Memorandum

Date November 18, 2014

To: Forrest Westall, UNRBA

From: Alix Matos, Cardno ENTRIX and Dr. Neely Law, Center for Watershed Protection, Inc.

RE: **Findings of the Screening-Level Analysis to Select Priority Measures**

1 Introduction

In May 2013, the UNRBA released a Request for Qualifications (RFQ) for the UNRBA Nutrient Credit Study and Credit Tool Development Project. The RFQ listed 55 measures that the UNRBA wanted to consider in the credit development project. In June 2013, the UNRBA awarded the contract to Cardno ENTRIX (Cardno) and the Center for Watershed Protection, Inc., (Center), and the contract was signed in February 2014.

On May 13, 2014, Cardno ENTRIX and the Center for Watershed Protection, Inc. submitted a Technical Memorandum titled *Preliminary Practice Definitions*. On May 22, 2014, the Path Forward Committee held a meeting that included other stakeholders in the watershed to finalize the definitions and groupings of measures that would be included in the screening analysis for the Nutrient Credits Project. On June 19, 2014, Cardno ENTRIX and the Center submitted a revised Technical Memorandum entitled *List of Practices to Include in the Screening Analysis for the UNRBA Nutrient Credit Project* which listed the 48 measures to be included in the Screening Analysis. A second Technical Memorandum entitled *Attributes for the Screening Level Literature Review* described a set of key attributes to review the quality of the information available for each measure.

This Technical Memorandum provides the results of a screening-level literature review for the 48 practices and forms the basis of the recommended priority measures for more detailed research and proposed credit development in the next phase of the project. This version of the memorandum has been finalized based on feedback received from stakeholders during the October 20th PFC meeting, the November 4th PFC, as well as email communications and correspondence with the contacts listed below.

Nutrient Reducing Measure	Contact	Affiliation
Stream Restoration	Dr. Barbara Doll	North Carolina State University
Multiple urban measures	Ryan Winston	North Carolina State University
Blue roof	Matthew Jones	Hazen and Sawyer
Hydraulic modification of urban degraded streams	Ken Pensyl	Anne Arundel County
Enhanced E&SC	Rich McLaughlin	North Carolina State University
Nutrient benefits of existing stormwater management structures	Bill Frost	KCI Technologies
Multiple agricultural measures	Deanna Osmond	North Carolina State University
	Anne Coan	NC Farm Bureau
Equine operations	Joey Hester	NCDA&CS Division of Soil and Water Conservation
	Barbara Oslund	NC Horse Council
Biosolids	Dr. David Hardi	NC Department of Agriculture

In addition to the quality of the literature, the practices selected for full credit development will also depend on their implementation potential. Over the past year, Cardno and the Center have participated in several meetings with members of the agricultural community, NCDWR staff, local government representatives at the TJCOG Water Resources Advisory Committee, and at various UNRBA meetings. The feedback received at these meetings as well as email communications form the basis of the implementation potential for each measure.

Table 1 and Appendix A describe the characteristics assigned to rank the quality of the literature and the implementation potential. Each of the measures included in the screening analysis received a separate ranking for data quality and implementation potential. The recommendations for which measures to select for full credit development is based on the combination of these two ranks as summarized in Section 5.

Table 1. Description of the Rankings for the Screening-Level Analysis and Implementation Potential

Quality Rankings Assigned to Measures	**Screening-Level Literature Review**	**Implementation Potential**
High	Received high rankings for at least five of the seven screening attributes. Of particular importance was study location in, or representative of North Carolina Piedmont.	Strong interest identified by stakeholders.
Medium	Received a majority of medium rankings for the seven attributes; or a mix of high and low	No clear indication of interest in measure by stakeholders.
Low	Received a majority of low rankings and, or limited studies available to adequately assess measure performance.	Low interest or applicability in the Falls Lake watershed identified by stakeholders.

The basis of the key attributes selected for this process are included in Appendix A and is based on the "*Studies Factors for Each Study*" from the **DWR Approval Framework For Alternative Nutrient Load-Reducing Measures** (*September 30, 2014*). These represent one set of evaluation factors included in the DWR guidance of the 2-Tier approval process. Cardno and the Center will take into account additional evaluation factors to include measure design and operation specifications, load estimation method, uncertainties in data collection approach and results, nutrient transformation process, and estimation design method in the next phase of the project.

In conducting the screening-level analysis, the project team divided the practices into four categories, including *Urban, Wastewater, Agricultural, and Other*. Among the practices screened, those in the Urban category had the highest number of practices reviewed, and practices in this category generally had the greatest available body of research to support developing nutrient credits. The results of the screening analysis summarized in Section 5, as well as the data tables presented in Appendix B of this report are grouped and summarized according to these four categories. Appendix C provides the rankings of each key attribute for each study. Over 350 publications and reports are included in this preliminary screening analysis, and full references are provided in Appendix D.

2 Urban Measures

This section summarizes the screening analysis for the urban measures. This information is summarized in Section 5.

Bioretention with Design Variants (#1)

Ranking: High data quality – High implementation potential

Bioretention practices are one of the most studied practices among the measures reviewed for this screening analysis. A total of 66 publications were reviewed with all of the attributes ranked as 'high' with the exception of study location. Sixteen of the 66 studies were located in either North Carolina Piedmont or the Piedmont physiographic province, elsewhere (e.g. Maryland). NC State research on bioretention is ongoing, including both monitoring and modeling efforts. Notably, NC State has recently developed the HyPer Model to evaluate long-term performance of bioretention for reducing the volume of runoff and nutrient loads. The studies reviewed included both field and laboratory analyses, and were able to capture the effects of specific design features such as soil media, depth and underdrain configuration. A specific design variant to consider is the use of media enhancements. Recent research by Liu and Davis (2014) suggest that phosphorus enhancing media added to a bioretention soil mixture may improve its performance.

In addition to the large number of high quality studies associated with this practice, implementation potential is High based on feedback received during the May 22nd PFC meeting. In addition, current studies are underway in the City of Durham and Charlotte, NC.

Bio-Swales (#2) and Swales with Design Variants (#16)

Ranking: Medium data quality – High implementation potential

A total of 14 studies were reviewed to quantify the effectiveness of Bio-Swales and Swales with Design Variants. These practices have not been extensively studied in the North Carolina Piedmont, with one recent study reported (Winston, et al., 2011). When compared with other practices, there are relatively few recent studies available for swales, with only six of the 14 conducted within the last ten years. This result is largely due to a switch in focus from these practices to bioretention (#1) or other innovative practices such as Regenerative Stormwater Conveyance (#48) in open channels. These studies included a combination of modeling and monitoring efforts, and most were rigorously performed and about two-thirds had gone through the peer review process. NCSU is conducting an additional study on check dams that should be available in May 2015.

Of the 14 studies reviewed, nine investigated the impacts of a specific design feature such as presence of check dams or channel geometry, on practice performance. It is recommended that these two practices (Bio-Swales and Swales with Design Variants) be combined into one practice if they are selected for final review, resulting in a credit for bio-swales, with a range of performance based on addition of specific design features.

This practice was identified during the October 20th PFC meeting as having High implementation potential.

Swales with Design Variants (#16)

Ranking: Low - reassign to other measure(s)

As described above, we recommend combining bio-swales and swales with design variants into one measure.

Permeable Pavement with Design Variants (#3)

Ranking: High data quality – High implementation potential

A total of 43 publications were reviewed, with fifteen of these publications located in North Carolina Piedmont or Virginia. With the exception of a few older publications, most of the studies were rated highly for most other review factors. In addition, recent research by NC State, including Collins et al (2009) is highly relevant with the study location in Raleigh, NC. A forthcoming monitoring study on permeable pavement in Durham, NC should be available from NCSU in May 2015. While, the development of a HyPER model for permeable pavement is not expected until the Fall or Winter 2015 (personal communication, Ryan Winston, NCSU).

In addition to the large number of high quality studies associated with this practice, implementation potential is High based on feedback received during the May 22nd PFC meeting. In addition, current studies are underway in the City of Durham.

