that meeting the Stage II load reduction targets is not technically, logistically, or financial feasible. Additional sources of information including local and regional studies indicate that treatment costs are highly variable and are generally more expensive on existing development compared to agriculture. The analyses presented in this section support the need for a re-examination of the Stage II rules as described in Section 6.

ES.4 Linking Water Quality in Falls Lake to Designated Uses

An essential component of the framework for re-examining Stage II of the Falls Lake Nutrient Management Strategy is a tool that links nutrient loads to lake water quality, designated uses, implementation costs, water treatment costs, and recreational value. Cardno ENTRIX used the available physical, chemical, and biological data to develop a spreadsheet based tool (the Falls Lake Framework Tool) that establishes these linkages using existing data.

Figure ES-4 illustrates how the various components of the Falls Lake Framework Tool (the Tool) link nutrient inputs and predicted lake water quality to designated uses, attainment of water quality criteria, and implementation costs. The Falls Lake Framework Tool uses baseline (2006) nutrient loads and user-selected management scenarios to calculate nutrient loading to the lake. These loads are input to the US Army Corps of Engineers (USACE) BATHTUB model (Section 4.1.1) to estimate total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* concentrations in Falls Lake. Regression equations based on data collected in Falls Lake (Section 4.1.3) are then used to estimate concentrations of total organic carbon (TOC), total suspended sediment (TSS), turbidity, and dissolved oxygen (DO) in Falls Lake. Finally, the Tool uses existing information to link water quality with attainment of water quality criteria and status of designated uses (Section 4.2). The output from the Tool includes implementation costs for the selected management scenarios as well as impacts to designated uses.

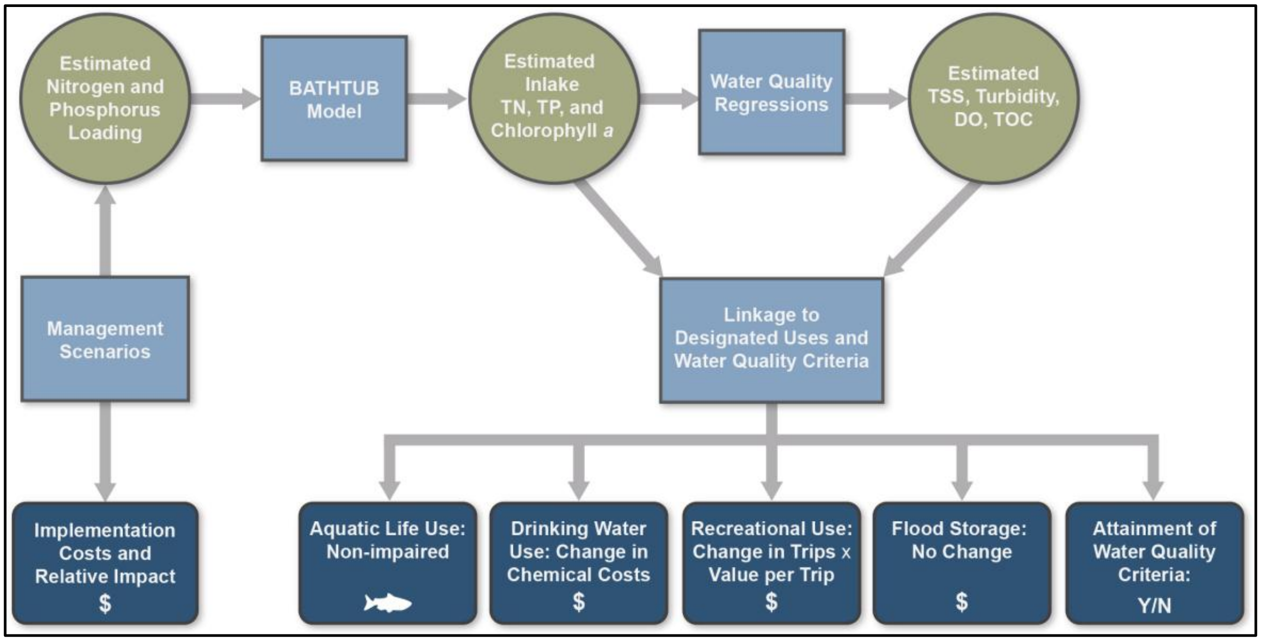


Figure ES-4 Graphical Illustration of the Falls Lake Framework Tool

ES 4.1 Linkage of Nutrient Loading, Water Quality, and Designated Uses

The Tool allows the user to select from two options to calculate baseline loading to the lake. The user may also select from various nutrient reduction scenarios to test the impacts on water quality (nutrients, chlorophyll *a*, TOC, etc.). The Tool uses multiple calculations to link changes in water quality, resulting from implementation of nutrient management scenarios, to changes in designated uses and attainment of water quality criteria.

The Tool provides a comparison of predicted lake water quality to water quality criteria. Under existing conditions, the lake attains the DO and pH criteria. Nutrient management scenarios are not expected to shift the lakes status from Attainment to Non-Attainment for these criteria, so these parameters are categorized as Attainment for the baseline and nutrient management scenarios. The Tool predicts changes in the lake chlorophyll *a* concentrations and turbidity levels and provides an assessment of whether or not these criteria will be met.

Falls Lake is on the 303(d) list due to violations of the turbidity and chlorophyll *a* values. The Aquatic Life beneficial use is not considered “Not Impaired” based on existing biological data. No fish kills due to eutrophication or low DO have been reported in Falls Lake, and the lake supports a healthy sports fishery. Future studies are recommended to further assess the aquatic life use. Based on existing information, the Falls Lake Framework Tool categorizes the Aquatic Life use as “Not Impaired” based on the biology of the lake. Nutrient management strategies are not expected to cause biological impairments in the lake, so the Falls Lake Framework Tool categorizes the Aquatic Life use as “Not Impaired” for the baseline and nutrient management scenarios. The Tool addresses non-attainment of the water quality criteria separately.

To provide a linkage between water quality and the drinking water supply use, the Tool estimates the cost of chemical usage at the City of Raleigh’s water treatment plant based on Falls Lake water quality. The Tool uses TOC concentrations in the raw water supply to estimate the pounds of ferric sulfate needed to treat the water. The output from the Tool is a change in annual cost to treat an average of 50 MGD of water.

The Tool also estimates the annual change in the value of the recreational use of Falls Lake based on total phosphorus, turbidity, and dissolved oxygen concentrations. The Tool uses a recreational model developed by researchers at North Carolina State University to link water quality with the monetary value of associated ecosystem services including recreational use (Phaneuf et al. 2008). The Tool outputs the change in the annual value of recreation for Falls Lake.

One of the main reasons for constructing Falls Lake was to provide flood control benefits to communities downstream. Data provided by the USACE suggests that Falls Lake provides annual average flood control benefits of $21 million, and the lake prevented an estimated $259 million dollars in damages in 1996 associated with Hurricane Fran. The Tool assumes nutrient management practices will not impact flood control benefits. Revisions to the Tool in the future may add a linkage between nutrient reductions and the flood control use to account for practices that reduce storm volumes and peak flows, increase infiltration in the watershed, disconnect impervious surfaces, etc. For the current version, the change in flood control storage resulting from nutrient management is assumed to be zero.

ES 4.2 Estimation of Implementation Costs and Fiscal Impact

The Falls Lake Framework Tool also estimates annual nutrient management implementation cost based on the cost per pound of phosphorus reduction. The Tool assumes that the relative proportions of nitrogen and phosphorus reductions are similar to those required by Stage I and Stage II of the Falls Lake Nutrient Management Strategy. Implementation costs are calculated based on the simulated phosphorus reduction only and do not include additional costs to achieve nitrogen reductions. The user can either select the NCDWQ fiscal analysis as the basis of the cost estimate, or use the “user-specified $/lb-P” to run the calculation.

The Tool also includes the USEPA Municipal Preliminary Screener (described in Section 4.3) that USEPA uses to rank the relative social and economic impact of pollution controls. This Municipal Preliminary Screener calculates economic impacts based on USEPA’s “Interim Economic Guidance for Water Quality Standards,” EPA-823-B-95-002 (1995) (hereinafter WQS Economic Guidance). The Municipal Preliminary Screener uses median household income (MHI) and number of households affected by the pollution controls to estimate the financial impacts to the regulated communities. If the cost per household of achieving compliance is over 2 percent of MHI, the cost is considered a “Large” financial impact. Costs between 1 and 2 percent of MHI are a “Mid-range Impact.” If the costs are less than 1 percent, the impact is assumed to be “Little.”

The output from the USEPA Municipal Preliminary Screener may be used to support various regulatory options such as use attainability analyses and variances, and the USEPA recommends that impacts in the “Mid-range” or “Large” category undergo further analysis. Figure ES-5 shows an example of the annual implementation costs associated with changing the percent reductions of nitrogen and phosphorus loading using the Falls Lake Framework Tool. The relative proportions of nitrogen and phosphorus reductions are similar to those required by Stage I and Stage II of the Falls Lake Nutrient Management Strategy. The categories on the x-axis are the percent reductions of total nitrogen and total phosphorus, respectively. The category (40, 77) represents the Stage II scenario. Percent reductions and implementation costs that cause a “Large” impact according to the USEPA Municipal Preliminary Screener are shaded orange. “Mid-range” impacts are shaded purple, and “Little” impacts are shaded green.

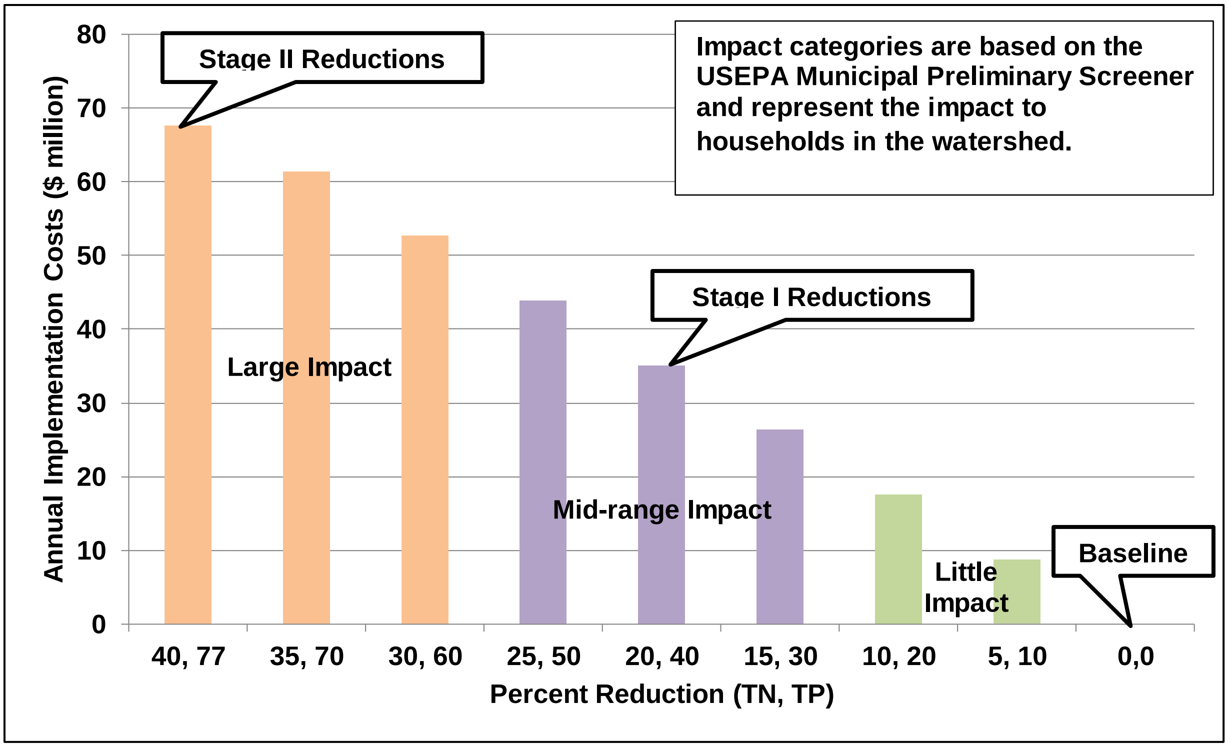


Figure ES-5 Annual Implementation Costs Associated with Varying Percent Reductions in Nitrogen and Phosphorus Loading

ES 4.3 Example Application of the Falls Lake Framework Tool–Stage II Reduction Scenario

An example application of the Falls Lake Framework Tool, which assumed Stage II nutrient reductions, is presented below. The values presented in the NCDWQ fiscal analysis are used to calculate costs. For this example, the Falls Lake Framework Tool estimates the following:

> Nutrient reductions of 658,000 pounds of nitrogen and 35,000 pounds of phosphorus are required for the upper five tributaries draining to Falls Lake to meet the Stage II reductions of 40 percent for nitrogen and 77 percent for phosphorus.

> Falls Lake will continue to attain DO and pH criteria under the Stage II scenario.

> Mean chlorophyll *a* concentrations in the lake will not exceed 20 µg/L, and the standard of 40 µg/L is not likely to be exceeded.

> Mean turbidity will remain less than 10 NTU (the water quality standard is 25 NTU).

> Mean TOC concentrations near the dam will decrease by approximately 0.9 mg/L.

> The Aquatic Life use is categorized as “Not Impaired” under the Stage II scenario based on compliance with biological indices even under the baseline scenario.

> Full implementation of the Stage II scenario may decrease the drinking water treatment costs for the City of Raleigh by approximately $194,000 per year. The City is studying the need for advanced technologies at the water treatment plant that may cost approximately $125 million if TOC concentrations increase over the next several years (Hazen and Sawyer 2012).

> The Tool estimates that full implementation of the Stage II scenario may increase the value of the recreational designated use by approximately $168,000 per year based on local studies.

> For the current version, the change in flood control storage resulting from nutrient management is assumed to be zero.

> Implementation costs for the Stage II scenario are approximately $67.5 million per year with total projected costs of $945 million (NCDWQ 2010). However, it is unlikely that this expenditure will actually achieve the Stage II phosphorus reductions given the current limits of technology and limited number of NCDWQ-approved BMPs.

> Based on the USEPA Municipal Preliminary Screener, the financial impact of the Stage II rules is "Large."

Cardno ENTRIX (2013b) recommends future monitoring and modeling studies that will provide additional information to link water quality to designated uses. The data will also provide an indication of the lake response to the nutrient load reductions that have already been achieved. Following collection of the additional data and development of future models such as the empirical model linking water quality to designated uses, the Falls Lake Framework Tool may be updated to refine the predicted impacts on water quality and designated uses.

ES.5 Regulatory Options for Falls Lake

Section 5 of this TM provides an overview of the regulatory options for Falls Lake including a discussion of Use Attainability Analyses, variances, and site-specific criteria. The options are described in relation to the State and Federal laws, Falls Lake designated uses, water quality criteria, existing water quality impairments, the Falls Lake Nutrient Management Strategy, and the Consensus Principles. A discussion of the applicability of each option and examples of its use elsewhere in the country are provided. The section provides a foundation for the recommended path forward that is described in Section 6.

ES.6 Recommendations for the Re-examination of the Stage II Rules

Cardno ENTRIX and Barnes and Thornburg have a developed a set of recommendations for the UNRBA in moving forward with the re-examination of the Stage II rules. These recommendations include a multi-part process including monitoring, modeling, and regulatory actions for moving forward with the re-examination of the Stage II rules. The following recommendations are presented briefly below with more detailed information provided in Section 6:

> Conduct monitoring studies for a minimum of four to five years (the rules require a minimum of three years) to support revised lake response modeling (tributary load estimation, inlake water quality, and inlake processes) and support the regulatory options. These studies are needed to support the re-examination process described below. Full monitoring years are anticipated as 2014 through 2017, and monitoring may continue into 2018 depending on weather patterns or unforeseen events. These monitoring studies are discussed in detail in the Task 4 TM and are summarized in Section 6.1 of this memorandum.

> In the near term, immediate regulatory relief may be sought through the legislative or administrative process (Section 6.2). For example, the UNRBA may petition NCDWQ to delay implementation of the Stage I rules until a more complete set of nutrient reduction accounting procedures are in place. Additionally, the UNRBA may want to press NCDWQ to account for delivery factors in the estimation of nutrient loading to the lake. This would likely reduce the implementation costs for nutrient load reductions by accounting for fate and transport in the watershed. These options should be pursued in 2013.

Part 1 of the re-examination process is to revise and recalibrate the lake response modeling following data collection, and use the recalibrated model to estimate the nutrient loading reductions needed to comply with the chlorophyll *a* standard throughout the lake (Section 6.3). This part of the process is required by the Falls Lake Nutrient Management Strategy and is an integral component of the overall plan. After this analysis, the preliminary screening factor for the fiscal impact of pollution control should be recalculated to determine if the impact is little, mid-range, or large.

Part 1 requires collection of data to support tributary load estimation, lake water quality, and lake processes to revise the lake nutrient response modeling and recalculate the nutrient reduction targets. Model revisions and recalculation of loading targets may occur in 2018 depending on the duration of the monitoring period, which may need to be extended if abnormal weather patterns occur. Cardno ENTRIX recommends preliminary model updates following the first one or two years of monitoring to provide planning level results. The results of the modeling will be used to reassess the technical and financial feasibility of the revised load allocations and provide the modeling platform for the other parts of the re-examination process.

Part 2 of the re-examination process is to petition NCDWQ to develop a new designated use category that would represent the existing functions of the upper lake (recreational use, aquatic life use, water supply protection) recognizing the limitations imposed by the authorized purposes of the lake as a Corps of Engineers project (i.e. flood protection) (Section 6.4). This is a two-step process. The first step is the creation of the new sub-category of the Class C use. The second step is to change the use classification for the Upper Lake from its current classification to the newly created sub-classification. That change will require a sub-classification use attainability analysis (SC-UAA) which is not a removal of a designated use and will still maintain the fishable, swimmable classification of the lake. This option will use the data and revised lake nutrient response modeling conducted for Part 1. Collection of additional supporting data to demonstrate that the lake is meeting the existing and revised designated uses should occur simultaneously with the other monitoring studies (2013 through 2017). In addition to the revised lake nutrient response model, a supporting empirical lake model (Cardno ENTRIX 2013b) should be used to ensure that the water quality in the Lower Lake is protected as a drinking water supply. In addition, modeling may be needed to demonstrate that the chlorophyll *a* levels are not achievable due to either natural conditions or hydrologic modification, if either or both of these justifications are used for the SC-UAA. If the SC-UAA is to be justified based on economic and social impacts, then an economic analysis must be performed. Part 2 may be controversial because it entails a permanent change in the designated use of the upper lake.

Part 3 of the re-examination process is development of a site specific chlorophyll *a* criterion for the upper lake. This part of the overall plan requires the same data sets and models used for parts 1 and 2 with additional analyses to determine the site-specific chlorophyll *a* criteria for the upper lake that continues to meet the aquatic life, recreation, and water supply designated uses. Demonstration that a site-specific chlorophyll *a* criterion in the upper lake continues to protect the existing use classifications for the Upper Lake and drinking water supply use in the Lower Lake will be required. If the future monitoring studies demonstrate that the lake is meeting its designated uses (as appears the case based on existing biological indicators), a site specific criteria based on current conditions may be a favorable option to all parties.

It is likely that the revised lake nutrient response model will still result in nutrient load allocations that are financially burdensome to the regulated community and beyond the limits of technology. Development, approval, and regulatory change associated with an SC-UAA or a site-specific chlorophyll *a* criteria may take several years in addition to the monitoring and modeling studies that are required for the process. While these more permanent paths are being considered, the UNRBA may need to apply for a variance (**Part 4**). The State's fiscal analysis (NCDWQ 2010) states repeatedly that "We expect more cost-effective measures than structural stormwater BMP retrofits to emerge even during the course of Stage I" and that "one reason to expect that more cost-effective solutions will emerge is that both this rule and federal regulatory changes will drive innovation to address loading contributions from existing developed lands." If new technologies do not emerge over the next seven years and the re-examination process cannot be completed before implementation of Stage II begins in 2021, a variance would allow for additional time to complete the process. While this would not be a permanent solution, and would likely need to be reissued periodically, it would provide financial relief to the local governments. A variance must be supported by the same types of analyses that support a SC-UAA. This part of the plan is less controversial than the SC-UAA or site specific criteria because variances are temporary and do not involve permanent changes in designated uses or criteria.

The current schedule described in the Falls Lake Nutrient Management Strategy provides little time to conduct the necessary monitoring and modeling studies, analyses, negotiations, and regulatory changes that are required of the re-examination process. Figure ES-6 illustrates the recommended schedule for this process which includes seeking immediate regulatory relief, conducting monitoring studies, revising the lake modeling, and exploring each part of the re-examination process concurrently.

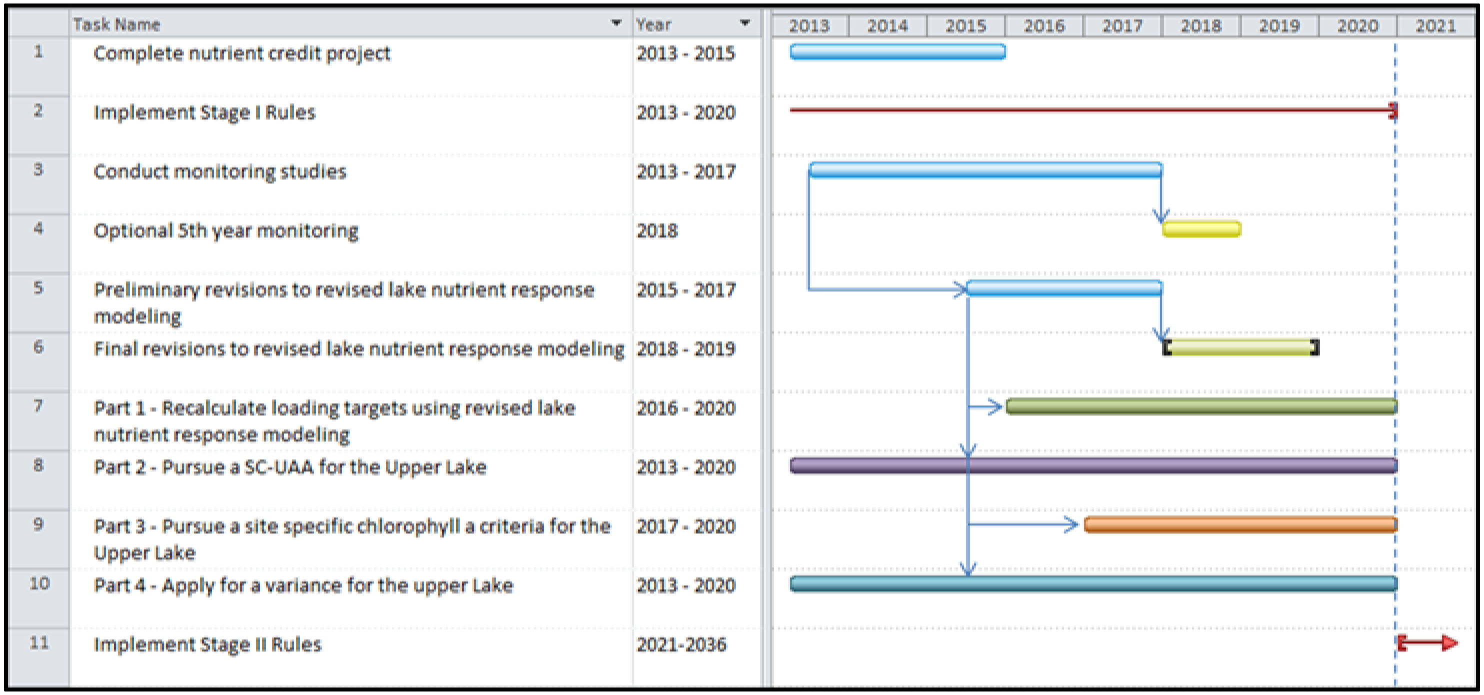


Figure ES-6 **Potential Schedule for the Re-examination of Stage II**

ES. 7 Conclusions

The Falls Lake Nutrient Management Strategy presents technical and financial challenges to the regulated community in the watershed. While the State estimated that Stage II of the Strategy would cost approximately $945 million to implement, a review of the analysis (Section 3) indicates that these expenditures are not likely to achieve the Stage II nitrogen or phosphorus reductions. Achieving the nitrogen reductions from the upper watershed would require 1) treating every acre of existing development (which is not technically feasible) 2) use of a limited set of BMPs, and 3) installation of approximately 1,000 BMPs each year (which is not logistically feasible). The Stage II phosphorus reduction goals for existing development are beyond the limits of technology. In agricultural areas, the Stage II goals are not feasible for nitrogen or phosphorus given the assumption of one BMP type applied to pasture land only.

The Falls Lake Framework Tool provides an estimation of the monetary impact of the Stage II reductions on the designated uses of Falls Lake. Benefits to the lake from enhanced recreation and reduced chemical cost are approximately $354 thousand per year, based on local information. The Tool compares simulated water quality to water quality criteria and categorizes the aquatic life use as “Not Impaired” based on current observations of biological indices. The current version of the Tool assumes there is no change to the flood control use. Implementation costs associated with these benefits are approximately $67.5 million per year, or $945 million total based on the NCDWQ (2010) fiscal analysis. Based on the Cardno ENTRIX review of the fiscal analysis, it is unlikely that these expenditures will achieve the Stage II reduction goals.

Given the high cost of implementing Stage II and the uncertainty with respect to the outcome, Cardno ENTRIX and Barnes and Thornburg recommend a multi-part process for moving forward with the re-examination process which includes four main components. The overall process relies on collection of additional monitoring and modeling studies to provide a scientific basis for the re-examination. These studies will support revised lake response modeling and support the various regulatory options that comprise the overall plan for the re-examination process.

Under the current schedule for the Falls Lake Nutrient Management Strategy, the UNRBA has less than eight years to move through the re-examination process. The Consensus Principles require a minimum of three years of data collection followed by revised modeling studies to provide a basis for altering Stage II of the rules. The UNRBA Path Forward Committee has recommended at least four years of monitoring to incorporate variations in weather and environmental conditions, with an optional fifth year as needed. Following monitoring, modeling studies may take one to two years to complete and negotiations with State and Federal agencies may take several years. Cardno ENTRIX recommends that the UNRBA conduct preliminary updates to the lake nutrient response modeling and begin exploring each part of the re-examination process as soon as appropriate for each part of the process. In addition, Cardno ENTRIX recommends that the UNRBA petition the State for a delay in the implementation of the Strategy to allow more time for 1) the re-examination process and 2) development of credits for additional BMPs that may be useful for the Stage I and Stage II local programs.

The re-examination process is likely to cost somewhere between $5 million to $10 million in monitoring, modeling, negotiation, and potential litigation costs. Relative to the Stage II implementation costs that are estimated to cost approximately $67.5 million per year beginning in 2021, the costs of moving forward with the re-examination process is relatively small.

1 Introduction

1.1 Purpose, Objectives, and Organization

Cardno ENTRIX is assisting the Upper Neuse River Basin Association (UNRBA) in determining the best approach to address the nutrient management rule requirements and the Consensus Principles regarding the re-examination of Stage II of the Falls Lake Nutrient Management Strategy. The re-examination should consider existing data, models, nutrient management strategies, the Consensus Principles, water quality standards (including designated uses and water quality criteria), implementation costs, and regulatory flexibility (0).

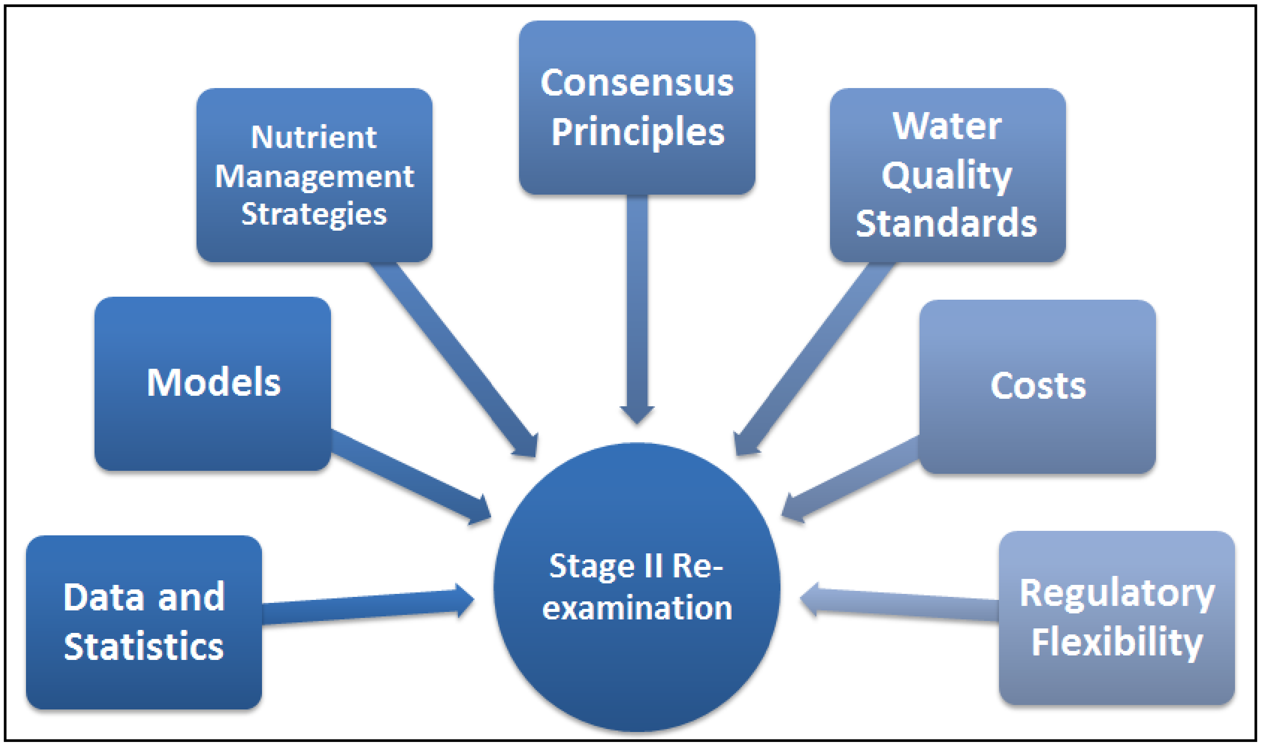


Figure 1-1 Components of the Stage II Re-examination

Four project tasks are designed to provide the UNRBA with the information needed to make informed decisions regarding the next steps to implementation of the re-examination and to develop jurisdictional loads for regulatory and program implementation purposes:

> Task 1. Develop a Framework for a Re-examination of Stage II of the Falls Lake Nutrient Management Strategy (described in this TM)

> Task 2. Review Existing Data and Reports to Summarize Knowledge of Falls Lake and the Falls Lake Watershed (Cardno ENTRIX 2012)

> Task 3. Review Methods for Delivered and Jurisdictional Nutrient Loads (Cardno ENTRIX 2013a)

> Task 4. Recommend Future Monitoring and Modeling (Cardno ENTRIX 2013b)

The objective of Task 1 is to integrate the findings from Tasks 2, 3, and 4 into a recommended path forward for the re-examination of the Stage II rules. This task also includes development of a spreadsheet tool that predicts the impacts of various nutrient reduction scenarios on lake water quality.

The Falls Lake Framework Tool has been set up using preliminary information and models to link water quality to designated uses. The output of the Tool is intended to provide planning level information with the understanding that the results of future monitoring and modeling studies will be used to refine the Tool when necessary.

This TM is organized into several sections to address the objectives of Task 1:

> Section 2 provides a summary of the physical, chemical, and biological conditions of Falls Lake.

> Section 3 reviews the cost assessments for Stage II of the Falls Lake Nutrient Management Strategy.

> Section 4 describes how the Falls Lake Framework Tool links nutrient loading to lake water quality and impacts to designated uses.

> Section 5 describes the regulatory options applicable to the Falls Lake Watershed.

> Section 6 provides recommendations for moving forward with the re-examination of Stage II of the Falls Lake Rules.

> Section 7 summarizes the Task 1 TM.

> Section 8 provides a list of references.

1.2 Background Information

Falls Lake was constructed by the US Army Corps of Engineers in the late 1970s. The Congressionally authorized uses of the project were flood control, water supply, recreation, fish and wildlife enhancement, and augmentation of low flows for purposes of pollution abatement and water-quality control in the Neuse River Basin. P.L. 89-298 (Oct. 27, 1965). The NCDWQ designated uses of Falls Lake under the Clean Water Act are drinking water supply, recreation, fishing, aquatic life including propagation and survival, and wildlife.

The North Carolina General Assembly's 2005 "Clean Lakes Act" (S.L. 2005-190) generated intensive data collection in water supply reservoirs across the State, including Falls Lake. Based on water quality monitoring conducted primarily in 2006, a portion of Falls Lake, from the confluence of the Eno and Flat River arms to the Interstate 85 Bridge (I-85), was identified as impaired due to violations of the turbidity and chlorophyll a water quality criteria (NCDENR 2012a). Another portion of Falls Lake, from the I-85 Bridge downstream to the dam also exceeds the chlorophyll a water quality criterion (NCDENR 2012a). The water quality criteria for chlorophyll a and turbidity are 40 µg/L and 50 nephelometric turbidity units (NTU), respectively. NCDWQ identifies a waterbody as impaired if ten percent or more of the data (minimum of ten samples) exceeds the water quality criteria. The impairment status is based on data collected between 2002 and 2006.

Table 1-1 summarizes the impairments for Falls Lake segments. The impairment status is specified by assessment unit number, which is a unique identifier that NCDENR uses to define specific segments of a waterbody. The UNRBA may recommend revisions to this segmentation in the future based on collection of additional data or to pursue specific regulatory options. The designated use associated with these water quality standards violations is the Aquatic Life use. However, there is no existing biological evidence to support an impaired status for this use; i.e., the lake does not have issues with fish kills due to eutrophication or low DO and supports a healthy sports fishery, etc. (A large fish kill occurred in 2008 due to temperature and infection.) The lake is considered impaired because it is does not meet all of the applicable water quality criteria assigned to the aquatic life use. Other designated uses of the lake include municipal drinking water supply and recreation.

Table 1-1 Falls Lake Water Quality Attainment and Impairment Status

Listing Year	Water Body	Assessment Unit Number	Cause of Impairment	Use Support Category	Use Support Rating
2008	Flat River (incl. Flat R. Arm of Falls Lake)	27-3-(9)	Low Dissolved Oxygen	Aquatic Life	Impaired
	Neuse River (From Source to I-85 Bridge)	27-(1)	Turbidity; Chlorophyll a	Aquatic Life	Impaired
	Neuse River (From I-85 Bridge to Dam)	27-(5.5)	Chlorophyll a	Aquatic Life	Impaired
2010	Flat River (incl. Flat R. Arm of Falls Lake)	27-3-(9)	Low Dissolved Oxygen	Aquatic Life	Impaired
	Neuse River (From Source to I-85 Bridge)	27-(1)	Turbidity; Chlorophyll a	Aquatic Life	Impaired
	Neuse River (From I-85 Bridge to Panther Creek)	27-(5.5)a	Turbidity; Chlorophyll a	Aquatic Life	Impaired
	Neuse River (From Panther Creek to Falls Dam)	27-(5.5)b	Chlorophyll a	Aquatic Life	Impaired
2012	Flat River (incl. Flat R. Arm of Falls Lake)	27-3-(9)	Low Dissolved Oxygen	Aquatic Life	Impaired
	Neuse River (From Source to I-85 Bridge)	27-(1)	Turbidity	Aquatic Life	Impaired
	Neuse River (From I-85 Bridge to Panther Creek)	27-(5.5)a	Turbidity	Aquatic Life	Impaired

In 2010, the Environmental Management Commission (EMC) passed the Falls Lake Nutrient Management Strategy, requiring two stages of nutrient reductions (N.C. Rules Review Commission 2010). The Rules establish a Nutrient Management Strategy for Falls of the Neuse Reservoir aimed at attaining:

> "…the classified uses of Falls of the Neuse Reservoir set out in 15A NCAC 02B .0211 from current impaired conditions related to excess nutrient inputs; protect its classified uses as set out in 15A NCAC 02B .0216, including use as a source of water supply for drinking water; and maintain and enhance protections currently implemented by local governments in existing water supply watersheds encompassed by the watershed of Falls of the Neuse Reservoir." (15NCAC 02B .0275)

Stage I of the Nutrient Management Strategy requires "intermediate or currently achievable controls throughout the Falls watershed with the objective of reducing nitrogen and phosphorus loading, and attaining nutrient-related water quality standards in the Lower Falls Reservoir as soon as possible but no later than January 15, 2021, while also improving water quality in the Upper Falls Reservoir…" (15NCAC 02B .0275 (4) (a)). Based on modeling and evaluation by the NC Division of Water Quality (NCDWQ), this will require a 20 percent and 40 percent reduction in total nitrogen and total phosphorus loading, respectively, for point sources and agriculture. For development based sources, the rules require that loading be reduced to the levels of the baseline year that NCDWQ established (2006). For Stage I, the rules require local jurisdictions to establish requirements to control nutrient input from new development sources as well.

Stage II requires that all areas of Falls Lake achieve the nutrient-related water quality standards. Based on NCDWQ modeling and evaluation, the additional loading reductions required to achieve this goal are 40 percent and 77 percent for total nitrogen and total phosphorus, respectively, relative to the baseline year. NCDWQ reservoir monitoring data will be used to assess compliance with the goals of the Strategy and determine if additional load reductions to a particular lake segment are needed. As stated in the Rules:

> "Stage II requires implementation of additional controls in the Upper Falls Watershed beginning no later than January 15, 2021 to achieve nutrient-related water quality standards throughout Falls Reservoir by 2041 to the maximum extent technically and economically feasible…" (15NCAC 02B .0275 (4) (b))

In 2010, the Consensus Principles were adopted to guide the Falls Lake Nutrient Management Strategy. The Consensus Principles also call for a review of the attainability of the designated uses for the Upper Lake, the feasibility of achieving Stage II reduction goals and meeting the water quality standard for chlorophyll a, and whether existing uses of the Upper Lake can be protected with alternative water quality standards.

