Data Collection in Support of Upper Yadkin River Watershed-High Rock Lake Chlorophyll-a and Turbidity TMDL Modeling

FINAL REPORT

Prepared for:

North Carolina Department of Environment and Natural Resources

Division of Water Quality 319 Grant Program

July 31, 2010

LimnoTech
Water | Environment | Scientists | Engineers

Division of Water Quality

Yadkin/Pee-Dee River Basin Association

ALCOA

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Prepared for:
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Prepared by:
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Ann Arbor, Michigan

Sponsor:	Yadkin Pee-Dee River Basin Association
Fiscal Year of Grant:	2007
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Project Coordinator:	Stan Webb

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North Carolina Department of Environment and Natural Resources

Yadkin Pee-Dee River Basin Association

High Rock Lake Technical Advisory Committee

City of Lexington, North Carolina

Environment 1 Analytical Laboratories

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Appendix A: Data Collection in Support of Upper Yadkin River Watershed - High Rock Lake Chlorophyll-a and Turbidity TMDL Modeling
319 Grant Application

Appendix B: Correspondence with all participating Public Agencies (on CD)

Appendix C: Quarterly Progress Reports

Appendix D: High Rock Lake TMDL Monitoring Project – July 13, 2010 Public Meeting Presentation Materials for Public Meeting

Appendix E: High Rock Lake TMDL Database Structure Report 2008-2010 Monitoring Program.

Appendix F: High Rock Lake TMDL Monitoring Project Quality Assurance Project Plan

Appendix G: Laboratory Reports, Laboratory QA/QC, Field Notes and Calibration Logs (on CD)

Appendix H: High Rock Lake TMDL Monitoring Project Database (on CD)

Appendix I: GIS Information for Project Area Maps

Appendix J: Watershed Data Figures

Appendix K: Lake Data Figures

Appendix L: Particle Size Distribution Data

Appendix M: 319 Grant Budget Details

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1. EXECUTIVE SUMMARY

High Rock Lake is an impoundment of the Yadkin River and was constructed in 1929 to provide hydroelectric power. The lake is also classified for aquatic life, water supply and primary recreation. It is owned and operated by the Yadkin Division of Alcoa Power Generating, Inc. (APGI). High Rock Lake has a large watershed, including portions of 11 counties and 34 municipalities. There are more than 23 major NPDES dischargers with flows greater than 1 million gallons per day (MGD) in the lake watershed, including discharges direct to the lake or close to the lake. The total permitted discharge to the watershed is approximately 126 MGD. The watershed also contains a significant proportion of North Carolina's total capacity for dairy production, including 76 registered animal operations.

The lake has been monitored since the early 1970s, and has consistently shown a high level of eutrophication, with elevated chlorophyll-a, nutrient concentrations, and dissolved gas levels. The lake also receives large inputs of sediment. The sediment load, combined with algal production, results in turbidity problems throughout the lake. High Rock Lake has been placed on the North Carolina list of impaired waters for exceedances of the chlorophyll-a (entire lake), turbidity (upper portion of the lake and the Abbotts Creek Arm), and pH (entire lake with exception of the upper portion of the Abbotts Creek Arm) standards and requires development of Total Maximum Daily Loads (TMDLs).

The TMDLs for High Rock Lake will provide allowable nutrient loads associated with attainment of the chlorophyll-a standard and the allowable sediment load associated with the turbidity standard. Completion of the TMDLs for High Rock Lake will require the development of water quality models for nutrient response and watershed loading. The objective of this project was to collect the necessary data to develop, calibrate, confirm and apply a linked watershed-lake model aimed at quantifying the relationship between land use and activities in the watershed, nutrient and sediment loading from watershed to the lake, and the lake quality response in terms of turbidity and nutrient driven trophic conditions. In 2007, the North Carolina Department of Environment and Natural Resources Division of Water Quality (NCDWQ) and the project management team, after consultation with Region 4 EPA, decided upon using HSPF to model the watershed and WASP7 linked to EFDC to model the hydrodynamic and nutrient responses in the lake. The project team verified that the database developed as part of this project would support the chosen models.

The Data Collection in Support of Upper Yadkin River Watershed-High Rock Lake Chlorophyll-a and Turbidity TMDL Modeling project (referred to as the High Rock Lake TMDL Water Quality Monitoring project) was funded by an EPA 319 grant to collect the data necessary to develop the models used in the TMDL process. As stated in the 319 grant application, the project goals were as follows:

1. Collect watershed and lake data acceptable for input to an approvable TMDL for High Rock Lake.

2. Estimate the relative point and non-point source contributions to nutrient loads, including generated and delivered loads. Provide spatial and temporal information regarding the sources of non-point source loads.
3. Provide data for development, calibration and validation of a watershed model and a lake water quality model.
4. Support the development of non-point source management strategies, voluntary and mandatory, to reduce nutrient and sediment loading in the watershed.

Project deliverables included the following:

- Quality Assurance Project Plan (QAPP)
- Hard copy and electronic copy of all data sets
- Quarterly Progress Reports
- GIS Maps
- Access database with data for model development and evaluation
- Correspondence with all participating public agencies
- Presentation materials for final meeting to present 319 Project results to NCDWQ, High Rock Lake TAC, YPDRBA, and other interested parties.
- Preliminary characterization and relative contribution from point sources and non-point sources within the watershed
- Data-based pollutant load estimates to High Rock Lake
- Baseline conditions for prioritizing and then evaluating implementation of BMPs
- Semi-annual public meetings of the TMDL Technical Advisory Committee
- Public outreach event
- Final meeting to present 319 project results to NCDWQ, High Rock Lake Technical Advisory Committee, Members of YPDRBA, Alcoa Power Generation Inc. and other interested parties
- Final Project Report

The Data Collection activities were conducted from April 7, 2008 through April 5, 2010. Samples were collected on a routine basis in the lake and watershed, as well as in response to high flow events in the watershed. The data from the sampling events will be used to characterize both the lake and watershed response to various stimuli, including seasonal weather changes. The field study also included collection of bathymetry, temperature, weather data, hydrology, physical parameters, turbidity, total dissolved solids, total suspended solids, and nutrient data for High Rock Lake and the watershed. Specifically, the two-year field study incorporated four tasks:

- High Rock Lake monitoring at ten stations, conducted by NCDWQ Intensive Survey (IS) and APGI. This work was done through matching funds from APGI and in-kind services from NCDWQ.
- Enhanced Ambient Watershed monitoring at twelve stations (a subset of watershed and tributary sampling locations that routinely are monitored for ambient water quality data, but are included for enhanced monitoring in support of the TMDL modeling study). This sampling work was done through matching funds from YPDRBA and in-kind services from NCDWQ.
- Focused (High Flow) Watershed monitoring at 14 stations. Twelve of these stations also correspond to those that were sampled for enhanced watershed monitoring. Funding for the high flow monitoring task was provided through YPDRBA's Section 319 Grant.
- Construction of an Access Database to include all information derived from the monitoring project. This work was completed with the 319 Grant funds.

The data collected during the April 2008 -April 2010 sampling program suggest general system behaviors that the models will need to capture to give NCDWQ confidence in computing and allocating the TMDL. The following observations can be made from the watershed data:

1. Total Phosphorus (TP) and Total Suspended Solids (TSS) generally increase with increasing flow in the Yadkin River at Yadkin College (sampling station Q2810000), suggesting that the river is carrying more suspended solids by fraction of TP as particulate matter. This also suggest the importance of non-point source runoff in terms of the load to the lake.
2. The South Yadkin at Mocksville tributary (sampling station Q3460000) is the second largest contributor of loads to High Rock Lake. Here, TP and TSS generally increase with increasing flow, as at station Q2810000.
3. At the Abbotts Creek sampling station (Q5930000), TP concentrations do not appear to have much of a response to flow. This indicates a greater point source load.
4. TP and turbidity concentrations show some increase with flow at Enon (sampling station Q2040000), as compared to Abbotts Creek.
5. The bulk of the watershed loads of NH_3, N+N, TP and TSS are coming into the system at the head of the reservoir (sampling stations Q2810000 and Q3460000). However, the two study years are very different in terms of the magnitude of loads to the system. Very high flows occurred during the early part of 2010, with correspondingly higher loads when compared to early 2009.

The following observations can be made from the lake data:

1. In late summer, the dissolved oxygen (DO) in the main stem of the lake is supersaturated at the surface of the lake, but declines sharply with depth after one meter. The higher DO concentrations at and near the lake surface are the result of high primary productivity, which produces oxygen. Concentrations of DO decline sharply with depth because of the high oxygen demand exerted in the hypolimnion exerted by decay of settling phytoplankton and sediment oxygen demand (SOD).

2. The abundance of algal growth at the surface of the lake during the summer months also results in higher pH near the surface, with a fairly significant drop in pH with depth. This results from the consumption of CO_2 (an acid) by algae.

3. Suspended solids (TSS) along the main stem of the lake respond strongly to spring high flow and November high flow periods. . TSS peaks are highest further upstream along the main stem of the lake because of the influence of the Yadkin River loads, which enter at the upstream end of the lake. Further downstream, the system is not responding much to the high flow peaks. This is likely the result of lower suspended solids concentrations from dilution and settling of solids as the reservoir widens and deepens going downstream.

4. The lake arm stations show the highest concentrations of TSS during January and February, and are not showing the spring and fall peaks observed along the main stem. This likely is due to the smaller arm drainage areas relative to the main stem drainage area.

5. Chlorophyll-a is relatively high at the furthest upstream main stem station, suggesting that additional algal growth may be occurring in the river upstream of the lake.

6. Chlorophyll-a concentrations at the main stem stations generally range between 50 to 70 ug/l during the summer months and drop off significantly during the winter months.

7. At the lake arm stations, chlorophyll-a concentrations also are highest during the summer months, but do not drop off as much during the winter months.

2. INTRODUCTION/BACKGROUND

The Data Collection in Support of Upper Yadkin River Watershed-High Rock Lake Chlorophyll-a and Turbidity TMDL Modeling project (referred to as the High Rock Lake TMDL Water Quality Monitoring project) was funded by an EPA 319 grant to collect the data necessary to develop the models used in the TMDL process.

High Rock Lake is an impoundment of the Yadkin River and was constructed in 1929 to provide hydroelectric power. The lake is also classified for aquatic life, water supply and primary recreation. It is owned and operated by the Yadkin Division of Alcoa Power Generating, Inc. (APGI). The average daily flow in the Yadkin River above the lake exceeds 3,000 cubic feet per second (cfs), resulting in short average hydraulic retention times for the reservoir, typically ranging from 15 to 30 days. Due to hydropower operation, outflow from the lake is relatively constant, but lake levels vary dramatically according to inflows. The maximum reported depth is 52 feet. Although most of the flow occurs along the main axis of the lake, there are significant tributary cove areas, such as Abbotts Creek and Second Creek (see Figure 1).

High Rock Lake has a large watershed, including portions of 11 counties and 34 municipalities (see Figure 2). There are more than 23 major NPDES dischargers with flows greater than 1 million gallons per day (MGD) in the lake watershed, including discharges direct to the lake or close to the lake. The total permitted discharge to the watershed is approximately 126 MGD. The watershed also contains a significant proportion of North Carolina's total capacity for dairy production, including 76 registered animal operations.

2.1 PROBLEM DEFINITION

The lake has been monitored since the early 1970s, and has consistently shown a high level of eutrophication, with elevated chlorophyll-a, nutrient concentrations, and dissolved gas levels. The lake also receives large inputs of sediment. The sediment load, combined with algal production, results in turbidity problems throughout the lake. High Rock Lake was placed on the North Carolina list of impaired waters in 2004 for exceedances of the chlorophyll a and turbidity standards in the lake, and requires development of Total Maximum Daily Loads (TMDLs). The specific impairments from the 2008 303(d) list are shown in Table 1 and now include high pH. However, this study was designed to address the issues of high turbidity and chlorophyll-a concentrations and collect the data necessary to develop, calibrate, confirm and apply a linked watershed-lake model required for development of the chlorophyll- a and turbidity TMDLs.

Table 1. Yadkin Pee-Dee River Basin 2008 303(d) List Impairments

Assessment Unit	Waterbody	Description	Assessment Unit size	Parameters
12-(108.5)b	Yadkin River (including upper portion of High Rock Lake (HRL) below normal operating level	From mouth of Grants Creek to a line across HRL from the downstream (d/s) side of mouth of Crane Creek to the d/s side of mouth of Swearing Creek	5,569 acres	Chlorophyll-a, High pH, Turbidity
12-(114)	Yadkin River (including lower portion of HRL)	From a line across HRL from the d/s side of mouth of Crane Creek to the d/s side of mouth of Swearing Creek to a point 0.6 miles upstream (u/s) of dam of HRL, except for the Abbotts Creek Arm of HRL from source to a point 1.7 miles u/s of Rowan County SR 1004	4,870 acres	Chlorophyll-a, High pH
12-(124.5)a	Yadkin River (including lower portion of HRL)	From a point 0.6 miles upstream of dam of HRL to High Rock Lake Dam	10.8 acres	Chlorophyll-a, High pH
12-118.5a	Abbotts Creek Arm of HRL	From source at I-85 to NC 47	3.7 miles	Chlorophyll-a
12-118.5b	Abbotts Creek Arm of HRL	From NC 47 to Davidson County SR 2294	5.9 miles	Chlorophyll-a, High pH, Turbidity
12-117-(3)	Second Creek Arm of HRL	From a point 1.7 miles downstream of Rowan County SR 1004 to High Rock Lake	894.9 acres	Chlorophyll-a, High pH

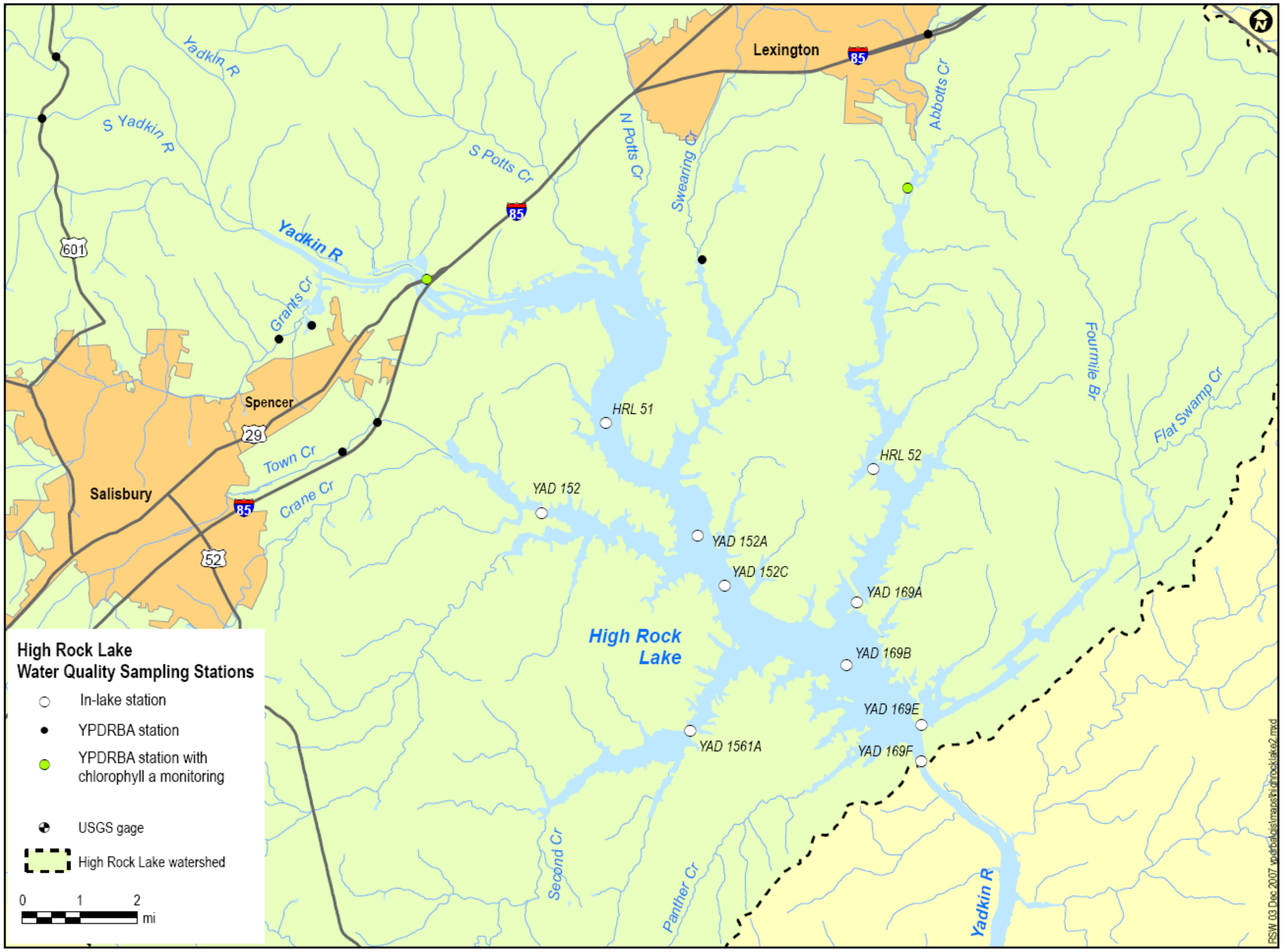

Figure 1. High Rock Lake Monitoring Location Map

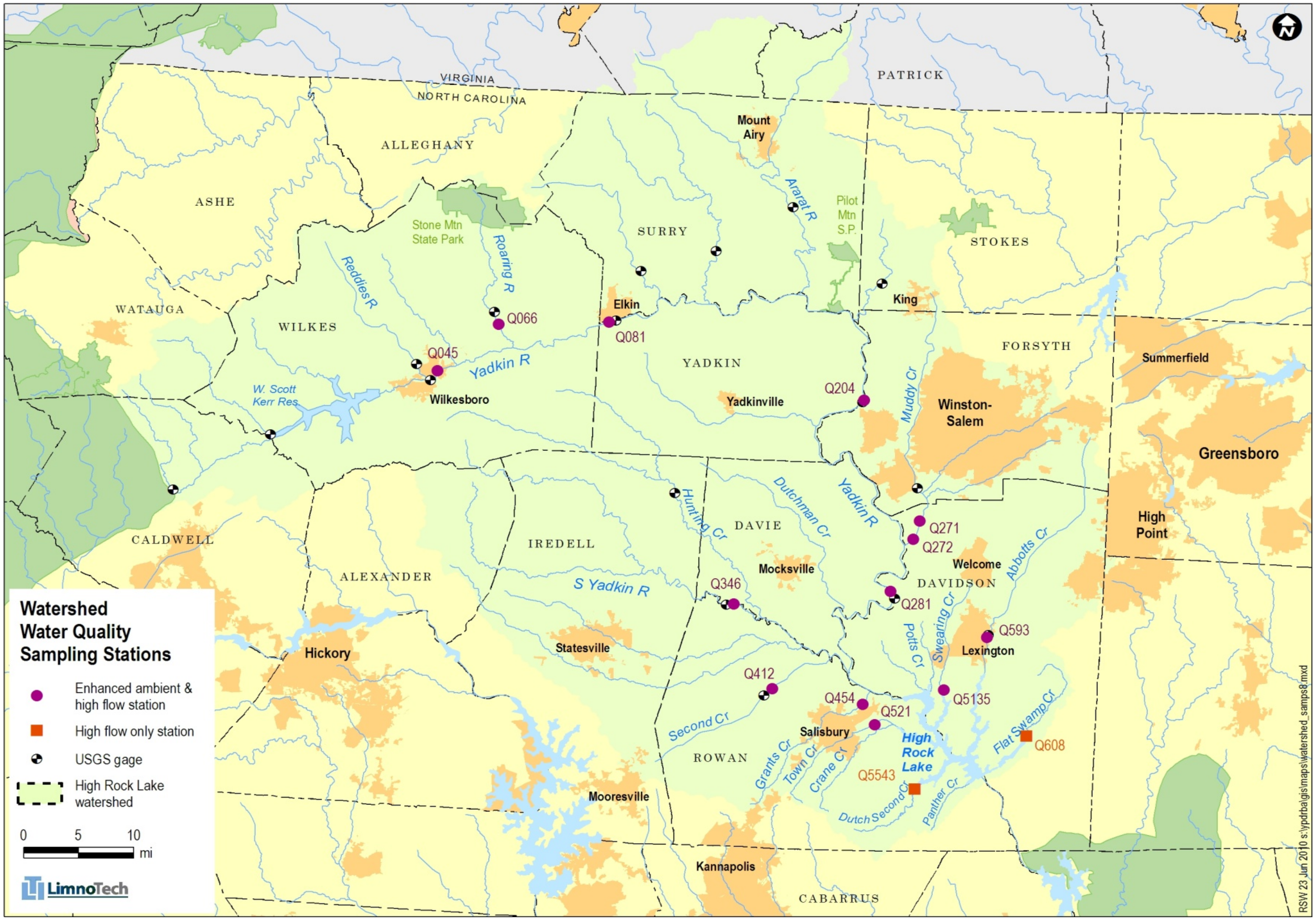

Figure 2. High Rock Lake Watershed Monitoring Location Map

EPA requires that TMDLs should be completed within 8 to 13 years of the original listing. Thus, the TMDLs for High Rock Lake should be completed by 2012 to 2017. The TMDL process requires an initial planning, design and budgeting phase. A review of the existing data was conducted in 2004. A monitoring and modeling study plan that addressed project responsibilities, goals and approaches was prepared by the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (NCDWQ) in January 2006. The monitoring and modeling must be conducted prior to developing the TMDL strategy which includes: target setting; allocation; and point and non-point strategies. The results of the High Rock Lake TMDL Water Quality Monitoring project will provide information for models of the watershed and the lake, to support the TMDL development.

