Quality Assurance Project Plan

NC Department of Transportation
Hydraulics Unit
1590 Mail Service Center
Raleigh, NC 27699-1590
919.707.6700

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Document History

Version	Date	Summary of Changes
0.1	04/10/2013	Initial draft
0.2		Revised draft based on internal NCDOT comments

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average daily traffic
ANSI	American National Standards Institute
ASTM	American Society of Testing Materials
BMP	Best management practices
COV	Coefficient of variation
DQO	Data quality objectives
EMC	Event mean concentration
HDPE	High density polyethylene
HSP	Highway Stormwater Program
IQR	Inter quartile range
MDL	Method detection limit
NCDENR	North Carolina Department of Environmental and Natural Resources
NCDOT	North Carolina Department of Transportation
NPDES	National Pollutant Discharge Elimination System
PE	Polyethylene
PI	Principal investigator
POC	Parameter of concern
PPE	Personal protective equipment
PQL	Practical quantitation limit
QAPP	Quality assurance project plan
QPR	Quarterly progress report
RL	Reporting limit
RPD	Relative percent difference
ROS	Regression of order statistics
SOP	Safe operating procedure
STORMDATA	Stormwater Research Monitoring Database
TN	Total nitrogen
TP	Total phosphorous
USGS	United States Geological Survey
VOC	Volatile organic compounds

1 Introduction

1.1 Research Program Background

The Highway Stormwater Research Program evolved as a requirement of the North Carolina Department of Transportation's (NCDOT) National Pollutant Discharge Elimination System (NPDES) permit NCS000250, originally issued in June 1998. The original permit and subsequent reissuances have required NCDOT to conduct a research program with universities and independent research agencies to quantify the impacts of stormwater from permitted activities, to evaluate the effectiveness of various Best Management Practices (BMPs), and enhance existing or develop new methods and processes to ameliorate these impacts.

The Highway Stormwater Program (HSP) is charged with managing compliance with the Department's NPDES permit. Management of the HSP is a collaboration of several NCDOT operating units, with the Hydraulics Unit in Preconstruction and the Roadside Environmental Unit in Field Support, serving in primary management roles. The Hydraulics Unit and the Roadside Environmental Unit co-manage the HSP research program, although one Unit may play a more active role in managing a given research project based on the nature of the project and staff expertise in the given area of investigation.

The HSP's primary funding mechanism for research projects is the NCDOT's Annual Research Cycle, which solicits ideas for new research projects in July or August, followed by a review process of pre-proposals and full proposals that results in kickoff of awarded projects the following August. A detailed discussion of this process can be found in the HSP Research Plan, which is available upon request from the Hydraulics Unit.

In addition to the Annual Cycle, the HSP contracts directly with universities under Masters Services Agreements to provide varied research services, including execution of pilot projects and monitoring studies, review of technical documents, and training services. A discussion of these services is also discussed in the HSP Research Plan.

1.2 Plan Scope

The purpose of this Quality Assurance Project Plan (QAPP) is to ensure consistent application of quality principles in the planning, design and execution of research projects under the HSP Research Program. Following the implementation of this QAPP, all researchers performing research projects under the purview of this QAPP will be required to comply with the requirements of this plan, unless explicitly exempted in writing from specific requirements by the NCDOT Program Manager or Research Coordinator (Section 2.1).

None of the requirements of this QAPP eliminate the requirement for appropriate due diligence to quality concerns by the research team's Principal Investigator (PI). Rather, this document serves as a minimum framework for quality, and also sets requirements to facilitate consistency among projects to allow comparison of results across studies.

2 Research Program Management Approach

2.1 Program Management Team

The key personnel with the HSP organization are listed in Table 1. The personnel and their roles are subject to change; an updated list can generally be found on the HSP Research Sharepoint site.

Table 1. Research Program Management Team

Staff Member	Role	Responsibilities
Andy McDaniel, PE	HSP Program Co-Manager and Research Co-Manager	Manage program funding; set strategic goals; approve funding of research projects; provide design engineers' perspective; advise Project Manager on invoices
Ken Pace, PE	HSP Program Co-Manager	Manage program funding; set strategic goals; approve funding of research projects; provide roadside environmental engineers' perspective
Chris Niver, PG	Roadside Env. Engineer	Provide roadside environmental engineers' perspective
Bob Holman, PhD	Research Co-Manager	Set strategic goals; evaluate research proposals; provide maintenance perspective
Karthik Narayanaswamy, PhD	Research Coordinator	Ensure the day-to-day execution of the Research Program; develop long-range planning products; review quarterly progress reports and technical deliverables; review and provide feedback on invoices
Brian Lipscomb, PE	Retrofits Manager	Oversee field activities; ensure research projects support Retrofit Program goals; liaison with Division staff for construction support

Staff Member	Role	Responsibilities
Ryan Mullins, PE	Principal Engineer	Coordinate field activities and NCDOT equipment; ensure compliance with NCDOT safety requirements
John Kirby	Research Project Manager	Manage contract; review and approve invoices; manage change requests; close out projects

2.2 Quality Oversight

The management team listed in Section 2.1 will provide broad oversight of the Research Program Quality Program; however, the principal responsibility for oversight rests on the PI for each individual project. NCDOT recommends a member on the project team be designated as a Quality Officer for the university research project team to coordinate compliance with this QAPP as well as providing quality oversight and training to graduate students on the team. This could be the PI, a staff member, or a graduate student.

To assist the Research Coordinator with ensuring compliance with the QAPP, the PI(s) or Quality Officer for each research project shall be responsible for providing the following information:

- **Project QAPP.** At the start of each research project, the researchers shall provide a brief project QAPP discussing the Data Quality Objectives (DQO; see Section 3), conformance with (or proposed variations from) this program QAPP, analytical standards, etc. A form is provided in Appendix A for convenience and efficiency; however, the researchers are not required to use this template.
- **Quarterly Progress Reports (QPR).** Universities are required to submit quarterly progress reports describing the status of projects, potential or ongoing issues, and resources needed for continued project success. All

future projects will be required to also report on project quality; e.g., is the project meeting its DQOs, is data generated of sufficient quality to be useful, proposed changes in the monitoring approach to address quality concerns, etc. If there are significant site issues that prevent the generation of quality data (e.g. poor drainage conditions), the QPRs shall propose site or design modifications to ameliorate these issues. The QPR shall include the cumulative dataset to date.

- **Draft and Final Reports.** The draft and final reports for every research project shall include the project QAPP (as an appendix), and shall discuss DQOs and compliance with this QAPP. All data shall be required to be submitted using the Stormwater Research Monitoring Database (STORMDATA) template provided in Appendix B.

3 Data Quality Objectives

Data Quality Objectives (DQOs) refer to the qualitative and quantitative objectives of the project with respect to the project purpose and scope, quality control, performance measures, and decision framework. The DQO framework, as defined by the USEPA, consists of a series of planning steps to prepare for data collection and is discussed in extensive detail in the USEPA's *Guidance on Systematic Planning Using the Data Quality Objectives Process* (USEPA, 2006). This QAPP provides the minimum requirements for HSP research projects based on USEPA's DQO guidance.