The NCDWQ believes that the Stage II nutrient reductions are needed for all of Falls Reservoir to achieve compliance with water quality standards. The rules identify the parties (municipalities, counties, agriculture, and state and federal entities) responsible for implementing the nutrient reductions, which are to be achieved by requiring stormwater controls and implementation of best management practices (BMPs) for new and existing development, point source discharges, and agricultural non-point sources.

Stage I and Stage II requirements are summarized below:

- **Existing Development Stormwater Management.** The Existing Development rules are based on when the development occurred: prior to the baseline period or between the baseline period and the implementation of the new development stormwater programs (July 2012).
  - For lands developed prior to the end of the baseline period (December 2006), there are no Stage I requirements.
  - For lands developed after the baseline period but before implementation of the new development stormwater programs, Stage I requires that "the current loading rate shall be compared to the loading rate for these lands prior to development for the acres involved, and the difference shall constitute the load reduction need in annual mass load, in pounds per year. Alternatively, a local government may assume uniform pre-development loading rates of 2.89 pounds/acre/year N and 0.63 pounds/acre/year P for these lands. The local government shall achieve this Stage I load reduction by calendar year 2020."
  - Stage II applies to all lands developed prior to the baseline period: "If a local government achieves the Stage I reduction objectives described in this Item, a local government's initial Stage II load reduction program shall, at the local government's election, either (A) achieve additional annual reductions in nitrogen and phosphorus loads from existing development greater than or equal to the average annual additional reductions achieved in the last seven years of Stage I or (B) provide for an annual expenditure that equals or exceeds the average annual amount the local government has spent to achieve nutrient reductions from existing development during the last seven years of Stage I. A local government's expenditures shall include all local government funds, including any state and federal grant funds used to achieve nutrient reductions from existing developed lands. The cost of achieving reductions from municipal wastewater treatment plants shall not be included in calculating a local government's expenditures….If Stage I reduction objectives are not achieved, a local government's initial Stage II load reduction program shall, at the local government's election, either (A) achieve additional annual reductions in nitrogen and phosphorus loads from existing development greater than or equal to the average annual additional reductions achieved in the

highest three years of implementation of Stage I or (B) provide for an annual expenditure that equals or exceeds the average annual amount the local government has spent to achieve nutrient reductions from existing development during the highest three years of implementation of Stage I."

> **New Development Stormwater Management.** The New Development rules apply to development that occurred after implementation of the new development stormwater programs (July 2012). All local governments affected by the Strategy are required to develop stormwater management programs and limit nutrient loading from new development to 2.2 pounds per acre per year of nitrogen and 0.33 pounds per acre per year of phosphorus. All stormwater systems shall be designed to control and treat, at a minimum, the runoff generated by one inch of rainfall and shall ensure that there is no net increase in peak flow leaving the site compared to pre-development conditions for the one year, 24-hour storm event.

> **Wastewater Discharge Requirements.** For the Upper Falls Watershed, Stage I minimum nutrient control requirements have been established for point source wastewater discharges in the Falls Lake Watershed, and facility-specific nutrient allocations have been determined. Mass nitrogen and phosphorous allocations have been established for Stage II for facilities with flows <0.1 MGD and ≥ 0.1 MGD. The total Stage II allocations will be apportioned to existing dischargers based on proportion of permitted flow. By January 2027, all facilities with permitted flows ≥ 0.1 MGD in the Upper Falls Watershed must submit a plan and schedule for achieving the Stage II loadings by 2036. Requirements for new and expanding discharges have also been established in the rule. For the Lower Falls Watershed, all point sources with a permitted flow of ≥ 0.1 MGD shall meet monthly and annual average discharge limits for total nitrogen and total phosphorus by 2016. An annual mass limit of 911 pounds of total phosphorus per calendar year has been established for all facilities. The rules establish that new wastewater discharges or expansions in the Lower Falls Watershed will not be permitted.

> **Agricultural Requirements.** Stage I requires a 20 percent reduction in nitrogen loading and a 40 percent reduction in phosphorus loading (relative to 2006) by 2020 from agricultural lands. Stage II requires a 40 percent reduction in nitrogen loading and a 77 percent reduction in phosphorus loading by 2035. By January 2013, the Watershed Oversight Committee shall provide the Environmental Management Commission (EMC) with an initial assessment of the reductions that have been achieved since 2006. Annual reporting will be required. Stage II will only include requirements for individual operators if the collective Stage I reductions have not been met.

> **Adaptive Management Options.** Beginning in 2016, and every five years afterwards, NCDWQ will review all available data, such as loading reductions, best management practice effectiveness data, and instream loading estimates and determine whether any rule revisions are needed. The NCDWQ evaluations will be conducted in order to address uncertainty, changes in scientific understanding, technological advances, economic feasibility, and incorporate new information and data. In July 2025, NCDWQ will review and report to the EMC the physical, chemical, and biological conditions, and nutrient loading impacts within the Upper Falls Reservoir (defined as Falls Lake upstream of State Route 50) as well as the influence nutrient management actions have had on water quality. This report will include a re-assessment of the methodology used to determine compliance with nutrient-related water quality standards and the potential for using other methods, as well as describe the feasibility and costs and benefits of achieving the Stage II objective. This report will also recommend to the EMC the need for alternative regulatory action such as, water quality standards revision, waterbody reclassification, or issuance of a site-specific variance.

1.3 Overview of the Framework for Re-examining Stage II of the Falls Lake Rules

The overall objectives of this project are to compile, assess, and summarize the existing data and knowledge regarding Falls Lake and its watershed to support the UNRBA in identifying strategies for re-examining Stage II of the Falls Lake Nutrient Management Strategy. The Nutrient Management Strategy was developed using modeling and analysis procedures that required a significant number of assumptions, and the work was done with a limited database. Legislative deadlines for the development of the Nutrient Management Strategy required quick agency decisions. This resulted in a regulatory program that includes a significant amount of uncertainty. The extensive work done by local governments in the watershed to develop the Consensus Principles and the member governments' decision to expand the activities of the UNRBA indicates that there is a keen interest in making sure that the Falls Lake Nutrient Management Strategy reflects a program that balances improving water quality with the resources available and considers the constraints and unique characteristics of the Lake and its watershed. The nutrient load reductions required by the Strategy, particularly for phosphorus, are higher than the relative effectiveness provided by best management practices (NSAB 2012). Therefore, the financial demands of the Stage II nutrient reductions are daunting. All of these considerations are the foundation of the work being done under this project.

The framework for re-examining the Stage II rules relies on linking management actions (reducing nutrient loading) to inlake water quality and finally to designated uses. USEPA (2010b) proposed a similar approach for developing numeric nutrient criteria in Florida's tidally influenced waters. While this example includes estuarine specific factors (e.g., SAV coverage), it provides a visual depiction of how nutrient loading effects designated use impairments (Figure 1-2). (EPA recently approved the numeric nutrient criteria for lakes and streams developed by the Florida Department of Environmental Protection. Florida's criteria also include biologic indicators that link water quality to designated uses.)

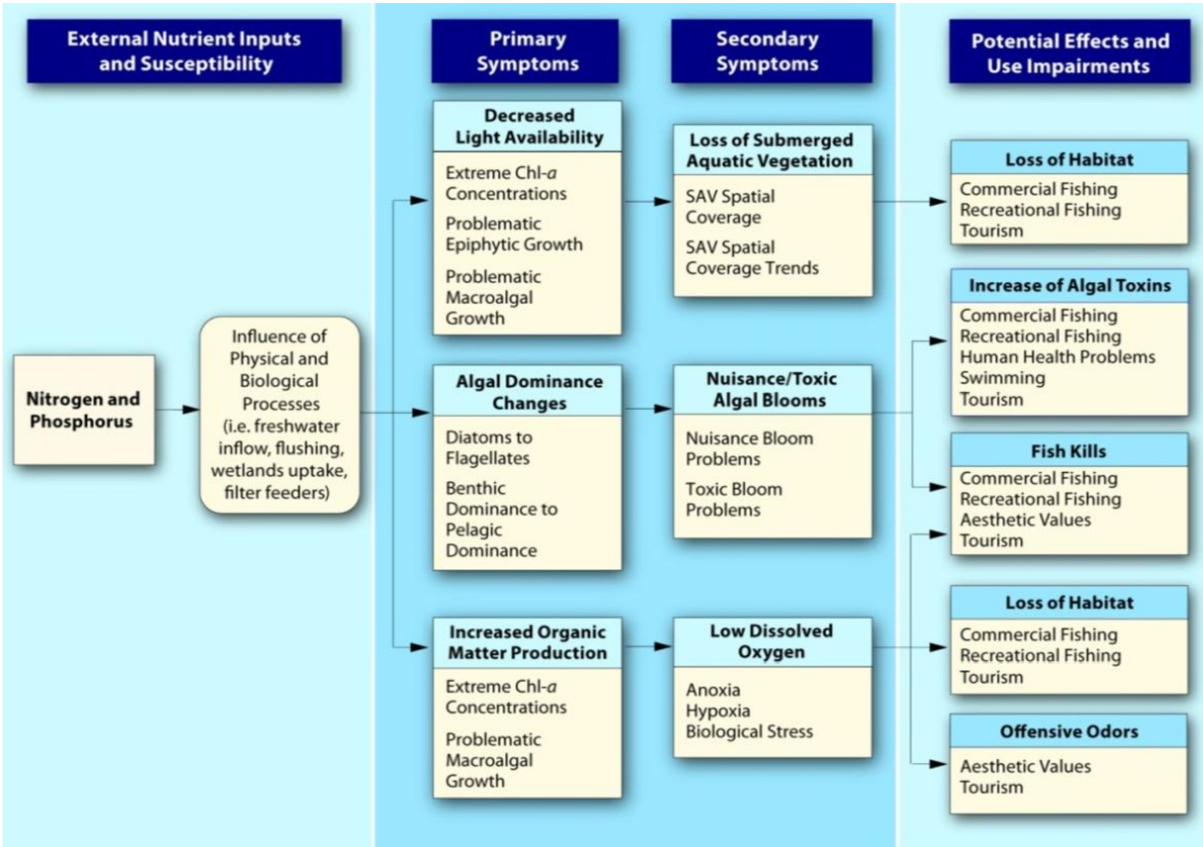


Figure 1-2 The Impacts of Nitrogen and Phosphorus Pollution on Designated Use Impairments (based on guidance from USEPA 2010b)

Cardno ENTRIX recommends using a similar framework for the re-examination of the Stage II rules (Figure 1-3). The remainder of this TM explains how existing data and information are used to provide the linkages between nutrient loading and designated uses in Falls Lake.

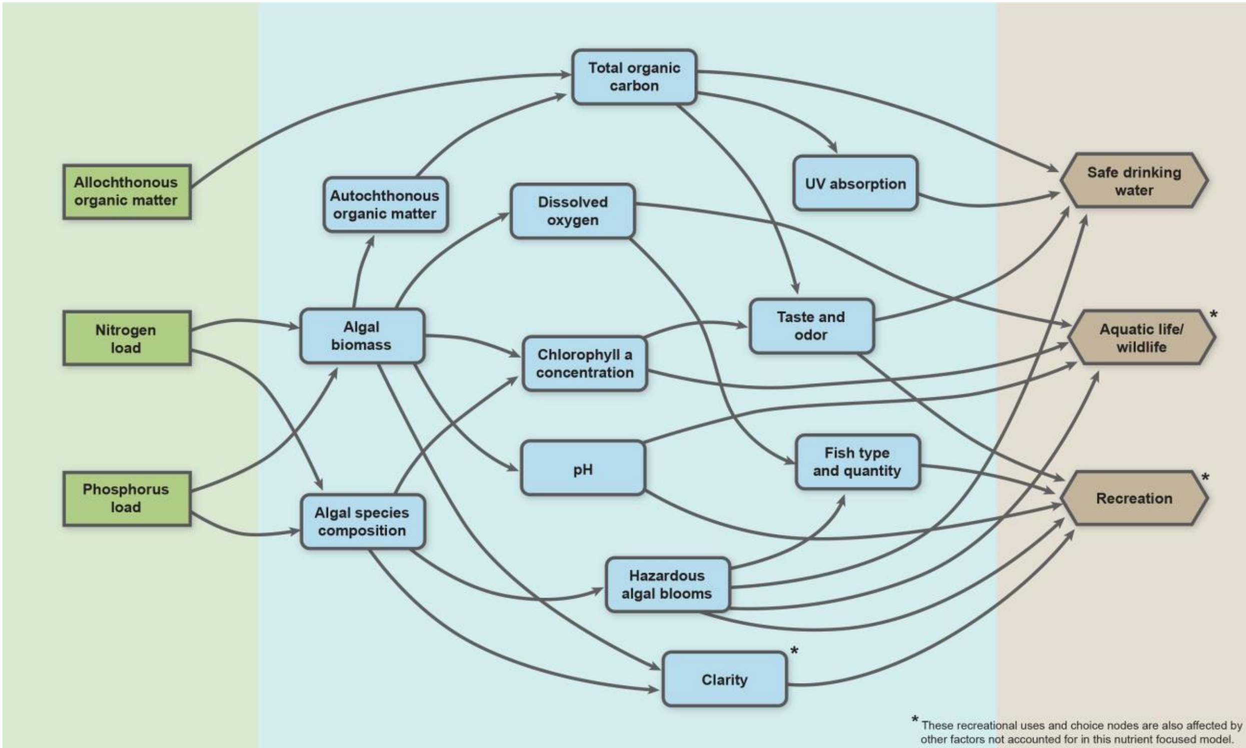


Figure 1-3 Graphical Model of Falls Lake (Cardno ENTRIX 2013b)

2 Summary of the Physical, Chemical, and Biological Conditions of Falls Lake

Cardno ENTRIX compiled existing data and reports from 1999 to 2011 on Falls Lake and its watershed. The resulting database was used to summarize spatial and temporal trends in lake water quality and to identify gaps in monitoring data (Cardno ENTRIX 2012). Figure 2-1 shows a map of the monitoring stations in the watershed along with the jurisdictional boundaries.

The water quality database was also used to calculate tributary nutrient loading to the lake and to describe how the data gaps may affect watershed and lake response modeling (Cardno ENTRIX 2013a). Cardno ENTRIX recommended future monitoring and modeling studies to fill monitoring gaps and reduce the uncertainty associated with the watershed and lake response modeling conducted by the State (Cardno ENTRIX 2013b).

This section briefly summarizes the findings of these reports and highlights some of the areas of uncertainty associated with the Falls Lake Nutrient Management Strategy.

2.1 Summary of findings from Task 2

Cardno ENTRIX (2012) summarizes and combines the existing reports and studies with the current water quality data available in the watershed and focuses on data and studies from year 1999 to 2011. Tables of summary statistics and box plots were used to assess spatial and temporal trends in water quality data in both the watershed and in Falls Lake. The discussions in this Task 1 TM focus primarily on lake water quality.

2.1.1 Spatial Resolution of the Lake Data Comparisons

To facilitate spatial comparisons of the data, the lake was divided into six segments. Monitoring stations located in Falls Lake or the Beaverdam Impoundment were grouped into either the Lower Lake (LowLk-downstream of Hwy 50) or Upper Lake (UppLk – upstream of Hwy 50) regions. To provide additional resolution, distance categories were assigned relative to Falls Lake Dam.

Stations in the Lower Lake downstream of Hwy 50 were grouped into three segments:

> Lower Lake 0 to 4 miles upstream from the Dam (LowLk,0-4)

> Lower Lake 4 to 8 miles upstream from the Dam (LowLk,4-8)

> Lower Lake 8 to 13 miles upstream from the Dam (LowLk, 8-13).

Stations in the Upper Lake upstream of Hwy 50 were also grouped into three segments:

> Upper Lake 13 to 18 miles upstream from the Dam (UppLk,13-18)

> Upper Lake 18 to 21 miles upstream from the Dam (UppLk,18-21)

> Upper Lake upstream of Interstate 85 (UppLk>21).

Figure 2-1 is a map of the monitoring stations in the watershed along with the jurisdictional boundaries. Figure 2-2 shows the monitoring stations in the lake categorized by the organization that collected the data as well the lake segment. All of the stations in the Beaverdam Impoundment grouped with the Lower Lake data and are assigned to the category BvrDmImp.

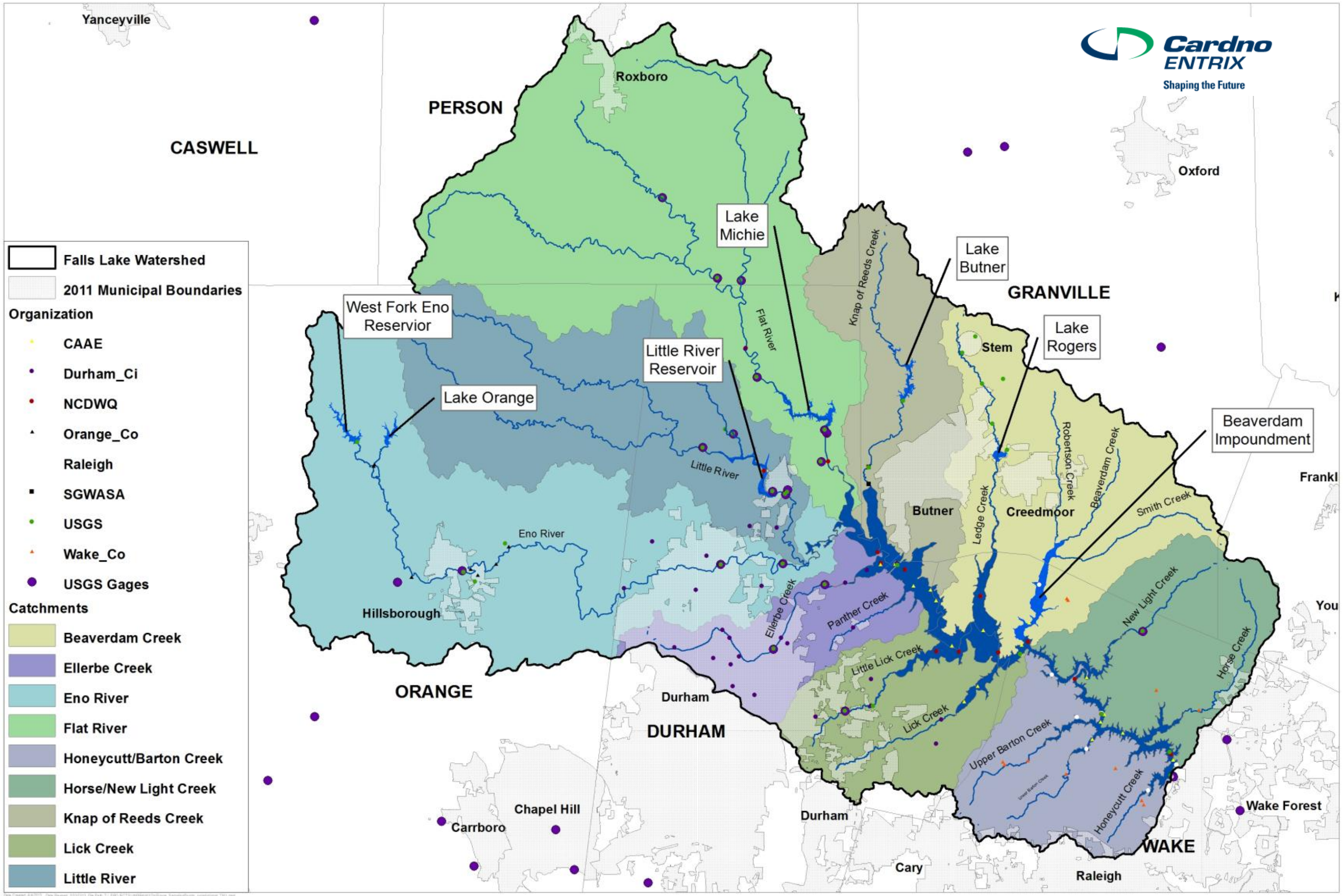


Figure 2-1 Water Quality and Flow Monitoring Stations in Falls Lake Watershed

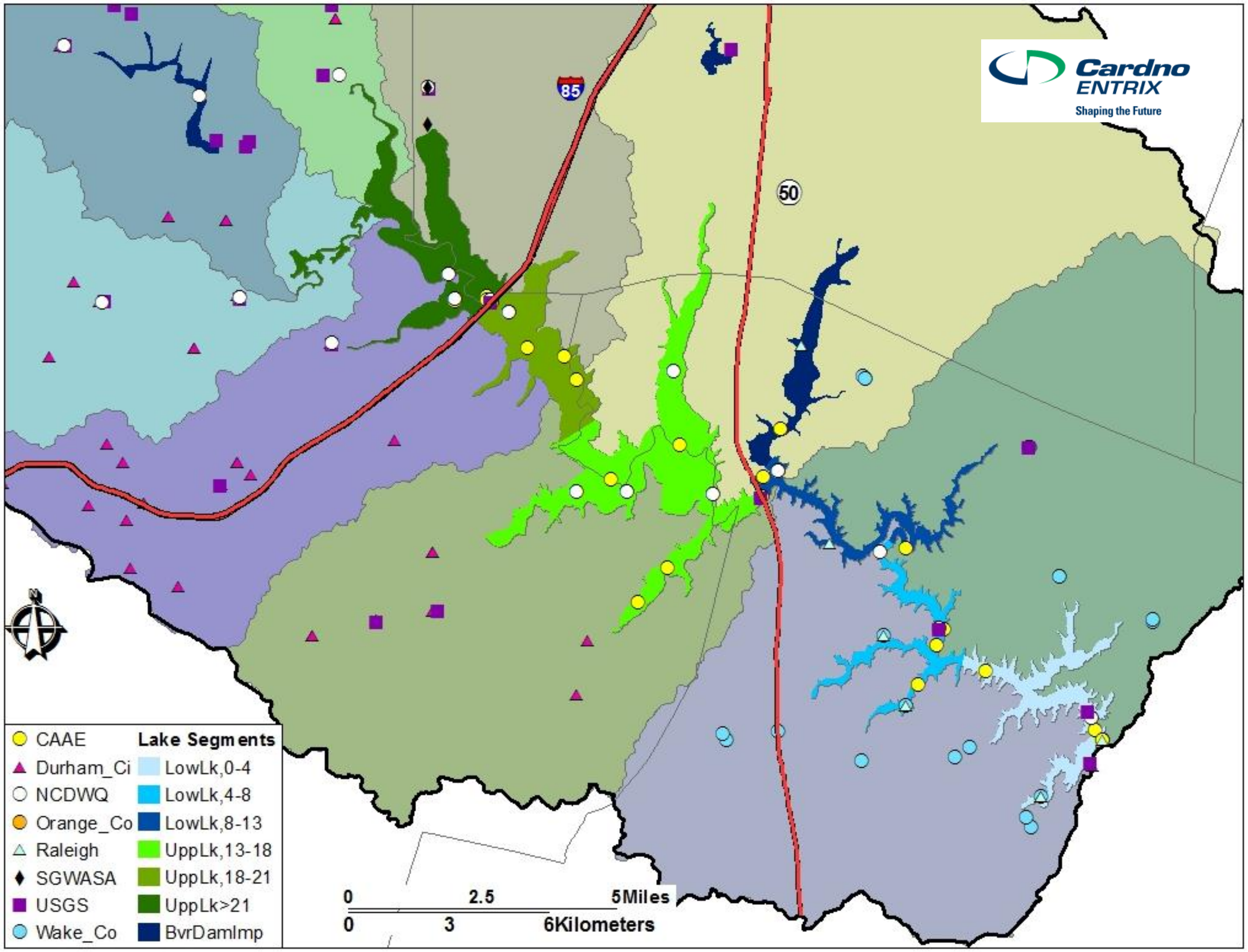


Figure 2-2 Falls Lake Sampling Locations by Lake Segment

2.1.2 Comparison of Existing Reports and Models to Data Summaries

Cardno ENTRIX (2012) confirmed that existing reports and studies are consistent in their message regarding water quality in Falls Lake and confirm the trends reported by NCDENR and others. In particular, several studies demonstrated that water quality improves in the lake from the upstream end to the downstream end near the dam (NCDENR 2001, 2006, 2010, 2011, 2012c; Ecoconsultants 2009; Giorgino 2012; and Huisman 2012). This pattern was predicted by the State and USACE prior to the construction of the dam (State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources 1973, USACE 1974).

Falls Lake is listed as impaired for chlorophyll *a* due to exceedances of the ambient water quality standard (40 µg/L). Figure 2-3 presented by NCDWQ staff at the 2012 NC Lake Management Society shows the percent exceedance for chlorophyll *a* at various locations in the lake based on data collected from 2005 to 2007. This figure summarizes data collected only by NCDWQ during a three-year period and is different from the data summaries that include all available data from 1999 to 2011. The highest levels of chlorophyll *a* occur in the upstream segments of the lake, with stepwise improvements occurring downstream toward the dam. As described in Section 2.1.2.2, this longitudinal improvement in water quality was predicted in the studies that preceded construction of the dam (State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources 1973, USACE 1974). Based on the data presented in this figure (2005 to 2007), the entire portion of the Upper Lake and a portion of the Lower Lake was impaired (exceeded the standard in more than 10 percent of observations). Since 2009, the Lower Lake has not exceeded the chlorophyll *a* standard in 10 percent or more of samples. None of the samples collected in the Lower Lake by NCDWQ exceeded the chlorophyll *a* criteria in 2010, 2011, or 2012 except for Station NEU019L where 8 percent of the samples exceeded the criteria in 2012 (Figure 2-4, NCDENR 2012b). NCDWQ may remove the Lower Lake from the list of impaired waters following attainment of water quality standards for two consecutive use support assessments, which occur every two years based on the previous five years of data.

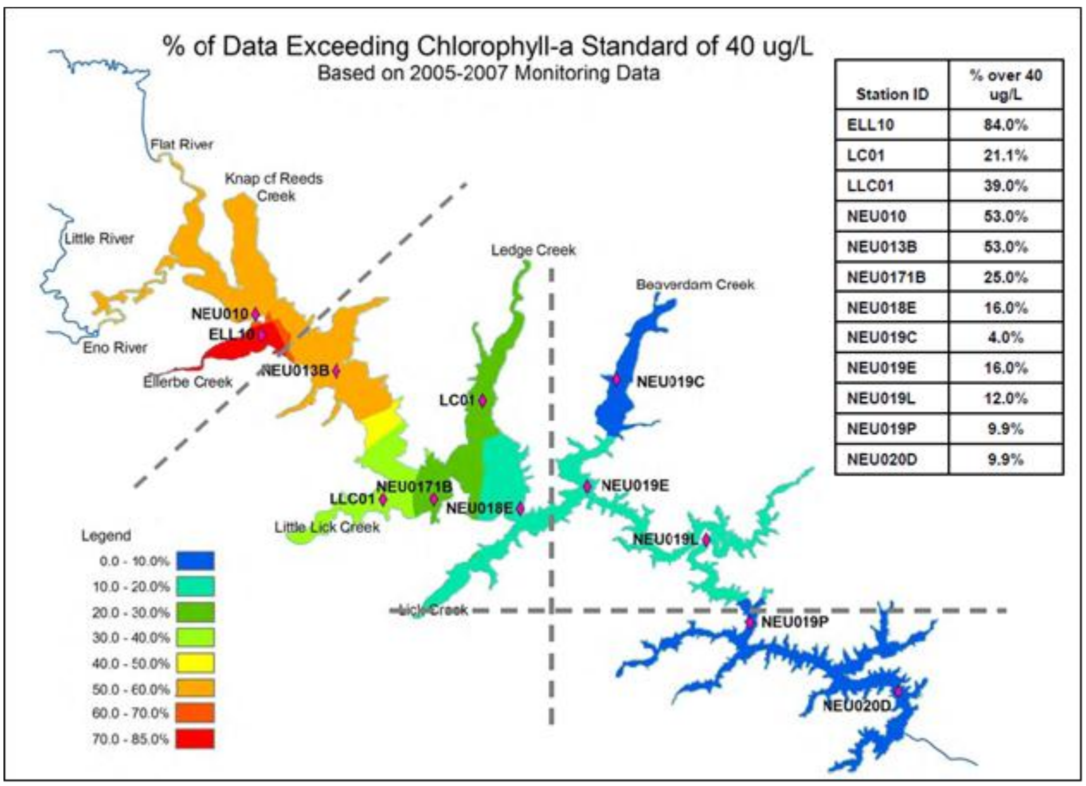
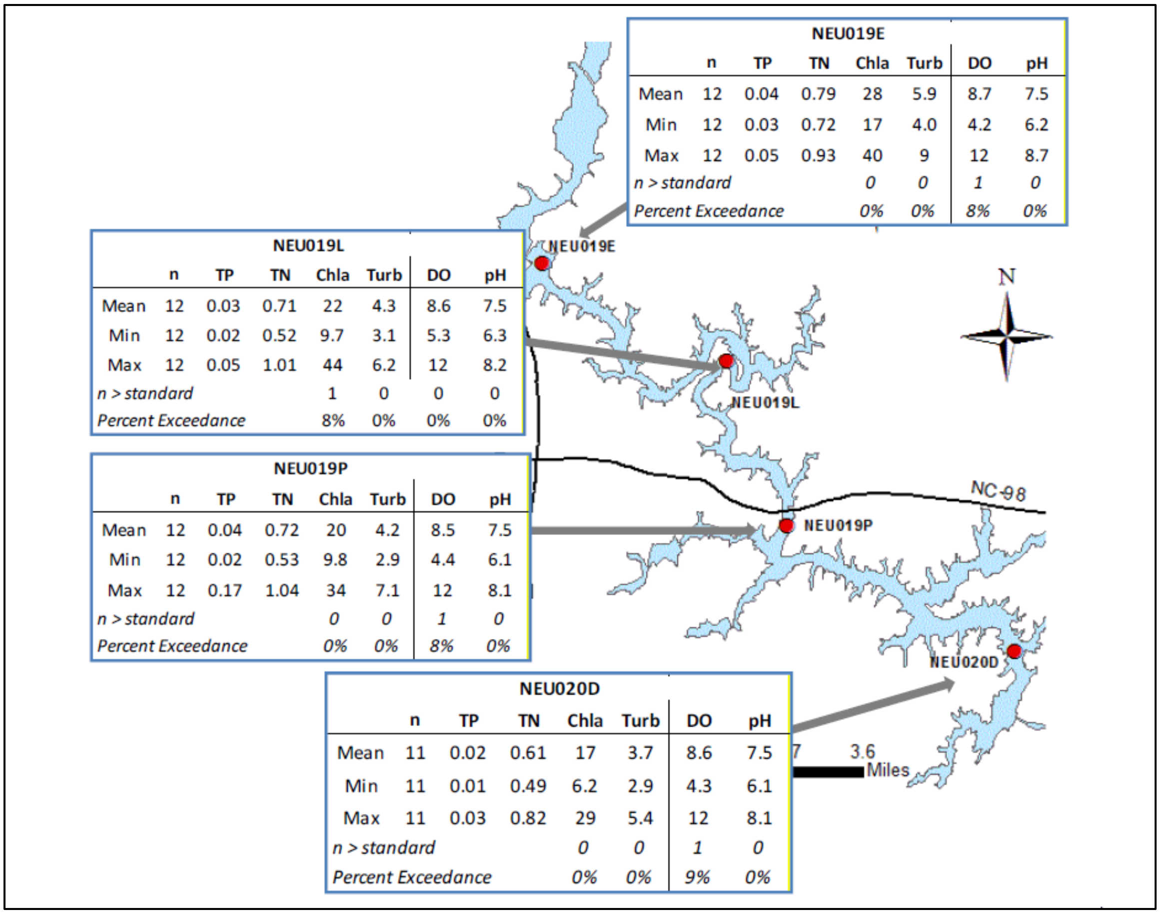


Figure 2-3 Percent Exceedance of Chlorophyll *a* Standard by Lake Segment (from Huisman 2012)



NEU019E	n	TP	TN	Chla	Turb	DO	pH
Mean	12	0.04	0.79	28	5.9	8.7	7.5
Min	12	0.03	0.72	17	4.0	4.2	6.2
Max	12	0.05	0.93	40	9	12	8.7
n > standard				*0*	*0*	*1*	*0*
Percent Exceedance				*0%*	*0%*	*8%*	*0%*

NEU019L	n	TP	TN	Chla	Turb	DO	pH
Mean	12	0.03	0.71	22	4.3	8.6	7.5
Min	12	0.02	0.52	9.7	3.1	5.3	6.3
Max	12	0.05	1.01	44	6.2	12	8.2
n > standard				1	0	0	0
Percent Exceedance				8%	0%	0%	0%

NEU019P	n	TP	TN	Chla	Turb	DO	pH
Mean	12	0.04	0.72	20	4.2	8.5	7.5
Min	12	0.02	0.53	9.8	2.9	4.4	6.1
Max	12	0.17	1.04	34	7.1	12	8.1
n > standard				*0*	*0*	*1*	*0*
Percent Exceedance				*0%*	*0%*	*8%*	*0%*

NEU020D	n	TP	TN	Chla	Turb	DO	pH
Mean	11	0.02	0.61	17	3.7	8.6	7.5
Min	11	0.01	0.49	6.2	2.9	4.3	6.1
Max	11	0.03	0.82	29	5.4	12	8.1
n > standard				*0*	*0*	*1*	*0*
Percent Exceedance				*0%*	*0%*	*9%*	*0%*

Figure 2-4 Results of NCDWQ 2012 Water Quality Sampling in the Lower Lake (NCDENR 2012b)

The remainder of Section 2.1.2 provides a summary of the existing reports and studies as well as supporting tables and figures created from the Task 2 water quality database.

2.1.2.2 Agency Reports

2.1.2.2.1 Historic Documents

Two historic documents are summarized in this TM to provide a point of reference of current water quality trends relative to what was expected before the dam was constructed. This section provides a brief description of these reports and their predictions of water quality in Falls Lake.

The Falls Lake Dam was constructed from 1978 to 1981. In 1973, the State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources released its Special Analysis of the Falls of the Neuse Project. Predictions of water quality in the proposed lake were an important focus of the report, and it was generally accepted that water quality in the upper end of the lake would result in algal blooms due to the shape and residence time of the waterbody. The expectation was that this area of poorer water quality would not negatively impact the drinking water supply intake at the downstream end of the lake, and that the benefits of the lake (flood protection in particular) outweighed the risks associated with eutrophic conditions in the upper most segment. It was expected that taste and odor problems at the water treatment plant would sometimes occur following fall turnover, but for the most part algal blooms would not cause problems for the facility. (Recent monitoring indicates that blooms in the lower lake sometimes occur in the spring and fall). The objectives of the Falls Lake project (flood control, water supply, water quality enhancement, and recreation) were reported to be a source of contention amongst the various stakeholder groups.

The Final Environmental Impact Statement (Revised) Falls Lake Neuse River Basin North Carolina predicted similar spatial trends in water quality (USACE 1974). The Corps predicted that the upper end of the lake would be highly eutrophic, and that recreational use in that area would likely be limited to fishing.

Both historic documents acknowledged that the uppermost section of the lake would be highly eutrophic.

2.1.2.2.2 Recent Assessment Reports

Water quality impairments in the lake include turbidity in the Upper Lake, corresponding to the two most upstream segments (UppLk, 18-21 and UppLk>21), and chlorophyll *a* in the entire lake. Both regions of the lake were listed as impaired for chlorophyll *a* based on data collected by NCDWQ from 2005 to 2006. [Based on the master water quality database, approximately 13 percent of NCDWQ samples from the Lower Lake exceeded the 40 µg/L standard (5 percent in 2005 and 16 percent in 2006). CAAE and USGS also collected data during this period in the Lower Lake, and the percent exceedances based on those data are approximately 6 percent and 8 percent, respectively (when all three data sets are combined, the percent exceedance is approximately 10 percent). In 2007, approximately 8 percent of NCDWQ samples in the Lower Lake exceeded the standard. There were no NCDWQ observations of chlorophyll *a* greater than the standard in the Lower Lake in 2010 or 2011; 2 percent of NCDWQ samples exceeded the standard in the Lower Lake in 2012.] NCDENR reports indicate that the lake maintains other water quality standards, such as DO and pH.

When all chlorophyll *a* samples are considered together (1999 to 2011), chlorophyll *a* measurements in the Upper Lake exceed the 40 µg/L standard more than 10 percent of the time in each segment (Figure 2-5 and Table 2-1). Chlorophyll a concentrations continually decrease in the downstream direction. [Red lines on the figures indicate the water quality criteria. Whiskers on the box plots extend from the 10th to 90th percentile concentrations. Tables are included to show minimum and maximum values.]