A general stakeholder group was formed in 2005 and designated as the High Rock Lake Technical Advisory Committee (TAC). The group has met regularly and provided input on the field study and modeling plan presented by NCDWQ. A summary of the data that existed when this project began is shown in Table 2. The 2006 TAC recommendations for addressing significant data gaps for model development are shown in Table 3.

Table 2. Existing Data Prior to 2007

Time Period	Location	Parameters	Frequency	Agency	Program
Since 1973	High Rock Lake	Dissolved oxygen, Secchi depth, suspended solids, chlorophyll-a, nutrients		NCDWQ	Lakes Assessment Monitoring Program
Since 1974	HRL tributaries	Flow, stage, dissolved oxygen, nutrients, turbidity	monthly	NCDWQ	Ambient Surface Water Monitoring Program
1989-1990	HRL 2 stations	Algal biomass and species numbers		NCDWQ	Lakes Assessment Monitoring Program
1989-1990	HRL - lake arms/tribs 13 sites	Dissolved oxygen, nutrients, chlorophyll-a	Monthly for 6 months each year	NCDWQ	
	HRL tributaries 18 sites			YPDRBA	

Table 3. 2006 TAC Recommendations for Addressing Significant Data Gaps

Location	Parameters	Notes
High Rock Lake	Chlorophyll-a	Use current method (EPA 445) with adequate quality control in place High frequency sampling
High Rock Lake	NH3, TKN, Nitrite+Nitrate, Total Phosphorus, Orthophosphate, Total Organic Carbon, Total Suspended Solids, Volatile Suspended Solids, Total Dissolved Solids, Total Solids, Total Volatile Solids, turbidity, Soluble Total Silica	Routine monitoring schedule
High Rock Lake	Biochemical Oxygen Demand (BOD)	Use to support a dissolved oxygen model of the lake
High Rock Lake	2006 Sediment Oxygen Demand (SOD)	Use to support a dissolved oxygen model of the lake
Tributaries	NH3, Nitrite+Nitrate, TKN, Total Phosphorus, Orthophosphate, BOD5, Total Organic Carbon, Total Solids, Total Volatile Solids, Total Suspended Solids, Volatile Suspended Solids, Total Dissolved Solids, turbidity	During high and low flows to define nutrient and sediment loads

2.2 EPA 319 GRANT APPLICATION

The 319 grant application was submitted to NCDENR in May 2006 requesting funds to support the TMDL monitoring project. Matching funds came from the YPDRA, the City of Winston-Salem, APGI and in-kind services from NCDWQ.

The grant application is included in Appendix A.

2.3 PROJECT PARTNERS

The Yadkin/Pee-Dee River Basin Association (YPDRBA) was the project sponsor for the monitoring program. Stan Webb, retired from the City of Winston-Salem, served as the project manager and was responsible for general oversight of the project, including review and approval of all work products.

Consultants to the project included LimnoTech of Ann Arbor, Michigan and Environment 1, Inc. of Greenville, North Carolina. The YPDRBA was responsible for management and oversight of the consultants, as well as development of the QAPP. LimnoTech was primarily responsible for technical support, guidance, and coordination of the watershed monitoring program during high flow conditions. Environment 1, Inc. was responsible for laboratory analytical testing associated with the monitoring program (with the exception of some special analyses that were performed by other laboratories) and they performed ambient monitoring at six (6) watershed sites on behalf of the YPDRBA and high flow (focused flow) monitoring at fourteen (14) watershed stations on behalf of the YPDRBA..

The NCDWQ was responsible for the routine lake sampling at ten (10) locations, continuous temperature monitoring at three (3) lake locations, specialized sampling at select lake locations, ambient monitoring in the watershed at eight (8) locations and laboratory analysis for the ambient samples they collected and for split lake samples analyzed for chlorophyll-a. Alcoa Power Generating Inc. was responsible for providing supplemental ambient lake monitoring during the summer months.Purpose and Goals

The TMDLs for High Rock Lake will provide allowable nutrient loads associated with attainment of the chlorophyll-a standard and the allowable sediment load associated with the turbidity standard. Completion of the TMDLs for High Rock Lake will require the development of water quality models for nutrient response and watershed loading. The objective of this project was to collect the necessary data to develop, calibrate, confirm and apply a linked watershed-lake model aimed at quantifying the relationship between land use and activities in the watershed, nutrient and sediment loading from watershed to the lake, and the lake quality response in terms of turbidity and nutrient driven trophic conditions.

In 2007, NCDWQ and the project management team, after consultation with Region 4 EPA, decided upon using HSPF to model the watershed and WASP7 linked to EFDC to model the hydrodynamic and nutrient responses in the lake. The project team verified that the database developed as part of this project would support the chosen models.

2.4 PROJECT GOALS

As stated in the 319 grant application, the project goals were as follows:

1. Collect watershed and lake data acceptable for input to an approvable TMDL for High Rock Lake.
2. Estimate the relative point and non-point source contributions to nutrient loads, including generated and delivered loads. Provide spatial and temporal information regarding the sources of non-point source loads.
3. Provide data for development, calibration and validation of a watershed model and a lake water quality model.
4. Support the development of non-point source management strategies, voluntary and mandatory, to reduce nutrient and sediment loading in the watershed.

These goals did not change over the course of the monitoring period.

The success of the project was measured by the quality of the data acquired and its usefulness in developing the water quality models required for TMDL development. This goal was accomplished by:

- Strict adherence to the Quality Assurance Project Plan for all data collection.

- Using one state qualified laboratory for the majority of the analytical work performed and a significant portion of the sample collection.

- A well-constructed and executed monitoring plan, which was designed over a two year period, to provide the data necessary to develop and to evaluate the linked watershed – High Rock Lake hydrodynamic-water quality model necessary for accomplishing the TMDLs.

- Having oversight by a senior scientist with more than 35 years of experience in watershed and water quality monitoring, modeling, and assessment, including 30 years in academia

3. DELIVERABLES

As stated in the 319 grant application, the original project deliverables included the following:

- Quality Assurance Project Plan (QAPP)
- Hard copy and electronic copy of all data sets
- Quarterly Progress Reports
- GIS Maps
- Access database with data for model development and evaluation
- Correspondence with all participating public agencies
- Presentation materials for a stakeholder meeting to present the field study results
- Preliminary characterization and relative contribution from point sources and non-point sources within the watershed
- Data-based pollutant load estimates to High Rock Lake
- Baseline conditions for prioritizing and then evaluating implementation of BMPs
- Periodic public meetings of the TMDL Technical Advisory Committee
- Public outreach event
- Stakeholder meeting to present final study results
- Final Project Report

In the process of preparing for the 2010 stakeholder meeting, NCDWQ's Modeling and TMDL Unit expressed concern that it was too early to begin stakeholder meetings and that to do so prior to July 31, 2010 may adversely impact the TMDL implementation schedule. Therefore, the proposed stakeholder meeting was changed to a public meeting to present the results of the monitoring project only. A letter requesting this change in deliverables was sent to Kim Nimmer (NCDWQ) from Stan Webb (YPDRBA) on April 13, 2010. This letter is included in Appendix B. Technical memoranda generated during the course of the project also are included in Appendix B.

The revised project deliverables are shown in Table 4, along with a description of where these deliverables are documented.

Table 4. High Rock Lake TMDL Monitoring – Revised Project Deliverables

Deliverable	Documentation Location
Quality Assurance Project Plan	Version 1. Submitted to NCDWQ on May 30, 2007 Version 2. Submitted to NCDWQ on November 30, 2007 Included in Appendix F of this report
Hard copy/electronic copy of data sets	All of the data is in the project database and is available from NCDWQ. All laboratory reports, laboratory QA/QC, calibration logs and field notes are included in Appendix G of this report (on CD due to the size). The particle size distribution data are included in Appendix L.
Quarterly Progress Reports	Included in Appendix C of this report, along with annual reports
GIS maps	Included in this report as Figures 1 and 2. The maps and location coordinate files are included in Appendix I (on CD)
Access database	Provided to NCDWQ on July 31, 2010 and included as Appendix H of this report (on CD)
Correspondence with all participating public agencies	Included in Appendix B of this report
Presentation materials for final meeting to present 319 Project results to NCDWQ, HRL TAC, YPDRBA and other interested parties.	Included in Appendix D of this report
Preliminary characterization and relative contribution from point and non-point sources	Included in this report
Data-based pollutant load estimates to High Rock Lake	Included in this report
Baseline conditions for prioritizing and then evaluating implementation of BMPs	Included in this report
Periodic public meetings of the HRL TAC	Minutes included in Appendix B
Final meeting to present 319 project results to NCDWQ, HRL TAC, YPDRBA, APGI and other interested parties	Meeting was held on July 13, 2010 in Raleigh, NC
Final project report	Submitted to NCDWQ on July 30, 2010

4. METHODOLOGY/EXECUTION

The field study was conducted over a two year period beginning April 1, 2008 and involved extensive monitoring in the lake and in the watershed. The sampling program was originally planned to begin in November 2007, however due to the drought conditions in the southeastern United States at that time, the sampling program was postponed until April 1, 2008 when precipitation returned to a more normal level.

Samples were collected on a routine basis in the lake and watershed, as well as in response to high flow events in the watershed. Specifically, the two-year field study incorporated the following four tasks:

- **High Rock Lake Monitoring**. This was conducted at the ten (10) stations depicted in Figure 1. Monitoring was conducted by NCDWQ Intensive Survey (IS) and APGI. This work was done through matching funds from APGI and in-kind services from NCDWQ.

- **Enhanced Ambient Watershed Monitoring.** This was conducted at the twelve (12) stations depicted in Figure 2. These stations are a subset of watershed and tributary sampling locations that routinely are monitored for ambient water quality data, but are included for enhanced monitoring in support of the TMDL modeling study. This sampling work was done through matching funds and in-kind services from NCDWQ.

- **Focused (High Flow) Watershed Monitoring**. This was conducted at the fourteen (14) stations depicted in Figure 2. Twelve of these stations also correspond to those that were sampled for enhanced watershed monitoring. Funding for the high flow monitoring task was provided through YPDRBA's Section 319 Grant.

- **Construct Access Database**: An ACCESS database was constructed to include all information derived from the monitoring project. This work was completed with the 319 Grant funds.

The data from the sampling events will be used to characterize both the lake and watershed response to various stimuli, including seasonal weather changes. The field study also included collection of bathymetry, temperature, weather data, hydrology, physical parameters, turbidity, total dissolved solids, total suspended solids, and nutrient data, as summarized in Tables 5, 9 and 13 for High Rock Lake and the watershed (enhanced ambient and focused monitoring plans), respectively. These parameters were selected in order to best constrain the calibration of the watershed and lake models. In addition to representing a good spatial and temporal distribution of observations of model state variables (e.g. chlorophyll-a, dissolved oxygen, phosphorus, etc.), the selected parameters and the monitoring plan were also intended to provide valuable information for parameterizing specific processes in the models (e.g., nitrification, sediment oxygen demand, etc.).

4.1 LAKE SAMPLING

The lake monitoring program was conducted over a two-year period beginning in April 2008. The program consisted of the following:

- Twenty-nine (29) lake monitoring events were conducted during summer months (May through October), and sixteen (16) monitoring events were conducted during winter months (November through April) at the 10 locations depicted in Figure 1 and described in Table 5. NCDWQ's Intensive Survey Unit performed sampling on the lake year round and Alcoa Power Generating Inc. collected samples once a month during the summer months only. The sampling dates are included in Table 6. Please note that due to the weather, the lake was sampled twice in February 2010 instead of in January 2010 (one sampling date in January 2010 because of uncharacteristically cold weather and freezing conditions in some portions of the lake).

- The chemical and water solids parameters were collected as composited samples from the photic zone (i.e., from the lake surface to twice the secchi depth).

- Lake samples were analyzed for the parameters listed in Table 5 and Tables 7 and 8.

- All chemical and water solids samples were analyzed by Environment 1.

- Depth profiling of dissolved oxygen, water temperature, pH and conductivity was conducted at each station for the sample depths specified in Table 5. Secchi depth and Depth to Bottom in Meters (DBM) also were determined during the depth profiling.

- Throughout the study, continuous temperature monitoring was measured every two hours at two stations (YAD169F and YAD1561A). Thermistors (tidbit) and a buoy also were installed for continuous monitoring at YAD152C, but were lost/stolen at the beginning of June 2008 and subsequently replaced. The buoy and equipment were missing again in mid-July 2008; consequently, no temperature data were ever retrieved from this station. It was determined based on previous data that there was not a significant difference in the temperature at YAD152C and YAD169F (Kathy Stecker email of July 23, 2008). Therefore, it was agreed that a third buoy would not be placed at this location. In addition, the tidbit at YAD169F went missing in January or February 2010. Data from YAD169F and YAD1561A were collected through October 30, 2009.

- Chlorophyll-a data was collected from photic zone composite samples (i.e., from the lake surface to twice the secchi depth). NCDWQ collected an extra sample for chlorophyll-a analysis only at one station (on a rotating schedule) during each monitoring trip. This sample was analyzed as a split sample for chlorophyll-a at the NCDWQ lab.

- Once per month, NCDWQ assessed phytoplankton assemblages from photic zone composite samples collected at four stations (YAD152C, YAD169B, HRL052 and YAD1561A). The relative abundance characterization covered three general categories of phytoplankton: blue-greens, greens and diatoms.

- Once per month, NCDWQ collected depth profiled measurements of Photosynthetically Active Radiation (PAR) through the photic zone at four stations (YAD152C, YAD169B, HRL052 and YAD1561A).

- Once every three months, particle size distribution samples were collected by NCDWQ at two stations (HRL051 and HRL052) from composite samples collected from the photic zone. These samples were submitted to LimnoTech for analysis using Laser In-Situ Scattering and Transmissometry (LISST).

- NCDWQ collected discrete samples for nutrient analysis below the photic zone (hypolimnion), at a depth of approximately 1 meter above lake bottom at three stations (YAD169B, YAD169F and YAD152C).

- Bathymetry was measured once at each of the 10 stations, and twice at Station HRL051 only (i.e. at the beginning and at the end of the study to determine changes in bathymetry due to sedimentation). Cross-sectional data was collected as close to normal pool elevation as possible. Notes describing the condition of the lake bottom were recorded at each cross-section. NCDWQ and/or EPA collected the bathymetry data, which was not included in the database, as directed by NCDWQ.

- Benthic nutrient flux was measured once during late summer 2009 at up to four stations (YAD152C, YAD169A, YAD169B and YAD1561A). This data was not included in the database, as directed by NCDWQ.

- APGI provided NCDWQ with hourly reservoir elevation and discharge data for the two-year sampling period. Reservoir elevation is measured by a sensor located on the upstream face of High Rock Dam that continuously monitors reservoir elevation. Data from the sensor is entered into a database by the APGI Power Dispatchers at the top of each hour. In addition, High Rock discharge is calculated based on generator output and the net head (difference between headwater and tailwater elevation). In the event of spill over High Rock Dam, a separate calculation based on spill gate headwater elevation and spill gate opening is added to the High Rock discharge calculation for a total flow over and through the dam. The elevation of the top of the intakes is 605.9 feet USGS datum (18 feet below the normal full pool elevation of the reservoir) and the elevation of the bottom of the intakes is 568.9 feet. This data was not entered into the database, as directed by NCDWQ.

Table 5. High Rock Lake Monitoring – Summary of Locations and Parameters

					Photic Zone Analyses (i.e. composite samples collected over twice the secchi depth)																
Site ID	Description of Sampling Site	Physical Data Measurements*	In-Situ Temp Monitors**	Hypolimnion Nutrients***	NH_3	Tot & Sol TKN	NO_2+NO_3	Tot & Sol TP	Ortho-P	BOD_5	TOC	TSS/VSS	TDS	TS/TVS	Turbidity	Total Soluble Silica	Hardness	Particle Size Distribution ^	Chlorophyll -a	PAR^^	Phytoplankton Relative abundance
HRL051	HRL051 above Potts Creek	29 summer 16 winter	NONE	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	once/ 3mo	29 summer 16 winter	NONE	NONE
YAD152A	High Rock Lake at Town Creek	29 summer 16 winter	NONE	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	NONE	NONE
YAD152C	High Rock Lake at 2nd Creek	29 summer 16 winter	Every 2 hrs	Monthly***	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	monthly^^	monthly
YAD169B	High Rock Lake at Abbotts Creek	29 summer 16 winter	NONE	Monthly***	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	monthly^^	monthly
YAD169F	High Rock Lake at Dam	29 summer 16 winter	Every 2 hrs	Monthly***	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	NONE	NONE
HRL052	HRL above Abbotts Creek Arm above Holloway	29 summer 16 winter	NONE	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	once/ 3mo	29 summer 16 winter	monthly^^	monthly
YAD169A	HRL Abbotts Creek Arm at Hwy 8	29 summer 16 winter	NONE	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	NONE	NONE
YAD169E	HRL at Flat Creek Cove Mouth	29 summer 16 winter	NONE	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	NONE	NONE
YAD 152	Town Creek Cove/Crane Creek	29 summer 16 winter	NONE	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	NONE	NONE
YAD1561 A	Dutch Second Creek Cove (DSCC)	29 summer 16 winter	Every 2 hrs	NONE	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	29 summer 16 winter	NONE	29 summer 16 winter	monthly^^	monthly

* Physical Data measurements include Temperature, Dissolved Oxygen, Conductivity, pH, Depth to Bottom in Meters (DBM) and Secchi Depth. Collected as profiles at each monitoring location for each monitoring event.
Depth Profiles: Start at 0.15 m below surface and then 1 m below surface, 2 m below surface, and so on down to bottom.

** In-Situ Temperature Monitoring with temperature thermistors was conducted every 2 hours at two stations. Seven (7) depths intervals were monitored as follows:
YAD169F: Five (5) thermistors set at 1m, 2m, 5m, 9m and 12m below the lake surface.
YAD1561A: Two (2) thermistors set at 1m and 3m below the lake surface.

*** Hypolimnion nutrients were analyzed monthly during the months of May through November for Ammonia-n, Nitrite+nitrate, soluble TKN, TKN, Total P, Soluble Total P and ortho-phosphate as P.
Samples were collected approximately meter above bottom of lake.

^ PSD samples were collected from the lake approximately every 3 months and shipped to LimnoTech for analysis.

^^ PAR readings were collected once per month at the following depth intervals: just below lake surface and then at 1 meter increments until the PAR was 1% of the surface measurement.

^^^ Benthic nutrient flux was measured on one occasion during the late summer of 2009. This study also included nutrient characterization of the sediment.

