Upper Neuse River Basin Association
Special Study Plan
Date Issued: August 4, 2015

Special Study Name, ID# and Origination:

Storm Event Sampling, SS.LR.1

This Special Study originated within Cardno FY 2015 monitoring contract and continued in 2016 monitoring contract. A detailed planning and methodology document (entitled ***Storm Event Sampling Study***) was prepared for this effort during FY2015. DWR reviewed the ***Storm Event Sampling Study*** and had no objections to the monitoring plan or associated quality assurance procedures. That document is attached to this study plan overview.

Responsible Contractor(s):

Cardno – Project planning, management, oversight, sampling, data analysis and reporting

Environment 1 – Laboratory analysis

Purpose of Study:

This special study is focused on obtaining additional water quality data from the major tributaries to Falls Lake under varying storm conditions over time. In contrast to the twice monthly grab samples taken under the Routine Monitoring process, this data collection effort employs automated sampling equipment to collect multiple discrete samples over time as stream flows rise and then fall following a storm event. Such data allow for a better understanding of the contribution of nutrients and related parameters associated with storm events. Data from this study will be used to better inform model calibration for simulating water quality conditions in Falls Lake.

This Special Study supports these objectives of the UNRBA Monitoring Program:

- Lake response modeling,
- Support of regulatory options, and
- Source allocation and estimation of jurisdictional loading

Anticipated Schedule:

A total of four sampling events are anticipated during FY 2016 (July 1, 2015 through June 30, 2015). Sampling events are based on actual storm events and target rainfall amounts between 0.75 and 2.0 inches from a single storm. Cardno determines when Storm Event Sampling occurs based on weather forecasts and observations. The attached ***Storm Event Sampling Study*** document provides a detailed discussion of the rationale for determining when sampling is to occur.

Summary of Study Methods:

The attached ***Storm Event Sampling Study*** document provides a detailed overview of the study methods, including parameters, use of specialized equipment, record-keeping, QA/QC, QAPP and health and safety considerations. Parameters to be quantified include total Kjeldahl nitrogen, ammonia, nitrate plus nitrite, total nitrogen (calculated from total Kjeldahl nitrogen and nitrate plus nitrite), total phosphorus, total organic carbon and total suspended solids. The plan targets the collection and analysis of approximately 15-20 individual samples associated with a single storm event to characterize pollutant concentrations over the course of the rising and falling storm hydrograph.

Because of the logistic demands for doing this study and to limit costs to the established study budget, Storm Event Sampling is only conducted at two locations for any given event. Sampling is planned for FY 2016 at one station on Ellerbe Creek (downstream of the City of Durham wastewater treatment facility) and one station on the Eno River (downstream of Highway 501). Specific locations for the sampling stations are provided in the attached ***Storm Event Sampling Study*** document. Cardno is evaluating locations on the other three major tributaries to Falls Lake (Little River, Flat River and Knap of Reeds Creek) for possible future Storm Event Sampling. However, storm event/streamflow relationships are more complex on those streams due to reservoirs on each of them, making streamflow predictions and sampling logistics more difficult.

Quality Assurance/Quality Control:

The attached ***Storm Event Sampling Study*** document provides details of QA/QC considerations for this effort. All laboratory analyses will be performed by the same state-certified lab that analyzes samples for the UNRBA Routine Monitoring and will follow the DWR-approved UNRBA QAPP for sample analysis. Specific provisions associated with use of autosampling equipment were developed for the UNRBA QAPP and those have been reviewed and accepted by DWR.

Reporting/Deliverables:

Cardno will communicate with the UNRBA Executive Director on a regular basis on the progress of this Special Study. Status updates will be provided to the UNRBA Path Forward Committee and the Board of Directors at their regular meetings during Cardno's updates on the overall Monitoring Program status.

Discussion of the status and any available results from this Special Study will be included as part of the Mid-Year and Annual Reports. Data generated by this Special Study will largely be used to inform future lake modeling efforts, thus there will not necessarily be a separate detailed analysis of the storm event data, but summary statistics and graphics are expected to be developed.

Data from the Storm Event Sampling will be included in the overall UNRBA database and will thus be available online to UNRBA members, agencies, and the general public.

Storm Event Sampling Study

for

The Upper Neuse River Basin Association

Water Quality Monitoring Program

Prepared for:

The Upper Neuse River Basin Association

P.O. Box 270

Butner, NC 27509

Program Administered and Plan Prepared by:

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5400 Glenwood Avenue

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April 30, 2015

Version 1.0

Concurrence from Division of Water Resources, NC-DENR received on

June 23, 2015

1 Introduction

The Storm Event Sampling Study for the UNRBA is a special study focusing on storm-event-based high-frequency sampling on a subset of tributaries to Falls Lake during and immediately following rain events. The number of storm events and tributaries to be sampled will be considered by the UNRBA annually and may vary from year to year.

Appendix A is a set of standard operating procedures for the actual sampling effort, including monitoring of weather forecasts, equipment set-up, sample collection, and transport of samples to the analytical laboratory.

Appendix B provides an addendum to the Quality Assurance Project Plan (QAPP) already in place for the regular UNRBA monitoring program. Most of the project structure, analyses, data management, and QA/QC procedures are the same as for the UNRBA program. The QAPP addendum provides additions pertinent to the specifics of the Storm Event Sampling Program.

2 Storm Event Sampling

2.1 Summary

Purpose: This study is designed to provide data on nutrient loading under varying streamflows for evaluating different load estimation techniques which may be used with the Falls Lake Nutrient Response Model. Storm event sampling will also provide data to the UNRBA on how nutrient and carbon concentrations vary over relatively short time periods with changes in streamflow.

Precipitation Targets: The sampling plan targets rain events predicted to deliver between 0.75 and 2.0 inches of rain within an approximately 24-hour period, and which therefore have a significant effect on streamflow and stream discharge to Falls Lake.

Locations: Initial sampling is focused on Ellerbe Creek and the Eno River near existing USGS flow gages. Future sampling will be determined based on findings of the initial data collection.

Parameters: The following parameters will be analyzed from samples collected via automatic water samplers: total Kjeldahl nitrogen, ammonia, nitrate plus nitrite, total nitrogen (calculated from total Kjeldahl nitrogen and nitrate plus nitrite), total phosphorus, and total organic carbon. Total suspended solids (TSS) will be collected at least daily via manual grab samples and may be collected more frequently via automatic water samplers.

Sample Distribution: Automated sampling frequency will be managed in an attempt to collect several individual samples beginning before tributary streamflow significantly increases in response to a storm event, a series of samples on the rising limb of the storm hydrograph, and a series of samples on the receding limb of the hydrograph.

2.2 Purpose

In March 2014, Cardno submitted a technical memorandum to the UNRBA (Evaluation of the Sensitivity of the Falls Lake Nutrient Response Model) that described various load estimation techniques and how those methods could generate significantly different estimates of loading from a tributary to Falls Lake, using the same water quality observations and estimates of flow.

Review of three load estimation methods resulted in total nitrogen loads to the lake that varied by over 200,000 pounds per year and total phosphorus loads that varied by 35,000 pounds per year for Ellerbe Creek in the baseline year (2006).