All new research projects shall be required to establish Data Quality Objectives during project initiation, to be presented at the project kickoff meeting or shortly after that, prior to initiation of any activities under the project. Specifically, the following elements should be discussed:

- ***Problem statement***, discussing why the project is necessary, proposed schedule and budget, and resources needed. The problem statement should be based on the approved proposal but should highlight any material changes to the proposed approach since the proposal.
- ***Project goals***, including an identification of specific study questions to meet the project's objectives (Section 5.1)
- ***Boundaries of the study***, including spatial and temporal coverage, and scope of the investigation (Section 5.2)
- ***Field methods***, including types of samples, sampling methods (Section 6), and safety considerations (Section 4.2)
- ***Analytical approach***, including identification of parameters of concern (Section 5.3), sample size (Section 5.5), analytical methods (Section 7), and data presentation (Section 11.5)

- ***Data evaluation methods***, including the approach to developing statistically valid conclusions based on available data (Section 11) and confidence intervals
- ***Quality objectives*** such as precision, accuracy, and completeness (Section 0)
- ***Sampling design*** (Section 5) to meet the quality objectives (Section 0) and other considerations
- ***Communication strategy*** for dissemination of study results at the conclusion of the project (Section 12)

4 Training Requirements

4.1 New Staff Training

Every member of the research team shall be subject to staff training at the initiation of the project. When a new staff member is added to the team, he/she will undergo similar training prior to participation in NCDOT-funded research. The exact scope of the training will be at the discretion of the PI; however, at a minimum, this training shall include:

- The requirements of this QAPP, including providing every team member with an electronic or hard copy of this document
- Laboratory analytical procedures, equipment maintenance, and laboratory safety protocols
- Field safety (Section 4.2)

Elements of the training may be eliminated if outside the scope of the staff member's work; for example, no field safety training is required for a laboratory technician without any responsibility for field work.

After completion of the training, the PI will document the scope of the training. Training records should be kept for the duration of the research project. Record retention is discussed in greater detail in Section 10.3.

4.2 Field Safety

Field operations in the highway environment can represent a significant safety risk to the members of the Research Program. New members should be trained on all safety protocols relevant to the specific project. The Research Program has several safety-related training materials and videos that can be used for this purpose; contact the Research Coordinator for access to this information. The PI should initiate every meeting with a safety review to emphasize the importance of safety, review principal hazards from laboratory and field operations, discuss any emerging safety concerns within the project, and identify safer methods of performing work. A safety meeting should be held at least once a month during routine field operations, and a brief 'tail gate' safety meeting should be held at the start of each field outing.

4.2.1 Safety Controls

Every research team member in the field should have appropriate personal protective equipment (PPE). In general, this will include, at a minimum, an American National Standards Institute (ANSI) 107-2004 Class 2 safety vest and safety toe shoes or boots, but could also include hard hats, safety glasses, or other PPE at different stages of the project.

Figure 1 shows acceptable and unacceptable styles of safety vests. Other Class 2 styles exist; always check the label or manufacturer's certification. Every researcher is required to bring their own safety vest and wear it while in the field. Staff without an approved vest should not be allowed to disembark from the vehicle.

Figure 1. Unacceptable and Approved Safety Vest Design

In addition, other PPE may be needed during construction, operation of equipment or other special conditions. The PI is responsible for determining appropriate safety requirements. Consideration should be given to the Division of Highways' Safe Operating Procedure (SOP) 10-16 *Personal Protective Equipment - DOH*, included in Appendix C. Staff are required to wear full-length pants and not shorts during field work. Tank tops, sandals and canvas shoes are also not appropriate while performing field work for NCDOT.

All staff must wear appropriate protective shoes, compliant with one of the following standards: American Society of Testing Materials (ASTM) F2412-05 *Standard Test Methods for Foot Protection*, ASTM F2413-05 *Standard Specification for Performance Requirements for Protective Footwear* or ANSI Z41-1999 or Z41-1991 *American National Standard for Personal Protection - Protective Footwear*. This generally means appropriate steel toe or composite-toe shoes.

Safety controls also include administrative controls, such as limiting sun exposure. See NCDOT SOP 10-18 *Sun Exposure*, included in Appendix C, for a discussion of sun exposure.

4.2.2 Work Zone Safety

NCDOT SOP 10-21 *Work Zone Safety/Traffic Control* included in Appendix C discusses work zone safety. During the execution of research projects, it is not always practicable to have traffic control. In such circumstances, it is advisable to follow the following steps:

- If the vehicle has a safety light such as strobes that can be mounted on the vehicle, turn the lights on. If no safety lights is available, discuss acquisition of one with the Research Coordinator at the initiation of the project. Safety lights are strongly recommended while performing work at the edge of roadways.
- If no strobe light is available, use your vehicle lights well in advance to signal your intention to move into the shoulder.
- Drive on the shoulder and slowly come to a stop. Park upstream of traffic from the work location (e.g. sampling location) so that the vehicle serves as a barrier from stray vehicles. Leave your hazard lights on.
- If you will be on site for more than 15 minutes, place orange cones around the perimeter for additional safety.
- In general, research staff should not work after dark. If there is a need for such work during the course of the project, at a very minimum, the researcher must have a meeting with the PI(s) to review appropriate safety procedures and the anticipated night time hours of work. It is recommended that the researcher call the PI at the conclusion of the night time work to verify their safe return.

4.2.3 Confined Space Entry

A confined space is any space whose configuration hinders the activities of employees to enter, work in, and exit them. In a stormwater setting, this typically relates to catch basins, manholes, pipes, and certain culverts. Confined spaces pose the risk of a worker being entrapped or exposed to poor air quality and unable to exit. Depending on the nature of the confined space, there might be other hazards associated with the space.

No individual should engage in confined space entry at any time while performing NCDOT sponsored research.

If the PI envisions that confined space entry will be necessary to successfully conduct the research project then the PI must meet with NCDOT representatives and receive approval prior to conducting any work in confined spaces. For reference, NCDOT SOP 11E-1 *Confined Space Entry* is included in Appendix C.

5 Sampling Process Design

This QAPP requires researchers to define the monitoring strategy during project initiation or prior to the initiation of field activities. Specifically, the sampling process should be designed to address the specific research questions the study aims to answer (Section 5.1), and should include the sampling site selection criteria (Section 5.2), parameters of concern (5.3), definitions of what constitutes a qualifying storm and the number of qualifying storms that will be monitored (Section 5.4), a monitoring strategy including sampling frequency (Section 5.5), and triggers for the researcher to perform sampling, including information on how sample holding times will be met.

5.1 Project Goals

At the initiation of every project, the researchers must present a clearly stated project goal, including specific statements of the purpose(s) and the proposed application of generated data, e.g.

> "*a) to characterize the particle size distribution of total suspended solids in stormwater runoff and after vegetative treatment to support predictive models of vegetative treatment efficiency, and*
>
> *b) to determine the variability in particle size distribution by physiographic region, traffic density, and adjacent land use.*"

Clearly defined project goals are vital in the successful design of a research project. Specifically, due consideration must be given at every stage of the research project to the collection of quality data that would allow statistically valid conclusions to be reached that would support the project goals. Generic goals such as characterizing runoff coming from bioretention basins should generally be eschewed in favor of specific goals that said data would support, as in the stated example above. This allows the design of the research project to be oriented towards generating data that facilitates specific actions that NCDOT can readily apply, rather than simply information. A critical consideration in evaluating project goals is to identify what actions NCDOT may be able to implement based on the study.

5.2 Sampling Site Selection

The selection of sampling sites should be driven by the definition of project goals. Specifically, it is necessary to identify the spatial and temporal boundaries of the study, what factors need to be evaluated, and the constraints that may limit selection of adequate sites and samples. For example, if physiographic variability is of interest, then sites should be located in different ecoregions. However, care must be exercised to not include additional variability in the process, e.g. using an urban watershed in the Piedmont and a rural watershed in the Blue Ridge ecoregion for the study of nutrient levels in runoff.

Sampling in a highway environment presents unique challenges:

- Traffic loads present risk exposure to field staff and equipment. See safety considerations in Section 4.2.
- Limited right-of-way can result in restricted ability to install monitoring equipment.
- Small drainage areas can result in short times of concentration, which can impose challenges such as the need to increase the frequency of flow monitoring, or in subpar data quality. In general, flow data must be collected as frequently as the time of concentration.
- Difficulty in controlling site conditions, such as longitudinal slope of the highway, can disrupt flow regimes and compromise data quality.
- The monitored site may not be representative of other highway sites, and there might be a need to select a diverse cross-section of sites in different

ecoregions, with different average daily traffic loads (ADT) and different pavement types.

- Clear recovery restrictions (Section 5.2.1), which prevent the installation of equipment within the clear recovery zone.