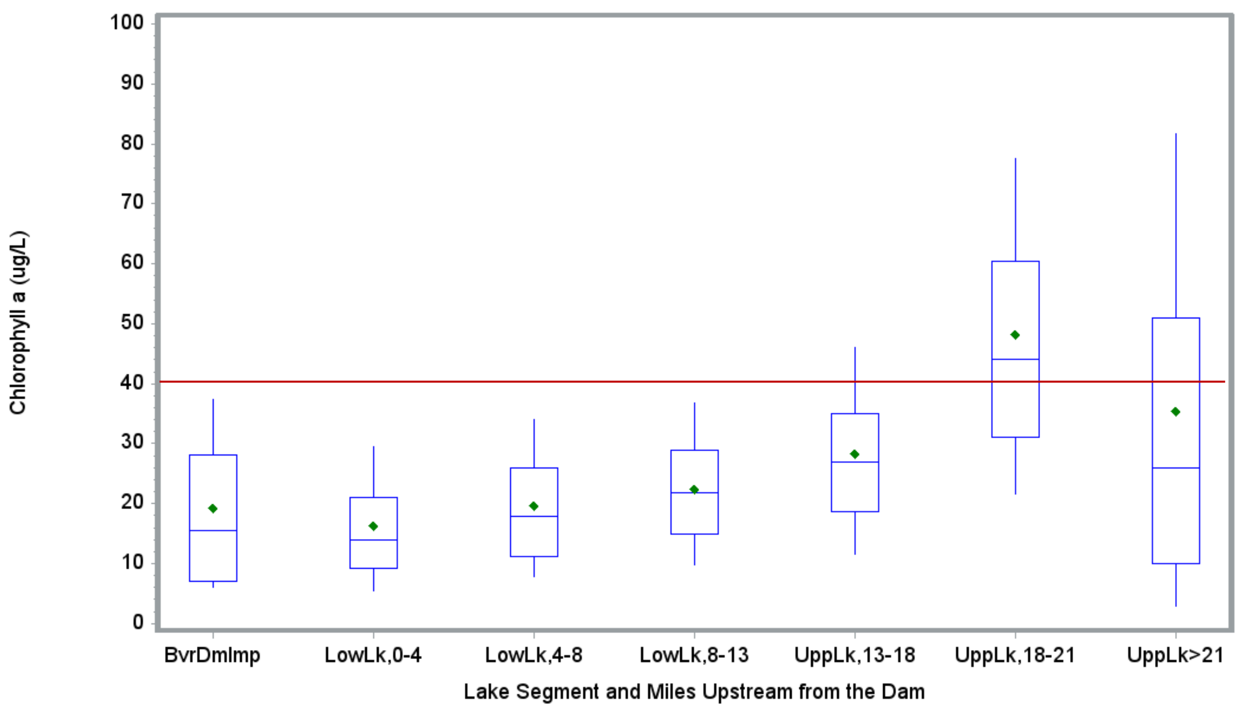


Figure 2-5 Chlorophyll *a* Samples Categorized by Lake Segment and Miles Upstream

Table 2-1 Chlorophyll *a* (µg/L) Samples Categorized by Lake Segment and Miles Upstream

Lake Segment	Count	Minimum	10th	25th	Mean	Median	75th	90th	Maximum
BvrDmImp	120	3.56	6.00	7.00	19.19	15.45	28.15	37.30	69.70
LowLk,0-4	617	1.00	5.40	9.30	16.32	14.00	21.00	29.50	110.00
LowLk,4-8	434	2.00	7.80	11.20	19.67	17.80	26.00	34.00	60.80
LowLk,8-13	353	3.60	9.90	14.90	22.46	21.90	29.00	36.80	73.00
UppLk,13-18	433	0.30	11.60	18.70	28.30	27.00	35.00	46.00	121.00
UppLk,18-21	160	3.00	21.70	31.00	48.26	44.00	60.50	77.50	173.00
UppLk>21	911	1.00	3.00	10.00	35.36	26.00	51.00	81.60	230.00

Assessment of the turbidity observations in the Lake confirms this trend of improving water quality from the upstream to downstream end (Figure 2-6 and Table 2-2). In the upper most segment (UppLk>21), turbidity observations exceed the standard of 25 NTU approximately 75 percent of the time. The high turbidity levels in this segment likely impede algal growth in this area which may explain why the chlorophyll a concentrations are typically lower in this segment compared to the next segment downstream (UppLk, 18-21). Turbidity levels continue to decline in the downstream direction.

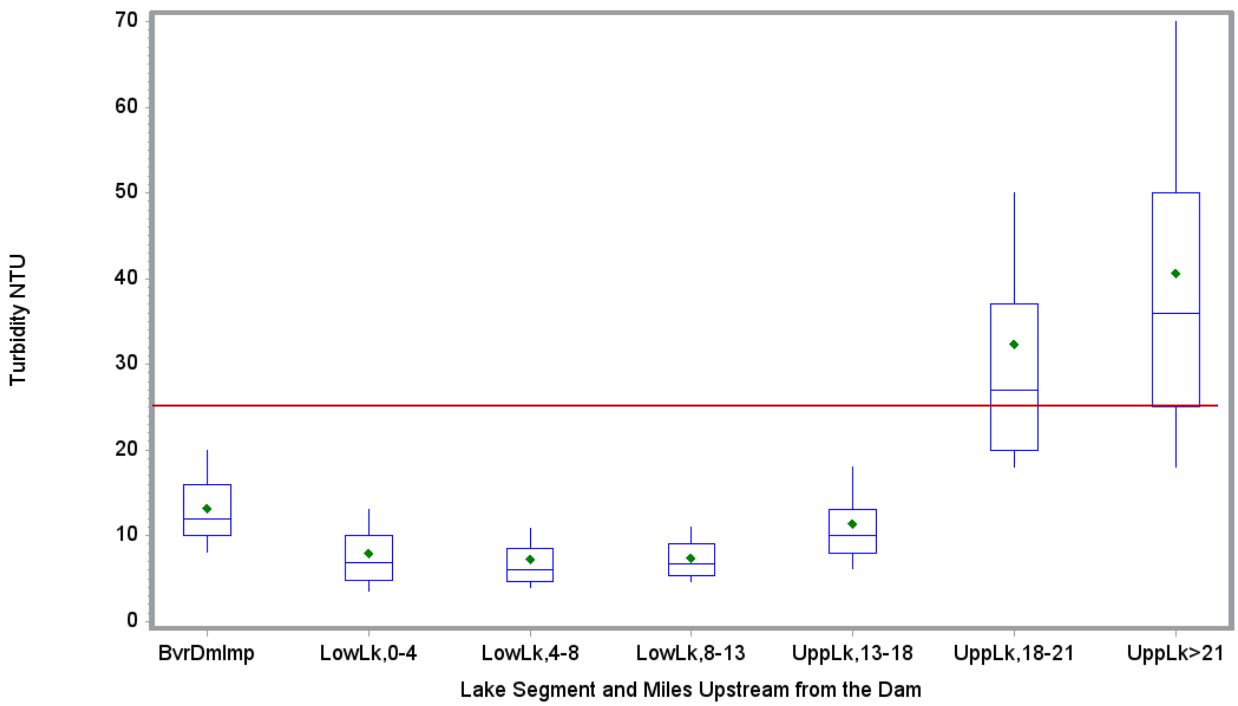


Figure 2-6 Turbidity Samples Categorized by Lake Segment and Miles Upstream

Table 2-2 Turbidity (NTU) Samples Categorized by Lake Segment and Miles Upstream

Lake Segment	Count	Minimum	10th	25th	Mean	Median	75th	90th	Maximum
BvrDmImp	82	5	8	10	13	12	16	20	30
LowLk,0-4	280	2	4	5	8	7	10	13	33
LowLk,4-8	514	1	4	5	7	6	9	11	58
LowLk,8-13	143	3	5	5	7	7	9	11	19
UppLk,13-18	290	4	6	8	11	10	13	18	60
UppLk,18-21	83	10	18	20	32	27	37	50	180
UppLk>21	149	13	18	25	41	36	50	70	170

2.1.2.3 Annual Variability in Tributary and Lake Water Quality

The database compiled for Task 2 was also used to assess annual trends in tributary and lake water quality. The following trends were observed for the main parameters of concern (box plots and summary statistics showing annual trends and additional parameters are available in the Task 2 TM):

> Median total phosphorus measurements are similar from year to year in the tributaries, but years 2004 through 2007 have the highest observed concentrations. In the Upper Lake, median concentrations vary from year to year with the highest concentrations observed in 2002. In the Lower Lake, total phosphorus measurements are relatively stable.

> Median total nitrogen concentrations in the tributaries were similar from year to year; higher concentrations showed an increasing trend from 2002 to 2007 and a decreasing trend from 2008 to 2010. Total nitrogen concentrations in the Upper Lake were highest in 2002 and had an increasing trend from 2006 to 2009. In the Lower Lake concentrations were highest in 2008 through 2011.

> Chlorophyll *a* concentrations in the lake increased from 2003 to 2006. After 2006, concentrations have generally leveled off in the Upper Lake and declined in the Lower Lake.

> TOC concentrations in the Upper Lake were highest in 2008 and 2009 relative to the other six years monitored (2005 through 2012). TOC concentrations in the Lower Lake fluctuate from year to year with the highest concentrations observed in 2002 and 2003. Concentrations decreased in 2004 followed by an increasing trend in 2005 and 2006, stable concentrations from 2006 to 2008, and a decreasing trend from 2008 to 2010.

2.1.3 <u>Potential for achieving the Stage I Goal in the Lower Lake</u>

The water quality database developed in Task 2 was used to assess the percent exceedance of the chlorophyll *a* standards in each segment of the lake by year. Table 2-1 lists the percent exceedance of available data collected in the lake by USGS, NCDWQ, the City of Raleigh, the City of Durham, and the Center for Applied Aquatic Ecology (CAAE) for each lake segment (sample size is included in parentheses). Segments and years that exceed ten percent are shaded orange [NCDWQ lists a waterbody as impaired if ten percent or more of the data (minimum of ten samples) violates a water quality criterion.] NA (not applicable) indicates that no samples were collected in that year and segment.

It is evident that excursions of the chlorophyll *a* standard occur more frequently in the Upper Lake segments compared to the Lower Lake segments. Although the segment of the Lower Lake from 8 to 13 miles upstream of the dam has exceeded the chlorophyll *a* standard more than ten percent of the time in 3 of the 11 years represented, the segment from 4 to 8 miles upstream of the dam has only had one year that exceeded the ten percent threshold, and this occurred in 2006 (the baseline year for the Falls Lake Nutrient Management Strategy). The segment within four miles of the dam has not had any years where the ten percent threshold was exceeded. Based on the NCDENR (2010, 2011, 2012c) lake assessments for Falls Lake, the Lower Lake has been compliant with the chlorophyll a standard every year since 2010.

Table 2-3 Percent Exceedance[1] (and Sample Count) of Chlorophyll *a* Standard in Segments of Falls Lake

Year	UppLk>21	UppLk,18-21	UppLk,13-18	LowLk,8-13	LowLk,4-8	LowLk,0-4
2001	100% (6)	66.7% (3)	16.7% (6)	0% (4)	0% (8)	0% (4)
2002	3.6% (56)	NA	NA	0% (3)	0% (3)	NA
2003	0% (59)	NA	NA	0% (3)	0% (3)	NA
2004	3.4% (59)	100% (2)	NA	0% (3)	0% (4)	NA
2005	14.5% (83)	56.3% (16)	18.2% (22)	14.3% (14)	3.7% (27)	2.4% (41)
2006	32.7% (104)	58.1% (31)	16.9% (89)	14.8% (27)	18.5% (54)	7.8% (51)
2007	32.4% (102)	72.4% (29)	32.5% (77)	9.1% (22)	4.4% (45)	4.5% (67)
2008	44.6% (65)	50% (14)	0% (6)	3.6% (56)	0% (13)	8.6% (81)
2009	41.4% (70)	NA	0% (6)	30% (20)	7.4% (54)	3.5% (57)
2010	42.5% (120)	45.2% (31)	9.1% (99)	0% (104)	0% (105)	0% (163)
2011	64.1% (184)	58.8% (34)	11.7% (128)	0% (97)	0% (118)	0% (147)
2012[2]	NA	50% (12)	25% (48)	4% (24)	0% (12)	0% (12)

1. Segments and years that exceed ten percent are shaded orange.
2. Year 2012 results are based on the Study for the Ongoing Assessment of Falls of the Neuse Reservoir (NCDENR 2012b) and only include sampling conducted by NCDWQ.

Table 2-4 condenses the information for the Upper Lake and Lower Lake. At this scale, the Upper Lake typically exceeds the chlorophyll *a* standard more than 10 percent of the time. The Lower Lake exceeded the 10 percent threshold in 2006.

Table 2-4 Percent Exceedance[1] (and Sample Count) of Chlorophyll a Standard in Upper and Lower Falls Lake

Year	UppLk	LowLk
2001	60% (15)	0% (16)
2002	3.6% (56)	0% (6)
2003	0% (59)	0% (6)
2004	6.6% (61)	0% (7)
2005	20.7% (121)	4.9% (82)
2006	29.9% (224)	13.6% (132)
2007	38% (208)	5.2% (134)
2008	42.4% (85)	6% (150)
2009	38.2% (76)	9.2% (131)
2010	29.6% (250)	0% (372)
2011	44.2% (346)	0% (362)
2012[2]	30% (60)	2% (48)

1. Segments and years that exceed ten percent are shaded orange.
2. Year 2012 results are based on the Study for the Ongoing Assessment of Falls of the Neuse Reservoir (NCDENR 2012b) and only include sampling conducted by NCDWQ.

Stage I of the Nutrient Management Strategy requires "intermediate or currently achievable controls throughout the Falls watershed with the objective of reducing nitrogen and phosphorus loading, and attaining nutrient-related water quality standards in the Lower Falls Reservoir as soon as possible but no later than January 15, 2021, while also improving water quality in the Upper Falls Reservoir…" (15NCAC 02B .0275 (4) (a)). While local governments are required to begin implementing their Stage I local programs in January 2014, several entities have been implementing nutrient management strategies over the past several years. Based on the data presented in Table 2-3 and Table 2-4, the Lower Lake as a whole has not exceeded the chlorophyll a standard more than ten percent since 2006. One subsection of the Lower Lake (LowLk, 8-13) exceeded the standard more than ten percent in 2009.

2.1.4 Identification of Potential Gaps in the Monitoring Data

Data needs (gaps) to estimate nutrient loads and to support models are appropriately assessed using sensitivity and uncertainty analyses with the models to be applied. For nutrient loads, the model typically is a "rating curve" based on flow-concentration relationships or a watershed loading model that simulates runoff and associated nutrient loads. For the reservoir and watershed, the models may be process-based (e.g., the Falls Lake Nutrient Response Model and the Falls Lake Watershed Model) or empirical (e.g., USGS SPARROW).

One obvious gap presents itself when comparing the existing NCDENR models to the available data. As described in the Task 4 TM, the chlorophyll *a* and TOC loads used to develop the input files for the EFDC lake response model were based on lake concentrations, not tributary concentrations. Sensitivity analyses on the tributary chlorophyll *a* concentrations indicate that the simulated lake response is sensitive to this input parameter, particularly during nutrient reduction scenarios. Thus, collection of chlorophyll *a* and TOC data in the tributaries just upstream of the lake would provide more accurate information from which to base simulations of lake response.

Several other parameters have limited data in the segments just upstream of the lake, as well as Beaverdam Impoundment. Collection of additional data in these segments will support tributary load estimation and future lake response modeling. The downstream segments (within two miles of the lake) with the least amount of data include the Eno River, Horse/Barton/Cedar, Horse/Newlight, Knap of Reeds, Lick Creek, Little River, the Beaverdam Creek Subwatershed, and the Beaverdam Impoundment. Tables summarizing the parameters and sample counts in these areas are provided in the Task 2 TM.

2.2 Summary of Issues with the Existing Lake Nutrient Response Modeling

To provide the basis for setting the loading targets in the Falls Lake Nutrient Management Strategy, NCDWQ developed a Falls Lake Nutrient Response Model using the Environmental Fluid Dynamics Code (EFDC) model (NCDENR 2009a). The EFDC model is a three dimensional hydrodynamic/water quality model capable of simulating eutrophication with multiple algal species including cyanobacteria, diatoms, and green algae. The model is described in detail in the Task 3 TM and Task 4 TM. This section highlights some of the findings from Tasks 3 and 4 and reiterates the data gaps summarized during Task 2.

2.2.1 Model Development

There are several sources of uncertainty regarding the development and application of the Falls Lake EFDC model. For example, the simulated nutrient loads used to drive the lake response model are 1.4 times to 2.0 times higher than those estimated using the WARMF model (See TM 4). Ideally, when watershed and lake response models are developed for a given waterbody, the results should be somewhat similar even if the models cannot be formally linked.

In addition, simulated loading to the Lower Lake is highly uncertain since there are no flow gages in this part of the watershed, many of these tributaries are intermittent with little to no discharge in the summer, and water quality monitoring has not occurred at the same frequency and for the same length of time as the upper lake monitoring. The Task 4 TM describes monitoring studies that are needed to reduce the uncertainty regarding pollutant loading to the lake.

Also, the Falls Lake nutrient response model was calibrated separately for years 2005 and 2006, and then validated for year 2007 using the 2005-based calibration. Thus year 2006, which was used as the basis for determining the load allocations, was never validated using an independent data set. As described in TM 4, extending the allocation period to include a greater range in hydrologic variability will provide greater confidence in projected lake response.

As described in Section 2.1.4, when NCDWQ developed the lake response model, there were no chlorophyll *a* data collected at the mouths of the tributaries. To provide an input for the time series for each tributary, NCDWQ assumed that the chlorophyll *a* concentration at the mouth of each tributary was equal to observations collected at the nearest lake station. This assumption not only affects model development and calibration, but also the simulated response to nutrient reductions. Additionally, as nitrogen and phosphorus reductions were assumed in the watershed as a result of Stage I and Stage II implementation, the chlorophyll *a* inputs to the lake were not altered (neither were TOC or TSS). It is expected that nutrient reductions in the watersheds would also reduce chlorophyll *a* concentrations in the tributaries. Maintaining the baseline tributary chlorophyll *a* concentrations while running nutrient reduction scenarios likely results in higher inlake chlorophyll *a* concentrations relative to what would be observed following a reduction in watershed nutrient loading (e.g., implementation of Stage I or Stage II). Inlake benthic flux rates were also assumed to remain at existing levels.

To compare the impacts of the tributary chlorophyll *a* concentrations on simulated chlorophyll *a* concentrations at the compliance point (NEU013B), Cardno ENTRIX ran four scenarios with the 2006 EFDC model: baseline, Stage I reductions, baseline with tributary chlorophyll *a* concentrations set to 10 µg/L continuously, and Stage I reductions with tributary chlorophyll *a* concentrations set to 10 µg/L continuously. The results are shown in Figure 2-7. The model shows that in 2006, there was a spring bloom in early May. Through the remainder of that year, chlorophyll *a* concentrations remained above the standard of 40 µg/L until late December and were greater than that standard 52 percent of the time (baseline). With Stage 1 reductions, the concentrations would have been slightly less with concentrations greater than the standard one-third of the time. If chlorophyll *a* concentrations were held to a constant 10 µg/L throughout the year at year 2006 nutrient loading levels, the standard would be exceeded at NEU013B 35 percent of the time. A combination of Stage 1 reductions and chlorophyll *a* concentrations at 10 µg/L lessened the concentration during the spring bloom and throughout the summer with the standard only consistently being exceeded starting in October. Simulated percent exceedance at the compliance point is 20 percent of the time for this scenario. Thus the model is highly sensitive to the assumption regarding tributary chlorophyll *a* concentrations, and predicted exceedance varies by 15 percent for a given loading scenario. [In the Task 4 TM, Cardno ENTRIX recommended collection of tributary chlorophyll *a* concentrations to refine the model inputs. Following collection of additional data, the model should be recalibrated.]

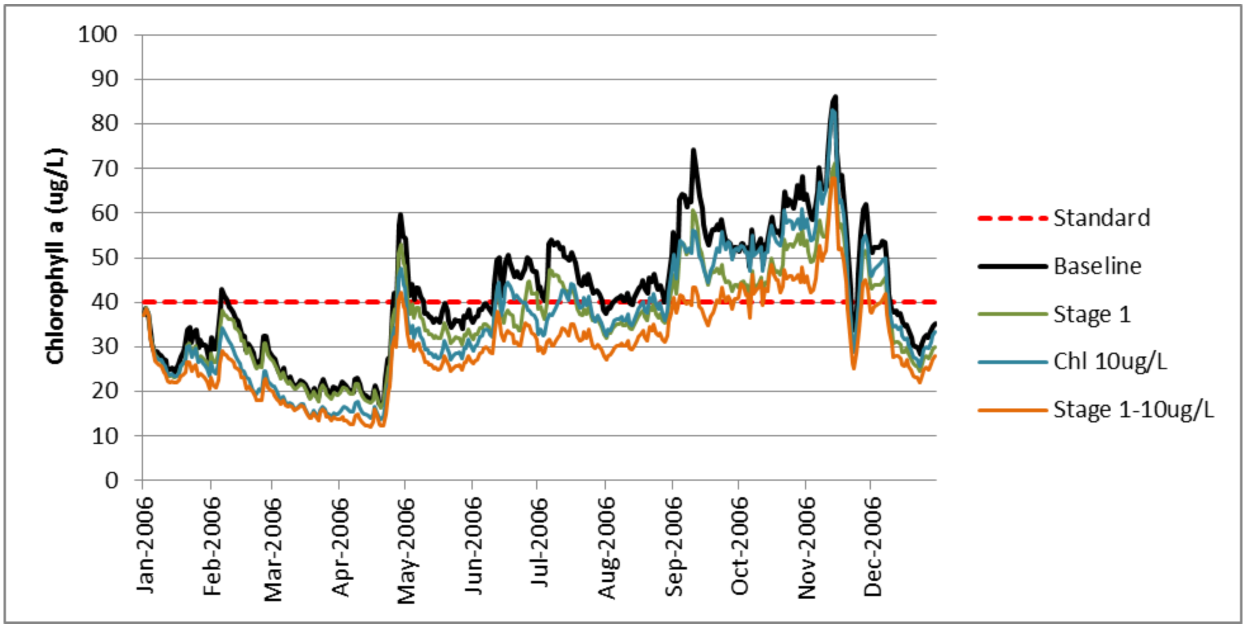


Figure 2-7 Sensitivity of the EFDC Model to Tributary Chlorophyll *a* Assumptions for Baseline and Stage I Scenarios (at NEU013B)

The current version of the Falls Lake EFDC model also assumes that lake processes do not vary spatially in the lake. For example, background light extinction, nutrient flux, and sediment oxygen demand are assumed to be the same across the entire lake and do not vary within the arms or longitudinally from upstream to downstream. Given the size and loading patterns to Falls Lake, these rates likely vary spatially, but existing data are not available to characterize spatial variation. In the Task 4 TM, Cardno ENTRIX recommends additional studies to measure the spatial variability for these parameters. Similar studies are recommended by the Triangle J Council of Governments (TJCOG 2012).

2.2.2 Model Application

There is also uncertainty regarding how the model output was used to set the required nutrient load reductions in the Falls Lake Nutrient Management Strategy. For example, the model was used to determine the limiting factors on algal growth at various locations in the lake (Figure 2-8). With respect to nitrogen and phosphorus limitation, in the upper part of the lake, algal growth is nitrogen limited between 70 percent and 80 percent of the time, and phosphorus limited 20 to 30 percent of the time. Further down the lake, the percent of time N and P limit algal growth is more similar, but nitrogen limits algal growth more frequently than phosphorus at every location that was assessed (13 stations along the length of the lake). It is not clear why the Falls Lake Nutrient Management Strategy requires much higher phosphorus load reductions relative to nitrogen when nitrogen seems to be limiting algal growth 70 percent to 80 percent of the time in the upper part of the lake.

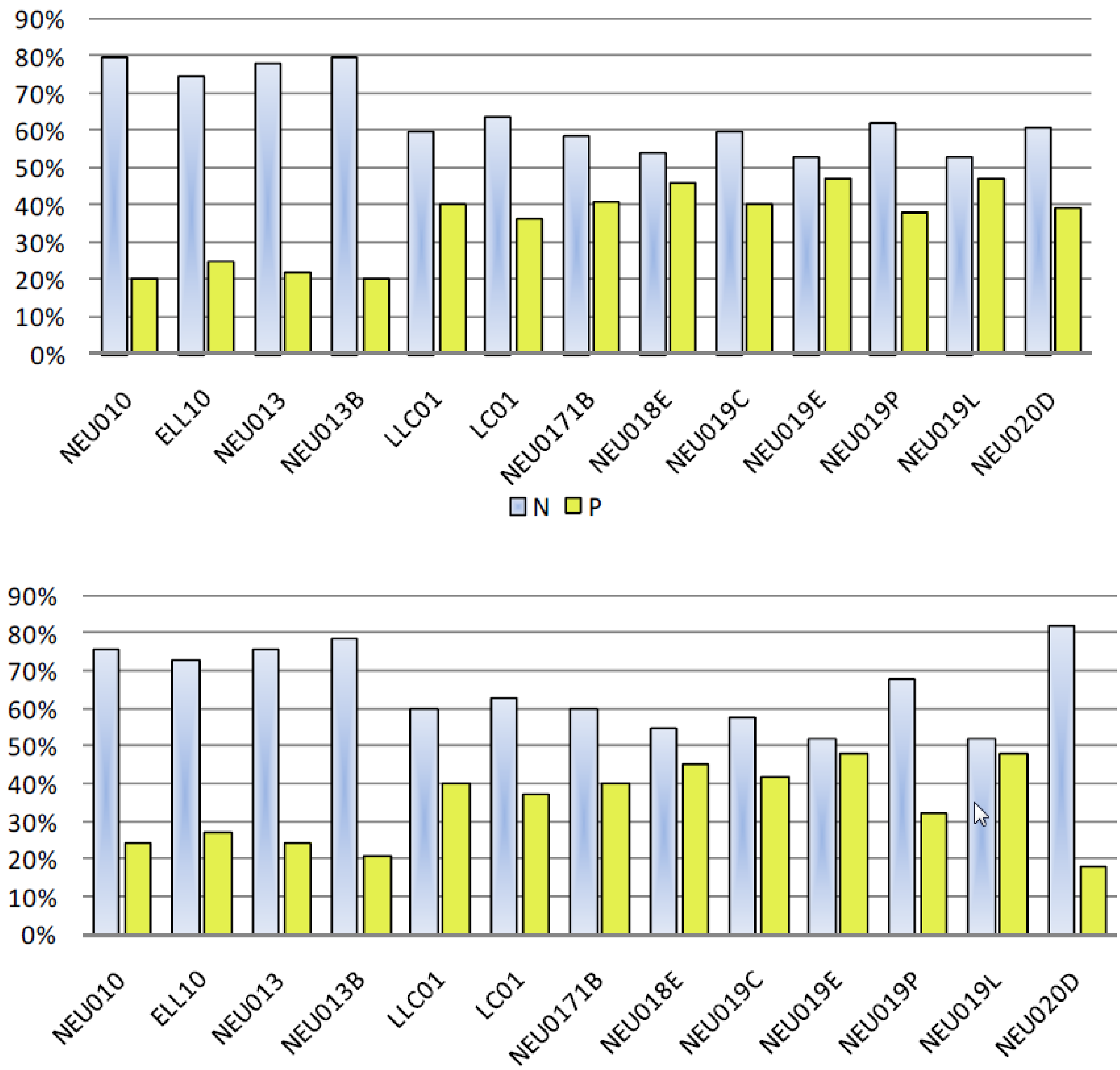
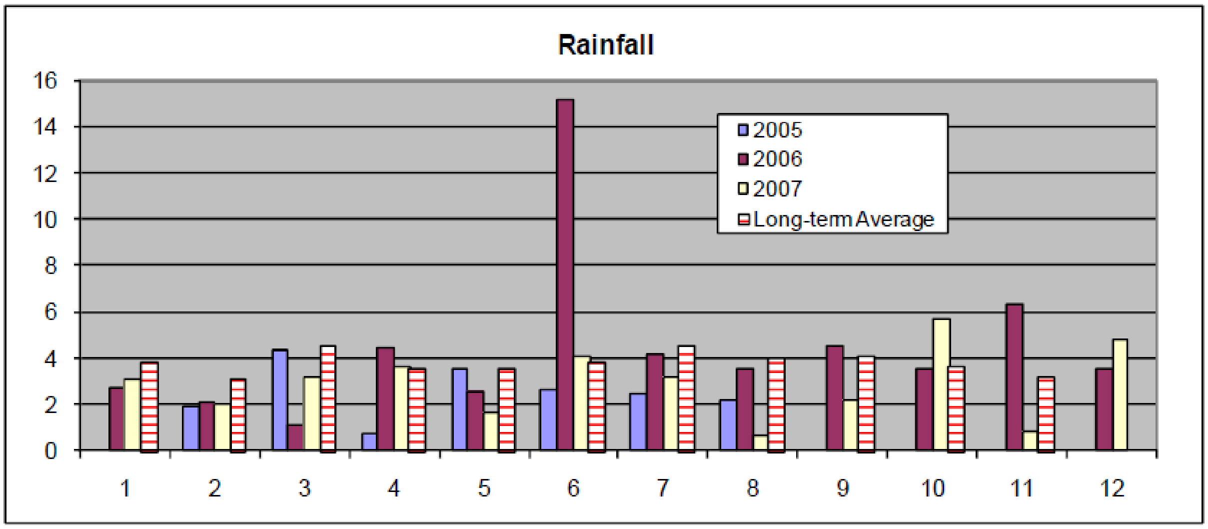


Figure 2-8 Percent of Time Algal Growth is Limited by Nitrogen or Phosphorus at the Surface Layers (Top Panel) and Bottom Layers (Bottom Panel) in Year 2006 (from NCDENR 2009a)

There is also uncertainty regarding the appropriateness of selecting year 2006 as the baseline year for setting the Stage II reduction requirements. Typically, load allocations such as the Falls Lake Nutrient Management Strategy are developed using multiple years to determine the load reduction requirements for a waterbody. This approach accounts for various hydrologic conditions (wet, dry, and average years) and prevents allocations based on conditions that may have been impacted by extreme events, such as hurricanes or severe droughts. For the purposes of developing the Falls Lake nutrient response model, 2005 and 2007 were considered dry years and 2006 was considered a normal year based on total annual precipitation. While annual precipitation for year 2006 may be similar to the annual average, analysis of monthly totals shows that year 2006 was not an average year (Figure 2-9). Rainfall during the months of January to May was generally less than the long-term monthly averages. In June 2006, the total monthly rainfall was approximately 11 inches higher than the long-term average for that month due to Tropical Storm Alberto which deposited up to 8 inches of rainfall in the lower part of the watershed and up to

4 inches in the upper part. In November, the total monthly rainfall was approximately 3 inches higher than the long-term average.

As a result, monthly inflows to the lake were significantly impacted by the rainfall patterns. Inflows from January to May were very low compared to the long-term averages observed during those months, and these low inflow months followed a drought year (2005). Inflows in June and November of 2006 were 3 to 4 times higher than those typically observed. Also, the precipitation input for year 2006 used to drive the EFDC model for Falls Lake indicates an annual precipitation of over 88 inches. The USGS reports a total annual rainfall at Falls Lake above the dam of approximately 48 inches in 2006. It is unclear how this discrepancy in precipitation to the lake surface impacts model results.



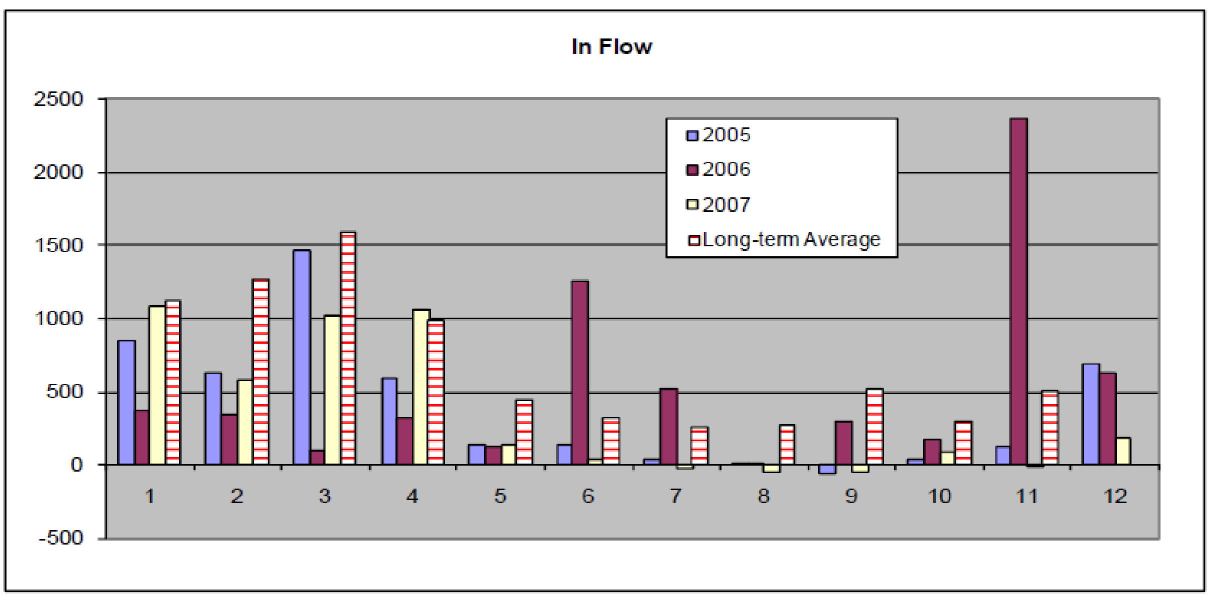


Figure 2-9 Monthly Rainfall (Top Panel, inches) and Monthly Inflow (Bottom Panel, monthly average cfs) Relative to the Longer Term Average (from NCDENR 2009a)

To test the models sensitivity to Tropical Storm Alberto which impacted the watershed in June 2006, Cardno ENTRIX ran the Falls Lake EFDC with and without the tropical storm. Daily average chlorophyll *a* concentrations at the compliance point (NEU013B) were used to calculate the percent exceedance for year 2006 under the two scenarios. Under baseline conditions with Tropical Storm Alberto included, the simulated percent exceedance at the compliance point is 52 percent. Without the storm, the percent exceedance at the compliance point is 51 percent. While the overall percent exceedance is not significantly affected by the storm, the magnitude of the concentrations is much higher. Figure 2-10 shows the simulated daily average chlorophyll *a* concentrations at the compliance point under these two scenarios. Following the storm in June, simulated chlorophyll *a* concentrations are up to 16 µg/L higher when the inputs from the storm are included.

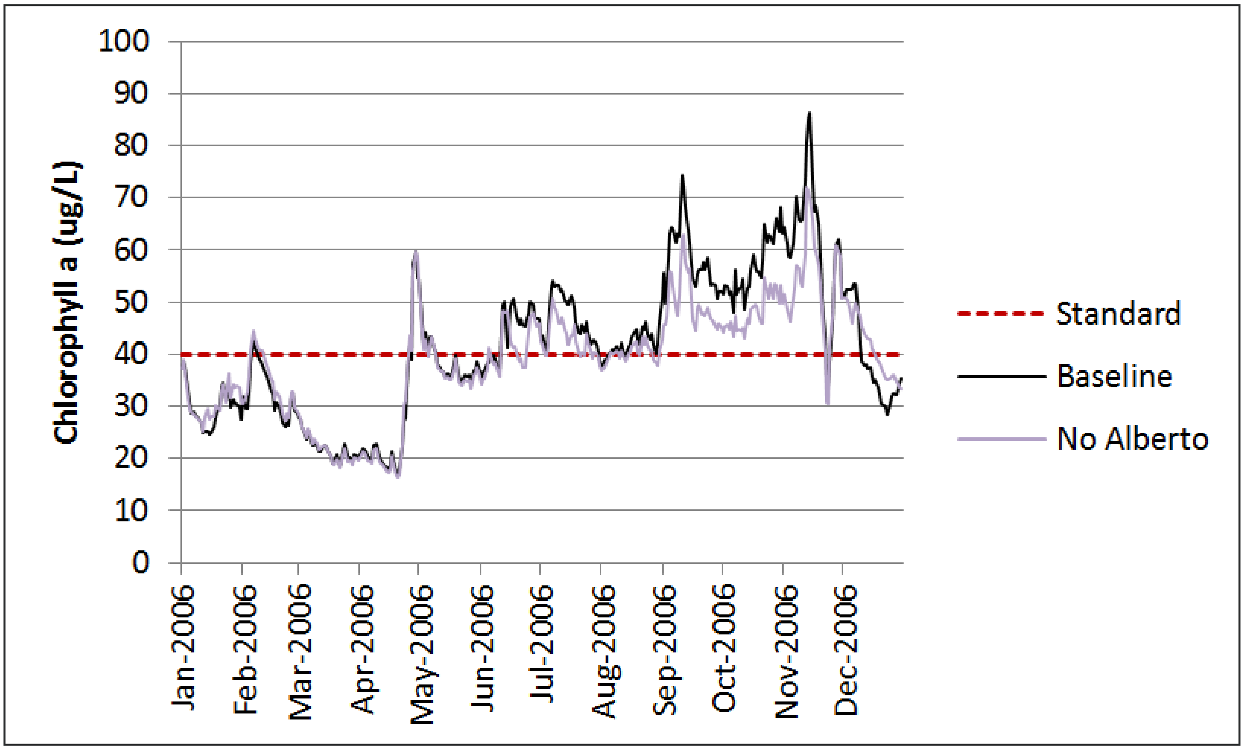


Figure 2-10 Sensitivity of the EFDC Model to Tropical Storm Alberto Under Baseline Conditions (at NEU013B)

In addition to the anomalous hydrologic conditions in 2006, tributary inputs to Falls Lake generally had poorer water quality in 2006 relative to the other years. Tributary samples had lower dissolved oxygen and higher ortho-phosphate, total phosphorus, organic nitrogen, nitrate plus nitrite, and total nitrogen concentrations relative to most of the other years (concentrations of nitrate plus nitrite, total nitrogen, and total phosphorus were increasing over the period 2003 to 2007 and peaked in 2007). Figure 2-11 shows the tributary total phosphorus concentrations as an example of the observed tributary water quality in 2006 relative to the other years.

