

Jordan Lake Watershed Trading Project – BMP Cost Estimates and Cost-Effectiveness

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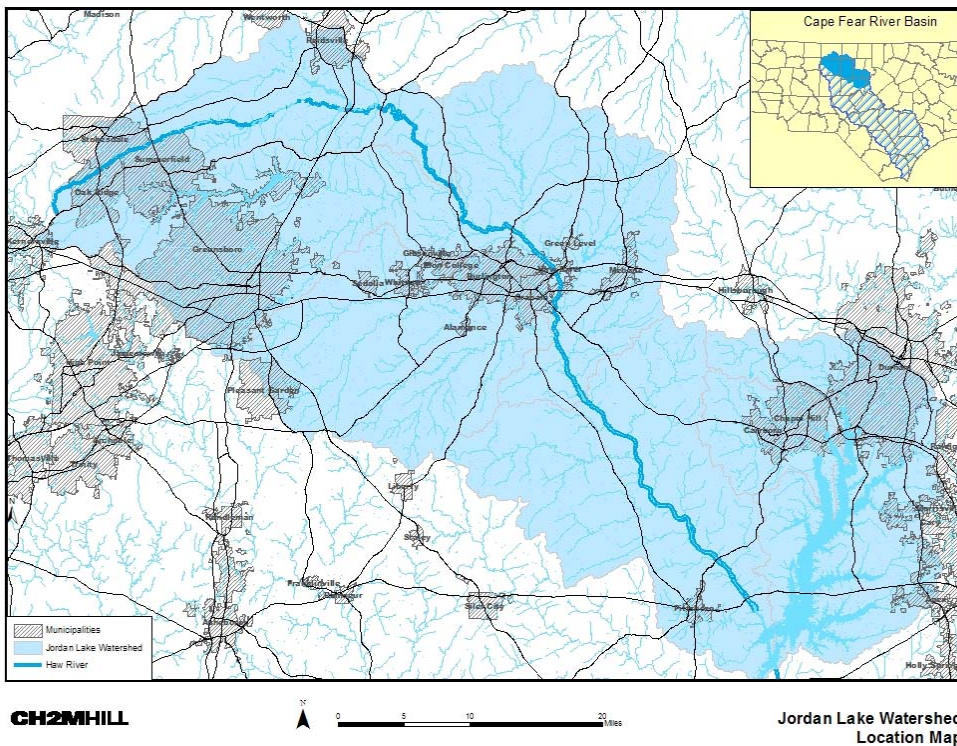
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1.0 Introduction

Continued economic growth in the Cape Fear River Basin (the Basin) is essential for North Carolina’s economy and quality of life. The Basin includes many of the state's largest urban areas – Greensboro, High Point, Burlington, Durham, Cary, Fayetteville, and Wilmington, as seen in Exhibit 1. As the largest watershed in the state, it represents 23 percent of the state’s land area (CFRA, 2002). The Basin is currently home to 26 percent of the state’s population and supports jobs in a variety of industries, including manufacturing, high-tech, and agriculture (CFRA, 2002). Growth rates currently exceed the state-wide average – water usage, one key growth indicator, is projected to increase nearly 95 percent by 2030 (NC DWR, 2002).

Jordan Lake is an important resource within the Cape Fear River Basin. Jordan Lake was created by the US Army Corps of Engineers (USACE) and provides the following services: downstream flood protection; downstream water quality protection; water supply; and recreation. Two main tributaries form Jordan Lake: the Haw River which accounts for the majority of the lake’s drainage area and New Hope Creek. The North Carolina Division of Water Quality considers Jordan Lake impaired due to chlorophyll *a* violations.

EXHIBIT 1
 Cape Fear River Basin and Jordan Lake Watershed Detail



Water quality impairments such as the chlorophyll a impairment in Jordan Lake can limit---and even stop – economic growth opportunities. In the early 1980s, North Carolina’s Water Quality Assessment Report (305(b)) included many waters in the Cape Fear River Basin as impaired by specific toxic chemicals. Recent efforts have been successful in improving water quality – see for example Exhibit 2. As a result, very few waters remain on the impaired waters list because of toxic pollutants.

EXHIBIT 2

Successful Cape Fear River Basin Partnerships

Partnerships formed in the Basin have resulted in water quality improvements. Examples of successful efforts include:

- Addressed toxic substances and color problems in the Haw and Deep Rivers through a combination of grassroots groups, state regulatory efforts, and pretreatment.
- Improved the water quality of Jordan Lake through policies developed by NC DWQ in concert with the watershed stakeholders that addressed nutrient loads from upstream communities. This effort began with a voluntary water supply watershed program in the mid-1980s, followed by mandatory rules in the early 1990s.
- USGS Monitored water supply watersheds on a regional scale to ensure long term data to evaluate quality and protect public health through local funding.
- Developed a nutrient response model for Jordan Lake through local funding.

Although these improvements benefit all in the Basin, there is still considerable work to accomplish. Twenty percent of the Basin's waters remain on the 303(d) list including Jordan Lake for nutrient enrichment. Nutrients are also a concern along the Cape Fear River and may contribute to the low dissolved oxygen in the estuarine portion of the river, also a 303(d) listed water.

Accordingly, watershed management strategies must be formulated and implemented in a manner to balance the competing goals of growth and the environment. The Mid-Carolina Council of Governments (MCCOG) and the Cape Fear River Assembly (CFRA) are proposing to establish a framework for water quality credit trading as a potentially important component of a strategy that will build upon past successes and integrate powerful incentive-based options with existing regulatory and voluntary approaches.

The MCCOG and the CFRA were awarded a targeted watershed grant from EPA to evaluate water quality credit trading within the Jordan Lake Watershed. The goal of this grant project is to develop, demonstrate, and evaluate a water quality credit trading program for the Jordan Lake Watershed that will build on work conducted to date and provide an innovative, incentive-based framework to support implementation of the regulatory requirements based on the final TMDL embodied in the Jordan Water Supply Nutrient Strategy Rules (the “Rules” located in 15A NCAC 02B .0262-.0273) and support cost-effective water quality management strategies.

This study is organized into the following tasks:

1. Visioning and Project Chartering;
2. Designing the Trading Program;
3. Developing an Implementation Framework;
4. Evaluating the Monitoring Program;
5. Demonstrating the Trading, Implementation, and Monitoring Frameworks in a Pilot Subwatershed; and
6. Expanding Innovative Approaches throughout the Basin.

This Technical Memorandum (TM) is submitted in fulfillment of the deliverable requirements for Task 2.4, Cost-Effectiveness Analysis. This analysis addresses total nitrogen and total phosphorus from agricultural and urban sources. The following steps were used to develop unit cost rates: (1) develop cost estimates for selected BMPs; (2) make assumptions about flows and pollutant loading without BMPs for each land use; (3) calculate load reductions using appropriate removal efficiency rates; and (4) divide cost estimates by pounds removed to estimate \$/lb/yr.

This TM is organized under the following major headings:

2. Cost-Effectiveness Methodology: Selected Agricultural BMPs
3. Cost-Effectiveness Methodology: Selected Urban BMPs
4. Cost-Effectiveness Results for Selected Agricultural and Urban BMPs
5. Pro Forma Credit/Debit Examples
6. In-Lieu Fee Program Offered through EEP
7. Summary Conclusions
8. References

2.0 Cost-Effectiveness Methodology: Selected Agricultural BMPs

2.1 Summary Methodology

Unit costs are estimated by dividing the total cost of installing and maintaining a BMP for a specified period of time by the amount of pollutants removed or otherwise prevented from reaching the relevant waterbody.

The cost of agricultural BMPs is dependant on a wide variety of variables, including: capital infrastructure, operation and maintenance, land costs, and the amount of land consumed by the BMP. In addition, site specific conditions such as soils, hydrology, and the type of agriculture will impact BMP cost. As a result, cost estimates are very site specific and can range widely by BMP within the same land use category and across land uses. For this reason, this analysis develops cost estimates for “categorical” BMPs that represent the application of a specific BMP, e.g., “50-ft riparian buffer”, on a defined parcel, e.g., pastureland or cropland. However, the estimates provided in this TM are planning level estimates.

After reviewing a number of publications,¹ and consulting with regional experts,² the primary bases for capital and operation and maintenance cost estimates for the agricultural BMPs were the North Carolina Division of Water Quality (NCDWQ) Fiscal Note and Phil Ross at the Alamance Soil and Water Conservation District.

2.2 BMP Installation and Maintenance Cost Estimates

Capital estimates for each BMP were taken from the NCDWQ Fiscal Note and Phil Ross at Alamance Soil and Water Conservation District and were inflated to 2008 dollars as needed using the Engineering News Record (ENR) index.³ For a number of BMPs, both low and high estimates were provided for capital costs and these ranges are presented in Exhibit 3. In these cases, an average cost was used in the results to follow.

The capital estimates provided were for an acre of BMP. In order to compare on the basis of an acre treated, each BMP was multiplied by its land consumption percentage (BMP land area/1 acre). For those BMPs that consume some amount of agricultural land, land costs were also included in the unit costs. In addition, a design and contingency percentage of 35 percent was applied based upon information provided by Julie Henshaw at the Division of Soil and Water Conservation (DSWC). This resulted in a final BMP capital cost on a per acre treated basis.

¹ See Section 8, References.

² Personal communications with Phil Ross at Alamance Soil and Water Conservation District.

³ Engineering News Record, <http://enr.construction.com/features/coneco/recentindexes.asp>.