The researcher should evaluate these and other concerns during initial site selection, and discuss any issues with NCDOT staff as appropriate. A discussion of site selection considerations should be included in the draft and final research reports.

5.2.1 Clear Recovery Zone

NCDOT highways must comply with the American Association of State Highway and Transportation Officials (AASHTO) design standards, which include a stipulation for a *clear recovery zone*. When a vehicle accidentally leaves the travel zone, the clear recovery zone is used by the driver to safely navigate the vehicle back into the travel lane. The size of the clear recovery zone depends in part on the ADT and the posted speed limit. Researchers should coordinate with NCDOT staff to determine the clear recovery zone.

The key implication of the clear recovery zone requirements is that no stormwater sampling equipment shall be positioned such that it impedes a vehicles ability to traverse the zone. Equipment that will not impede the vehicle's safe travel is allowed. Researchers are encouraged to consult with NCDOT staff regarding the location of the clear recovery zone when scouting for potential monitoring sites.

5.3 Parameters of Concern

NCDOT uses the concept of parameters of concern (POC) to identify analytes of relevance to the Research Program. A POC is defined here as an analytical constituent whose maximum concentration in a field monitoring investigation might be expected to exceed the most stringent water quality criteria as defined by federal or state standards. Essentially, the concept is to focus resources on parameters that may be environmentally relevant. It should be noted that identification of a water quality analyte as a POC should not be construed to imply deleterious effects on the environment.

Potential parameters of concern (POCs) in the highway environment, and their sources are listed in Table 2. Actual POCs should be identified on a project-by-project basis.

Table 2. Potential Parameters of Concern and Sources in the Highway Environment

Potential Parameter of Concern[a]	Potential Sources in the Highway Environment[b]
Total Suspended Solids	Pavement wear, vehicles, atmospheric deposition, maintenance activities, soil erosion
Nitrogen, Phosphorus	Atmospheric deposition and fertilizer application
Lead	Leaded gasoline from auto exhausts, tire wear, lubricating oils, grease
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, break lining and bearing wear, steel highway structures such as bridges and guardrails, moving engine parts
Copper	Metal plating, bearing and brushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear, insecticide application
Chromium[c]	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline exhaust, lubricating oil, metal plating, bushing wear, brake lining wear, and asphalt paving
Arsenic	Fossil fuel combustion products, insecticides, atmospheric deposition[d]
Aluminium	Construction materials[e]
Mercury	Batteries, atmospheric deposition[d]
Manganese	Moving engine parts
Sodium, Calcium, Chloride[c]	Deicing salts
Petroleum[c]	Spill, leaks, antifreeze and hydraulic fluids, and asphalt surface leachate

Notes:

a. POCs listed are as identified in URS (2010)
b. Sources: USDOT (2000); Wang et al. (1980); McKenzie et al. (2009)
c. Not identified as POCs in URS (2010) but listed here because they are common analytes of interest in stormwater monitoring
d. Mitchell et al. (n.d.)
e. Malina et al. (2005)

The following POCs are of broad interest across much of NC and should be considered for inclusion in every research project:

- Total Suspended Solids
- Nitrogen species, including total nitrogen (TN), ammonia N and nitrate+nitrite N, reported as mg/L N, so the summation of the different species is comparable to TN
- Phosphorous species, including total phosphate (TP) and ortho-phosphate, reported as mg/L P, so the summation of the different species is comparable to TP

In addition, it may be desirable to consider inclusion in the monitoring protocol of the following parameters of concern:

- Total and dissolved metals, especially copper, cadmium, lead and zinc, to be performed by an approved "clean hands" method
- Particle size distributions
- Total hardness (especially when metals analyses are included)

5.4 Representative Storms

Unless explicitly requested and approved by NCDOT, a *representative storm* must yield at least 0.1 inch of precipitation; must be preceded by at least 72 hours with less than 0.1 inch of precipitation; and, if possible, the total precipitation and duration should be within 50% of the average or median storm event for the area (USEPA, 1992; USDOT, 2001). Where the scope of work identifies a certain number of storms that will be monitored, only representative storms shall count towards this number. The quarterly progress report and the draft report should report the number of representative storms monitored (Section 0 and 10.2).

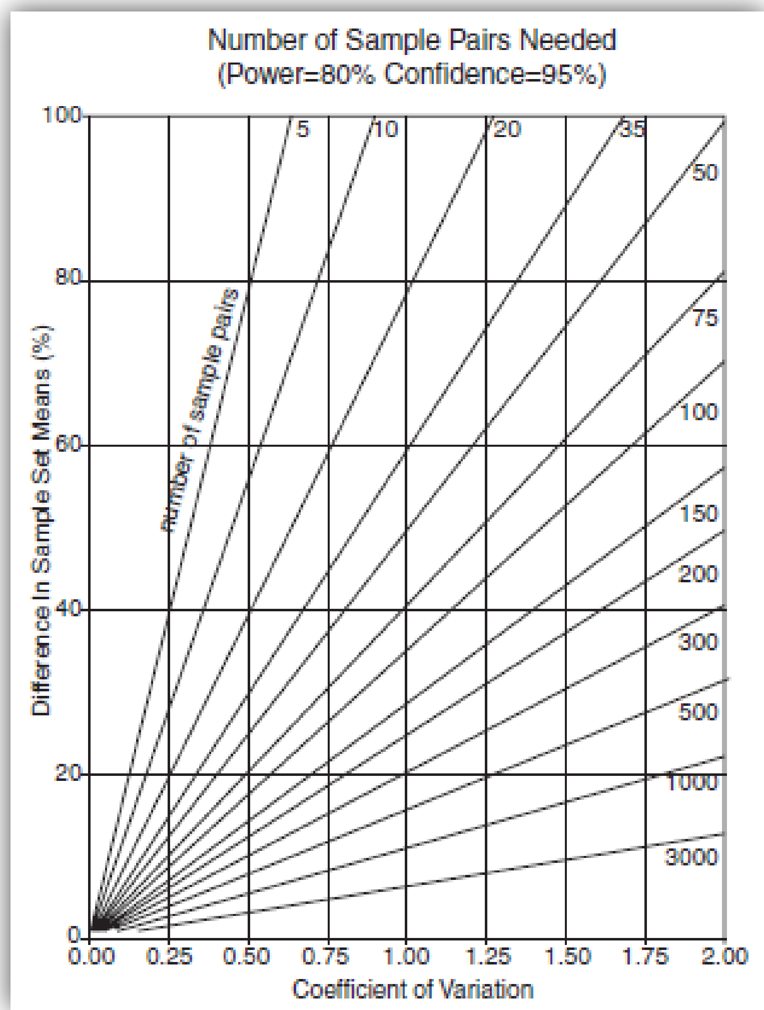
5.5 Sampling Size

The number of samples required for statistically relevant conclusions is a function of the variability of the parameter in question between the study site and control site and the temporal variability at each site. The most common method to rigorously determine the number of samples required is using a power equation.

There are two types of error in hypothesis testing. A Type I error is a false positive, e.g. when a water was deemed to be polluted when the water was free of the pollutant, and the probability of this type of error is denoted by α. A Type II error (also known as β) refers to the inference that the hypothesis is false when it truly is valid, e.g. when a polluted sample exceeding a regulatory limit is deemed to be below regulatory levels. *Confidence* refers to the probability of not making a Type I error, and *power* refers to the probability of not making a Type II error. Unless otherwise approved by NCDOT, the sample size is expected to have 95% confidence and a power of 80%; the target confidence and power should be stated during the DQO process (Section 3) during project initiation.

Burton and Pitt (2002) present several nomographs for a variety of situations to assist with the determination of the sample size to meet these requirements. These figures should only be used as a guide as they are based on several assumptions, including normality of the underlying distributions and equivalence of the standard deviation when there are multiple sites or timeframes. Neither is entirely accurate in reality; nevertheless these nomographs offer an estimate for sample size.