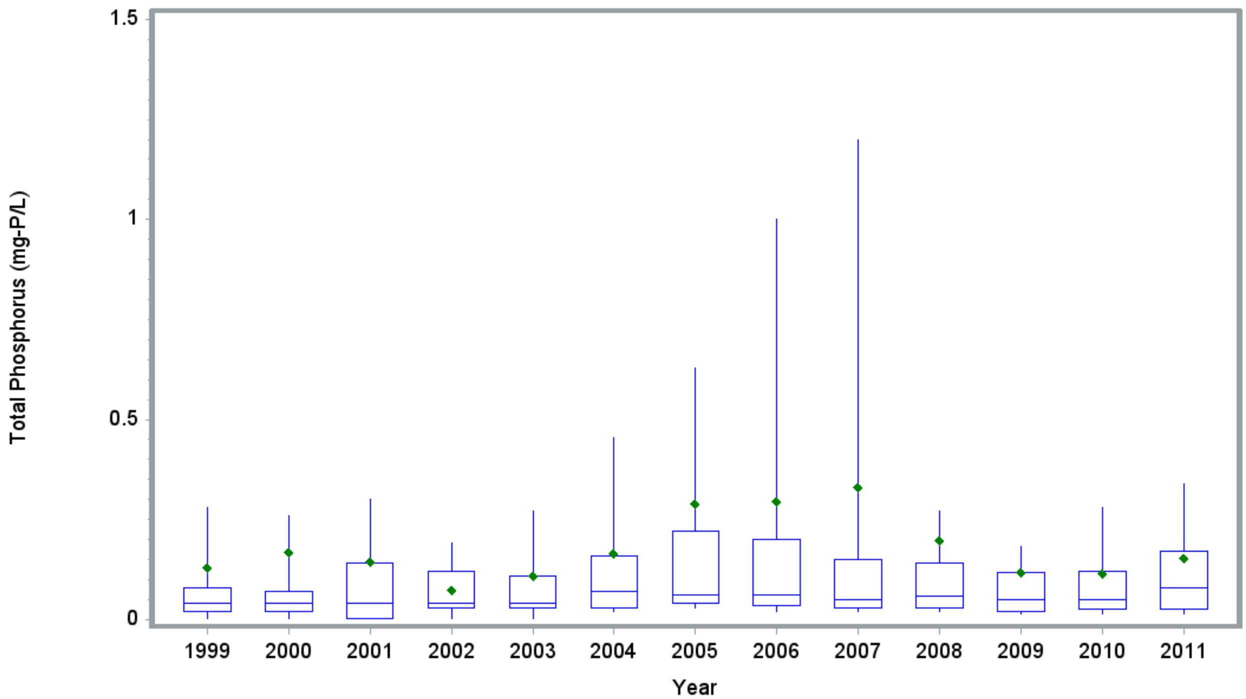


Figure 2-11 Total Phosphorus Tributary Samples Categorized by Year

In addition to the poor tributary water quality in 2006, the lake also experienced more water quality issues during that year. Both the Upper and Lower Lake experienced lower DO concentrations relative to other years represented in the Task 2 database. Chlorophyll *a* in the Upper Lake was near the end of an increasing trend in concentrations that occurred from 2003 to 2007; TOC concentrations were in an increasing trend from 2005 to 2008. In the Lower Lake, year 2006 had typical TOC concentrations and the highest 90th percentile chlorophyll *a* concentrations observed. The total nitrogen and total phosphorus concentrations observed in the Upper and Lower Lake segments, however, were lower in 2006 compared to many of the years. Based on visible interpretation of the data, higher nutrient concentrations in both the Upper and Lower Lake segments occurred in years 2007 through 2009. Total nitrogen and total phosphorus in the Upper Lake show an increasing trend from year 2006 to 2009. Higher total nitrogen concentrations occur in the Lower Lake in 2008, 2009, and 2010; total phosphorus concentrations in the Lower Lake were relatively stable from year to year. These trends are displayed in the box plots and tables provided in the Task 2 TM.

2.3 Linking Nutrient Concentrations to Chlorophyll *a*

An essential component of the re-examination process is a formal linkage between nutrient concentrations in Falls Lake and eutrophication response measured by chlorophyll *a*. While a mechanistic model exists that simulates these relationships (The Falls Lake Nutrient Response Model), the modeling is uncertain with respect to the inputs and predicted outcomes. Cardno ENTRIX (2013b) recommends future monitoring studies and revisions to the Falls Lake Nutrient Response Model to reduce the uncertainty associated with the predicted nutrient targets. In addition, Cardno ENTRIX (2013b) recommends an empirical model for Falls Lake that uses data analysis to formulate the mathematical equations that link nutrient concentrations to algal response. Knowledge of these relationships is a crucial component of the re-examination. For example, they provide an independent means to verify the outcomes of the revised Falls Lake Nutrient Response Model and provide more confidence with its application for setting loading targets. These relationships may also be included in the larger empirical model for Falls Lake (Cardno 2013b) used to link watershed loading, lake response, and designated uses such as drinking water protection.

The current scope of work does not include a statistical analysis of the Falls Lake water quality data to develop these relationships. For the purposes of developing the Falls Lake Framework Tool, existing empirical equations developed by the US Army Corps of Engineers (USACE) have been programmed into a spreadsheet-based tool to predict nutrient and chlorophyll *a* concentrations resulting from nutrient loading the lake. Future versions of the Falls Lake Framework Tool may be revised to include the statistical analyses of the Falls Lake data.

3 Assessment of Stage II Feasibility

The purpose of this section is to review the feasibility and costs of achieving the Stage II goals set forth in the Falls Lake Nutrient Management Strategy. This review focuses on existing development and agriculture because they are the most pertinent to the members of the UNRBA. Sources of information include the NCDWQ (2010) fiscal analysis, the Chesapeake Bay economic analysis (RTI 2012), the second annual report of the Nutrient Scientific Advisory Board (NSAB 2012), as well as local studies (Wossink and Hunt 2003; Hunt et al. 2012). Based on the existing information, Cardno ENTRIX concludes that the Stage II rules are not technically, logistically, or financially feasible. This section describes these findings in more detail.

3.1 Overview of the NCDWQ Fiscal Analysis

In 2010, NCDWQ published a fiscal analysis of the Falls Lake Nutrient Management Strategy that estimated that the total costs of Stage I would be approximately $605 million ($2010) and the total costs of Stage II would be approximately $1 billion ($2010). Table 3-1 lists the anticipated cost for each sector to implement the Stage I rules as well as the percentage of regulated loading (requiring nutrient reductions) for nitrogen and phosphorus based on baseline conditions (excluding non-regulated sources such as forest and shrub land). The regulated baseline loading percentages are calculated from delivered loading numbers presented in NCDWQ's Fiscal Analysis (2010).[1] The report cites the NCDWQ WARMF modeling as the basis of the nutrient loading estimates, but the total delivered loading is not consistent with the State's final draft of the WARMF modeling report (NCDENR 2009b). New development is not included in this percentage (NA: not applicable) of regulated loading because under baseline conditions there is no new development to offset (i.e., only existing development is present at baseline.)

Table 3-1 Stage I Implementation Costs ($2010) by Sector over a Seven Year Implementation Period (from NCDWQ 2010)

Sector	Approximate Cost (million)	Percentage of Total Cost	Percent of Regulated Baseline Nitrogen Loading	Percent of Regulated Baseline Phosphorus Loading
Wastewater	$249	41	34	37
Existing development	$225	37	20	6
New development	$109	18	NA	NA
State and Federal Entities	$15.8	3	2	<1
Agriculture	$6.6	1	44	56
Total	**$605**	**100**	**100**	**100**

[1] The baseline delivered loads in the Fiscal Analysis do not match those presented in the final lake modeling report (NCDENR 2009a) or in the final watershed WARMF modeling report (NCDENR 2009b), but the figures resemble those from the WARMF report. Since the baseline loading figures presented in the Fiscal Analysis are similar to those in the final WARMF report, Cardno ENTRIX speculates that a draft WARMF report was used by NCDWQ when preparing the Fiscal Analysis.

The State's fiscal analysis of the Stage II requirements estimates costs of $946 million ($2010). Table 3-2 provides a breakdown of Stage II costs by sector (NCDWQ 2010).

Table 3-2 Stage II Costs ($2010) by Sector over a 15 Year Implementation Period (from NCDWQ 2010)

Sector	Approximate Costs (million)	Percentage of Costs	Percent of Regulated Baseline Nitrogen Loading	Percent of Regulated Baseline Phosphorus Loading
Wastewater	$229	24	34	37
Existing development	$551	58	20	6
New development	$129	14	NA	NA
State and Federal Entities	$30.9	3	2	<1
Agriculture	$6.1	<1	44	57
Total	$946	100	100	100

Cardno ENTRIX reviewed the State's fiscal analysis with respect to assumptions, feasibility, and resulting costs. The review focuses on implementation costs for existing development because this sector will have the greatest impact for the members of the UNRBA. The review also includes agriculture because the NCDWQ watershed model estimates that this sector generates the largest percentage of loading to Falls Lake. Technical and financial issues associated with the NCDWQ cost estimates for existing development and agriculture are discussed in the following sections.

3.2 Existing Development

The Falls Lake Nutrient Management Strategy requires that all counties and municipalities in the watershed achieve nutrient reductions from existing developed lands. For existing development, Stage I of the Strategy requires offsets of the increase in nutrient loading resulting from development that occurred between January 2007 and July 2012. Stage II of the Strategy requires reductions of nitrogen and phosphorus loading of 40 percent and 77 percent respectively, from the baseline year of 2006. This section reviews the assumptions used by NCDWQ to generate their fiscal analysis of the Strategy and describes why the Stage II rules are technically, logistically, or financial feasible.

3.2.1 Overview of the NCDWQ Fiscal Analysis for Implementing Nutrient Reductions on Existing Development

The NCDWQ fiscal analysis of the Falls Lake Nutrient Management Strategy was developed using the best information available at the time and was conducted on a very tight schedule to comply with the requirements of the Rules. For example, in determining their cost estimates for Stage I, NCDWQ assumes that the costs for reductions are driven by total nitrogen reductions. The Stage II implementation costs are assumed to be driven by cost of total phosphorus reductions. For both Stages, NCDWQ (2010) assumes that "reduction requirements for the less costly nutrient are met through its co-control at no added cost to that of the more costly one." Cardno ENTRIX agrees with this approach in determining costs as BMPs typically treat both nitrogen and phosphorus.

NCDWQ also assumes that there are sufficient opportunities available for the installation of BMPs to achieve the required nutrient reductions for existing development (2010). Cardno ENTRIX does not agree with this assumption as described below.

The NCDWQ fiscal analysis categorizes existing developed land into three types: county residential, municipal residential, and commercial/industrial/multi-family residential. Areal nutrient loading rates applied to these three categories are presented in Table 3-3 and vary for each stage of implementation. Stage I areal loading rates apply to development that occurred between 2007 and 2013 and were considered "treated" based on the MS4 Phase II requirements, Water Supply Watershed, and Neuse stormwater requirements. Areal loading rates for development that occurred before or during year 2006 (the baseline period for the Stage II requirements) were higher and considered "untreated." Loading rates from county residential are assumed the same for both periods because they are not subject to the same regulations as the other two categories.

Table 3-3 Areal Nutrient Loading Rates for Existing Development Categories

Existing Development Category	2007 -2013 Areal Loading Rates (lb/ac/year) for Calculating Stage I Requirements		Areal Loading Rates for Calculating Stage II Requirements (lb/ac/year)	
	Nitrogen	Phosphorus	Nitrogen	Phosphorus
County Residential	2.8	0.46	2.8	0.46
Municipal Residential	5.03	0.52	7.50	0.90
Commercial/Industrial/ Multi-family Residential	8.38	0.72	12.50	1.10

In order to provide a fiscal analysis of the existing development requirements, NCDWQ calculated the amount of development that was expected to occur from year 2000 to 2013. The following datasets were used:

> The year 2000 National Land Cover Dataset (NLCD) used in the WARMF watershed model

> US Census Bureau population data for year 2001

The NLCD data was used to quantify the amount of development that was present in year 2000. The population data was used to project population growth assuming an annual growth rate of 1.7 percent. NCDWQ assumed that land development occurs at the same rate as population growth and calculated the area of development in 2006 and 2012 as shown in Table 3-4.

Table 3-4 NCDWQ Calculated Acreage of Existing Development for 2000-2012

Watershed	2000 Acreage	2006 Estimated Acreage	2013 Estimated Acreage
Upper Five Tributaries Draining to Falls Lake	36,822	40,023	43,793
Falls Lake Downstream of I-85	16,984	19,931	23,515

Stage I nutrient reductions were calculated by multiplying the "treated" areal loading rates by the increase in development from 2007 to 2013 for both the upper and lower watershed. Stage II nutrient reductions were calculated by multiplying the developed area in the upper five tributary watersheds in 2006 by the "untreated" areal loading rates and the required Stage II percent reductions. Table 3-5 summarizes the Stage I and Stage II reduction requirements.

Table 3-5 Estimated Stage I and Stage II Reduction Requirements (NCDWQ 2010)

Existing Development Type	Stage I Nutrient Reduction Requirements		Stage II Reduction (lb/yr)	
	Nitrogen (lb)	Phosphorus (lb)	Nitrogen (lb)	Phosphorus (lb)
County Residential	15,373	2,526	31,877	10,081
Municipal Residential	6,695	692	21,853	5,010
Commercial/Industrial	4,465	384	19,862	3,360
Total	26,534	3,601	73,592	18,451

3.2.2 Economic and Technical Feasibility of Meeting Stage II Goals on Existing Development

The NCDWQ fiscal analysis reported that a portfolio of BMPs would be implemented on existing development in an attempt to meet the Stage II reductions; the analysis assumed that BMPs would not be used in series. The recommended use percentages for each BMP, with corresponding nutrient removal efficiency rates, are shown in Table 3-6.

Table 3-6 Recommended BMP Portfolio for Implementing Existing Development Rules (NCDWQ 2010)

BMP	DWQ Expected Use Proportion	Nutrient Removal Efficiency for Each BMP Type	
		Nitrogen	Phosphorus
Stormwater Wetlands	30%	40%	40%
Bioretention	27%	35%	45%
Infiltration Devices	25%	30%	35%
Buffer Restoration	13%	30%	35%
Grassed Swales	5%	20%	20%

Based on these percentages, Stage I reductions are technically feasible for nitrogen (20 percent) and phosphorus (40 percent). However, the removal efficiencies for each BMP indicate that the Stage II phosphorus reductions (77 percent) are not technically feasible and the Stage II nitrogen reductions (40 percent) can only be achieved using stormwater wetlands. Assuming the NCDWQ BMP use proportions to the estimated 2013 acreage for each land use type results in annual phosphorus load reductions of 10,335 pounds per year, which is 56 percent of the required Stage II reductions. For nitrogen, the NCDWQ BMP use proportions result in an estimated reduction of 67,475 pounds per year which is 91 percent of the required Stage II reductions. Given the limits of technology for NCDWQ-approved BMPs, the Stage II targets are not technically feasible.

To estimate the costs associated with the Stage II nutrient reductions, NCDWQ (2010) first calculates the number of BMPs required to achieve the nutrient reductions and then multiplies that number the by the cost per BMP provided in Wossink and Hunt (2003). However, Cardno ENTRIX notes that this approach does not account for the amount of area available for implementation. For example, based on the median drainage area reported by BMP type (Wossink and Hunt 2003), an implementation area nearly two times the area occupied by existing development would be needed to meet the Stage II requirements. Because the Stage II phosphorus reduction requirements are approximately two times the phosphorus removal efficiencies reported for the more effective BMPs, the implementation of BMPs on the existing developed area only results in approximately half of the required reductions.

As noted earlier, for Stage II NCDWQ assumed the costs were driven solely by phosphorus removal and that nitrogen removal would occur simultaneously at the required amounts. While the Stage II nitrogen reductions are technically feasible, attainment would require implementing approximately 1,000 structural BMPs per year in the upper watershed. Given the amount of time it takes to design, permit, and construct these systems, this implementation rate is not logistically feasible.

Implementing this number of BMPs each year will likely costs more than the $551 million projected in the fiscal analysis for implementation of Stage II on existing development. BMP implementation costs are higher for retrofitting existing development compared to implementation on new development. NCDWQ (2010) applied a BMP cost adjustment factor ranging from 1 to 7 depending on the BMP type based on data from Schueler et al. (2007) to account for increase in costs of BMP retrofits relative to new development. Given the high percent reduction requirements for Stage II and site specific constraints, the cost adjustment factors may be much higher.

Cardno ENTRIX used the USEPA Municipal Preliminary Screener (Section 4.3) to calculate the financial impact of the Stage II Rules using the cost estimates provided by NCDWQ. The projected cost of $945 million ($2010) ranks as a “Large Impact” to the affected communities with each household contributing approximately $1,400 per year. This analysis assumes the local households will contribute to nutrient reductions from existing development and wastewater treatment plant upgrades. While USEPA recommends further analysis for an impact ranking “Mid-range” or “Large,” this Preliminary Screener indicates that the Stage II requirements would be financially burdensome given the number of households in the watershed and median household income of the community.

3.2.3 Local Feasibility Information for Existing Development Nutrient Reductions

As indicated in Section 3.2.2, the Stage II reduction goals for existing development are not technically, logistically, or financially feasible given the assumptions provided by NCDWQ (2010). This section briefly summarizes additional sources of information that indicate that the Stage II requirements (40 percent reduction in total nitrogen loading and 77 percent reduction in total phosphorus loading) are not feasible.

For example, Hunt et al. (2012) warns that “30% or greater reduction requirements are going to often be impossible without converting large amounts of impermeable surfaces and space to permeable green landscapes.” The study includes several example subwatersheds and estimates the amount of nutrient reductions that could be achieved if every conceivable BMP were implemented. Overall, the study indicated limited opportunities for BMP utilization due to a lack of space and high imperviousness in highly urbanized settings (Hunt et al. 2012). The greatest opportunities for BMP implementation were in institutional areas, which often have large amounts of open space, and in commercial/industrial areas given the large area of parking lots. The feasibility of retrofitting residential areas was correlated with the development’s age: older development typically had more open space, narrower roadways, and more permeable driveways. Hunt et al. (2012) found that regional BMPs were more cost-effective than site-specific BMPs because the cost per unit of removal decreases as more area is treated. However, regional BMPs may be more difficult to permit than site specific BMPs. Hunt et al. recommends that this information be used to target BMPs on land uses that typically offer the conditions for higher nutrient load reduction (2012).

Part of determining the feasibility of NCDWQs reduction requirements involves selecting the optimum mix of BMPs that will achieve the greatest reduction for the least cost. Hunt et al. (2012) illustrates the diminishing returns of BMPs in the Ellerbe Creek Watershed which is one of the fiver upper tributaries to Falls Lake. Figure 3-1 taken from Hunt et al. (2012) was created by first sorting the potential BMPs that could be installed in the watershed by the lowest dollar per pound of nitrogen removed, and then plotting the cumulative percent reduction of total nitrogen in the watershed versus costs. While Ellerbe Creek is only part of the Falls Lake Watershed, it is a reasonable representation of opportunities for nutrient reduction in highly urbanized areas in the watershed.

For the Ellerbe Creek example, a cumulative percent reduction in total nitrogen loading of approximately 8.5 percent is the maximum achievable with reasonable returns on investment (the return or nutrient reduction decreases significantly despite increasing costs). In other words, for each additional dollar spent over approximately $4 million in this watershed, fewer nutrients are removed relative to the money spent. The maximum cumulative percent reduction in this watershed is ten percent for total nitrogen, but the costs to gain the additional 1.5 percent reduction was over $8 million which is twice the amount spent to gain the original 8.5 percent. An important consideration for implementation is whether or not the costs are worth the additional removal of nutrients.

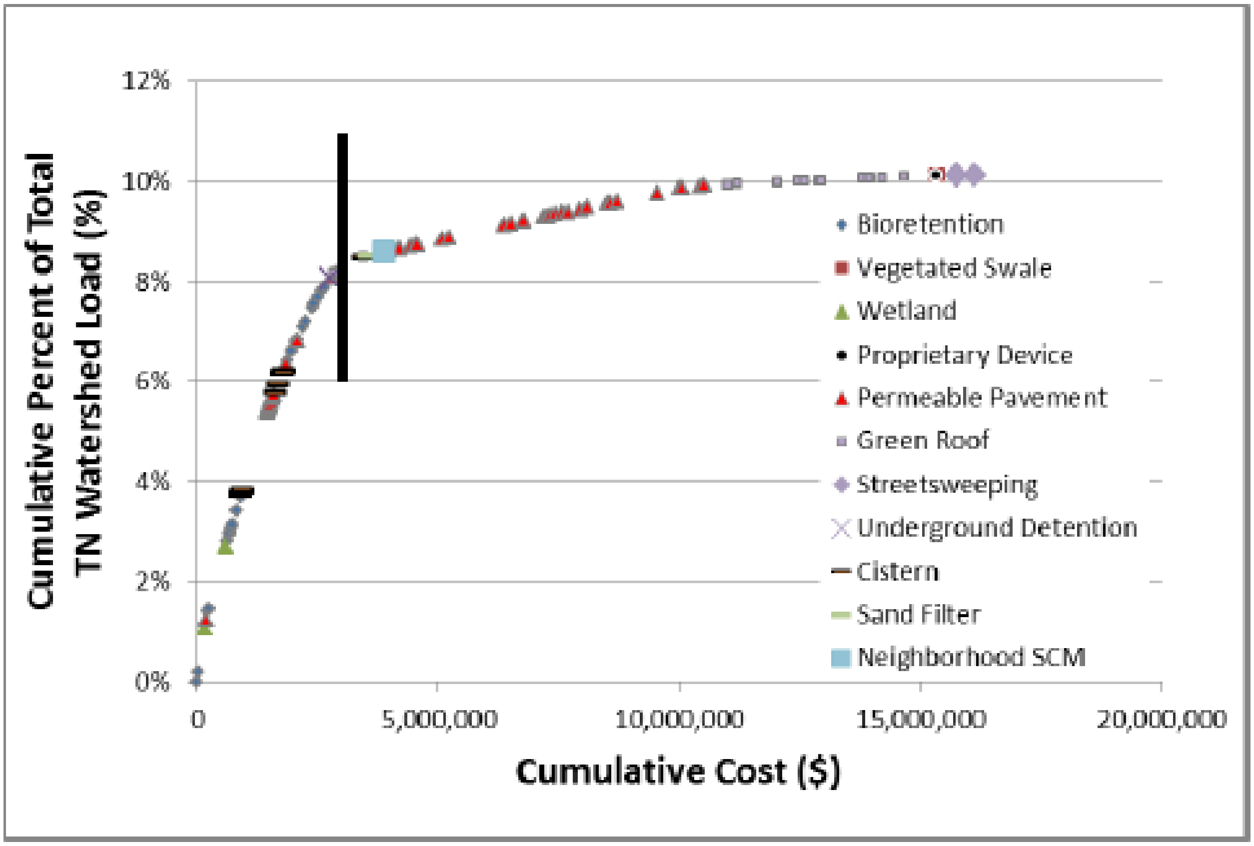


Figure 3-1 Cumulative Nitrogen Load Reduction versus Cumulative Costs in Ellerbe Creek Watershed (Hunt et al. 2012)

Hunt et al. (2012) found similar results for total phosphorus. In the Ellerbe Creek watershed, the estimated annual total phosphorus load was 718 pounds per year. Cost effective phosphorus load reductions began to taper off at approximately 80 kg per year at a cumulative cost of $4 million. Thus the cumulative percent reduction for a reasonable return on investment was approximately 11.1 percent. Additional expenditures of $12 million only increased the cumulative reduction to about 84 kg/yr for a cumulative percent reduction of 11.6 percent.

While Hunt et al. (2012) conclude that BMP retrofits are feasible in terms of meeting the initial Jordan Lake reduction requirements (8 percent for nitrogen and 5 percent for phosphorus), these local studies indicate that the Stage II requirements for the Falls Lake watershed (40 percent for nitrogen and 77 percent for phosphorus) are not feasible with current technology. The Ellerbe Creek Watershed Management Improvement Plan developed for the City of Durham confirmed these findings (Brown and Caldwell 2010).

Table 3-7 and Table 3-8 provide supporting tables from the Hunt et al. (2012) report. Table 3-7 shows the six BMPs identified as the most cost-effective for total nitrogen and total phosphorus reduction. Table 3-8 lists the percent mass reductions achievable with these technologies. While there are BMPs capable of meeting the Stage II nitrogen reductions, none of the technologies meet the Stage II phosphorus reductions. Furthermore, treating every acre of existing development will not be technically feasible given site constraints such as topography, imperviousness, soil type, etc.

Table 3-7 Most Cost Effective BMPs for Total Nitrogen and Total Phosphorus Reductions (from Hunt et al. 2012)

Most Cost Effective SCMs With Respect to TN Removal	Most Cost Effective SCMs With Respect to TP Removal
Daylighting Downspouts	Level Spreader/Filter Strips
Level Spreader/Filter Strips	Streetsweeping
Bioretention	Daylighting Downspouts
Stormwater Wetlands	Stormwater Wetlands
Water Harvesting	Vegetated Swales
Sand Filters	Bioretention

Table 3-8 Removal efficiencies of BMPs (from Hunt et al. 2012)

SCM Type	Mass Reduction (%)		
	TSS	TN	TP
Bioretention	85	55	60
Blue Roof	65	30	50
Daylight Downspouts	85	60	45
Dry Detention Pond	65	15	10
Green Roof	0	20	20
Level Spreader	85	60	45
Permeable Pavement	70	40	70
Proprietary BMP	30	10	5

SCM Type	Mass Reduction (%)		
	TSS	TN	TP
Rainwater Harvesting	75	75	75
Sand Filter	85	40	45
Street Sweeping	50	0	40
Underground Detention	65	30	45
Vegetated Swale	75	0	50
Wet Pond	70	30	45
Wetland	65	50	65

In addition, NCDWQ does not currently have approved nutrient load accounting methods developed for three of the most cost effective BMPs identified by Hunt et al. (2012). Accounting methods are expected in late 2013 for daylighting downspouts and grassed swales with various designs, and in late 2014 for street sweeping. Given their relative cost-effectiveness for total nitrogen and total phosphorus reduction, further investigation is encouraged for their inclusion in the Stage I and Stage II nutrient management plans to be developed by each local government.

3.3 Agriculture

The Falls Lake Nutrient Management Strategy requires that all persons engaging in agricultural activities in the watershed (crops, horticulture, livestock, and poultry) achieve Stage I nutrient reductions by the end of 2020 and Stage II nutrient reductions by the end of 2035. Stage I requires nutrient reductions of 20 percent for nitrogen and 40 percent for phosphorus relative to the baseline year of 2006. Stage II of the Strategy requires reductions of nitrogen and phosphorus loading of 40 percent and 77 percent respectively, from the baseline year of 2006.

3.3.1 Overview of the NCDWQ Fiscal Analysis for Implementing Nutrient Reductions in Agricultural Areas

NCDWQ estimates there were 29,225 acres of pasture and 55,459 acres of cropland in the watershed in 2006 (the baseline year.) One acre of pasture contributes an estimated seven pounds of nitrogen and one pound of phosphorous each year; one acre of cropland contributes an estimated 13 pounds of nitrogen and three pounds of phosphorous each year. Given these assumed values, the 2006 baseline loads are presented in Table 3-9 below. The amount of reduction required by the end of Stage II for the entire watershed is also presented.

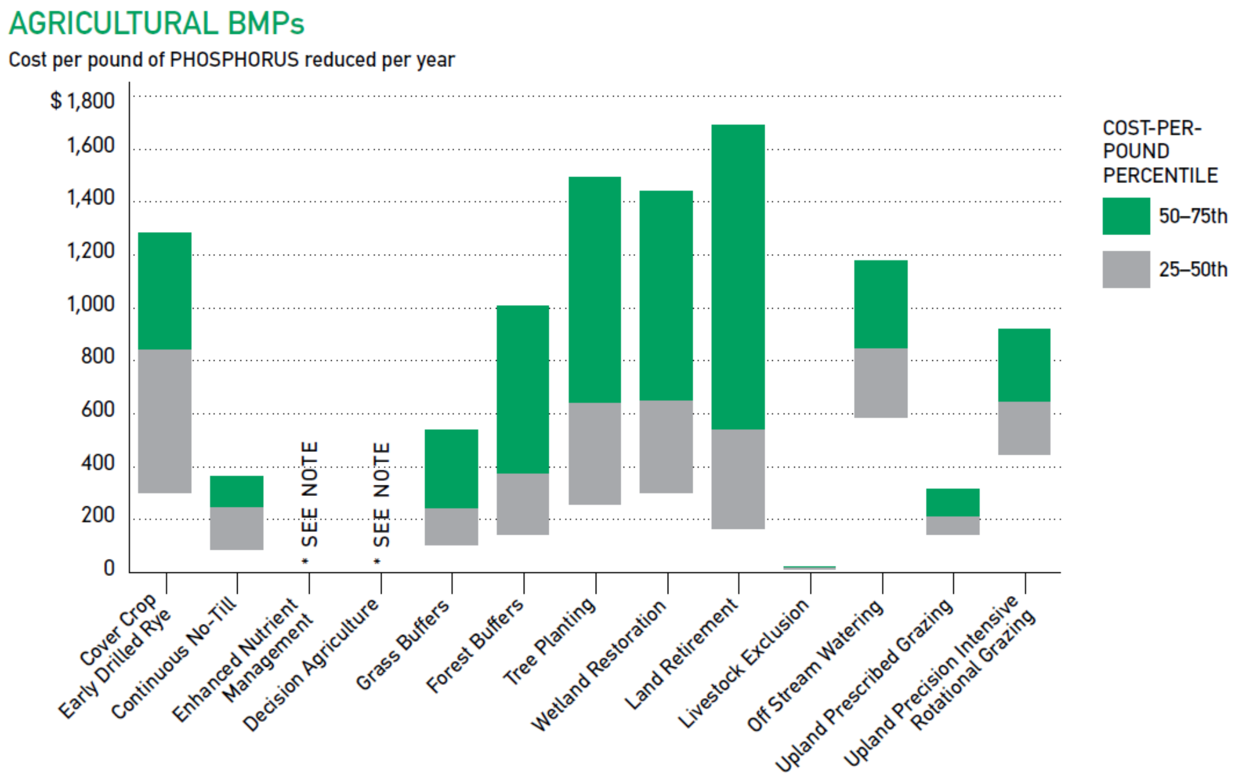
Table 3-9 Baseline Loading from Agriculture and Stage II Reduction Requirements

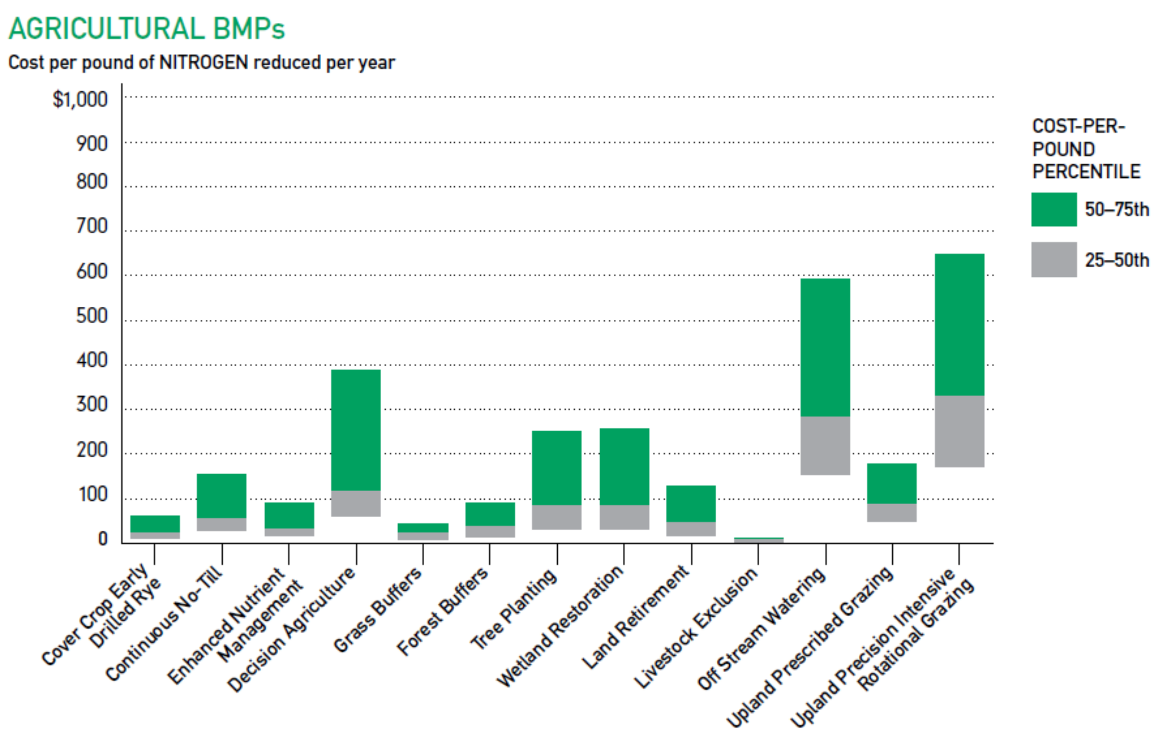
Land Type	Acres	Baseline Loading Rate (lbs/year)		Stage II Reduction Needs (lbs/yr)	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Pasture	29,225	204,575	29,225	81,830	22,503
Crop	55,459	720,967	166,377	288,387	128,110
Total	84,684	925,542	195,602	370,217	150,614

NCDWQ (2010) assumes in its fiscal analysis that all nutrient reductions will occur on pasture land. The report indicates that additional reductions from cropland are not feasible given current compliance with the Neuse Agriculture Rule, which required a 30 percent reduction in nitrogen loading relative to a 1991-1995 baseline (15A NCAC 2B .0238). The cost of compliance with Stage II is $6.1 million (NCDWQ 2010).

The NCDWQ fiscal analysis assumes that the required nutrient reductions calculated from all agricultural areas will be satisfied using a single BMP type on pasture land only. The BMP option selected by NCDWQ for agriculture is the stream protection system which includes livestock exclusion, alternative water supply, restored riparian buffer, and hardened stream crossings. The State assumes a nitrogen reduction of 50 percent for this practice. With respect to phosphorus, the fiscal analysis states, “While the rule requires specific reductions in phosphorus as well, the current available accounting criteria are qualitative in nature and would not allow for meaningful cost estimation (NCDWQ 2010).”

This assumption raises an important question regarding the ability to estimate compliance costs when the removal efficiency for phosphorus is unknown for this BMP. A study conducted by RTI (2012) for the Chesapeake Bay Program shows that phosphorus removal for agricultural sources is more costly than nitrogen removal (Figure 3-2). Given the relative costs of removing total nitrogen and total phosphorus, it is reasonable to assume that the costs to meet the Stage II reductions from agriculture will be higher than the estimates provided by NCDWQ.





NOTE: The values for these BMPs are not presented because they do not have associated phosphorus reductions.

Figure 3-2 Cost estimates for TN and TP removal on agricultural lands with various BMPs (RTI 2012)

As with the existing development analysis (Section 3.2), the assumptions used by NCDWQ for agriculture are inconsistent with features of the watershed. For example, if all necessary Stage II reductions for agriculture (cropland and pasture) are achieved only on pasture land using the stream protection system, nitrogen loading from pasture would need to be reduced by 181 percent and phosphorus loading would need to be reduced by 515 percent. In other words, if all acres of pasture (29,225 acres) were equipped with the stream protection system, nitrogen loading would be reduced by 102,288 pounds per year. However, Stage I requires a reduction of 185,108 pounds of nitrogen per year and Stage II requires a cumulative reduction of 370,217 pounds of nitrogen per year. Thus, the option presented by NCDWQ only achieves 55 percent of the reduction required for Stage I and 28 percent of the reduction required for Stage II.

The limitation of this BMP for achieving the required nutrient reductions is the length of stream present in pastured areas. NCDWQ indicates that 431.7 miles of stream protection systems would be necessary to achieve the Stage II goals for nitrogen and reports stream density factor of 2.27 miles of stream per square mile of land area. Given that the area of pasture is 29,225 acres, or 45.7 square miles, the length of stream on pasture land is approximately 103.7 miles. There is not enough stream miles on pasture land to accommodate the required 431.7 miles of stream protection systems needed to achieve the Stage II nitrogen reductions.

Given that the stream protection system BMPs on pastureland are not capable of achieving the Stage II nitrogen reductions (40 percent), it is unlikely they will be able to achieve the Stage II phosphorus reductions either (77 percent). Because the reductions cannot be met, the cost estimates must be considered as the cost of attempting to achieve the reductions. With the current approved technology, the feasibility of meeting the Stage II reductions is unknown and therefore the cost is unknown as well.

3.4 Additional Uncertainties in the Fiscal Analysis

There are several additional sources of uncertainty regarding the implementation costs for Stage II reported by NCDWQ (2010). These are described briefly in this section.

3.4.1 Presentation of Costs

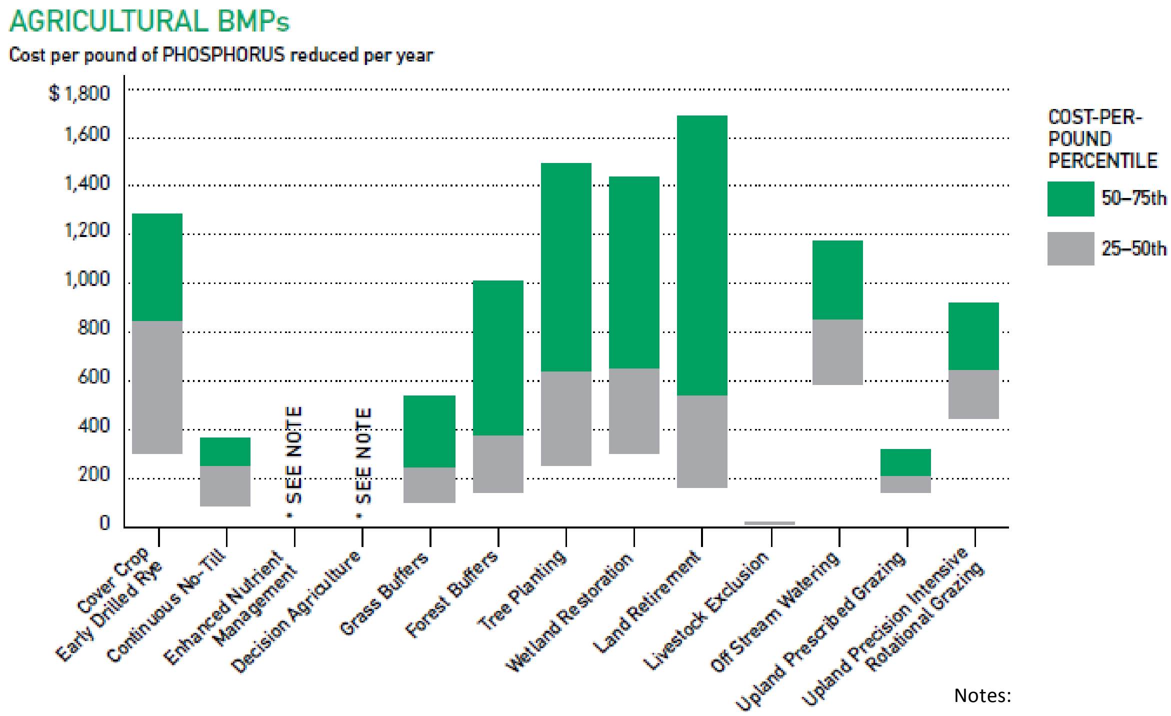
Representing future costs in present value can make costs appear more palatable, even though the actual costs are theoretically equal. The NCDWQ (2010) fiscal analysis presents the costs of Stage II in 2010 dollars as $945.8 million. However, the same costs presented in 2021 dollars (the year Stage II will begin) is approximately $1.86 billion. In other words, costs occurring in the future can appear smaller when reported in present (or past) dollar values. For planning purposes, it is important for the UNRBA to consider the presentation of costs: the affected parties should not expect that $946 million in 2021 will cover the costs to implement Stage II reductions.