EXHIBIT 3
Unadjusted Agricultural BMP Installation and Maintenance Cost Estimates

BMP⁴	Capital Cost Estimate (Base\$ Year)	Maintenance as Percent of Construction Cost or Annual Cost per Acre (Base\$ Year)	BMP Land Consumption (ac BMP/ 1 ac treated)
50 Ft. Riparian Buffer ¹	\$251 per ac of BMP (2006)	15%	0.025
Nutrient Scavenger Crop (cover crop) ²	\$0	\$25 (2008)	0
Grassed Waterway ²	\$825 - \$2,575 per ac of BMP (2008)	\$120 (2008)	0.05
Land Conversion: Crop to Forest ²	\$85 - \$175 per acre of BMP (2008)	15%	1
Land Conversion: Crop to Pasture ²	\$300 per acre of BMP (2008)	15%	1
Land Conversion: Pasture to Forest ²	\$135 to \$225 per acre of BMP (2008)	15%	1
Cattle Exclusion (No Buffer) ²	\$173 per acre treated (2007) ³	15%	0
50 Ft. Excluded Riparian Buffer ²	\$179 per acre treated (2007) ³	15%	0.025
¹ NCDWQ Fiscal Note. ² Phil Ross, DSWC. ³ Cattle Exclusion and 50 Foot Excluded Riparian Buffer are presented on a per acre treated basis because the exclusion fencing is linear and can not be calculated on a per acre of BMP basis. ⁴ Dry stacking also initially examined since there is an established poultry industry in the Haw pilot area. There was not a good way to identify the reduction in TP and TN that was transported to streams through this practice so it is not included in this TM.			

In addition to the capital cost estimates, operations and maintenance (O&M) costs over the life of the BMP were incorporated into the unit costs. The O&M costs were assumed to be annual costs occurring over the 10-year life of the BMP. In order to incorporate the 10-year O&M cost into the unit cost, a Net Present Value (NPV) was calculated assuming the following:

- Interest Rate (2007 Prime Rate) - 7.5%;
- Inflation Rate (20 Year Average) - 5%;
- Life of BMP - 10 years; and
- NPV Factor = $\frac{1}{((\text{Inflation Rate} + 1) / (\text{Interest Rate} + 1))^{\text{Life of BMP}} - 1} \times (\text{Inflation Rate} - \text{Interest Rate})$.

The resulting NPV was applied to the annual O&M cost and resulted in the O&M cost per acre treated. The adjusted capital and O&M costs were added to result in the total cost per unit area treated. These results are presented in Exhibit 4.

EXHIBIT 4

Adjusted Annualized Agricultural BMP Installation and Maintenance Cost Estimates (Present Value over 10 yrs)

BMP	Total Cost per Acre Treated	BMP	Total Cost per Acre Treated
50 Ft. Riparian Buffer	\$20	Land Conversion: Crop to Pasture	\$507
Nutrient Scavenger Crop (cover crop)	\$283	Land Conversion: Pasture to Forest	\$549
Grassed Waterway	\$156	Cattle Exclusion (No Buffer)	\$555
Land Conversion: Crop to Forest	\$396	50 Ft. Excluded Riparian Buffer ¹	\$574

¹The 50 Foot Excluded Riparian Buffer is the Combination of the 50 Foot Riparian Buffer and Cattle Exclusion.

2.3 Land Cost Assumptions

The cost of land for agricultural use was investigated for the Jordan Lake watershed and estimated to be \$20,000 per acre in 2008 dollars. This value was developed through the review of multiple listings within the pilot areas and presented to the stakeholder group for input. While this value was believed to be higher than actual market value, stakeholders agreed that it would be a good value to use in this analysis as opportunity costs for the land were not taken into consideration. See Exhibit 3 for the land consumption assumption for each BMP per area treated, which was the basis for applying the land costs when included in the calculations.

2.4 BMP Effectiveness Assumptions

BMP effectiveness assumptions were detailed in the TM, “Opportunities for Water Quality Credit Trading in the Jordan Lake Watershed” (CH2M HILL, 2007b). Selected summary information is replicated here with some tailoring for purposes of completeness. Definitions of the evaluated BMPs were provided in Appendix A of that TM (CH2M HILL, 2007b).

Significant literature research and coordination with representatives from agricultural agencies were conducted to determine the pollutant removal efficiencies of the agricultural BMPs. Ms. Julie Henshaw of DSWC, Mr. Phil Ross of Alamance County Soil and Water Conservation District, and Drs. Greg Jennings and Deanna Osmond of North Carolina State University participated in developing the removal efficiencies. The assumed pollutant removal efficiencies for the BMPs evaluated are included in Exhibit 5.

As shown in Exhibit 5, for the cover crop BMPs, the removal efficiency for nitrogen varied depending upon the cover crop selected and was provided as a range for all crops for phosphorus. In order to simplify the analysis, the average removal efficiency among the crops for nitrogen and the average of the range for phosphorus was used. It is important to note therefore that the unit costs for cover crop may be lower or higher depending upon which crop is selected for nitrogen and the actual efficiency of the cover crop for phosphorus removal.

EXHIBIT 5
Potentially Creditable Agricultural BMP and Assumed Removal Efficiencies

	Assumed Percent Removal	
	TN	TP
Agricultural BMPs¹		
Nutrient Scavenger Crop (#340 – Cover Crop)		
<i>Rye and Triticale</i>	15 ²	7-15 ⁴
<i>Oats and Barley</i>	10 ²	7-15 ⁴
<i>Wheat</i>	5 ²	7-15 ⁴
Grassed Waterway (#412 – Grassed Waterway)	40	45
50 Foot Riparian Buffer	50 ²	75 ³
Land Conversion		
<i>Cropland Conversion to Pasture (#512 – Pasture and Hay Planting)</i>	49 ⁶	80 ⁶
<i>Cropland Conversion to Forest(#327 – Conservation Cover, #490 – Tree/Shrub Site Preparation, #612 – Tree/Shrub Establishment)</i>	88 ⁶	94 ⁶
<i>Pastureland Conversion to Forest (#342 – Critical Area, #472 – Livestock Exclusion, #382 - Fencing#490 – Tree/Shrub Site Preparation, #612 – Tree/Shrub Establishment)</i>	76 ⁶	69 ⁶
Pasture Management Systems		
<i>Cattle Exclusion (No Buffer) (#472 – Livestock Exclusion, #576 - Stream Crossing, #614 Trough/Tank, #642 - Well)</i>	32 ⁵	28 ⁷
<i>50 Foot Excluded Riparian Buffer (#472 – Livestock Exclusion, #391 – Riparian Forest Buffer, #576 - Stream Crossing, #614 Trough/Tank, #642 - Well)</i>	66 ⁷	82 ⁷

¹ NRCS Equivalent specification code number in parentheses where applicable were taken from the Alamance County Field Office Technical Guide.

² NC Nitrogen Loss Estimation Worksheet (NLEW)

³ Source: Osmond, Crouse, Hodges, Johnson, and May, 2007

⁴ Source: Chesapeake Bay Nutrient Subcommittee, 2004

⁵ Source: NCDSWC, Pasture Point System, 2007

⁶ Based on changes in aerial loading rates due to land use change.

⁷ Based on the DSWC Pasture Point System.

2.5. Pollutant Loading Rate Assumptions

To examine total costs for the various BMPs placed on the agricultural land uses of cropland and pastureland, nitrogen and phosphorus loading rates for each of the land uses needed to be determined. Ms. Julie Henshaw of DSWC participated in developing the loading rate assumptions. The assumed loading rates for each of the land uses are included in Exhibit 6.

EXHIBIT 6
Pollutant Loading Rates for One Acre of by Land Use

Land Use	TN Loading (lbs/ac-yr)	TP Loading (lbs/ac-yr)
Cropland ¹	13.37	5.32
Pastureland ²	6.76	1.48
¹ Load values presented in the Jordan Lake TMDL. ² Pasture Point System for Tar Pamlico and communication/verification from Julie Henshaw, DSWC.		

2.6 Nutrient Reduction Estimates

Following the methodology outlined above, annual loading reduction estimates were calculated for each BMP-land use combination. These were divided into the annualized BMP capital and maintenance costs to arrive at the unit cost estimates (\$/lb/yr) presented in the next section. Exhibits 7 and 8 present the graphic result of these calculations for nitrogen and phosphorus.

EXHIBIT 7

Nitrogen Pounds/Acre/Year Removed by BMP in Row Crops and Pastureland

The results below show that for all of the BMPs, there is greater nitrogen removal than phosphorus removal. The results show that the land conversion and the 50 Foot Riparian Buffer BMPs provide the greatest pollutant removal on an annual basis.

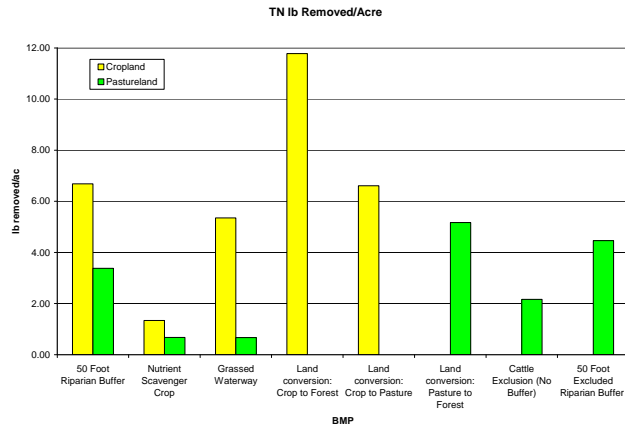
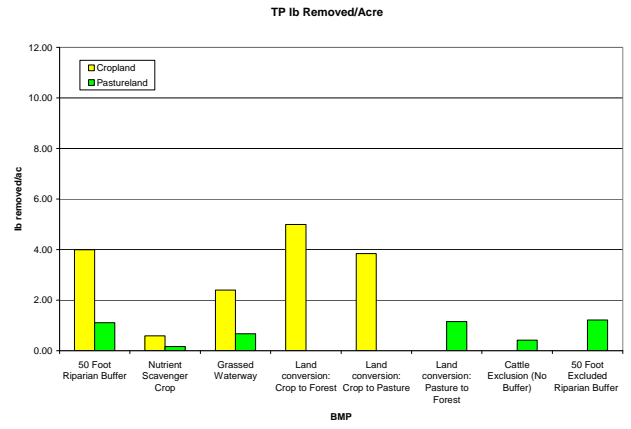


EXHIBIT 8

Phosphorus Pounds/Acre/Year Removed by BMP in Row Crops and Pastureland

The results below show that for all of the BMPs, there is greater nitrogen removal than phosphorus removal. The results show that the land conversion and the 50 Foot Riparian Buffer BMPs provide the greatest pollutant removal on an annual basis.