Infiltration Devices, Basins, or Trenches (#4)

Ranking: Medium data quality – High implementation potential

Quite a few studies have investigated the effectiveness of infiltration practices, with 22 papers included in the project database. However, none of the studies were conducted in the North Carolina Piedmont. NC State has done research on a dune infiltration practice recently (Bright et al., 2011), however this practice was located in the Coastal Plain, and infiltration will likely perform differently in the soils of the Piedmont. In spite of the lack of local data, it is possible that these practices can be credited using HyPer Model or DRAINMOD. The project team will consult with NC State to determine the feasibility of crediting the practice in this manner.

The data quality for this measure ranks as Medium due to the location of the studies outside of the North Carolina Piedmont, however, the implementation potential is High due to feedback received during the May 22nd PFC meeting.

Upland Tree Planting / Increased Canopy Cover (#9)

Ranking: Medium data quality – High implementation potential

The prevailing research on the benefits of urban tree planting focuses on the hydrologic impacts, specifically runoff volume reduction through interception, evapotranspiration and infiltration. The focus of the literature review was a review of studies to evaluate the water quality benefits from upland tree planting (that does not include riparian forest buffers). Only two studies are included in the review. Recent research by Mittman (2009) studying the effect urban tree canopy in the Maryland Piedmont supports the hydrologic benefits (i.e., reduction of runoff volume) by converting suburban turfgrass to urban tree canopy, but did not address nutrient load reductions. There are many additional studies on the hydrologic benefits of urban trees, but these were not a part of this screening analysis.

While there are limited field studies to evaluate the nutrient load reduction associated with this process, there is sufficient ecological understanding and research to demonstrate the volume reduction of upland tree planting, combined with empirical stormwater runoff data and models to recommend this for further development. For example, recent developments of the i-tree Hydro model[1] can simulate a modest nutrient reduction for urban watersheds with a high tree canopy. Similar results are presented by Band et al (date unknown) where EMC data is applied to model output to estimate the pollutant load reduction from urban tree canopy. Further, there is likely abundant opportunity for this practice in urban and suburban areas along transportation corridors, vacant lots, open space, parks, etc. For the Falls Lake Watershed, this credit could be credited as a programmatic measure to demonstrate a net increase in nutrient loading associated with increased canopy cover relative to the baseline period.

[1] http://www.itreetools.org/hydro/

This practice was identified during the October 20th PFC meeting as having High implementation potential.

Land or Forest Protection (#10)

Ranking: Medium data quality – High implementation potential

Research clearly documents lower nutrient EMCs and loading rates from forested compared to urban developed land uses. Land and forest protection for new development is an approach used in environmental site design to reduce the effect of development (e.g. impervious cover) on water quality. However, crediting this practice to offset loading from existing development may be challenging since the land use is not likely to change relative to the baseline year. Potential methods for overcoming these challenges include the following:

- Additional management measures could be implemented on the conserved land for which crediting measures are currently available or being developed that would result in a change in baseline loading.
- The conservation could be used to offset requirements due to new development. Money exchanged for purposes of these credits could then be reinvested in the watershed to assist with existing development requirements. Since land and forest protection would change future land use rather than control an existing stormwater load, it could be credited by comparing loads from a presumed development load to one that includes protection of sensitive lands. This practice is credited by the Chesapeake Bay Program, but can only be credited if future land use scenarios are also defined. These scenarios would need to consider the New Development Rules for the Falls Lake watershed including the amount of onsite and offsite reductions allowed under the rules. Credits associated with land conservation near Falls Lake could potentially be adjusted based on the trapping factors currently under development.

While the data quality for this measure ranks as Medium, the implementation potential is High due to feedback received during the May 22nd PFC meeting. The City of Raleigh has also been evaluating the nutrients avoided by implementing land conservation programs as part of their Watershed Protection Program. DWR has also been calculating potential credits based on differences between forest and developed land use loading rates. Once these analyses are finalized, they may provide additional useful information for establishing credits.

Structural Stormwater Devices/ Proprietary Devices (#11)

Ranking: Low data quality – Medium implementation potential

Several states and independent organizations have developed testing protocols to review specific devices. In North Carolina, the Preliminary Evaluation Period (NCPEP) program evaluates manufactured devices to determine if they meet state criteria as stormwater practices, and other programs such as Virginia's VTAP program also evaluate these practices. If these practices are credited in North Carolina, the best option may to categorize specific types of practices that have had independent evaluation sufficient to characterize performance, or to adopt efficiencies reported by another crediting program rather than to develop a new crediting methodology for them. Structural devices that capture material may be weighed and nutrient concentrations applied to estimate a creditable load. If such an approach is adopted, it is recommended that the material captured is characterized as sediment, detritus/organic material and an appropriate concentration applied. It may be necessary to provide monitoring data to support this credit.

Another possible approach to crediting these practices is to assign a range of efficiencies to specific practice categories. Some general categories of Structural (or Manufactured) Stormwater Devices include the following:

- Catch Basin Inserts[2]: This category includes practices that are inserted in the catch basin to filter stormwater runoff. These practices vary widely both in terms of the filtering medium or method of the insert and the volume of stormwater that can be treated by the practice. As a group, these practices tend to have very high maintenance requirements, particularly when leaf debris is captured by the devices.

[2] Some catch basin inserts function as a filtering device, but are described separately here.

- Hydrodynamic Separation Devices: These are practices that remove pollutants from stormwater though settling or separation. Some examples include the Stormceptor or Vortex devices. Although these devices have different configurations, ranging from a "swirl concentrator" in place of a traditional manhole to a multi-chambered "water quality inlet," these practices all function through settling of sediments and separation of floatable pollutants such as trash and oil.
- Stormwater Filters: Stormwater filters remove pollutants by filtering stormwater through some medium. There is a tremendous variety in the specific design characteristics of these products, including vegetative filters such as Filterra and StormTreat, as well as non-vegetative practices such as BaySaver or StormFilter.
- Infiltration devices: These practices are manufactured products that treat stormwater runoff by encouraging infiltration into native soils. These practices, while often proprietary, can typically be evaluated as traditional infiltration practices, based on the storage available and the permeability of the underlying native soils. Infiltration devices are covered as a separate measure for this study.

Two options are available for crediting these practices, including accepting efficiencies for specific technologies based on the results of studies approved by the Technology Acceptance Reciprocity Partnership (TARP) program, or conducting ongoing tracking of material collected in these practices to document long-term performance.

The first option for documenting performance of structural practices is to accept performance rates certified by the TARP program (TARP, 2001). The TARP outlines stringent standards for accepting stormwater technologies, including a Level 1 (Lab) assessment and a Level 2 (Field) assessment. While not all practices are certified for nutrient removal, it may be useful to review reports submitted to TARP member states, which include California, Maryland, Massachusetts, New Jersey, Pennsylvania and Virginia.

There are some practices for which an alternative option may be preferable. For example, few Catch Basin Inserts have been approved by TARP-member states. In addition, one concern for implementing these practices is the ongoing maintenance burden. Although TARP certification requires an ongoing maintenance plan and cost analysis, some of these practices require frequent maintenance, particularly during the fall when these small volume practices can be overwhelmed by debris. This is particularly true for the smaller-volume catch basin inserts (Pitt, 2001; Versar, 2008). One potential approach for these practices is to certify pollutant removal based on the amount of material collected from these practices during regular maintenance, and then multiplying by a nutrient enrichment factor. This approach is used by the Chesapeake Bay Program to certify pollutant removal achieved by street sweeping (Goulet, 2011) and could be used for these practices as well.

Very little peer-reviewed studies have been conducted for these proprietary devices. While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so these practices receive a Medium ranking for implementation potential.