3.4.2 Variability in Treatment Costs

Cardno ENTRIX compiled additional information to assess the implementation costs associated with Stage II of the Falls Lake Nutrient Management Strategy. Each analysis indicates a wide range in projected costs per pound removed.

3.4.2.1 Chesapeake Bay Economic Analysis

The Chesapeake Bay study (RTI 2012) provides comparisons of the cost per pound removal for several BMPs that treat either agricultural or urban areas. The cost estimates do not include retrofitting, planning, or regulatory costs. For example, the annual costs for urban stormwater BMPs range from approximately $100 per pound of phosphorus to $85,000 per pound of phosphorus, depending on the type of BMP selected. Annual nutrient reduction cost for agriculture typically ranges in costs from $100 per pound to $1,700 per pound for phosphorus. Figure 3-3 shows the comparisons by BMP type and illustrates the variability in costs of phosphorus removal between sectors and within each sector for this study.



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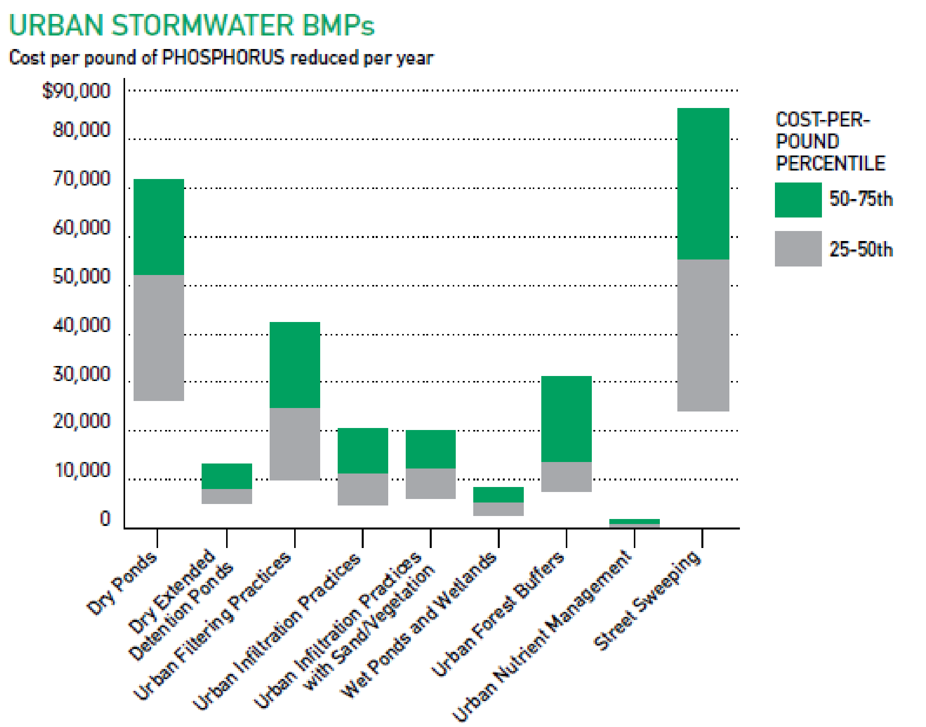

The reported value ranges cover all areas available for BMP application, including areas where the cost per pound removed is relatively high (i.e., not cost-effective) and the BMPs are therefore less likely to be implemented.

* The values for Enhanced Nutrient Management and Decision Agriculture are not present because they do not have associated phosphorus reductions.

In constructing the range of BMP opportunities, we incorporated early drilled rye as the only cover crop option because, according to the available estimates, it accomplishes the most reductions for the least cost compared to other cover crops. However, in parts of the watershed, this BMP is not preferred because of its invasive characteristics.

Figure 3-3 Range in Phosphorus Removal Costs for Agriculture and Existing Development (from RTI 2012)

3.4.2.2 Nutrient Scientific Advisory Board Estimates

The Nutrient Scientific Advisory Board (NSAB 2012) reports varying costs per pound for nutrient removal for several BMPs available for use in urban areas (Table 3-10). The cost estimates do not include land acquisition or operation and maintenance costs. For nitrogen, the cost per pound ranges from $8 to $7,400. For phosphorus, the cost per pound ranges from $8 to $54,000.

Table 3-10 Range in Costs for Urban BMPs (NSAB 2012)

Practice	**$/lb N removed**	**$/lb P Removed**
Level Spreader/Filter Strip	$8 - $200	$8 - $300
Constructed Wetland	$18 - $236	$76 - $1,600
Dry Detention	$50 - $440	$34 - $3,900
Bioretention with IWS	$80 - $670	$300 - $54,000
Bioretention w/o IWS	$85 - $850	$320- $6,700
Rainwater Harvesting	$90- $1,000	$170 – $8,200
Grassed Swale	$146 - $2,200	$164 - $1,700
Wet Detention	$220 - $5,300	$100 - $7,300
Sand Filter	$630 - $2,900	$2,200 – $42,800
Permeable Pavement	$2,000 - $3,000	$7,300 – 26,500
Green Roof	$4,900 - $7,400	$35,400 - $53,100

3.4.2.3 Cardno ENTRIX Analysis

Cardno ENTRIX conducted a Monte Carlo analysis (USEPA 1997) using the ranges of costs provided in the Chesapeake Bay (RTI 2012) and NSAB (2012) report to provide an estimate of the range of per pound removal costs for phosphorus. This analysis uses the minimum, maximum, and most likely values of phosphorus removal costs ($8, $54,000, and $3,900, respectively) to predict the probability of costs as well as an upper and lower bound. The analysis focuses on phosphorus because it is the more costly of the two primary nutrients to reduce. Figure 3-4 uses the agricultural costs from the RTI study and the urban stormwater BMP costs from NSAB 2012 to demonstrate the range in cost per pound of phosphorus removed for agriculture and existing development and illustrates why nutrient trading may be feasible to reduce the overall costs of reducing nutrient loading to Falls Lake. If the RTI study had been selected for the urban stormwater BMP costs, the results would be more variable. The NSAB values were selected because they reflect local information.

Figure 3-4 illustrates the large range of costs per pound of phosphorus removal and shows that the uncertainty, or range of costs, is much greater for existing development than for agriculture. It is important to note the difference in the X-axis scales in each of the graphs. The median annual cost per pound to reduce phosphorus from agriculture is approximately $627 per pound with an upper bound of the 90 percent confidence interval falling under $1,200 per pound. On the other hand, the median annual cost per pound to reduce phosphorus from existing development is $9,800 per pound with the 90 percentile confidence interval falling at $28,000 per pound.

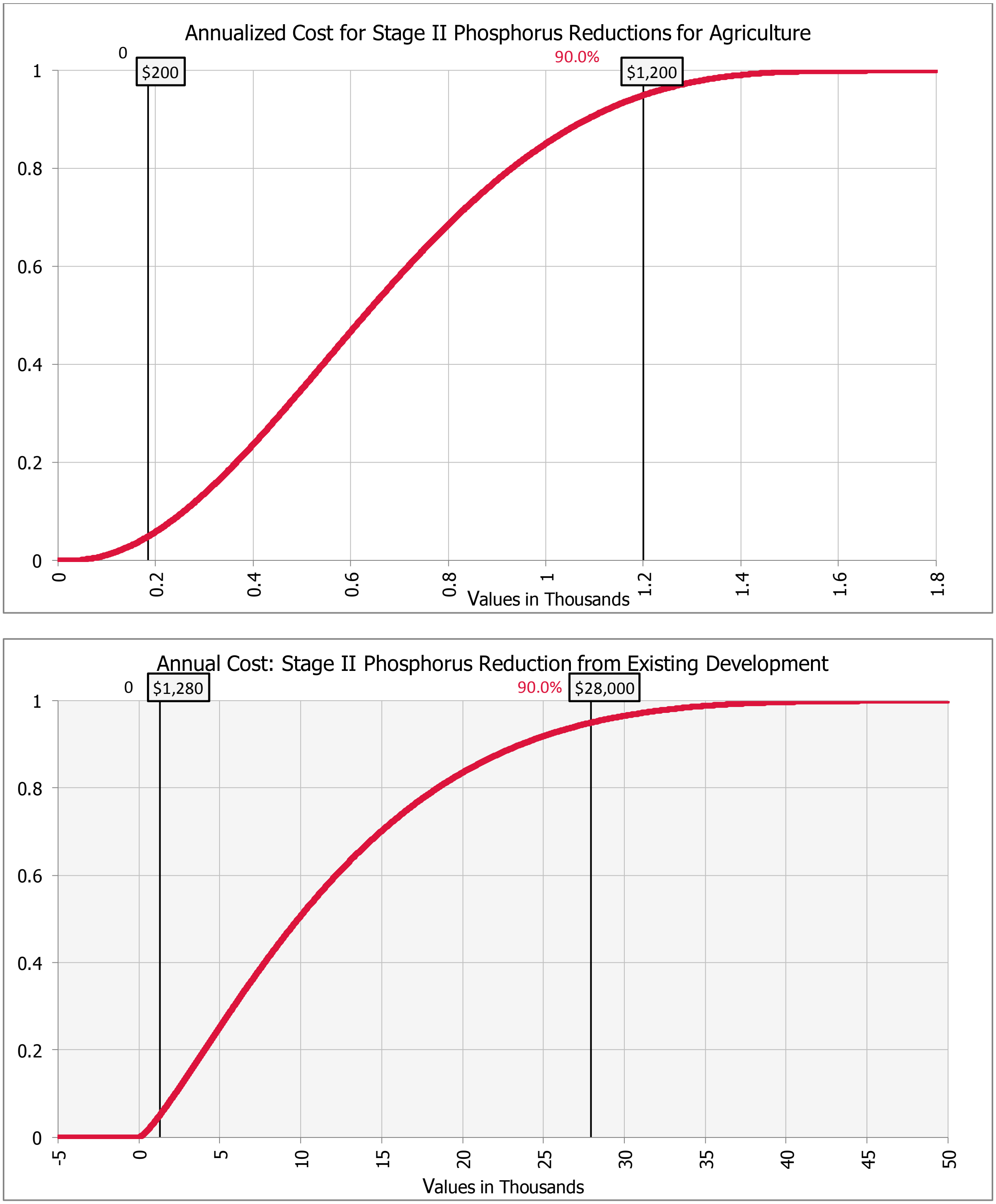

Figure 3-4 Cumulative Probability Functions for the Annualized Costs for Stage II Reductions for Agriculture and Existing Development

3.4.2.4 Additional Local Studies

Local researchers suggest that uncertainties associated with cost estimates are due to many factors. For example, Wossink and Hunt (2003) report that BMP costs are primarily driven by the size of the drainage area to be treated. Some BMPs are inherently designed to treat larger drainage areas, indicating a correlation between the selection of BMP type and the size of the drainage area to be treated. Information on the number of sites available for each BMP type is therefore required to choose a least-cost portfolio of BMPs for a given watershed.

Hunt et al. (2012) report that BMPs designed to treat larger areas are more cost-effective than site specific BMPs. The NSAB (2012) reports a high range in costs based on the amount of imperviousness in the drainage area. The actual total cost of Stage II reductions will be greatly affected by the availability of large-scale drainage areas, the amount of imperviousness, and the BMPs chosen to treat those areas.

3.5 Summary of Stage II Feasibility

In 2010, NCDWQ published the fiscal analysis of the Falls Lake Nutrient Management Strategy (NCDWQ 2010). The report concluded that Stage I of the Strategy would cost approximately $604 million ($2010) in implementation costs and Stage II would cost approximately $946 million ($2010). Cardno ENTRIX reviewed the feasibility and cost estimates for the Stage II implementation based on the NCDWQ assumptions as well as additional sources of information. Based on the Cardno ENTRIX review, the Stage II loading targets are not technically, logistically, or financial feasible:

> The Stage II phosphorus reduction goal of 77 percent is beyond the limits of current technology. Meeting the Stage II nitrogen reduction goal of 40 percent will require treating nearly every acre of existing development. Given site specific constraints (topography, soil type, etc.) treating every acre of existing development is not technically feasible. In addition, these percent reductions rely heavily on a limited number of BMPs.

> Approximately 1,000 BMPs will need to be installed during each year to achieve compliance with Stage II nitrogen targets. Designing, permitting, and installing this number of BMPs in the watershed is not logistically feasible. Implementing this number of BMPs each year will likely cost more than the $551 million projected in the fiscal analysis due to the high percent reduction requirements and site specific constraints.

> Local studies conducted in North Carolina indicate that watersheds relying on retrofitting existing development to meet nutrient reduction goals will likely not be able to reduce nutrient loading by more than 20 percent for total nitrogen or 50 percent for total phosphorus. In an example watershed (Ellerbe Creek), cumulative nutrient reductions greater than 10 percent for nitrogen and 12 percent for phosphorus were not achievable given the constraints in the watershed including lack of space and high imperviousness (Hunt et al. 2012).

> NCDWQ does not currently have approved nutrient load accounting methods for three of the most cost effective BMPs identified by Hunt et al. (2012).

> The NCDWQ (2010) fiscal analysis acknowledges that cost effective practices for reducing nutrient loading from existing development may not be available today, but that new, more cost-effective technologies and accounting procedures would likely be developed during the Stage I period that would help the local governments meet the Stage II requirements. If new technologies and credit accounting tools are not developed over the next several years, achieving the Stage II goals will not be technically feasible.

> While agriculture is estimated to contribute the largest percentages of baseline nutrient loads according to the modeling performed by NCDWQ, they have the lowest expected implementation costs of any sector. The NCDWQ (2010) fiscal analysis limits the amount of reductions achievable by agriculture by assuming only one BMP system will be applied to pasture lands. While the fiscal

analysis indicates that the Stage II nitrogen targets are attainable for agriculture, there are not enough stream miles available for implementation to meet this goal.

> The NCDWQ (2010) fiscal analysis does not address the significant phosphorus reductions required of the agricultural community: "While the rule requires specific reductions in phosphorus as well, the current available accounting criteria are qualitative in nature and would not allow for meaningful cost estimation." Given that the stream protection BMPs on pastureland are not capable of achieving the Stage II nitrogen reductions, it is unlikely they will be able to achieve the Stage II phosphorus reductions which are nearly two times higher.

> In other parts of the country, the agricultural community is able to earn nutrient credits using BMPs that are generally more cost effective than those implemented on existing development. In North Carolina, many of these BMPs do not have accounting measures in place to allow agriculture to earn nutrient credits. Increasing the number and type of BMPs that the agricultural community can use to earn credits may reduce overall implementation costs in the watershed.

> The USEPA Municipal Preliminary Screener indicates that the Stage II loading targets will cause a "Large Impact" to the community in the Falls Lake watershed. The projected cost of $945 million ($2010) will require each household to contribute approximately $1,400 per year to reduce nutrient loading from existing development and wastewater treatment plants. This preliminary ranking indicates that additional studies are needed to confirm that the rules are not financially feasible.

In summary, a review of the available information indicates that meeting the Stage II load reduction targets is not technically, logistically, or financial feasible. Additional sources of information including local and regional studies indicate that treatment costs are highly variable and are generally more expensive on existing development compared to agriculture. The analyses presented in this section support the need for a re-examination of the Stage II rules as described in Section 6.

4 Linking Water Quality in Falls Lake to Designated Uses

An essential component of the framework for re-examining Stage II of the Falls Lake Nutrient Management Strategy is a tool that links nutrient loads to lake water quality and attainment of (or impacts to) designated uses. Cardno ENTRIX used the available physical, chemical, and biological data to develop a screening level spreadsheet tool (the Falls Lake Framework Tool) that establishes these linkages using existing data. The Tool also provides estimates of implementation costs based on the cost per pound of phosphorus reduction. As future monitoring and modeling studies proceed, the tool may be revised to incorporate new information.

This section of the TM describes in more detail how the various components of the spreadsheet tool were developed. Figure 4-1 illustrates how the various components of the Tool link nutrient inputs and predicted lake water quality to the impacts on designated uses, attainment of water quality criteria, and implementation costs. First, baseline nutrient loads and management scenarios are input to the Tool. Equations developed for the US Army Corps of Engineers (USACE) BATHTUB model (Section 4.1.1) are used to estimate total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* concentrations in the lake. Next, regression equations based on data collected in Falls Lake (Section 4.1.3) are used to estimate inlake concentrations of total organic carbon (TOC), total suspended sediment (TSS), turbidity, and dissolved oxygen (DO). Finally, simulated inlake water quality is compared to water quality criteria and linked to designated uses based on existing information (Section 4.2). The output from the Tool includes implementation costs for the selected management scenario as well as impacts to designated uses.

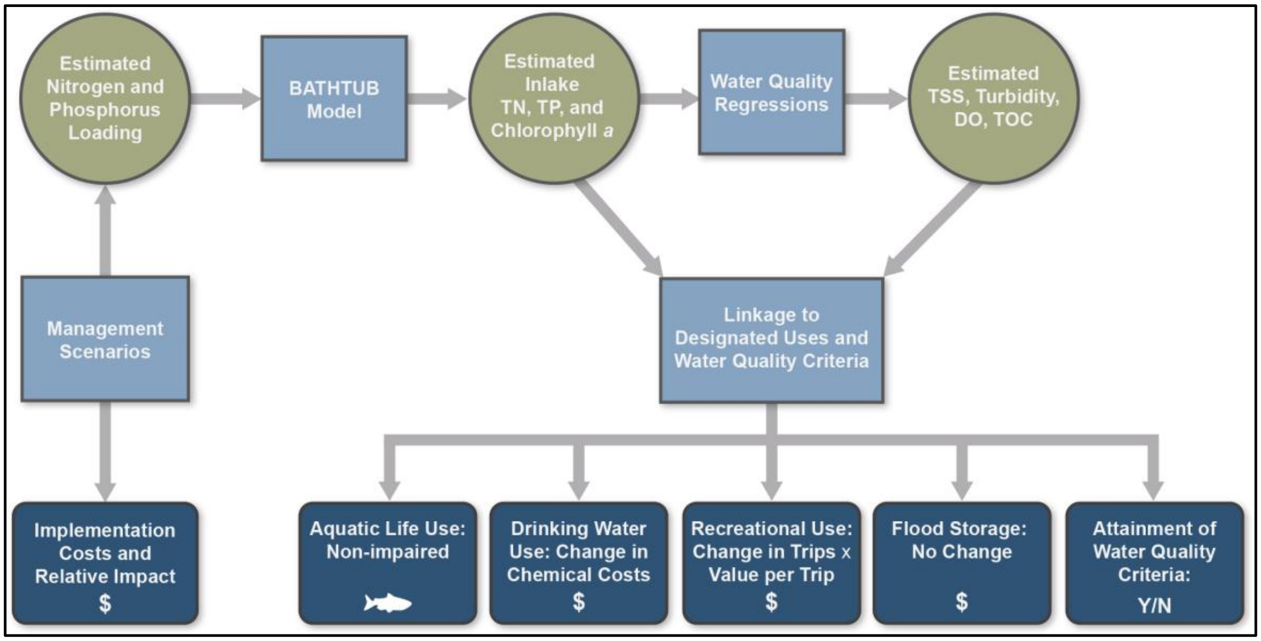

Figure 4-1 Graphical Illustration of the Falls Lake Framework Tool

4.1 Supporting Models

4.1.1 Eutrophication Model

The foundation of the Falls Lake Framework Tool is a eutrophication model that links nutrient loading to inlake water quality for each of the three main lake segments that are created by bridge crossings at I-85 and Highway 50. Nutrient loads and bathymetric information for each lake segment are described in detail in the Task 3 TM (Cardno ENTRIX 2013a).

To predict the impacts of nutrient loading on lake water quality, Cardno ENTRIX applied the US Army Corps of Engineers BATHTUB model (Walker 1999) to predict mean growing season (May through September) total nitrogen, total phosphorus, and chlorophyll *a* concentrations based on the amount of nutrient loading delivered to each lake segment. The models for each lake segment were adjusted using the BATHTUB calibration factors to match simulated inlake concentrations to those observed during the baseline year (2006).

Points of interest for were identified in each lake segment to identify the monitoring stations used for calibration. For example, the chlorophyll *a* compliance point for Stage II of the Falls Lake Nutrient Management Strategy is station NEU013B, which is just downstream of I-85. Due to the high turbidity levels observed west of I-85, chlorophyll *a* concentrations in the upstream segment are often lower than those observed at the compliance point. Nutrient concentrations at the compliance point are representative of the outflow from the segment west of I-85. Because the point of interest is near I-85 in the upper lake, the BATHTUB model developed for the west of I-85 segment is calibrated to water quality concentrations observed at NEU013B. Another point of interest is near the City of Raleigh water treatment plant intake. The BATHTUB model for the segment between Highway 50 and the dam was calibrated to data collected near the dam. For the segment between I-85 and Highway 50, stations located near Highway 50 (Table 4-1), at the downstream end of that segment, were selected for model calibration.

Mean growing season concentrations of total phosphorus, total nitrogen, and chlorophyll *a* were calibrated to water quality stations located near each of these points of interest. The database compiled during Task 2 provides the observations needed for calibration. The Tool was calibrated to match observed loads and lake water quality for the baseline year (2006) to provide a basis for evaluating the Falls Lake Nutrient Management Strategy. Because the Tool was calibrated to a single year, application of these models and calibration factors for other years would likely not result in simulated values matching those observed under different hydrologic conditions. Future revisions to the Falls Lake Framework Tool may include more robust statistical analyses and represent average conditions for the lake, rather than focus on a single baseline year as specified in the Strategy. In addition to predicting mean growing season chlorophyll *a* concentration, the BATHTUB model also provides the percent exceedance for specific chlorophyll *a* concentrations based on the simulated mean and a coefficient of variation. .

The BATHTUB model allows the user to select one of several equations to simulate growing season total nitrogen, total phosphorus, and chlorophyll *a* concentrations. Table 4-1 lists the empirical methods selected from the BATHUB modeling options for each lake segment. The table also includes the calibration factors applied to the nitrogen and phosphorus models and the simulated chlorophyll *a* concentrations. Increasing the calibration factors for nitrogen and phosphorus decreases the simulated mean concentrations because the calibration factors for nutrients are applied to the sedimentation rate (i.e., an increase in the calibration factor increases the sedimentation rate which decreases the simulated concentration). The calibration factor for chlorophyll *a* is applied directly to the simulated concentration, so increasing the calibration factor for chlorophyll *a* increases the simulated chlorophyll *a* concentration.

The empirical equations used in the BATHTUB model are based on data collected in approximately 300 USACE reservoirs. The BATHTUB model uses calibration factors to allow the user to adjust the simulations to local conditions. A calibration factor of 1 results in no adjustment to the values simulated by the BATHTUB model.

Table 4-1 Summary of BATHTUB Empirical Formulations and Calibration Factors for Falls Lake Framework Tool

Segment (representative stations)	Phosphorus Model (Calibration Factor)	Nitrogen Model (Calibration Factor)	Chlorophyll *a* Model (Calibration Factor)	Coefficient of Variation for Chlorophyll *a*
West of I-85 (NEU013B)	Second order decay rate function (1.35)	Second order available N (2.70)	Jones and Bachman (0.94)	0.161
I-85 to Hwy 50 (NEU19E)	Second order decay rate function (1.0)	Second order available N (0.75)	Jones and Bachman (1.8)	0.111
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	Second order decay rate function (1.0)	Second order available N (1.65)	Jones and Bachman (1.8)	0.251

4.1.2 Description of the Eutrophication Component of the Spreadsheet Tool

The Falls Lake Framework Tool has a single input tab for the user ("Input") which has a tab color of green. On this tab, the user selects assumptions for calculating the baseline loading to the lake as well as the nutrient management scenario and basis of the cost estimates.

Each of the output tabs for the Tool have a color of purple. These include a "Summary of Loading" to the lake, estimated water quality "Estimated WQ", impacts to designated uses "Impacts to DU," and results of the Municipal Screener "Muni Screener." These inputs and outputs are described more fully the remainder of this section.

4.1.2.1 Inputs to the Falls Lake Framework Tool

The Falls Lake Framework Tool allows the user to specify the assumption used for the baseline loads using two options (Cell A3 on the "Input" tab of the workbook). These options only apply to loading from the five upper tributaries (Eno River, Flat River, Little River, Ellerbe Creek, and Knap of Reeds Creek).

Baseline loading from the other tributaries is calculated from observed mean annual flows and average concentrations because of data limitations for these tributaries. The selected stations, concentrations, and flows for estimating loading from these tributaries are summarized in the Task 3 TM. Loading to each segment from atmospheric deposition also varies for each baseline loading assumption based on the EFDC modeling input files described in the Task 3 TM.

The “Rules” option for estimating baseline loads for the upper five tributaries back calculates the baseline nutrient loads based on the Falls Lake Nutrient Management Strategy which specifies the Stage II allowable loading and required percent reductions. Table 4-2 summarizes the nitrogen and phosphorus loading to each lake segment using this assumption. The “Rules” option was used to evaluate the impacts of the Falls Lake Nutrient Management Strategy in terms of required load reductions, impacts to designated uses, and fiscal impacts.

Table 4-2 Summary of Nutrient Loading to the Falls Lake Segments (Loading Assumption=Rules)

TN Loading Summary by Segment (lb/yr)	West of I-85	I-85 to Hwy 50	Hwy 50 to dam
Watershed Loading	1,096,667	73,035	137,302
Loading from Upper Segment	-	827,274	713,660
Loading from atmospheric deposition	23,473	53,900	30,427
Total	1,120,140	954,208	881,390
TP Loading Summary by Segment (lb/yr)	**West of I-85**	**I-85 to Hwy 50**	**Hwy 50 to dam**
Watershed Loading	152,174	12,692	7,804
Loading from Upper Segment	-	82,272	39,695
Total	152,174	94,964	47,500

The "2006 Observed" option calculates the baseline nutrient loading based on observed flows and concentrations for the baseline year. This option was used to calibrate the BATHTUB models to observations collected in 2006 using the models and factors specified in Table 4-1. For the upper five tributaries, nutrient loads were calculated using the USGS LOADEST tool described in the Task 3 TM. Table 4-3 summarizes the loading to the lake using the option.

Table 4-3 Summary of Nutrient Loading to the Falls Lake Segments (Loading Assumption=2006 Observed)

TN Loading Summary by Segment (lb/yr)	West of I-85	I-85 to Hwy 50	Hwy 50 to dam
Watershed Loading	765,361	56,236	137,302
Loading from Upper Segment	-	569,962	506,702
Loading from atmospheric deposition	29,395	67,500	38,105
Total	794,756	693,697	682,108
TP Loading Summary by Segment (lb/yr)	**West of I-85**	**I-85 to Hwy 50**	**Hwy 50 to dam**
Watershed Loading	122,501	9,773	7,804
Loading from Upper Segment	-	58,606	28,000
Total	122,501	68,379	35,804

The Falls Lake Framework Tool also allows the user to specify various nutrient reduction strategies (Cell A6 on the “Input” tab). The options include the baseline scenario (zero percent reductions), Stage II reductions (40 percent for nitrogen and 77 percent for phosphorus), or user specified reductions that are input into cells G6 and H6 on the “Input” tab. The selected nutrient reduction scenarios are applied to the baseline loads from the upper five tributaries. Regardless of the management scenario selected, the watershed loading to tributaries that drain downstream of I-85 remain at baseline levels. Future revisions to the Tool may alter this assumption as needed. For example, if the Loading Assumption is “Rules” and the nutrient management scenario is “Stage II,” nutrient load reductions required for the upper watershed are 438,667 pounds of nitrogen and 8,369 pounds of phosphorus. There is no change in loading for the tributaries draining to the segments downstream if I-85.

4.1.2.2 TN, TP, and Chlorophyll a Output from the Falls Lake Framework Tool

The eutrophication model in the Falls Lake Framework Tool predicts growing season average concentrations of total nitrogen, total phosphorus, and chlorophyll *a* at points of interest within three lake segments (Section 4.1.1). Table 4-4 summarizes the output from the BATHTUB models developed for each lake segment assuming the baseline nutrient loading is based on the “Rules” and the nutrient loading reduction scenario is “Baseline” (zero percent reductions). The simulated percent exceedance of the chlorophyll *a* standard is presented in the table as well. NCDWQ considers a waterbody impaired if more than 10 percent of samples (minimum sample size of ten) do not meet the water quality standard. Under the baseline scenario, the Falls Lake Framework Tool predicts that more than 10 percent of samples collected near I-85 at the compliance point, near Highway 50, and near the dam will exceed the chlorophyll *a* standard.

Table 4-4 Summary of BATHTUB Model Output (Loading Assumption =Rules, Scenario = Baseline)

Segment (representative stations)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Percent Exceedance of 40 µg/L Chlorophyll *a* Criteria
West of I-85 (NEU013B)	0.105	1.05	67.8	69
I-85 to Hwy 50 (NEU19E)	0.043	0.77	35.1	30
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	0.031	0.57	22.2	12

Table 4-5 summarizes the BATHTUB model results assuming Stage II nutrient reductions (40 percent for total nitrogen and 77 percent for total phosphorus for the upper lake tributaries (Eno River, Flat River, Little River, Ellerbe Creek, and Knap of Reeds Creek). The reductions have the greatest impact on water quality in the segment west of I-85. Based on the results of this analysis, the lake is not expected to exceed the chlorophyll *a* standard in any lake segment.

Table 4-5 Summary of BATHTUB Model Output (Loading Assumption =Rules, Scenario = Stage II)

Segment (representative stations)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Chlorophyll *a* (µg/L)	Percent Exceedance of 40 µg/L Chlorophyll *a* Criteria
West of I-85 (NEU013B)	0.035	0.70	13.5	0
I-85 to Hwy 50 (NEU19E)	0.026	0.58	16.6	0
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	0.023	0.48	14.3	0

4.1.3 Regressions Models

The eutrophication model in the Falls Lake Framework Tool (Section 4.1.1) predicts nutrient and chlorophyll *a* concentrations in each main lake segment (West of I-85, I-85 to Highway 50, and Highway 50 to the dam). The model was calibrated using observations collected during the baseline year (2006) and may be used to predict inlake concentrations of total nitrogen, total phosphorus, and chlorophyll *a* under various nutrient management scenarios. In order to assess the impacts of nutrient management on other designated uses (Section 4.2), the Tool must also estimate total organic carbon (TOC), total suspended sediment (TSS), turbidity, and dissolved oxygen (DO) concentrations under future management scenarios.

To predict how changes in nutrient loading may affect these additional water quality parameters, the database compiled under Task 2 was used to calculate mean total nitrogen, total phosphorus, chlorophyll *a*, TOC, TSS, DO, and turbidity in each of the smaller six lake segments (See Figure 2-2 for a map of these smaller lake segments). Simple linear regression models for various combinations of variables were tested in log space to identify the strongest relationships to provide a basis for this screening level assessment. Regressions with the highest R^2 values[2] were selected to predict changes in water quality resulting from implementation of nutrient reductions.

The regression models in the Falls Lake Framework Tool are based on data collected in Falls Lake. While the BATHTUB model predicts total nitrogen, total phosphorus, and chlorophyll *a* concentrations under baseline and nutrient management scenarios, it is not capable of predicting the impacts on TOC, TSS, DO and turbidity under nutrient management scenarios. The regression models were used to predict these additional parameters under nutrient management scenarios using the output generated by the BATHTUB model.

Using these regression models to predict the impacts of nutrient management on TOC, TSS, DO and turbidity relies on the assumption that Falls Lake essentially functions as a large, structural BMP and that the improvement in water quality observed from the upstream to downstream end of the lake will mimic the impacts of nutrient reductions in the watershed. These regressions are simplistic and may be updated following additional data collection in the lake that occurs as implementation of nutrient reduction strategies proceeds in the watershed. It is recommended that future versions of the Falls Lake Framework Tool rely on more robust statistical analyses.

Table 4-6 shows the mean values for each lake segment based on the database compiled for Task 2.

[2] R^2 indicates how well a model explains the relationships between variables.

Table 4-6 Mean Values of Water Quality Parameters in Falls Lake Segments Used to Develop Regression Models

BATHTUB Modeling Segments	Highway 50 to the Dam			I-85 to Highway 50		West of I-85
Water Quality Regression Segments	LowLk 0-4	LowLk 4-8	LowLk 8-13	UppLk 13-18	UppLk 18-21	UppLk >21
Mean Total Phosphorous (mg/L)	0.03	0.04	0.04	0.05	0.11	0.27
Mean Total Suspended Sediment (mg/L)	5.4	6.6	7.6	11.7	24.9	33.2
Mean Total Organic Carbon (mg/L)	6.6	6.7	7.5	8.1	9	9.4
Mean Chlorophyll a (µg/L)	16.3	19.7	22.4	28.3	48.3	NA1
Mean Total Nitrogen (mg/L)	0.94	0.91	0.75	0.92	1.17	1.92
Mean Turbidity (NTU)	8	7.2	7.4	11.4	32.4	40.6
Mean Dissolved Oxygen (mg/L)	6.4	6.5	7.2	7.4	7.2	6.7

Chlorophyll *a* data are no longer collected by NCDWQ west of I-85.Chlorophyll *a* concentration provides the strongest regression model for predicting TSS concentrations in the lake. This relationship provides a linkage between nutrient management scenarios and inlake TSS concentrations by using output from the BATHTUB model (chlorophyll *a*) to predict the corresponding inlake TSS concentration. Estimates of TSS are needed to predict TOC and turbidity levels that are required to link water quality to designated uses (Sections 4.2.3 and 4.2.4). The model used to predict TSS from chlorophyll *a* (Figure 4-1) has an R^2 value close to one. Even though the sample size is small, the relationship between these variables is reasonable: implementation of nutrient management strategies in the watershed will likely lower TSS loading to the lake and result in lower inlake chlorophyll *a* concentrations.

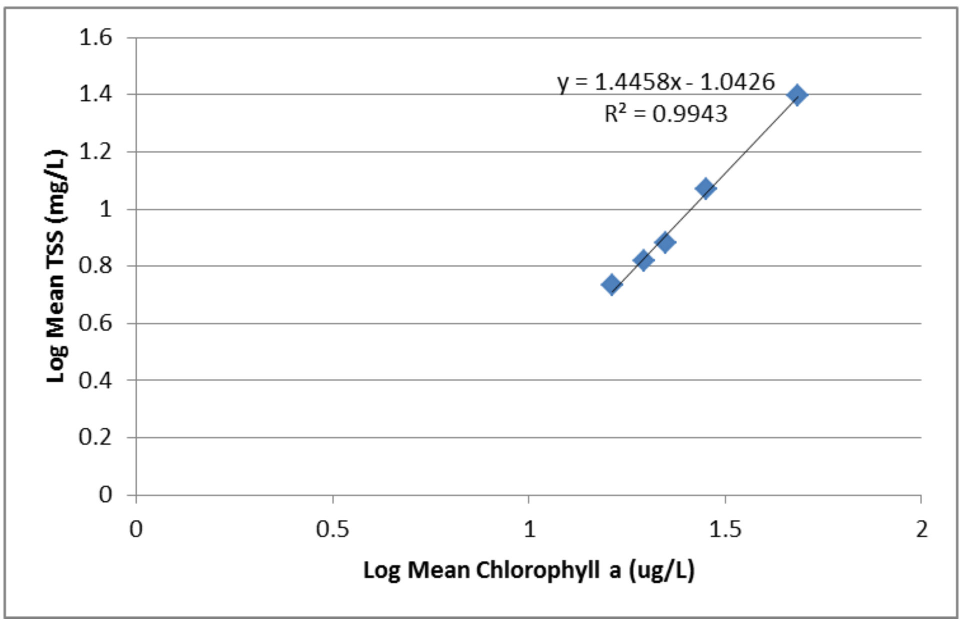

Figure 4-1 Log Mean TSS as a Function of Log Mean Chlorophyll *a*

TSS concentration is the strongest predictor of both turbidity and TOC, as shown in Figure 4-2 and Figure 4-3. The regression models used to predict both of these water quality variables have R^2 values of approximately 0.95. Because the water quality regressions rely on mean concentrations in six lake segments, the sample size is relatively small. The purpose of these regressions is to provide a preliminary linkage between nutrient loading and impacts on lake water quality. Turbidity is an input parameter to the recreation model (Section 4.2.3) and TOC is an input to the drinking water use assessment (Section 4.2.4).