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Table 6. Lake Sampling Dates

LAKE Summer Event	Date	Sampling Agency	LAKE Winter Event	Date	Sampling Agency
1	5/6/08	NC-DWQ	1	4/8/08	NC-DWQ
	5/7/08	NC-DWQ		4/9/08	NC-DWQ
2	5/13/08	APGI	2	11/5/08	NC-DWQ
	5/14/08	APGI		11/6/08	NC-DWQ
3	5/20/08	NC-DWQ	3	11/19/08	NC-DWQ
	5/21/08	NC-DWQ		11/20/08	NC-DWQ
4	6/3/08	NC-DWQ	4	12/9/08	NC-DWQ
	6/4/08	NC-DWQ		12/10/08	NC-DWQ
5	6/11/08	APGI	5	1/13/09	NC-DWQ
	6/12/08	APGI		1/14/09	NC-DWQ
6	7/8/08	NC-DWQ	6	2/3/09	NC-DWQ
	7/9/08	NC-DWQ		2/4/09	NC-DWQ
7	7/15/08	APGI	7	3/4/09	NC-DWQ
	7/16/08	APGI		3/5/09	NC-DWQ
8	7/22/08	NC-DWQ	8	3/17/09	NC-DWQ
	7/23/08	NC-DWQ		3/18/09	NC-DWQ
9	8/5/08	NC-DWQ	9	4/14/09	NC-DWQ
	8/6/08	NC-DWQ		4/15/09	NC-DWQ
10	8/12/08	APGI	10	11/3/09	NC-DWQ
	8/13/08	APGI		11/4/09	NC-DWQ
11	9/2/08	NC-DWQ	11	12/1/09	NC-DWQ
	9/3/08	NC-DWQ		12/3/09	NC-DWQ
12	9/9/08	APGI	12	1/7/10	NC-DWQ
	9/10/08	APGI		1/13/10	NC-DWQ
13	9/16/08	NC-DWQ	13	2/3/10	NC-DWQ
	9/17/08	NC-DWQ		2/4/10	NC-DWQ
14	10/7/08	NC-DWQ	14	2/23/10	NC-DWQ
	10/8/08	NC-DWQ		2/24/10	NC-DWQ
15	10/14/08	APGI	15	3/9/10	NC-DWQ
	10/15/08	APGI		3/10/10	NC-DWQ
16	5/5/09	NC-DWQ	16	3/16/10	NC-DWQ
	5/6/09	NC-DWQ		3/17/10	NC-DWQ
17	5/12/09	APGI			
	5/13/09	APGI			
18	6/2/09	NC-DWQ			
	6/3/09	NC-DWQ			
19	6/9/09	APGI			
	6/10/09	APGI			
20	6/23/09	NC-DWQ			
	6/24/09	NC-DWQ			
21	7/7/09	NC-DWQ			
	7/8/09	NC-DWQ			
22	7/14/09	APGI			
	7/15/09	APGI			
23	8/4/09	NC-DWQ			
	8/5/09	NC-DWQ			
24	8/11/09	APGI			
	8/12/09	APGI			
25	9/1/09	NC-DWQ			
	9/2/09	NC-DWQ			
26	9/8/09	APGI			
	9/9/09	APGI			
27	9/22/09	NC-DWQ			
	9/23/09	NC-DWQ			
28	10/6/09	NC-DWQ			
	10/8/09	NC-DWQ			
29	10/13/09	APGI			
	10/14/09	APGI			

Table 7. Lake Analytical and Field Parameters Monitored at all Stations

Analytical Parameters Collected at All Stations	
NH3	Total Suspended Solids
Total TKN	Volatile Suspended Solids
Soluble TKN	Total Dissolved Solids
$NO_2 + NO_3$	Total Solids
Total Phosphorous	Total Volatile Solids
Soluble Total Phosphorus	Turbidity
Orthophosphate	Soluble Total Silica
BOD_5	Chlorophyll A
Total Organic Carbon	Hardness
Field Parameters Collected at All Stations	
Water Temperature	Conductivity
Dissolved Oxygen	pH
Secchi Depth	Depth Profiles/Bathymetry

Table 8. Lake Analytical Parameters – Monitoring Station Specific

Site ID	Particle Size Distribution*	Phytoplankton Relative Abundance	Photosynthetically Active Radiation	Sediment Nutrient Characterization & Benthic Flux
HRL051	once/3 months	none	none	none
YAD152A	none	none	none	none
YAD152C	none	monthly	monthly**	once/study
YAD169B	none	monthly	monthly**	once/study
YAD169F	none	none	none	once/study
HRL052	once/3 months	monthly	monthly**	none
YAD169A	none	none	none	once/study
YAD169E	none	none	none	none
YAD152	none	none	none	none
YAD1561A	none	monthly	monthly**	once/study

* Lake particle size distribution samples were depth integrated over length of the photic zone (2 x Secchi depth). Particle size distribution samples were collected from the lake during the next lake sampling event following a particle size distribution sampling in the watershed.

Particle size distribution samples were shipped to LimnoTech in Ann Arbor for analysis.

** PAR readings were collected once a month at the same intervals as physical profiles, i.e. 0.15 meters below the surface and then at one meter increments, starting at 1 meter below the water surface.

4.2 AMBIENT/ENHANCED AMBIENT WATERSHED MONITORING

Routine ambient monitoring was conducted at 12 stations in the watershed for this modeling study from April 7, 2008 through April 5, 2010. NCDWQ performs monitoring at 11 of these sites as part of the Ambient Monitoring System (AMS). NCDWQ added Station Q2710000 to their monitoring program for this study, because the monitoring station is representative of urban land use in the watershed. However, Station Q272000, located downstream of Q2710000 on Muddy Creek, was inadvertently sampled over the course of the study. Therefore, there are no data for Station Q2710000 included in the database. NCDWQ sampled eight (8) of the 12 stations as part of the Enhanced Ambient monitoring program. The cost for the AMS sampling at the 12 stations (ambient and enhanced ambient) was not included in the matching funds for this 319 Grant because it had already been applied to other grants.

YPDRBA performed routine monitoring at six (6) locations on a monthly basis. This sampling was considered enhanced because additional parameters were included in addition to the existing routine YPDRBA monitoring parameters. All YPDRBA's costs for enhanced ambient sampling were included as matching funds for this 319 Grant.

The enhanced ambient watershed monitoring program consisted of the elements described below.

- Samples were collected from the 12 watershed and tributary locations depicted in Figure 2 and described in Table 9 (Q5543000 and Q6080000 were not included in the enhanced ambient watershed monitoring). These stations are a subset of all ambient monitoring stations that routinely are sampled by NCDWQ in the watershed. Note that NCDWQ sampled Q2720000 (Muddy Creek) instead of Q2710000 throughout the study. Therefore, there are no ambient data for Station Q2710000 in the database. Sampling location Q2720000 is shown in Figure 2.

- Sampling was conducted each month by NCDWQ (8 stations) and YPDRBA (6 stations) according to the schedule outlined in Tables 9 and 10. Sample collection dates are shown in Table 11.

- Four stations were sampled twice per month (i.e. every other week if possible) as outlined in Tables 9 and 10. These stations (Q0660000, Q2810000, Q5930000 and Q2720000 (instead of Q2710000) are critical points in the watershed for model calibration and strategy development and require more frequent monitoring. Note that stations Q2810000 and Q5930000 were sampled once per month by both YPDRBA/ENV1 and NCDWQ, whereas Q0660000 and Q2720000 were sampled twice per month by NCDWQ only.

- Routine watershed and tributary samples were analyzed for the physical, chemical and sediment parameters listed in Table 9 and Table 12.

Table 9. Enhanced Ambient Watershed Monitoring – Summary of Locations and Parameters

Site ID	Description of Site	Field Measurements*	Nutrient Monitoring**	BOD-5	TOC	TS/TVS	TSS/VSS	Chlorophyl-a	Turbidity	Hardness	TDS	Silica	Photostructure density + biovolume	Particle Size Distribution
Q2810000	Yadkin River at US 64, Yadkin College	2x per month	2x per month	2x per month	2x per month	2x per month	2x per month	NONE	2x per month	NONE	2x per month	NONE	NONE	NONE
Q3460000	S.Yadkin River at SR1159 nr Mocksville	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q4120000	2nd Creek at US70 nr Barber	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q4540000	Grants Ck.at SR1915 nr Salisbury	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q5210000	Town Creek at SR1915 near Spencer	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q5930000	Abbotts Ck at SR1243 Lexington	2x per month	2x per month	2x per month	2x per month	2x per month	2x per month	NONE	2x per month	NONE	2x per month	NONE	NONE	NONE
Q5135000	Swearing Ck at SR1272 nr Linwood	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q0450000	Yadkin River at Bus 421 nr N. Wilkesboro	Monthly	Monthly	NONE	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q0660000	Roaring River at SR1990	2x per month	2x per month	NONE	2x per month	2x per month	2x per month	NONE	2x per month	NONE	2x per month	NONE	NONE	NONE
Q0810000	Yadkin River at Bus 21 in Elkin	Monthly	Monthly	NONE	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q2040000	Yadkin River at SR1605 Enon	Monthly	Monthly	NONE	Monthly	Monthly	Monthly	NONE	Monthly	NONE	Monthly	NONE	NONE	NONE
Q2720000	Muddy Ck at SR1485	2x per month	2x per month	NONE	2x per month	2x per month	2x per month	NONE	2x per month	NONE	2x per month	NONE	NONE	NONE

* Field Measurements include Water Temp, Dissolved Oxygen, Conductivity and pH

** Nutrient Monitoring includes NH3, NO2+NO3, TKN, TP, ortho-P

Sites highlighted in yellow were monitored by NCDWQ.
NOTE: Station Q2720000 was sampled instead of Q2710000

Sites highlighted in teal were monitored once per month by both NCDWQ and YPDRBA.

Sites that are not highlighted and are outlined in bold were monitored only by YPDRBA.

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Table 10. Enhanced Ambient Monitoring Schedule

Site ID	Description of Site	Sampling Frequency	Sampling Agency
Q2810000	Yadkin River @ US64, Yadkin College	2X per month	NCDWQ/YPDRBA*
Q3460000	S. Yadkin River @ SR1159 near Mocksville	monthly	NCDWQ
Q4120000	2nd Creek @ US70 near Barber	monthly	NCDWQ
Q4540000	Grants Creek @ SR1915 near Salisbury	monthly	YPDRBA
Q5210000	Town Creek @ SR1915 near Spencer	monthly	YPDRBA
Q5930000	Abbotts Creek @ SR1243 Lexington	2X per month	NCDWQ/YPDRBA*
Q5135000	Swearing Creek @ SR1272 near Linwood	monthly	YPDRBA
Q0450000	Yadkin River at Bus 421 near N. Wilkesboro	monthly	YPDRBA
Q0660000	Roaring River @ SR1990	2X per month	NCDWQ
Q0810000	Yadkin River at Bus 21 in Elkin	monthly	NCDWQ
Q2040000	Yadkin River @ SR 1605 Enon	monthly	NCDWQ
Q2720000	Muddy Creek @ SR 1485	2X per month	NCDWQ

* These stations were sampled twice per month, once by NCDWQ and once by YPDRBA.

Table 11. Ambient and Enhanced Ambient Monitoring Dates

Monthly Sampling Event	Six Watershed Stations^ Sampling Dates	Sampling Agency	Eight Watershed Stations* Sampling Dates	Sampling Agency	Q066 and Q272** Additional Monthly Sample Dates	Sampling Agency
1	4/20-22/2008	YPDRBA/ENV1	4/7, 10, 14, 17/2008	NC-DWQ	4/24, 30/2008	NC-DWQ
2	5/4-6/2008	YPDRBA/ENV1	5/6, 12, 13, 15/2008	NC-DWQ	5/27, 29/2008	NC-DWQ
3	6/8-10/2008	YPDRBA/ENV1	6/3, 9, 10, 12/2008	NC-DWQ	6/23, 25/2008	NC-DWQ
4	7/13-15/2008	YPDRBA/ENV1	7/7-10/2008	NC-DWQ	7/21/2008	NC-DWQ
5	8/10-12/2008	YPDRBA/ENV1	8/6-7/2008	NC-DWQ	8/18, 21/2008	NC-DWQ
6	9/7-9/2008	YPDRBA/ENV1	9/3, 9, 10, 25/2008	NC-DWQ	9/22, 25/2008	NC-DWQ
7	10/5-7/2008	YPDRBA/ENV1	10/6, 8, 9, 13/2008	NC-DWQ	10/20, 30/2008	NC-DWQ
8	11/2-4/2008	YPDRBA/ENV1	11/4, 12, 13, 20/2008	NC-DWQ	11/20/2008	NC-DWQ
9	12/7-9/2008	YPDRBA/ENV1	12/2, 3, 4, 8/2008	NC-DWQ	12/17/2008	NC-DWQ
10	1/25-27/2009	YPDRBA/ENV1	1/8, 12, 20, 28/2009	NC-DWQ	1/27-28/2009	NC-DWQ
11	2/15-17/2009	YPDRBA/ENV1	2/3-5/2009	NC-DWQ	2/17, 19/2009	NC-DWQ
12	3/15-17/2009	YPDRBA/ENV1	3/5, 10, 17/2009	NC-DWQ	3/25-26/2009	NC-DWQ
13	4/19-21/2009	YPDRBA/ENV1	4/14, 15, 16, 21/2009	NC-DWQ	4/28, 30/2009	NC-DWQ
14	5/3-5/2009	YPDRBA/ENV1	5/12, 13, 14, 26/2009	NC-DWQ	5/26-27/2009	NC-DWQ
15	6/7-9/2009	YPDRBA/ENV1	6/3, 9, 10, 11, 25/2009	NC-DWQ	6/24/2009	NC-DWQ
16	7/12-14/2009	YPDRBA/ENV1	7/7, 14, 16, 22, 23, 28/2009	NC-DWQ	7/22-23/2009	NC-DWQ
17	8/9-11/2009	YPDRBA/ENV1	8/4, 5, 11, 24, 27/2009	NC-DWQ	8/31-9/1/2009	NC-DWQ
18	9/13-14/2009	YPDRBA/ENV1	9/9, 16, 21 and 10/1/2009	NC-DWQ	9/30/2009	NC-DWQ
19	10/18-20/2009	YPDRBA/ENV1	10/1, 5, 13, 15, 26/2009	NC-DWQ	10/26, 29/2009	NC-DWQ
20	11/15-17/2009	YPDRBA/ENV1	11/4, 16, 18, 30/2009	NC-DWQ	11/30-12/1/2009	NC-DWQ
21	12/13-15/2009	YPDRBA/ENV1	12/7, 10, 14, 21, 29/09 & 1/4/10	NC-DWQ	12/21/2009	NC-DWQ
22	1/10-12/2010	YPDRBA/ENV1	1/7, 19, 27, 28/2010	NC-DWQ	1/27-28/2010	NC-DWQ
23	2/7-9/2010	YPDRBA/ENV1	2/4, 9, 11, 17/2010	NC-DWQ	2/17, 22/2010	NC-DWQ
24	2/21-23/2010	YPDRBA/ENV1	3/4, 10, 11, 16, 17, 23/2010	NC-DWQ	3/23-4/5/2010	NC-DWQ

^ Stations Q2810000, Q454000, Q5210000, Q5930000, Q5135000 and Q0450000 were sampled one a month by Environment 1.

* Stations Q0660000, Q0810000, Q2040000, Q2720000, Q2810000, Q3460000, Q4120000 and Q5930000 were sampled once per month by NCDWQ.

** Station Q2720000 was sampled inadvertently instead of Q2710000 by NCDWQ.

Note: Station Q2810000 and Q5930000 were sampled once per month by both YPDRBA/ENV1 and NCDWQ.

Table 12. Enhanced Ambient Watershed Monitoring - Analytical and Field Parameters

Analytical Parameters
NH_3
$NO_2 + NO_3$
TKN
Total Phosphorus
Orthophosphate[1]
BOD_5 *
TOC
Total Solids
Total Volatile Solids
Total Suspended Solids
Volatile Suspended Solids
Total Dissolved Solids
Turbidity
Field Parameters
Water Temperature
Dissolved Oxygen
Conductivity
pH

* As originally planned, samples collected from Stations Q0450000, Q0660000, Q0810000, Q2040000 and Q2720000 were not analyzed for BOD_5.

4.3 FOCUSED (HIGH FLOW) WATERSHED MONITORING

Focused (high flow) monitoring in the watershed was conducted by YPDRBA during high flow events occurring from April 2008 through January 2010. The results of these samples will be used to characterize the watershed response to various stimuli, including seasonal weather changes. The focused watershed monitoring program consisted of the elements described below.

- Samples were collected from the 14 watershed and tributary locations depicted in Figure 2 and described in Table 13. Twelve of these 14 stations also were included in the enhanced ambient monitoring program; however, stations Q5543000 and Q6080000 were only monitored during high flow events and were not included in the ambient enhanced monitoring program.

[1] OPO4 watershed samples collected by YPDRBA/ENV1 from April 2008 through January 2009 were not filtered prior to analysis. These sample results are flagged with an "R" qualifier in the database.

- Sampling was conducted by YPDRBA during high flow events to supplement NCDWQ and the YPDRBA's monitoring at these sites during ambient flow conditions. The collection of watershed and tributary samples during high flow events will provide the best information for estimating tributary loads to the lake.

- Samples were collected at watershed and tributary locations during 19 wet weather events resulting in high flow conditions. While 20 flow events were targeted over the two-year study period (i.e. 10 events per year), 10 events was considered the minimum number necessary to calibrate the models. High flow conditions were determined based on USGS gages throughout the watershed, evaluations of precipitation rates and historic data on stream gage heights obtained from the USGS. Figure 2 depicts the locations of the USGS gages. The high flow events were not required to be watershed wide events. Precipitation in only a part of the watershed sometimes resulted in high flows at a subset of the project sampling locations; therefore, only these locations were sampled and the more localized precipitation was considered an event for the stations involved. The sampling protocol is described in more detail in Section 5.3.1 below.

- At 11 of the 14 watershed monitoring locations, one (1) surface grab sample was collected during each high flow event (refer to Table 14). The sample was collected as near to the peak flow as possible.

- At three monitoring locations, three samples were collected over the course of the high flow event in an attempt to catch the rising, peak and falling limbs of the hydrograph, respectively. These locations (Q2810000, Q3460000 and Q5930000) are identified in Figure 2 and in Table 14.

- Focused Flow sampling was conducted on the dates listed in Table 15.

- At four monitoring locations (Q2810000, Q5930000, Q2710000 and Q0660000) surface grab samples were collected once every three months for particle size distribution analysis during focused flow events.

- Each sample collected was analyzed for the parameters summarized in Tables 13 and 16, with the exception that samples collected from Stations Q0450000, Q0660000, Q0810000, Q2040000 and Q2710000 were not analyzed for BOD_5.

Table 13. Focused (Wet Weather) Watershed Monitoring – Summary of Locations and Parameters

Site ID	Description of Site	Field Measurements*	Nutrient Monitoring **	BOD-5	TOC	TS/TVS	TSS/VSS	Chlorophyl-a	Turbidity	Hardness	TDS	Silica	Photostructure density + biovolume	Particle Size Distribution
Q2810000	Yadkin River at US 64, Yadkin College	30/Yr***	30/Yr***	30/Yr***	30/Yr***	30/Yr***	30/Yr***	NONE	30/Yr***	NONE	30/Yr***	NONE	None	1X per 3 Months
Q3460000	S.Yadkin River at SR1159 nr Mocksville	30/Yr***	30/Yr***	30/Yr***	30/Yr***	30/Yr***	30/Yr***	NONE	30/Yr***	NONE	30/Yr***	NONE	None	NONE
Q4120000	2nd Creek at US70 nr Barber	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q4540000	Grants Ck.at SR1915 nr Salisbury	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q5210000	Town Creek at SR1915 near Spencer	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q5930000	Abbotts Ck at SR1243 Lexington	30/Yr***	30/Yr***	30/Yr***	30/Yr***	30/Yr***	30/Yr***	NONE	30/Yr***	NONE	30/Yr***	NONE	None	1X per 3 Months
Q5135000	Swearing Ck at SR1272 nr Linwood	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q0450000	Yadkn River at Bus 421 nr N. Wilkesboro	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q0660000	Roaring River at SR1990	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	1X per 3 Months
Q0810000	Yadkin River at Bus 21 in Elkin	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q2040000	Yadkin River at SR1605 Enon	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q2710000	Muddy Ck at Frye Bridge Road SR1493	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	1X per 3 Months
Q5543000	Dutch 2nd Creek at SR 2370 nr Rockwell	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE
Q6080000	Flat Swamp Creek at NC 47 nr Denton	10/Yr	10/Yr	NONE	10/Yr	10/Yr	10/Yr	NONE	10/Yr	NONE	10/Yr	NONE	None	NONE

* Field Measurements included Water Temp, Dissolved Oxygen, Conductivity and pH

** Nutrient Monitoring included NH3, NO2+NO3, TKN, TP, ortho-P

*** Three samples per event were collected at these locations.

(Highlighted) These locations were sampled only during high flow events. No ambient monitoring was done by NCDWQ at these sites.