As an example, Figure 1 presents the sample size required for paired sampling when 95% confidence and 80% power is desired. If the coefficient of variation is 50% and the difference in the treated site versus the control site is 80% (e.g. high concentration in runoff versus effluent from a BMP), only 5 sample pairs are required. In contrast, when the difference between the treated and control sites are only 20%, then a total of 75 sample pairs are required, and a reasonable conclusion might be that field monitoring is not a feasible strategy to distinguish between these treatments.



Source: Burton and Pitt, 2002. Figure is presented as an example only, and not to be interpreted as a recommended method.

Figure 2. Sample size required for paired testing for 95% confidence and 80% power

Of course, this requires an *a priori* estimate of the levels of the concentrations in question, which could be based on historical records from similar projects.

Researchers are encouraged to identify other appropriate methods to identify sampling size, as long as the selected method represents sufficient statistical rigor. Alternative methods should be proposed to NCDOT and approved prior to adoption.

6 Sampling Methods

6.1 Water Quality Sampling

In general, all water quality sampling for parameters of concern should be based on flow-weighted composite sampling (or equal-weighted composite sample, in the case of streams). The exception is for the collection of samples for bacterial analysis or oil and grease, where grab samples are appropriate (USDOT, 2001).

Composite samples must be collected over at least 80% of the total hydrograph to be considered a representative sample. Samples that represented over 60% but less than 80% of the total runoff event should be presented with an appropriate qualifier. Composite samples collected over less than 60% of the hydrograph have little analytical value, except in special cases (e.g. first flush) and should generally not be included in the project's dataset, and should not count toward the number of samples collected under the project's scope of work.

Flow must be recorded in conjunction with sampling, with a frequency that is generally sufficiently smaller than the time of concentration for the drainage area. If flow is not recorded during a sampling event, or is recorded at such a frequency that the duration of the storm event only spans relatively few measurements (i.e., high error expected in total runoff estimation), the samples should not be included in the use of aggregate statistics, and should not count in the number of samples required under the project scope of work.

The autosampler should also be located as close to the sampling location as possible, and at an elevation as similar to the sampling tube as feasible. Clark et al. (2009) found little effect of autosampling on the particle size distribution of fractions finer than 250 μm in the sample relative to the runoff up to 8 feet elevation difference, but at higher elevation differences, recovery of these solids by the autosampler was affected. Recovery of solids coarser than 250 μm was poor independent of elevation differentials, and autosampling should not be used to characterize gross solids in runoff.

Sample holding times and preservation requirements are generally prescribed in the analytical method used to quantify the analyte (Section 7). Table 3 presents suggested holding times, containers and preservation requirements for several analytes or classes of analytes; however, these should be verified against the test methods used for quantifying the analyte in question.

Table 3. Suggested sample handling parameters for analyte handling (for reference purposes only)

Analyte	Holding Time (days)	Container	Preservation
Total Hardness	180	250-mL glass or PE	HNO3
Metals (ICP/MS)	180[a]	250-mL HDPE	Ultra HNO3[c]
Ammonia Nitrogen (NH3)	28	1-L amber glass	H2SO4 to pH < 2 & 4°C
Nitrate Nitrogen (NO3)	48 hours	125-mL glass or PE	4°C
Nitrite Nitrogen (NO2)	48 hours	125-mL glass or PE	4°C
Nitrate+Nitrite Nitrogen (NO3+NO2)	28	125-mL glass or PE	H2SO4 to pH < 2 & 4°C
Total Kjeldahl Nitrogen (TKN)	28	1-L amber glass or PE	H2SO4 to pH < 2 & 4°C
Nitrogen, Total	28	1-L amber glass or PE	H2SO4 to pH < 2 & 4°C
Oil and Grease	28	500-mL amber glass	H2SO4 to pH < 2 & 4°C
Ortho-Phosphorus, Dissolved	48 hours	250-mL glass	4°C[b]

Analyte	Holding Time (days)	Container	Preservation
Phosphorus, Total	28	250-mL glass	H_2SO_4 to pH < 2 & 4°C
Total Suspended Solids	7	1-L glass or PE	4°C
Total Organic Carbon (TOC)	28	250-mL glass	H_2SO_4 to pH < 2 & 4°C

Notes

a. Sample must be filtered and acidified within 48 hours.
b. Samples must be filtered using a phosphorous-free filter.
c. For mercury, preservation of samples is at 4°C with 5 mL/L of pretested 12N HCl or 5 mL/L BrCl solution.
d. Sources for this table include USDOT (2001) and Caltrans (2003)
e. PE – polyethylene, HDPE – high density polyethylene

6.2 Sediment Sampling

As used in this section, sediment refers to solids collected in the solid phase, such as collection of streambed sediment, solids from the roadway surface, from a weir or sampling gutter, a mesh net installed in a roadway gutter, etc.

6.2.1 Sediment Collection

When collecting sediment from a BMP, the following best practices should be implemented:

- Sediment samples are collected using manual grab methods.
- Sampling equipment will be cleaned with tap water, detergent, reagent grade water and reagent grade methanol, and stored in aluminum foil prior to use.
- If the BMP or trough is not dry, attempt to drain the location using a drain hole or pump, or sample the site when the location is dry. Use a stainless steel spoon or scoop and nitrile gloves to extract solids into a stainless steel bowl. The contents of the stainless steel bowl are to be composited and any debris or large sediment particles removed prior to transferring

the composited sediment to appropriate storage bags. The exception to this is when collecting volatile organic compounds (VOC), where mixing on the stainless steel bowl is skipped to avoid excessive volatilization of VOCs.

- In general, sediment samples should be stored in wide-mouth glass containers with Teflon-lined caps.

6.2.2 Sweeping Solids

Sediment might also be collected to characterize solids on the pavement surface. When this type of evaluation is required, it will be performed using a vacuum-assisted or regenerative-air sweeper; mechanical sweepers typically have poor removal efficiency of finer solids. Unless otherwise approved, the following best practices should be followed during implementation of a street sweeping sampling protocol (URS, 2010):

- A dry period of 2-3 days preceding the sweeping event
- Sweeper hopper to be cleaned prior to the start of each sweep event
- Three full hoppers of sediment material for sampling of each event
- When the hopper is emptied at an NCDOT maintenance yard, field staff will collect a "grab sample" representative of all sediment in the hopper and transfer into a glass jar

The composite sample should be sieved once the glass jar is received by the laboratory. At a minimum, the percent fines (62.5 μm or less) should be determined. In general, it is preferable to perform a comprehensive particle size distribution (Section 7.1), and researchers should consider including this in the sample protocol.

6.3 Biological Sampling

Benthic sampling shall be conducted in accordance with the relevant North Carolina Department of Environmental and Natural Resources (NCDENR) Division of

Water Quality Standard Operating Procedure (NCDENR, 2012). These standards only apply to freshwater streams that are wadeable, and greater than 1 meter wide. If the sampling site does not conform to these criteria, the PI shall propose an alternate method during project initiation or as part of a project-specific quality plan.

Bioassays shall be conducted in accordance with the time-variable bioassay guidance developed by NCDENR for assessing the toxicity of bridge deck runoff (NCDENR, 2009). This method is similar to the chronic whole effluent toxicity (WET) method, except that the sample collection time is the duration of the runoff event (as opposed to 24 hours for the traditional WET test) and the exposure time is the duration of the runoff event (as opposed to seven days for the traditional WET method).

Other biological water quality indicators such as phytoplankton and fish sampling shall be approved by the Program Management Team prior to the start of the sampling effort. These and other water quality indicators can be utilized and are dependent on the specific scope and focus of the research project.

7 Analytical Methods

Compliance with this QAPP requires researchers to evaluate and present reporting limits (RL) associated with laboratory analysis. Several different types of reporting limits exist; the PI must define the type of reporting limit used and method of determining the limit during the DQO definition process. Generally, the reporting limit is the *practical quantitation limit* (PQL), which is the lowest concentration of a constituent that the laboratory determines can be reliably quantified within specified limits of precision and accuracy during routine laboratory conditions.