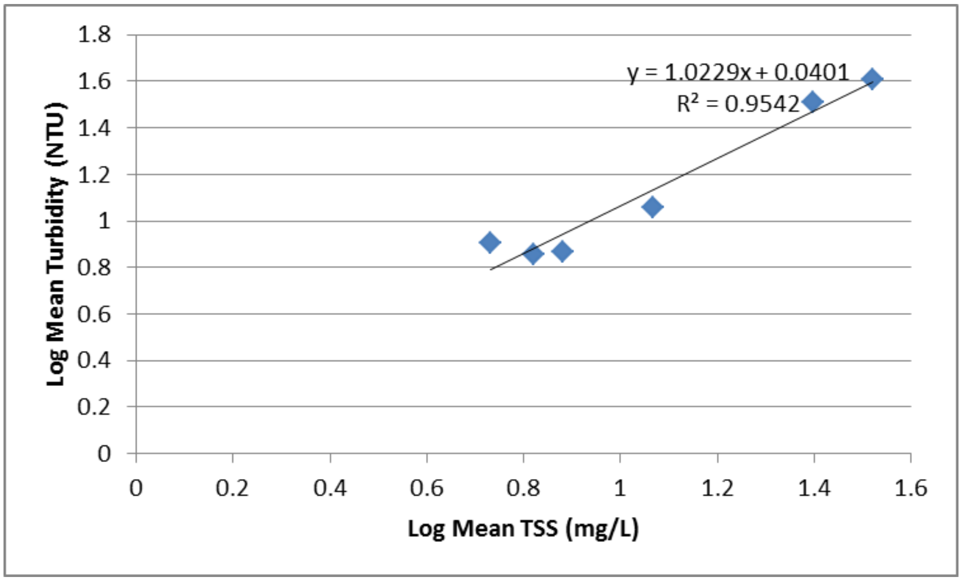

Figure 4-2 Log Mean Turbidity as a Function of Log Mean Total Suspended Sediment

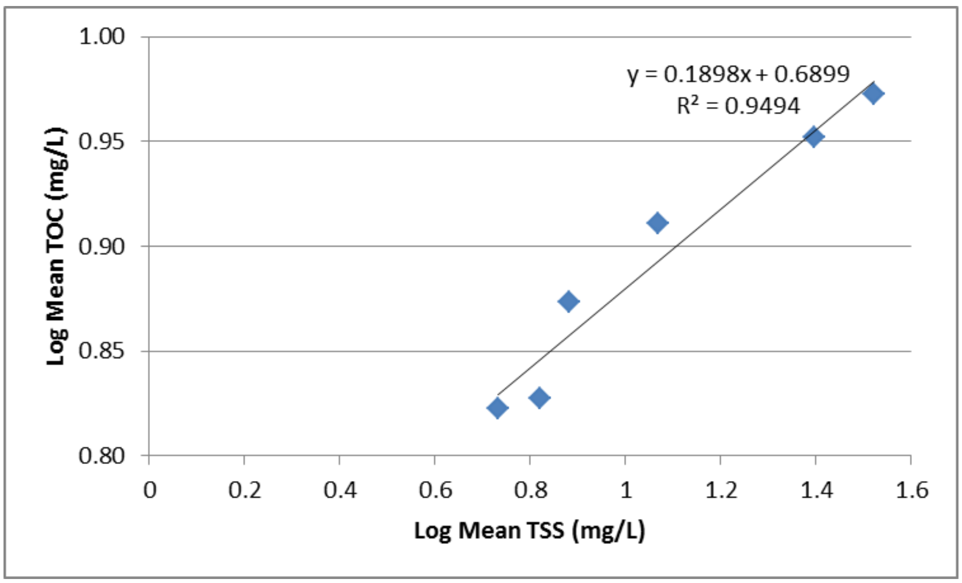

Figure 4-3 Log Mean TOC as a Function of Log Mean Total Suspended Sediment

The recreation model (Section 4.2.3 also requires an estimate of dissolved oxygen (DO) concentrations under the management scenarios. While the chlorophyll *a* – DO model has the highest R^2 value of all of the DO models tested (0.50), the existing relationship based on the water quality observations in the lake indicates that increasing chlorophyll *a* concentrations lead to increasing DO concentrations. While this relationship is scientifically sound based on the process of photosynthesis and corresponding production of oxygen by algae, it is counterintuitive in terms of the predicted outcomes of nutrient management. Rather than assume that nutrient management activities in the watershed will result in a reduction in DO concentration, the Falls Lake Framework Tool assumes that DO concentrations remain at baseline levels.

4.1.3.2 TSS, Turbidity, DO, and TOC Output from the Falls Lake Framework Tool

The Falls Lake Framework Tool uses regression models to predict TSS, turbidity, DO, and TOC concentrations under various nutrient management scenarios. For example, Table 4-7 and Table 4-8 show the predicted water quality under the baseline scenario and Stage II scenario, respectively. DO is held constant under each scenario as explained in Section 4.1.3.

Table 4-7 Summary of Output from Regression Models Under Baseline Scenario (Loading Assumption = Rules, Scenario = Baseline)

Segment (representative stations)	Mean Total Suspended Sediment (mg/L)	Mean Turbidity (NTU)	Mean Dissolved Oxygen (mg/L)	Mean Total Organic Carbon (mg/L)
West of I-85 (NEU013B)	40.3	48.1	6.7	9.9
I-85 to Hwy 50 (NEU19E)	15.6	18.2	7.3	8.2
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	8.0	9.2	6.7	7.3

Table 4-8 Summary of Output from Regression Models Under Stage II Scenario (Loading Assumption = Rules, Scenario = Stage II)

Segment (representative stations)	Mean Total Suspended Sediment (mg/L)	Mean Turbidity (NTU)	Mean Dissolved Oxygen (mg/L)	Mean Total Organic Carbon (mg/L)
West of I-85 (NEU013B)	3.9	4.4	6.7	6.3
I-85 to Hwy 50 (NEU19E)	5.3	6.0	7.3	6.7
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	4.2	4.8	6.7	6.4

Table 4-9 shows the percent change in predicted water quality from baseline to Stage II. Stage II reductions have the greatest impact on the lake segment west of Interstate 85: average TSS and turbidity are estimated to decrease by 90 percent or more and TOC levels are estimated to decrease by 36 percent. Relative changes in the segments downstream of I-85 are dampened due to the improvements in water quality that occur as a result of physical, chemical, and biological processes in the lake.

Table 4-9 Estimated percent change from baseline to Stage II reductions

Segment (representative stations)	Mean Total Suspended Sediment (mg/L)	Mean Turbidity (NTU)	Mean Dissolved Oxygen (mg/L)	Mean Total Organic Carbon (mg/L)
West of I-85 (NEU013B)	-90%	-91%	0%	-36%
I-85 to Hwy 50 (NEU19E)	-66%	-67%	0%	-18%
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	-47.5%	-47.8%	0%	-12%

4.2 Assessment of Designated Uses and Attainment of Water Quality Criteria

The Falls Lake Framework Tool provides a basis for predicting inlake water quality based on changing nutrient loads and provides a means to link lake water quality to designated uses. This section describes how the Tool uses existing information to compare simulated lake water quality to water quality criteria and to quantify the impacts on the aquatic life use, recreational use, and drinking water supply use. Figure 4-1 illustrates how the Tool links nutrient inputs and predicted lake water quality to impacts on designated uses and implementation costs using the BATHTUB models and regression models described in Section 4.1.

4.2.1 <u>Water Quality Criteria</u>

The numeric water quality criteria for Falls Lake include the following:

> Instantaneous DO concentration not less than 4 mg/L

> Average daily DO concentration not less than 5 mg/L (lake coves or backwaters and lake bottom waters may have lower values if caused by natural conditions)

> pH should remain between 6 and 9

> Chlorophyll *a* concentration not to exceed 40 µg/L

> Turbidity not to exceed 25 NTU.

If more than ten percent of observations exceed these criteria then NCDWQ considers the waterbody impaired due to violations of water quality criteria.

4.2.1.1 Framework Assessment

The Falls Lake Framework Tool assesses compliance with these criteria based on existing information. For DO and pH, the Tool assumes that the lake is compliant with these criteria under baseline and nutrient management scenarios (based on the data compiled for Task 2 and the NCDENR (2001, 2006, 2010, 2011, 2012c) Basinwide Assessment Reports and Lake Water Quality Reports for Falls Lake.

For turbidity, the Falls Lake Framework Tool use the coefficient of variation observed in 2006 along with simulated mean values to calculate the percent exceedance of the water quality criteria. For chlorophyll *a*, the same approach was used.

4.2.1.2 Framework Output

The Falls Lake Framework Tool uses the predicted percent exceedance of the turbidity and chlorophyll *a* criteria to compare attainment of water quality standards under various nutrient management scenarios. Under the baseline scenario when the loading to the lake is back calculated from the load allocations specified in the Falls Lake Nutrient Management Strategy, none of the lake segments are predicted to meet the chlorophyll *a* criteria and only the segment between Highway 50 and the dam is compliant with the turbidity criterion. The entire lake is predicted to meet the water quality criteria when a user specified percent reduction of 32 percent for nitrogen and 64 percent for phosphorus is assumed.

For DO and pH, the Tool assumes that the lake is compliant with these criteria under baseline and nutrient management scenarios

4.2.2 <u>Aquatic Life Use</u>

Algae form the basis of the food chain for many of the aquatic resources (zooplankton, invertebrates, fish, etc.) in lakes. When chlorophyll *a* concentrations are very low, this indicates that algal biomass is low and that organism growth and reproduction may be limited by food supply. As algal biomass increases, populations begin to thrive. Past a certain point, however, excess algal biomass leads to algal blooms, die off, and decay, which all lower the DO concentrations in the water. Certain organisms, particularly fish, become stressed at low DO concentrations. Depending on the frequency, duration, and percent volume of the low DO conditions, organism survival and reproduction may decline. In addition, excessive algae and vegetation cause large swings in DO and pH, with levels increasing during photosynthesis during the day and decreasing at night during respiration.

During the Basinwide Assessments conducted by NCDENR since 2001, Falls Lake has not exhibited DO or pH problems. There was one observed DO concentration less than 4 mg/L in the hypolimnion during one of the Basinwide Assessments (NCDENR 2001). As presented in the Task 2 TM, pH levels in the lake are generally between 6.5 to 8.5. Based on existing data and reports, the lake is not impaired for DO or pH. In addition, the lake does not exhibit typical problems associated with impairment of the aquatic life use: there are no recorded fish kills due to eutrophication or low DO, frequent nuisance algal blooms, or poor biological scores for fish or benthos. Although a fish kill occurred in 2008 near Highway 50, it was limited primarily to one species, channel catfish, and water quality measurements, total algal counts, and algal speciation during the event were within normal ranges (NCDWQ 2008). A North Carolina Wildlife Resources commission representative considered it a natural event likely “caused by a combination of spawning activities and high water temperature which may have allowed a bacterial infection to sicken weakened fish” (NCDWQ 2008). The impairment of the lake is due only to violations of the chlorophyll *a* and turbidity criteria. Attainment of water quality criteria is assessed separately in the Falls Lake Framework Tool (Section 4.2.1).

4.2.2.1 Framework Assessment

The original plan for the assessment of the aquatic life designated use included analysis of fish sampling data and corresponding inlake water quality data. Cardno ENTRIX obtained data from the North Carolina Wildlife Resources Commission which collects data in Falls Lake for two recreationally important fish species: largemouth bass and black crappie. Largemouth bass are sampled during odd numbered years in the spring (usually late April and early May), and black crappie are sampled during even numbered years in the fall (usually late October and early November). Over the past 11 years of data collection, over five thousand fish have been sampled. These data are summarized by species below:

> Largemouth bass
  - 2,078 total fish sampled, 97.7% of which were taken in the lower lake.
  - 41.0 percent of fish sampled in the lower lake were taken in the segment that is within 4 miles of the dam.
  - Though data are limited in the upper part of the lake, fish lengths were comparable between the lower lake and upper lake, and between lake segments.
  - Little variation in fish length was observed across sampling years.
  - Largemouth bass were not sampled in 2001 and 2003.
  - More fish were sampled in 2005 and 1999, with the fewest number of fish sampled in 2009.

> Black crappie
  - 2,954 total fish sampled, 91.6% of which were taken in the lower lake.
  - 43.9 percent of fish sampled in the lower lake were taken in the segment that is within 4 miles of the dam.
  - Though data are limited in the upper part of the lake, fish lengths were comparable between the lower lake and upper lake, and between lake segments.
  - Little variation in fish length was observed across sampling years.

- More fish were sampled in 2006 and 2000, with the fewest number of fish sampled in 2004 and 2002.

The current fish sampling plan tends to focus on the Lower Lake, particularly within the vicinity of the dam. Cardno ENTRIX has recommended (Task 4 TM) that additional biological sampling be conducted throughout the lake to provide the data needed to adequately assess the aquatic life designated use. In the meantime, since the existing biological data (e.g., fish data) and reports do not indicate an impairment in the lake with baseline levels of chlorophyll *a*, the current version of the Falls Lake Framework Tool assumes there is no existing impairment of the aquatic life use. Furthermore, nutrient management strategies assessed within the Falls Lake Framework Tool will result in further improvements to water quality that should not result in a change in status from unimpaired to impaired. The Tool addresses violations of the water quality criteria separately (Section 4.2.1).

4.2.2.2 Framework Output

Falls Lake is on the 303(d) list due to violations of the turbidity and chlorophyll *a* values. The Aquatic Life beneficial use is not considered “Impaired” based on biological indices. No fish kills due to eutrophication or low DO have been reported in Falls Lake, and the lake supports a healthy sports fishery. Future studies are recommended to further assess the aquatic life use. Based on existing information, the Falls Lake Framework Tool categorizes the Aquatic Life use as “Not Impaired” based on the biology of the lake. Nutrient management strategies are not expected to cause biological impairments in the lake, so the Falls Lake Framework Tool categorizes the Aquatic Life use as “Not Impaired” for the baseline and nutrient management scenarios. The Tool addresses non-attainment of the water quality criteria separately.

In addition, Falls Lake is currently meeting both the DO and pH criteria, which are direct stressors for aquatic life. Because nutrient management scenarios are not expected to cause biologic impairment to the lake, the aquatic life use was assigned a categorical value of “Not impaired” As future studies are conducted to assess the status of designated uses, the Falls Lake Framework Tool may be revised to incorporate new information.

4.2.3 Recreational Use

The recreational designated use for Falls Lake supports activities such as fishing, boating, swimming, and hiking around the lake. Lake water quality can affect these recreational activities in various ways. For example, chlorophyll *a* represents the amount of food available for sport fish, but in excess can cause DO problems that stress aquatic life. Algal blooms may cause aesthetic and odor nuisance, impede boat motors, alter pH to harmful levels for swimmers, decrease water clarity, and provide unsafe algal mats or slippery surfaces.

4.2.3.1 Framework Assessment

To assess the linkage between water quality and recreational use, the Falls Lake Framework Tool uses a recreational model developed by researchers at North Carolina State University to value water quality and the associated ecosystem services in Wake County (Phaneuf et al. 2008). This model uses total phosphorus, turbidity[3], and ambient dissolved oxygen as water quality indicators to predict the impact of water quality on the value of local recreation trips

The Falls Lake Framework Tool predicts the impacts of reduced nutrient loading on water quality using either the empirical BATHTUB equations (Section 4.1.1) or the regression models (Section 4.1.3). The change in water quality parameters is input to the recreational model to calculate the impacts on recreational utility. The equation to predict the annual change in trips relative to baseline is as follows:

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[3] Phaneuf et al. 2008 uses the terminology TSS, but the units are measured in lab nephelometric turbidity units, which indicates a turbidity measurement.

Change in Trips = ln[(1-share)+(maximum nutrient value x share)] x Total trips

where the share is the percent of total recreation trips that are taken to Falls Lake. Based on State Park data, the actual annual trips to Falls Lake range from about 789,000 to 954,000 from 2005 to 2011 with an average of 873,456. For this preliminary assessment, the baseline trips were assigned to each lake segment based on the percent of the total surface area. The baseline share to Falls Lake is assumed to be 10 percent of total trips in the area, implying that the total recreation trips averages about 8.7 million per year.

The maximum nutrient value based on the Phaneuf (2008) model is calculated as the maximum of:

$$\mathrm{Exp}(-1.914 \times (P_{New} - P_{Current}))$$
$$\mathrm{Exp}(-0.002 \times (TSS_{New} - TSS_{Current}))$$
$$\mathrm{Exp}(0.465 \times (DO_{New} - DO_{Current}))$$

Where P, TSS, and DO indicate the total phosphorus, turbidity, and DO concentrations. These are specified for baseline conditions (current) and management scenarios (new). For the Falls Lake Stage II scenario, the maximum nutrient value for each lake segment is based on the change in total phosphorus concentrations.

4.2.3.2 Framework Output

The Falls Lake Framework Tool outputs the change in value for recreational trips resulting from improved water quality. Based on the Phaneuf (2008) study, the value of a recreational trip is calculated using the average wage rate from the counties surrounding Falls Lake (U.S. Census Bureau 2012), average vehicle operating costs (AAA 2012), and an estimated average speed of 40 mph. The resulting value of a trip averages $3.68 (note that value of trip is different than cost per trip).

Table 4-10 summarizes the change in recreational value assuming the Stage II reduction scenario. The change in trips relative to baseline, multiplied by the value per trip, results in an estimate of the change in recreational value for Falls Lake. The recreational value of Falls Lake is assumed to increase approximately $168,000 per year (based on the current value of trip) as a result of the Stage II reductions.

Table 4-10 Increase in Annual Falls Lake Recreational Value Assuming Stage II Reductions

Segment (representative stations)	Annual Baseline Trips	Annual Stage II Trips	Change in Trips	Value of Change in Trips
West of I-85 (NEU013B)	190,188	217,429	27,241	$100,251
I-85 to Hwy 50 (NEU19E)	436,728	451,295	14,567	$53,609
Hwy 50 to Dam (FLIN_1, Falls Lake Intake, NEU020D)	246,540	250,414	3,874	$14,255
Total	873,456	919,138	45.682	$168,115

4.2.4 Drinking Water

The City of Raleigh has been studying water quality in Falls Lake in order to optimize and manage the E.M. Johnson Water Treatment Plant (WTP). Of particular interest is the formation of disinfection byproducts which are toxic to humans and regulated by USEPA. When lake water is treated to produce drinking water and disinfection is achieved with the use of chlorination techniques, there is a potential to produce harmful disinfection byproducts (DBP). Because DBP formation is correlated to the amount of organic material in the raw water, USEPA requires removal of organic material prior to treatment and disinfection (USEPA 2010a). The City of Raleigh monitors total organic carbon (TOC) for compliance and operational planning and currently relies on ferric sulfate to enhance removal of TOC from the raw water.

The City of Raleigh has recently conducted a study to determine if more sophisticated technologies are needed to comply with the Comprehensive Disinfectants and Disinfection Byproducts Rules (USEPA 2010a). The report suggests that technologies such Granular Activated Carbon (GAC) contactors or an ion exchange process such as magnetic ion exchange (MIEX®) resins may be needed during the next 7 to 23 years to ensure compliance with the Safe Drinking Water Act. These technologies may cost $125 million in addition to the $264 million needed to expand the treatment plant to a 100 MGD capacity (Hazen and Sawyer 2012).

This analysis (Hazen and Sawyer 2012) assumed an annual average increase in raw water TOC concentrations of 0.11 mg/L. As described in Section 2.1.2.3, TOC concentrations in the lower lake appear cyclical. Additional monitoring of TOC in the lower lake as the Stage I reductions continue are needed to assess trends in raw water quality and better predict when advanced technologies may be needed.

4.2.4.1 Framework Assessment

The Falls Lake Framework Tool assesses the drinking water designated use by linking TOC concentrations in the raw water supply to the pounds of ferric sulfate needed to treat the water using existing information. Based on the water quality regressions described in Section 4.1.3, the strongest relationship for TOC is with TSS, and strongest relationship for TSS is with chlorophyll *a*. To predict changes in TOC due to decreases in nutrient loading, first the BATHTUB model is used to estimate mean chlorophyll *a* concentration near the intake. Then the water quality regressions are used to translate chlorophyll *a* to TSS and finally to TOC. For example, under baseline conditions, the water quality regressions predict a TOC concentration near the dam of 7.3 mg/L (Table 4-7) (observed TOC concentrations near the dam during the baseline year (2006) were actually 6.9 mg/L). When Stage II nutrient reductions are input to the model, the TOC concentration is estimated to be 6.4 mg/L near the dam (Table 4-8).

The City of Raleigh provided daily application of ferric sulfate as well as raw water treated from October 1997 to December 2011. Cardno ENTRIX calculated the pounds of ferric sulfate per MGD (usage) on a daily basis and then averaged those for each full year of data. The annual usage was paired with average annual TOC concentrations observed each year at stations near the dam (0208717595, Falls Lake Intake, FLIN_1, and NEU020D). Figure 4-4 shows the average usage (average ferric lb/MGD) and average annual TOC concentrations for years 2000 through 2011 (TOC data near the dam were collected beginning in 2000). Visual assessment of Figure 4-4 shows a different pattern in the relationship between annual average TOC and annual usage between year 2000 and 2006 compared to years 2007 through 2011.

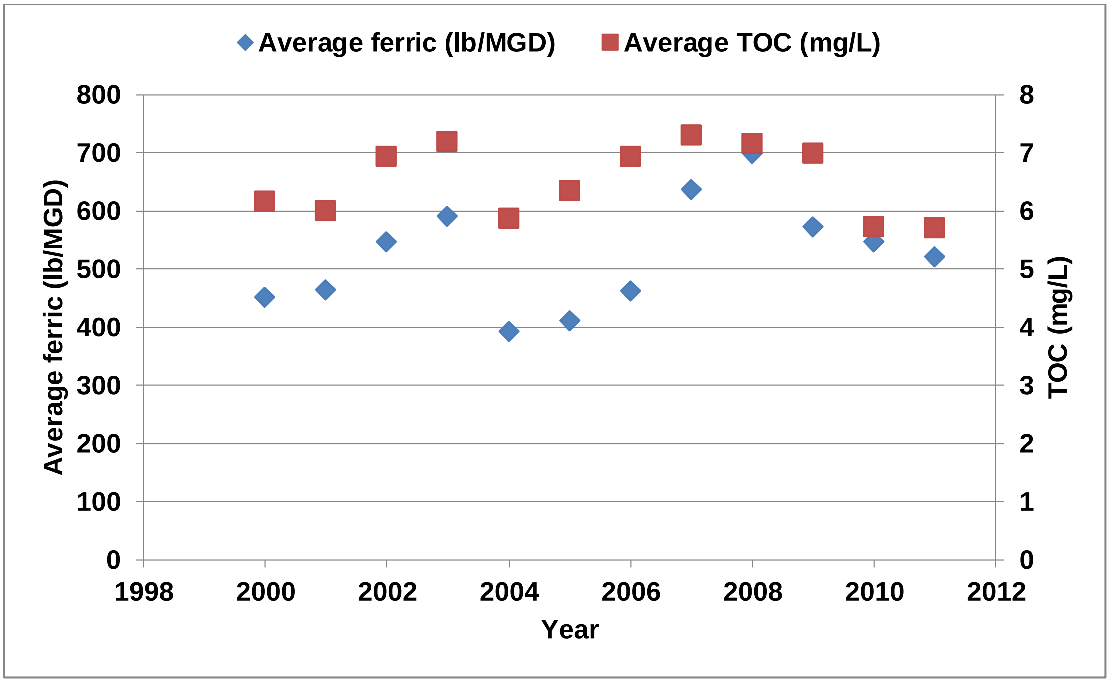

Figure 4-4 **Average Pounds of Ferric Sulfate per MGD and Average Annual TOC Concentrations for Years 2000 through 2011**

Figure 4-5 shows two linear regression models that predicting average annual usage from average annual TOC concentrations. One model uses the full range of data (burgundy data points and regression line and one model uses data from years 2007 through 2011 (purple data points and regression line). The latter regression resulted in a higher R^2 value (0.66) and a more conservative estimate of the annual usage. This regression model was selected to link estimated TOC concentrations to the amount of ferric sulfate applied.

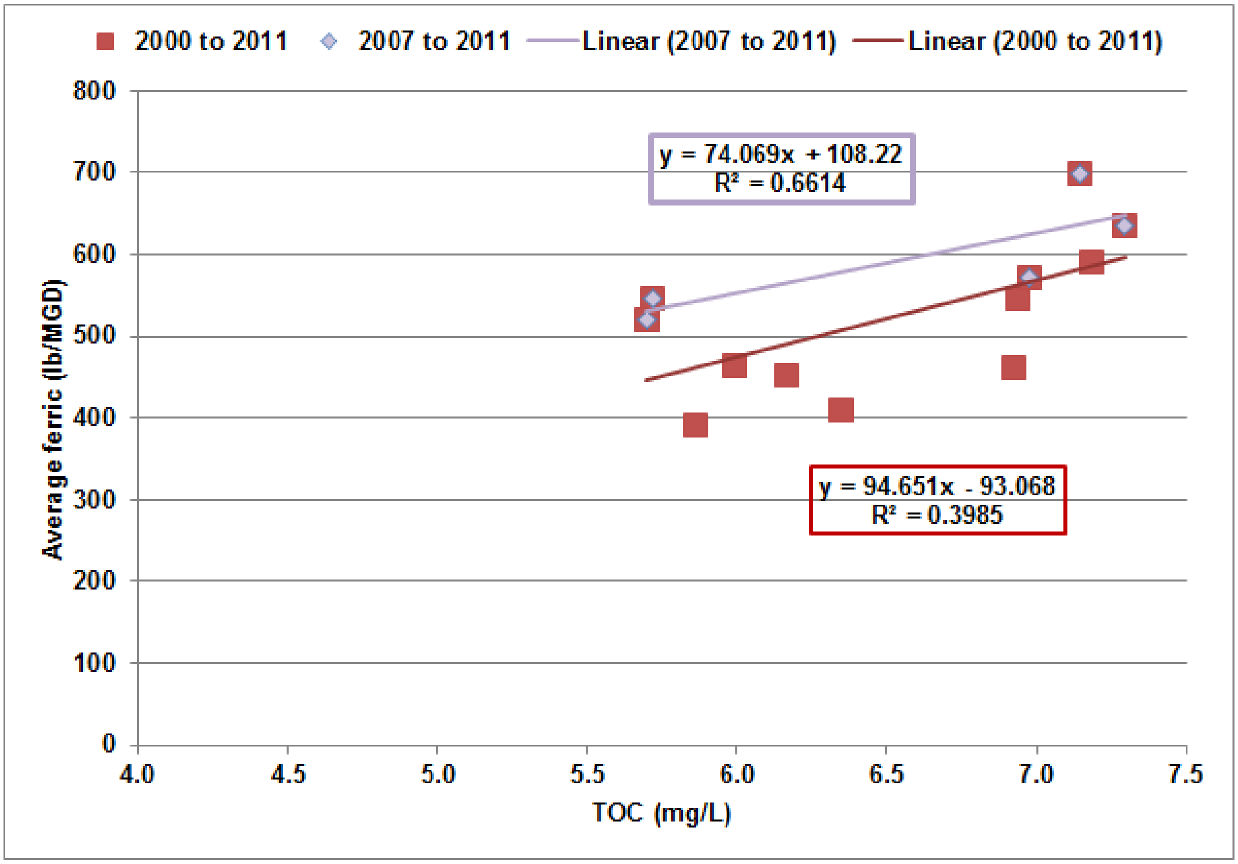

Figure 4-5 Average Usage (Pounds of Ferric Sulfate per MGD) Versus Average Annual TOC Concentrations

4.2.4.2 Framework Output

The Falls Lake Framework Tool predicts changes in TOC concentrations resulting from nutrient reduction scenarios based on the BATHTUB and water quality regression models described in Section 4.1. Next, the regression model described in Figure 4-5 is used to predict the average annual usage of ferric sulfate. To provide an assessment of costs over a typical year, the Tool assumes an average daily treated flowrate of 50 MGD based on the data provided by the City of Raleigh.

Under baseline conditions with an assumed average TOC concentration of 7.3, the Falls Lake Framework Tool estimates that 648.9 pounds of ferric sulfate are needed to treat 1 MGD of raw water. Assuming the water treatment plant treats 50 MGD, the amount of chemical needed per day is 32,445 pounds. Under the Stage II scenario, the TOC concentration is predicted to decrease to 6.4 mg/L, so the application rate would decrease to 582.3 pounds of ferric sulfate to treat 1 MGD of raw water, or 29,115 pounds per day assuming a treatment rate of 50 MGD.

The City of Raleigh indicates that ferric sulfate costs approximately $0.16 per pound. The difference in application rates under the baseline and Stage II scenarios is approximately 3,330 pounds per day. Over a 365 day period, the Stage II scenario may reduce chemical costs by approximately $194,000 per year.

4.2.5 Flood Protection

One of the main reasons that Falls Lake was constructed was to provide flood control benefits to communities downstream. Estimates of flood control benefits were computed prior to construction of the Falls Lake dam based on analyses from the State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources and Comptroller General of the United States. The estimates appear to be the result of a damage function approach, which the USACE continues to use. Although the accepted approach to valuing flood control benefits has not changed, the characteristics of the watershed may be significantly different. Changes to land use, watershed characteristics, and water resources management may all contribute significant sources of uncertainty to these estimates.

4.2.5.1 Historic Projections

The State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources (1973) estimated that total annual flood control benefits would be approximately $819,000, in 1972 dollars. Adjusting this number using the consumer price index yields an annual benefit of about $4.5 million per year in 2012 dollars. This level of flood protection is roughly equivalent to a 30 to 70 percent reduction in flood damage from a major flood event.

In addition to the estimate provided above, a 1974 letter from the Comptroller General of the United States to Senator Jesse Helms estimates annual flood control benefits at about $931,000 in 1973 dollars, equivalent to $4.8 million in 2012 dollars. This letter indicates that these benefits represent approximately 22 percent of total project benefits and about 33 percent of project recreation benefits. Table 4-11 specifies the benefits provided by the project and the dollar value of those benefits, as estimated in the Comptroller General's letter.

Table 4-11 Comptroller Estimates of Flood Control Benefits of Falls Lake Project

Project Benefits	July 1973 Estimate ($1,000)	Percent of total benefits
Recreation	$2,581	60%
Flood Control	$931	22%
Water Supply	$359	8%
Water Quality	$454	10%

The State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources (1973) analysis also provides a table of flood frequencies and associated damage estimates. Annual flood damages are estimated to be about $1.3 million per year (in 1973 dollars) even though the expected value of damages using the probabilities and damages listed in the table is closer to $2 million. The basis for the $1.3 million in estimated annual damages is not specified.

4.2.5.2 Recent Data

The USACE provided Cardno ENTRIX with annual estimates of flood damages prevented by Falls Lake from 1984 to 2011 (Table 4-12). The lake prevented an estimated $259 million dollars in damages in 1996 when Hurricane Fran occurred. In 2010 the lake prevented $21 million in damages, which is near the average for the years data were provided. The realized flood control benefit is much higher than what was projected before the dam was constructed. [Damages prevented are provided in terms of the year they were realized and were not normalized to a common year.]

Table 4-12 Annual Flood Damages Prevented by Falls Lake

Year	Damages Prevented ($)	Year	Damages Prevented ($)
1984	2,448,000	1998	70,656,100
1985	419,000	1999	139,919,200
1986	2,367,000	2000	29,400
1987	12,839,000	2001	4,819,000
1988	0	2002	0

1989	10,545,000	2003	32,814,200
1990	2,219,000	2004	1,763,400
1991	3,528,000	2005	23,600
1992	0	2006	2,995,000
1993	6,395,000	2007	3,362,000
1994	10,755,000	2008	2,651,200
1995	8,777,000	2009	3,243,700
1996	259,422,000	2010	21,232,300
1997	5,395,300	2011	456,000

4.2.5.3 Framework Assessment and Output

The Falls Lake Framework Tool has been set up to estimate impacts to designated uses resulting from various nutrient management scenarios relative to the baseline year (2006). The Tool assumes that nutrient management practices will not impact flood control benefits. Revisions to the Tool in the future may include a linkage between nutrient reductions and the flood control use by account for practices that reduce storm volumes and peak flows, increase infiltration in the watershed, disconnect impervious surfaces, etc. For the preliminary analysis, the change from nutrient management is assumed zero.

4.3 Implementation Cost Estimates in the Falls Lake Framework Tool

Cardno ENTRIX set up the Falls Lake Framework Tool to estimate the costs of implementation for two options. Each option assumes that the removal costs are higher for phosphorus than nitrogen, and if BMPs are implemented to achieve the 77 percent reduction in phosphorus required under Stage II of the Strategy, the Stage II nitrogen reductions of 40 percent will also be achieved at no additional costs.

The first option for the cost basis is the NCDWQ fiscal analysis which estimates a Stage II implementation cost of $946 million to reduce phosphorus loading by 117,174 pounds per year. The estimated cost per pound is $8,073. This value is calculated from the load reductions and expected costs across all sectors provided by NCDWQ (2010). (If the projected costs are calculated by sector, costs range from approximately $71/lb-P to $29,860/lb-P.) The second option allows the user to specify the average cost per pound of phosphorus removal. For example, If the $/lb-P is $30,000 (near the high range calculated from the sector costs provided by NCDWQ (2010), the Stage II implementation costs are approximately $3.5 billion.

The Falls Lake Framework Tool also provides a preliminary screening of the financial impact associated with the selected nutrient management scenario (baseline, Stage 2, or user specified) based on the USEPA Municipal Preliminary Screener (Section 5.6.3.3). This calculation relies on data from the US Census Bureau including median household income (assumed $50,000 per year) and number of households in the watershed (39,000). For this analysis, it was assumed that current pollution control costs are zero although communities are already paying for implementation of regulations in place prior to the Falls Lake Nutrient Management Strategy. According to the Preliminary Screener, if the current and new pollution control costs (allocated per household) are more than 2 percent of the median household income, the impact is “Large Impact.” If the percentage falls between 1 and 2 percent the impact is “Mid-range Impact”; less than 1 percent is considered “Little Impact.”

Assuming that households will contribute approximately 82 percent of the costs to implement nutrient management in the watershed (costs to reduce loading from existing development and wastewater based on the NCDWQ fiscal analysis), the Falls Lake Framework Tool indicates that the Stage 2 reduction scenario is a “Large Impact” to the stakeholders in the watershed. This “Large Impact” is likely underestimated due to two additional conditions: 1) the calculation does not account for current pollution control costs and 2) the costs presented in the fiscal analysis are not likely to achieve the Stage 2 phosphorus loading targets.

The user-specified load reduction scenario may be used to determine the nutrient reductions that transition from Mid-range to Large Impact. In addition to predicting annual implementation costs, the Falls Lake Framework Tool also incorporates the USEPA Municipal Preliminary Screener (described in Section 4.3) to assess whether the required pollution controls will result in a “Large,” “Mid-range,” or “Little” financial impact to the community. The output from the USEPA Municipal Preliminary Screener may be used to support various regulatory options such as use attainability analyses and variances, and USEPA recommends that impacts in the “Mid-range” or “Large” category undergo further analysis. Figure 4-6 shows an example of the annual implementation costs associated with varying percent reductions in nitrogen and phosphorus loading. The relative proportions of nitrogen and phosphorus reductions are similar to those required by Stage I and Stage II of the Falls Lake Nutrient Management Strategy. The categories on the x-axis are the percent reductions of total nitrogen and total phosphorus, respectively. The category (40, 77) represents the Stage II scenario. Percent reductions and implementation costs that cause a “Large” impact according to the USEPA Municipal Preliminary Screener are shaded orange. “Mid-range” impacts are shaded purple, and “Little” impacts are shaded green.

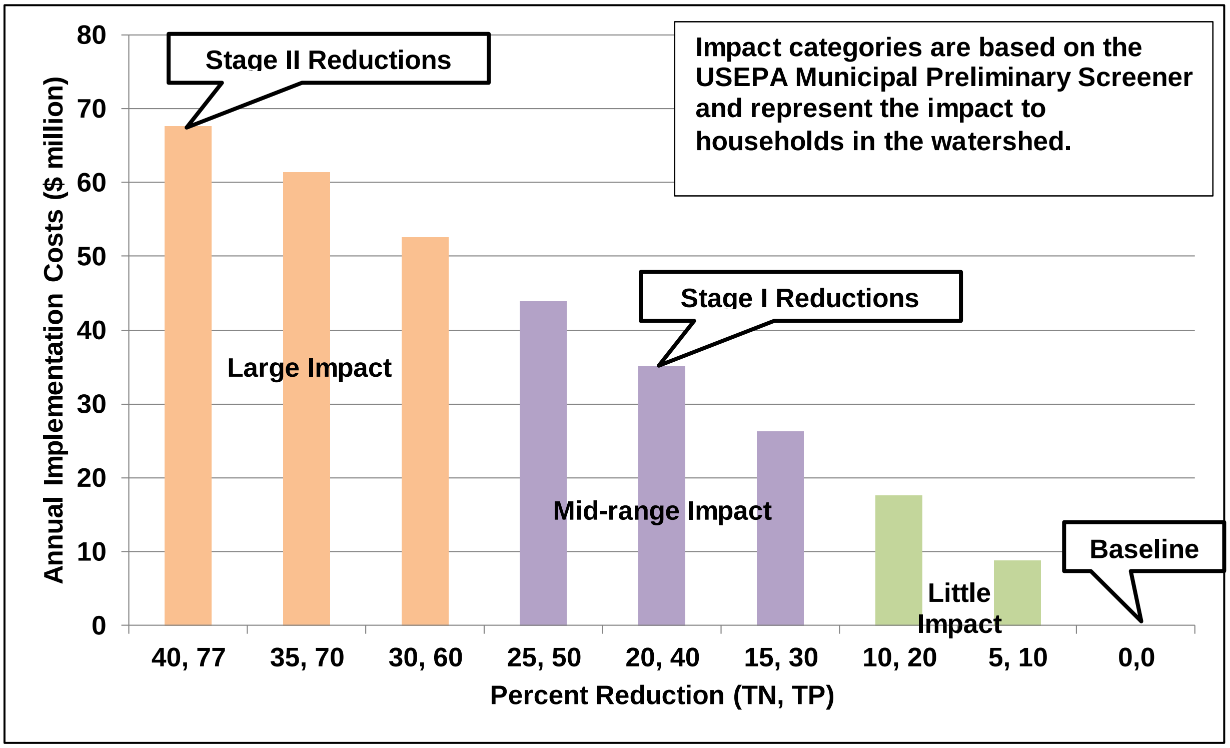

Figure 4-6 Annual Implementation Costs Associated with Varying Percent Reductions in Nitrogen and Phosphorus Loading

Future revisions to the Falls Lake Framework Tool may include estimates of current pollutant control costs to gain a more accurate representation of the fiscal impact of nutrient reduction strategies. In addition, the Municipal Screener requires that impacts greater than 1 percent resulting from the Preliminary Screener be further tested. Additional data to support calculation of the Secondary Score (Section 5.6.3.3) include direct net debt, overlapping debt, market value of property, bond rating, etc. for each local government.

5 Regulatory Options for Falls Lake

The Clean Water Act contains measures to allow the States flexibility in setting and implementing water quality standards (Figure 5-1). Use attainability analyses and adoption of subcategories of designated uses fall under the designated uses part of the water quality standards. Variances and site-specific criteria fall under the water quality criteria component. These mechanisms are described briefly in this section, along with examples of their application across the country and their applicability to Falls Lake.