Sand Filters (with media enhancement) (#12)

Ranking: Medium data quality – Medium implementation potential

Quite a few studies have investigated the effectiveness of infiltration practices, with 14 papers included in the project database. However, none of the studies were conducted in the North Carolina Piedmont, and the one that was completed in nearby Virginia was from 20 years ago (Yu, 1994). This practice can potentially be modeled with DRAINMOD. In general, designers have moved away from sand filters in recent years, using bioretention where space permits, and using proprietary filter options where space is limited. The use of enhanced media (such as iron filings) may increase the phosphorus removal of sand filters based on a literature review by Law et al (2014) and modeling and field studies completed in Minnesota (Erickson et al 2012). The recommendation to further develop sand filters as a measure would be based on the use of enhanced media as part of the design specifications.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Enhancement of Constructed Wetlands (#13)

Ranking: Medium data quality – Medium implementation potential

The initial review included 32 papers that focused on wetland performance, of which 12 were in the North Carolina Piedmont. Studies investigated several specific wetland design characteristics, including the use of wetlands in series (Hathaway and Hunt, 2009), importance of ongoing maintenance of wetlands (Hunt et al., 2011, Merriman et all, 2014), the role of vegetation (Lenhart et al., 2012, Merriman et al., 2012), use of innovative substrate materials (Rosenquist et al., 2011, Yates, 2008, Zhao, 2006). Despite the available research for this measure, the weight of evidence to attribute an increase in performance of a constructed wetland to an 'enhancement' is limited. The best option for this practice may be to identify specific design features that enhance pollutant removal, as well as maintenance recommendations to ensure continued performance. Alternatively, enhancement can be defined as achieving "high end" pollutant removal based on the range of performance reported.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Soil Amendment (#15)

Ranking: Medium data quality – High implementation potential

The purpose of this practice is to enhance and restore soil infiltration capacity. Soil amendments can be accounted for as a stand-alone practice (e.g., restoring urban soils) or in combination with other practices such as filter strips, swales and rooftop disconnection (i.e., media enhancement that may be defined as another measure when additives are mixed in with soil media). The data for this practice is limited with little recent data to evaluate water quality benefits. While several states and organizations have developed credits for this practice, the credits are typically based on results from relatively few studies, most of which focus on runoff reduction rather than nutrient removal. The initial literature review revealed only nine studies, and none of these were from the North Carolina Piedmont region. There is currently an NSCU downspout disconnection study underway that includes sites with soil amendments. The final report is expected December 2014, and this study could be used to support credit development for this practice.

While the data quality for this measure ranks as Medium, the implementation potential is High due to feedback received via email from the City of Durham after the October 20th PFC meeting.

Enhancing or Repairing Existing Riparian Buffers (#8)

Ranking: Low - reassign to other measure(s)

This practice was originally defined in the Preliminary Practice Definitions memorandum as "Replacing, replanting, or managing appropriate vegetation for the purposes of maximizing net nutrient reductions in riparian buffers." During the Path Forward Committee meeting held on May 22, 2014, the attendees requested that if sufficient literature was not available to credit this practice separately, that these management actions would be included under Riparian Buffer Restoration (#26). Based on the current research, Cardno and the Center do not recommend developing this measure separately. Additional research may provide clarification to better distinguish the practice of "enhancing or repairing existing riparian buffers" from restoration in the future.

Repair or Enhancing Failing BMPs (#45)

Ranking: Low – evaluate projects individually

The publications reviewed relate primarily to BMP maintenance to address failing BMPs. These publications, combined with ranges of performance of specific BMPs, could be used to estimate the benefits of restoring or enhancing practices. However, because baseline and enhanced conditions would vary widely at each site, a credit for this measure should likely be evaluated on a case by case basis. While we don't recommend this measure for general credit development, we do suggest that credits be allowed based on site specific calculations.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Stream Restoration (#5)

Ranking: Low - practice standard currently scheduled for development by DWR

A detailed review of stream restoration is provided in Tetra Tech (2013) and is currently being reviewed for development as a practice standard by DWR. The recommendations in Tetra Tech (2013) are based on Schueler and Stack (2013) as part of the EPA Chesapeake Bay Program Expert Panel. The recommendations reflect a robust review of the science to account for nutrient and sediment reductions as a result of stream processes (e.g. reduction in stream bank & bed erosion, floodplain deposition and baseflow denitrification). The Chesapeake Bay Program recently approved a revised set of recommendations on September 8, 2014 for the *default rate* of TN, TP and sediment load reductions. The three protocols to estimate the nutrient and sediment load reduction from stream restoration did not change, however, the default rate for TN, TP and TSS was revised and are presented in Table 2. The default rate for TSS reflects a sediment delivery factor that is specific to the Chesapeake Bay for non-coastal and coastal streams. Further, the revised default rate for TN and TSS also include an efficiency of 37.5 percent and 80 percent, respectively applied to the default rate to reflect the effectiveness of stream restoration as a practice. These efficiencies are based on a stream restoration project, Spring Branch in Baltimore County, MD (Piedmont). The removal rate of 0.068 lb TP/ft/yr accounts for a 50 percent efficiency, and this value was not revised relative to the draft numbers. Schueler and Stack (2013) provide qualifying conditions to apply this credit to non-urban stream restoration projects.

Table 2. Adapted from the Chesapeake Bay Program Recommendations for a Default Pollutant Loading Reduction Rate (lb/ft/yr) for Stream Restoration Practices (the default rate is of the edge-of-stream)

Source	TN	TP	TSS
Prior Interim CBP Rate[1]	0.20	0.068	310 (56.11)[2]
Revised Default Rate	0.075[2]	0.068	248[2] (44.88 non-coastal plain[1])

[1]Derived from six stream restoration monitoring studies: Spring Branch, Stony Run, Powder Mill Run, Moore's Run, Beaver Run, and Beaver Dam Creek located in Maryland and Pennsylvania

[2] To convert edge of field values to edge of stream values a sediment delivery ratio (SDR) was applied to TSS. The SDR was revised to distinguish between coastal plain and non-coastal plain streams. The SDR is 0.181 for non-coastal plain and 0.061 for coastal plain streams. Additional information about the sediment delivery ratio is provided in Section 2.5 and Appendix B in Schueler and Stack (2014)

[3] Stream restoration practice efficiencies of 37.5% and 80% applied to TN and TSS respectively

The implementation potential for this measure ranks High based on feedback received during the May 22nd PFC meeting. However, DWR is already developing the practice standards for this measure and it is therefore ranked as a low priority measure for this contract. Current local studies are ongoing in the City of Durham, and once these studies are finalized, it may be prudent to update the practice standard at this time.

Riparian Buffer with Varying Widths in Urban/Suburban Areas (#7)

Ranking: Medium data quality – High implementation potential

The prevailing science indicates that a wider buffer is necessary to achieve effective reductions in nutrient and sediment loadings to streams. However, research by Speiran (2012) and Mayer et al (2007) suggest that subsurface hydrologic flowpaths are more critical to nitrate pollutant load reduction than riparian buffer width. Most research supports riparian buffer widths for water quality improvement in the 50–150 foot range. An updated synthesis literature review by Sweeney and Newbold (2014) concluded that adequate removal of sediment requires widths substantively wider than 33-ft, while narrow buffers yield higher removal where water flux is low; however few studies documented water flux across buffers. Weller et al (2010) indicate that an evaluation of the impact of varying width of riparian buffer may be site specific and related to its spatial configuration in the watershed.

While the data quality for this measure ranks as Medium, the implementation potential is High due to feedback received during the May 22nd PFC meeting. If this practice is selected for further credit development, practice standards developed for applications in urban/suburban areas would differ from those developed in agricultural areas.

Leaf Litter Recovery (#14)

Ranking: Medium data quality – High implementation potential

Currently, there are no studies that directly demonstrate the impact of leaf litter recovery and water quality improvement. A number of indirect studies and a couple of forthcoming publications provide support that would suggest a positive impact on this practice. For example, phosphorus loads collected by street sweepers increased in Minnesota neighborhoods with higher tree canopy cover. Further, studies consistently show the significant amount of leaf litter washed-off from urban drainage areas into net collection systems in streams. While leaf litter provides a necessary carbon source for aquatic ecosystems, an overabundance of nutrients and carbon can impact water quality. Current studies are underway by Wisconsin USGS and by NSCU to study the water quality impact of leaf litter collection in curbs. The NCSU study is being carried out in four municipalities in NC over a one year period. This study which is assessing nitrogen and phosphorus will end with forthcoming results expected in May 2015 that may provide insight to the nutrient load contributed by leaf litter in urban stormwater runoff. Further, recommendations on this practice from a Chesapeake Bay Program expert panel report are expected in early 2015. While the data quality for this measure ranks as Medium, the implementation potential is High due to feedback received during the May 22nd PFC meeting.