The *method detection limit* (MDL) is the minimum concentration of an analyte that can be measured and reported with 99% confidence that the concentration is non-zero. A useful rule of thumb for the required MDL is that it should be a fraction of the anticipated median concentration in the samples, based on a coefficient of variation (COV) (Burton and Pitt, 2002). It should be noted that these values are presented here for reference purposes, but the key requirement for this QAPP is that the precision meet the requirements of Section 8.2 (which have separate precision requirements for low concentration duplicates and high concentration duplicates).

Table 4. Suggested multipliers and RPD objectives for MDL

COV[a]	Multiplier[b]	RPD Objective[c]	Example Constituents[d]
<0.5	0.8	<10%	Specific conductance, turbidity, chloride, sulfates, nitrates, calcium, sodium
0.5-1.25	0.23	<30%	Copper, lead[d], nickel, zinc
>1.25	0.12	<50%	

Source: Burton and Pitt (2002)

Notes:

a. COV = coefficient of variance
b. Multiplier is equal to the recommended method detection limit (MDL) divided by the anticipated median concentration.
c. RPD = relative percent difference of duplicate analysis
d. Example constituents are as presented in the reference document, and are presented here for illustration purposes only. The actual levels of variability in the NCDOT dataset may differ.
e. Lead is an illustration of the comment (d). The median concentration presented in Table 6.26 of the reference document is 30 µg/L and the recommended MDL is 7 mg/L; however, the median concentration in the NCDOT dataset is less than the recommended MDL.

NCDOT practice is to adopt the United States Geological Survey (USGS) protocol, which assumes RL = z*MDL, where z =2 if recovery from spikes (Section 8.3) is 100%, or divided by the percent recovery in other cases (Bonn, 2008). If the research laboratories have different methods of reporting limits, this should be reported during project initiation.

Specific analytical methods that will be used in the analysis of various POCs should be defined at the start of the project and presented during the project kickoff meeting, along with estimates of the RL achievable by such methods. Methods should be selected that will yield RLs below the expected Event Mean Concentration (EMC) of the constituent in runoff and in effluent from various BMPs. If stormwater EMC levels are below permissible RLs, the researchers should contact other laboratories to contract out analysis for the parameters in question. For example, the North Carolina

Department of Agriculture's Soil Testing Laboratory has been used successfully in the past for metals analysis.

A summary of the POCs and corresponding RLs is presented in Table 5. If the researcher proposes to use a different analytical method, or anticipates a significant deviation in the RLs from the values listed in Table 5, such information should be shared during project kickoff or as soon as the necessity is discovered.

Table 5. Target Reporting Limits Required for Stormwater Monitoring

Analyte	Reporting Limit	Suggested Method(s)
Total Suspended Solids	1 mg/L	EPA 160.2, SM 2540B, or SM2540D
Total Hardness	10 mg/L	EPA 130.1, EPA 130.2, or SM 2340B
Particle size distribution	N/A	Coulter counter, laser diffraction or SM 2560B
Nutrients		
Total Kjeldahl Nitrogen	0.20 mg/L	EPA 351.1, EPA 351.2, SM 4500-N_{org}
Ammonia-N	0.02 mg/L	EPA 350.1, SM 4500-NH3
Nitrate+Nitrite-N	0.02 mg/L	EPA 353.2 or SM 4500-NO3
Total Phosphorus	0.02 mg/L	EPA 365.1, EPA 365.3, EPA 365.4, SM 4500-P
Orthophosphate-O	0.02 mg/L	EPA 365.1, EPA 365.1, 365.3, SM 4500-P
Metals		
Total Recoverable Cadmium	0.5 µg/l	EPA 200.8
Total Recoverable Lead	2 µg/l	EPA 200.8
Total Recoverable Copper	2 µg/l	EPA 200.8
Total Recoverable Zinc	10 µg/l	EPA 200.8
Dissolved Cadmium	0.5 µg/l	EPA 200.8
Dissolved Lead	2 µg/l	EPA 200.8
Dissolved Copper	2 µg/l	EPA 200.8
Dissolved Zinc	10 µg/l	EPA 200.8

Notes

a. References consulted for development of this table include NCDENR (2013), Caltrans (2003), USDOT (2001), NEMI (n.d.) and the respective EPA methods.

7.1 Particle Size Distribution Analysis

When laser diffraction methods are used to analyze particle size distribution of solids in sediment samples or runoff samples, the activity shall be performed in concert with a laboratory-based standard operating procedure and/or manufacturer's recommendations that ensure appropriate quality control. Specifically, the following considerations apply:

- If the concentration of suspended solids is outside the manufacturer's recommended limits for quality data, the samples shall be centrifuged or diluted to result in an appropriate solids concentration.
- The equipment used should feature a stirring motor or other method to ensure that coarser solids do not settle during analysis of the particle size distribution.

8 Quality Control

As part of the quality control process, laboratories must include matrix spikes, replicates and blanks as part of their sampling protocol.

8.1 Blanks

Contamination of samples can occur during the sampling process or during analysis. Blanks are required as control samples to identify such contamination. Two types of blanks are required:

- ***Field blanks*** should be prepared preferably once per sampling event, and at least every time a new field operator is used.
- ***Method blanks*** should be used for every batch of samples, to determine the level of contamination associated with glassware and laboratory reagents.

8.2 Replicates

Replicate samples involve the measurement of the same sample multiple times. Two types of replicate samples are required (duplicates are specified, but greater number of replicates can be used for low level concentrations):

- ***Field duplicate samples*** provide an indication of the representativeness of the sampling and analysis procedures. Field duplicate samples should be collected at a frequency of 5% or a minimum of one per sampling event, whichever is more frequent. Field replicates should be reported as separate values, but averaged into a single value before computation of summary statistics.

* ***Laboratory duplicates*** highlight the repeatability of the analytical measurement and should be performed at least once per batch of samples, or once every 20 samples, whichever is more frequent.

The precision of low-level duplicates (defined as having a concentration < 20 times the MDL) should be ±25% for metals, anions, nutrients, other inorganics, and total organic carbon, and ±40% for all other analytes. For high-level duplicates (> 20 times MDL), the corresponding numbers should be ±10% and ±20% respectively (WEF, 1995).

8.3 Matrix Spikes

A matrix spike is a representative environmental sample that is spiked with target analytes of interest prior to being taken through the entire analytical process in order to evaluate matrix interference effects. Matrix spikes and spike duplicates determine the accuracy of the analytical method in the sample matrix, and are performed by adding a known amount of the target analyte to a representative environmental sample and estimating "recovery" of the added compound. Generally, the recovery rate should be in the 80-120% range for metals, anions, nutrients, inorganics and total organic carbon, and in the 70-130% range for volatile and base/neutral organics (WEF, 1995). The frequency of matrix spikes and spike duplicates is to be determined by the PI based on sample conditions; however, it should at a minimum be performed for the first sample batch, and ideally for different sample conditions that may result in different levels of matrix interferences (e.g., short intense precipitation event versus longer, intermittent event).

9 Equipment Testing, Inspection & Maintenance

This section offers some general recommendations for equipment inspection and maintenance, and testing while appropriate. However, the researchers are ultimately responsible for reviewing the manufacturer's instructions and developing an appropriate maintenance protocol.

In general, the following elements must be included as part of an inspection protocol:

- When DC power is used, verify the duration of continual operation permissible during continual operation of the equipment. Battery life reduces with time, so it is important to verify this periodically.
- Flow monitoring equipment should be calibrated according to manufacturer specifications. Flow meters typically contain desiccant packets and moisture indicators to keep the internal components of the equipment dry. The moisture indicators should be checked during each site visit, or at least once between each monitoring event. The sensor(s) should be checked periodically and calibrated on an as-needed basis. The sensor cables should be inspected at least prior to each phase of intensive stormwater monitoring. All connections into the flow meter should be visually inspected prior to each monitoring event.
- At a minimum, the autosampler calibration should be tested prior to major phases of monitoring. After each stormwater monitoring event, the volume of the sample should be verified against the expected value, and the autosampler calibrated if the deviation is outside of manufacturer's recommendations.
- Rain gages should be inspected after every sampling event to make sure they are free from debris. They should be inspected and calibrated at least before every monitoring project, and ideally before every major phase of monitoring.