Given the variability associated with the various load estimation techniques, Cardno suggested in the Final Monitoring Plan (May 2014) that a high-priority special study was the collection of water quality samples over the rise and fall of a storm hydrograph at a real-time USGS gage in the watershed. Water quality samples are typically collected monthly or bi-weekly in this watershed, so the ability to pair sub-daily water quality observations to gaged flows can provide a more accurate estimate of daily loading from which to compare the various load estimation techniques.

This document discusses the hydrologic conditions in the watershed and the general plan for the storm event sampling. Storm size, frequency, and flow response have been analyzed to support this process. A literature review was also conducted to determine whether other researchers, such as the USGS, have designed monitoring programs with similar objectives and to learn from these studies. The objective of this data acquisition is to align real-time measurements of gaged stormwater flows with synoptic nutrient concentrations for select tributaries to upper Falls Lake. Quantifying the loading of nutrients at sub-daily increments will better inform the development of future input files for the Falls Lake EFDC model. This data will be used to evaluate the relative accuracy of different methods for estimating the loading concentrations needed for future modeling efforts.

2.3 Sampling Equipment

The equipment and procedures detailed in this plan pertain specifically to the use of automated sampling devices for the collection of storm event discharge. Automated samplers collect grab samples from the water body using a peristaltic pump to fill each sample bottle (the pump tubing is automatically purged and rinsed prior to sample collection). The automated sampler holds 24 1-liter bottles which can have preservative pre-loaded for water quality parameters requiring acid preservation. If more than one sample preservation technique is required for different parameters, or if the suite of parameters requires sample volumes greater than one liter, multiple bottles may be filled for each sample. However, given that the automated sampler holds only 24 bottles, filling two bottles at one time will halve the number of samples collected before field staff must visit the sampler to replenish bottles. This affects the possible frequency of sampling and therefore the selection of water quality parameters for analysis needs to be weighed against the desired sample frequency and the cost of using multiple samplers per site.

2.4 Constituents to Be Measured

The Final UNRBA Monitoring Plan developed last year proposed that storm event sampling include measurements of NH3, NO2/NO3, TKN, Ortho-P, total P, TOC, TSS, turbidity, field parameters, and sediment partitioning. The monitoring plan does not include routine measurement of turbidity at any tributary monitoring locations and therefore turbidity is also not included in this storm event plan. Ortho-P requires immediate field filtration and has a short hold time and therefore is not suited to collection via automated sampler.

The following water quality constituents will be analyzed in samples: ammonia nitrogen, total Kjeldahl nitrogen, nitrate + nitrite, total phosphorus, total organic carbon, and total suspended solids (in some cases, see text).

Depending on sediment load, TSS analysis can require large sample volumes which exceed the capacity of the automated samplers or reduce the number of samples which can be collected to less than the frequency necessary for meeting this study's goals. Analysis of TSS requires a full 1-liter bottle of water and therefore necessitates a separate collection bottle every time a sample is collected. This reduces the number of samples that can be collected between field staff visits from 24 to 12. Collection of samples for TSS will be decided on a case-by-case basis if the anticipated sample collection schedule permits the reduced number of samples between field visits. If TSS is not sampled using the automated sampler, manual grab samples can be collected before the rain event and at least daily when field staff visit the site to retrieve sample bottles.

Details on analytical methods, sample preservation, maximum holding times, and volume required for analysis follow the specifications in the UNRBA's Monitoring Program QAPP (version 1.0). All constituents except TSS will be collected in single 1-liter polypropylene sample containers pre-loaded with H_2SO_4 preservative and kept ≤ 6° C until analysis. TSS will be collected in separate 1-liter bottles.

2.5 Sampling Locations

The initial storm event sampling will use sampling locations on the Eno River near the USGS gage (USGS 02085070) at Highway 501/Roxboro Road, Durham, NC and on Ellerbe Creek near the North Durham Wastewater Reclamation Facility (36.0326, -78.86176).

Eno River and Ellerbe Creek were selected for the initial storm event sampling because they are among the top five contributors of water and/or nutrients to Falls Lake and they provide a contrast in watershed characteristics, most notably impervious surface cover and resulting stream flashiness.

2.6 Storm Event Characteristics

A review of USGS discharge records and precipitation measurements indicates that relatively small rain events are the most common and that the frequency of rain events decreases with increasing precipitation totals (Figure 1). USGS stations used in the analysis are presented in Table 1. Over the period examined (August 2008 through January 2015), approximately 60 rain events delivering less than 0.75 inches occurred annually and approximately 15 events delivering between 0.75 and 2 inches occurred annually. Fewer than 5 events greater than 2 inches typically occurred each year. Despite their high frequency, events less than a half to three-quarters of an inch often produced only very small changes in river stage and discharge (Figure 2) and individually provided only small increases in flow to Falls Lake. Storms greater than 2 inches individually deliver large amounts of water to Falls Lake, but as a group, their relative rarity of occurrence means that they do not generally provide a large volume of water to Falls Lake on an annual basis (Figure 3). In the middle of this range, storms between 0.75 and 2 inches occurred approximately 15 times per year and storm flow associated with these storms accounted for about 25 percent of the water delivered to Falls Lake. Given their delivery of water to Falls Lake and their frequency of occurrence, this plan targets storms predicted to deliver between 0.75 and 2 inches of rain. Pursuing smaller storms may result in data which do not represent elevated flow conditions. Waiting for storms greater than 2 inches limits the number of sampling opportunities and may result in few or no samples being collected at all. Sampling safety hazards also increase with storm event size since sampling personnel may have to work in flooding conditions.

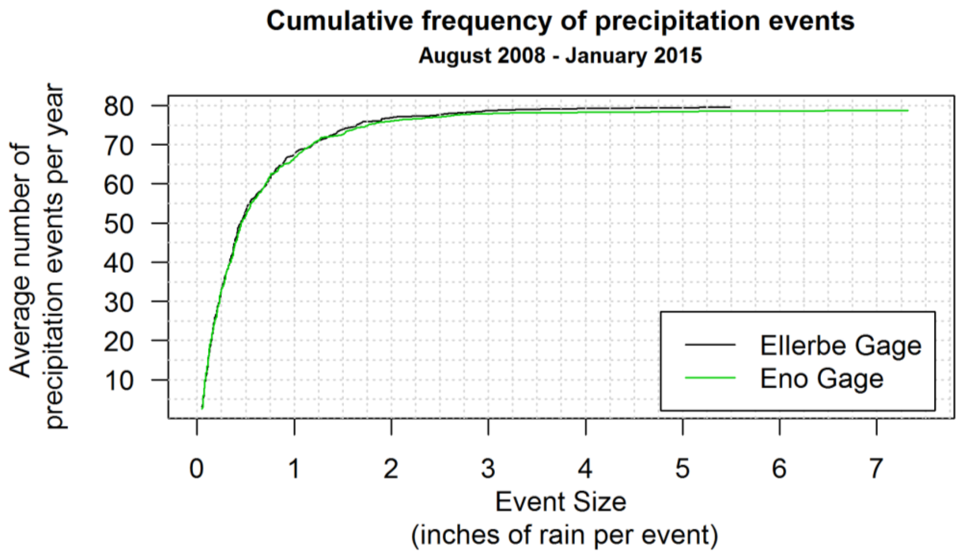

Figure 1. Average annual cumulative number of rain events (vertical axis) ranked by amount of precipitation received (horizontal axis) for August 2008 through January 2015. For this analysis, a precipitation event is defined as a period of rain with consecutive dry gaps of no more than 6 hours. Rain events separated by more than 6 hours are defined as separate events. Approximately 60 precipitation events delivering less than 0.75 inches of rain occurred annually (with some year-to-year variability). Another 15 events per year delivered between 0.75 and 2 inches of rain and approximately 4 events per year delivered greater than 2 inches of rain, for a total of 79 rain events per year. This analysis does not include rain events comprising 0.1 inches or less.