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Table 14. Focused (High Flow) Monitoring Schedule

Station ID	Station Description	Samples per Event
Q2810000	Yadkin River @ US64, Yadkin College	3
Q3483000	Hunting Creek @ SR 2115 near Harmony	1
Q3460000	S. Yadkin River @ SR1159 near Mocksville	3
Q4120000	2nd Creek @ US70 near Barber	1
Q4540000	Grants Creek @ SR1915 near Salisbury	1
Q5210000	Town Creek @ SR1915 near Spencer	1
Q5930000	Abbotts Creek @ SR1243 Lexington	3
Q5135000	Swearing Creek @ SR1272 near Linwood	1
Q0450000	Yadkin River at Bus 421 near N. Wilkesboro	1
Q0660000	Roaring River @ SR1990	1
Q0810000	Yadkin River at Bus 21 in Elkin	1
Q2040000	Yadkin River @ SR 1605 Enon	1
Q2710000	Muddy Creek @ Frye Bridge Road SR 1493	1
Q5543000	Dutch 2nd Creek @ SR2370 near Rockwell	1
Q6080000	Flat Swamp Creek @ NC 47 near Denton	1

Table 15. Focused (High Flow) Monitoring Dates

Focused Flow Event	Start Date	End Date
1	4/6/08	4/8/08
2	4/29/08	5/1/08
3	5/11/08	5/13/08
4	7/10/08	7/12/08
5	7/23/08	7/25/08
6	8/27/08	8/29/08
7	10/25/08	10/27/08
8	11/15/08	11/17/08
9	12/11/08	12/13/08
10	1/7/09	1/9/09
11	3/29/09	3/30/09
12	5/7/09	5/9/09
13	6/6/09	6/8/09
14	9/27/09	9/29/09
15	10/28/09	10/30/09
16	11/11/09	11/13/09
17	12/3/09	12/5/09
18	1/17/10	1/19/10
19	1/26/10	1/28/10

Table 16. Focused (High Flow) Monitoring – Analytical and Field Parameters

Analytical Parameters
NH_3
$NO_2 + NO_3$
TKN
Total Phosphorus
Orthophosphate[2]
BOD_5 *
TOC
Total Solids
Total Volatile Solids
Total Suspended Solids
Volatile Suspended Solids
Total Dissolved Solids
Particle Size Distribution
Turbidity
Field Parameters
Water Temperature
Dissolved Oxygen
Conductivity
pH

* Samples collected from Stations Q0450000, Q0660000, Q0810000, Q2040000 and Q2710000 were not analyzed for BOD_5.

4.3.1 Focused (High Flow) Sampling Protocol

The decision protocol used to initiate and continue Focused Flow sampling is summarized below:

1. LimnoTech monitored the weather forecasts (www.accuweather.com) and flow conditions within the study area over the course of the study. The USGS flow gage locations are listed in Table 17.

2. When significant rain (greater than 0.5 inches) was predicted in the watershed the sampling team (Environment 1) was put on alert by LimnoTech.

3. Once the decision was made to sample, LimnoTech would notify Environment 1 to mobilize to the study area and begin sampling. Sampling

[2] OPO4 watershed samples collected by YPDRBA/ENV1 from April 2008 through January 2009 were not filtered prior to analysis. These sample results are flagged with an "R" qualifier in the database.

was conducted during daylight hours only. Samples were collected beginning in the upper watershed and proceeding down to the lower watershed stations.

4. Sampling occurred when USGS flow gages indicated a response (approximately 25% increase in flow) to a significant precipitation event, generally greater than one inch.

5. Precipitation events were not always watershed wide and on occasion, high flow sampling took place in only a portion of the watershed for a particular rain event. Consequently, only the associated locations were sampled and the more localized precipitation was considered an event for the stations involved.

Table 17. USGS Gage Locations

Station Number	Station Name
Upper Yadkin River	
02112000	Yadkin River @ Wilkesboro
02112120	Roaring River near Roaring River
02112250	Yadkin River @ Elkin
02112360	Mitchell River near State Road
02113000	Fisher River near Copeland
02113850	Arafat River near Arafat
02114450	Little Yadkin River @ Dalton
02115360	Yadkin River @ Enon
02115860	Muddy Creek near Muddy Creek
02116500	Yadkin River near Yadkin College
South Yadkin River	
02118000	South Yadkin near Mocksville
02118500	Hunting Creek near Harmony
02120780	Second Creek near Barber
Lower Yadkin River	
02121500	Abbotts Creek @ Lexington

4.4 ACCESS DATABASE

An ACCESS database was constructed to include all information derived from water quality monitoring, weather data and various hydrologic and physical characteristics of the watershed and tributary sites. The database was constructed and maintained on an "on-going basis" to enable the quality of the data to be monitored as it was being generated. This database is available to the project partners on a "pass word protected-read only basis" using an internet File Transfer Protocol (FTP).

A report documenting the structure of the database is provided as Appendix E. The database is included in Appendix H (on CD).

5. OUTPUTS AND RESULTS

Two years of comprehensive data were collected during the April 2008 through April 5, 2010 sampling program to calibrate the High Rock Lake watershed and lake models. The data suggest general system behaviors that help inform the model interpretation to give NCDWQ confidence in computing and allocating the TMDL. These observations of system behaviors are summarized in the following paragraphs for the watershed and lake data.

5.1 WATERSHED MONITORING

As discussed in Section 5 above, samples were collected from 14 tributary locations throughout the watershed over the two year sampling period. Samples were collected on a routine basis and in response to high flow/wet weather events. All sample results are included in the database in Appendix H. The laboratory reports, laboratory QA/QC, field notes and calibration logs are included in Appendix G. The particle size distribution data is included in Appendix L.

The watershed data are summarized in Tables 18-21. Table 18 includes the field data collected for conductivity, dissolved oxygen, pH and temperature for all watershed samples (ambient/enhanced ambient and focused flow). The number of results is included along with the minimum, maximum and average values recorded. The lowest dissolved oxygen concentration (2 mg/L) was recorded at Station Q6080000 (Flat Swamp Creek) during a wet weather event. The maximum dissolved oxygen concentration (16.4 mg/L) was recorded at Station Q2040000 (Yadkin River at Enon) under ambient conditions. The minimum pH (4.1) was also recorded at Station Q6080000 and the maximum was observed at Station Q5950000 (Abbotts Creek). Both of these values were recorded during high flow events.

The analytical data for focused flow events is summarized in Table 19. The minimum BOD concentration was 2 mg/L at all stations. The flow data measured at corresponding USGS gages are included in the database (Appendix H). The precipitation measured at five (5) USGS gages and the Winston-Salem Airport is included in Table 20.

The maximum BOD concentration of 11 mg/L was found at Station Q4120000 (Second Creek). The minimum ammonia concentration was 0.01 mg/L at all stations with the exception of Q2710000 (Muddy Creek) where it was 0.03 mg/L. The maximum concentration (2.481 mg/L) was found at Station Q0660000 (Roaring River). The minimum nitrate+nitrite concentration (0.01 mg/L) was found at Station Q5543000 (Dutch Second Creek) and Q6080000 (Flat Swamp Creek) during a high flow event. The maximum nitrate+nitrite concentration (4.45 mg/L) was found at Q2710000 (Muddy Creek). Total phosphorus was not detected at nine stations and the maximum concentration (3.39 mg/L) was found at Station Q0660000 (Roaring River) during a high flow event. The minimum total suspended solids concentrations (1 mg/L) was found at Q6080000 (Flat Swamp Creek) and the maximum (4,374 mg/L) was at Q0660000 (Roaring River) during a high flow event. The highest average total suspended solids concentration was 564.1 mg/L at Q4120000 (Second Creek). The lowest turbidity readings were observed at Station Q6080000 (Flat Swamp Creek), with the highest at Station Q0810000 (Yadkin River at Elkin). The highest average turbidity was found at Station Q4120000 (Second Creek), which had also the highest average total suspended solids concentration.

The analytical data for the watershed stations during ambient/enhanced ambient conditions are summarized in Tables 20 and 21. The focused flow data are compared to all the ambient data in Table 22. The biggest difference between focused flow and the enhanced ambient data is shown in the solids results. The total suspended solids average concentrations at high flow conditions are approximately an order of magnitude greater than the average concentrations seen at ambient conditions.

The concentrations for NH_3, N+N, TP and TSS are plotted against flow for all watershed data (focused flow, ambient/enhanced ambient) sampling for each watershed station. These graphs are included in Appendix J Figures 1 through 28. Time series graphs of ambient/enhanced ambient watershed water quality data are included in Appendix J Figures 29 through 31 for data collected by YPDRBA/Environment 1and in Appendix J Figures 32 through 34 for data collected by NCDWQ. Scatter plots of focused flow concentrations versus flow for upper and lower watershed stations are also included in Appendix J Figures 35 through 37.

Table 18. Watershed Physical Data Summary (April 2008 through April 2010)
High Rock Lake, North Carolina

	FOCUSED FLOW DATA (April 2008 through January 2010)																				
	Conductivity (umhos/cm)					Dissolved Oxygen (mg/l)					pH					Temperature (degrees Centigrade)				
Station	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average
Q0450000	14	0	27	67	49.36	14	0	7.6	13.1	10.49	14	0	3.9	6.5	5.39	14	0	3.8	20.1	11.79
Q0660000	15	0	22	50	33.80	15	0	7.7	12.7	10.66	15	0	4.4	6.4	5.67	15	0	3.8	19.3	11.57
Q0810000	15	0	40	68	53.20	15	0	6.5	12.9	10.05	15	0	5.8	6.8	6.27	15	0	3.8	23.04	12.58
Q2040000	19	0	43	79	61.26	19	0	7.3	13.2	10.13	19	0	5.1	7.5	6.55	19	0	3.3	28.3	14.23
Q2710000	18	0	45	318	112.56	18	0	6.3	12.1	8.94	18	0	6	7	6.48	18	0	5.4	24.1	14.81
Q2810000	57	1	41	204	78.91	56	1	5.1	13.3	9.48	57	1	5.4	7.1	6.49	57	1	3.8	27.2	14.70
Q3460000	54	0	38	116	65.31	54	0	6.1	12.8	9.05	54	0	4.5	7.3	6.34	54	0	4.4	24.7	13.54
Q4120000	18	0	52	146	94.72	18	0	5.7	11.9	9.04	18	0	5.2	7	6.39	18	0	5.2	23.3	14.67
Q4540000	18	0	45	161	100.56	18	0	6	11.8	8.44	18	0	5.7	7.3	6.58	18	0	5.9	24.1	15.58
Q5135000	18	0	52	176	89.78	18	0	5.3	11.7	8.18	18	0	5.4	7.2	6.49	18	0	5.3	24.6	15.46
Q5210000	18	0	32	245	110.33	18	0	6.8	13.8	9.41	18	0	5.1	7.9	6.77	18	0	5.6	25.58	15.85
Q5543000	18	0	38	183	109.83	18	0	5.8	13.3	8.44	18	0	4.9	7.1	6.62	18	0	6.4	23.2	15.23
Q5930000	51	0	31	311	125.55	51	0	5.2	12.1	8.59	51	0	4.9	9.2	6.63	51	0	4.5	25.1	14.01
Q6080000	18	0	39	121	79.44	18	0	2	14.2	8.13	18	0	4.1	7	6.36	18	0	6.3	23.44	15.60
Total/Avg:	**351**	**1**	**22**	**318**	**83.19**	**350**	**1**	**2**	**14.2**	**9.22**	**351**	**1**	**3.9**	**9.2**	**6.36**	**351**	**1**	**3.3**	**28.3**	**14.26**

	NC-DWQ AMBIENT/ENHANCED AMBIENT DATA (April 2008 through April 2010)																				
	Conductivity (umhos/cm)					Dissolved Oxygen (mg/l)					pH					Temperature (degrees Centigrade)				
Station	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average
Q0660000^	47	0	31	84	40.81	45	0	6.4	16.2	10.72	46	0	6.8	8.2	7.42	46	0	1.2	26.6	13.88
Q0810000	23	0	45	164	69.57	22	0	5.4	15.3	9.97	22	0	6.8	7.8	7.31	23	0	2	28.2	14.56
Q2040000	24	0	36	86	66.33	23	0	6.1	16.4	10.40	24	0	6.7	8.2	7.39	24	0	0.8	31.1	15.07
Q2810000*	24	0	55	156	99.83	24	0	6.1	14.8	9.60	24	0	6.4	7.7	7.23	24	0	3.2	28.9	16.76
Q3460000	24	0	67	182	82.38	24	0	6.2	14.6	9.43	24	0	6.8	7.9	7.32	24	0	3.2	27.3	15.54
Q4120000	23	0	92	172	129.09	23	0	6.4	13	9.33	23	0	5.9	7.3	6.60	24	0	3.8	25.7	14.08
Q5930000*	23	0	105	321	187.70	23	0	4.5	13	8.37	23	0	6.8	7.6	7.24	23	0	4.9	27.8	16.67
Q2720000^	49	0	103	505	255.65	48	0	5.6	16.1	9.24	46	0	6.5	7.8	7.22	49	0	3.6	29.4	16.40
Total/Avg:	**237**	**0**	**31**	**505**	**116.42**	**232**	**0**	**4.5**	**16.4**	**9.63**	**232**	**0**	**5.9**	**8.2**	**7.22**	**237**	**0**	**0.8**	**31.1**	**15.37**

	YPDRBA/ENV1 AMBIENT/ENHANCED AMBIENT DATA (April 2008 through February 2010)																				
	Conductivity (umhos/cm)					Dissolved Oxygen (mg/l)					pH					Temperature (degrees Centigrade)				
Station	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average	# Results	# Dups	Min	Max	Average
Q0450000	24	0	50	105	68.88	24	0	5.7	11.9	8.33	24	0	6.1	7.2	6.89	24	0	3.8	26.6	16.45
Q2810000*	24	0	85	185	119.21	24	0	7	13	9.34	24	0	6.6	7.3	7.06	24	0	3.3	25.3	14.34
Q4540000	24	0	118	225	165.96	24	0	5.4	12.8	8.32	24	0	6.6	7.3	6.89	24	0	3.2	27	16.40
Q5135000	24	0	133	410	244.75	24	0	4.2	12.8	7.47	24	0	6.3	6.8	6.56	24	0	3.1	26.9	16.40
Q5210000	23	0	129	282	193.17	23	0	5.3	12.7	7.98	23	0	6.5	7.2	6.88	23	0	3.4	28.1	17.34
Q5930000*	23	0	92	352	155.39	23	0	6.1	11.8	8.46	23	0	6.5	7.2	6.95	23	0	3.6	25.5	15.17
Total/Avg:	**142**	**0**	**50**	**410**	**157.89**	**142**	**0**	**4.2**	**13**	**8.31**	**142**	**0**	**6.1**	**7.3**	**6.87**	**142**	**0**	**3.1**	**28.1**	**16.02**

Upper Watershed Stations
Lower Watershed Stations
* Stations Q2810000 and Q5930000 sampled once per month by both YPDRBA/ENV1 and NC-DWQ.
^ Stations Q0660000 and Q2720000 sampled twice per month by NC-DWQ (Q2720000 sampled instead of Q2710000).

Table 19. Watershed FOCUSED FLOW Sample Data Summary (April 2008 through January 2010)
High Rock Lake, North Carolina

	5-Day BOD						
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000							
Q0660000							
Q0810000							
Q2040000							
Q2710000							
Q2810000	58	16	0	2	2	9.4	3.50
Q3460000	70	35	0	16	2	8.4	3.07
Q4120000	18	4	0	0	2	11	4.29
Q5930000	52	13	0	1	2	5.5	2.90
Q4540000	18	3	0	0	2	7	3.36
Q5210000	18	3	0	0	2	10	3.54
Q5135000	18	7	0	0	2	6.3	3.22
Q5543000							
Q6080000							
Total/Avg:	**252**	**81**	**0**	**19**	**2**	**11**	**3.41**

	Ammonia						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	2	0	0	0.01	0.77	0.16
Q0660000	17	4	0	2	0.01	2.481	0.26
Q0810000	16	3	0	1	0.01	0.41	0.13
Q2040000	22	3	0	3	0.01	0.402	0.10
Q2710000	21	0	0	3	0.03	0.72	0.32
Q2810000	58	7	0	2	0.01	0.608	0.13
Q3460000	70	9	0	16	0.01	0.498	0.09
Q4120000	18	1	0	0	0.01	0.62	0.16
Q5930000	53	0	0	2	0.01	0.36	0.06
Q4540000	24	4	0	6	0.01	0.26	0.07
Q5210000	18	3	0	0	0.01	0.277	0.06
Q5135000	18	3	0	0	0.01	0.75	0.13
Q5543000	19	3	0	1	0.01	0.214	0.08
Q6080000	18	7	0	0	0.01	0.18	0.04
Total/Avg:	**386**	**49**	**0**	**36**	**0.01**	**2.481**	**0.13**

	Nitrate + Nitrite						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	0	0	0.236	0.776	0.53
Q0660000	17	0	0	2	0.19	0.911	0.45
Q0810000	16	0	0	1	0.31	1.06	0.64
Q2040000	22	0	0	3	0.28	0.847	0.52
Q2710000	21	0	0	3	0.5	4.45	1.13
Q2810000	58	0	0	2	0.37	3.06	0.87
Q3460000	70	0	0	16	0.15	1.14	0.67
Q4120000	18	0	0	0	0.37	0.9	0.65
Q5930000	53	10	0	2	0.109	1.26	0.42
Q4540000	24	0	0	6	0.147	0.54	0.33
Q5210000	18	0	0	0	0.09	0.553	0.31
Q5135000	18	0	0	0	0.17	0.63	0.35
Q5543000	19	1	0	1	0.01	0.81	0.42
Q6080000	18	7	0	0	0.01	0.63	0.16
Total/Avg:	**386**	**18**	**0**	**36**	**0.01**	**4.45**	**0.53**

	Orthophosphorus (including non-filtered results^)						
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	0	0	0.037	0.20	0.09
Q0660000	16	0	2	1	0.00	0.28	0.07
Q0810000	15	0	0	0	0.04	0.202	0.09
Q2040000	22	0	0	3	0.01	0.16	0.06
Q2710000	20	0	0	2	0.02	0.33	0.15
Q2810000	57	0	0	1	0.019	0.43	0.11
Q3460000	62	0	3	8	0.00	0.18	0.05
Q4120000	18	0	0	0	0.01	0.39	0.10
Q5930000	52	0	1	1	0.00	0.18	0.06
Q4540000	21	0	0	3	0.02	0.43	0.07
Q5210000	18	0	0	0	0.01	0.19	0.05
Q5135000	18	0	0	0	0.021	0.24	0.08
Q5543000	18	0	0	0	0.019	0.17	0.05
Q6080000	18	0	7	0	0.00	0.08	0.02
Total/Avg:	**369**	**0**	**13**	**19**	**0.00**	**0.43**	**0.07**

	Orthophosphorus (excluding non-filtered results^)						
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	7	0	0	0	0.037	0.086	0.06
Q0660000	7	0	0	0	0.014	0.28	0.07
Q0810000	7	0	0	0	0.044	0.202	0.08
Q2040000	9	0	0	0	0.015	0.111	0.04
Q2710000	8	0	0	0	0.032	0.208	0.12
Q2810000	27	0	0	0	0.019	0.132	0.07
Q3460000	24	0	2	0	0.00	0.094	0.04
Q4120000	8	0	0	0	0.044	0.142	0.08
Q5930000	24	0	1	0	0.00	0.076	0.04
Q4540000	7	0	0	0	0.022	0.068	0.04
Q5210000	8	0	0	0	0.014	0.058	0.03
Q5135000	8	0	0	0	0.021	0.072	0.04
Q5543000	8	0	0	0	0.019	0.091	0.05
Q6080000	8	0	3	0	0.002	0.072	0.02
Total/Avg:	**160**	**0**	**6**	**0**	**0.00**	**0.28**	**0.06**

	Total Phosphorus						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	1	0	0	2.02	0.49
Q0660000	17	0	3	2	0	3.39	0.55
Q0810000	16	0	0	1	0.03	2.681	0.55
Q2040000	22	0	0	3	0.02	0.945	0.27
Q2710000	21	0	0	3	0.05	1.26	0.44
Q2810000	58	0	2	2	0	1.68	0.38
Q3460000	70	0	3	16	0	1.078	0.29
Q4120000	18	0	0	0	0.08	1.957	0.68
Q5930000	53	0	3	2	0	0.76	0.18
Q4540000	24	0	1	6	0	0.705	0.25
Q5210000	18	0	1	0	0	0.395	0.16
Q5135000	18	0	0	0	0.084	0.48	0.22
Q55430000	19	0	1	1	0	0.9	0.20
Q6080000	18	0	1	0	0	0.283	0.09
Total/Avg:	**386**	**0**	**16**	**36**	**0.00**	**3.39**	**0.34**