10 Data Management

NCDOT's use of data generated by a given research project may extend for many years after the conclusion of the project. Hence the PI is expected to follow sound data management principals to ensure adequate documentation and the integrity of the data. To support these objectives, NCDOT requires several data management protocols by all researchers as discussed below.

10.1 Periodic Reporting

Quarterly progress reports for all research projects shall include provisional data collected to date, including raw data along with data qualifiers.

10.2 Deliverables

The draft and final deliverable for each research project should include the entire raw dataset, with appropriate data qualifiers for data that were excluded or that is associated with other quality control issues. An Excel template for submission of this data is available by contacting the Research Coordinator, and is presented in Appendix B.

10.3 Record Retention

Raw field and laboratory records, including notes by field personnel on site conditions and potential data quality concerns, should be retained by the Principal Investigator for a minimum of three (3) years after the completion of project and ideally longer. The Principal Investigator should notify NCDOT before destroying any historical records.

11 Data Analysis and Presentation

11.1 Data Validation

As part of the project closeout process, researchers are required to verify compliance with the project's DQOs prior to cessation of field activities and submission of the draft report to the Steering Committee. Specifically, the following activities are required:

- Verify the number of qualified sampling events (as defined in Section 5.4) exceeds the minimum requirements in Section 5.5 based on the variability of the data in question.
- Submit the draft dataset in Excel in the format specified by the Research Coordinator, with appropriate data qualifiers for data, including presenting left-censored data (Section 11.2) and identifying data associated with site conditions that could result in compromised data quality.
- Do not remove monitoring equipment from site until NCDOT signs off on the draft dataset, in the event it is deemed that additional sampling is required.

11.2 Handling of Censored Data

Data that are below the reporting limit represents lower reliability, and the method of handling these data affects the statistical aggregates of the parameter in question, and consequently could influence the conclusions of a study. This is especially true when two datasets with left-censored values are being compared for statistical testing.

The common practice of researchers historically has been to report an individual data point as less than a reporting or detection limit (e.g. "<5 mg/L"), and to use half of that value in the computation of statistical aggregates like the mean. However, the use of this type of substitution could result in compromised data quality, as discussed extensively by Bonn (2008). Substitution methods are not allowed unless explicitly approved by NCDOT. In general, NCDOT's preference is for the use of Regression of Order Statistics (ROS) for data that follows a normal, lognormal or gamma distribution, or Kaplan Meier method when they do not. However, if the research team includes a statistician who proposes a different method, the research team shall present a memo to NCDOT during the project initiation phase or prior to the execution of the statistical analysis. NCDOT will review the method and unless there are specific concerns, will defer to the opinion of the research team.

The HSP Research Program follows the USGS convention for managing reporting limits (Bonn, 2008), described briefly below. For the purposes of the discussion below, an "information-rich" method is a method such as a spectrometric method that is able to confirm the presence of the analyte in question.

In the draft and final report, the following reporting protocols should be observed:

- When the data value is less than the MDL and the method is not information rich, the value should be reported as "<RL"
- When the data value is greater than the MDL but less than the RL and the method is not information-rich, the value should be reported as the recorded value preceded by an "E" to indicate a greater degree of uncertainty
- When the data value is less than RL, but the method is information-rich, the recorded value is reported with an "E" qualifier, even if the value is below the MDL
- When the value is greater than the RL, the value is reported as recorded
- In all cases, the MDL is also reported

11.3 Identification of outliers

In general, it is necessary to have a systematic process to identify outliers. The rationale for identifying and eliminating outliers must be clearly defined, ideally at project initiation but, at a minimum, discussed in the draft report.

One method to handle outliers that has been used by NCDOT is to identify potential outliers using the Tukey Fence method, which is based on identification of data that represent extreme values on a normal distribution. The conditions surrounding the exclusion of these data points were then investigated for quality issues, such as backwater conditions, equipment issues, etc. and only excluded if there were physical factors that supported their exclusion.

Researchers should include in the project report a section discussing how outliers were identified and what verification processes were used to identify true outliers that should be excluded versus statistical outliers that were not excluded.

11.4 Computation of EMCs and Loads

A variety of methods exist to estimate EMCs and loads. Analysis by NCDOT indicates considerable variation in the estimates of loads based on the methodology used. NCDOT may in the future identify a single method to compute EMCs and loads. For the time being, researchers are required to document clearly the method used for estimation of these parameters, and preferably include a sample calculation in the project report.

All influent and effluent concentrations related to a BMP must be presented in the project report in the form of absolute concentration levels and mass loadings. In addition, there must be a statistical evaluation of the significance of the difference of influent and effluent concentrations.

11.5 Data Presentation

Data from research projects should be presented in a variety of ways, including, at a minimum, the mean and median influent and effluent concentrations, with a description of how the EMCs and loads (Section 11.4) were computed. Additional clarity can be achieved by presenting percentiles of concentration, typically the 25th and 75th percentile and the Inter Quartile Range (IQR). It is also beneficial to compare the data presented to relevant benchmarks, e.g. a relevant drinking water standard, an instream water quality or receiving water-based benchmark such as that presented by McNett et al. (2010). The project report should also include an evaluation of the statistical significance of the difference between the influent and effluent concentration distributions.

12 Data Dissemination

An important element of the Research Program is dissemination of research results both within NCDOT and outside. Researchers are generally expected to produce at least one journal article and two conference proceedings based on each research project. Funding for participation in conferences may be available from NCDOT; researchers should contact the Research Coordinator for more information.

Researchers shall submit draft journal articles and conference abstracts for NCDOT approval prior to submission. At a minimum, researchers should provide the NCDOT HSP team listed in Table 1 three (3) days for review of conference abstracts and two (2) weeks for journal articles. (Note that research contracts require a longer review window for approval by the State Research and Analysis Engineer, so researchers should work with the Research Coordinator in advance of the 30-day window generally required for this approval).

References

Bonn, B.A. 2008. *Using the U.S. Geological Survey National Water Quality Laboratory LT-MDL to evaluate and analyze data*. Open-File Report 2008-1227, 73p. U.S. Geological Survey, Reston, Virginia.

Burton, G.A. Jr. and R.E.Pitt. 2002. *Stormwater effects handbook: a toolbox for watershed managers, scientists, and engineers*. CRC Press, 929p.

California Department of Transportation. 2003. Caltrans Comprehensive Protocols Guidance Manual. CTSW-RT-03-105.51.42. November.

Clark, S.E., C.Y.S.Siu, R.Pitt, C.D.Roenning, and D.P.Treese. 2009. Peristaltic Pump Autosamplers for Solids Measurements in Stormwater Runoff. *Water Environment Research*. 81(2), pp. 192-200.

Malina, J.F., M.E.Barrett, A.Jackson, T.Kramer. 2005. Characterization of Stormwater Runoff from a Bridge Deck and Approach Highway, Effects on Receiving Water Quality. Prepared for the Texas Department of Transportation, Austin, TX.

McKenzie, E.R., J.E. Money, P.G. Green, and T.M. Young. 2009. Metals associated with stormwater-relevant brake and tire samples. *Science of the Total Environment*. 407, pp. 5855-5860.

McNett, J.K., W.F.Hunt, J.A.Osborne. 2010. Establishing Storm-Water BMP Evaluation Metrics Based upon Ambirnt Water Quality Associated with Benthic Macroinvertibrate Populations. *Journal of Environmental Engineering*. 136(5), pp. 535-541.