Table 1. USGS rain and flow gages used in this review of precipitation and flow data.

USGS Gage Number	Station Name	Parameters used	Dates of Available Data
02086849	Ellerbe Creek near Gorman, NC	discharge and stage	1985-10-01 to present
02085070	Eno River near Durham, NC	discharge and stage	1985-10-01 to present
360419078543145	Raingage at Eno River near Durham, NC	Precipitation, 15 min	2008-08-08 to present
360334078584145	Raingage at Eno River near Huckleberry Spring, NC (Cole Mill Road)	Precipitation, 15 min	2008-08-01 to present
360143078540945	Raingage at West Murray Avenue at Durham, NC	Precipitation, 15 min	2008-08-06 to present

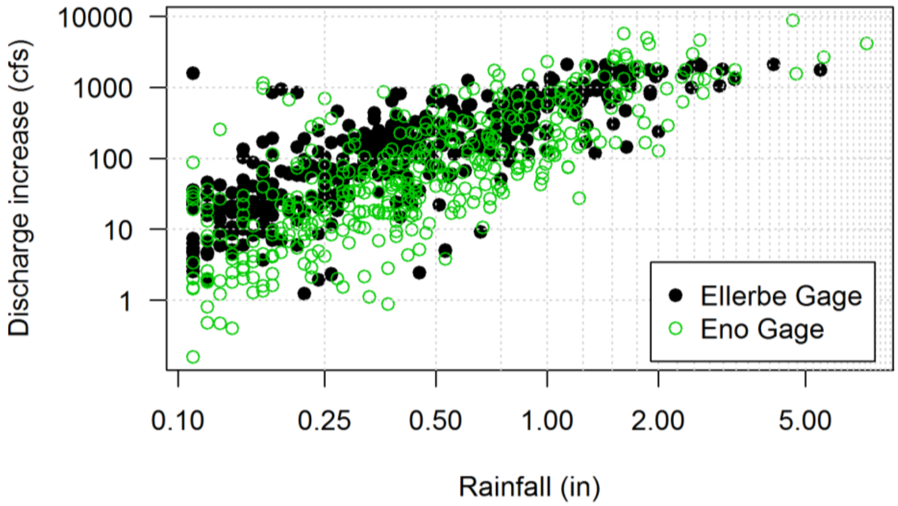

Figure 2. The increase in discharge above pre-rain conditions for individual rain events between August 2008 and January 2015. Only events with a preceding 24-hr dry period and following 3-day dry period are included in this figure in order to better attribute the increased discharge to a single storm, rather than back-to-back storms of varying sizes. Rain events less than one-quarter inch often showed only modest increases in discharge. Events greater than about 0.75 inches generally resulted in flow increases of at least 20 cfs, with most events showing increases above 100 cfs. Storms delivering greater than 0.75 inches typically produced hydrographs with well-defined rises and falls after the storm.

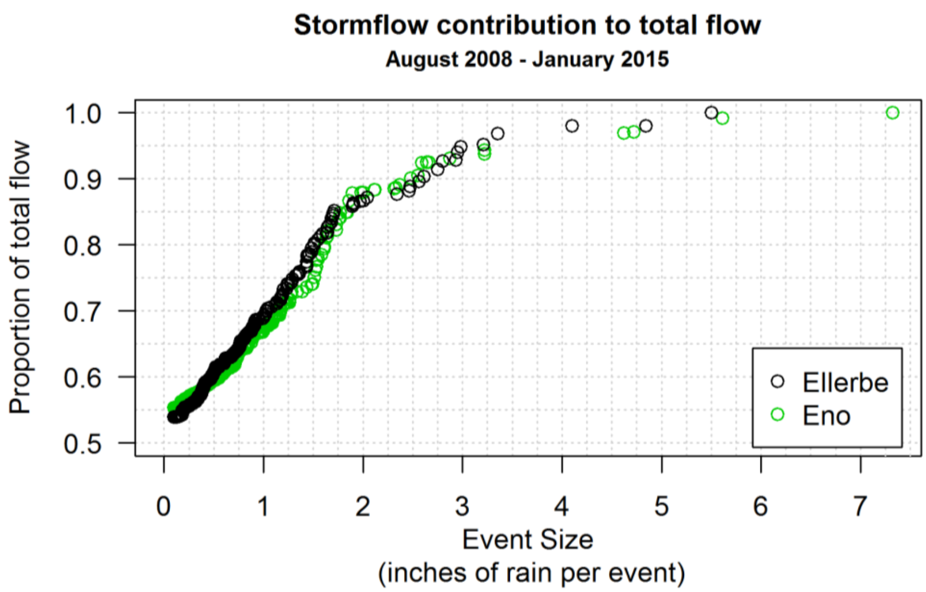

Figure 3. The cumulative contribution of storm flow to discharge from Ellerbe Creek and Eno River to Falls Lake. Approximately 55 percent of the flow to Falls Lake from these systems came from base flow, dry periods, and precipitation events smaller than 0.1 inches. The remaining 45 percent of water delivered to Falls Lake was a direct result of storm flow. Storms between 1 and 2 inches provided approximately 20 percent of the water delivered to Falls Lake, while storms less than 1 inch and storms greater than 2 inches (2 - 7.5 inches) each provided approximately 12 percent of the water delivered to Falls Lake over the period examined. The combination of storm size with frequency of occurrence makes storms in the 0.75-2 inch range significant contributors of water to Falls Lake.

Regional weather forecasts using tools such as the National Weather Service's regional Graphical Weather Forecast web resource[1] and location-specific forecasts for sites of interest from the National Weather Service[2] and the Weather Underground[3] will be routinely monitored to identify prospective storm events. Forecasts from multiple sources will be considered in evaluating the suitability of forecasted rain events for stream sampling in order to maximize probability of catching appropriate storms and minimize false starts. Storm event rainfall amounts will be acquired from USGS rain gages near the monitoring locations (Table 1).

2.7 Sampling frequency

This plan targets storm events forecasted to deliver 0.75 to 2 inches of rain with the intent of collecting numerous discrete samples through the phases of the storm hydrograph; *i.e.*, antecedent conditions, first flush, peak discharge, and the rising and receding limbs of the hydrograph (e.g. Figure 4). Streamflows following a 1-2 inch rain event can remain elevated up to several days, depending on antecedent rainfall and the flashiness of the watershed.