Filter Strip with Design Variants (#17)

Ranking: High data quality – High implementation potential

Seven studies are available to quantify credits associated with this practice, and most of the quality rankings were high for the various attributes. The most recent research on filter strips is provided by NCSU that evaluate this practice for volume and nutrient reduction and mitigating thermal impacts on streams. This research provided information to support the development of the level spreader- vegetated filter strip BMP in the State's Stormwater Design Manual. The designs of the filter strips evaluated included a blind swale with level spreader (Winston et al 2011) and soil amended with ViroPhos (Knight et al 2013).

Implementation potential is High based on feedback received during the May 22nd PFC meeting.

Impervious Disconnection/Rain Catchers (#21)

Ranking: Low – Awaiting additional data

Tetra Tech (2013) provided a review of this practice and DWR has drafted a practice standard that includes nitrogen and phosphorus credits based on volume reduction. Data is forthcoming from a residential downspout disconnection study in South Ellerbe Creek watershed in Durham, NC. A final report is expected December 2014. Stakeholders at the May 22nd PFC meeting indicated a High implementation potential for this practice. However, we do not recommend further development of this credit until additional data are collected and analyzed.

Urban Nutrient Management (#23)

Ranking: Medium data quality – High implementation potential

The study of nutrient runoff and leaching from turfgrass fertilizer use is a well-documented area of research with highly variable results. Of the 13 studies reviewed, 8 studies were located in North Carolina Piedmont or similar in characteristics. The export of nutrients from managed urban turfgrass may differ based on management practices (e.g. the frequency, timing, application rate of fertilizer, fertilizer type) as well as the physical-chemical characteristics of the soil and turfgrass species. Crediting this measure will require a translation of the key factors affecting nutrient export into management actions or behaviors to reduce input and export of nutrients from turfgrass or adjacent impervious cover. For example, the Chesapeake Bay Urban Nutrient Management expert panel report (2013) translated these main factors affecting nutrient export into a set of risk factors.

While the data quality for this measure ranks as Medium, the implementation potential is High due to feedback received via email from the City of Durham after the October 20th PFC meeting.

Street Sweeping (#42)

Ranking: Low - practice standard currently scheduled for development by DWR

A number of studies to evaluate the performance of street sweeping are available and date back to the National Urban Runoff Pollutant (NURP) program in the early 1980s. However, the majority of the street sweeping studies focus on the 'pick-up' efficiency of street sweeping with fewer studies documenting the load reduction, or water quality benefits from this practice. Recent results presented by Sorenson (2013) suggest potential load reductions ranging from 2.7 percent to 19 percent for total solids and 1.4 percent to 9.3 percent for total phosphorus based on the type of street sweeper and frequency of cleaning.

Stakeholders at the May 22nd PFC meeting indicated a High implementation potential for this practice. DWR has recently drafted a practice standard for street sweeping and will be revising the preliminary credits based on model runs and additional analyses by the Chesapeake Bay Program. Therefore, this practice is ranked as low priority for inclusion in this study.

Enhanced Erosion and Sediment Control (#47)

Ranking: Medium data quality –Medium implementation potential

Erosion and sediment control is a required practice for construction sites. A review of E&SC practices in the Chesapeake Bay watershed that included studies from North Carolina find a significant reduction in sediment loadings, with highly variable nutrient loads as a result of practice implementation. The research studies that examine nutrient export from construction sites are limited in sample size to reliably inform general performance or effect from specific ESC measures. For example, there was no consistent pattern shown by McLaughlin and King (2008) with respect to total nitrogen effluent concentrations and enhanced ESC measures at construction sites in 3 NC counties. For nitrogen, concentrations decreased by approximately 2 percent up to 20 percent when enhanced ESC measures were used. For phosphorus, some sites with enhanced ESC measures had lower total phosphorus concentrations and some had higher. For the Falls Lake Watershed, this credit would

likely need to be credited as a programmatic measure to demonstrate a net reduction in nutrient loading from erosion and sediment due to enhanced practices relative to the baseline period.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Regenerative Stormwater Conveyance (RSC) (#48)

Ranking: Low - practice standard currently scheduled for development by DWR

A review of RSC as nutrient load reducing measure is provided in Tetra Tech (2013) and is currently being reviewed for development as a practice standard by DWR. Schueler and Stack (2014) differentiate between a dry channel RSC and a wet channel RSC. A dry channel RSC was defined as a stormwater retrofit practice, while a wet channel RSC was defined as a stream restoration BMP and implemented in intermittent streams, or further down perennial stream networks than dry channel RSC. However, the distinction between these two RSC types are not well- differentiated in the literature. Regenerative stormwater conveyance (RSC) projects are also referred as to sand-seepage wetland systems and typically occur within the stream channel. There is limited published data for RSC projects in Piedmont areas but preliminary data is available from Cizek (2014) for two RSC projects in ephemeral channels in Brunswick and Alamance Counties, NC in coastal and Piedmont regions, respectively (Table 3). The project is being done in coordination between NC DOT and NCSU. It should be noted that NC DOT references this practice as biofiltration conveyances.

Table 3. Preliminary results of two RSC projects in Brunswick and Alamance Counties, NC (Source: Cizek, 2014).

Project site	**Volume Reduction**	**Peak Discharge Reduction**
Brunswick County (coastal)	95%	82%
Alamance County (piedmont)	75%	90%
Pollutant Load Reduction		
TSS: 75%	TN: 31%	TP: 30%

The implementation potential for this measure ranks High based on feedback received during the May 22nd PFC meeting. However, because DWR is already developing the practice standards for this measure, this is a low priority measure for this contract.

Hydraulic Modification of Urban, Degraded Streams (#6)

Ranking: Low - reassign to other measure(s)

Research indicates that the components that would make up this practice are generally covered by other measures that are included in this project such as stream restoration and regenerative stormwater conveyance. For example, the Center for Watershed Protection contacted Ken Pensyl with Anne Arundel County, MD to discuss the application and performance of hydraulic modifications of urban degraded streams. This application is a step pool conveyance design that is considered an “edge of perennial” stream application of regeneration stormwater conveyance practice designs.

The implementation potential for this measure ranks High based on feedback received during the May 22nd PFC meeting. However, we recommend reassigning the various components of this measure to other measures included in this study based on the available literature.

Blue Roof (#18)

Ranking: Low data quality – Medium implementation potential

A blue roof is a green roof without the soil and vegetation. A conversation with Matthew Jones with Hazen Sawyer provided a summary of a current blue roof project currently being monitored in New York City. Based on this single study, there is insufficient information to evaluate the performance of blue roof as a nutrient reducing measure at this time. A blue roof study will begin at UNC in 2015. While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Nutrient Benefits of Existing Stormwater Management Structures (#19)

Ranking: Low – evaluate projects individually

The evolution of a stormwater management structure may include features that provide water quality benefits, above and beyond the design specifications of the practice at the time of implementation. This includes for example dry detention ponds that have 'voluntarily' converted to shallow marsh or forested wetland systems. This results largely from a lack of maintenance, rather than a design intervention through retrofitting the practice. Baltimore County, MD is currently studying the effects of self-converting dry ponds to wetland systems with results expected in 2015 (personal communication, Bill Frost, KCI Technologies). Credits for these types of conversions may be available on a case by case basis, but establishing a general credit that would be appropriate for widely varying site conditions (both pre and post) would not be appropriate. Stakeholders at the May 22nd PFC meeting indicated a High implementation potential for this practice.

Pond Retrofits/Upflow Filter (#20)

Ranking: Low - practice standard currently scheduled for development by DWR

There are no additional reports or publications to add to the Tetra Tech (2013) review for this practice. Recommendations from a Chesapeake Bay Program expert panel on floating wetlands, as a specific type of pond retrofit, are expected in the Fall 2014. DWR is currently developing a practice standard for floating wetland islands, which were the most promising pond retrofit measure according to the Tetra Tech (2013) report.

The implementation potential for this measure ranks High based on feedback received during the May 22nd PFC meeting. However, because DWR is already developing the practice standards for floating wetland islands, this is a low priority measure for this contract. The other pond retrofit practices did not warrant further credit development because the impact on nutrient loading is minor.