3.0 Cost-Effectiveness Methodology: Selected Urban BMPs

3.1 Summary Methodology

The cost of stormwater BMPs is dependant on a wide variety of variables, including: runoff volume treated, percent imperviousness, soil characteristics, site characteristics, and overall area required for the BMP footprint, which drives costs for capital expenditures (design, planning, permitting, and construction) and operation and maintenance. As a result, cost estimates are very site specific and can range widely by BMP within the same land use category and across land uses. For this reason, this analysis develops cost estimates for “categorical” BMPs. For the purposes of this analysis, categorical BMPs are defined as a specific BMP-land use combination, for example a “grassed swale” on a parcel that is 65 percent impervious. For this analysis there are 45 categorical BMPs: nine BMP types on five defined land uses.

To develop the parcel definitions, the list of land uses specified in the Jordan Lake TMDL Watershed Model Development (Tetra Tech, Draft 2003) were reviewed along with the annual loading rates for Total Nitrogen and Total Phosphorous. Five imperviousness-based land use categories were selected to represent a range of urban development densities: 85 percent (e.g., commercial-industrial); 65 percent (e.g., eight dwelling units per acre); 38 percent (e.g., four dwelling units per acre); 25 percent (e.g., two dwelling units per acre); and 20 percent (e.g., one dwelling unit per acre). Because local jurisdictions sometimes use different zoning category names for the same percent imperviousness, the land use categories presented in this analysis are identified by their percent imperviousness, rather than by a density- or unit-related zoning definition. The percent imperviousness for a land use category was based on the USDA Natural Resources Conservation Service, Technical Release 55: Urban Hydrology for Small Watersheds recommendations. The percent impervious values were used to develop a water quality volume estimate (i.e., runoff generated from the one-inch rainfall event) and annual pollutant loading for each land use category.

After reviewing a number of publications,⁴ and consulting with regional experts,⁵ “*Preliminary Data Summary of Urban Storm Water Best Management Practices*,” published by the US Environmental Protection Agency (EPA, 1999) was selected as the primary basis for capital and O&M cost estimates for the stormwater BMPs selected for analysis in this TM. Supplemental sources consulted included: July 2007 NCDENR Stormwater BMP Manual; and July 2005 NCDENR Public Comment version of the Updated Draft Manual of Stormwater Best Management Practices. Further, because land costs can be a significant component of the overall BMP cost – but are not always newly incurred (e.g., already owned land)), the categorical unit costs are developed with and without land acquisition costs.

Categorical unit cost estimates were developed for selected urban stormwater BMPs identified in the TM “Opportunities for Water Quality Credit Trading in the Jordan Lake Watershed” (CH2M HILL, 2007b). The BMPs presented in that TM were selected based primarily on their effectiveness at removing nutrients and their implementation feasibility given the established constraints within the watershed. Notably, the BMPs for which cost estimates are presented in

⁴ See list of references at the end of this TM.

⁵ Personal communications with DWQ staff and William F. Hunt, III, Ph.D., P.E., NC State University, Biological and Agricultural Engineering, Assistant Professor and Extension Specialist.

this TM represent exclusively structural options. Selected nonstructural BMPs were accepted by the stakeholders and addressed in CH2M HILL, 2007b including: street sweeping, disconnection of impervious area, conservation development practices, stream or wetland restoration, land use management/planning and land conservation/conversion, illicit discharge elimination, public education and participation, and encouragement of low phosphorus fertilizers. However, these nonstructural BMPs could not be evaluated in this TM because the cost and efficiency data is insufficient to develop categorical unit-cost estimates.

3.2 BMP Installation and Maintenance Cost Estimates

Base estimates taken from EPA 1999 (1997 dollars) and NCDENR 2005 (2004 dollars) were inflated to 2008 dollars and adjusted in several other respects for the purposes of this analysis. Exhibit 9 presents the unadjusted cost estimates.

EXHIBIT 9

Unadjusted BMP Installation and Maintenance Cost Estimates (Base\$ Year Source: EPA 1999 Unless Otherwise Noted)

BMP	Capital Cost Estimate	Operation and Maintenance Costs as a Percent of Construction Cost Unless Otherwise Noted
Bioretention	\$5.30 per cu ft (1997)	5-7%
Stormwater wetlands	\$.60 to \$1.25 per cu ft (1997)	3-6%
Wet detention basin	\$.50 to \$1.00 per cu ft (1997)	3-6%
Sand filter	\$3 to \$6 per cu ft (1997)	11-13%
Restored riparian buffer	\$600 to \$950 per acre (2004) ¹	\$9 per acre (2004)
Grassed swale	\$0.50 per cu ft (1997)	5-7%
Infiltration devices	\$1.30 to \$4.00 per cu ft (1997)	5-20%
Filter strip	\$0 to \$1.30 per cu ft (1997)	\$320 per acre
Dry extended detention basin	\$.50 to \$1.00 per cu ft (1997)	<1%

¹Draft July 2005 NCDENR Public Comment Version of the Updated Draft Manual of Stormwater Best Management Practices

All the EPA estimates were adjusted using a Regional Adjustment factor that accounts for whether a region receives more or less than the national average rainfall assumed in the cost estimates and are adjusted for regional construction cost index. The adjustment factor for rainfall region 2, including North Carolina, is 0.90. Therefore the base costs were divided by this factor, which increased the base estimates by 11.1 percent.⁶

Next, because the unadjusted cost estimates do not include certain cost components that are typically considered in a total cost value, the EPA and NCDENR estimates were further adjusted as follows: increased by 35 percent to account for design, permitting, contingency, and other costs assumed to be excluded from the estimates; escalated using historical ENR data

⁶ EPA 1999, Table 6-3, page 6-5.

(Construction Cost Index Series) from the assumed base year to account for inflation and bring final cost estimates to 2008 dollars.⁷

Present value estimates for annual operation and maintenance costs were calculated by assuming: 20 year BMP life; interest rate of 7.5 percent⁸; and an inflation rate of 5 percent.⁹ Exhibit 10 presents the adjusted annualized cost estimates in 2008 dollars, inclusive of planning, capital, and maintenance costs using the average of the capital and maintenance cost range as applicable.

EXHIBIT 10

Adjusted Annualized BMP Installation and Maintenance Cost Estimates (Present Value over 20 yrs / 20)

See Section 3.1 for an example of land uses typically associated with each imperviousness level.

BMP	Imperviousness-Based Land Use Category				
	85%	65%	38%	25%	20%
Bioretention	\$3,260	\$2,540	\$1,570	\$1,100	\$920
Stormwater wetlands	\$500	\$390	\$240	\$170	\$140
Wet detention basin	\$390	\$300	\$190	\$130	\$110
Sand filter	\$4,080	\$3,180	\$1,960	\$1,380	\$1,150
Restored riparian buffer	\$60	\$60	\$60	\$60	\$60
Grassed swale	\$310	\$240	\$150	\$100	\$90
Infiltration devices	\$2,470	\$1,920	\$1,190	\$830	\$700
Filter strip	\$230	\$180	\$120	\$90	\$80
Dry extended detention basin	\$260	\$200	\$130	\$90	\$70

⁷ Engineering News Record, <http://enr.construction.com/features/coneco/recentindexes.asp>. The exact escalator depends on the base year, for example: estimates in 1997\$ were inflated by a factor of 1.43; and estimates in 2004\$ were inflated by a factor of 1.10.

⁸ This estimate was developed using an average of 20 years of historical data (<http://research.stlouisfed.org/fred2/data/PRIME.txt>).

⁹ This estimate was developed based on work conducted by CH2M HILL for the Virginia Nutrient Credit Exchange Association in 2006 and updated in 2007.

3.3. Land Cost Assumptions

The cost of land by various land uses was investigated for the Jordan lake watershed and consolidated in to three categories for each of the two pilot areas as shown in Exhibit 11. These values were developed through the review of multiple listings within the pilot areas and presented to the stakeholder group for input.

EXHIBIT 11 Land values for properties within the Jordan Lake Watershed		
Cost Per Acre in Watershed		
Land Use Category	Upper New Hope	Haw
85% Impervious (Commercial/Industrial)	\$400,000	\$350,000
65% Impervious (Multiuse Residential)	\$350,000	\$175,000
38% to 20% Impervious (Residential)	\$150,000	\$100,000

Exhibit 12 presents the cost per acre used in this analysis, the land consumption value for each BMP associated with the percent impervious value of the drainage area that the BMP is treating, and the resulting land cost component for each BMP-land use category combination. The land consumption value is the area of land needed to treat a site of a certain percent impervious cover by a BMP, and are taken from the 1999 EPA report previously cited. Per EPA 1999, the calculation is performed as follows:

$$\text{Land Cost} \times \text{Land Consumption \%} \times \text{Impervious \%} = \text{Land Cost of BMP}$$

EXHIBIT 12

Land Consumption Costs by BMP-Land Use Combination¹⁰

		% Impervious				
		85%	65%	38%	25%	20%
		Land Cost/ac				
		\$ 400,000	\$ 350,000	\$ 150,000	\$ 150,000	\$ 150,000
BMP	% Land Consumption	Land Cost/ac for BMP Footprint				
Bioretention	5.00%	\$ 17,000	\$ 11,380	\$ 2,850	\$ 1,880	\$ 1,500
Stormwater wetlands	4.00%	\$ 13,600	\$ 9,100	\$ 2,280	\$ 1,500	\$ 1,200
Wet detention basin	2.50%	\$ 8,500	\$ 5,690	\$ 1,430	\$ 940	\$ 750
Sand filter	1.50%	\$ 5,100	\$ 3,410	\$ 860	\$ 560	\$ 450
Restored riparian buffer	2.30%	\$ 7,820	\$ 5,230	\$ 1,310	\$ 860	\$ 690
Grassed swale	15.00%	\$ 51,000	\$ 34,130	\$ 8,550	\$ 5,630	\$ 4,500
Infiltration devices	2.50%	\$ 8,500	\$ 5,690	\$ 1,430	\$ 940	\$ 750
Filter strip	2.30%	\$ 7,820	\$ 5,230	\$ 1,310	\$ 860	\$ 690
Dry extended detention basin	2.50%	\$ 8,500	\$ 5,690	\$ 1,430	\$ 940	\$ 750

¹⁰ The term of 20 years for the PV calculation was used for convenience and consistency with the other elements of the analysis. It would not be unreasonable to use a longer term for the land, which would have the effect of reducing the PV of the land. See the notation regarding issues associated with including or excluding land costs in Section 5.