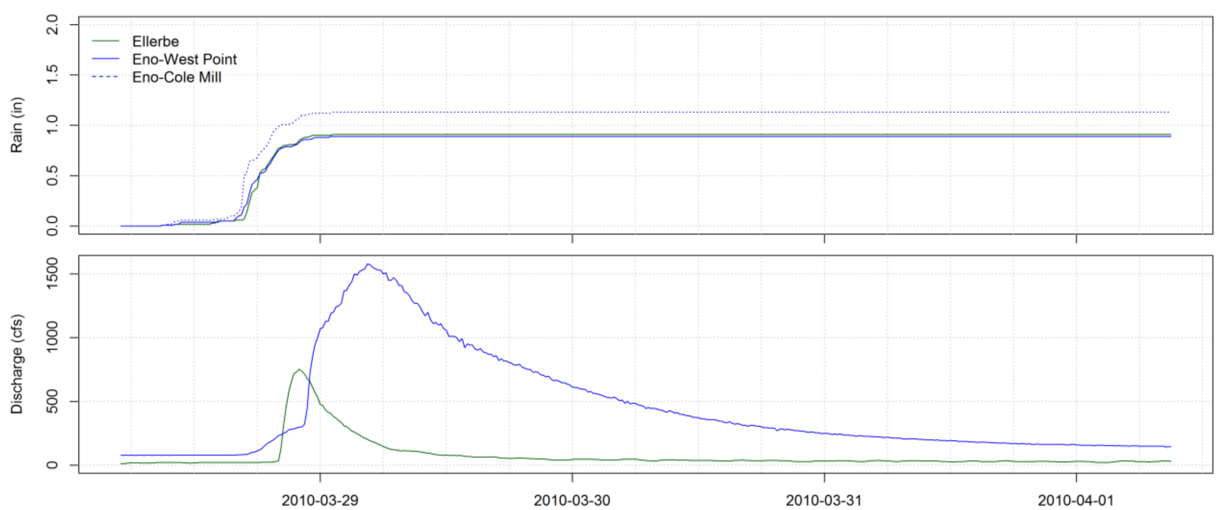

Figure 4. Cumulative rainfall (upper panel) paired with stream discharge (lower panel) for Ellerbe Creek and Eno River. Two USGS rain gages are located within the Eno River watershed and are shown in blue solid and dotted lines. Only one rain gage is located in the Ellerbe Creek watershed and data from it is shown in green. Ellerbe Creek discharge (lower panel, green line) typically responds more quickly to rainfall and rises to its peak often in just a couple of hours. Eno River usually responds more slowly and often takes 10-12 hours to reach its peak discharge. In this example, discharge in Ellerbe is back to baseline after 24 hours, while Eno River is nearing baseline after 2 to 3 days.

Sampling timing and frequency will be dependent upon actual storm size, along with the stream response magnitude and timing. Understanding that it is not possible to predict the exact timing and magnitude of storms, the sampling goal is to obtain up to 24 samples over the range of the stream hydrograph, including a few samples before the stream begins rising in response to a storm, a set of samples during the rising limb of the hydrograph, and a set of samples during the receding limb, ideally including the return to approximately the pre-storm discharge. In the case

[1] http://graphical.weather.gov/sectors/midatlantic.php#tabs

[2] http://forecast.weather.gov/MapClick.php?lat=36.05&lon=-78.92

[3] http://www.wunderground.com/cgi-bin/findweather/getForecast?query=36.05%2C-78.92

of extended periods of rain, or consecutive storms, it may not be possible to continue sampling over multiple days waiting for a stream to decline to baseflow conditions.

Stream hydrograph responses to similar amounts of rain are varied across systems and though time. The length of time between the start of the hydrograph rise and its peak is usually (but not always) much shorter for Ellerbe Creek than for the Eno River. Of all storms between August 2008 and January 2015, the middle 50% in Ellerbe ranged from 1.25 to 5 hours (median = 2 hours) for the peak to be reached. For the Eno River, the middle 50% of storms reached the discharge peak between approximately 3 and 16 hours after the start of the rise (median = 10 hours) (Figure 5).

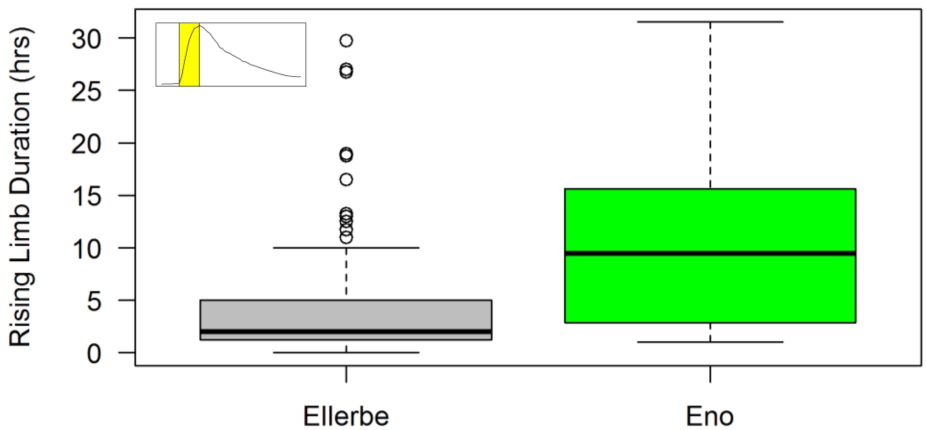

Figure 5. Duration of the rising limbs of hydrographs (region in yellow in inset graph) for storms delivering between 0.75 and 2 inches of rain and with a dry-period for the 24 hours preceding the rain event. Sample sizes are 103 and 92 storms for Ellerbe and Eno, respectively. The 25th, 50th, and 75th percentiles are 1.25, 2.0, and 5 hours for Ellerbe and 2.9, 9.5, and 15.6 hours for Eno.

It is impossible to predict how high the hydrograph will rise for any given storm event, thus it is also impossible to predict the sample spacing required to obtain the desired coverage on all slopes of the hydrograph. Instead, the sample collection frequency must aim to cover the hydrograph as well as possible within the constraint of the number of samples available to be collected (24 bottles between field staff visits). For a slowly-responding hydrograph typical of the Eno River, simply collecting samples every hour can provide good coverage of the hydrograph, and if more samples are collected than necessary, a subset can be selected for analysis.

In the case of a quickly changing hydrograph like that of Ellerbe Creek (Figure 4, green line), a uniform (e.g. hourly) sampling frequency may only provide 1 or 2 samples on the rising limb. In this case, higher sampling frequency is desired as the hydrograph rises, with decreasing the frequency through time as the hydrograph begins to recede. This type of custom sample pacing can be achieved through the use of a telemetry unit in conjunction with real-time monitoring of USGS rain and streamflow data.

An example set of sample frequencies which would provide 24 samples in 24 hours, with increased coverage over quickly changing periods of the hydrograph, is the schedule shown in Table 2. The details of such a schedule can be altered on a case-by-case basis.

Table 2. Possible sample frequency and timing to capture the various segments of the hydrograph in flashy systems. The spacing between samples in bottles 0, 1, and 2 would be altered such that bottle two is collected at the predicted start of the stream level rise. If the equipment were set up six hours before the anticipated start of the storm, bottle 1 would be collected at 3 hours and bottle 2 would be collected at 6 hours. Collection of sample bottle 3 would be remotely triggered at the start of the hydrograph rise. This level of customization is possible through the use of remote telemetry.