Conversion of Impervious Surfaces to Pervious Surfaces (#22)

Ranking: Medium data quality – Medium implementation potential

In order to pursue this measure, a baseline would need to be established for each case of implementation to make comparisons. Similar to upland tree planting, or land or forest protection, the water quality benefits for this measure from monitored data are limited. Comparative methods have been used in the past, and one option would be to use the difference in estimated land use load from the Jordan/Falls Lake Stormwater Load Accounting Tool (JFSLAT).

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential. During the October 20th PFC it was suggested that this practice may be reduced to Low implementation potential because credits can already be evaluated using the JFSLAT. After that meeting, DWR indicated that implementation potential should remain Medium because even though the tool is available, development of a practice standard to accompany the tool would still be needed.

Reduce Pet Waste Transmissions to Surface Waters (#43)

Ranking: Low data quality – Medium implementation potential

No relevant studies were found for quantifying nutrient reductions associated with this practice. If this practice is selected, effectiveness will need to be based on a series of assumptions regarding education effectiveness, pet waste composition and quantity of pet waste treated. City of Austin, TX pet waste program and Dietz et al (2004) suggest that targeted and intensive public outreach campaigns can significantly affect adoption of behaviors such as picking up pet waste to reduce negative impacts on water quality.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Permeable Reactive Barriers (#24)

(Previously named Wood Chip Bioreactors)

Ranking: High data quality – Low implementation potential

Woodchip bioreactors have been used substantially in the Midwest as well as other areas of the world in agricultural settings with subsurface drainage. While typically used in conjunction with tile drained agricultural fields, this technology may also be used in urban and rural settings to intercept and treat collected subsurface flow. In the Falls Lake watershed, agricultural fields are not tile drained, so the conventional application is not applicable here; however, permeable reactive barriers, whether using sawdust to promote denitrification, or a specialized material to remove a pollutant of concern would be highly applicable. These facilities generally include a trench backfilled with a mixture of sawdust and sand perpendicular to groundwater flow. Though the most notable example of this concept was done in New Zealand, results show predictable reductions as well as a useful life of over 15 years. Denitrifying walls are also starting to appear in the US with installations on Maryland's Eastern Shore recently coming online. Water quality data tend to be for septic systems; however, the source of nitrate likely does not matter.

Though studies are starting up in North Carolina, published literature is still sparse for this geographic area. A primary limiting factor to permeable reactive barriers is the amount of water treated as opposed to bypassing the facility since design tends to allow peak flows to bypass. Preliminary screening for permeable reactive barriers included 10 papers, though the body of literature available is much more substantial. Preliminary screening for denitrifying walls included 10 papers. Implementation potential is Low in agricultural areas based on feedback received during the May 22nd PFC meeting. In urban, suburban, and rural applications, stakeholders have identified this practice as having Low implementation potential.

3 Rural / Agricultural Practices

This section summarizes the screening analysis for the rural / agricultural measures. This information is summarized in Section 5. Credits associated with agricultural applications of these measures would be developed in coordination with the WOC as specified in the Falls Lake Nutrient Management Strategy.

Practices implemented in rural areas could include some of the measures identified as "urban" in Section 2, as well as measures described in this section. A very limited set of practices are recommended for agricultural application as high priority for credit development under this project based on the following factors:

- Representatives from the agricultural community expressed high implementation potential for measures directly impacting streams such as livestock exclusion, stream restoration, and buffer restoration.
- In the Falls Lake Watershed, the majority of the agricultural land is pasture with low animal densities, so the majority of measures typically credited for agriculture would have limited applicability in this watershed. However, interest has been expressed in developing credits for many of these measures for equine operations.
- Representatives from the agricultural community indicate that most row crop agriculture already utilizes some form of conservation tillage as well as nutrient management plans. For most of the year, fields are in crop production and not barren. These characteristics limit the applicability of some of the practices in this watershed.

Livestock Exclusion (#25)

Ranking: Medium data quality – High implementation potential

Literature for this measure is generally focused on vegetation health; however, there is adequate information on this topic to recommend this measure for credit development. Work done in North Carolina suggests significant reductions in phosphorus and Total Kjeldahl Nitrogen due to exclusion. Recent work in the Jordan Lake Watershed suggest a combination of livestock exclusion and nutrient management has potential to reduce phosphorus and sediment loads. Likely riparian buffer and stream restoration papers could be used to infer water quality benefits as well by estimating nutrient loss prevention (i.e. the result of which could be livestock exclusion).

Stakeholders at the May 22nd PFC meeting indicated a High implementation potential for this practice.

Buffer Installation in Agricultural Areas (#26)

Ranking: Medium data quality – High implementation potential

The method proposed for estimating credits for buffers of varying width in the urban section may be used to estimate credits associated with buffer installation in agricultural areas as well. Much interest in developing credits for this practice was expressed during the May 22nd PFC meeting and the March 23rd meeting with WOC representatives. If this practice is selected for further credit development, practice standards developed for applications in urban/suburban areas would differ from those developed in agricultural areas.

Managed Grazing (#27)

Ranking: Medium data quality – Medium implementation potential

This practice has multiple specific practices (to varying degrees). There is a limited amount of water quality data associated with each specific management practice reported in the literature. In addition, the majority of the agriculture in the Falls Lake Watershed is pasture with low densities of animals, so this measure would not have a significant impact on nutrient loading and this is a Low Priority measure for credit development under this project.

Stakeholders at the May 22nd PFC meeting indicated a Low implementation potential for this practice because of the low number of confined animals in the basin. However, interest was expressed for extending this measure to equine operations, so the implementation potential has been elevated to Medium. Based on feedback received during the October 20th PFC meeting, this measure will be included as part of a system of measures for waste management at equine operations. During the October 20th PFC meeting, it was also noted that this measure is applicable to animal operations other than equine, and that these credits should be available for all animal operations in the watershed even if additional implementation is most likely to occur at equine operations.

Proper Animal Waste Handling, Storage and Disposal (#28)

Ranking: Low - evaluate projects individually

These measures typically address how manure is managed, stored, and disposed of (e.g., covered, concrete pads used to store manure and protect from precipitation). Because the majority of the agriculture in the Falls Lake Watershed is pasture with low densities of animals, this measure would likely not have a significant impact on nutrient loading, so this is a Low Priority measure for general credit development under this project. For example, manure application tends to be low in the Neuse River Basin with a 2011 report suggesting only ~2 percent of the fields having manure applied. However, representatives from the agricultural community indicate that certain facilities with confined animals and poor operating conditions may be good candidates for this practice and site specific credit estimation may be appropriate at these sites.

Stakeholders at the May 22nd PFC meeting indicated a Low implementation potential for this practice because of the low number of confined animals in the basin. However, interest was expressed for extending this measure to equine operations, so the implementation potential has been elevated to Medium.

Proper Animal Nutrient Supplementation and Feeding Strategies (#29)

Ranking: Medium data quality – Medium implementation potential

Changing animal diets is a great idea for a farmer when considering the economic impact of feed mixes and vitamin supplementation. For example, the Swinker (2010) reports that horses are fed 161 percent of the amount of protein and 184 percent of the amount of phosphorus recommended. Correcting these ratios provides an opportunity to reduce nutrients in manure. Very little information exists on water quality impacts of feed regime so inferences are needed about manure application and runoff. Ultimately, changing feeding regimes would need to be factored into the nutrient management plan.

Stakeholders at the May 22nd PFC meeting indicated a Low implementation potential for this practice because of the low number of confined animals in the basin. However, interest was expressed for extending this measure to equine operations, so the implementation potential has been elevated to Medium. Based on feedback received during the October 20th PFC meeting, this measure will be included as part of a system of measures for waste management at equine operations. During the October 20th PFC meeting, it was noted that this measure is also applicable to animal operations other than equine, and that these credits should be available for all animal operations in the watershed even if additional implementation is most likely to occur at equine operations.

Animal Waste Composting (#30)

Ranking: Medium data quality – Medium implementation potential

Five studies were identified for this practice, and most included information on specific practices (i.e., composting hog waste with various carbon sources).The addition of compost to soil enhances soil quality, reduces runoff and erosion, and increases plant growth and processing of nutrients. In addition, reductions in nitrogen due to denitrification and pathogens due to high composting temperatures have been documented. However, the majority of the agriculture in the Falls Lake Watershed is pasture with low densities of animals, so this measure would not have a significant impact on nutrient loading and this is a Low Priority measure for credit development under this project.