3.4 BMP Effectiveness Assumptions

BMP effectiveness assumptions were detailed in the TM, “Opportunities for Water Quality Credit Trading in the Jordan Lake Watershed” (CH2M HILL, 2007b). Selected summary information is replicated here with some tailoring for purposes of completeness. Definitions of the evaluated BMPs were provided in Appendix A of that TM (CH2M HILL, 2007b).

The primary reference for urban BMP effectiveness values was the NCDENR Stormwater Best Management Practices Manual (2007)). For BMPs that did not have a specified removal efficiency in the NCDENR BMP Manual, other references were used to determine an efficiency, including consultation with regional experts.¹¹

The final removal efficiency values shown in Exhibit 13 were presented to NC DWQ for approval with the understanding that the values are exclusively proposed for use in the development of cost-effectiveness estimates and credit trading examples under this study and do not establish a precedent to be used when the Jordan Lake Rules are implemented.

EXHIBIT 13

Assumed Nutrient Removal Efficiencies for Evaluated BMPs (DWQ Stormwater Best Management Practices Manual, 2007c)

Structural Urban Stormwater BMPs	% TN reduction	% TP reduction
Bioretention	35%	45%
Stormwater wetlands	40%	35%
Wet detention basin	25%	40%
Sand filter	35%	45%
Restored riparian buffer	30%	35%
Grassed swale	20%	20%
Infiltration devices	30%	35%
Filter strip	20%	35%
Dry extended detention basin	10%	10%

3.5 Pollutant Loading Rate and Water Quality Volume Assumptions

To examine total costs for the categorical BMPs defined for this analysis (as described in the Summary Methodology presented at the beginning of this section), the required water quality volume (WQv) generated per unit area for each land use was calculated. Exhibit 14 presents the percent impervious associated with each land use category. The annual loading values are calculated using event mean concentrations (EMC) values based on percent impervious values, the runoff coefficient, the annual precipitation, and watershed area. The EMC values are calculated using equations developed from the regression analysis performed to relate percent impervious to pollutant loading rates.¹²

The WQv was determined based on the percent impervious of the site using the Simple Method (the higher the percent impervious, the larger the water quality volume to be treated). The

¹¹ Personal communication with William F. Hunt, III, Ph.D., P.E., NC State University, Biological and Agricultural Engineering, Assistant Professor and Extension Specialist.

¹² Source: CH2M HILL, 2000. *Technical Memorandum: Urban Stormwater Pollutant Assessment*.

water quality volume represents the volume of runoff that must be controlled for the design storm. Water quality volume is a result of the multiplication of the design storm rainfall depth (Rd) which is 1 inch in North Carolina, the Runoff Coefficient (Rv), the watershed area and the unit conversion factor.

EXHIBIT 14
Pollutant Loading Rate and Water Quality Volume Assumed for Each Land Use Category

% Impervious Land Use Category ¹	Example Associated Development	TN Loading (lbs/ac-yr) ²	TP Loading (lbs/ac-yr) ²	WQv (ft ³ /ac) ³
85%	Commercial-Industrial	24.63	3.06	2,958
65%	8 Dwelling Units/ac	14.80	1.94	2,305
38%	4 Dwelling Units/ac	6.43	0.90	1,423
25%	2 Dwelling Units/ac	3.81	0.55	998
20%	1 Dwelling Unit/ac	2.99	0.44	835

¹Values found in USDA Natural Resources Conservation Service Technical Release 55 (TR-55): Urban Hydrology for Small Watersheds, 1986.
²The annual loading values shown here were proposed to NC DWQ and accepted for use in this analysis with the understanding that the values are exclusively approved for use in the development of cost-effectiveness estimates and credit trading examples under this study and do not establish a precedent to be used when the Jordan Lake Rules are implemented. Personal communication with Rich Gannon, DWQ Supervisor, NPS Management Program, June 8, 2008.
³Calculated using the Simple Method as presented in Chapter 3 of the *DWQ Stormwater Best Management Practices Manual*, 2007c).

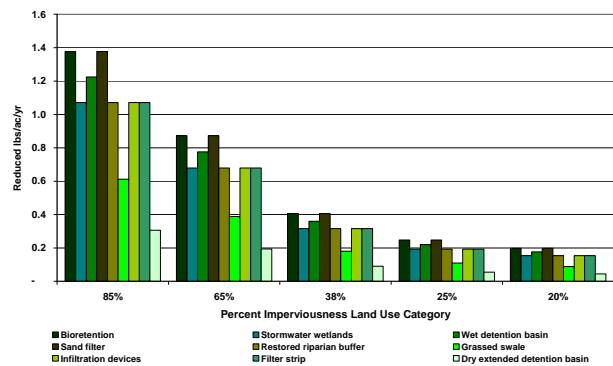
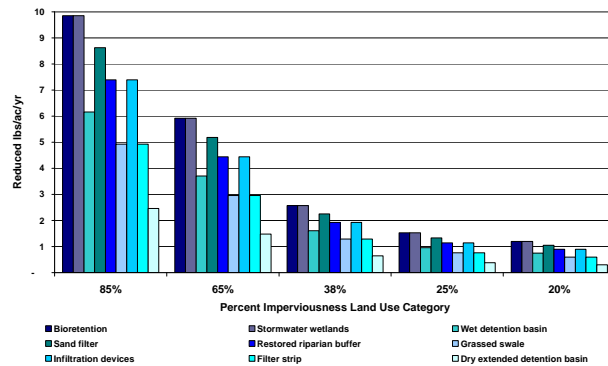
3.6 Nutrient Reduction Estimates

Following the methodology outlined above, annual loading reduction estimates were calculated for each categorical BMP. These were divided into the annualized BMP capital and maintenance costs to arrive at the unit cost estimates (\$/lb/yr) presented in the next section. Exhibits 15 and 16 present the graphic results of these calculations for nitrogen and phosphorus.

EXHIBIT 15
Nitrogen Pounds/Acre/Year Removed by BMP, Land Use

EXHIBIT 16
Phosphorus Pounds/Acre/Year Removed by BMP, Land Use

For each pollutant, BMPs on land uses with higher levels of imperviousness and higher loading rates understandably deliver greater absolute levels of nutrient reductions. In both graphs, the darker colors roughly identify the BMPs delivering the most reductions, while the lighter colors roughly represent the relatively less effective BMPs. These relationships correspond to the assumed removal efficiencies presented in Exhibit 13. Note the different y-axis scales for the two pollutants.



4.0 Unit Cost Estimates Results for Agricultural and Urban BMPs

The unit cost estimates for the eight agricultural BMPs on two land uses and nine urban BMPs on the five land use categories examined are presented in two subsections below through a series of tables and graphs. Captions highlight the most important findings observed in the results. Additional narrative on the implications of the results for each major land use category (agriculture and urban), alone and in conjunction with the other category, and in relation to other aspects of this project is presented in Section 7.

As explained in the methodology, estimates were prepared without and with the cost of the land the BMP would physically occupy. The manner in which potential credit market participants may include land costs in their calculations – if at all – will vary by the nature of their situation. Whether the cost can be amortized, depreciated, written off, or mortgaged could significantly increase or decrease the actual cost experienced. Because land costs can be a significant component of unit costs, they are included in these results for reference. However, for screening purposes, given the variability among land owners with respect to how they will account for land costs, the most internally consistent comparison is probably among BMP-land use combinations without land costs.

4.1 Agriculture BMP Cost-Effectiveness Screening Results

The screening-level unit cost estimates developed for agriculture BMPs are presented below: nitrogen results are presented in both tabular and graphic form; because there is not expected to be demand for a phosphorus credit market, results are presented in tabular form only.

This section presents the unit cost estimates for the agriculture BMPs following the methodology described in Section 2. Exhibits 17 and 18 present the unit cost estimates in tabular form for TN and TP. Exhibits 19 and 20 present additional graphic detail for the screening-level nitrogen unit removal costs.

EXHIBIT 17

Tabular Unit Cost Control Estimates for Total Nitrogen, \$/lb/yr

BMP	Cropland			Pastureland		
	lb removed/acre	\$/lb/yr w/o Land	\$/lb/yr with Land	lb removed/acre	\$/lb/yr w/o Land	\$/lb/yr with Land
50 Foot Riparian Buffer	6.7	\$0.30	\$8	3.4	\$1	\$15
Nutrient Scavenger (Cover) Crop	1.3	\$21.00	\$21	0.7	\$42	\$42
Grassed Waterway	5.4	\$3.00	\$20	0.7	\$6	\$40
Land conversion: Crop to Forest	11.8	\$3.00	\$173	n/a	n/a	n/a
Land conversion: Crop to Pasture	6.6	\$8.00	\$303	n/a	n/a	n/a
Land conversion: Pasture to Forest	n/a	n/a	n/a	5.17	\$11	\$397
Cattle Exclusion (No Buffer)	n/a	n/a	n/a	2.16	\$26	\$26
50 Foot Excluded Riparian Buffer	n/a	n/a	n/a	4.46	\$13	\$35

EXHIBIT 18

Tabular Unit Cost Control Estimates for Total Phosphorus, \$/lb/yr

BMP	Cropland			Pastureland		
	lb removed/acre	\$/lb/yr w/o Land	\$/lb/yr with Land	lb removed/acre	\$/lb/yr w/o Land	\$/lb/yr with Land
50 Foot Riparian Buffer	4.0	\$1	\$13	1.1	\$2	\$46
Nutrient Scavenger Crop	0.6	\$48	\$48	0.2	\$174	\$174
Grassed Waterway	2.4	\$7	\$45	0.7	\$23	\$161
Land conversion: Crop to Forest	5.0	\$8	\$409	n/a	n/a	n/a
Land conversion: Crop to Pasture	3.8	\$13	\$534	n/a	n/a	n/a
Land conversion: Pasture to Forest	n/a	n/a	n/a	1.2	\$48	\$1,787
Cattle Exclusion (No Buffer)	n/a	n/a	n/a	0.4	\$134	\$134
50 Foot Excluded Riparian Buffer	n/a	n/a	n/a	1.2	\$47	\$129

As more clearly seen in Exhibits 19 and 20 than in the tables above, the cost effectiveness for each of the BMPs with and without land costs is presented. When land costs are not considered, the land conversion BMPs are the most cost effective. For the analysis with land costs included, the land conversion BMPs are the least cost effective.