Bottle	Elapsed Time (hours)	Hydrograph Time (hours after beginning of rise)
0 (manual grab)	0	-3 (approx. 2 hours before rainfall)
1	1	-2 (approx.1 hour before rainfall)
2	2	-1 (rain begins)
3	3	0 (beginning of hydrograph rise)
4	3.25	0.25
5	3.50	0.50
6	3.75	0.75
7	4.00	1.00
8	4.33	1.33
9	4.67	1.67
10	5.00	2.00 (median time of peak)
11	5.50	2.50
12	6.00	3.00
13	6.50	3.50
14	7.17	4.17
15	7.83	4.83
16	8.50	5.50
17	9.50	6.50
18	10.50	7.50
19	12.00	9.00
20	13.50	10.50
21	15.50	12.50
22	17.50	14.50
23	20.00	17.00
24	22.50	19.50
Replenish bottles prior to this sample	25.00	22.00

2.8 Antecedent Weather Conditions

The goal of this study is to relate elevated streamflow conditions with synoptically-measured nutrient levels, which is not necessarily the same as the determination of conventional “event mean concentrations” considered in regulatory stormwater evaluations. Therefore, this plan does not require a pre-storm “dry” period. Nonetheless, to the extent practical, the effort will attempt to capture discrete events where the pre-storm discharge approximates seasonal base flow. The project team will consider each impending storm event, in light of the real-time USGS-reported discharge, on a case-by-case basis.

2.9 Adaptive Approach and Data Validity

Automated storm event sampling can be challenging with many variables affecting the quantity and timing of sample collection. This sampling plan allows for an adaptive sampling approach to maximize the likelihood of obtaining data useful for the study's purpose. Storm event sampling will be considered successful if samples collected by the automated sampler represent multiple stages of a storm's hydrograph. Since each individual water quality sample can be paired with a simultaneous measurement of stream discharge, each sample has value. The distribution of samples across a storm hydrograph brings enhanced insight to the understanding of the water quality/discharge linkage. Thus, while a full complement of ideally-spaced samples brings the optimal value, less ideal sample numbers or distributions also bring value, particularly when considered across storm events or from one stream to another.

Nevertheless, storm event samples may be considered unsuccessful if any of the following occur:

- Bottles are only partially filled due to suction issues (e.g., clogged intake screen),
- Samples are not properly preserved on ice at the time of retrieval,
- Substantive irregularities in the flow data (can be caused by debris obstruction of the flow equipment),
- There is evidence of compromised samples due to tampering/vandalism.

Appendix A Standard Operating Procedure for Automated Surface Water Sample Collection

A.1 Introduction

These Standard Operating Procedures provide specific direction for individuals conducting sample acquisition for the UNRBA Storm Event Sampling Plan. Such individuals are required to read carefully the entirety of the overall plan document prior to performing any sample collection activities. The Plan document, as well as its QAPP appendix, contains details on the basis and requirements for the study that are important for a thorough understanding of the sampling effort.

All field activities, as well as equipment mobilization and demobilization, will be conducted under the supervision of the Project Manager and/or Project Quality Assurance Officer.

A.1.1 Sampling Equipment Overview

Storm event monitoring will be performed with ISCO 6712 portable full-sized automated samplers (ISCO). The automated sampler consists of a programmable control unit, peristaltic pump, 24 bottle rotating carousel, and dispensing arm.

Reusable and/or exchangeable equipment associated with the automated samplers include: 12-volt deep cycle marine battery, 3/8 inch ID, 1/2 inch OD vinyl tubing, 1-L polypropylene bottles, and an intake strainer. Cleaning and maintenance of this equipment is described in Section A.5.

The following equipment is generally needed for automated surface water sample collection:

- Field security enclosure (e.g. Jobox)
- Chain, anchors, and locks
- Keys for equipment enclosure
- ISCO 6712 automated sampler properly configured for 24 1-liter bottles.
- ISCO 6712CI cellular telemetry unit with magnetic mount antenna (if applicable)
- 12-volt deep cycle battery and connection cables
- Cleaned sample collection (intake) tubing (vinyl or polyethylene) and strainer
- Landscape staples or other mechanism appropriate for securing tubing to bank
- Cement block and fasteners for securing strainer and end of tubing in the stream
- Hip waders, rubber boots
- Measuring tape
- Cleaned, labeled, and capped 1-liter wedge shaped bottles with preservative pre-loaded
- Additional 1-liter bottles, unpreserved, for TSS samples
- Disposable gloves
- Clean re-sealable plastic bags (such as Ziploc) for storing caps
- Tap water (cold) for creating an ice water bath in sample chamber
- Coolers for storing samples on ice
- Ice for ISCOs and for transporting samples
- Thermometer for measuring temperature of water bath upon sample retrieval
- Camera (smartphone camera is sufficient)
- Permanent markers, pens, pencils, field notebooks
- Chain of Custody forms
- Field log sheets
- Personal protection equipment consistent with standard field protocols

A.1.2 Sampler Set-up

Automated samplers will be programmed to collect samples at pre-determined and/or adaptive time intervals. The sample collection timing will be user-defined according to the predicted size of the forecasted storm based on a review of existing flow data for that size storm and water body. The timing of sample collection will be estimated so that sampling begins a few hours prior to storm arrival and continues throughout the duration of the storm. Time intervals may be adjusted mid-storm to allow more frequent collection during the initial storm pulse. Such adjustment would either be scripted into the ISCO programming (*e.g*., Two-Stage Programming), or manually changed via telemetry and/or during one of the daily field visits. Field staff are fully trained in automated sampler programming and will have access to user manuals.

The automated samplers will be revisited daily to acquire the samples, restock clean pre-preserved sample bottles, and replenish ice. This may continue for several days to allow for representative collection through the storm hydrograph.

A.2 Site Setup/Installation

This section details the site setup and installation procedures that should be completed in advance of storm event monitoring. Equipment-blank samples should be collected prior to the sampling event.

Each automated sampler will be secured onsite within a locked metal enclosure to protect the equipment and samples from the physical elements as well as from tampering and vandalism. The positioning of the enclosure will be determined by field staff with the goal being to deploy the equipment in areas where it can be safely accessible during high-water events. The peristaltic pump may be able to draw water up to a 28-ft vertical distance and a 99-foot total tubing length. However, the longer the intake tubing and greater the height of the sampler above the water, the slower the water transfer, which results in longer pump runtimes and shorter battery life.

Site set-up

1. Identify a suitable site to locate the automated sampler depending on the objectives of the program.

2. Set up metal enclosure (e.g. Jobox) near the stream to be sampled but far enough away to be out of the flow range during storm events.

3. Screw the trailer anchors into the ground near the enclosure and lock the enclosure to the anchor and around a tree with the chain. Configure the chain, anchor, and tree to reduce the possibility of vandals being able to tip the enclosure over.