Stakeholders at the May 22nd PFC meeting indicated a Low implementation potential for this practice because of the low number of confined animals in the basin. However, interest was expressed for extending this measure to equine operations, so the implementation potential has been elevated to Medium. Based on feedback received during the October 20th PFC meeting, this measure will be included as part of a system of measures for waste management at equine operations. During the October 20th PFC meeting, it was noted that this measure is also applicable to animal operations other than equine, and that these credits should be available for all animal operations in the watershed even if additional implementation is most likely to occur at equine operations.

Cover Crops (#31)

Ranking: Medium data quality – Low implementation potential

Substantial work has been done to quantify the water quality benefits associated with cover crops, but none of the studies were conducted in the Piedmont of NC. However, representatives from the agricultural community in the Falls Lake Watershed indicate that the crop rotations in this basin generally have a crop growing during all seasons, which limits the implementation of this particular practice.

Stakeholders at the May 22nd PFC meeting indicated a Low implementation potential for this practice because most agricultural land has crop or vegetation during all seasons.

Conversion to Trees or Grass (#32)

Ranking: Medium data quality – High implementation potential

In order to pursue this measure, a baseline would need to be established for each case of implementation to make comparisons. Similar to upland tree planting, or land or forest protection, the water quality benefits for this measure from monitored data are limited. Comparative methods have been used in the past (i.e., load from soybeans compared to the load from forest for the same soil type and same climatic region). One option would be to use the difference in estimated land use load from the Jordan Lake Watershed Model. Additionally, much of the agricultural land consists of small plots which may limit the ability to pull marginal land out of production.

This practice was identified during the October 20th PFC meeting as having High implementation potential.

Pond Creation (#33)

Ranking: Low data quality – Medium implementation potential

Ponds are generally used for irrigation or livestock watering, and most literature is about the actual water quality in a pond, not the benefit of watershed water quality provided by a pond. Ponds could be modeled based on sediment delivered and surface area of the pond or urban literature could be used as a surrogate for agricultural water quality benefits. In addition, volume losses due to application of pond water for irrigation could be used to estimate credits. Finally, agricultural ponds tend to be installed where a consistent supply of relatively clean water can be captured, which tends to be in contrast to the goals of nutrient reduction. That being said, based

on best professional judgment of the NRCS, these practices have been listed as being a good practice for water quality.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Pond Renovation (#34)

Ranking: Low - evaluate projects individually

See Pond Creation (#33). NRCS cost share documentation indicates that this is a good measure (sealing or lining) for reducing excessive nutrients. Credits due to pond renovation will likely vary on a case by case basis.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Conservation Tillage (#35)

Ranking: Medium data quality – Low implementation potential

Conservation tillage has been shown to be a suitable agricultural water quality measure; however, representatives from the agricultural community indicate that this practice is already widely used in the Falls Lake watershed so additional credits from this practice would be minimal.

Stakeholders at the May 22nd PFC meeting indicated a Low implementation potential for this practice because this practice is already widely used in the Falls Lake watershed.

Constructed Wetland (#36)

Ranking: Medium data quality – Medium implementation potential

This practice can be modeled based on surface area, if desired, though inflow concentrations of nitrogen as well as hydraulic loading have an impact on performance. An Illinois report suggested 42 percent reductions in phosphorus; however, long term impacts on phosphorus are likely negligible if systems are not adequately maintained. This practice likely has potential for nitrogen removal and should be carried forward, so long as there are enough potential installation sites in the Upper Neuse to make potential water quality enhancement practical. Phosphorus reductions would likely be tied to sediment captured in the wetlands.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Nutrient Management Plans, Comprehensive Nutrient Management Plans, and Waste Management Plans (#37)

Ranking: Medium data quality – Medium implementation potential

The effectiveness of nutrient management plans is determined by the baseline (or comparative) scenario as well as the level of implementation. For example, if the baseline scenario is a confined animal feeding operation with 700 head applying manure on 200 acres, there would likely be substantial water quality improvement by developing a nutrient management plan as the number of acres used to apply manure would increase. The EPA suggests approximately 23 percent reduction in nitrogen and phosphorus due to new confined feeding operation rules.

The majority of the agriculture in the Falls Lake Watershed is pasture with low densities of animals, so this measure would not have a significant impact on nutrient loading. However, representatives from the agricultural community indicate that some farmers may be over applying phosphorus to tobacco in the Falls Lake Watershed, so reductions may be achievable for these fields. In addition, this measure may be applicable at equine operations that do not currently have a nutrient management plan. Therefore, the implementation potential for this measure is ranked as Medium. Based on feedback received during the October 20th PFC meeting, this measure will be included as part of a system of measures for waste management at equine operations. During the October 20th PFC meeting, it was noted that this measure is also applicable to animal operations other than equine, and that these credits should be available for all animal operations in the watershed even if additional implementation is most likely to occur at equine operations.

Decommissioning of Failing Facilities (#38)

Ranking: Low - evaluate projects individually

This measure should not be pursued for general credits because reductions in nutrient loading will vary considerably at each site. Decommissioning of failing facilities should be credited on a case by case basis. A limited number of specific facilities have been identified in the Falls Lake Watershed that may benefit from this measure, so the implementation potential is ranked as Medium.

Waste Management for Equine Operations (#39)

Ranking: Medium data quality – Medium implementation potential

Barbara Oslund with the NC Horse Council currently has 319 grant studying BMPs for equine operations in the Falls Lake watershed. Researches at Penn State are also studying the impacts of measures such as livestock exclusion; managed grazing; proper animal waste handling, storage and disposal; proper animal nutrient supplementation and feeding strategies; nutrient management planning; and properly drained high-use areas. While stakeholders in the Falls Lake watershed have expressed interest in developing credits for this measure, it may be premature to develop as a separate measure for equine operations until data collection and analysis is complete. However, some of the credits already listed above should be extended to equine operations such as livestock exclusion, buffer installation, etc.

During the October 20th PFC meeting, it was suggested to rename this measure “waste management for equine operations,” and include four separate measures in this category: managed grazing, proper feeding and nutrient supplementation, nutrient management plans, and animal waste composting.

4 Wastewater Practices, Air Emissions & Other Measures

This section summarizes the screening analysis for the wastewater and other measures. This information is summarized in Section 5.

Replace/Repair Leaking Collection System Lines and Identify and Remove Stormwater Discharges Connected to Sanitary Sewer System (inflow) (#40)

Ranking: Low data quality – Medium implementation potential

While many studies have documented the benefits of removing stormwater discharges to the sanitary sewer system, as a part of Infiltration and Inflow studies and modeling efforts, the results are difficult to generalize. While there may be a high implementation potential for this practice, the credit for removing these discharges should be awarded based on a particular modeling effort for a specific storm drain system or accompanied with monitoring data to quantify the removal of the discharge given the site-specific characteristics of individual discharges.

While this practice was discussed during the May 22nd PFC meeting, no input was received that would warrant a High or Low ranking for implementation potential, so this measure is assigned a Medium implementation potential.

Remove Illegal Wastewater Connection to Stormwater Systems or Surface Waters (#41)

Ranking: Medium data quality – High implementation potential

This practice has very high potential to improve water quality, but the performance is not easily generalized based on existing literature (i.e., differences in type of discharge, frequency, pollutant of concern etc.). This is because the contribution of each wastewater generating source is so highly variable. At the same time, long-term monitoring in North Carolina demonstrate sustained decreases of in-stream nutrient concentrations during baseflow (Cox, Personal Communication), and available data suggest that removing illicit discharges is one of the most cost-effective techniques to reduce nitrogen pollution (Lilly et al., 2012). The best strategy for crediting practices that manage these pollutant sources may be a hybrid approach that combines a general programmatic credit for implementing better Illicit Discharge Detection and Elimination (IDDE) programs with specific monitoring protocols.