EXHIBIT 19

Nitrogen Cost per Pound Removed by BMP

The results below show that for all of the BMPs, nitrogen removal can be achieved for less than \$50/lb/yr, exclusive of land costs. The removal from pastureland costs more on a \$/lb/yr basis because the loading rates from pastureland are lower than for cropland but the removal efficiencies are the same. For the land conversion BMPs, the nutrient removal costs with land are included with hatch-markings to indicate what the cost would be if the entire acre were not used for any type of profit following the land conversion.

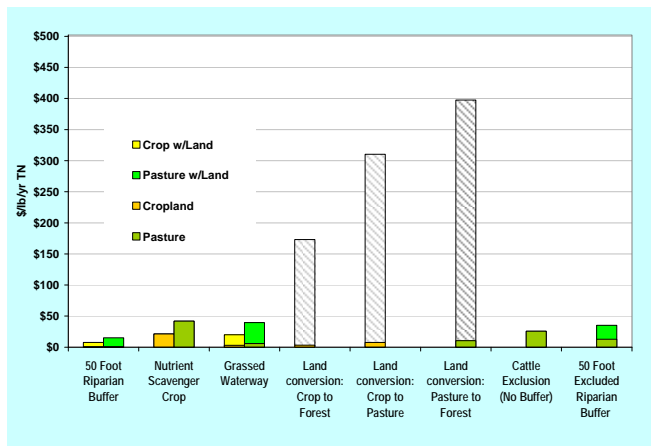
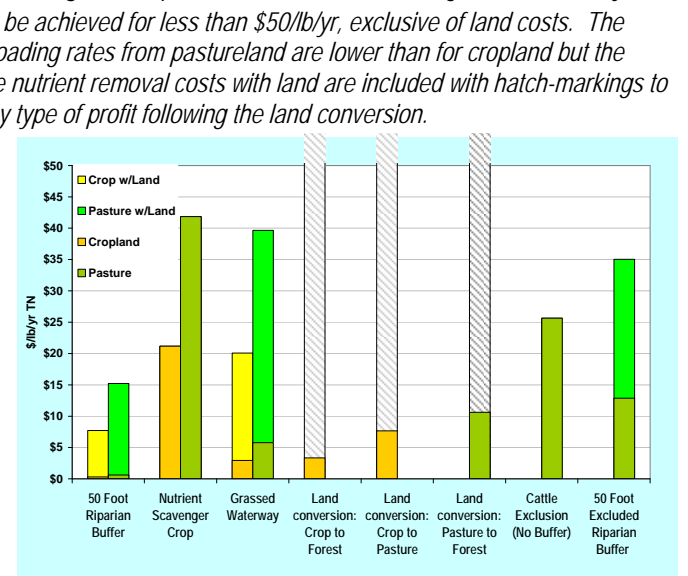


EXHIBIT 20

Nitrogen Cost per Pound Removed: Showing results <\$50/lb/yr



4.2 Urban BMP Cost-Effectiveness Screening Results

The screening-level unit cost estimates developed, which are the primary focus of Task 2.4, are presented below. Sections 5 and 6 present additional unit cost estimates developed for six pilot area conceptual design BMPs, BMPs evaluated in series, and pricing information about the in-lieu offset fee program offered by the Ecosystem Enhancement Program (EEP). These other estimates are presented for rough comparison and benchmarking purposes, and to provide additional detail. However, because the costing methodology for these other estimates differs from that used for the screening analysis, the estimates should not be statistically compared.

The unit cost estimates presented below follow the methodology described in Section 3. Exhibits 21 and 22 present the unit cost estimates in tabular form for TN and TP. Exhibits 23 through 25 present additional graphic detail for the nitrogen unit removal costs. Exhibits 26 and 27 illustrate the effect of land costs on the unit cost estimates. Additional detail on phosphorus unit costs is not presented due to the expected absence of a market for these credits.¹³

EXHIBIT 21

Tabular Unit Cost Control Estimates for Total Nitrogen, \$/lb/yr

\$/lb/yr TN reduced - No Land \$ and With Land \$	Percent Imperviousness Land Use Category				
	85%	65%	38%	25%	20%
Bioretention - No Land \$	\$330	\$430	\$610	\$720	\$770
Bioretention - With Land \$	\$420	\$530	\$660	\$780	\$830
Stormwater wetlands - No Land \$	\$50	\$70	\$90	\$110	\$120
Stormwater wetlands - With Land \$	\$120	\$140	\$140	\$160	\$170
Wet detention basin - No Land \$	\$60	\$80	\$120	\$140	\$150
Wet detention basin - With Land \$	\$130	\$160	\$160	\$190	\$200
Sand filter - No Land \$	\$470	\$610	\$870	\$1,030	\$1,100
Sand filter - With Land \$	\$500	\$650	\$890	\$1,050	\$1,120
Restored riparian buffer - No Land \$	\$8	\$14	\$32	\$54	\$68
Restored riparian buffer - With Land \$	\$61	\$73	\$66	\$91	\$107
Grassed swale - No Land \$	\$60	\$80	\$110	\$140	\$150
Grassed swale - With Land \$	\$580	\$660	\$450	\$510	\$520
Infiltration devices - No Land \$	\$330	\$430	\$610	\$730	\$780
Infiltration devices - With Land \$	\$390	\$500	\$650	\$770	\$820
Filter strip - No Land \$	\$50	\$60	\$90	\$120	\$130
Filter strip - With Land \$	\$130	\$150	\$140	\$170	\$190
Dry extended detention basin - No Land \$	\$110	\$140	\$200	\$230	\$250
Dry extended detention basin - With Land \$	\$280	\$330	\$310	\$350	\$370

EXHIBIT 22

Tabular Unit Cost Estimates for Total Phosphorus, \$/lb/yr

\$/lb/yr TP reduced - No Land \$ and With Land \$	Percent Imperviousness Land Use Category				
	85%	65%	38%	25%	20%
Bioretention - No Land \$	\$2,370	\$2,910	\$3,870	\$4,440	\$4,650
Bioretention - With Land \$	\$2,980	\$3,560	\$4,220	\$4,820	\$5,020
Stormwater wetlands - No Land \$	\$470	\$580	\$770	\$880	\$920
Stormwater wetlands - With Land \$	\$1,100	\$1,250	\$1,130	\$1,270	\$1,310
Wet detention basin - No Land \$	\$320	\$390	\$520	\$600	\$620
Wet detention basin - With Land \$	\$660	\$760	\$720	\$810	\$840
Sand filter - No Land \$	\$2,960	\$3,640	\$4,840	\$5,560	\$5,810
Sand filter - With Land \$	\$3,150	\$3,840	\$4,950	\$5,670	\$5,930
Restored riparian buffer - No Land \$	\$60	\$90	\$190	\$320	\$400
Restored riparian buffer - With Land \$	\$420	\$480	\$400	\$540	\$620
Grassed swale - No Land \$	\$500	\$620	\$820	\$940	\$990
Grassed swale - With Land \$	\$4,670	\$5,010	\$3,200	\$3,500	\$3,540
Infiltration devices - No Land \$	\$2,300	\$2,830	\$3,770	\$4,320	\$4,520
Infiltration devices - With Land \$	\$2,700	\$3,250	\$3,990	\$4,570	\$4,760
Filter strip - No Land \$	\$210	\$270	\$380	\$460	\$500
Filter strip - With Land \$	\$580	\$650	\$590	\$680	\$720
Dry extended detention basin - No Land \$	\$850	\$1,050	\$1,390	\$1,600	\$1,670
Dry extended detention basin - With Land \$	\$2,240	\$2,510	\$2,190	\$2,450	\$2,530

¹³ This expectation is based on the assumptions that BMPs meeting sediment requirements will almost always meet phosphorus targets, and the point sources appear to have no demand for phosphorus credits (see forthcoming TM, CH2M HILL, 2008b).

As more clearly seen in Exhibits 23 through 25 than in the tables above, the relative cost-effectiveness ranking of each BMP-land use combination, without considering land costs, persists across the land uses (see Exhibit 23). These results relate directly to the assumed pattern of WQv and loading rates observed among the five land use categories – higher WQvs are associated with higher loading rates (see for example Exhibit 14). The relative ranking across BMP type, illustrated in Exhibits 24 and 25 shows more variation across land use, due to the interaction of assumed removal rates and costs – the highest percent removals are not always associated with the highest costs.

EXHIBIT 23

Graphic Unit Cost Estimates Grouped by Land Use Category for Nitrogen: Incremental land cost is lighter top bar
Across the land use categories, unit costs increase as imperviousness decreases. This is because the percent imperviousness is decreasing which causes the WQv and the pollutant influent loading rate to decrease. . So even though BMPs on less impervious land uses are sized smaller for lesser WQv, the pollutant influent loading rate is such that proportionately fewer pounds are removed, so the unit costs are relatively higher for the same BMP on different land uses.