4. Place the automated sampler inside the enclosure along with a fully charged 12-volt battery. Battery voltage should be tested with a voltmeter to verify the battery is charged. A fully charged 12 volt battery should have a voltage of 12.7 volts after sitting for several hours post-charge. (The surface charge of a 12V battery immediately after charging may be above 13V and may not be a reliable indicator of the battery's state of charge.)

5. Secure the intake strainer to the end of the sample intake tube and position it within a flowing section of the stream channel. The intake strainer must be positioned well above the substrate to prevent bottom sediments from being drawn during sample collection. This may be accomplished by affixing the strainer to a structure in the stream, such as a

tree root or stable snag. Alternately, the strainer may be attached to a concrete block placed on the bottom of the stream.

6. Connect a measured length of vinyl tubing (in 1 foot increments) from the intake strainer to the sampler through the bottom of the enclosure. Leave enough tubing inside the box so the top of the unit can be removed from the lower unit and set aside without having to disconnect the tubing.

7. Secure the tubing to the bank by running through vegetation, using landscape staples, wire ties, or other attachment mechanisms. Place tubing so it closely and securely follows the contours of the bank in order to minimize risk of debris snagging the line. If necessary, the tubing can be run through PVC pipe that is secured to the bank with stakes or ties. Note that tubing installation should not be so permanent as to preclude regular inspection and or replacement.

8. Record the length of the tubing in feet from the strainer to the intake point on the sampler.

9. Test fill a bottle using the “manual grab” option set at 1000 ml to verify the sampler is delivering the correct volume to sample bottles.

A.3 Storm Event Sampling

A.3.1 Storm Event Mobilization

This section details the pre-storm mobilization procedure for preparing for an impending storm. It is assumed that all site setup and installation procedures detailed in **Section A.2** have been recently completed.

1. Inspect full length of sample intake tubing. Kinked or fouled tubing should be replaced prior to sampling.

2. Inspect the sample intake screen. Remove any debris that may have accumulated on or around the sample intake area.

3. Remove the ISCO cover and detach the programmable control unit (upper half) from the insulated sample chamber (lower half). Set the upper half aside.

4. Place capped and numbered bottles into the insulated sample chamber. All bottles are labeled with a unique identification number. Make sure bottles are in sequence such that the lowest number is installed in bottle location number one and the highest number is in location 24.

5. Replace bottles in positions 1 and 2 with two bottles for collection of initial grab samples—1 preserved and 1 unpreserved (for TSS). Make sure to note which bottle has preservative and which does not. Secure the bottles using the plastic retaining ring with the three elastic draw cords. Remove the lids from bottles 1 and 2 only.

6. Secure the programmable control unit section of the sampler onto the sample bottle compartment.

7. Wearing a clean pair of gloves, connect the sample intake tubing to the short end of the silicone pump tubing.

8. Connect the 6712 power cables to a fully charged 12-V deep cycle battery. Test battery voltage to ensure the battery is fully charged at the start of the sampling.

9. Turn ISCO on. Wait for ~10 seconds for program to load.

10. Select the appropriate program to collect two 1-liter grab samples in bottles 1 and 2.

11. Remove the programmable control unit and verify that the samples were collected correctly; that the appropriate volume of sample went into the bottle and that it did not overflow the sample bottle.

12. Cap the bottles, record the date, time, location, and presence or absence of preservative on the Field Log Sheet and Chain of Custody (COC) for these samples. Place the bottles on ice in a cooler for transport back to the lab and keep the COC form with the samples.

13. Replace the original (empty, except for preservative) sample bottles into positions 1 and 2 of the automated sampler.

14. Fill out the Field Log Sheet to record the bottle numbers in the sampler along with their positions (1-24), the site name, and sample begin date.

15. Arrange 10–20 lbs of ice into the middle of the bottle array and add clean cold tap water to make an ice water bath. If much of the ice melted with the water, drain some of the water and add more ice to maximize the ice:water ratio, while maintaining an ice water bath.

16. Wearing a clean pair of gloves, carefully remove the bottle lids and store them together in a clean, sealed zip-top bag, to be left inside of the enclosure for sample collection.

17. Secure the programmable control unit section of the sampler onto the sample bottle compartment.

18. Attach the telemetry unit to the ISCO sampler (if applicable) and verify settings indicating that the modem remains powered on at all times

19. Check that the date and time on the ISCO are correct. If not, set the correct date and time.

20. Complete the initial programming of the 6712 sampler per pre-determined sampling frequency. Refer to the ISCO operating manual and consult the project manager for further details. Ensure that the program is initialized.

21. Photographically document general stream condition both upstream and downstream of sample collection point.

22. Lock equipment enclosure.

A.3.2 <u>Mid-Storm Event Replenishment</u>

This section details the mid-storm replenishment procedure for restocking ice and in some cases exchanging collected samples with fresh bottles. These steps are meant to occur as the storm event is occurring and so no in-water work, such as tubing inspections, should occur. Field staff should also remain vigilant of storm-related hazards, such as lightning and wind (falling tree limbs). If properly set up, the equipment enclosure should not be within the limits of high flow; if this is not the case, staff should wait for flood waters to fully recede before approaching the unit.

1. Remove the ISCO cover and stop the active program. If a sample is in progress, wait for cycle to complete before stopping.

2. Slowly detach the programmable control unit (upper half) from the insulated sample chamber (lower half) being careful not to disturb the sample distributor arm

3. Secure caps on each of the 24-bottles within the carousel.

4. Measure and record the temperature of the water bath.

5. Open the spout on the lower compartment to drain melted ice water.

6. Remove bottles individually, recording the following details on the Field Log Sheet for each sample:

    a. Note from which numbered slot on the bottle carrier the filled sample container was pulled from. Record this on the Field Log Sheet. This number will be needed to cross-check the sample date/time from the ISCO Event Log.

    b. Record the sample date/time and the unique bottle identification number on the Field Log Sheet. This information should be obtained from the ISCO Event Log.

    c. Each bottle should be filled with liquid and have a small amount of headspace at the top of the bottle. Make note of lower fill levels on the Field Log sheet.

    d. Any bottles which have not yet been filled can be retained for replacement in the sampler.

7. Follow instructions under Storm Event Mobilization (section A.3.1) starting with step 5 to replace sample bottles, collect 2 grab samples, replace sample bottles, add ice, and reprogram sampler according to the sampling frequency necessary.

8. Check the power used since the initial deployment and check against the battery capacity. The marine deep-cycle batteries currently in use have a capacity of over 80 Ah which should be more than enough for a 5 to 6 day deployment.

9. Check battery voltage to make sure battery has enough charge for continued sampling. As a general guideline, a 12V battery has 75% of its capacity with a voltage of 12.4V, 50% of capacity at 12.2V, and 25% of capacity at 12.0V.

A.3.3 Storm Event Demobilization

This section details the post-storm procedure for acquiring and transporting samples and for demobilizing the automated sampling equipment.

1. Remove the ISCO cover and stop the active program. If a sample is in progress, then wait for the sample collection to complete before stopping.

2. Record the sample date and time each sample was collected and record on the Field Log Sheet. This information can be obtained from the ISCO Event Log.

3. Slowly detach the programmable control unit (upper half) from the insulated sample chamber (lower half) being careful not to disturb the sample distributor arm.