The Chesapeake Bay Program has convened a “Grey Infrastructure” expert panel to evaluate measures for crediting these practices and programs, and the final report is forthcoming in the Fall of 2014. The expert panel report will identify monitoring protocols, depending on the source removed, with one approach for cross-connections, which monitors the source before and after, a second for infrastructure upgrades that includes collecting data at the outfall or in-stream, and a final protocol that addresses programs to reduce Fats Oils and Grease to the sewer system. The report will also recommend using “Interim Credits” that are conservative estimates of potential reduction in baseflow loads for implementing an IDDE program that meets minimum criteria for identifying and removing illicit discharges to the storm sewer system. The final report, when released, will be valuable for developing credits in North Carolina.

This practice was identified during the October 20th PFC meeting as having High implementation potential.

Improved Biosolids Management (#44)

Ranking: Low data quality – High implementation potential

This practice is broadly defined to include a range of practices both at the Wastewater Treatment Plant (WWTP) and land application sites to reduce phosphorus mobility from biosolids applications. The initial literature review revealed only five articles that investigated nutrient export from biosolids applications, and none of these are in North Carolina. The USGS is currently working on a study in Orange County, but results from this study are not yet available.

Stakeholders at the May 22nd PFC meeting indicated a High implementation potential for this practice. It may make sense to revisit this practice once the Orange County data are available.

Emission Reduction (#46)

Ranking: Low – credits not available based on assumptions in current rules

Although atmospheric deposition accounts for a significant amount of the total nitrogen, particularly in coastal regions, the source of this deposition can be from an entirely different region. Reduced emissions both regionally and nationally may impact nitrogen concentrations in stormwater runoff, and these concentrations should be monitored over time to determine if they should be adjusted (see for example research by K. Eshleman[3] that shows significantly decreasing stream nitrogen loads as a result of reduced atmospheric deposition.

This credit may be best evaluated using calibrated, local watershed models. However, for the Falls Lake Watershed, NCDWR already assumed declining deposition rates of nitrogen based on EPA regional nitrogen deposition models. Therefore, additional credits would not be available in this watershed (personal communication, John Huisman, NCDWR). Participants at the May 22nd PFC meeting acknowledged that this measure would likely be removed from the list of measures to pursue.

[3] http://www.umces.edu/al/project/improvements-surface-water-quality-due-declining-atmospheric-n-deposition

5 Summary of Screening Analysis

As described above, each measure was assigned a ranking of High, Medium, or Low based on the available studies and the implementation potential. Table 4 summarizes these rankings and provides recommendations on whether or not these measures should be pursued for full credit development.

Table 4. Summary of Screening Analysis Results

Ranking	Measures	Recommendation
High data quality – High implementation potential	Urban Measures: ▪ Bioretention with design variants (#1) ▪ Permeable pavement with design variants[1] (#3) ▪ Filter strip with design variants (#17)	Urban Measures: Develop credits for these **3** practices [1] NCSU monitoring to be complete by with report to follow. Data should be available May 2015.
High data quality – Low implementation potential	Urban Measure: ▪ Permeable reactive barriers (# 24)	Urban Measure: There was discussion at the October 20th meeting to move this Low implementation potential based on high costs. Others indicate this can be a low cost option. No further input was received during the November 4th meeting or via email regarding development of this **1** practice. The name of this practice was also changed from wood chip bioreactcors and categorized as an agricultural measure
Medium data quality – High implementation potential	Urban Measures: ▪ Infiltration devices (# 4) ▪ Riparian buffer with varying widths in urban / suburban Areas (# 7) ▪ Land or forest protection (# 10) ▪ Leaf litter recovery[2] (# 14) ▪ Bioswales (#2) and swales with design variants (#16) [3] ▪ Upland tree planting / increased canopy cover (# 9) ▪ Remove Illegal Wastewater Connection to Stormwater Systems or Surface Waters (#41) ▪ Soil Amendment[4] (# 15) ▪ Urban nutrient management (# 23)	Urban Measures: Develop credits for these **9** practices [2] NCSU leaf litter study is expected in May 2015. [3] NCSU study is expected May 2015. [4] NSCU downspout disconnection study includes sites with soil amendments. The final report is expected December 2014.

Ranking	Measures	Recommendation
	Rural / Agricultural Measures: ▪ Livestock exclusion (# 25) ▪ Buffer installation in agricultural areas (# 26) ▪ Cropland conversion to trees or grass (# 32)	Rural / Agricultural Measures: Work with the Watershed Oversight Committee to develop credits for these **3** measures for agricultural applications.

Medium data quality – Medium implementation potential	Urban Measures and Wastewater Practices:
	▪ Sand filters (# 12)
	▪ Enhancement of constructed wetlands (# 13)
	▪ Enhanced erosion and sediment control (# 47)Conversion of impervious surfaces to pervious surfaces (#22)
	
	Rural / Agricultural Measures:
	▪ Waste Management for Equine Operations
	  ▪ Managed grazing (# 27and # 39)
	  ▪ Proper animal nutrient supplementation and feeding strategies (# 29 and # 39)
	  ▪ Nutrient management plans (# 37 and # 39)
	  ▪ Animal waste composting (# 30 and # 39)
	▪ Constructed wetland (# 36)
		Urban Measures and Wastewater Practices:
		Develop credits for these **3** practices depending on decision of the PFC regarding deliverables format
		
		Rural / Agricultural Measures:
		Work with the Watershed Oversight Committee to develop credits for these **5** measures depending on decision of the PFC regarding deliverables format for agricultural applications.

Medium data quality – Low implementation potential	Rural / Agricultural Measures: ▪ Cover crops (# 31) ▪ Conservation tillage (# 35)	Rural / Agricultural Measures: Do not develop credits for these **2** measures based on low implementation potential.
Low - practice standard currently scheduled for development by DWR	Urban Measures: ▪ Stream restoration (# 5) ▪ Pond retrofits/upflow filters (floating wetland islands) (# 20) ▪ Street sweeping (# 42) ▪ Regenerative stormwater conveyances (# 48)	Urban Measures: DWR is in the process of developing practice standards for these **4** measures. We will coordinate with DWR to make sure all information compiled during the screening analysis is available for their development of these credits.
Low data quality – High implementation potential	Urban Measures: ▪ Improved biosolids management (# 44)	Urban Measures: Do not develop credits for this **1** measure until additional data is collected and analyzed.

Ranking	Measures	Recommendation
Low data quality – Medium implementation potential	Urban Measures and Wastewater Practices: ▪ Structural stormwater devices / proprietary devices (# 11) ▪ Blue roof[6] (# 18) ▪ Replace / repair leaking collection system lines (# 40) ▪ Reduce pet waste transmission to surface waters (# 43) Rural / Agricultural Measure: ▪ Pond Creation (# 33)	Urban Measures: Do not develop credits for these **4** measures until additional data is collected and analyzed. [6] UNC blue roof project will be underway in 2015. Andrew Anderson at NCSU is the contact. Rural / Agricultural Measures: Do not develop credits for this **1** measure based on data quality.
Low – awaiting additional data	Urban Measures: ▪ Impervious disconnection/rain catchers[7] (#21)	Urban Measures: Do not develop credits for this **1** measure until additional data is collected and analyzed. DWR currently has a draft practice standard based on currently available data out for public comment. [7] The final report from NCSU is expected in December 2014.
Low – evaluate projects individually	Urban/Other Measures: ▪ Nutrient benefits of existing stormwater management structures (# 19) ▪ Repairing or enhancing failing BMPs (# 45) Rural / Agricultural Measures: ▪ Proper animal waste handing, storage and disposal (# 28) ▪ Pond renovation (# 34) ▪ Decommission of failing facilities (# 38)	Urban/Other Measures: Credits may be developed for these **2** measures on a case by case basis. Rural / Agricultural Measures: Credits may be developed for these **3** measures on a case by case basis.
Low - reassign to other measure(s)	Urban Measures: ▪ Hydraulic modification of urban degraded streams (# 6) ▪ Enhancing or Repairing Existing Riparian Buffers (# 8) ▪ Swales with Design variants (# 16)	Urban/Other Measures: Assign these **3** measures to other categories.

Ranking	Measures	Recommendation
Low – credits not available based on assumptions in current rules	Other Measure: ▪ Emission reduction (#46)	Other Measure: Do not develop credits for this **1** measure because the Falls Lake Nutrient Management Strategy already assumes emission reductions and decreased loading from atmospheric deposition to Falls Lake, so additional credits are not available for this measure in this watershed.