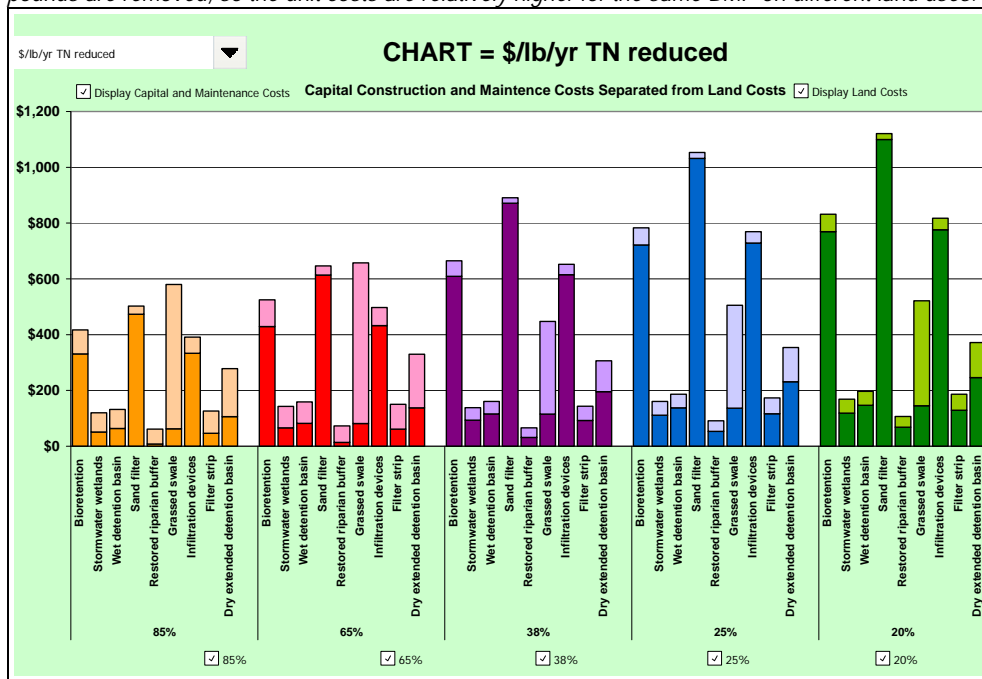


EXHIBIT 24

Graphic Unit Cost Estimates Grouped by BMP for Nitrogen: Incremental land cost is lighter top bar

The three least cost-effective BMPs are color-coded with red/orange. Grassed swales, which are colored purple-lavender, are relatively more expensive if land costs are included, are relatively less expensive without land costs. The other five BMPs are color-coded from less to most cost effective with blues, turquoise, and greens respectively.

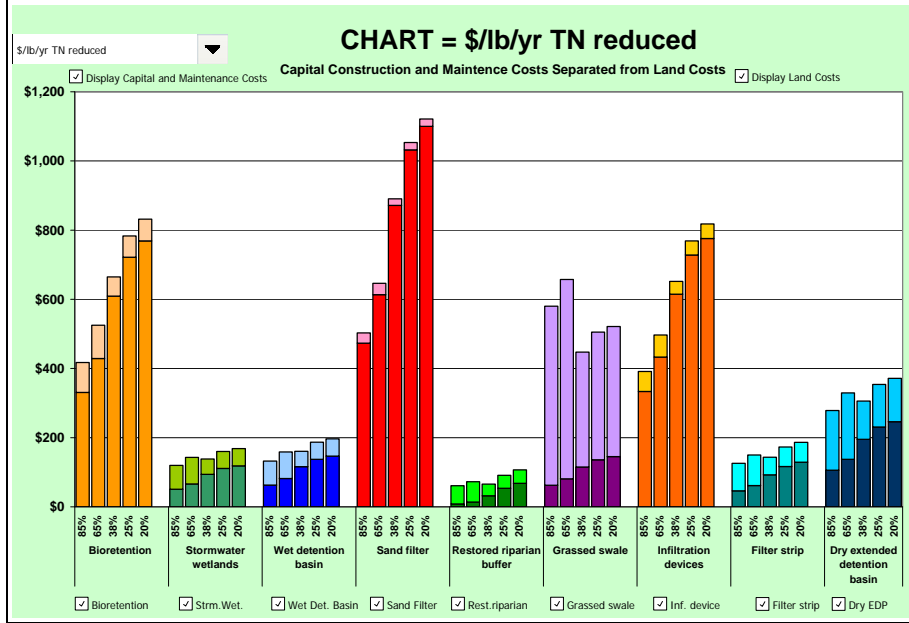


EXHIBIT 25

Graphic Unit Cost Estimates Grouped by BMP for Nitrogen, Scale Capped at \$200/lb/yr

This presents the same data as Exhibit 24 with a truncated unit cost scale to show greater detail for the BMP-land use combinations less than \$200/lb/yr. This view shows that stormwater wetlands, wet detention basins, and filter strips with and without land costs, and grassed swales without land costs are all within about \$20/lb/yr of each other by land use category. It also clearly shows that restored riparian buffers are estimated as the least expensive option overall by a significant margin compared to the other BMP-land use combinations.

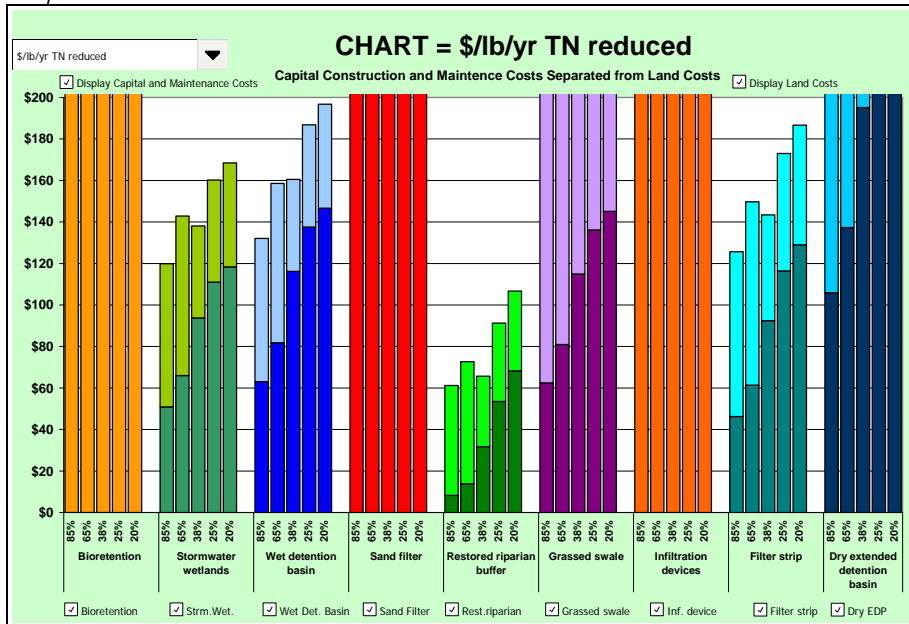


EXHIBIT 26

Unit Costs for Nitrogen Removal Sorted Using the 38% Imperviousness Land Use Category from Most to Least Cost-Effective
This table shows that some BMP-land use combinations with and without land costs included fall in sequential ranking, compared to other combinations, while some are separated in ranking by other options. The greater the separation between the "without and with land costs" pair in ranking, the more significant land cost considerations will be in comparing feasible options.

\$/lb/yr TN reduced - No Land \$ and With Land \$	Percent Imperviousness Land Use Category				
	85%	65%	38%	25%	20%
Restored riparian buffer - No Land \$	\$10	\$10	\$30	\$50	\$70
Restored riparian buffer - With Land \$	\$60	\$70	\$70	\$90	\$110
Filter strip - No Land \$	\$50	\$60	\$90	\$120	\$130
Stormwater wetlands - No Land \$	\$50	\$70	\$90	\$110	\$120
Grassed swale - No Land \$	\$60	\$80	\$110	\$140	\$150
Wet detention basin - No Land \$	\$60	\$80	\$120	\$140	\$150
Filter strip - With Land \$	\$130	\$150	\$140	\$170	\$190
Stormwater wetlands - With Land \$	\$120	\$140	\$140	\$160	\$170
Wet detention basin - With Land \$	\$130	\$160	\$160	\$190	\$200
Dry extended detention basin - No Land \$	\$110	\$140	\$200	\$230	\$250
Dry extended detention basin - With Land \$	\$280	\$330	\$310	\$350	\$370
Grassed swale - With Land \$	\$580	\$660	\$450	\$510	\$520
Infiltration devices - No Land \$	\$330	\$430	\$610	\$730	\$780
Bioretention - No Land \$	\$330	\$430	\$610	\$720	\$770
Infiltration devices - With Land \$	\$390	\$500	\$650	\$770	\$820
Bioretention - With Land \$	\$420	\$530	\$660	\$780	\$830
Sand filter - No Land \$	\$470	\$610	\$870	\$1,030	\$1,100
Sand filter - With Land \$	\$500	\$650	\$890	\$1,050	\$1,120

EXHIBIT 27

Land Costs as a Percent of Nitrogen BMP Capital and Maintenance

This table shows the range of land costs estimated for the BMP footprint across the BMP-land use combinations. They range from a low of 102%, with the BMP footprint costing just 2% of the BMP, to a high of 967% where the land costs almost 10 times what the BMP does. This illustrates that land costs may or may not be a significant cost factor, and either way should not be ignored. However, because different owners will have different opportunities and preferences to account for land costs (e.g., sunk cost, amortized, depreciated, lump payment), within the context of a screening analysis it is not possible to speculate beyond this rough comparison.

No Land \$ & With Land as a Percent of No Land	Percent Imperviousness Land Use Category				
	85%	65%	38%	25%	20%
Bioretention - No Land \$	\$330	\$430	\$610	\$720	\$770
Bioretention - With Land \$	127%	123%	108%	108%	108%
Stormwater wetlands - No Land \$	\$50	\$70	\$90	\$110	\$120
Stormwater wetlands - With Land \$	240%	200%	156%	145%	142%
Wet detention basin - No Land \$	\$60	\$80	\$120	\$140	\$150
Wet detention basin - With Land \$	217%	200%	133%	136%	133%
Sand filter - No Land \$	\$470	\$610	\$870	\$1,030	\$1,100
Sand filter - With Land \$	106%	107%	102%	102%	102%
Restored riparian buffer - No Land \$	\$8	\$14	\$32	\$54	\$68
Restored riparian buffer - With Land \$	739%	527%	207%	170%	156%
Grassed swale - No Land \$	\$60	\$80	\$110	\$140	\$150
Grassed swale - With Land \$	967%	825%	409%	364%	347%
Infiltration devices - No Land \$	\$330	\$430	\$610	\$730	\$780
Infiltration devices - With Land \$	118%	116%	107%	105%	105%
Filter strip - No Land \$	\$50	\$60	\$90	\$120	\$130
Filter strip - With Land \$	260%	250%	156%	142%	146%
Dry extended detention basin - No Land \$	\$110	\$140	\$200	\$230	\$250
Dry extended detention basin - With Land \$	255%	236%	155%	152%	148%

5.0 Pro Forma Credit/Debit Examples

5.1 Overview

Two sets of urban BMP analyses provide a basis to examine pro forma nutrient credit and debit situations relative to the baseline requirements established by the Rules: the six pilot area conceptual design BMPs, developed under Task 4 and 5 (see CH2M HILL, 2007c); and an analysis of the nutrient reduction capabilities of BMPs in series and their relative cost-effectiveness, developed to illustrate the effect of the nutrient limits and buy-down thresholds (see CH2M HILL, 2007a).