	Toal Dissolved Solids						
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	0	0	41	61	48.9
Q0660000	17	0	0	2	41	82	49.5
Q0810000	16	0	0	1	41	88	58.8
Q2040000	22	0	0	3	41	82	55.3
Q2710000	21	0	0	3	64	210	93.2
Q2810000	58	0	0	2	24	718	86.0
Q3460000	70	0	0	16	41	147	69.7
Q4120000	18	0	0	0	72	166	111.3
Q5930000	53	0	0	2	60	2400	148.1
Q4540000	24	0	0	6	85	1790	169.9
Q5210000	18	0	0	0	57	134	99.7
Q5135000	18	0	0	0	63	114	88.8
Q55430000	19	0	0	1	66	120	98.9
Q6080000	18	0	0	0	43	99	72.2
Total/Avg:	**386**	**0**	**0**	**36**	**24**	**2400**	**89.31**

	Total Kjeldahl Nitrogen						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	1	0	0	0.20	6.6	1.9
Q0660000	17	1	0	2	0.02	11.3	2.0
Q0810000	16	1	0	1	0.20	7.7	2.0
Q2040000	22	1	0	3	0.20	3.0	1.0
Q2710000	21	0	0	3	0.69	3.5	1.5
Q2810000	58	2	0	2	0.20	3.7	1.2
Q3460000	70	5	0	16	0.20	3.3	1.2
Q4120000	18	1	0	0	0.20	3.6	1.7
Q5930000	53	2	0	2	0.20	3.8	0.9
Q4540000	24	1	0	6	0.20	2.2	1.1
Q5210000	18	0	0	0	0.25	12.9	1.6
Q5135000	18	0	0	0	0.24	1.8	0.9
Q55430000	19	0	0	1	0.24	1.7	0.9
Q6080000	18	0	0	0	0.29	2.0	0.9
Total/Avg:	**386**	**15**	**0**	**36**	**0.02**	**12.90**	**1.34**

	Total Organic Carbon						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	0	0	1.7	9.3	4.0
Q0660000	17	0	0	2	1.8	15.0	5.9
Q0810000	16	0	0	1	2.4	11.4	6.2
Q2040000	22	0	0	3	2.1	8.3	4.2
Q2710000	21	0	0	3	3.9	9.8	6.2
Q2810000	58	0	0	2	2.4	10.9	5.0
Q3460000	70	0	0	16	1.9	14.9	5.4
Q4120000	18	0	0	0	2.2	13.3	8.0
Q5930000	53	0	0	2	2.7	13.0	7.5
Q4540000	24	0	0	6	3.2	11.8	7.0
Q5210000	18	0	0	0	6.4	13.5	9.7
Q5135000	18	0	0	0	3.1	10.7	7.0
Q55430000	19	0	0	1	3.3	12.4	7.3
Q6080000	18	0	0	0	6.9	16.8	11.3
Total/Avg:	**386**	**0**	**0**	**36**	**1.72**	**16.84**	**6.77**

	Total Residue						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	1	0	0	25	1880	376.6
Q0660000	17	0	0	2	33	3450	415.0
Q0810000	16	0	0	1	41	1800	368.1
Q2040000	22	0	0	3	36	673	230.7
Q2710000	21	0	0	3	113	879	327.4
Q2810000	58	0	0	2	84	1110	281.4
Q3460000	70	0	0	16	79	788	250.8
Q4120000	18	0	0	0	124	1240	499.1
Q5930000	53	0	0	2	69	577	201.2
Q4540000	24	0	0	6	115	660	281.8
Q5210000	18	0	0	0	110	446	201.2
Q5135000	18	0	0	0	99	402	203.6
Q55430000	19	0	0	1	93	330	180.5
Q6080000	18	0	0	0	60	246	125.6
Total/Avg:	**386**	**1**	**0**	**36**	**25**	**3450**	**281.64**

	Total Soluble Residue						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	0	0	7.8	1773	326.1
Q0660000	17	0	0	2	1.8	4374	415.3
Q0810000	16	0	0	1	5	1272	338.2
Q2040000	22	0	0	3	2.9	678	157.8
Q2710000	21	0	0	3	15	1779	340.2
Q2810000	58	0	0	2	3.6	1509	231.8
Q3460000	70	0	0	16	3.7	1144	165.4
Q4120000	18	0	0	0	12.3	3094	564.1
Q5930000	53	0	0	2	6.5	510	75.1
Q4540000	24	0	0	6	3.7	756	157.0
Q5210000	18	0	0	0	13	350	85.3
Q5135000	18	0	0	0	2.8	267	96.8
Q55430000	19	0	0	1	4.9	224	61.0
Q6080000	18	0	0	0	1	213	37.7
Total/Avg:	**386**	**0**	**0**	**36**	**1**	**4374**	**217.97**

	Turbidity						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (NTU)	Max (NTU)	Average (NTU)
Q0450000	14	0	0	0	7.4	900	193.5
Q0660000	17	0	0	2	4.8	850	169.5
Q0810000	16	0	0	1	9.1	1500	240.5
Q2040000	22	0	0	3	7.5	320	96.0
Q2710000	21	0	0	3	15	400	159.5
Q2810000	58	0	0	2	10	720	163.1
Q3460000	70	0	0	16	9.8	550	170.4
Q4120000	18	0	0	0	13	900	355.7
Q5930000	53	0	0	2	11	440	75.2
Q4540000	24	0	0	6	4.8	400	147.1
Q5210000	18	0	0	0	5.1	250	91.2
Q5135000	18	0	0	0	8	240	114.5
Q55430000	19	0	0	1	8.2	220	71.1
Q6080000	18	0	0	0	3	120	30.9
Total/Avg:	**386**	**0**	**0**	**36**	**3.00**	**1500.0**	**148.45**

	Total Volatile Residue						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	2	0	0	25	255	76.1
Q0660000	17	4	0	2	25	588	100.6
Q0810000	16	3	0	1	25	281	84.0
Q2040000	22	6	0	3	25	173	59.8
Q2710000	20	1	0	3	25	126	63.6
Q2810000	58	10	0	2	25	203	73.5
Q3460000	70	11	0	16	25	226	71.0
Q4120000	18	1	0	0	25	242	91.0
Q5930000	53	6	0	2	25	175	63.7
Q4540000	24	1	0	6	25	138	70.4
Q5210000	18	2	0	0	25	104	61.6
Q5135000	18	1	0	0	25	146	66.3
Q55430000	19	4	0	1	25	121	68.2
Q6080000	18	3	0	0	25	129	51.8
Total/Avg:	**385**	**55**	**0**	**36**	**25**	**588**	**71.55**

	Volatile Soluble Residue						
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q0450000	14	0	0	0	2	245	47.3
Q0660000	17	1	0	2	1	795	79.2
Q0810000	16	0	0	1	2.0	220	54.1
Q2040000	22	1	0	3	1	100	22.1
Q2710000	21	0	0	3	3.4	171	40.0
Q2810000	58	0	0	2	1	182	30.6
Q3460000	70	0	0	16	1.1	127	25.0
Q4120000	18	0	0	0	2.3	365	66.2
Q5930000	53	0	0	2	1.3	45	9.9
Q4540000	24	1	0	6	1	89	21.8
Q5210000	18	0	0	0	3	53	12.5
Q5135000	18	0	0	0	1	37	13.9
Q55430000	19	0	0	1	1	29	8.6
Q6080000	18	1	0	0	1	28	5.9
Total/Avg:	**386**	**4**	**0**	**36**	**1.00**	**795.00**	**31.21**

Upper Watershed Stations (Q0450000, Q0660000, Q0810000, Q2040000)
Lower Watershed Stations (Q2710000 through Q6080000)

NOTES:
* Total # Results includes duplicate samples
^ OPO4 samples collected during the first ten focused flow events (FF-1 thru FF-10 or Apr-08 thru Jan-09) were not filtered prior to analysis; these results are flagged as rejected in the databas

Table 20. Watershed Precipitation Data Related To Focused Flow Events

Focused Flow Event Number	Date	Roaring River	Enon	Yadkin College	Mocksville	Second Creek	Winston-Salem Airport
1	4/3/08	0.57	0.84	0.64	0.72	0.54	0.72
	4/4/08	0.24	0.99	0.48	0.79	0.65	1.23
	4/5/08	0.2	0.27	0.3	0.37	0.44	0.24
	4/6/08	0.4	0.49	0.04	0.06	0.12	0.43
	4/7/08	0.01	0	0	0	0.01	0
	4/8/08	0	0	0	0	0	0.01
2	4/27/08	0.47	0.79	1.05	0.7	1.27	0.85
	4/28/08	0.34	0.43	1.61	0.43	1.22	0.6
	4/29/08	0	0	0.01	0	0	0
	4/30/08	0	0	0	0	0	0
	5/1/08	0	0	0	0	0	0
3	5/9/08	0.01	0.03	0.1	0.07	0.16	0
	5/10/08	0	0	0	0	0	0
	5/11/08	0.22	0.47	0.2	0.15	0.44	0.44
	5/12/08	0	0	0	0	0	0
	5/13/08	0	0	0	0	0	0
4	7/8/08	0.01	0.01	0.17	0	0.32	0.11
	7/9/08	0.23	0.34	0.37	1.26	0.01	0.44
	7/10/08	0.46	0.04	0.11	0.2	0.11	0.01
	7/11/08	0	0	0.01	0	0	0
	7/12/08	0	0	0	0	0	0
5	7/22/08	0.01	0.09	0.11	0.69	0.21	0.58
	7/23/08	0.37	0.5	0.49		1.19	0.18
	7/24/08	0	0.01	0.01	0.01	0.01	0.01
	7/25/08	0	0	0	0	0	0
6	8/26/08	1.32	0.71	1.41	1.07	1.73	0.79
	8/27/08	3.35	6.52	3.57	2.96	4.68	2.43
	8/28/08	0.1	0.04	0	0	0	0.03
	8/29/08	0	0	0	0	0	0
7	10/24/08	0.45	0.01	0.01	0	0.01	0.02
	10/25/08	0.41	0.46	0.45	0.35	0.38	0.58
	10/26/08	0.00	0	0	0	0	0
	10/27/08	0.00	0	0	0	0	0
8	11/13/08	0.95	0.38	0.19	0.27	--	0.58
	11/14/08	0.01	0.35	1.60	0.93	--	1.25
	11/15/08	0.07	0.07	0.17	0.50	---	0.1
	11/16/08	0.00	0	0	0	0	0
	11/17/08	0.00	0	0	0	0	0
9	12/10/08	0.56	0.86	0.59	1.05	0.86	1.03
	12/11/08	2.25	1.09	1.08	1.75	1.44	1.16
	12/12/08	0.00	0.13	0.18	0.20	0.00	0.19
	12/13/08	0.00	0	0.00	0.00	0.00	0
10	1/5/09	0.02	0.16	0	0.00	0.01	0.32
	1/6/09	1.04	0.79	1.23	1.17	1.22	0.85
	1/7/09	1.69	0.95	0.48	0.87	0.58	0.85
	1/8/09	0.00	0	0	0	0	0
	1/9/09	0.00	0	0	0	0	0
11	3/27/09	0.72	0.6	0.33	0.37	0.28	0.44
	3/28/09	0.29	0.41	0.40	0.47	0.55	0.39
	3/29/09	0.04	0.01	0.02	0.05	0.02	0.03
	3/30/09	0.00	0	0	0	0	0
	3/31/09	0.00	0	0	0	0	0
12	5/5/09	0.7	0.52	0.71	0.56	0.49	0.89
	5/6/09	0.65	0.13	0.18	0.47	0.33	0.3
	5/7/09	0.08	0.04	0.43	0.04	0.06	0.02
	5/8/09	0	0	0	0	0	0
	5/9/09	0	0.12	0.68	0	0.17	0.16
13	6/4/09	0.39	1.88	1.66	1.80	1.41	0.08
	6/5/09	0.57	2.07	1.82	1.57	2.12	1.87
	6/6/09	0	0	0	0.01	0	0.04
	6/7/09	0	0	0	0	0	0
	6/8/09	0.18	0	0	0	0	0
14	9/26/09	1.19	0.84	1.49	1.14	1.08	0.84
	9/27/09	0	0.02	0.03	0.06	0.03	0.08
	9/28/09	0	0.01	0.23	0.11	0.14	0.3
	9/29/09	0	0	0.01	0.01	0	0
15	10/27/09	0.99	1.09	1.29	1.01	1.36	1.26
	10/28/09	0.09	0.08	0.11	0.11	0.07	0.09
	10/29/09	0	0	0	0	0	0
	10/30/09	0	0	0	0	0	0
16	11/10/09	1.12	0.97	0.79	0.77	0.85	0.8
	11/11/09	1.27	2.01	2.29	2.39	2.81	2.36
	11/12/09	0.07	0.62	0.56	0.45	0.45	1.1
	11/13/09	0	0.02	0.01	0	0.02	0
17	12/2/09	1.97	1.3	1.19	1.25	1.58	1.2
	12/3/09	0.01	0	0	0	0	0
	12/4/09	0	0	0	0	0	0
	12/5/09	0.29	0.26	0.21	0.16	0.12	0.24
18	1/17/10	1.42	1.27	1.47	1.39	1.70	1.31
	1/18/10	0	0.01	0	0.01	0	0
	1/19/10	0	0	0	0	0	0
19	1/24/10	2.45	2.15	2.14	2.10	1.93	1.6
	1/25/10	0.81	0.34	0.59	0.38	0.25	0.34
	1/26/10	0	0	0	0	0	0
	1/27/10	0	0	0	0	0	0
	1/28/10	0	0	--	0	0	0

(yellow highlight) = Focused Flow Event sampling days. Stations Q3460000, Q2810000, Q593000 were sampled for three days per event. All other stations were sampled once per event.

Table 2M. NC-DWQ Watershed Ambient/Enhanced Ambient Grab Sample Data Summary (April 2008 through April 2010)
High Rock Lake, North Carolina

	5-day BOD					Total Organic Carbon					Nitrate + Nitrite					Turbidity				
Station	# Results*	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (NTU)	Max (NTU)	Average (NTU)
Q066^						48	25	2	23	3.05	48	0	0.21	0.75	0.46	48	0	1.1	250	16.50
Q081						24	4	2	5.3	3.03	24	0	0.36	1.1	0.71	24	0	5.2	80	18.52
Q204						24	6	2	4.9	2.85	24	0	0.38	1	0.60	24	0	3.90	130	26.18
Q272^						49	0	2.8	13	4.81	49	0	0.8	5.8	2.33	48	0	4.4	390	35.06
Q281**	23	18	2	4.7	2.22	24	1	2	22	4.04	23	0	0.55	2.2	1.13	24	0	3.3	160	30.34
Q346	23	19	2	3.4	2.10	24	5	2	7.1	2.97	24	0	0.18	0.96	0.65	24	0	4	170	42.47
Q412	24	22	2	2	2.00	24	5	2	4.5	2.79	24	0	0.25	0.86	0.60	24	0	5.7	100	22.68
Q593**	23	18	2	4	2.11	24	0	4.5	9.3	6.14	24	0	0.31	1.4	0.66	24	0	2.6	120	26.23
Total/Avg:	**93**	**77**	**2**	**4.7**	**2.11**	**241**	**46**	**2**	**23**	**3.71**	**240**	**0**	**0.18**	**5.8**	**0.89**	**240**	**0**	**1.1**	**390**	**27.25**

	Ammonia					Total Kjeldahl Nitrogen					Total Phosphorus					Orthophosphorus				
Station	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results*	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q066^	48	40	0.02	0.06	0.02	48	28	0.20	1.1	0.27	48	4	0.02	0.93	0.07	48	44	0.02	0.06	0.02
Q081	24	8	0.02	0.17	0.05	24	0	0.20	0.94	0.40	24	0	0.05	0.41	0.14	24	6	0.02	0.3	0.06
Q204	24	11	0.02	0.09	0.03	24	3	0.20	0.69	0.33	24	0	0.04	0.31	0.11	24	8	0.02	0.1	0.03
Q272^	49	1	0.02	0.47	0.10	49	0	0.47	1.5	0.75	49	0	0.09	1.4	0.52	49	0	0.02	1.2	0.39
Q281**	23	2	0.02	0.14	0.05	23	1	0.20	1.9	0.52	22	0	0.09	10	0.69	24	0	0.02	0.36	0.12
Q346	24	5	0.02	0.09	0.04	24	4	0.2	0.97	0.39	24	0	0.02	0.98	0.14	24	23	0.02	0.02	0.02
Q412	24	6	0.02	0.1	0.03	24	4	0.20	0.54	0.32	24	0	0.03	0.21	0.08	24	13	0.02	0.07	0.03
Q593**	24	4	0.02	0.1	0.05	24	0	0.42	0.71	0.55	24	0	0.07	0.24	0.12	24	5	0.02	0.1	0.04
Total/Avg:	**240**	**77**	**0.02**	**0.47**	**0.05**	**240**	**40**	**0.2**	**1.9**	**0.44**	**239**	**4**	**0.02**	**10**	**0.23**	**241**	**99**	**0.02**	**1.2**	**0.09**

	Total Residue					Total Dissolved Solids					Total Soluble Residue					Total Volatile Residue					Volatile Soluble Residue				
Station	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results*	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	Min (mg/l)	Max (mg/l)	Average (mg/l)
Q066^	48	0	27	414	65.06	48	0	20	62	33.29	48	33	6.2	130	15.72	48	13	8	86	20.04	48	44	6.2	25	8.13
Q081	24	0	41	160	82.04	24	0	16	78	48.13	24	4	6.2	76	20.49	24	0	16	68	26.75	24	20	6.2	14	7.25
Q204	24	0	29	183	85.58	24	0	34	89	47.88	24	7	6.2	110	26.87	24	1	12.00	54	26.75	24	20	6.20	16	8.28
Q272^	49	0	30	480	202.78	49	0	70	296	159.76	49	10	6.2	295	32.89	49	1	12	344	53.37	49	37	6.2	41	9.14
Q281**	23	0	57	824	135.30	24	0	53	478	92.71	24	5	6.2	410	42.95	23	1	12	136	33.43	24	18	6.2	59	10.27
Q346	23	0	46	266	110.91	24	0	43	73	59.92	24	4	6.2	222	45.89	23	1	12	108	32.17	24	16	6.2	36	10.60
Q412	23	0	96	180	123.30	24	0	88	122	104.29	24	5	6.2	90	17.79	23	0	18	57	30.57	23	21	6.2	13	7.76
Q593**	24	0	107	378	167.17	24	0	76	192	129.04	24	3	6.2	85	18.32	24	0	28	358	55.92	24	23	6.2	13	7.45
Total/Avg:	**238**	**0**	**27**	**824**	**121.52**	**241**	**0**	**16**	**478**	**84.38**	**241**	**71**	**6.2**	**410**	**27.62**	**238**	**17**	**8**	**358**	**34.87**	**240**	**199**	**6.2**	**59**	**8.61**

Upper Watershed Stations (blue shading)
Lower Watershed Stations (yellow shading)

NOTES:
- * Duplicate and split samples were not collected for ambient data
- ** Stations Q2810000 and Q5930000 sampled once per month by both YPDRBA/ENV1 and NC-DWQ.
- ^ Stations Q0660000 and Q2720000 sampled twice per month by NC-DWQ (Q2720000 sampled instead of Q2710000).