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Appendix A: Proposed Preliminary Screening Attributes and Their Quality Ranking to Evaluate Nutrient Reducing Measures

Table A.1. Proposed Preliminary Screening Attributes and Their Quality Ranking to Evaluate Nutrient Reducing Measures

Year	Study Location	Site Characteristics	Peer review	Scientific Support	Data Collection & Analytical Methods	Analysis of Results
High (published 2004+, or seminal research)	High (North Carolina, Piedmont (may include adjacent states)	High (applicable land use/land cover)	High (peer review, professional publication)	High (local university research unpublished/published; operational scale research; majority of cited works has peer reviewed)	High (approved EPA or NC lab analytical methods)	High (sample size supports statistical testing, results are supported by analysis)
Medium (1994 - 2003)	Medium (representative but outside of North Carolina)	Medium (not directly applicable but somewhat transferrable based on study documentation)	Medium (non-peer review, professional publication)	Medium (research scale; some peer reviewed)	Medium (Other lab and data collection methods (e.g., voluntary, limited storm sizes sampled)	Medium (lacks statistical testing of conclusions but makes reasonable, inferences)
Low (before 1994, not seminal research)	Low (outside North Carolina, not representative)	Low (not applicable)	Low (no review, independent study)	Low (not peer reviewed; gray literature[3])	Low (methods not documented, insufficient data)	Low (inconclusive; insufficient data)

[1] Operational scale research is defined as studies to evaluate a BMP in the field under natural environmental conditions compared to bench or laboratory scale research that controls for parameters such as rainfall intensity.

[2] Seminal research is defined as studies upheld by experts in the field that continue to significantly influence and inform current practices

[3] Gray literature refers to reports, articles and other publications that are internal publications produced by a department or organization that are not peer-reviewed and are typically project-specific final reports. Note: Unpublished data may also be considered high given scientific and statistical methods used to document practice evaluation(as per D. Osmond comment May 22, 2014)

Note: The implementation potential of individual measures will document the current use of a measure (as per T. Davis comment May 22, 2014)

Appendix B: Individual Ranking of Data Quality Ranking Attributes for Each Measure

Table B.1. Summary of Reviewed Measures

Nutrient Reducing Measure	No. of References	Study Year	Study Location	Site Characteristics	Peer Review	Scientific Support	Data Collection, Methods	Analysis of Results	Implementation Potential
URBAN									
Bioretention with design variants (#1)	66	High	Medium	High	High	High	High	High	High
Bioswales & Swales Bioswales (#2) and Swales with Design Variants (#16)	13	Medium	Medium	High	High	High	High	High	High
Permeable Pavement with design variants (#3)	43	High	Medium	High	High	High	High	High	High
Infiltration Devices (#4)	22	High	Medium	High	High	High	High	High	High
Upland Tree Planting[4]/Increase Canopy Cover (#9)	5	High	Medium	High	Medium	High	Medium	Medium	High
Land or Forest Protection (#10)	0	See upland tree planting (#9) for relevant research							High
Structural Stormwater Devices[5] /Proprietary Devices(#11)	3	High	Medium	High	Medium	Low	High	High	Medium
Sand Filters with media enhancements (#12)	14	Medium	Medium	High	High	High	High	High	Medium

[4] Despite the high data quality in the literature reviewed, the analysis was limited to volume reduction rather than water quality benefits.

[5] Insufficient information to characterize a 'class' of structural stormwater devices

Nutrient Reducing Measure	No. of References	Study Year	Study Location	Site Characteristics	Peer Review	Scientific Support	Data Collection, Methods	Analysis of Results	Implementation Potential
Enhancement of Constructed Wetlands (#13)	32	High	Medium	High	High	High	High	High	Medium
Soil Amendment (#15)	9	Medium	Medium	High	High	High	High	High	High
Enhancing or Repairing Riparian Buffers (#8)	0	Assign to other measures							
Repairing or enhancing failing BMPs (#45)	16	High	Medium	High	High	High	High	High	Low
Stream Restoration (#5)	13	High	Medium	Medium	High	High	High	High	High
Riparian Buffer with Varying widths (#7)	11	High	Low	Low	High	High	High	High	High
Leaf Litter Recovery (#14)	4	High	Low	High	Medium	Medium	Medium	Medium	High
Filter strip with Design Variants (#17)	7	High	High	High	High	High	High	High	High
Impervious disconnection/rain catchers (#21)	2	High	Medium	High	Medium	High	High	High	High
Urban Nutrient Management (#23)	13	High	Low	Medium	High	High	High	High	High
Street Sweeping (#42)	8	High	Low	High	High	High	High	High	High
Enhanced ESC (#47)	10	High	High	High	High	High	High	High	Medium
Regenerative stormwater conveyance (#48)	2	High	Medium	High	Medium	High	High	High	High

Nutrient Reducing Measure	No. of References	Study Year	Study Location	Site Characteristics	Peer Review	Scientific Support	Data Collection, Methods	Analysis of Results	Implementation Potential
Hydraulic Modification of Urban, Degraded Streams (#6)	0	Assign to other measures							High
Blue Roof (#18)	1	High	Low	High	Low	Medium	High	High	Medium
Nutrient Benefits of Existing SWM Structures (#19)	0	Evaluate individual projects							High
Pond Retrofits/Upflow Filters (#20)	0	Scheduled for development by DWR. No additional studies beyond Tetra Tech (2013)							High
Conversion of Impervious Surfaces to Pervious Surfaces (#22)	0	Calculation method. See upland tree planting for relevant research.							Medium
Reduce Pet Waste Transmission to Surface Waters (#43)	0	Limited research							Medium
Wood Chip Bioreactors	10	High	Low	High	High	High	High	High	Low
Permeable Reactive Barriers (#24)	10	Medium	Low	High	High	High	High	High	Low
RURAL / AGRICULTURAL									
Livestock Exclusion (#25)	13	Medium	Medium	High	High	High	Medium	Medium	High
Buffer installation (#26)	11	High	Low	Low	High	High	High	High	High
Managed Grazing (#27)	9	Medium	Low	Medium	High	High	Medium	Medium	Medium
Proper animal waste handing, storage and disposal (#28)	0	Evaluate individual projects							Medium

Nutrient Reducing Measure	No. of References	Study Year	Study Location	Site Characteristics	Peer Review	Scientific Support	Data Collection, Methods	Analysis of Results	Implementation Potential
Proper animal nutrient supplementation and feeding strategies (#29)	6	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium
Animal Waste Composting (#30)	5	Medium	Low	Medium	High	High	Medium	Medium	Medium
Cover Crops (#31)	15	High	Low	High	High	High	High	High	Low
Conversion to Trees or Grass (#32)	0	NA	NA	NA	NA	NA	NA	NA	High
Pond Creation (#33)	1	High	High	Low	Medium	Medium	Low	Low	Medium
Pond Renovation (#34)	0	Evaluate individual projects							Medium
Conservation Tillage (#35)	2	High	Medium	Medium	Medium	Medium	Medium	Medium	Low
Constructed Wetland (#36)	6	Medium	Low	Medium	Medium	Medium	High	High	Medium
NMP and Comprehensive NMP (#37)	2	Medium	Low	Medium	Medium	Medium	Medium	Medium	Medium
Decommission of Failing Facilities (#38)	0	Evaluate individual projects							Medium
Management of Equine Operations (#39)	0	Assign to other measures							Medium
WASTEWATER									
Replace/Repair Leaking Collection System Lines (#40)[6]	1	N/A	Medium	N/A	High	High	N/A	High	Medium

[6] The publication reviewed is a draft of the Chesapeake Bay Program Expert Panel Report on Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure. A final report is expected by early 2015.

Nutrient Reducing Measure	No. of References	Study Year	Study Location	Site Characteristics	Peer Review	Scientific Support	Data Collection, Methods	Analysis of Results	Implementation Potential
Remove illegal wastewater connection to stormwater systems or surface waters [7] (#41)	1	N/A	Medium	N/A	High	High	N/A	High	High
Improved biosolids management (#44)	5	Medium	Low	High	High	High	High	High	High
OTHER									
Emission Reduction (atmospheric) (#46)	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Low