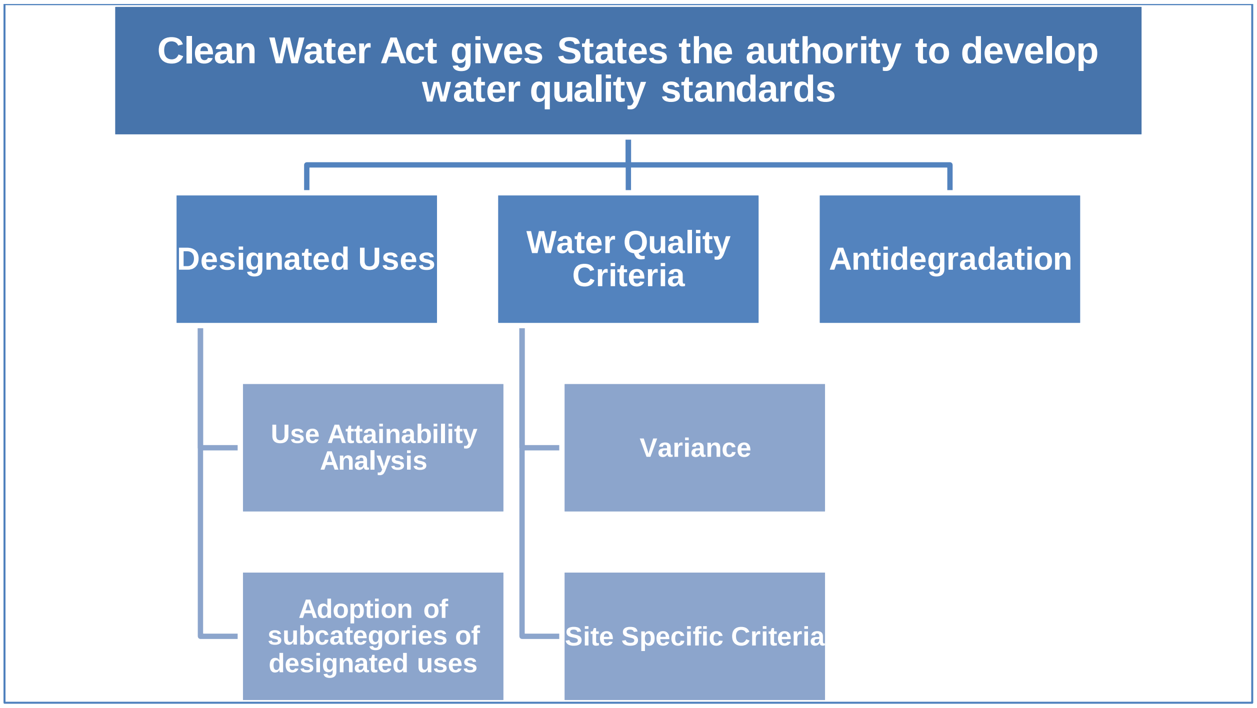

Figure 5-1 Federal Flexibility Afforded to States Under the Clean Water Act

5.1 Falls Lake Designated Uses

The entire Falls Lake watershed is classified as a critical water supply watershed and as Nutrient Sensitive Waters. In addition, all waters in North Carolina must have at least a Class C classification: freshwaters protected for secondary recreation, fishing, and aquatic life including propagation and survival, and wildlife.

Falls Lake itself is divided into two water bodies for classification purposes (the lake was divided into three segments for the Falls Lake Framework Tool (Section 4)):

In addition to the Class C classification, Falls Lake from the confluence of the Eno River Arm of Falls Lake and Flat River Arm of Falls Lake to I-85 bridge is classified as:

> WS-IV (waters protected as water supplies which are generally in moderately to highly developed watersheds), and

> CA (critical area, meaning the area adjacent to a water supply intake or reservoir where risk associated with pollution is greater than from the remaining portions of the watershed).

In addition to the Class C classification, Falls Lake from the I-85 bridge to the dam at Falls Lake is classified as:

> WS-IV,

> B (freshwaters protected for primary recreation which includes swimming on a frequent or organized basis as well as all Class C uses) and

> CA.

5.2 Falls Lake nutrient related water quality standards

The nutrient related water quality standards applicable to Falls Lake are as follows.

For all Class C waters (15A NCAC 02B .0211):

> Chlorophyll a (corrected): not greater than 40 µg/l

> Dissolved oxygen: for non-trout waters, not less than a daily average of 5.0 mg/l with a minimum instantaneous value of not less than 4.0 mg/l;

> For lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level shall not be increased.

For all WS-IV waters (5A NCAC 02B .0216):

> Sewage, industrial wastes, non-process industrial wastes, or other wastes: none shall be allowed except for those specified in Item (2) of this Rule and Rule .0104 of this Subchapter and none shall be allowed that shall have an adverse effect on human health or that are not effectively treated to the satisfaction of the Commission and in accordance with the requirements of the Division of Environmental Health, North Carolina Department of Environment and Natural Resources.

> Nonpoint Source and Stormwater Pollution: none shall be allowed that would adversely impact the waters for use as water supply or any other designated use.

For Critical Areas (5A NCAC 02B .0216):

> The rules set forth specified non-point source controls and stormwater controls for critical areas.

For all Class B waters (15A NCAC 02B .0219)

> The waters shall meet accepted standards of water quality for outdoor bathing places and shall be of sufficient size and depth for primary recreation purposes. Sources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard.

For Nutrient Sensitive Waters (15A NCAC 02B .0223)

> Nutrient strategies applicable to NSW shall be developed by the Commission to control the magnitude, duration, or frequencies of excessive growths of microscopic or macroscopic vegetation so that the existing and designated uses of the waterbody are protected or restored.

5.3 Falls Lake Impairment

Falls Lake above Panther Creek is identified by North Carolina as impaired due to exceedances of both the 40 µg/l standard for chlorophyll *a* and the 25 NTU turbidity standard.

Falls Lake below Panther Creek is identified by North Carolina as impaired for exceedances of the 40 µg/l standard for chlorophyll *a*.

5.4 Falls Lake Rules

The Falls Lake rules adopt goals for Falls Lake of (1) attaining classified uses that are currently impaired due to excess nutrients, (2) protecting those uses that are being attained (including use as a drinking water supply), and (3) maintaining and enhancing protections in water supply watersheds within the watershed of the Falls Lake.

The goals are to be met in two stages. Under Stage I, nutrient-related water quality standards are to be met in the Lower Falls Lake by January 15, 2021. Under Stage II, nutrient-related water quality standards are to be met in the Upper Falls Lake by 2041, to the maximum extent technically and economically feasible. The Stage II objective is estimated to require a 40 percent reduction in the loading of Total Nitrogen (TN) and a 77 percent reduction in the loading of Total Phosphorus (TP).

The Falls Lake Rules adopt an adaptive implementation approach and expressly call for a review of the feasibility of achieving the Stage II objectives and whether alternative regulatory actions will protect existing uses. Alterative regulatory actions available in North Carolina and under federal law include reclassification of a water body, revision of water quality standards, and variances.

5.5 Falls Lake Consensus Principles

In 2010, the Consensus Principles were adopted to guide the Falls Lake Nutrient Management Strategy. The Consensus Principles also call for a review of the attainability of the designated uses for the Upper Lake, the feasibility of achieving Stage II reduction goals and meeting the water quality standard for chlorophyll *a*, and whether existing uses of the Upper Lake can be protected with alternative water quality standards.

To meet the Consensus Principles a threshold issue is to identify the existing uses of the Upper Lake. Under the North Carolina Code "existing uses" are defined as follows:

Existing uses mean uses actually attained in the water body, in a significant and not incidental manner, on or after November 28, 1975, whether or not they are included in the water quality standards, which either have been actually available to the public or are uses deemed attainable by the Environmental Management Commission. At a minimum, uses shall be deemed attainable if they can be achieved by the imposition of effluent limits and cost‑effective and reasonable best management practices (BMPs) for nonpoint source control (15A NCAC 02B .0202(30)).

Protection of existing uses is also required by the Clean Water Act and North Carolina anti-degradation requirements under 40 C.F.R. 131.12 and 15A NCAC 02B .0201. Further, Federal and North Carolina law do not allow a designated use to be removed if it is an existing use or is a use attainable through the application of technology-based standards. 40 C.F.R. 131.10(g); 15A NCAC 02B .0101(f).

5.6 Alternative Regulatory Actions

The criteria that are not met in the Upper Lake are criteria that are intended to protect the uses of the lake for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife, as well as drinking water supply.

5.6.1 <u>Variances</u>

5.6.1.1 Applicable law

Both federal and North Carolina law allow variances that relieve a point source discharger from the obligation of meeting an otherwise applicable standard or effluent limitation. A variance is a temporary modification to a designated use or a water quality criterion. Generally variances are for a specific time period, but are renewable. However variances also can be approved for longer periods of time.

A variance can apply to either a water body or a specific discharger. Because a variance is not a permanent change in a water quality standard it should not be a basis for making a determination whether a water body is in attainment or whether it needs a TMDL under section 303(d) of the Clean Water Act. Water Quality Standards Handbook: Second Addition. EPA-823-B-94-005 (U.S. EPA 1994).[4]

North Carolina law allows variances to be established for fixed or for indefinite periods of time. G.S. 143-215.3(e); 15A NCAC 02B .0226.[5]

Under the North Carolina General Statutes, before granting a variance the Environmental Management Commission (Commission) must hold a hearing or provide at least 90 days public notice and must find that:

> (1) The discharge of waste or the emission of air contaminants occurring or proposed to occur do not endanger human health or safety; and
>
> (2) Compliance with the rules, standards, or limitations from which variance is sought cannot be achieved by application of best available technology found to be economically reasonable at the time of application for such variances, and would produce serious hardship without equal or greater benefits to the public, provided that such variances shall be consistent with the provisions of the Federal Water Pollution Control Act as amended or the Clean Air Act as amended; and provided further, that any person who would otherwise be entitled to a variance or modification under the Federal Water Pollution Control Act as amended or the Clean Air Act as amended shall also be entitled to the same variance from or modification in rules, standards, or limitations established pursuant to G.S. 143-214.1, 143-215, and 143-215.107, respectively.

Under the North Carolina Administrative Code, variances from applicable standards, revisions to water quality standards or site-specific water quality standards may be granted by the Commission on a case-by-case basis pursuant to G.S. 143-215.3(e), 143-214.3 or 143-214.1. Exemptions are to be reviewed as part of the Triennial Review of Water Quality Standards conducted pursuant to 40 CFR 131.20; 15A NCAC 02B.0226.

Under federal law, states are authorized to grant variances but a variance constitutes a new or revised water quality standard and must be approved by EPA. 40 C.F.R. 131.13. The standards for approving a variance are the same as those that apply to removing a designated use through a use attainability analysis under 40 C.F.R. 131.10(g).[6] These standards are discussed below, in the section on use attainability analyses.

5.6.1.2 Policy/Legal Considerations

EPA advises states to use variances when a state believes that a water quality standard can be met at some point in the future. As a practical matter, variances are often used in lieu of a change in a designated use, even though the standards for granting both are the same. The reason for this is reluctance among both state regulators and EPA to be perceived as down-grading the quality of a water body and the perception that variances have greater public acceptance.

Recently, as part of its agenda for states to adopt numeric nutrient criteria, EPA has been suggesting that states should not be concerned about the inability of dischargers to meet strict new criteria, because variances are available.[7]

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[4] *But see* Chesapeake Bay TMDL (Dec. 2010) (using Maryland's restoration variance as a basis for TMDL allocation).
[5] The North Carolina Administrative Code also offers variances (with mitigation) from specific watershed protection requirements such as the requirement for a riparian buffer in the watersheds of nutrient sensitive waters (such as Falls Lake). 15A NCAC 02B .0233. This memorandum does not address site-specific variances from specific requirements.
[6] *In re Bethlehem Steel Corp*. EPA General Counsel Op. No. 58. Mar. 29, 1977.
[7] *See* 75 Fed. Reg. 75762, 75789 (Dec. 6, 2010) (establishing federal numeric nutrient criteria for Florida lakes and flowing waters and suggesting variances as an implementation mechanism). EPA also relied on the assumption that variances or site specific

Approval of a variance by EPA is a final agency action that can be challenged in court under the Administrative Procedure Act. Great Lakes mercury variances in Michigan have been challenged by environmental groups.

5.6.1.3 Applicability to Falls Lake

UNRBA could seek a variance from the chlorophyll *a* and turbidity criteria for the Upper Falls Lake. Possible bases for the variance are 40 C.F.R. 131.10(g)(2) natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use); (g)(4) (hydrologic modifications preclude the attainment of the use) and (g)(6) (adverse social and economic impacts if measures to attain the use were taken).

Data supporting a (g)(2) variance include (1) the fact that prior to its impoundment, the Neuse River above the proposed dam was determined to be a poor source of water quality due to the "poor quality of the water during low flows" and the "high sediment loads," and the need to maintain minimum flows downstream (State of North Carolina Department of Natural and Economic Resources (NCDENR) Office of Water and Air Resources 1973), and (2) according to NCDENR (2012b), modeling suggests that drought conditions could deplete the water supply pool of Falls Lake by 2030.

Data supporting a (g)(4) variance include (1) the fact that the lake is a reservoir created and regulated by the Corps of Engineers, (2) historic monitoring data showing non-compliance in Upper Falls Lake from the date that the Neuse River was dammed and the pool reached its design level, and (3) the fact that the Environmental Impact Statement for this project predicted that the lake would be eutrophic and recreational use would be limited to fishing would support this determination.[8]

A (g)(6) variance is based on the demonstration that meeting the water quality standard is not affordable. The data needed to support this demonstration is included in the discussion of use attainability analyses, below. Based on a compendium of variances developed by an EPA contractor, the most common basis for granting a variance is the economic basis under section 131(g)(6).
Variance Compendium, Jan. 24, 2011 (available at
http://www.deq.state.or.us/wq/standards/docs/toxics/humanhealth/rulemaking/VarianceCompendium110124.pdf)

While it may be easier to obtain, a variance may not be of significant benefit to the UNRBA because it is not permanent and would have to be reviewed every three years as part of the triennial review of water quality standards. Further, notwithstanding a variance, Falls Lake would remain in non-attainment status.

5.6.1.4 Examples

EPA is willing to approve state-wide or multiple discharger variances. A compendium of EPA approved variances is found at
http://www.deq.state.or.us/wq/standards/docs/toxics/humanhealth/rulemaking/VarianceCompendium110124.pdf)

a. Montana.

criteria would be adopted, in lieu of actual compliance with the federal standards, in assuming a very low cost of compliance. Economic Analysis of Final Water Quality Standards in Lakes and Flowing Waters in Florida, EPA, Nov. 2010. *See also*, letter from Karl Brooks, Regional Administrator, EPA Region 7, to Chick Gipp, Director, Iowa Department of Natural Resources and Bill Northey, Secretary, Iowa Department of Agriculture and Land Stewardship, Jan. 9, 2013 (commending Iowa's draft nutrient reduction strategy, agreeing that Iowa's strategy addressed al the elements of EPA's March 2011 Nutrient Reduction Framework, but asserting that EPA still believes numeric criteria are important tools and that Iowa should recognize the existence of implementation flexibilities (such as site-specific criteria, revisions to designated uses, permit compliance schedules, water quality standards variances, and trading) once "protective criteria are in place."

[8] Final Environmental impact Statement (Revised) Falls Lake Neuse River Basin North Carolina (USACE 1974).

For example, on January 3, 2012, EPA approved Montana's variance from its numeric criteria for nitrogen and phosphorus, to allow implementation of those new criteria in an incremental fashion. The Montana law establishes interim effluent limitations of 1 mg/L for TP and 10 mg/L for TN for large dischargers (1 million gallons a day or more) and 2 mg/L of TP and 15 mg/L TN for smaller dischargers.[9] Montana's variance is based on a use attainability analysis that determined that compliance with the nutrient criteria would result in substantial and widespread social and economic impacts on Montana dischargers because compliance with the Montana standards would require reverse osmosis to treat effluent and EPA agrees that application of reverse osmosis on such a large scale is not demonstrated as practical or necessary.[10] The Montana variance is to be reviewed every three years.

b. Great Lakes States Mercury Variances.

EPA also has approved many variances in Great Lakes States from the Great Lakes Initiative mercury standard of 1.3 ppt. These variances are based on state regulations that adopt state-wide variances that incorporate by reference a use attainability analyses performed by the Ohio EPA (1997) that concluded that compliance with the standard would result in substantial and widespread social and economic impacts because treatment technology is either unavailable or prohibitively expensive.[11] *See, e.g.,* OH Admin. Code 3745-33-07(D)(10); WI Admin. Code NR106.145.

c. Lake Roosevelt, AZ

The US Forest Service operates a sewage treatment system that discharges to Lake Roosevelt in Arizona. Total nitrogen and total phosphorus criteria of 0.3 mg/L and 0.03 mg/L apply to the discharge. In 2007, an economic variance was approved. This variance is to be reviewed every three years to reassess the economic impacts.

d. Maryland Chesapeake Bay Restoration Variance.

In 2005, EPA approved a variance from Maryland water quality standards for the deep parts of the Chesapeake Bay. This variance was based on the *Use Attainability Analysis for Tidal Waters of the Chesapeake Bay Mainstem and Its Tributaries Located in the State of Maryland*, which relied on natural conditions, human-caused conditions, and hydrologic modifications (40 CFR 131.10(g) factors). This UAA relied on a complex mechanistic model of the Chesapeake Bay developed by EPA's Chesapeake Bay Program.

Human-caused conditions were examined by modeling theoretical levels of best management practice implementation. Maryland scientists were able to establish that anthropogenic impacts, such as all forms of nutrient enrichment caused by agriculture, urban nonpoint sources, and other nonpoint sources, could not be remedied. The results of these modeling scenarios demonstrated that, even under pristine (100% forested) conditions, the desired dissolved oxygen criteria could not be attained in the deep channels and deep waters of the Chesapeake Bay during the summer.

Because Maryland determined that the designated uses for the Chesapeake Bay and its tidal tributaries did not fully reflect natural conditions, Maryland decided to adopt refined designated uses. The original criteria included a dissolved oxygen (DO) standard of 5 mg/L maintained throughout the Bay for the protection of aquatic life. The UAA defined five designated use categories, or habitat zones, in the Bay rather than one designated use of aquatic life. The UAA considered the natural conditions, bathymetry,

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[9] These are variances from total phosphorus numeric nutrient criteria (NNC) of between 0.006 and 0.124 mg/L and total nitrogen NNC of between 0.13 and 1.358 mg/L.

[10] Letter from James Martin, Regional Administrator, EPA Region 8, to Richard Opper, Director, Montana Department of Environmental Quality, Jan. 3, 2012. See also MT DEQ, Demonstration of Substantial and Widespread Economic Impacts to Montana That Would Result if Base Numeric Nutrient Standards had to be Met by Entities in the Private Sector in 2011/2012 December 2012; MT DEQ Demonstration of Substantial and Widespread Economic Impacts to Montana That Would Result if Base Numeric Nutrient Standards had to be Met in 2011/2012, available at http://deq.mt.gov/wqinfo/nutrientworkgroup/default.mcpx

[11] Assessing the Economic Impacts of the Proposed Ohio Water Rules on the Ohio Economy, OH EPA and Foster Wheeler Environmental Corporation, 1997.

hydrology, species presence and life cycles, and physical features of each habitat zone. Once the designated uses were identified, specific dissolved oxygen criteria were developed for each habitat zone on a seasonal basis.

The deep-water and deep-channel uses in the middle of the Chesapeake Bay mainstem were shown to be unattainable. Maryland officials believed that partial attainment would be possible, but making this change to the water quality standard was not politically viable. In addition, the state did not believe that traditional approaches such as use removal, specific discharger variance, or establishment of less protective criteria would be consistent with the state's long-term water quality goals. To solve this problem, a restoration variance was added to Maryland's water quality standards as a refinement. The restoration variance allows dissolved oxygen criteria to slightly exceed the DO criterion by up to 7% in the deepest areas of the Bay. The State is required to review the restoration variances at least every three years, and adjust it accordingly.

5.6.2 Compliance Schedules.

State water quality regulations may include provision for compliance schedules, which authorize permits that do not require immediate compliance with water quality standards. 40 C.F.R. 122.47(a). Currently, North Carolina has not adopted such a provision for chlorophyll *a* and turbidity. However, such a provision may be of limited use to UNRBA because EPA takes the position that compliance schedules are only available for pre-1977 water quality standards. *In the Matter of Star-Kist Caribe, Inc*. (NPDES Appeal No. 88-5) (interpreting section 303(b)(1)(C) to require compliance with regulations existing on July 1, 1977 by that date). The North Carolina chlorophyll a and turbidity criteria were adopted in 1976. As a result, EPA would not approve a compliance schedule for these criteria, even if North Carolina law were to provide for one. Furthermore, a compliance schedule does not provide meaningfully regulatory relief if the underlying criteria are not attainable.

North Carolina has provided for compliance schedules for nitrogen and phosphorus discharge limits that are imposed under G.S. 143-215.1(c)(1) (5.5 mg/L TN) and (2) (2 mg/L TP) and that apply to dischargers into nutrient sensitive waters if they are pre-1997 dischargers of more than 500,000 gallons per day or if they are post-1997 dischargers. G.S. 143-215.1B. Under this section, a compliance extension is available for a permit holder to develop a calibrated nutrient response model that would justify a change in the standard (discussed below under changes in water quality standards). This section authorizes an extension of six years plus the amount of time that the Commission needs to develop a nutrient management strategy and adopt rules to modify the limits based on the modeling.

Falls Lake already has a nutrient management strategy and caps on loadings of TN and TP for the three dischargers into Upper Falls Lake. Under the Falls Lake Rules, the date for compliance with the Phase II load allocations is January 15, 2036. However:

If a discharger determines that it cannot meet its limitations by calendar year 2036, the discharger may include its findings in the plan and request an extension of its compliance dates for the nitrogen and phosphorus limitations. This alternate plan shall document the compliance strategies considered and the reasons each was judged infeasible; identify the minimum loadings that are technically and economically feasible by 2036; and propose intermediate limits for the period beginning with 2036 and extending until the Stage II limitations can be met. 15A NCAC 02B .0279(6)(d).

As the limits must eventually be met, this provision for an extension of the compliance schedule may not provide meaningful relief.

5.6.3 Revision of Designated Uses

5.6.3.1 Applicable Law

Both federal and North Carolina law allow for revision of the designated use of a water body. If a non-attaining use is removed, a discharger no longer needs to meet the criteria designed to protect that use, and a water body would no longer be listed as impaired. A change in designated use is a permanent change in a water quality standard.

North Carolina law authorizes changes in designated uses. G.S. 143-214.3; G.S. 143-214.1(d)(4); 15A NCAC 02B.0101(f) and (g**).**

Under the North Carolina General Statutes, before revising a water quality standard the Environmental Management Commission must hold a hearing. The Commission is authorized to change a standard if the Commission finds that:

> (1) Natural background conditions in the stream segment preclude the attainment of the applicable water quality standards; or

> (2) Irretrievable and uncontrollable man-induced conditions preclude the attainment of the applicable water quality standards; or

> (3) Application of effluent limitations for existing sources established or proposed pursuant to G.S. 143-215.1 more restrictive than those effluent standards and limitations determined or promulgated by the United States Environmental Protection Agency pursuant to section 301 of the Federal Water Pollution Control Act in order to achieve and maintain applicable water quality standards would result in adverse social and economic impact, disproportionate to the benefits to the public health, safety or welfare as a result of maintaining the standards; and

> (4) There exists no reasonable relationship between the cost to the petitioner of achieving the effluent limitations necessary to comply with applicable water quality standards to the benefits, including the incremental benefits to the receiving waters, to be obtained from the application of the said effluent limitations;

The new standard cannot be less stringent than the water quality achieved by "highest level of treatment which will result in benefits, including the incremental benefits to the receiving waters, having a reasonable relationship to the cost to the petitioner to apply such treatment, as determined by the evidence." In addition, the new standard cannot be less stringent that what can be achieved by technology based standards under section 301 of the Clean Water Act. Finally, a revised standard cannot endanger human health or safety. G.S. 143-214.3

Under the North Carolina Administrative Code, to change a use the Commission must meet the requirements of 40 CFR 131.10(g) based on a use attainability analysis (UAA) in accordance with 40 C.F.R. 131.10(j). A designated use may be removed based on any one of the following factors:

> Naturally occurring pollutant concentrations prevent the attainment of the use.

> Natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of discharges without violating state water conservation requirements to enable uses to be met.

> Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.

> Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use.

> Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses.

> Controls more stringent than those required by sections 301(b) and 306 of the Act [technology based effluent limitations] would result in substantial and widespread economic and social impact.

In addition to the removal of a designated use under 40 C.F.R. 131.10(g), federal law also allows states to develop subcategories of uses and associated water quality criteria that are more refined. 40 C.F.R. 131.10(c).

5.6.3.2 Policy/Legal Considerations

It can be difficult to gain public acceptance for the removal of a designated use of a water body even if the use is demonstrated to be unattainable through a UAA. Notwithstanding this difficulty, EPA has acknowledged that UAAs are valuable water quality management tools. "Improving the Effectiveness of the Use Attainability Analysis (UAA) Process," memorandum from Ephraim King, Director, Office of Science and Technology, EPA Office of Water, to EPA Regional Water Division Directors (USEPA 2006). Further, the National Research Council of the National Academy of Sciences has recommended UAAs as a first step in the development of a TMDL. "Assessing the TMDL Approach to Water Quality Management," NRC/NAS 2001.

Approval of the removal of a designated use by EPA is a final agency action that can be challenged in court under the Administrative Procedure Act. If the action is controversial, a legal challenge is likely. To avoid a legal challenge, it may be necessary to convince the public that the drinking water uses of the Lower Lake are protected, as well as existing recreational and aquatic life uses of the Upper Lake.

5.6.3.3 Applicability to Falls Lake

A UAA could support the removal of a designated use from Upper Falls Lake. However, the chlorophyll *a* and turbidity criteria support the Class C designation of the lake as "freshwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife." Some of those uses may be existing uses, which may not be removed. As a result, before seeking a removal of a designated use for Upper Falls Lake, it may be necessary for North Carolina to first adopt a sub-classification under which some, but not all, Class C uses are attained.

Like North Carolina, all Florida waters were initially designated as swimmable and fishable, at a minimum (Class C in North Carolina, Class III in Florida). However, Florida recently adopted (and EPA approved) a classification for man-made waters called Class III-Limited. The uses of Class III-Limited waters are: "Fish Consumption; Recreation or Limited Recreation; and/or Propagation and Maintenance of a Limited Population of Fish and Wildlife." This classification is restricted to waters with human-induced physical or habitat conditions that, because of those conditions, have limited aquatic life support and habitat that prevent attainment of Class III uses (fish consumption, recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife). Moving a water body from Class III to Class III-Limited requires a UAA. North Carolina could adopt a similar sub-classification in its water quality regulations.

UNRBA would have to perform a UAA to justify changing the classification of the Upper Lake. As noted above, naturally occurring conditions or hydrologic modification could be bases for the change in designated use. 40 CFR 131.10(g)(2) and (g)(4). In addition, significant and widespread social and economic impacts could be the basis for a change. 40 CFR 131.10(g)(6).

Existing studies that could support a UAA based on natural conditions or hydrologic modification are identified above. A demonstration of economic impacts must be based on EPA's "Interim Economic Guidance for Water Quality Standards," EPA-823-B-95-002 (1995) (hereinafter WQS Economic Guidance).

For public sector permittees, the first calculation is called the Municipal Preliminary Screener. If the cost per household of achieving compliance is over 2 percent of median household income (MHI), the cost is considered an unreasonable financial burden. Costs between 1 and 2 percent are mid-range. If the costs are less than 1 percent, it is assumed that the project is not expected to impose a substantial economic hardship on the community.[12]

The second calculation, called the Secondary Score is comprised of Debt Indicators (bond rating, overall net debt as a percent of the full market value of taxable property), Socioeconomic Indicators (unemployment rate, MHI), and Financial Management Indicators (property tax as a percent of the full market value of taxable property, property tax collection rate).

In the WQS economic guidance, a MHI in the service area that is more than 10 percent above the state median is strong, a MHI that matches the state median is mid-range, and a MHI that is more than 10 percent below the state median is considered weak.

Each weak indicator is given a score of 1, each mid-range indicator is given a score of 2, and each strong indicator is given a score of 3. The Secondary Scores are then averaged together to create a single score and compared to the Municipal Preliminary Screener in the following matrix:[13]

Assessment of Substantial Impacts Matrix

Secondary Score	Municipal Preliminary Screener		
	Less than 1.0 Percent	Between 1.0 and 2.0 Percent	Greater than 2.0 Percent
Less than 1.5	?	X	X
Between 1.5 and 2.5	✓	?	X
Greater than 2.5	✓	✓	?

Based on this matrix, if the two scores intersect in a box labeled "X," then the impact of meeting water quality standards is considered likely to be substantial. If the scores intersect in a box labeled "?," but the score is closer to one side or another, then the community falls in the closest category. If the score is not on the borderline, EPA will look at additional factors such as impacts on low income households, the presence of a failing local industry, and other projects a community would have to forego to meet water quality standards.[14]

For the private sector the WQS guidance first requires verification of the cost of projects needed to attain the standards, including annualized capital costs. Then financial tests are applied to measure the impacts of these costs. These include indicators of liquidity, solvency, and leverage.

After there is a determination that economic and social impacts will be substantial, the community must demonstrate that it is widespread. According to the WQS Economic Guidance, that demonstration is based on the estimated change in socioeconomic conditions expected to occur if the community must comply with water quality standards. Thus, the community must calculate the change from pre-compliance conditions for each socioeconomic indicator. The guidance does not establish benchmarks to determine when a change is significant enough to be considered widespread because that will depend on

[12] WQS Economic Guidance, at 2-7.
[13] *Id.* at table 2-2.
[14] WQS Economic Guidance, at 2-13.

how socioeconomically healthy the community is to begin with.[15] Finally, the guidance does not require consideration of benefits of meeting water quality standards because the regulation does not include a cost-benefit analysis. However, the guidance leaves it up to the state and the EPA Region to determine if the benefits of cleaner water can be monetized and considered in the economic analysis.

The WQS Guidance includes worksheets for making these demonstrations. Examples of completed worksheets are found in the Variance Compendium, referenced above.

5.6.3.4 Examples

a. Deep Creek, North Carolina.

USEPA (2002) approved a UAA for Deep Creek, North Carolina to reclassify the creek from Class C to Class C Swamp. The creek did not attain the DO criterion for Class C waters. However, the state demonstrated that the DO levels were due to natural conditions resulting from seasonal low flow and high temperature. 40 C.F.R. 131.10(g)(2). A description of this UAA is available at: http://water.epa.gov/scitech/swguidance/standards/upload/2002_06_11_standards_handbook_handbookappxT.pdf.

b. Patapsco River in Maryland.

Maryland's Use Attainability Analysis for the Federal Navigation Channels Located in Tidal Portions of the Patapsco River (MDE 2004a and b) describes a number of federally authorized hydrologic modifications under the Rivers and Harbors Act and a complex pattern of tidal circulation that has caused nonattainment of existing designated uses in the Patapsco River.

Maryland ran six sensitivity scenarios of the Chesapeake Bay Model to estimate the influence of the different loading sources and estimate the extent of impairments due to natural- and human-caused conditions. Results showed 77 percent nonattainment, even at a simulated point source reduction level of "everything, everywhere, by everybody," or E3. Due to this significant nonattainment, Maryland proposed a limited use designation for the deep portion of this segment with the applicable dissolved oxygen criteria being 0 mg/L from June 1 to September 30.

c. Valley Creek, Alabama

In August 2000, the Alabama Department of Environmental Management's (ADEM's) Environmental Management Commission adopted new water quality standards regulations that eliminated the Industrial Operations use classification. ADEM also adopted a new classification, Limited Warmwater Fishery (LWF). All provisions of the Fish and Wildlife (F&W) use apply to the LWF use, with the exception of the criteria for dissolved oxygen (DO), bacteria, and chronic aquatic life. At that time the use designation of Valley Creek was changed to from Industrial Operations use to Agriculture and Industrial water supply (A&I).

In 2001, ADEM conducted a UAA to support a proposed use classification change for Upper Valley Creek from A&I to LWF. Even though LWF is a more protective classification than A&I, because LWF is not a "fishable/swimmable" use as defined in Clean Water Act (CWA) section 101(a)(2), the change required a UAA. At that time ADEM also proposed that Lower Valley Creek be classified for the F&W use, which meets the goals of CWA section 101(a)(2 (so no UAA was needed for the Lower Valley Creek).

ADEM's UAA (2001) demonstrated that the F&W use of Upper Valley Creek is precluded by factor 3 (human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place) and factor 5 (physical conditions related to the natural features of the waterbody, such as the lack of a proper

[15] *Id.* at 4-3.

substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude the attainment of aquatic life protection) of 40 C.F.R. 131.10(g).

The UAA is based on water quality monitoring by ADEM, the U.S. Geological Survey (USGS), and EPA. In a 1989 study, EPA examined biological conditions in Village, Valley, Opossum, and Fivemile creeks. Opossum Creek was cited as having poor habitat and deposits of tar-like substances, with growth impairment to the fathead minnow. In addition, the study showed mortality to daphnia at two sampling points on Valley Creek. A biological survey conducted by EPA in 1997 documented degraded habitat at two of three sampling stations in Upper Valley Creek (habitat scores of 66 and 64 versus 118 in the reference F&W stream), and fewer fish species were reported than in the lower segment. On the basis of this information, EPA suggested that Upper Valley Creek would need significant enhancements to improve stream habitat and removal of excess nutrients to be able to achieve the F&W designated use.

USGS data from the Birmingham Watershed Project confirmed the water quality impacts that EPA and ADEM had found. Sampling at several locations from 1998 to 2001 showed that sewer overflows, leaking sewer lines, and other regulated and nonregulated stormwater runoff were contributing the high pathogen loads. EPA, USGS, and ADEM data showed that conditions improved downstream such that F&W uses could be met in Lower Valley Creek.

In a review of these data, EPA concluded that the aquatic community structure showed degraded water quality, negatively affected by anthropogenic impacts in the watershed over an extended period.

The UAA was approved based on factors 3 (human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place) and 5 (physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses) of 40 C.F.R. 131.10(g).

d. Kansas UAAs

Kansas has developed a simple worksheet approach to UAAs and has successfully used this approach on several waterbodies. The worksheet provides reviewers with information such as the name, location, and description of the waterbody; an assessment of its current recreational uses; and observations of aquatic life. Users can evaluate this information and develop a justification for retaining or changing designated uses.

One example of using this worksheet is the Crosby Creek UAA conducted in 2001. In the UAA KDHE proposed primary contact recreation use for Crosby Creek, an upgrade from the secondary contact recreation use designated previously. KDHE also proposed to maintain the current aquatic life use designation. Kansas adopted this change their water quality standards and EPA approved it.

KDHE's UAA worksheet was used for the Antelope Creek UAA conducted in 2001. In that UAA, KDHE did not recommend primary contact recreation as a designated use for this water because of the low flow conditions in the stream (131.10(g)(2) (natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of discharges without violating state water conservation requirements to enable uses to be met). The segment fits Kansas' definition of an ephemeral stream, grass or vegetative waterway, culvert, or ditch. Photos were provided with the worksheet to show the dry conditions in the streambed. This change was adopted into Kansas' water quality standards and approved by EPA.

5.6.4 <u>Site-Specific Standards</u>

5.6.4.1 Applicable Law

Both North Carolina law and federal law allow the use of site-specific standards. G.S. 143.214.3; 40 C.F.R. 131.11(b)(1)(ii). A site-specific standard does not need to involve the removal of a designated use. Instead, it can be a change in the water quality criteria that are adopted to protect the designated use, based on a demonstration that different criteria are protective. A change in water quality criteria is based on a scientific demonstration and can be made without a UAA.

The bases for revising a water quality standard in G.S. 143.214.3 are identified above. Under federal law, the bases for revising a water quality standard to adopt site-specific criteria are found in EPA's Water Quality Standards Handbook (U.S. EPA 1994). The Water Quality Standards Handbook contains three procedures for calculating site-specific criteria, based on these types of differences:

> *Recalculation* considers differences between the sensitivities of the aquatic organisms used to develop national criteria and the site-specific sensitivities of organisms;

> *Water-Effect Ratio* considers differences between the toxicities of the chemical in laboratory dilution water and in site water; and

> *Resident Species* considers both kinds of differences.

When the physical/chemical characteristics of the site alter the bioavailability / toxicity of the pollutant different from the laboratory dilution water you can use the Water-Effect Ratio (WER). When the sensitivities of the site species differ from those used to develop the national criteria (*e.g.,* trout don't exist at the site) you can use the Recalculation Procedure. When both chemical and biological differences are involved you can use the Resident Species Procedure. When there are naturally high background levels of a pollutant you can use a reference water body approach.

As noted above, North Carolina law allows for revision of the TP and TN standards that would be otherwise applicable to dischargers into nutrient sensitive waters based on a calibrated nutrient response model. "A calibrated nutrient response model shall be developed and maintained with current data, be capable of predicting the impact of nitrogen or phosphorus in the surface waters, and incorporated into nutrient management plans by the Commission." G.S. 143-215.1(c)(5).

In addition, the Falls Lake Rules expressly call for changes to the Falls Lake load reduction targets for TN and TP based on new modeling data:

Recognizing the uncertainty associated with model-based load reduction targets, to ensure that allowable loads to Falls Reservoir remain appropriate as implementation proceeds, a person may at any time during implementation of the Falls nutrient strategy develop and submit for Commission approval supplemental nutrient response modeling of Falls Reservoir based on additional data collected after a period of implementation. The Commission may consider revisions to the requirements of Stage II based on the results of such modeling as follows:

> (i) A person shall obtain Division review and approval of any monitoring study plan and description of the modeling framework to be used prior to commencement of such a study. The study plan and modeling framework shall meet any Division requirements for data quality and model support or design in place at that time. Within 180 days of receipt, the division shall either approve the plan and modeling framework or notify the person seeking to perform the supplemental modeling of changes to the plan and modeling framework required by the Division;

> (ii) Supplemental modeling shall include a minimum of three years of lake water quality data unless the person performing the modeling can provide information to the Division demonstrating that a shorter time span is sufficient;

> (iii) The Commission may accept modeling products and results that estimate a range of combinations of nitrogen and phosphorus percentage load reductions needed to meet the goal of the Falls nutrient strategy, along with associated allowable loads to Falls Reservoir, from the watersheds of Ellerbe Creek, Eno River, Little River, Flat River, and Knap of Reeds Creek and that otherwise comply with the requirements of this Item. Such modeling may incorporate the results of studies that provide new data on various nutrient sources such as atmospheric deposition, internal loading, and loading from

tributaries other than those identified in this Sub-item. The Division shall assure that the supplemental modeling is conducted in accordance with the quality assurance requirements of the Division;

> (iv) The Commission shall review Stage II requirements if a party submits supplemental modeling data, products and results acceptable to the Commission for this purpose. Where supplemental modeling is accepted by the Commission, and results indicate allowable loads of nitrogen and phosphorus to Falls Reservoir from the watersheds of Ellerbe Creek, Eno River, Little River, Flat River, and Knap of Reeds Creek that are substantially different than those identified in Item (3), then the Commission may initiate rulemaking to establish those allowable loads as the revised objective of Stage II relative to their associated baseline values. 15A NCAC 02B .0275(5).