4. Secure caps on each of the 24-bottles within the carousel.

5. Measure and record the temperature of the water bath.

6. Open the spout on the lower compartment to drain melted ice water.

7. Remove bottles individually.

    a. Note from which numbered slot on the bottle carrier the filled sample container was pulled from. Record this on the Field Log Sheet. This number will be needed to cross-check the sample date/time form the ISCO Event Log.

    b. Record the sample date and time and the unique bottle identification number on the Field Log Sheet.

    c. Each bottle should be filled with liquid. Make note of lower fill levels on the Field Log Sheet.

    d. Place sample on ice for delivery to lab.

8. Discard remaining ice/water from the insulated chamber and reseat the upper half.

9. Detach the battery and return it to the lab for charging.

10. Remove automated sampler from the enclosure and return to the lab for cleaning.

11. Gather intake tubing and strainer and return to lab for cleaning.

12. Complete Field Log Sheet. Photographically document general stream condition.

13. Lock equipment enclosure.

14. Deliver samples on ice to analytical lab.

A.4 Documentation and Record Keeping

Hardcopy documentation will include the Field Log Sheet and Chain-of-Custody (COC) forms. Field Log Sheets will be completed by field staff during each mobilization and demobilization visit and are meant to record a variety of observations ranging from equipment condition to prevailing weather patterns. Chain-of-Custody forms will accompany the samples from the time that they are retrieved from the automated sampler until they are accepted by the laboratory.

A.5 Equipment Cleaning Procedure

Reusable equipment components, which include the polypropylene sample bottles, bottle lids, silicone peristaltic pump tubing, stainless steel hose barbs and connectors, and the stainless steel strainer, will be cleansed prior to use. A subset of the lab-cleansed sample bottles will be tested for the target analytes prior to their use in the field. The cleaning procedure involves washing with analyte-free detergent, a triplicate rinse with cold tap water, a minimum of a 5-minute soak in 10% HCl solution, followed by a final triplicate rinse with deionized water. Cleansed bottles are set upside down on a clean surface to dry. Other equipment, including pump tubing, bottle lids, barbs, etc., are also laid on a clean surface with a clean paper towel draped over the top. Once dry, bottles are capped and set aside for later use. All other items are packaged in a clean, sealable plastic bag to await deployment. After cleaning and before use, equipment blanks should be analyzed and verified as below the reporting level for each analyte of interest, per the UNRBA Quality Assurance Project Plan.

A.6 Health and Safety

Cardno operates under a strict Zero Harm Policy and provides thorough safety training and guidance to all staff. The following health and safety procedures will be followed by Cardno staff during field collections:

- At least two Field staff will be present at the sampling site during equipment installation, maintenance, and sample retrieval;
- Field staff will exercise prudence in the presence of potential biological hazards (poisonous plants, ticks, dogs, venomous snakes, etc.) and atmospheric electrical activity (lightning);
- Personnel will be careful when lifting to avoid injury and/or spilling the samples;
- Clean sterile, nitrile gloves will be worn by all field crew members during sampling;
- All electronic equipment will be kept as dry as possible;
- Field staff will be equipped with a first aid kit, as well as be trained in basic first aid and CPR;
- Field staff will have access to emergency numbers such as local police and fire department (911), closest hospital, and county environmental health;
- Field staff will be made familiar with driving routes to the nearest medical emergency facility.

APPENDIX B

UNRBA MONITORING PROGRAM
QUALITY ASSURANCE PROJECT PLAN
ADDENDUM

To Address the
Storm Event Sampling Study

Prepared for:

The Upper Neuse River Basin Association
P.O. Box 270
Butner, NC 27509

Program Administered and Plan Prepared by:

Cardno
5400 Glenwood Avenue
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April 30, 2015
Version 1.0

Division of Water Resources Concurrence received
23 June 2015

PURPOSE OF ADDENDUM

The storm event sampling plan will generally follow the quality assurance procedures set forth in the DWR-approved UNRBA Water Quality Monitoring Program QAPP. However, some details associated with using automated samplers are not contained in the original Water Quality Monitoring Program QAPP. Together with the original QAPP, this document outlines the quality assurance project plan for the high-frequency storm water sampling project. The UNRBA QAPP will be updated to include the revisions herein.

SECTION A — **PROJECT MANAGEMENT**

A.1 Signature and Approval Sheet

Upper Neuse River Basin Association
Storm Event Sampling Plan
Quality Assurance Project Plan, Version 1.0

Approved by:

Doug Durbin, Cardno Project Manager	Date
Matthew Van de Bogert, Cardno Project Coordinator and Quality Assurance Manager	Date
Forrest Westall, UNRBA Executive Director	Date
Pam Hemminger, UNRBA Chair, Board of Directors	Date
Tom Fransen, NC Division of Water Resources Water Planning Section Chief	Date
Cyndi Karoly, NC Division of Water Resources Water Sciences Section Chief	Date

A.2 Table of Contents

A.3 Distribution List

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

A.4 Project Organization

The project organization is essentially unchanged from the UNRBA Monitoring QAPP with the following exception: Field set-up of automated monitoring equipment and collection of field data and samples may be conducted by staff from Cardno and will be overseen by the Project Manager.

A.5 Problem Definition and Background

The overarching general project definition and background for the UNRBA monitoring program remain unchanged from the UNRBA Water Quality Monitoring Program QAPP. Details on the specific purpose and scope of the storm event sampling effort are provided in the UNRBA Event Sampling Plan.

A.6 Project Description and Schedule

Storm event sampling will occur for discrete storm events during the overall UNRBA monitoring program. Specific schedules, tributaries, and storm targets will be adaptively determined by the UNRBA. Each sampling event is anticipated to occur over a period of 2-5 days: the period from which the stream hydrograph moves from base flow, through storm flows, and returns to approximately base flow conditions after a rain event.

The Data Management and Measurement Methods Overview sections from this section of the UNRBA Water Quality Monitoring Program QAPP apply to the storm event sampling.

A.7 Quality Objectives and Criteria

The data collected as part of the storm event sampling will meet the quality objectives detailed in section A.7 of the UNRBA Water Quality Monitoring Program QAPP with the following adaptations:

The routine UNRBA Monitoring Program measures field precision via field duplicates which are prepared by splitting a single sample into two sample bottles immediately after collection in the field. This field precision measurement incorporates the effects of pouring samples into containers, variability in preservatives and bottles, field handling, and laboratory analysis on a single well-mixed sample. While the ISCO samples can collect two samples in sequence, they are not capable of splitting a single sample into two bottles. Variability in two consecutively collected samples is affected by field precision and temporal variability in stream water quality; these two sources of variability cannot be parsed in sequentially collected samples. Therefore, field precision will not be specifically assessed for samples collected with the automated sampler, but will be inferred from field precision measurements conducted for the routine monthly UNRBA sampling conducted under the UNRBA Water Quality Monitoring Program QAPP.

Equipment and bottle blanks will be collected and should have analyte concentrations below the appropriate method reporting limit. In the event that a parameter measurement is higher than the reporting limit in a blank, further investigations will be initiated in order to determine and correct the source of the contamination from among multiple possible sources including field equipment, sample bottles, laboratory reagent water, preservative and laboratory methods.