5.2 Credit Opportunities and Relative Cost-Effectiveness of the Pilot Area Conceptual Design BMPs

The BMPs selected for conceptual design were all located within the pilot subwatersheds and were either under local government ownership or had one landowner. The sites ranged from moderate to very high levels of imperviousness, and several of them provided education opportunities on school or park land. Many of the BMPs were stormwater wetlands, but bioretention, dry detention, and wet detention were also included in the designs. The BMPs selected include the more popular BMP choices by developers. Exhibit 28 provides summary information about the six sites and the designed BMPs.

EXHIBIT 28 Summary Detail for the Six Conceptual Design BMPs					
Site Name/Location	Watershed	Impervious	Site Description	Other Attributes	Designed BMP(s)
Wilson Park - Carrboro	UNH	Moderate	Open space and publicly-owned property.	Potential to treat watershed with grassed swales and wetland in depressed area. Need to relocate playground equipment.	Stormwater wetland
Carrboro Elementary School - Carrboro	UNH	Moderate	Open Space: drains to un-named tributary and to Bolin Creek. Publicly-owned property located on greenway	Potential to locate highly visible wetland system. High potential for elementary student and public education.	Stormwater wetland
Food Lion - Carrboro	UNH	High	Existing, undersized, dry detention basin.	Potential to easily retrofit dry pond to function as wet pond. Adjacent parking lot may allow for expansion room.	Dry detention
Burlington Public Works - Burlington	Haw	Very High	Light industrial site discharging various pollutants. Publicly-owned property with two separate drainage areas for BMP installation.	Able to treat various pollutants.	Bioretention and wetland (individual BMPs for separate drainage areas)
Eastgate Shopping Center - Chapel Hill	UNH	Very High	Large outfalls directly entering creek. Privately-owned property.	Potential to construct wetland to treat large pollutant load.	Stormwater wetland
Rainbow Intramural Field - Chapel Hill	UNH	Moderate	. Existing pond receiving flow from large 336 acre watershed. Current pond allows little settling and mixing time. University-owned property.	Potential to retrofit pond with minor modifications to control structure, internal water depths, flow-through path, and wetland vegetation.	Wet detention retrofit to stormwater wetland

Exhibit 29 presents the relevant information and calculations for the six conceptual design BMPs that enable a determination of credit potential and relative cost-effectiveness. The exhibits that follow provide additional detailed information.

EXHIBIT 29

Load Reduction and Unit Cost-Effectiveness for Nutrient Reductions from the Six Conceptual Design BMPs^{14,15}
 Rows 10 and 11 show the number of pounds per year of nitrogen and phosphorus reduced from the site with the BMPs.
 Rows 22-25 present the unit cost-effectiveness in \$/lb/yr to control the two nutrients. Burlington's two BMPs are calculated separately in the shaded columns and certain values are not applicable (n/a) for the combined results presented in the adjacent column.

Row	Credit and Cost-Effectiveness Calculation Element		Wilson Park Stormwater Wetland		Carrboro Elem. Stormwater Wetland		Food Lion Dry Extended Detention Basin	Burlington Public Works Bioretention	Burlington Public Works Stormwater Wetland	Burlington Public Works Total	Eastgate Stormwater Wetland	Rainbow Field Soccer Stormwater Wetland
	BMP LOCATION>		Upper New Hope	Upper New Hope	Upper New Hope	Haw	Haw	Haw	Upper New Hope	Upper New Hope		
Pollutant Loading and Removal Assumptions												
1	N % removal		40.0%	40.0%	10.0%	35.0%	40.0%	n/a	40.0%	40.0%		
2	P % removal		35.0%	35.0%	10.0%	45.0%	35.0%	n/a	35.0%	35.0%		
3	% Impervious		23.2%	26.1%	70.7%	98.0%	65.0%	70.4%	68.0%	23.0%		
4	Watershed Area	acres	26.8	47.8	27.4	2.5	12.7	15.2	30.9	336.3		
5	Rv		0.259	0.285	0.686	0.932	0.635	0.684	0.662	0.257		
6	TP EMC	mg/L	0.21	0.22	0.34	0.46	0.32	n/a	0.33	0.21		
7	TN EMC	mg/L	1.43	1.49	2.66	3.79	2.47	n/a	2.57	1.43		
8	TN Inflow Pollutant Load	lb	93.61	191.53	472.61	82.72	187.64	270.35	495.33	1166.56		
9	TP Inflow Pollutant Load	lb	13.68	27.77	61.02	9.95	24.59	34.54	64.41	170.51		
Pollutant Loading Reduction												
10	TN Reduced Pollutant Load	lb/yr	37.44	76.61	47.26	28.95	75.05	104.01	198.13	466.62		
11	TP Reduced Pollutant Load	lb/yr	4.79	9.72	6.10	4.48	8.61	13.08	22.54	59.68		
BMP Capital and O&M Costs (no Land)												
12	Total BMP Construction Cost	2008\$	\$ 466,200	\$ 414,000	\$ 106,300	\$ 119,600	\$ 323,900	\$ 443,500	\$ 236,600	\$ 560,200		
13	Maintenance Cost as % of Capital		4.5%	4.5%	0.5%	6.0%	4.5%	n/a	4.5%	4.5%		
14	Present Annual Maintenance (year 1)	2008\$	\$ 21,000	\$ 18,600	\$ 500	\$ 7,200	\$ 14,600	\$ 21,800	\$ 10,600	\$ 25,200		
15	NPV Total 20 yr Maintenance Cost	2008\$	\$ 315,000	\$ 279,700	\$ 8,000	\$ 107,700	\$ 218,900	\$ 326,600	\$ 159,900	\$ 378,500		
16	Total Cost (Construction and Maintenance)	2008\$	\$ 781,200	\$ 693,700	\$ 114,300	\$ 227,300	\$ 542,800	\$ 770,100	\$ 396,500	\$ 938,600		
BMP with Land Costs												
17	Land Consumption of BMP Footprint	%	4.0%	4.0%	2.5%	5.0%	4.0%	n/a	4.0%	2.5%		
18	Land Consumption	acres	0.25	0.50	0.49	0.12	0.33	0.45	0.84	1.93		
19	Land Cost	\$/ac	\$ 350,000	\$ 350,000	\$ 400,000	\$ 350,000	\$ 350,000	\$ 350,000	\$ 400,000	\$ 150,000		
20	Land Cost	\$	\$ 86,800	\$ 174,800	\$ 194,000	\$ 42,500	\$ 115,400	\$ 157,900	\$ 336,000	\$ 290,000		
21	Total Cost with Land	2008\$	\$ 868,000	\$ 868,500	\$ 308,300	\$ 269,900	\$ 658,100	\$ 928,000	\$ 732,400	\$ 1,228,700		
Unit Cost-Effectiveness												
22	TN no land	\$/lb/yr	\$ 1,040	\$ 450	\$ 120	\$ 390	\$ 360	\$ 370	\$ 100	\$ 100		
23	TN Land	\$/lb/yr	\$ 1,160	\$ 570	\$ 330	\$ 470	\$ 440	\$ 450	\$ 180	\$ 130		
24	TP no land	\$/lb/yr	\$ 8,160	\$ 3,570	\$ 940	\$ 2,540	\$ 3,150	\$ 2,940	\$ 880	\$ 790		
25	TP land	\$/lb/yr	\$ 9,070	\$ 4,470	\$ 2,530	\$ 3,010	\$ 3,820	\$ 3,550	\$ 1,620	\$ 1,030		

With respect to nutrient “credibility” – the extent to which nutrient reductions generate credits¹⁶ – all pro forma BMPs are considered retrofits, and therefore not subject to the control limits established for new developments or redevelopment. As such, the conceptual BMPs should be creditable as follows, under the Rules as of the date of this TM.

- **Privately Funded/Installed BMPs** – These include the Food Lion and Eastgate sites, which are on private property. As private landowners who don’t otherwise invoke new control requirements (i.e., doing nothing at the site except BMP installation, also known as a BMP retrofit), the BMP is not required and all credits generated should be fully bankable or exchangeable under the provisions of any future credit trading program. If circumstances were such that BMPs were deemed as part of a redevelopment project (i.e., making other improvements on the site), some of the reductions might still be creditable so long as (1)

¹⁴ Pollutant removal rates are taken from DWQ, 2007c.

¹⁵ Several of the values have been rounded for presentation purposes after they were calculated so reapplication of the formulas with these inputs will not produce the exact results.

¹⁶ In general, credits may be generated when landowners do better than applicable requirements. For example if the control requirement is 50%, and a landowner achieves 75% nutrient removal, then the incremental 25% additional reduction may be fully or partially creditable.

there was no net increase in impervious surface and stormwater controls were at least equal to the previous development, and (2) with a net increase in impervious surface, they would

have two options: (a) to achieve the percentage goals for the entire site associated with existing development¹⁷ or (b) to meet the loading rate targets.

- **Publicly Funded/Installed BMPs** – These include Wilson Park, Carrboro Elementary, Burlington Public Works, and Rainbow Field, which are on public property. Creditability will depend on how the owning jurisdiction complies with its own requirements as well as any requirements that may be placed on “existing or new development.” Under public jurisdictions’ current stormwater management programs, presumably some number and type of BMPs are required for compliance purposes. Additionally, the Rules contain a provision requiring “existing development” to meet applicable TMDL targets—8% and 5% reductions for TN and TP in the Haw, respectively, and 35% and 5% reductions for TN and TP in the Upper New Hope, respectively. It is assumed the “existing development” provision will be applied to the aggregate estimated existing development load, and that jurisdictions will not be required to meet these targets on a parcel by parcel basis. In that case potentially more (or less) reduction from any given public BMP project would be creditable depending on the jurisdiction’s overall progress toward the goal.