Table 2H. YPDRBA/ENV1 Watershed Ambient/Enhanced Ambient Grab Sample Data Summary (April 2008 through February 2010)
High Rock Lake, North Carolina

	5-Day BOD						Total Organic Carbon						Nitrate + Nitrite							
Station	# Results*	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects
Q045							24	0	0	1.49	4.91	2.72	24	0	0	0.27	1.28	0.58	24	0
Q281**	24	22	0	2	2	2.00	24	0	0	1.84	5.12	2.67	24	0	0	0.63	2.05	1.18	24	0
Q454	24	23	0	2	2.1	2.00	24	0	0	1.97	4.46	3.17	24	0	0	0.04	0.65	0.31	23	0
Q5135	24	18	0	2	6.4	2.39	24	0	0	1.67	7.46	3.45	24	1	0	0.01	0.716	0.33	24	0
Q521	22	20	0	2	7.9	2.35	23	1	0	2.55	10.2	5.15	23	2	0	0.01	1.1	0.40	23	1
Q593**	23	19	0	2	13	2.78	23	1	0	4.27	10	6.03	23	1	0	0.26	1.12	0.66	23	2
Totals/Ave	**117**	**102**	**0**	**2**	**13**	**2.30**	**142**	**2**	**0**	**1.49**	**10.2**	**3.84**	**142**	**4**	**0**	**0.01**	**2.05**	**0.58**	**141**	**3**

	Ammonia						Total Kjeldahl Nitrogen						Total Phosphorus						Orthophospho	
Station	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results*	# Non-Detects
Q045	24	6	0	0	0.25	0.07	24	7	0	0.20	1.23	0.48	24	1	0	0.02	0.64	0.16	24	2
Q281**	24	5	0	0.01	0.58	0.10	24	4	0	0.20	2.71	0.71	24	0	0	0.09	0.68	0.22	24	1
Q454	24	7	0	0.01	0.43	0.08	24	3	0	0.20	3.235	0.69	24	2	2	0	0.551	0.09	24	1
Q5135	24	4	0	0.01	0.36	0.10	24	2	0	0.2	3.05	0.73	24	0	0	0.04	0.585	0.12	24	1
Q521	23	12	0	0.01	0.96	0.08	23	5	0	0.20	2.62	0.65	23	2	0	0.02	0.59	0.10	23	2
Q593**	23	5	0	0.01	4.48	0.30	23	3	0	0.20	3.454	0.90	23	1	0	0.03	0.657	0.15	23	2
Totals/Ave	**142**	**39**	**0**	**0**	**4.48**	**0.12**	**142**	**24**	**0**	**0.20**	**3.45**	**0.69**	**142**	**6**	**2**	**0.00**	**0.68**	**0.14**	**142**	**9**

	Total Residue						Total Dissolved Solids						Total Soluble Residue							
Station	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results*	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects
Q045	24	0	0	38	359	95.67	24	0	0	20	162	58.58	24	0	0	2.3	360	38.80	24	13
Q281**	24	0	0	56	245	118.58	24	0	0	40	174	82.96	24	0	0	2	70	27.16	24	7
Q454	24	0	0	109	194	142.21	24	0	0	82	183	119.46	24	0	0	1.1	40	8.51	24	4
Q5135	24	0	0	96	156	124.29	24	0	0	48	118	96.13	24	0	0	2	51	12.54	24	2
Q521	23	1	0	116	231	183.48	23	1	0	94	346	167.09	23	4	0	1	35	6.74	23	1
Q593**	23	1	0	114	317	176.87	23	1	0	70	220	133.61	23	1	0	2.3	72	18.73	23	5
Totals/Ave	**142**	**2**	**0**	**38**	**359**	**139.62**	**142**	**2**	**0**	**20**	**346**	**109.06**	**142**	**5**	**0**	**1**	**360**	**18.83**	**142**	**32**

Upper Watershed Stations
Lower Watershed Stations

NOTES:

* Total # Results includes duplicate samples

^ OPO4 samples collected during the first ten enhanced ambient events (EA-1 thru EA-10 or Apr-08 thru Jan-09) were not filtered prior to analysis; these results are flagged as rejected in the database

** Stations Q2810000 and Q5930000 sampled once per month by both YPDRBA/ENV1 and NC-DWQ.

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Table 23. Focused Flow-Ambient/Enhanced Ambient Sampling Results Comparison

Parameter	Units	Focused Flow			Ambient/Enhanced Ambient		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Conductivity	umhos/cm	22	318	85.86	31	505	134.19
Dissolved oxygen	mg/L	2	14.2	9.14	4.2	16.4	9.07
pH	s.u.	3.9	9.2	6.41	5.9	8.2	7.07
Temperature	degrees C	3.3	28.3	14.28	0.8	31.1	15.65
BOD	mg/L	2	11	3.41	2	13	2.22
Ammonia	mg/L	0.01	2.481	0.13	ND	4.48	0.079
Nitrite+Nitrate	mg/L	0.01	4.45	0.53	0.01	5.8	0.76
Total Phosphorus	mg/L	ND	3.39	0.34	ND	10	0.19
Total Dissolved Solids	mg/L	24	2,400	89.31	20	478	95.2
TKN	mg/L	0.02	12.9	1.34	0.2	3.45	0.55
Total Organic Carbon	mg/L	1.72	16.84	6.77	1.49	23	2.12
Total Solids	mg/L	25	3,450	281.64	27	824	129.52
Total Suspended Solids	mg/L	1	4,374	217.97	1	410	23.81
Turbidity	NTU	3	1,500	148.45	0.04	390	25.02
Total Volatile Solids	mg/L	25	588	71.55	8	358	38.99
Volatile Suspended Solids	mg/L	1	795	31.21	1	59	6.45
Orthophosphate	mg/L	ND	0.28	0.06	ND	1.2	0.07

5.1.1 Watershed Loads

Annual tributary loads to High Rock Lake were calculated using Beale's Ratio Estimator and daily average flow values recorded at the USGS gage stations. Flows were calculated for the sampling locations without a USGS gage using a drainage area ratio estimate. The loads are summarized in Table 23. The loads are also plotted by station and by year (Figures 3-4) for tributaries discharging directly to High Rock Lake for NH_3, N+N, TP and TSS. The graphs show that the second monitoring year (April 1, 2009 to March 31, 2010) had much higher loads to the lake. This is likely due to the dry conditions that were encountered early in the first year of the monitoring study and the high flows that were observed at the end of the second monitoring year in early 2010. The graphs also show that most of the load entering High Rock Lake is coming from the Yadkin River as measured at the station at Yadkin College (Q2810000).

Table 24. Annual Watershed Loads (metric tons)

April 1, 2008 to March 31, 2009												
Station	BOD	NH3	N+N	OrthoP	Total P	Total Dissolved Solids	TKN	TOC	Total Solids	Total Suspended Solids	Total Volatile Solids	Volatile Suspended Solids
Q045	---	82.32	186.66	34.75	266.61	20,882.49	870.52	1,665.92	222,383.74	170,215.47	38,230.79	24,935.12
Q066	---	17.64	55.97	10.01	108.08	4,950.16	347.26	645.59	90,373.29	84,376.65	16,141.14	15,938.85
Q081	---	93.55	396.41	50.90	516.31	39,516.25	1,561.95	3,850.10	363,611.41	283,334.49	66,051.35	46,932.14
Q204	---	56.95	515.08	53.99	272.34	57,471.89	975.37	4,627.67	290,459.88	170,638.96	52,548.98	24,924.08
Q271/272	---	34.31	189.87	25.90	98.95	17,514.35	279.86	1,015.89	74,885.56	101,321.33	11,779.23	10,976.19
Q281	6,320.61	171.96	1,298.63	203.35	687.26	120,001.33	2,199.04	7,376.80	537,875.93	432,197.19	118,476.62	56,126.25
Q346	731.72	14.08	125.90	11.31	75.30	12,789.81	266.53	1,256.35	65,667.54	48,036.36	13,561.32	6,929.68
Q593	410.71	9.15	49.97	9.70	30.44	12,847.15	122.37	1,042.97	27,956.59	12,923.22	8,310.76	1,583.81
Q521	31.50	0.21	1.96	0.78	1.59	801.22	19.53	85.47	1,951.55	956.61	524.86	142.55
Q5135	85.05	2.05	10.35	2.52	6.17	2,335.65	22.94	185.07	5,876.66	2,652.01	1,471.91	367.08
Q412	337.93	14.10	43.91	8.10	49.13	7,023.41	120.38	563.99	41,470.80	28,577.66	6,568.85	3,415.69
Q454	129.36	2.01	11.41	6.19	9.24	3,544.09	33.51	294.25	9,675.30	4,740.86	2,590.66	678.46
April 1, 2009 to March 31, 2010												
Station	BOD	NH3	N+N	OrthoP	Total P	Total Dissolved Solids	TKN	TOC	Total Solids	Total Suspended Solids	Total Volatile Solids	Volatile Suspended Solids
Q045	---	7.35	53.02	3.58	20.72	4,568.82	92.25	288.22	16,471.97	16,252.58	4,304.24	2,207.93
Q066	---	23.41	187.30	17.69	79.02	14,204.95	343.35	1,602.62	49,648.70	53,198.25	14,633.82	10,955.58
Q081	---	89.28	660.47	59.68	371.46	49,012.74	1,452.94	5,012.57	228,059.33	222,343.33	57,478.07	37,089.22
Q204	---	56.95	515.08	53.99	272.34	57,471.89	975.37	4,627.67	290,459.88	170,638.96	52,548.98	24,924.08
Q271/272	---	51.45	265.92	39.73	130.64	24,942.84	370.37	1,742.61	82,561.09	85,213.53	17,668.19	10,498.97
Q281	20,000.71	1,219.73	4,609.99	336.13	2,623.20	544,125.21	9,290.01	35,135.80	1,926,896.60	1,753,777.29	454,453.83	238,771.50
Q346	1,511.90	84.10	386.27	22.65	187.68	36,746.73	658.36	3,161.13	148,560.34	98,382.04	44,664.67	15,137.82
Q593	746.67	17.65	87.48	10.16	46.79	31,983.86	234.61	2,171.53	48,183.04	20,905.58	17,250.80	2,903.22
Q521	62.63	1.92	7.08	0.68	3.56	2,115.33	20.10	191.23	4,242.39	1,926.25	1,193.38	256.88
Q5135	158.51	13.44	22.83	2.06	11.52	4,869.82	53.22	408.52	10,831.74	4,734.99	4,057.68	699.68
Q412	582.41	22.83	104.73	11.10	127.69	17,191.86	295.94	1,254.20	90,888.45	148,463.95	17,997.11	17,071.01
Q454	314.77	5.73	32.63	3.10	31.09	7,576.30	115.62	637.54	29,926.55	18,708.04	7,145.96	2,406.95

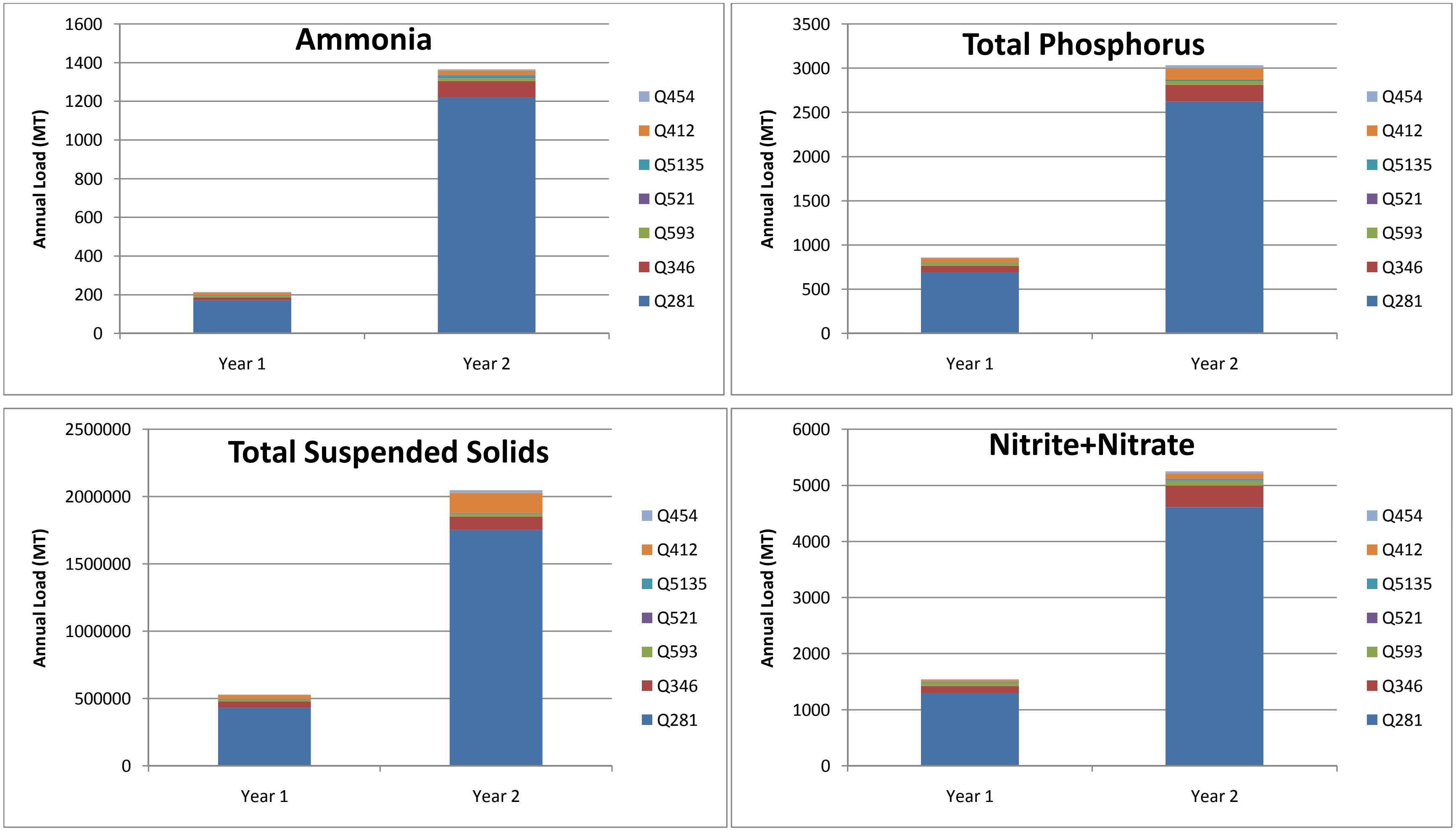

Figure 3. Annual Watershed Loads to High Rock Lake by Year (NH3, N+N, TP, TSS)

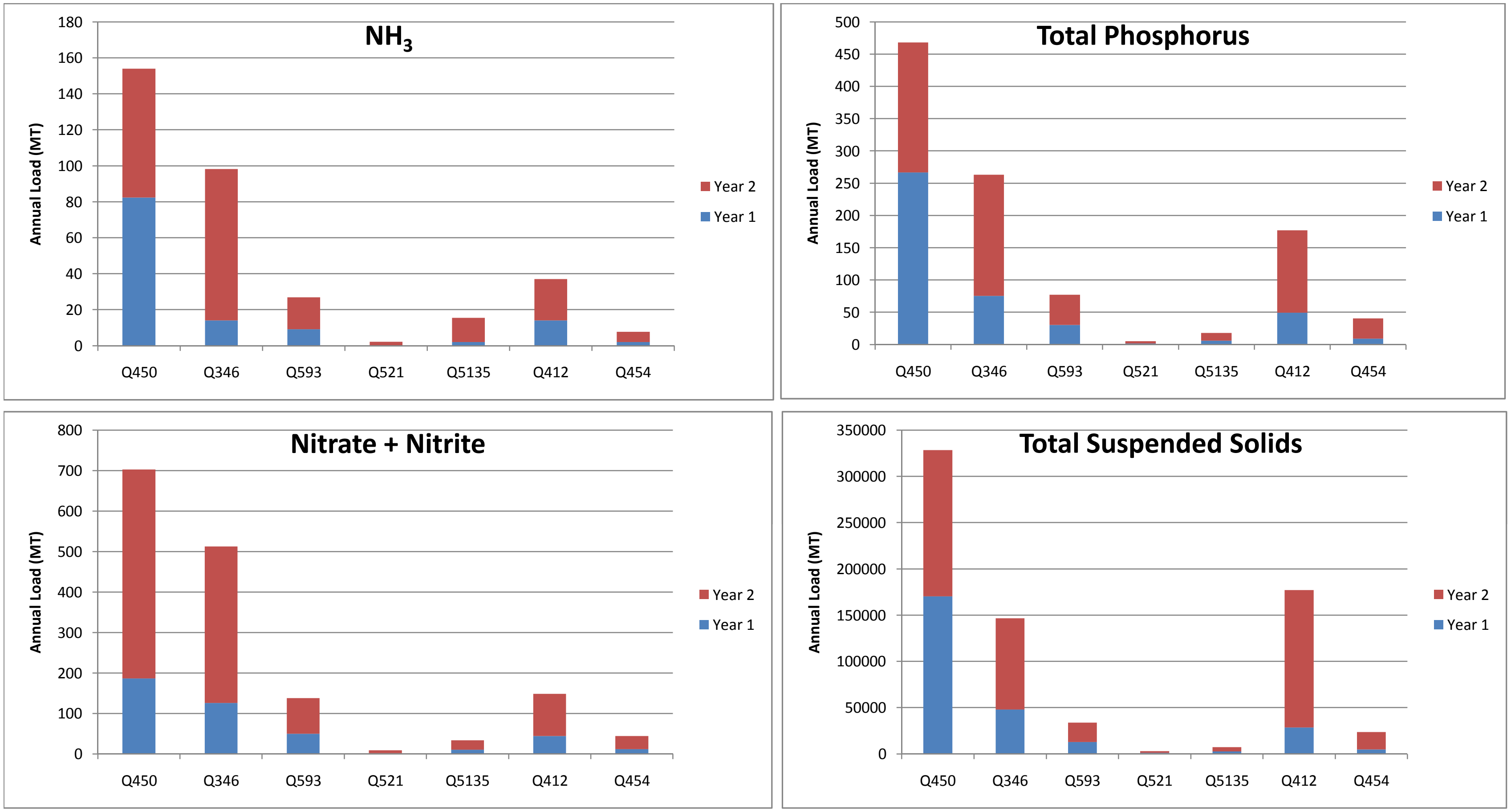

Figure 4. Annual Watershed Loads to High Rock Lake by Station (NH3, N+N, TP and TSS)

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5.1.2 Watershed System Behaviors

The nitrate plus nitrite (NN), ammonia (NH3), total phosphorus (TP), total suspended solids (TSS) and flow data from three representative watershed stations at Yadkin College (Q2810000), Mocksville (Q3460000) and Abbotts Creek (Q5930000) were compared to understand the watershed system behavior. In addition, TP and turbidity data were compared for a representative station in the lower portion of the upper watershed at Enon (Q2040000) and the lower watershed station at Abbotts Creek. These figures are included in Appendix J Figures 7, 8, 11, 12, 13, 14, 25 and 26.. The NPDES permit holders located on the tributaries included in this study are listed in Table 24.

The following observations can be made from the data:

1. TP and TSS generally increase with increasing flow in the Yadkin River at Yadkin College (Q2810000). This suggests that the river is carrying more suspended solids by fraction of TP as particulate matter. This also suggests the importance of non-point source runoff in terms of the load to the lake. The N+N response generally is manifested as an increase during the summer month periods of low flow and NH_3 drops off at the end of summer for both years. This is because NH_3 gets nitrified to nitrate, a soluble parameter that is not associated with particulate matter. Therefore, the point source load doesn't appear to change much. Nitrate increases during low flow conditions because the point source load of soluble constituents is diluted by the volume of runoff.
2. The South Yadkin at Mocksville tributary (represented by station Q3460000 data) is the second largest contributor of loads to High Rock Lake. Here, TP and TSS generally increase with increasing flow, as at Q2810000. NH_3 stays fairly constant over the study period but tends to drop off slightly at the end of summer.
3. At the Abbotts Creek station (Q5930000), TP concentrations do not appear to have much of a response to flow. This indicates a greater point source load. Higher concentrations of nitrite+nitrate are observed during low flow periods.
4. TP and turbidity concentrations show some increase with flow at Enon (Q2040000), as compared to Abbotts Creek.
5. The bulk of the watershed loads of NH_3, N+N, TP and TSS are coming into the system at the head of the reservoir (Q2810000 and Q3460000). However, the two study years are very different in terms of magnitude of the loads to the system. Very high flows occurred during the early part of 2010, with correspondingly higher loads when compared to early 2009.