Site-specific criteria must be approved by USEPA.

5.6.4.2 Policy/Legal Considerations

Although EPA has developed recommended nutrient criteria under section 304(a), EPA has made it clear that its criteria are merely a starting point and states should use EPA's technical guidance to develop water body specific criteria. In fact, nutrient criteria that fully reflect localized conditions and protect specific designated uses, using the process outlined in the technical guidance manuals, are preferred:

EPA strongly encourages states, territories and authorized tribes to refine these recommendations based on the key elements of nutrient criteria development (historical information, reference conditions, models, consideration of downstream effects, and expert judgment) discussed in EPA's published Technical Guidance Manuals (Lakes and Reservoirs: EPA-822-B00-001; Rivers and Streams: EPA-822-B-00-002). EPA recognizes that states and authorized tribes have several options available to them and recommends the following approaches, in order of preference: (1) Wherever possible, develop nutrient criteria that fully reflect localized conditions and protect specific designated uses using the process described in EPA's Technical Guidance Manuals for nutrient criteria development. Such criteria may be expressed either as numeric criteria or as procedures to translate a state or tribal narrative criterion into a quantified endpoint in state or tribal water quality standards.

November 14, 2001 memorandum from Geoffrey Grubbs, Director, Office of Science and Technology, EPA Office of Water, to EPA Regional Water Directors, "Development and Adoption of Nutrient Criteria into Water Quality Standards," at 15.

A change in criteria continues to protect the designated use so it may be more acceptable to the public.

If North Carolina seeks to change its water quality criteria for Upper Falls Lake, EPA may ask the state to adopt numeric criteria based on TP and TN, rather than continuing to rely on chlorophyll *a* and turbidity levels, given EPA's push for state adoption of numeric nutrient criteria. However, for the Chesapeake Bay, EPA guidance recommended water quality criteria based on dissolved oxygen, chlorophyll a and water clarity (measured by submerged aquatic vegetation). Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries, EPA 903-R-03-002 (USEPA 2003).

Approval of water quality standards by EPA is a final agency action that can be challenged in court under the Administrative Procedure Act. Environmental groups in Florida are challenging EPA's approval of Florida's NNC for lakes and flowing waters. Such standards are based on scientific determinations, and a court would likely defer to EPA on scientific matters.[16]

[16] *But see Florida Wildlife Fed'n Inc. v. Jackson,* No. 4:08-cv-00324, 2012 WL 537529 (N.D. Fla. Feb. 18, 2012) (agreeing with industry and municipalities that argued that EPA's numeric nutrient standards for streams were invalid; disapproving such standards based on a failure to show the adopted levels would result in biological harm).

5.6.4.3 Applicability to Falls Lake

EPA's 1985 *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Use* (USEPA 1985) (hereinafter National Guidelines) establish the threshold principles that all aquatic water quality criteria must meet. First, the purpose of criteria is to protect aquatic organisms and their uses from unacceptable effects. *See* National Guidelines, at vi. Thus, "[t]he concentrations, durations, and frequencies specified in criteria are based on biological, ecological, and toxicological data, and are designed to protect aquatic organisms and their uses from unacceptable effects." *Id.* at 16. To develop such criteria, adequate data must be available or the criteria should not be developed. *Id.* at 5-6. Specifically, there must be adequate data on pollutant levels that cause an unacceptable adverse effect on any of the specified biological measurements. *Id.* at 39. For materials that have a threshold effect, the threshold of unacceptable effect must be determined. *Id.* at 8.

There is significant debate currently about the use of biological response indicators, such as chlorophyll *a*, to protect water bodies from the adverse effects of nutrients. While EPA has taken the position that states must adopt numeric nutrient criteria for TN and TP it recognizes the value of biological indicators and recently approved Florida nutrient regulations that include a biological evaluation that would verify a stressor-response relationship before taking management action. Such an approach also is recommended by EPA's Science Advisory Board. SAB Review of Empirical Approaches for Nutrient Criteria Derivation, EPA-SAB-10-006 (Apr. 27, 2010) (emphasizing the importance of biological responses).

Providing site-specific chlorophyll *a* and turbidity criteria will require data demonstrating that the designated uses of the Upper Lake are protected even if levels of these indicators are higher. This demonstration can be made based on an evaluation of the health of the aquatic life present in the Upper Lake, notwithstanding higher levels of chlorophyll *a* and higher levels of turbidity, resulting in a recalculation of the criteria, in accordance with the Water Quality Standards Handbook, discussed above.

Given the fact that there also are specific TN and TP standards applicable to dischargers into nutrient sensitive waters such as Falls lake, UNRBA also would want to pursue the calibrated nutrient response model that would justify changing those standards as well, if needed.

Finally, UNRBA could use the new standards to justify changes to the allocations of TN and TP to Upper Falls Lake dischargers.

5.6.4.4 Examples

a. Arizona

Arizona has used site-specific criteria for lakes and reservoirs, including reservoirs that are shallow and situations where anthropogenic activities have severely altered natural conditions.

Arizona Department of Environmental Quality developed site-specific dissolved oxygen and ortho-phosphorus levels and limits on total phosphorus and chlorophyll *a*, pH, and ammonia for Lakeside Lake in Tucson, AZ, when developing a TMDL for that lake in 2005.

b. Los Angeles Area Lakes.

In March 2012, EPA Region IX approved TMDLs for several lakes in the Los Angeles region. Chlorophyll *a* criteria set by USEPA and the Los Angeles Regional Board are 20 µg/L as an annual mean and as a summer average (May to September) to protect these lakes from nuisance plant and algae growth.

The BATHTUB model was used to set site-specific nitrogen and phosphorus criteria to meet the regional chlorophyll *a* criteria. Site-specific models were developed to reflect local loading patterns, storm water diversions and discharges, and existing lake management measures such as aeration, adjacent treatment wetlands, and artificial circulation. Each model accounted for internal phosphorus loading based on the Nürnberg method as well as additional unquantified sources such as background wildlife populations, human-induced increases in bird and rodent populations, irrigation runoff, and adjacent onsite wastewater treatment systems. Total nitrogen and phosphorus criteria for each lake were selected such that the chlorophyll *a* target was met.

5.6.5 EPA Push for Numeric Nutrient Criteria.

EPA has been putting pressure on states to adopt numeric nutrient criteria. In March 2011, Acting Assistant Administrator Nancy Stoner issued a memorandum to EPA Regional Administrators called: "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions" (Nutrient Framework). The memorandum stated must take the lead in addressing nutrients and that: "states need room to innovate and respond to local water quality needs, so a one-size-fits-all solution to nitrogen and phosphorus pollution is neither desirable nor necessary."

The Nutrient Framework expressly contemplates that states that are making reductions in nutrient loadings through other means can delay the adoption of numeric criteria for TN and TP:

Accordingly the attached framework envisions that as states develop numeric nutrient criteria and related schedules, they will also develop watershed scale plans for targeting adoption of the most effective agricultural practices and other appropriate loading reduction measures in areas where they are most needed. The timetable reflected in a State's criteria development schedule can be a flexible one provided the state is making meaningful near-term reductions in nutrient loadings to state waters while numeric criteria are being developed.

However, EPA wants states to agree to a schedule for NNC development, as part of the work plans submitted as a condition of receipt of federal funding under section 106 of the Clean Water Act. The Nutrient Framework says:

Establish a work plan and phased schedule for N and P criteria development for classes of waters (e.g., lakes and reservoirs, or rivers and streams). The work plan and schedule should contain interim milestones including but not limited to data collection, data analysis, criteria proposal, and criteria adoption consistent with the Clean Water Act. A reasonable timetable would include developing numeric N and P criteria for at least one class of waters within the state (e.g., lakes and reservoirs, or rivers and streams) within 3-5 years (reflecting water quality and permit review cycles), and completion of criteria development in accordance with a robust, state-specific workplan and phased schedule.

North Carolina's current Nutrient Criteria Implementation Plan is dated October 25, 2005 and embraces the adaptive management strategies set for the in the Falls Lake Rules (and other watershed programs), which rely on reductions in TP and TN loadings to meet the state's nutrient response criteria (chlorophyll *a* levels). On November 5, 2009, North Carolina submitted a progress report to EPA that stated an intent to revise the state's chlorophyll *a* criteria, adopt chlorophyll *a* thresholds, and to impose TN and TP limits in POTW permits. The public expressed concern over the proposed rules and they have not been adopted. In May 2012, the state sponsored a "Nutrient Forum" to seek advice from experts on alternatives for nutrient management. EPA Senior Policy Advisor, Ellen Gilinsky spoke and reiterated EPA's belief that numeric criteria for TN and TP must be adopted. A revised nutrient management plan is due to EPA by June 30, 2013.

Even though North Carolina has had numeric criteria to address nutrients for decades (the chlorophyll a criteria), EPA does not give the state credit for this action. On its website EPA identifies North Carolina as a state with no numeric criteria to control nutrients. *See* http://www.epa.gov/nandppolicy/progress.html

As discussed above, EPA also reiterated its desire for numeric TN and TP criteria in comments on Iowa's nutrient management strategy.

However, EPA also has been under significant pressure from states and elected officials to recognize the validity of response variables to manage nutrients. As a result, EPA has approved or indicated a willingness to approve state water quality standards for nutrients that include a biological response component (such as Florida's standards discussed above, as well as standards under development in Maine and Ohio), and has softened its insistence that numeric TP and TN criteria be independently applicable.

These issues will play out relatively soon. However, if North Carolina can demonstrate success from its current approach to nutrient management, the state can demonstrate that numeric TN and TP criteria are not necessary to protect water quality.

6 Recommendations for the Re-examination of the Stage II Rules

The UNRBA has initiated a study to develop a framework for re-examining Stage II of the Falls Lake Nutrient Management Strategy. Based on the State's fiscal analysis, implementation costs for Stage II are expected to approach $1 billion on top of Stage I implementation costs expected to approach $500 million. A review of this analysis (Section 3) indicates that the Stage II expenditures are not likely to achieve phosphorus reductions of 77 percent due to the limits of current technology. While the local governments in the watershed have agreed that Stage I implementation is reasonable to protect water quality in the Lower Lake and provide a safe drinking water supply for the City of Raleigh, the Consensus Principles allow for a re-examination of the Stage II rules for the Upper lake segment:

"The process by which the proposed regulatory scheme has been developed relied on a limited data base which will be substantially enhanced by a more rigorous program of sampling, monitoring and analysis. In addition, it may not be feasible to attain all currently designated uses in the Upper Lake and attempting to do so may result in substantial and widespread economic and social impact. The EMC should therefore begin a re-examination of its nutrient management strategy for Falls Lake by January 1, 2018. The re-examination should consider, among other things, (i) the physical, chemical, and biological conditions of the Lake with a focus on nutrient loading impacts and the potential for achieving the Stage 1 goal by 2021 as well as the feasibility of both achieving the Stage 2 reduction goals and meeting the water quality standard for chlorophyll-a in the Upper Lake, (ii) the cost of achieving, or attempting to achieve, the Stage 2 reduction goals and the water quality standard in the Upper Lake, (iii) the existing uses in the Upper Lake and whether alternative water quality standards would be sufficient to protect those existing uses, and (iv) the impact of the management of Falls Lake on water quality in the Upper Lake."

Cardno ENTRIX recommends a multi-part process including monitoring, modeling, and regulatory actions for moving forward with the re-examination of the Stage II rules. The following sections describe the recommended process and tentative schedule.

6.1 Conduct Future Monitoring Studies

Cardno ENTRIX (2013b) recommended several types of monitoring studies that are needed to support the short term and long term needs of the UNRBA:

- Source allocation and estimation of jurisdictional loading,
- Lake response modeling,
- Compliance monitoring,
- Linkage of water quality to designated uses,
- Credit accounting/BMP effectiveness, and
- Support of regulatory options.

In terms of supporting the re-examination of Stage II of the Nutrient Management Strategy, the lake response modeling, linkage of water quality to designated uses, and support of regulatory options are required to provide a scientific basis for the process. The remaining objectives are related to optimizing BMP implementation in the watershed to reduce implementation costs, demonstrating compliance with the regulations, and providing data for developing nutrient credit accounting for BMPs that do not currently have methods in place.

Brief descriptions of the types of studies that meet the monitoring objectives for the re-examination process are described below (more detail on these and the other studies may be found in the Task 4 TM):

Supporting refinement of the lake response modeling requires quantifying tributary nutrient loading, refining the lake bathymetry data, and quantifying inlake processes such as benthic flux and reaction kinetics. These studies are expected to cost approximately $560,000 per year (less if the USEPA is able to conduct some of the inlake studies).

Linking water quality to designated uses involves collecting water quality data in the lake at the same time that other specific studies are conducted such as fish sampling by the NC Wildlife Resources Commission, profile data collected by NCSU-CAAE, and recreational use surveys conducted around the lake. These studies are expected to cost approximately $310,000 per year. Proper coordination of the studies will likely result in cost savings.

The monitoring studies needed to support long-term regulatory options include those required for refining the lake nutrient response modeling and linking water quality to designated uses. Thus, this objective does not require additional budget. However, some of the immediate regulatory actions being pursued by the UNRBA may require additional monitoring and modeling. The monitoring studies needed to support short term regulatory actions (Section 6.2) may costs approximately $100,000 per year for at least three years with modeling costs ranging from $150,000 to $300,000 (single contract).

The Falls Lake Nutrient Management Strategy requires a minimum of three years of monitoring data to proceed with the re-examination process. The UNRBA is planning to implement a monitoring program for a minimum of four years (maybe five years if weather patterns are anomalous (large hurricanes, extensive droughts, etc.)). Monitoring will likely begin in mid-2013 and continue until at least the end of 2017. There is potential for monitoring in 2018 as well. Given that Stage II implementation begins in 2021 under the existing Strategy, Cardno ENTRIX recommends preliminary analyses to provide planning level information regarding the four components of the re-examination process (Parts 1, 2, 3, and 4).

6.2 Recommended Short Term Regulatory Actions

The UNRBA is currently considering immediate regulatory (or administrative) changes that may provide temporary relief for implementing the Falls Lake Nutrient Management Strategy. For example, there is discussion of delaying implementation of the Stage I rules to allow NCDWQ to approve credit accounting procedures for practices that do have procedures in place before January 2014, when the Stage I model programs are due from the local governments. This delay would allow for additional practices to achieve nutrient reductions and hopefully reduce implementation costs by allowing more flexibility in how nutrient reductions may be achieved. In addition, a delay would provide more time for the re-examination process. A decision on whether or not the rules will be delayed should be resolved by the end of 2013.

The Falls Lake Nutrient Management Strategy in its current form does not account for delivery factors in the estimation of nutrient loading and required offsets. The NSAB clarifies this assumption in their 2012 report: “The Division [NCDWQ] does not propose the use of delivery factors in the Falls watershed. Assessment made as part of the Falls watershed modeling found that nutrient delivery differences were sufficiently small from disparate points within that watershed, which is roughly half the size of Jordan and more concentrically shaped, to reasonably forego the additional regulatory complication involved with applying delivery factors” (NSAB 2012). However, this assumption is inconsistent with the original Jordan Lake modeling and a recent statement by the NSAB regarding revised model development in the Jordan Lake watershed which basically said that large impoundments have a larger impact on water quality than BMPs (January 16, 2013 NSAB Meeting Notes). Thus, the Falls Lake Nutrient Management Strategy essentially assumes that nutrient reductions in the headwaters (which may be 25 miles upstream of the lake and potentially drain to a watershed impoundment) have the same effect on lake water quality as those achieved closer to the lake. In its current form, the Strategy requires stakeholders to implement BMPs based only on the distribution of disturbed area in the watershed. If delivery factors are included in the assignment of loading and credits, financial resources can be focused on areas that contribute the greatest delivered nutrient loading to Falls Lake (preliminary discussions with NCDWQ staff indicate that considering delivery factors in this watershed would be acceptable to the agency). Given that Stage I implementation may cost $500 million, Cardno ENTRIX recommends that these discussions with NCDWQ occur in 2013 so that local governments know if (and how) they may consider delivery factors in their implementation programs. If the implementation of the Strategy is delayed either administratively or through regulatory change, model development to determine these factors is recommended during the delay period. If the Strategy is not delayed, but NCDWQ agrees that delivery factors may be used in the Falls Lake watershed as they are in other parts of the State, the UNRBA and NCDWQ will need to negotiate how to move forward with the Stage I plans that are due in January 2014 and incorporate this element into the estimation of jurisdictional loads and required reductions.

6.3 Part 1: Revise the Lake Response Modeling

As described in Section 2.2, there is considerable uncertainty regarding the nutrient response modeling for Falls Lake. “Part 1” for the re-examination process is to collect monitoring data to support revised lake nutrient response modeling, recalculate the loading targets with the recalibrated model, and determine if the new loading targets are acceptable to the UNRBA. This part of the process is required by the Falls Lake Nutrient Management Strategy and is an integral component of the overall plan.

Because the existing model currently predicts that very large nutrient reductions are needed to comply with chlorophyll *a* criterion (40 percent for nitrogen and 77 percent for phosphorus in addition to the Stage I reductions), it is in the interest of the stakeholders in the watershed to reduce the uncertainty of the model inputs and predictions. While all models rely on assumptions and best professional judgment in their development, and it is typically not possible to collect site-specific data for every variable and parameter, there are several key issues and data gaps that should be considered in a revised lake nutrient response model:

- The load allocations resulting from the modeling should be based on a modeling period that covers a range of typical hydrologic conditions for the watershed rather than a single year.
- Better estimates of pollutant loading are needed for the tributaries downstream of I-85.
- Tributary concentrations of chlorophyll a and TOC should be based on data collected in free flowing waters upstream of the lake.
- A better understanding of the spatial variability in modeling parameters should be reflected in the revised modeling (background light extinction, benthic flux rates, etc.).

Following the revisions and recalibration of the lake nutrient response model, the load allocations need to be recalculated to determine the amount of nutrient loading that the lake can receive and still meet the chlorophyll *a* target of 40 µg/L throughout the lake. Model revisions and recalculation of loading targets may occur in 2018 depending on the duration of the monitoring period, which may need to be extended if abnormal weather patterns occur. Cardno ENTRIX recommends preliminary model updates following the first one or two years of monitoring to provide planning level results. The deadline for final model results will depend on the duration of the monitoring period. The results of the modeling will be used to reassess the technical and financial feasibility of the revised load allocations and provide the modeling platform for the other parts of the re-examination process.

6.4 Part 2: Seek a Sub-classification Use Attainability Analysis (SC-UAA) for the Upper Lake (upstream of Highway 50)

While it is likely that the recalibrated lake response model will result in higher allowable nutrient loads to Falls Lake (i.e., lower percent reductions) relative to the Stage II goals, it is still possible that revised targets will be technical infeasible and/or financially burdensome to the local stakeholders. For example, when the Falls Lake Framework Tool is used to predict the nutrient loading targets that will result in compliance with the chlorophyll *a* criterion of 40 µg/L, one possible combination of nutrient reductions that achieves the standard is a 34 percent reduction in nitrogen loading and a 68 percent reduction in phosphorus loading (these are based on the adjusted chlorophyll *a* calibration factor for the segment west of I-85 (see Section 4.1.1) and are higher than those needed if the calibration factor had been left at 0.92). Assuming the cost per pound reductions for phosphorus calculated from the NCDWQ fiscal analysis, the fiscal impact of these reductions is still “Large.” Therefore, complying with the chlorophyll *a* standard in the upper part of the lake may still be financially burdensome even with a revised lake nutrient response model.

Cardno ENTRIX and Barnes & Thornburg recommend that the UNRBA explore the development of a sub-classification use attainability analysis (SC-UAA) for the upper lake. This process would require that NCDWQ create a new designated use category that maintains existing recreation and aquatic life uses, including the use of the upper lake to protect water quality in the lower lake and provide a safe drinking water supply for the City of Raleigh. The following factors support a new designated use category for this purpose:

> The hydrodynamics of Falls Lake could be altered to promote flushing of upper lake waters and reduce the potential for algal growth (e.g., altered bridge crossings and restriction points). While alteration may improve water quality in the upper lake and potentially result in compliance with the chlorophyll *a* standard in conjunction with some level of nutrient reductions, most of the nutrients that are currently trapped in the upper lake would be moved downstream to the lower lake and likely cause higher chlorophyll *a* and TOC concentrations near the water intake. Therefore, a primary function of the upper lake is the protection of the lower lake as a water supply.

> Several impoundments in the State have restriction points that essentially form forebays or pools that serve to improve water quality in the downstream sections of those lakes. Additional waterbodies in the State may benefit from development of a new designated use that reflects that purpose and function.

> Prior to its impoundment, the Neuse River above the proposed dam was determined to be a poor source of water quality due to the “poor quality of the water during low flows” and the “high sediment loads,” and need to maintain minimum flows downstream (State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources 1973). The upper section of Falls Lake has improved Raleigh’s raw water supply relative to what was available before the river was impounded.

> Prior to construction of the Falls Lake Dam, State fiscal analyses (State of North Carolina Department of Natural and Economic Resources Office of Water and Air Resources 1973) and USACE (1974) environmental impact statements predicted that water quality in the upper part of the lake would be highly eutrophic and that while recreational uses such as swimming may not occur in that part of the lake, fishing would likely be popular. In addition, the poor water quality in the upper end of the lake was not expected to cause impacts at the drinking water intake near the dam. The consensus of the agencies at that time was that the benefits of the lake (flood protection, drinking water supply, aquatic life, and recreation) would outweigh any negative impacts associated with eutrophication. These reports are summarized in the Task 2 TM.

> The data summaries presented in the Task 2 TM show that water quality improves longitudinally from the upstream to downstream end of the lake with the most significant reductions in nutrient, chlorophyll *a*, and TOC concentrations occurring upstream of Highway 50.

> The upper most part of the lake near the compliance point undergoes periods of wetting and drying that alter the hydrologic function of the lake relative to segments downstream.

Pursuit of an SC-UAA for the upper lake would require development of a new designated use category and demonstration that the other designated uses were being met throughout the lake. These determinations would depend on the monitoring and modeling studies included in Part 1 of the re-examination process (revision of the lake nutrient response modeling) as well as additional studies:

> Cardno ENTRIX (2013b) recommends monitoring studies to provide a linkage between lake water quality and designated uses. This information will be used to confirm whether or not other designated uses (e.g., recreation and aquatic life) are met throughout the lake. These monitoring studies and the revised lake response modeling would also be needed to ensure that water quality near the dam continued to be safe for drinking water supply if the SC-UAA was granted. These studies should commence in 2013 at the same time the other water quality monitoring studies are being conducted.

> Cardno ENTRIX (2013b) also suggests developing an empirical model to link nutrient loading to lake water quality and designated uses. This will allow the UNRBA to make informed decisions regarding the impacts of nutrient management measures on designated uses. For example, the empirical model may be developed to predict changes in total organic carbon, UV absorption, taste and odor, and harmful algal blooms that affect safe drinking water. Another example would be to predict the impacts of nutrient management on recreational use by assessing changes in water clarity, harmful algal blooms, taste and odor, pH, fish type and quantity. This empirical model may be directly linked to both the watershed model that predicts nutrient loads resulting from management actions as well as the lake response model that predicts changes in lake water quality.

> In addition, modeling may be needed to demonstrate that the chlorophyll *a* levels are not achievable due to either natural conditions or hydrologic modification, if either or both of these justifications are used for the SC-UAA.

> If the SC-UAA is to be justified based on economic and social impacts, then an economic analysis must be performed.

Following one or two years of monitoring data, the UNRBA should obtain preliminary lake response modeling results to determine if preparation for the SC-UAA process is needed. If there is a high likelihood that a SC-UAA will be needed based on projected nutrient reductions compared to limits of technology and associated implementation costs, the UNRBA should commence the supporting modeling studies and negotiations with NCDWQ and USEPA as soon as possible because the process may take one to two years.

An SC-UAA for the upper lake may be controversial because it involves the permanent change of a use classification. Some may consider this to be “down-grading” the upper lake. However, if the SC-UAA can be supported based on naturally occurring conditions or hydrologic modification (rather than cost), then this change in use may have greater public acceptability. That is, if the existing classification cannot be met at any cost, then a change in use classification may be more acceptable to the public as long as the existing uses and the water supply remain protected.

6.5 Part 3: Consider a Site-Specific Chlorophyll *a* Criterion for the Upper Lake

A third component of the re-examination process is development of a site specific chlorophyll *a* criterion for the upper lake. This part of the overall plan requires the same data sets and models used for parts 1 and 2 with additional analyses to determine the site-specific chlorophyll *a* criteria for the upper lake that continues to meet the aquatic life, recreation, and water supply designated uses. Demonstration that a site-specific chlorophyll *a* criterion in the upper lake continues to protect the existing use classifications for the Upper Lake and drinking water supply use in the Lower Lake will be required. If the future monitoring studies demonstrate that the lake is meeting its designated uses (as appears the case based on existing biological indicators), a site specific criteria based on current conditions may be a favorable option to all parties.

6.6 Part 4: Apply for a Variance

As described in Section 6.4, it is likely that the revised lake nutrient response model will still result in nutrient load allocations that are financially burdensome to the regulated community and beyond the limits of technology. Development, approval, and regulatory change associated with an SC-UAA or a site-specific chlorophyll *a* criteria may take several years in addition to the monitoring and modeling studies that are required for the process. While these more permanent paths are being considered, the UNRBA may need to apply for a variance.

A variance is supported by the same justifications used to support a permanent change in use. As noted above, for the Upper Lake, the most likely justifications (1) natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, (2) hydrologic modifications preclude the attainment of the use) an or (3) adverse social and economic impacts if measures to attain the use are taken. Thus, demonstrating the need for a variance relies on the same data and analyses as a SC-UAA. While a variance is a temporary solution that requires reissuance at periodic intervals, it is also a lengthy process that should be included in the overall planning for the re-examination process. Because a variance does not involve a permanent change in use, it may be less controversial and more acceptable to the State and USEPA.

6.7 Re-examination Schedule

The current schedule described in the Falls Lake Nutrient Management Strategy provides little time to conduct the necessary monitoring and modeling studies, analyses, negotiations, and regulatory changes that are required of the re-examination process. In the near term, Cardno ENTRIX and Barnes & Thornburg recommend that the UNRBA begin collecting the data needed to support the re-examination process and seek a delay in implementation of the rules. During this time, the UNRBA can begin to conduct the economic analyses needed to support a variance or a SC-UAA.

After one or two years of monitoring, preliminary revisions to the lake nutrient response modeling should be conducted to assess how much the nutrient allocations may change (Part 1 of the re-examination process). The preliminary revisions to the model may also be used to test the feasibility of meeting the water quality standard for chlorophyll *a* in the Upper Lake, determine whether alternative water quality standards may be sufficient to protect the existing uses, and assess the impact of the management of Falls Lake on water quality in the Upper Lake. Some of the analyses required of Parts 2, 3, and 4 of the re-examination process may begin as early as 2013. For example, the economic analyses that justified either an SC-UAA or variance may begin immediately.

After the preliminary revisions to the lake nutrient response model have been made, the model may be used to test various scenarios with respect to attainment of existing and proposed use classifications. Because a final model and scenario results may not be available until 2019, and the regulatory process itself may take one to two years to result in definitive change, application for a variance may be needed to allow sufficient time for the re-examination process.

Figure 6-1 recommends a schedule that includes the near term and long term activities needed to support the re-examination process.

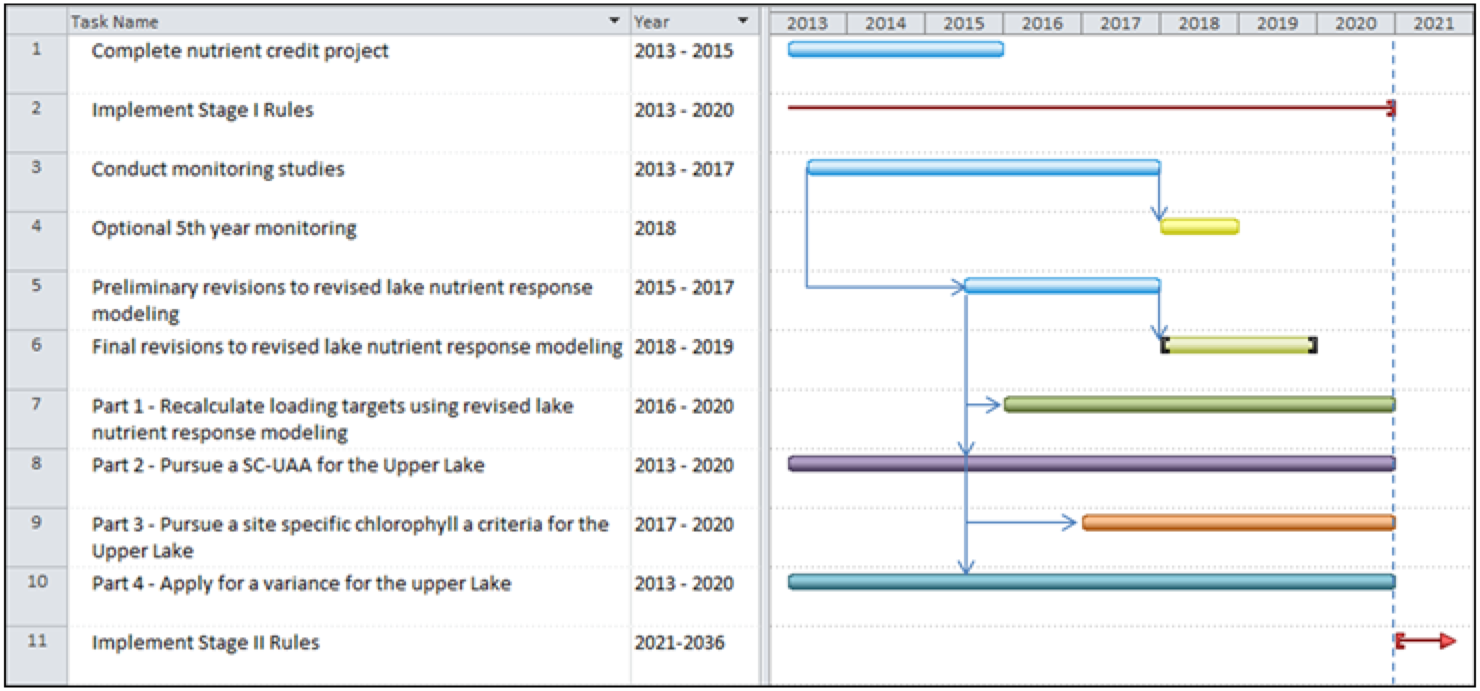

Figure 6-1 Potential Schedule for the Re-examination of Stage II

7 Conclusions

The Falls Lake Nutrient Management Strategy presents technical and financial challenges to the regulated community in the watershed. Stage I is estimated to cost approximately $604 million and should be completed by the end of 2020 (NCDWQ 2010). The State estimated that Stage II of the Strategy would cost approximately $945 million to implement, but a review of the analysis (Section 3) indicates that these expenditures are not likely to achieve the Stage II nitrogen or phosphorus reductions. Achieving the nitrogen reductions from the upper watershed would require 1) treating every acre of existing development (which is not technically feasible) 2) use of a limited set of BMPs, and 3) installation of approximately 1,000 BMPs each year (which is not logistically feasible). The Stage II phosphorus reduction goals for existing development are beyond the limits of technology. In agricultural areas, the Stage II goals are not feasible for nitrogen or phosphorus given the State's assumption of one BMP type applied to pasture land only (NCDWQ 2010).

The Consensus Principles that guided development of the Falls Lake Nutrient Management Strategy acknowledged the uncertainty associated with the Rules and allow for re-examination of Stage II. The Consensus Principles also call for a review of the attainability of the designated uses for the Upper Lake, the feasibility of achieving Stage II reduction goals and meeting the water quality standard for chlorophyll *a*, and whether existing uses of the Upper Lake can be protected with alternative water quality standards. Cardno ENTRIX has compiled and analyzed the existing information and data to assist the UNRBA in preparing for the re-examination. In addition, Cardno ENTRIX developed the Falls Lake Framework Tool to provide a basis for predicting the impacts that nutrient management scenarios have on lake water quality and designated uses. The Tool allows the user to select from various assumptions regarding nutrient loading to the lake, percent load reductions in the Upper watershed, and implementation costs. For example, if the values back-calculated from the Falls Lake Nutrient Management Strategy are used to calculate the baseline nutrient loads, the Stage II nutrient reduction scenario is applied, and the NCDWQ fiscal analysis is used to calculate costs, the Falls Lake Framework Tool estimates the following:

> Nutrient reductions of 658,000 pounds of nitrogen and 35,000 pounds of phosphorus are required for the upper five tributaries draining to Falls Lake.

> Falls Lake will continue to attain DO and pH criteria under the Stage II scenario.

> Mean chlorophyll a concentrations in the lake will not exceed 20 µg/L in any segment, and the standard of 40 µg/L is not likely to be exceeded.

> Mean turbidity will remain less than 10 NTU (the water quality standard is 25 NTU).

> Average TOC concentrations near the dam will decrease by approximately 0.9 mg/L.

> The Aquatic Life use is categorized as "Not Impaired" under the Stage II scenario based on compliance with biological indices even under the baseline scenario.

> To assess the linkage between water quality and recreational use, the Falls Lake Framework Tool uses a recreational model developed by researchers at North Carolina State University to value water quality and the associated ecosystem services in Wake County (Phaneuf et al. 2008). Full implementation of the Stage II scenario may increase the value of the recreational designated use by approximately $168,000 per year, based on local studies.

> The Falls Lake Framework Tool assesses the drinking water designated use by linking TOC concentrations in the raw water supply to the pounds of ferric sulfate needed to treat the water using existing information. Full implementation of the Stage II scenario may decrease the drinking water treatment costs for the City of Raleigh by approximately $194,000 per year. The City is studying the

need for advanced technologies at the water treatment plant may cost approximately $125 million if TOC concentrations increase over the next several years (Hazen and Sawyer 2012).

> One of the main reasons that Falls Lake was constructed was to provide flood control benefits to communities downstream. Falls Lake provides annual average flood control benefits of $21 million, and the lake prevented an estimated $259 million dollars in damages in 1996 when Hurricane Fran occurred based on data provided by the USACE. The Falls Lake Framework Tool has been set up to estimate impacts to designated uses resulting from various nutrient management scenarios relative to the baseline year (2006). The Tool assumes that nutrient management practices will not impact flood control benefits. Revisions to the Tool in the future may include a linkage between nutrient reductions and the flood control use by accounting for practices that reduce storm volumes and peak flows, increase infiltration in the watershed, disconnect impervious surfaces, etc. For the current version, the change from nutrient management is assumed zero.

> Implementation costs for the Stage II scenario are approximately $67.5 million per year with a total projected costs of $945 million based on the NCDWQ fiscal analysis (2010). However, it is unlikely that this expenditure will actually achieve the Stage II phosphorus reductions given the current limits of technology and number of NCDWQ-approved BMPs. Based on the USEPA Municipal Preliminary Screener, the financial impact of the Stage II rules is “Large.”

The Falls Lake Framework Tool provides an indication of the monetary impact of the Stage II reductions on the designated uses of Falls Lake. Benefits to the lake from enhanced recreation and reduced chemical cost are approximately $354 thousand per year, based on local information. The compares simulated water quality to water quality criteria and categorizes the aquatic life use as “Not Impaired” based on current observations of biological indices. The current version of the Tool assumes no change to the flood storage capacity). Implementation costs associated with these benefits are approximately $67.5 million per year, or $945 million total based on the NCDWQ (2010) fiscal analysis. Based on the Cardno ENTRIX review of the fiscal analysis, it is unlikely that these expenditures will even achieve the Stage II reduction goals.

Given the high cost of implementing Stage II and the uncertainty with respect to the outcome, Cardno ENTRIX and Barnes and Thornburg recommend a multi-part process for moving forward with the re-examination process which includes four main components. The overall process relies on collection of additional monitoring and modeling studies to provide a scientific basis for the re-examination. These studies will support revised lake response modeling, provide a linkage between water quality in the lake and designated uses, and support the various regulatory options included in the re-examination process.

Under the current schedule for the Falls Lake Nutrient Management Strategy, the UNRBA has less than eight years to move through the re-examination process. The Consensus Principles require a minimum of three years of data collection followed by revised modeling studies to provide a basis for altering Stage II of the rules. The UNRBA Path Forward Committee has recommended at least four years of monitoring to incorporate variations in weather and environmental conditions, with an optional fifth year as needed. Following monitoring, modeling studies may take one to two years to complete and negotiations with State and Federal agencies may take several years. Cardno ENTRIX recommends that the UNRBA conduct preliminary updates to the lake nutrient response modeling and begin exploring each part of the re-examination process as soon as appropriate for each part of the process. In addition, Cardno ENTRIX recommends that the UNRBA petition the State for a delay in the implementation of the Strategy to allow more time for 1) the re-examination process and 2) development of credits for additional BMPs that may be useful for the Stage I and Stage II local programs.

The re-examination process is likely to cost somewhere between $5 million to $10 million in monitoring, modeling, negotiation, legal support, and potential litigation costs. Relative to the Stage II implementation costs that are estimated to cost approximately $67.5 million per year beginning in 2021, the costs of moving forward with the re-examination process is relatively small.

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