Bias in monitoring design

The cautions regarding monitoring bias are stated in the UNRBA Water Quality Monitoring Program QAPP remain relevant to the storm event sampling. Nevertheless, the storm event sampling is biased by design—it is intended to sample water quality specifically during relatively rare high-flow events. Samples will be collected at discrete times and will be associated with a discharge reading obtained from a nearby USGS flow gage. Sample locations may vary from event to event, but will be selected based on site suitability and accessibility, proximity to USGS flow gages, and specific monitoring goals. As such, the data collected are meant to be representative of the locations and events identified. Use of the data for any other purpose must consider the intent of the storm event sampling to avoid unintentionally biased interpretations. Results from storm event sampling will be coded with a specific flag in the database identifying that they were collected under non-standard conditions.

Completeness

Complications with automated samplers, site conditions, or unexpected weather may interfere with the complete collection of data as intended. Individual monitoring events will be assessed for completeness on a case-by-case basis. Because of the potential of hysteresis in analyte concentration relative to flow on the rising versus falling limb of the hydrograph, generally a complete monitoring event should include samples which encompass most of both the rising and falling limbs.

A.8 Special Training/Certification

Field staff

Field staff may include Cardno employees and/or its subcontractors. The Project Manager and Project Quality Assurance Officer will determine training needs on a case-by-case basis and ensure such needs are met. At a minimum, all field staff are to be trained in the methods described in this QAPP, the relevant SOPs, and sections of the UNRBA Water Quality Monitoring Program QAPP pertinent to their assigned tasks.

Laboratory (analytical) staff

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

A.9 Documents and Records

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

SECTION B — DATA GENERATION & ACQUISITION

B.1 Sampling Process Design

Overview

The storm event sampling plan will obtain water quality data over the course of a stream's response to a single rainfall event. The variability of water quality concentration with flow has implications for the manner in which loading to Falls Lake is estimated. The data collected under this program will be used to evaluate the relative accuracy and precision of the available load estimation methods.

Station Locations

Water quality associated with storm events may be monitored at any tributary location in the Upper Neuse River Basin. Sites near existing USGS flow gages on tributaries constituting the major water and/or nutrient contributors to Falls Lake will be of highest priority for data acquisition.

Site Verification

Site locations will be verified by the Project Manager or their designee. Site coordinates will be recorded when equipment is set up for each monitoring event.

Parameters measured

During the course of the storm water monitoring event, samples may be obtained manually or with automated sampling equipment for any of the parameters included in the UNRBA Water Quality Monitoring Program QAPP. Due to the nature of automated sampling, the short hold times for some parameters, and the inability for the automated sampler to filter samples, analyses conducted on samples collected by the automated sampler will be limited to:

Total Kjeldahl nitrogen (TKN)
Nitrate + nitrite (NO3+NO2)
Ammonia (NH4)
Total phosphorus (TP)
Total organic carbon (TOC)
Total suspended solids (TSS)

B.2 Sampling Methods

Sampling and measurements

All field measurements and manual grab samples collected by Cardno or its contractors will be collected according to the methods specified in the UNRBA Water Quality Monitoring Program QAPP and its appendices.

Field samples collected with the automated sampling equipment will be obtained by trained individuals under the direction of the Project Manager and Project Quality Assurance Officer, and in accordance with the manufacturer's guidance for the equipment. The automated samplers can collect up to 24 1-liter bottles between visits from field staff. Sample bottles may be preloaded with preservative and samples are kept in an ice-water bath within an insulated compartment until retrieved for transport on ice to the laboratory.

If all desired analytes are able to be collected from a single bottle with the same preservative, then one 1-liter bottle will be collected at each sampling interval. If multiple bottles are necessary, the sampler can be programmed to fill more than one bottle at each sampling interval.

The specific programming of each automated sampler with respect to sample spacing is unique to an individual site and timing of each storm event and must be customized in order to collect representative samples. Modification of the program is based on knowledge of the site, expected conditions, anticipated safe return time, actual storm hydrograph, professional judgment and experience.

B.3 Sample Handling and Custody

Sample preservation

Samples will be preserved to the target pH values with the preservatives identified in Table B.2.1 of the UNRBA Water Quality Monitoring Program QAPP. Samples requiring acid preservation will have the acid pre-loaded into the sample bottles so that preservation happens immediately upon sample collection. The insulated bottle compartment of each automated sampler will be filled with ice and water to create an ice-water bath for sample preservation. The ice-water bath will be refreshed or replaced upon each visit by field staff as needed. The water bath temperature will be recorded on the sample chain of custody log sheets upon sample collection.

Upon collection from the field, samples will be placed in coolers with ice and samples will be returned to the Cardno office for storage at ≤ 6° C prior to delivery to or pickup by the analytical lab. Samples will be transported on ice and stored in designated refrigerators ≤ 6° C prior to delivery to the analytical lab.

Laboratory handling

Laboratory handling will be performed in accordance with the UNRBA Water Quality Monitoring Program QAPP.

B.4 Analytical Methods

Analytical procedures will be performed in accordance with the UNRBA Water Quality Monitoring Program QAPP.

B.5 Quality Control

An equipment blank will be collected from each automated sampler after the sampling equipment is cleaned and deemed ready for sampling but before the beginning of sample collection. These blanks can identify a number of error sources including reagent water, pre-preserved sample containers, and field equipment. In addition, separate bottle blanks will be periodically evaluated to verify that bottle cleaning procedures are adequate. Concentrations of analytes in blanks should be below the appropriate method reporting limit. In the event that a parameter measurement is above the reporting limit in a blank, further investigations will be initiated in order to determine the source of the contamination and to correct the problem. If contamination is suspected to be a result of the bottle cleaning process, bottles will be re-cleaned and re-tested prior to their use with the automated samplers.

Given the nature of the automated sampling, true field duplicates as described in the UNRBA Water Quality Monitoring Program QAPP are not possible and will not be collected. As described in section A.7, field precision will be inferred from the ongoing monthly UNRBA monitoring field duplicate analyses.

All other Quality Control practices remain as described in the UNRBA Water Quality Monitoring Program QAPP.

B.6 Instrument Testing, Inspection, and Maintenance

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

B.7 Instrument Calibration and Calibration Frequency

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

B.8 Inspection/Acceptance of Supplies & Consumables

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

B.9 Data Acquisition Requirements for Non-Direct Measurements

In addition to the specifications in Section B.9 of the UNRBA Water Quality Monitoring Program QAPP, the UNRBA will use precipitation and flow data from the USGS available from http://nc.water.usgs.gov. These data will be used to determine sampling frequency and to estimate nutrient loading from the sampled tributaries.

B.10 Data Management

Data collected under this program will be recorded in the UNRBA database with a unique Project ID tag to identify the data as belonging to the storm water monitoring project. This Project ID tag will allow the data to be isolated from the routine monitoring data for future analyses. All other aspects of data management will follow the guidelines set forth in the UNRBA Water Quality Monitoring Program QAPP.

SECTION C — ASSESSMENT AND OVERSIGHT

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.

SECTION D — DATA VALIDATION AND USABILITY

This section is unchanged from the UNRBA Water Quality Monitoring Program QAPP.