Table 25. NPDES Permit Holders

Facility	County	Type	Class	Receiving Stream
Patterson Mill	Caldwell	Industrial Process & Commercial	Minor	YADKIN RIVER
Blackberry Ridge WWTP	Caldwell	100% Domestic < 1MGD	Minor	YADKIN RIVER
Happy Valley Elementary School	Caldwell	100% Domestic < 1MGD	Minor	YADKIN RIVER
Patterson School	Caldwell	100% Domestic < 1MGD	Minor	YADKIN RIVER
Willow Creek WWTP	Davidson	100% Domestic < 1MGD	Minor	Abbotts Creek
Lexington WTP #1 & 2	Davidson	Water Treatment Plant	Minor	Abbotts Creek
Lexington Regional WWTP	Davidson	Municipal, Large	MAJOR	Abbotts Creek Arm of HRL
Wilderness-NC Lumber Plant	Davidson	Industrial Process & Commercial	Minor	Flat Swamp Creek
Lexington Manufacturing Facility	Davidson	Industrial Process & Commercial	Minor	North Potts Creek
Westside WWTP	Davidson	Municipal, Large	MAJOR	Rich Fork
City of Thomasville WTP	Davidson	Water Treatment Plant	Minor	Rich Fork Creek
Churchland Elementary School WWTP	Davidson	100% Domestic < 1MGD	Minor	South Potts Creek
Bill's Truck Stop WWTP	Davidson	100% Domestic < 1MGD	Minor	South Potts Creek
Salem Glen Subdivision WWTP	Davidson	100% Domestic < 1MGD	Minor	YADKIN RIVER
Davidson Water WTP	Davidson	Water Treatment Plant	Minor	YADKIN RIVER
Hilltop Living Center	Davidson	100% Domestic < 1MGD	Minor	YADKIN RIVER (including upper portion of HRL)
Linwood Yard	Davidson	Industrial Process & Commercial	Minor	YADKIN RIVER (including upper portion of HRL)
Dutchman's Creek WWTP	Davie	Municipal, < 1MGD	Minor	Dutchman Creek
Cooleemee WWTP	Davie	Municipal, Large	MAJOR	South Yadkin River
Bermuda Run WWTP	Davie	Municipal, < 1MGD	Minor	YADKIN RIVER
Sparks Road WTP	Davie	Water Treatment Plant	Minor	YADKIN RIVER
Stonington Subdivision - Well #1	Forsyth	Water Treatment Plant	Minor	Abbotts Creek
Frye Bridge WWTP	Forsyth	100% Domestic < 1MGD	Minor	Muddy Creek
Neilson WTP	Forsyth	Water Treatment Plant	Minor	Muddy Creek
Archie Elledge WWTP	Forsyth	Municipal, Large	MAJOR	Salem Creek
Salem Business Park remediation site	Forsyth	Groundwater Remediation	Minor	Salem Creek
RA Thomas WTP	Forsyth	Water Treatment Plant	Minor	Salem Creek
Lissara WWTP	Forsyth	100% Domestic < 1MGD	Minor	YADKIN RIVER
Muddy Creek WWTP	Forsyth	Municipal, Large	MAJOR	YADKIN RIVER
Harmony WWTP	Iredell	Municipal, < 1MGD	Minor	Dutchman Creek
Harmony plant	Iredell	Industrial Process & Commercial	Minor	Hunting Creek
Landis WTP	Rowan	Water Treatment Plant	Minor	Grants Creek
Salisbury Terminal	Rowan	Industrial Process & Commercial	Minor	Grants Creek
Salisbury Plant	Rowan	Industrial Process & Commercial	MAJOR	Second Creek (North Second Creek)
Second Creek WWTP	Rowan	Municipal, < 1MGD	Minor	Second Creek (North Second Creek)
Rowan Associates & Mercantile WWTP	Rowan	100% Domestic < 1MGD	Minor	Town Creek
High Rock Powerhouse	Rowan	Industrial Process & Commercial	Minor	YADKIN RIVER (including upper portion of HRL)
Buck Steam Station	Rowan	Industrial Process & Commercial	MAJOR	YADKIN RIVER (including upper portion of HRL)
Salisbury-Rowan WWTP	Rowan	Municipal, Large	MAJOR	YADKIN RIVER (including upper portion of HRL)
Pilot Mountain WWTP	Surry	Municipal, Large	MAJOR	Ararat River
Mount Airy WWTP	Surry	Municipal, Large	MAJOR	Ararat River
Hope Valley WWTP	Surry	100% Domestic < 1MGD	Minor	Fisher River
Surry County Office	Surry	Groundwater Remediation	Minor	Fisher River
Dobson Plant	Surry	Industrial Process & Commercial	Minor	Fisher River
Windgate Subdivision	Surry	Water Treatment Plant	Minor	Fisher River
Mitchell Bluff - Well #1	Surry	Water Treatment Plant	Minor	Mitchell River
True Elkin, Inc. WWTP	Surry	Industrial Process & Commercial	MAJOR	YADKIN RIVER
Blyth Homescents	Surry	Industrial Process & Commercial	Minor	YADKIN RIVER
Elkin WWTP	Surry	Municipal, Large	MAJOR	YADKIN RIVER
LP Roaring River WWTP	Wilkes	Industrial Process & Commercial	MAJOR	YADKIN RIVER
Cub Creek WWTP	Wilkes	Municipal, Large	MAJOR	YADKIN RIVER
Thurman Street WWTP	Wilkes	Municipal, Large	MAJOR	YADKIN RIVER
Roaring River Elementary School	Wilkes	100% Domestic < 1MGD	Minor	YADKIN RIVER
East Bend Industrial Park WWTP	Yadkin	Municipal, < 1MGD	Minor	YADKIN RIVER

5.2 LAKE MONITORING

As discussed in Section 5 above, samples were collected from 10 lake sampling stations over the two year sampling period. The lake sampling results are included in the database in Appendix H. The laboratory reports, laboratory QA/QC, field notes and calibration logs are included in Appendix G. The particle size distribution data is included in Appendix L.

The lake data are summarized by station in Tables 25, 26 and 27. Table 25 includes the field data collected for conductivity, dissolved oxygen, pH, temperature, average secchi depth, PAR, 1%-PAR and ambient PAR. The number of results is included along with the minimum, maximum and average values recorded. The lowest dissolved oxygen concentration (0.04 mg/L) was recorded at Station YAD169F (upstream of dam). The maximum dissolved oxygen concentration (13.45 mg/L) was recorded at Station YAD169B (High Rock Lake main stem). The minimum pH (4.17) was recorded at Station YAD169E (Flat Swamp Creek Arm inlet) and the maximum (9.5) was observed at Station YAD152C (High Rock Lake main stem).

The composited analytical data for each lake station are summarized in Table 26. The hypolimnion data are summarized by station in Table 27. These tables note that the results for some compounds were reported below the Environment 1 Practical Quantitation Limit (PQL). This reporting convention was done at the request of LimnoTech to provide screening level information on low level detections of orthophosphate and total phosphorus, in particular, because of the high PQL values associated with the lab analytical methods for these analytes. This information is useful to the modeling effort because it allows the modelers to identify overall trends in nutrient data that often occur at low concentrations in lake samples. The results in the data summary tables include laboratory detections below the PQL when these occurred. The Access database provides these lab results as they were reported by Environment 1 and also provides these results rounded up to the PQL.

The minimum BOD concentration was 2 mg/L at all stations. The maximum BOD concentration of 8.3 mg/L was found at Station YAD152C (South Yadkin River Arm). Ammonia was not detected at Station HRL052 (Abbotts Creek Arm). The maximum ammonia concentration (1.68 mg/L) was found at YAD169F (upstream of dam). Nitrate+nitrite was not detected at YAD152 (Town Creek Arm). The maximum nitrate+nitrite concentration (1.25 mg/L) was at HRL051 (High Rock Lake main stem). The minimum total phosphorus concentration was not detected at HRL051 (High Rock Lake main stem), YAD1561A (Second Creek Arm) and YAD169F (upstream of dam). The maximum total phosphorus concentration (1.33mg/L) was at YAD152C (High Rock Lake main stem). The minimum total suspended solids concentrations (4.2 mg/L) was found at YAD169A (Abbotts Creek Arm inlet) and the maximum (63 mg/L) was at HRL051 (High Rock Lake main stem). The lowest turbidity reading (2 NTU) was observed at Station YAD169E (Flat Swamp Creek Arm inlet), with the highest reading (120 NTU) at Station HRL051 (High Rock Lake main stem). The minimum chlorophyll-a concentration (1.1 ug/L) was detected at YAD152A (High Rock Lake main stem) and YAD152C (High Rock Lake mainstem), with the maximum also found at (95.4 ug/L) at YAD152A.

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Table 26. Discrete Lake Sample Physical Data Summary (April 2008 through March 2010)
High Rock Lake, North Carolina

	Conductivity (umhos/cm)				Dissolved Oxygen (mg/l)				pH				Temperature (degrees Centigrade)			
Station	# Results	Min	Max	Average	# Results	Min	Max	Average	# Results	Min	Max	Average	# Results	Min	Max	Average
HRL051	130	59	151	96.52	130	4.33	12.9	8.15	130	6.28	8.6	7.45	130	0.7	31.31	18.48
HRL052	320	89	263	133.50	320	0.09	12.45	6.69	320	6.58	8.9	7.64	320	2.5	30.7	19.61
YAD152	215	69	165	105.60	215	0.13	12.31	7.14	215	6.6	9.14	7.68	215	2.5	30.92	19.48
YAD152A	203	59	177	97.98	203	0.21	12.9	8.39	203	6.37	9.4	7.72	203	1.7	31.02	18.79
YAD152C	336	61	171	98.82	336	0.07	12.84	7.90	336	5.99	9.5	7.71	336	1.3	31.2	19.04
YAD1561A	357	65	151	98.75	357	0.09	12.66	6.95	357	6.2	9.4	7.67	357	3.5	31.1	19.22
YAD169A	472	66	1006	117.44	472	0.09	11.84	6.15	472	6.13	9.34	7.60	472	3.7	31.59	19.04
YAD169B	506	61	160	100.35	506	0.07	13.45	7.03	506	6.21	9.4	7.60	506	2.1	32.4	18.98
YAD169E	531	59	855	98.73	531	0.06	12.6	6.34	531	4.17	9.4	7.50	531	1.9	31.5	19.33
YAD169F	594	59	253	100.14	594	0.04	12.7	6.16	594	6.13	9.4	7.40	594	1.7	31.4	19.44
Totals/Averages:	3664	59	1006	104.78	3664	0.04	13.45	7.09	3664	4.17	9.5	7.60	3664	0.7	32.4	19.14

	Average Secchi Depth (meters)				Photosynthetically Active Radiation (PAR)				PAR 1%				PAR Ambient			
Station	# Results	Min	Max	Average	# Results	Min	Max	Average	# Results	Min	Max	Average	# Results	Min	Max	Average
HRL051	44	0.15	0.90	0.41												
HRL052	45	0.20	1.40	0.73	200	0.20	1649.00	189.52	32	0.60	4.10	2.11	232	57.20	1798.00	1009.93
YAD152	45	0.20	1.35	0.64												
YAD152A	45	0.20	0.90	0.53												
YAD152C	43	0.20	1.00	0.64	197	0.31	1986.00	219.72	32	0.60	3.60	2.02	230	45.10	1988.00	1085.66
YAD1561A	45	0.30	1.10	0.70	201	0.45	1574.00	232.07	32	0.60	3.00	2.11	233	89.70	2180.00	1186.48
YAD169A	44	0.20	1.15	0.77												
YAD169B	45	0.25	1.23	0.80	214	0.56	1693.00	239.05	32	0.75	3.70	2.44	246	203.30	2224.00	1191.66
YAD169E	45	0.20	1.35	0.94												
YAD169F	45	0.20	1.40	0.92												
Totals/Averages:	446	0.15	1.40	0.71	812	0.20	1986.00	220.09	128	0.60	4.10	2.17	941	45.10	2224.00	1118.43

Main Lake Body Stations (listed upstream to downstream).
Lake Arm Stations.

Table 27. Summaryof Composited Lake Sample Data (April 2008 through March 2010)
High Rock Lake, North Carolina

	5-day BOD								Chlorophyll-a								Hardness							
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (ug/l)	Max (ug/l)	Average (ug/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)
HRL051	50	17	0	5	0	2	5.7	2.51	49	0	0	0	4	1.5	81.9	22.54	50	0	0	5	0	17	44	26.92
HRL052	49	6	0	4	0	2	5.5	3.41	50	0	0	0	5	2.5	65.4	37.66	49	0	0	4	0	28	50	36.41
YAD152	50	5	0	5	0	2	6.5	3.55	48	0	0	0	3	2.7	86.8	44.72	50	0	0	5	0	18	43	30.96
YAD152A	50	14	0	5	0	2	5.7	3.01	48	0	0	0	3	1.1	95.4	36.89	50	0	0	5	0	19	39	27.46
YAD152C	50	10	0	5	0	2	8.3	3.42	48	0	0	0	3	1.1	93.6	40.32	50	0	0	5	0	19	50	28.42
YAD1561A	49	3	0	4	0	2	6.3	3.71	48	0	0	0	3	10.9	93.1	47.13	49	0	0	4	0	21	45	30.22
YAD169A	48	8	0	4	0	2	4.7	2.96	47	0	0	0	3	2.6	61.3	33.50	48	0	0	4	0	23	45	32.50
YAD169B	49	8	0	4	0	2	6.9	3.18	48	0	0	0	3	1.6	75.2	35.24	49	0	0	4	0	17	46	28.84
YAD169E	49	11	0	4	0	2	4.8	2.92	47	0	0	0	2	4.3	60.6	30.03	49	0	0	4	0	21	38	29.39
YAD169F	49	13	0	4	0	2	4.8	2.82	48	0	0	0	3	4	53.5	29.89	49	0	0	4	0	22	35	28.71
Totals/Averages:	**493**	**95**	**0**	**44**	**0**	**2**	**8.3**	**3.15**	**481**	**0**	**0**	**0**	**32**	**1.1**	**95.4**	**35.79**	**493**	**0**	**0**	**44**	**0**	**17**	**50**	**29.98**

	Ammonia								Nitrate + Nitrite								Turbidity							
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (NTU)	Max (NTU)	Average (NTU)
HRL051	51	5	0	5	1	0.01	0.36	0.10	51	0	0	5	1	0.33	1.247	0.81	50	0	0	5	0	12	120	45.44
HRL052	49	16	1	4	0	0	0.284	0.05	49	25	0	4	0	0.01	0.512	0.11	49	0	0	4	0	4.9	90	14.87
YAD152	50	18	0	5	0	0.01	1.318	0.08	50	15	1	5	0	0.00	0.342	0.09	50	0	0	5	0	6.10	65	16.32
YAD152A	50	12	0	5	0	0.01	0.32	0.08	50	0	0	5	0	0.15	1.178	0.61	50	0	0	5	0	7.1	100	30.80
YAD152C	50	10	0	5	0	0.01	0.26	0.07	50	1	0	5	0	0.01	1.09	0.47	50	0	0	5	0	6.1	110	23.13
YAD1561A	49	15	0	4	0	0.01	0.219	0.05	49	2	0	4	0	0.01	0.684	0.21	49	0	0	4	0	5.6	70	15.15
YAD169A	48	11	0	4	0	0.01	0.663	0.08	48	5	0	4	0	0.01	0.777	0.21	48	0	0	4	0	5	85	13.37
YAD169B	49	14	0	4	0	0.01	0.595	0.07	49	5	0	4	0	0.01	1.053	0.37	49	0	0	4	0	3.7	100	14.49
YAD169E	49	18	0	4	0	0.01	0.29	0.06	49	9	0	4	0	0.01	0.951	0.29	49	0	0	4	0	2	65	10.47
YAD169F	49	9	0	4	0	0.01	1.68	0.11	49	6	0	4	0	0.01	0.974	0.33	49	0	0	4	0	3.5	80	12.47
Totals/Averages:	**494**	**128**	**1**	**44**	**1**	**0**	**1.68**	**0.08**	**494**	**68**	**1**	**44**	**1**	**0**	**1.247**	**0.35**	**493**	**0**	**0**	**44**	**0**	**2**	**120**	**19.65**

	Orthophosphorus								Total Phosphorus								Soluble Total Phosphorus							
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)
HRL051	45	0	0	0	0	0.01	0.09	0.05	51	0	1	5	1	0.00	0.674	0.17	45	0	2	0	0	0.00	0.615	0.08
HRL052	45	0	32	0	0	0.00	0.027	0.01	49	0	0	4	0	0.025	0.60	0.11	45	0	9	0	0	0.00	0.64	0.06
YAD152	45	0	32	0	0	0.00	0.04	0.01	50	0	1	5	0	0.01	0.683	0.11	45	0	11	0	0	0.00	0.545	0.06
YAD152A	45	0	8	0	0	0.00	0.08	0.03	50	0	0	5	0	0.031	0.658	0.14	45	0	5	0	0	0.00	0.572	0.06
YAD152C	45	0	13	0	0	0.00	0.06	0.02	50	0	0	5	0	0.05	1.33	0.14	45	0	5	0	0	0.01	0.596	0.06
YAD1561A	45	0	30	0	0	0.00	0.038	0.01	49	0	2	4	0	0.00	0.624	0.09	45	0	12	0	0	0.00	0.528	0.05
YAD169A	44	0	26	0	0	0.00	0.04	0.01	48	0	0	4	0	0.027	0.621	0.10	44	0	12	0	0	0.00	0.542	0.05
YAD169B	45	0	21	0	0	0.00	0.09	0.01	49	0	1	4	0	0.01	0.628	0.10	45	0	11	0	0	0.00	0.519	0.05
YAD169E	45	0	29	0	0	0.00	0.033	0.01	49	0	1	4	0	0.016	0.33	0.09	45	0	13	0	0	0.00	0.21	0.05
YAD169F	45	0	25	0	0	0.00	0.041	0.01	49	0	2	4	0	0.00	0.26	0.08	45	0	12	0	0	0.00	0.44	0.05
Totals/Averages:	**449**	**0**	**216**	**0**	**0**	**0**	**0.09**	**0.01**	**494**	**0**	**8**	**44**	**1**	**0**	**1.33**	**0.11**	**449**	**0**	**92**	**0**	**0**	**0**	**0.64**	**0.06**

	Soluble Silica								Soluble Total Kjeldahl Nitrogen								Total Kjeldahl Nitrogen							
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)
HRL051	45	0	0	0	0	9	13.6	11.29	45	8	1	0	0	0.18	0.9	0.46	51	1	0	5	1	0.20	3.17	0.77
HRL052	45	0	0	0	0	5	14.7	10.29	45	5	0	0	0	0.20	1.144	0.54	49	1	0	4	0	0.20	1.651	0.88
YAD152	45	0	0	0	0	6.3	13.2	10.76	45	7	0	0	0	0.02	0.875	0.43	50	0	0	5	0	0.43	1.56	0.87
YAD152A	44	0	0	0	0	9.1	13.6	11.23	45	5	1	0	0	0.14	0.928	0.45	50	2	0	5	0	0.20	1.91	0.76
YAD152C	45	0	1	0	0	0.00	14.6	10.73	45	4	1	0	0	0.16	0.87	0.44	50	1	0	5	0	0.20	5.67	0.89
YAD1561A	45	0	0	0	0	6.4	12.4	10.64	45	5	1	0	0	0.02	0.98	0.43	49	0	0	4	0	0.263	1.462	0.75
YAD169A	44	0	0	0	0	5.9	13	10.37	44	6	1	0	0	0.02	0.93	0.49	48	1	0	4	0	0.20	1.485	0.79
YAD169B	45	0	0	0	0	6	13.7	10.54	45	4	1	0	0	0.16	0.83	0.40	49	1	0	4	0	0.20	3.539	0.73
YAD169E	45	0	0	0	0	4.5	12.1	9.60	45	6	0	0	0	0.20	2.75	0.46	49	1	0	4	0	0.20	1.25	0.70
YAD169F	45	0	0	0	0	6.2	12.9	10.22	45	6	2	0	0	0.16	1.06	0.47	49	1	0	4	0	0.20	1.471	0.75
Totals/Averages:	**448**	**0**	**1**	**0**	**0**	**0**	**14.7**	**10.57**	**449**	**56**	**8**	**0**	**0**	**0.02**	**2.75**	**0.46**	**494**	**9**	**0**	**44**	**1**	**0.2**	**5.67**	**0.79**

	Total Dissolved Solids								T otal Organic Carbon								Total Residue							
Station	# Results*	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)
HRL051	50	0	0	5	0	53	298	93.44	50	0	0	5	0	1.41	5.92	3.66	50	0	0	5	0	76	175	119.06
HRL052	49	0	0	4	0	46	119	90.02	49	0	0	4	0	4.6	11.64	5.91	49	0	0	4	0	82	227	116.98
YAD152	50	0	0	5	0	47	111	75.64	50	0	0	5	0	3.07	6.78	5.18	50	0	0	5	0	68	141	100.40
YAD152A	50	0	0	5	0	44	102	73.54	50	0	0	5	0	1.32	10.82	3.82	50	0	0	5	0	59	151	103.38
YAD152C	50	0	0	5	0	42	92	71.46	50	0	0	5	0	1.5	5.5	3.78	50	0	0	5	0	50	152	96.72
YAD1561A	49	0	0	4	0	47	98	70.27	49	0	1	4	0	0.476	6.88	4.36	49	0	0	4	0	68	143	95.65
YAD169A	47	0	0	4	0	56	122	80.02	48	0	0	4	0	3.1	7.26	4.80	48	0	0	4	0	68	154	103.31
YAD169B	49	0	0	4	0	44	108	71.51	49	0	0	4	0	1.41	5.4	3.85	49	0	0	4	0	54	207	95.98
YAD169E	49	0	0	4	0	50	91	69.41	49	0	0	4	0	1.56	6.68	4.00	49	0	0	4	0	62	129	87.55
YAD169F	49	0	0	4	0	45	102	70.86	49	0	0	4	0	1.45	5.42	3.73	49	0	0	4	0	62	164	89.63
Totals/Averages:	**492**	**0**	**0**	**44**	**0**	**42**	**298**	**76.62**	**493**	**0**	**1**	**44**	**0**	**0.476**	**11.64**	**4.31**	**493**	**0**	**0**	**44**	**0**	**50**	**227**	**100.87**

	Total Soluble Residue								Total Volatile Residue								Volatile Soluble Residue							
Station	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)	# Results	# Non-Detects	# Detects <PQL	# DUPs	# SPLITS	Min (mg/l)	Max (mg/l)	Average (mg/l)
HRL051	50	0	0	5	0	9.3	63	29.56	50	11	0	5	0	25	86	45.28	50	0	0	5	0	2.1	9.9	5.82
HRL052	49	0	0	4	0	5.4	35	11.05	49	15	0	4	0	25	112	45.45	49	0	0	4	0	2.4	8.5	5.26
YAD152	50	0	0	5	0	6	28	12.13	50	14	0	5	0	25.00	74	39.42	50	0	0	5	0	3.50	11	6.03
YAD152A	50	0	0	5	0	6.4	55	18.14	50	13	0	5	0	25	90	41.88	50	0	0	5	0	1.7	11	5.19
YAD152C	50	0	0	5	0	5.4	48	13.76	50	12	0	5	0	25	90	44.22	50	0	0	5	0	1.9	8.5	5.17
YAD1561A	49	0	0	4	0	6.2	27	10.69	49	14	0	4	0	25	84	40.14	49	0	0	4	0	3.2	7.7	5.34
YAD169A	48	0	0	4	0	4.2	34	9.32	48	13	0	4	0	25	71	39.65	48	0	0	4	0	2.7	7.3	4.35
YAD169B	49	0	0	4	0	5	35	9.59	49	11	1	4	0	15	149	42.51	49	0	0	4	0	2.2	8.3	4.47
YAD169E	49	0	0	4	0	4.6	26	7.70	49	18	0	4	0	25	76	40.69	49	0	0	4	0	2.3	6.8	4.00
YAD169F	49	0	0	4	0	4.3	30	8.14	49	16	0	4	0	25	84	39.76	49	0	0	4	0	2	5.9	3.82
Totals/Averages:	**493**	**0**	**0**	**44**	**0**	**4.2**	**63**	**13.01**	**493**	**137**	**1**	**44**	**0**	**15**	**149**	**41.90**	**493**	**0**	**0**	**44**	**0**	**1.7**	**11**	**4.94**

Main Lake Body Stations (listed upstream to downstream).
Lake Arm Stations.
Compounds with detected results below the associated PQL.