Mitchell, G.M., A.McDonald, and J.Lockyer. n.d. Pollution Hazard from Urban Nonpoint Sources: A GIS Model to Support Strategic Environmental Planning in the UK. Leeds University, UK http://www.geog.leeds.ac.uk/projects/nps/reports.htm

NCDENR. 2013. Inorganic and Microbiology Section - Methods and Reporting Limits (PQLs). North Carolina Department of Environment and Natural Resources, Division of Water Quality, Laboratory Services. Accessed on April 29, 2013 at: http://portal.ncdenr.org/c/document_library/get_file?uuid=88daac65-0b7f-4128-9898-2ae62a510765&groupId=38364

NCDENR. 2009. Time Variable Bioassay Guidance, Version 2 DRAFT. North Carolina Department of Environmental and Natural Resources, Division of Water Quality, Aquatic and Toxicology Unit, Raleigh, NC.

NCDENR. 2012. Standard Operating Procedure for Benthic Macroinvertibrates. Environmental Sciences Section, Biological Assessment Unit, Raleigh, NC.

NEMI. n.d. National Enviromental Methods Index. Accessed on April 29, 2013 at: https://www.nemi.gov

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. Report EPA QA/G-4. United States Environmental Protection Agency, Washington, DC.

USEPA, 1992. NPDES Storm Water Sampling Guidance Document. Report EPA 833-8-92-001. United States Environmental Protection Agency, Washington, DC.

USDOT, 2001. Guidance Manual for Monitoring Highway Runoff Water Quality. Report FHWA-EP-01-021. United States Department of Transportation, Washington, DC.

USDOT, 2000. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Publication No. FHWA-EP-00-002. United States Department of Transportation, Washington, DC.

Wang, T.-S., D. E. Spyridakis, B.W. Mar, and R.R. Horner. 1980. Transport Deposition and Control of Heavy Metals in Highway Runoff. Report WA-RD-39.10. Washington State Department of Transportation, Olympia, WA.

URS. 2010. Stormwater Runoff from Bridges. Prepared for North Carolina Department of Transportation. July.

WEF. 1995. *Standard Methods for the Examination of Water and Wastewater*. 19th edition. Water Environment Federation, Washington, DC.

APPENDICES:

Appendix A Project QAPP Template

Appendix B STORMDATA data collection template [UNDER DEVELOPMENT]

Appendix C Excerpts from the Workplace Safety Operations Procedure Manual

APPENDIX A

Project QAPP Template

Quality Assurance Project Plan
Data Quality Objectives

Date of QAPP	
Project ID	2013-XX
Project Title	
Principal Investigator(s)	
Quality Officer	

All research projects are required to establish Data Quality Objectives during project initiation, to be presented at the project kickoff meeting or shortly after that, prior to initiation of any activities under the project. Refer to the HSP Research Program Quality Assurance Project Plan (P-QAPP) for additional information.

1. Problem Statement

Discuss why the project is necessary, proposed schedule and budget, and resources needed, or attach a copy of the latest version of the proposal and highlight any modifications proposed to that document.

2. Project Goals

Identify specific study questions to meet the project's objectives (P-QAPP Section 5.1).

3. Boundaries of the Study

Discuss spatial and temporal coverage, and scope of the investigation (P-QAPP Section 5.2).

4A. Field Sampling Methods

Include types of samples that will be collected, and indicate any deviations from the holding times or preservation methods specified in P-QAPP Section 6, or include these for any analytes not listed there.

4B. Safety Considerations

Please list proposed safety protocols and any specific safety considerations for the project (P-QAPP Section 4.2).

5A. Parameters of Concern

Identify parameters of concern in the study (P-QAPP Section 5.3), proposed analytical method, and analytical limits (P-QAPP Section 6). [Use insert rows to add additional POCs].

Matrix (e.g. Water)	Parameter of Concern	Analytical Method	Reporting Limit

5B. Sampling Size

Discuss the proposed number of samples (P-QAPP 5.5) and the estimation method used to determine this value.

6. Data Evaluation Methods

Include the proposed approach to developing statistically valid conclusions based on available data (P-QAPP Section 11.0) and proposed confidence intervals.

7. Quality Control Measures

Measure	Frequency
Field blanks	
Method blanks	
Field duplicates	
Laboratory duplicates	
Matrix Spikes	

7. Quality Performance Standards

Metric	Performance Goal
Precision (C < 20*MDL) (list general baseline and analytes with different precision)	%
Precision (C>20*MDL) (list general baseline and analytes with different precision)	%
Matrix recovery (list general baseline and analytes with different precision)	%

9. Communication Strategy

Discuss the strategy for dissemination of study results at the conclusion of the projection (P-QAPP Section 12).

10. Variances

Discuss any other proposed variances from the requirements of the P-QAPP.

APPENDIX B

STORMDATA data collection template [UNDER DEVELOPMENT]

APPENDIX C

Excerpts from the Workplace Safety Operations Procedure Manual

- 10-16 Personal Protective Equipment (PPE)
- 10-18 Sun Exposure
- 10-21 Work Zone Safety/Traffic Control
- 11E-1 Confined Space Entry

Author:	Tom Werner	Revision #:	2
Approved by:	Len Sanderson	Date Issued:	3/2006

SAFE OPERATING PROCEDURES

Personal Protective Equipment - DOH SOP 10-16

The following are guidelines/requirements for the use of personal protective equipment (PPE). It is not possible to list every instance where PPE is required so it shall be the Supervisor's responsibility to exercise prudent judgement to determine if additional protective equipment is necessary and to insure that the appropriate equipment is worn. The failure to wear appropriate PPE could result in disciplinary action.

Hard Hats shall be worn:

- When there is a clear and present danger of falling objects that may cause injury.
- When exposed (or reasonably expected to be exposed) to falling or flying material.
- When exposed to overhead electrical conductors.
- At the direction of the supervisor.

Orange Caps shall be worn when flagging traffic except in hard hat areas.

Safety vest or approved orange shirts shall be worn:

- When exposed to moving traffic or equipment.
- At the direction of the supervisor.
- When operating equipment within the right-of-way and without an enclosed cab.
- Orange shirts must be supplemented with vests for nighttime operations.
- Reflectorized vests shall be worn for all nighttime operations on the right-of-way.

Safety glasses shall be worn:

- Whenever there is risk of injury to the eye such as: grinding, drilling or sawing.
- When operating various power tools or machines (e.g., weed eaters, woodworking tools, power or concrete saws, rock drills, chippers, jackhammers, etc.) which may throw particles.
- At the direction of the supervisor.
- By any person in a shop area outside of designated aisles or marked areas.
- When jump-starting a battery.

Safety goggles shall be worn:

- When their use is more appropriate than that of safety glasses (as determined by the supervisor).
- Whenever there is a need to protect the eye from dust, sawdust, and mist (e.g., during sandblasting or when using a chainsaw) which can enter or blow into an employee's eye even though he or she is wearing safety glasses.
- Whenever there is a danger of a foreign object entering through the side of the glasses.
- When working with chemicals that may be acidic or caustic.

Face shields shall be worn:

- § When there is danger of splashing chemicals or other substances that may cause injury to the face or neck area (grinding, drilling, etc.).
- § Whenever, in the judgement of the supervisor, their use is more appropriate than other eye protection.
- § When removing or installing a battery.
- § When working with chain saws.

Work gloves should be worn:

- § During any operation where there is a risk of abrasion, laceration, burns, blisters or puncture to the hands. Special impermeable gloves shall be worn when picking up dead animals.

Typical Operations include:

- Hot mix paving or patching
- Fence and guardrail repair
- Sign repair
- Tree trimming and related activities
- Welding and grinding
- Using shovels, picks, etc.
- Handling lumber
- Loading or unloading tanker or distributor
- Sharpening tools
- Operating chain saws, weedeaters or other gas-powered tools

Foot protection must be worn:

- § By all employees except those who do not have regular exposure to hazardous conditions (e.g., office personnel). Foot protection includes safety shoes or work boots, toe caps, or special orthopedic shoes and must meet ASTM F2412-05. If an employee, due to health reasons or physical abnormalities can not wear safety shoes then toe caps shall be worn. If an employee, due to health reasons or physical abnormalities cannot wear toe caps, then special orthopedic safety shoes or boots constructed under the supervision of a physician shall be worn. If an employee, due to health reasons or physical abnormalities, cannot wear special orthopedic safety shoes or boots, then efforts will be made to move the employee to a position with no exposure to foot hazards.

Special impermeable gloves shall be worn:

- § When working with hazardous chemicals or as directed by the Material Safety Data Sheets.

Coveralls or long-sleeved shirts should be worn:

- § When welding or cutting.
- § When exposed to poison oak, ivy or sumac.
- § When exposed to hot materials while hot mix patching or paving, crack sealing or placing thermoplastic markings.

Rubber boots shall be worn:

- § When required by the Material Safety Data Sheets.
- § When mixing and applying certain pesticides.

Fall protection devices (approved belt and lanyard or harness) shall be worn:

- When in the bucket of a traffic truck.
- While working on unguarded work platforms where the fall would be six feet or more.

Respirator protection shall be worn:

(filters/cartridge, supplied air, SCBA, etc.)

- When required by the product label or the Material Safety Data Sheets.
- When mixing and applying certain herbicides.
- When welding or cutting on galvanized metals.
- When sandblasting
- When working with bridge steel containing lead based paint
- When spray painting.
- When determined by the supervisor

Hearing protection must be worn:

- When ever the noise levels in the work environment exceed 85 dba. (The noise level can be determined by your Safety Engineer.

Examples include:

- Sandblasting
- Concrete Saw
- Jackhammers
- Pile drivers
- Chain saws and weedeaters

All types of heavy equipment (dozers, loaders, graders, mixers, etc.) may require hearing protection. This equipment is included in the ongoing testing by the Safety and Loss Control and employees will be advised on individual basis.

Floatation vests or life jackets shall be worn:

- When working over or near water, where the danger of drowning exists.
- All jackets or vests shall be inspected for defects that would alter the strength of buoyancy.
- Defective units shall not be used.
- All jackets or vests shall be U.S. Coast Guard approved.

Clothing NOT appropriate for NCDOT use:

- Shorts
- Tank tops that expose bare shoulders
- Sandals or canvas shoes

Author:	Karen H. Goodall	Revision #:	1
Approved by:	Len Sanderson	Date Issued:	October 1, 2004

SAFE OPERATING PROCEDURES

Sun Exposure SOP 10-18

Information for both on and off the job.

1. By far, the most common cause of skin cancer is overexposure to the sun. Ninety percent of all skin cancers occur on parts of the body that usually are not covered by clothing.
2. People who sunburn easily and have fair skin with red or blond hair are most prone to develop skin cancer. The amount of time spent in the sun also affects a person's risk of skin cancer.
3. To prevent skin cancer:
    a. Cover up with a wide-brimmed hat and a bandanna for your neck. Wear long-sleeved shirts and pants that the sun cannot penetrate.
    b. Use sunscreens to help prevent skin cancer as well as premature aging of your skin. Use a Sun Protective Factor (SPF) rating of 15 or higher. Women may receive added protection by using tinted opaque cosmetic foundation along with a sunscreen. Apply sunscreen at least an hour before going into the sun and again after swimming or perspiring a lot. Do not use indoor sunlamps, tanning parlors, or tanning pills.
    c. You can still get burned on a cloudy day. Try to stay out of the direct sun at midday, because sunrays are the strongest between 10 a.m. and 3 p.m. Beware of high altitudes – where there is less atmosphere to filter out the ultraviolet rays. Skiers should remember that snow reflects the sun's rays, too.
4. Know your skin. Whatever your skin type, do a monthly self-examination of your skin to note any moles, blemishes or birthmarks. Check them once a month and if you notice any changes in size, shape or color, or if a sore does not heal, see your physician without delay.

Related SOP's

General SOP's................................Chapter 10

SAFE OPERATING PROCEDURES

Work Zone Safety/Traffic Control SOP 10-21

Required Personal Protective Equipment (PPE)

Safety Vests	Safety Shoes	Gloves
Safety Glasses	Orange Hat or Hard Hat	

1. Follow Part VI of the Manual on Uniform Traffic Control Devices (MUTCD) and the NC Construction and Maintenance Operations Supplement to the MUTCD.
2. For typical daytime operations, the Work Zone Safety guidelines can be used.
3. Before going to the work site:
   a. Have a traffic control plan.
   b. Load needed traffic control devices and check their condition.
   c. Ensure employees have necessary Personal Protective Equipment. Employees exposed to falling objects must wear a hard hat.
   d. Make sure employees designated as flaggers are properly trained and equipped.
4. Vehicles and equipment in the work zone should be parked on the same side of the road in areas that:
   a. Provide safe entrances and exits for the work area.
   b. Do not create potential conflicts with vehicles/equipment operating in the work area.
   c. Provide maximum protection for workers getting in and out of vehicles.
5. Employees should work facing traffic as much as possible. If this is not practical, a lookout should be provided.
6. Employees should be alert to job site hazards and should identify appropriate escape routes.
7. Personnel may be positioned on a truck or trailer for the placement and retrieval of traffic devices in the workzone as long as appropriate fall protection measures are used.
8. When not actively placing or retrieving traffic cones or similar devices, employees must be transported in the cab of the vehicle.
9. Slow moving operations shall utilize a truck mounted impact attenuator behind the placement vehicle whenever possible.
10. Work zones should be inspected frequently to ensure devices are in place and that traffic is flowing adequately. When inspecting, ask yourself, “What is the driver’s view?”
11. Signs should not be left out during lunch or overnight unless necessary.
12. Police support may be useful under certain conditions. (Example: Traffic Signal Technician servicing a traffic signal.) However, they must be notified as early as possible.
13. Be alert to wide or oversized loads progressing through work zones.
14. If possible, avoid working during peak hours on high volume traffic routes.
15. Do not leave equipment (tripods, etc.) unattended when positioned in/adjacent to travel way.
16. Remove traffic control devices in a timely manner and in a manner that provides the workers with the most protection. Devices should be removed in the opposite order from how they were placed. Cones first (in reverse order) with signs last.

Related SOP’s

General SOP’s	Chapter 10

Author:	Larry Purvis	Revision #:	1
Approved by:	Len Sanderson	Date Issued:	October 1, 2004

SAFE OPERATING PROCEDURES

Confined Space Entry SOP 11E-1

Hazard Review

Engulfment Toxic Gases, Fumes Oxygen Deficiency
Space related hazards-See Entry Permit

Required Personal Protective Equipment (PPE)

Safety Shoes Multi-gas Monitor Retrieval System
Hard Hat **Special equipment-See Entry Permit**

NCDOT operates in many different areas and situations where confined spaces may exist. Typical locations include the holds of ferry vessels, paint truck storage tanks, weigh station scale pits, vertical drill shafts, and sometimes the area between tightly spaced bridge beams. Any area which has a limited opening for entry and exit, or unfavorable natural ventilation, or that is not designed for continuous worker occupancy may be classified as a confined space.

1. All employees shall be trained in the procedures and hazards of the space they are to enter.
2. Employees shall be in good physical condition before entering a confined space.
3. All spaces shall be checked and evaluated by a qualified person before entry.
4. A qualified person shall test for a hazardous atmosphere and complete a confined space entry permit before entry is allowed.
5. No entry will be allowed if any hazardous condition is detected, unless proper protective equipment is used.
6. All persons entering a confined space shall wear the personal protective equipment that is appropriate for the work to be performed.
7. If mechanical ventilation is provided, at least one person shall wear a multi-gas monitoring device. If an alarm sounds, all persons shall immediately evacuate the confined space.
8. Lockout/Tagout procedures shall be followed if the confined space contains mechanically active equipment.
9. The qualified person shall determine if the entry can be made without a qualified attendant or if a standby person is necessary.
10. If an attendant is required, he shall:
    a. Be trained in rescue from outside techniques
    b. Not enter confined space under any circumstances
    c. Be within sight or call of the entrant, and
    d. Have the means to summon assistance.