NOTES:
* Total # Results includes duplicate and split samples

Table 28. Summary of Lake Hypolimnion Discrete Sample Data

Station	Ammonia # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	0	0	0.02	0.34	0.13
YAD169B	14	1	0	0.01	0.30	0.16
YAD169F	14	0	0	0.03	0.48	0.21
Totals/Averages:	**42**	**1**	**0**	**0.01**	**0.48**	**0.17**

Station	Nitrate + Nitrite # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	0	0	0.06	0.69	0.42
YAD169B	14	1	0	0.01	0.64	0.36
YAD169F	14	1	0	0.01	0.66	0.34
Totals/Averages:	**42**	**2**	**0**	**0.01**	**0.69**	**0.37**

Station	Orthophosphorus # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	0	5	0.00	0.035	0.01
YAD169B	14	0	6	0.00	0.03	0.01
YAD169F	14	0	3	0.00	0.05	0.02
Totals/Averages:	**42**	**0**	**14**	**0.00**	**0.05**	**0.02**

Station	Total Phosphorus # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	0	0	0.04	0.76	0.15
YAD169B	14	0	0	0.03	0.15	0.09
YAD169F	14	0	0	0.03	0.29	0.11
Totals/Averages:	**42**	**0**	**0**	**0.03**	**0.76**	**0.12**

Station	Soluble Total Phosphorus # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	0	2	0.01	0.22	0.07
YAD169B	14	0	3	0.00	0.09	0.04
YAD169F	14	0	4	0.00	0.264	0.07
Totals/Averages:	**42**	**0**	**9**	**0.00**	**0.264**	**0.06**

Station	Soluble Total Kjeldahl Nitrogen # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	3	0	0.20	1.24	0.49
YAD169B	14	1	0	0.20	1.07	0.55
YAD169F	14	1	0	0.20	1.05	0.57
Totals/Averages:	**42**	**5**	**0**	**0.20**	**1.24**	**0.54**

Station	Total Kjeldahl Nitrogen # Results	# Non-Detects	# Detects <PQL	Min (mg/l)	Max (mg/l)	Average (mg/l)
YAD152C	14	0	0	0.47	1.35	0.71
YAD169B	14	0	0	0.21	1.20	0.66
YAD169F	14	1	0	0.20	1.26	0.78
Totals/Averages:	**42**	**1**	**0**	**0.20**	**1.35**	**0.72**

Main Lake Body Stations (listed upstream to downstream).

Compounds with detected results below the associated PQL.

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5.2.1 Lake System Behaviors

The lake data are plotted and included in Appendix K. Continuous temperature plots for statinos YAD169F and YAD1561A are provided in Appendix K Figures 1 and 2, respectively. Depth-profiled physical data for the months of January, March and August are plotted for stations HRL052, YAD1561A, YAD152C, YAD169B, YAD152 and YAD169F in Appendix K Figures 3 through 14. Time-series graphs of 1%PAR and/or 2xsecchi depth are plotted for all 10 lake stations, along with the time0series thermocline and 2 mg/l DO depths, in Appendix K Figures 15 and 16. Appendix K Figures 17 through 19 show seasonal monthly average concentrations of TSS, N+N, Chlorophyll-a, TP and OrthoP for representative main stem and lake arm stations . Appendix K Figures 20 through 24 show the seasonal monthly average time series graphs for every parameter at every lake station, including the minimum and maximum values. Appendix K Figures 25 through 27 show the time series graphs for every lake station and every compound grouped by main stem and lake arm stations. Hypolimnion data are plotted in Appendix K Figure 28.

The following observations can be made from the lake data:

1. The continuous temperature plots (Appendix K Figures 1 and 2) at main stem lake station YAD169F (just above dam) and lake arm station Y1561A (Second Creek) do not allow a comparison of winter data, but the summer temperature data is similar. Starting in mid to late spring, the temperature curves separate with depth, indicating stratification of the lake, most noticeably at Station YAD169F.

2. There are large differences in temperature between winter (generally 5 ^{o}C) and summer (generally 30 ^{o}C). The vertical depth profiling data for January show that 2010 was significantly colder in the winter than 2009, by almost 5 ^{o}C), as shown in Appendix K Figures 3, 5, 7, 9, 11 and 13.

3. Some temperature stratification is seen during March, but this occurs most dramatically during the summer (as illustrated in the January, March and August depth profiling data for main stem lake station YAD169B (Appendix K Figures 9 and 10). In March, dissolved oxygen (DO) is fairly high all the way to the bottom of the lake, and pH and conductivity are fairly constant through the water column. However, in August, the main stem is much warmer and much more stratified. DO is supersaturated at the surface of the lake and is even higher approximately one meter below the lake surface, but then declines sharply with depth. The higher DO concentrations at and near the lake surface are the result of high primary productivity, which produces oxygen. DO concentrations are lower at the surface where atmospheric equilibration is taking place faster. Concentrations of DO decline sharply with depth because of the high oxygen demand exerted in the hypolimnion due to decay of settling phytoplankton and sediment oxygen demand (SOD). The depth profiling data show periods during the summer when DO falls below 2 mg/l.

4. The abundance of algal growth at the surface of the lake during the summer months also results in higher pH near the surface, with a pretty significant drop in pH with depth. This results from the consumption of CO_2 (an acid) by algae.

5. The PAR depth profiled data indicate that the composited sampling interval of twice the secchi depth almost always occurred within the photic zone (i.e., above 1%PAR) and above the thermocline (as defined by a temperature change of greater than or equal to 1 ^{o}C per meter depth) (Appendix K Figures 15 and 16). This indicates that the majority of the composited lake samples were collected in the epilimnion.

6. Time series plots of monthly averages show that suspended solids along the main stem of the lake respond strongly to spring high flow and November high flow periods going downstream along the main stem of the lake from Stations YAD152A to YAD152C (Appendix K Figure 17). TSS peaks are highest further upstream along the main stem of the lake because of the influence of the Yadkin River loads, which enter at the upstream end of the lake. By the time Station YAD169B is reached further downstream, the system is not responding much to the high flow peaks. This is likely the result of a combination of factors, such as lower suspended solids concentrations from dilution and settling of solids as the reservoir widens and deepens going downstream.

7. The lake arm stations show the highest concentrations of TSS during January and February, and are not showing the spring and fall peaks observed along the main stem (Appendix K Figure 17). This likely is due to the smaller arm drainage areas relative to the main stem drainage area.

8. Chlorophyll-a (Appendix K Figure 18) is relatively high at the furthest upstream main stem station (HRL051). This suggests that additional algal growth may be occurring in the river upstream of the lake. ***If the lake model starts at the location of HRL051, then the chlorophyll-a load will need to be fairly significant at the upstream boundary. Chlorophyll-a data at watershed location Q281 (Yadkin River at Yadkin College may be helpful.***

9. Chlorophyll-a concentrations at the main stem stations generally range between 50 to 70 ug/l during the summer months and drop off significantly during the winter months. At the lake arm stations, chlorophyll-a concentrations also are highest during the summer months, but do not drop off as much during the winter months.

10. Monthly averaged TP concentrations (Appendix K Figure 19) may be skewed high in January and February at both the main stem and lake arm stations due to the high flows recorded during early 2010. ***Otherwise, TP is approximately 0.10 mg/l in the lake.***

11. Orthophosphate (OPO_4) concentrations (Appendix K Figure 19) generally are below 0.01 mg/l during the summer months and higher in the winter along the main stem of the lake. Algae consumes OPO_4 and CO_2 and produces O_2, resulting in increased DO, increased pH and lower OPO_4 in surface water during the summer months of high productivity. This also is observed in the lake arm station data; however algae appears to grow for longer periods in the lake arms, with resulting lower concentrations of OPO_4 for longer periods.

12. The time series monthly averaged N+N data (Appendix K Figure 17) indicate that nitrate concentrations decrease downstream along the main stem during the summer months, falling well below 0.30 mg/l at stations YAD152C and YAD169B. This drop in N+N concentration during the summer is even more severe in the lake arms. Algae generally prefer nitrate over NH_3 as their nitrogen source. When nitrate concentrations are low during the warm-water summer months in the lower parts of the lake and in the lake arms, nitrogen - fixing blue-green algae are likely to flourish. The phytoplankton data were not provided to LimnoTech for inclusion into the database; however, these data should be compared to the seasonal N+N concentrations to note when and where blue-green algae were observed during the study period.

13. The hypolimnion (Appendix K Figure 28) data suggest a summer release of nutrients into the overlying water column, particularly NH_3 and OPO_4 in July and August in the main part of the lake. OPO_4 is high in the hypolimnion samples when the corresponding epilimnion concentrations are low. The NH_3 and OPO_4 hypolimnion data could not be compared to the sediment flux data (which were not provided for inclusion into the database); however, they suggest a eutrophic lake pattern.

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6. OUTCOMES AND CONCLUSIONS

The High Rock Lake TMDL Monitoring Project was conducted over the period of April 1, 2008 to April 5, 2010. The project successfully met the goals set out in 2007. A robust data set has been collected for model calibration necessary for TMDL development. Over the course of the project the project team was able to:

1. Collect watershed and lake data acceptable for input to an approvable TMDL for High Rock Lake.

2. Estimate the relative point and non-point source contributions to nutrient loads, including generated and delivered loads. Provide spatial and temporal information regarding the sources of non-point source loads through evaluation of the data collected.

3. Provide data for development, calibration and validation of a watershed model and a lake water quality model.

4. Support the development of non-point source management strategies, voluntary and mandatory, to reduce nutrient and sediment loading in the watershed by determining a set of baseline conditions.

The success of the project was measured by the quality of the data acquired and its usefulness in developing the water quality models required for TMDL development. This goal was accomplished by:

- Strict adherence to the Quality Assurance Project Plan for all data collection.

- Using one state qualified laboratory for the majority of the analytical work performed and a significant portion of the sample collection. NCDWQ collected the other portion of samples and conducted the analytical work.

- A well-constructed and executed monitoring plan, which was designed over a two year period, to provide the data necessary to develop and to evaluate the linked watershed – High Rock Lake hydrodynamic-water quality model necessary for accomplishing the TMDLs.

- Having oversight by a senior scientist with more than 35 years of experience in watershed and water quality monitoring, modeling, and assessment, including 30 years in academia.

The methodology laid out in the Sampling and Analysis Plan (LimnoTech 2008) was followed with a few minor changes, which led to the collection of high quality data. Although there were many members of the project team, the sampling efforts were coordinated and the majority of the analysis was conducted by one main entity, which helped minimize variances in the data and data quality. Emphasizing adherence to the quality assurance procedures set out prior to the start of the data collection effort was also very helpful. The project partners worked well together to ensure the success of the project.

The construction and population of the Access database will be very helpful to the model development effort. It is a step in the modeling effort that is complete and ready for the modelers. The data validation step was also well worth the effort to ensure quality data. Including this task as part of the 319 Grant was an important aspect of the project that will be very beneficial.

This project was possible because of the 319 grant received from EPA plus the in-kind services provided by NCDWQ and contributions from the Yadkin Pee Dee River Basin Association, APGI and the City of Winston-Salem. This project has proved that this data collection effort has been an excellent use of the 319 grant funds. The stakeholder input and the High Rock Lake Technical Advisory Committee have been invaluable throughout this process. The data collected through this project are highly valuable to the TMDL development process and will increase confidence in the model calibration.

This project can be built on by conducting chlorophyll-a sampling confluence of the Yadkin River and High Rock Lake to determine the chlorophyll-a load that may be entering the lake from the watershed. The phytoplankton data should be compared to the seasonal N+N concentrations to note when and where blue-green algae were observed during the study period. In addition, correlating data collected at Station Q2710000 and Q272000 would increase the value of the data that was ultimately collected at Station Q2720000.

Project conclusions include the following:

1. TP and TSS generally increase with increasing flow in the Yadkin River at Yadkin College (Q2810000). This suggests that the river is carrying more suspended solids by fraction of TP as particulate matter. This also suggests the importance of non-point source runoff in terms of the load to the lake.
2. The N+N response generally is manifested as an increase during the summer month periods of low flow and NH_3 drops off at the end of summer for both years. This is because NH_3 gets nitrified to nitrate, a soluble parameter that is not associated with particulate matter. Therefore, the point source load doesn't appear to change much. Nitrate increases during low flow conditions because the point source load of soluble constituents is diluted by the volume of runoff.
3. The South Yadkin at Mocksville tributary (represented by the Q3460000 data) is the second largest contributor of loads to High Rock Lake. Here, TP and TSS generally increase with increasing flow, as at Q2810000.

4. At the Abbotts Creek station (Q5930000), TP concentrations do not appear to have much of a response to flow. This indicates a greater point source load.

5. TP and turbidity concentrations show some increase with flow at Enon (Q2040000), as compared to Abbotts Creek, and indicate a larger non-point source flow in this area of the watershed.

6. The bulk of the watershed loads of NH_3, N+N, TP and TSS are coming into the system at the head of the reservoir (Q2810000 and Q3460000).

7. In March, dissolved oxygen (DO) is fairly high all the way to the bottom of the lake. However, in August, the main stem is much warmer and much more stratified. The higher DO concentrations at and near the lake surface are the result of high primary productivity, which produces oxygen.

8. The abundance of algal growth at the surface of the lake during the summer months also results in higher pH near the surface, with a pretty significant drop in pH with depth.

9. Solids respond strongly to spring and fall high flow periods going downstream along the main stem of the lake. TSS peaks are highest further upstream in the lake because of the influence of the Yadkin River loads.

10. The lake arm stations show the highest concentrations of TSS during January and February, and do not show the spring and fall peaks observed along the main stem of the lake. This likely is due to the smaller arm drainage areas relative to the main stem drainage area.

11. Chlorophyll-a is relatively high at the furthest upstream main stem station (HRL051). This suggests that additional algal growth may be occurring in the river upstream of the lake.

12. Total Phosphorus is approximately 0.10 mg/l in the lake.

13. Orthophosphate (OPO_4) concentrations generally are below 0.01 mg/l during the summer months and higher in the winter along the main stem of the lake. Algae consumes OPO_4 and CO_2 and produces O_2, resulting in increased DO, increased pH and lower OPO_4 in surface water during the summer months of high productivity. This also is observed in the lake arm station data; however algae appears to grow for longer periods in the lake arms, with resulting lower concentrations of OPO_4 for longer periods.

14. N+N data indicate that nitrate concentrations decrease downstream along the main stem during the summer months. When nitrate concentrations are low during the warm-water summer months in the lower parts of the lake and in the lake arms, nitrogen -fixing blue-green algae are likely to flourish.

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7. BUDGET

The High Rock Lake TMDL Water Quality Monitoring Project was completed within the budget as modified by Contract Amendment #3. The budget, including 319 funds and matching funds, is shown in Table 28. Information on expenditures is provided in Appendix M.

Table 29. 2007 319 Grant Budget

Categories	319 Request	Non-Federal Match	Total
Personnel/Salary	$164,387	$126,563	$290,950
Supplies	$8,475	$6,525	$15,000
Equipment	$15,255	$11,745	$27,000
Travel	$2,825	$2,175	$5,000
Contractual - LAB	$176,523	$135,907	$312,430
Contractual - Sampling	$88,057	$67,796	$155,853
Other	$2,610	$2,010	$4,620
Total	$458,132	$352,721	$810,853
Total Direct	$458,132	$352,721	$810,853
Indirect	$4,068	$3,132	$7,200
Total	$462,200	$355,853	$818,053

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8. REFERENCES

Draft Field Study and Modeling Plan for the High Rock Lake Chlorophyll-a and Turbidity Total Maximum Daily Load – NC Department of Environment and Natural Resources Division of Water Quality – March 2006

Water Quality Data Review for High Rock Lake, North Carolina – Tetra Tech, Inc. – August 2004

2003 Yadkin Pee-Dee River Basinwide Water Quality Plan – NC Department of Environment and Natural Resources Division of Water Quality

2004 North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report) - NC Department of Environment and Natural Resources Division of Water Quality

2010 North Carolina Water Quality Assessment and Impaired Waters List (2010 Integrated 305(b) and 303(d) Report) - NC Department of Environment and Natural Resources Division of Water Quality

High Rock Lake TMDL Monitoring Project Sampling and Analysis Plan – LimnoTech 2008.

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APPENDIX A

DATA COLLECTION IN SUPPORT OF UPPER YADKIN RIVER WATERSHED - HIGH ROCK LAKE CHLOROPHYLL-A AND TURBIDITY TMDL MODELING

319 GRANT APPLICATION

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APPENDIX B:

CORRESPONDENCE WITH ALL PARTICIPATING PUBLIC AGENCIES

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APPENDIX C:

QUARTERLY PROGRESS REPORTS

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APPENDIX D:

HIGH ROCK LAKE TMDL MONITORING PROJECT – JULY 13, 2010 PUBLIC MEETING PRESENTATION MATERIALS FOR PUBLIC MEETING

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APPENDIX E:

HIGH ROCK LAKE TMDL DATABASE STRUCTURE REPORT 2008-2010 MONITORING PROGRAM

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APPENDIX F:

HIGH ROCK LAKE TMDL MONITORING PROJECT QUALITY ASSURANCE PROJECT PLAN

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APPENDIX G:

LABORATORY REPORTS, LABORATORY QA/QC, FIELD NOTES AND CALIBRATION LOGS

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APPENDIX H:

HIGH ROCK LAKE TMDL MONITORING PROJECT DATABASE (ON CD)

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APPENDIX I:

GIS INFORMATION FOR PROJECT AREA MAPS

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APPENDIX J:

WATERSHED DATA FIGURES

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APPENDIX K:

LAKE DATA FIGURES

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APPENDIX L:

PARTICLE SIZE DISTRIBUTION DATA

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APPENDIX M:

319 GRANT BUDGET DETAILS

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