As with the screening results presented for agricultural and urban BMPs in Section 4, the inclusion or exclusion of land costs has implications for the relative cost-effectiveness among the pro forma credits. Exhibit 30 graphically presents the unit cost estimates listed in Exhibit 29, Rows 22 - 25. Exhibit 31 on the next page illustrates some of the BMP possibilities on the private and public sites.

¹⁷ See 15A NCAC 02B .0265(3)(a)(v) as revised September 11, 2008..

EXHIBIT 30

Unit Cost-Estimates for the Six Conceptual BMPs: \$/lb/yr for Nitrogen and Phosphorus

The BMPs are ordered, top to bottom, from least to most expensive on a per pound basis inclusive of land costs. If land costs are not incurred or considered, credits generated from the two private sites, Eastgate and Food Lion would become relatively less expensive, while the credits generated from Rainbow Field and Burlington Public Works BMPs would become relatively more expensive among this set. The Wilson Park unit cost bar shows the portion associated with relocating the playground. As indicated by the data in Exhibit 29 (see Rows 3, 5, 6, and 7) all else being relatively equal, BMPs on sites with higher levels of imperviousness tend to have lower unit costs, as the BMPs remove more pollutant mass from the higher runoff volumes. However, when land costs are included, these effects will be diminished when higher land costs are associated with higher levels of imperviousness, as often is the case in urban areas.

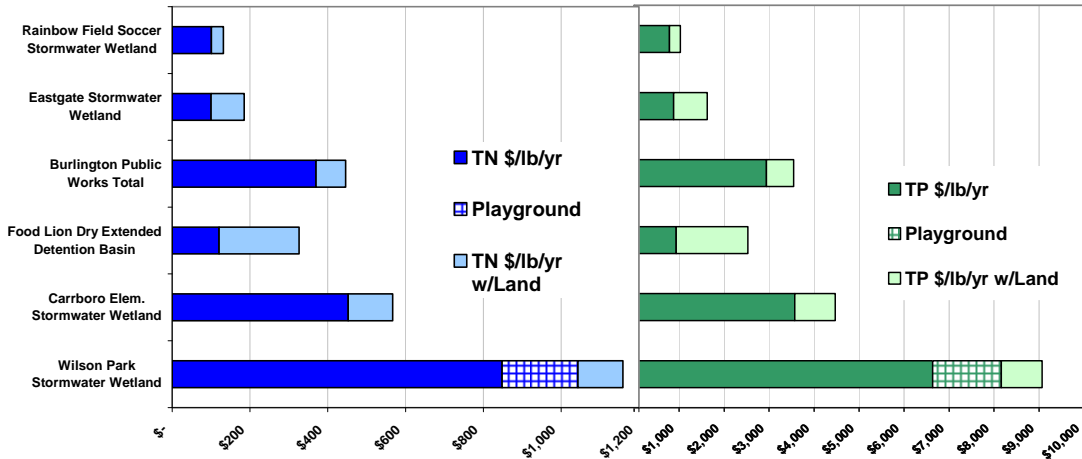


EXHIBIT 31

Potential Creditability of the Six Conceptual Design BMPs^{18,19}

If the two private sites—Food Lion and Eastgate—are not subject to redevelopment provisions, then 100% of their reduction is fully creditable (see Rows 10-11 and 12-13). The potential creditability of the public sites depends on the performance of the BMP against the applicable requirement. For example, if judged on a site-specific basis, the Rainbow Field BMP would not generate any Nitrogen credits because the removal rate of 25% is less than the applicable 35% target. The other BMPs beat their applicable requirement by the increment shown in Rows 8 - 9, and may generate credits up to the percent of total reduction shown in Rows 10 - 11, in the amounts shown in Rows 12- 13, if those reductions are not otherwise needed for stormwater management program compliance. Rows 14 and 15 show the potential credits generated per acre: the differences are primarily attributed to any differences in BMP pollutant removal rate and the relative relationship between the percent imperviousness, runoff coefficient (Rv), and event mean concentrations (EMC), as visible in Exhibit 29, Rows 3, 5, 6, and 7. Burlington's two BMPs are calculated separately in the shaded columns, and certain values are not applicable (n/a) for the combined results presented in the adjacent column.

Row	Credit and Cost-Effectiveness Calculation Element	SITE NAME> BMP LOCATION>	Wilson Park	Carrboro	Food Lion	Burlington	Burlington	Burlington	Eastgate	Rainbow
			Stormwater Wetland Upper New Hope	Elem. Stormwater Wetland Upper New Hope	Dry Extended Detention Basin Upper New Hope	Public Works Bioretention Haw	Public Works Stormwater Wetland Haw	Public Works Total Haw	Stormwater Wetland Upper New Hope	Field Soccer Stormwater Wetland Upper New Hope
Pollutant Loading and Removal Assumptions										
1	N % removal		40%	40%	10%	35%	40%	n/a	40%	40%
2	P % removal		35%	35%	10%	45%	35%	n/a	35%	35%
Pollutant Loading Reduction										
3	N Reduced Pollutant Load	lb/yr	37	77	47	29	75	104	198	467
4	P Reduced Pollutant Load	lb/yr	5	10	6	4	9	13	23	60
Applicable Removal Requirement										
5	N % removal		35%	35%	0%	8%	8%	8%	0%	35%
6	P % removal		5%	5%	0%	5%	5%	5%	0%	5%
Potentially Creditable Removal % Increment										
7	Nitrogen		5%	5%	10%	27%	32%	n/a	40%	5%
8	Phosphorus		30%	30%	10%	40%	30%	n/a	35%	30%
Potentially Creditable Removal as % of Requirement										
9	Nitrogen		13%	13%	100%	77%	80%	79%	100%	13%
10	Phosphorus		86%	86%	100%	89%	86%	87%	100%	86%
Potentially Creditable Pounds/Yr										
11	Nitrogen		5	10	47	22	60	82	198	58
12	Phosphorus		4	8	6	4	7	11	23	51

¹⁸ Pollutant removal rates are taken from DWQ, 2007c (updated September 2007).

¹⁹ Several of the values have been rounded for presentation purposes after they were calculated so reapplication of the formulas with these inputs will not produce the exact same results.

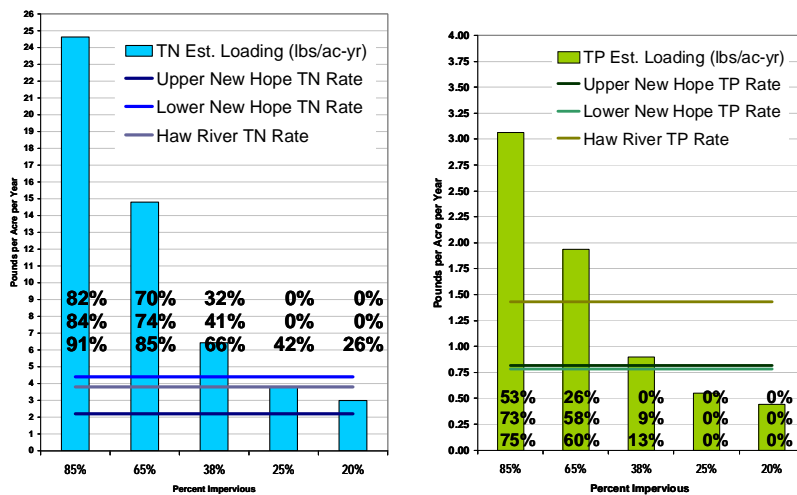
5.3 Complying with the New Development Loading Targets Using BMPs in Series

To supplement the information provided by the six BMPs selected for conceptual design, which all happened to be retrofits on existing development, additional analysis was developed to illustrate how new development projects might comply with the applicable requirements, meet the buy-down but need additional offsets, or possibly generate credits. Exhibit 32 identifies the targets and buy-down thresholds. Exhibit 33 graphically illustrates the effective percent reduction necessary to reach the threshold and targets for the five levels of imperviousness evaluated in Section 3 and 4.

EXHIBIT 32
Nitrogen Targets and Buy-Down Thresholds: All Values in Pounds/Acre/Year

	HAW		UPPER NEW HOPE	
	Target	Buy-Down	Target	Buy-Down
Single Family Residential	3.8	4	2.2	4
Multi Family Residential/Commercial	3.8	8	2.2	8

EXHIBIT 33
Effective Percent Reduction Necessary to Reach the Buy-Down Threshold and Loading Targets by % Impervious



The assessment of the compliance and credit-generating capabilities of BMPs in series was performed for four land uses, selected with stakeholder input: single family; multi-family; mixed-use residential; and commercial. Two local government stakeholders provided detailed site plans representative of each land use category to provide a basis for the analysis. These plans had been submitted to the local governments for approval and represent trends of development within the subwatersheds. Simplifying assumptions were made for this analysis, including: assuming only one drainage area per site even if there were more; and assuming site conditions would allow BMPs to be placed in series in the manner evaluated. After engineering judgment was applied, stakeholders provided input to the final selection of BMP types to be evaluated in series. BMP performance was evaluated against the requirements for new

development as established in the Rules. Because the buy-down thresholds are different in the Haw and Upper New Hope, separate analyses were prepared for each subwatershed.

For this analysis, pollutant loading rates and WQv-based cost estimates were developed using the same inputs and assumptions used for the screening analysis, as described in Section 3 and presented in Section 4. However, the percent impervious values were estimated from actual site plans. Costs for BMPs in series were additive – no economies of scale were assumed. Pollutant removal rates for the BMPs in series were assumed as presented in Exhibit 34, based on guidance in DWQ’s BMP Manual (DWQ, 2007c).

EXHIBIT 34
 Pollutant Removal Rates Assumed for BMPs in Series

BMP Code Key:	Series of BMPs	% TN Reduction	% TP Reduction
BR=Bioretention	GS+BR	48	56
CD=Cluster Development	BR+WL	61	64
GS=Grassed Swale	GS+BR+WL	69	71
RB=Riparian Buffer	GS+BR+WL+RB	78	81
SF= Sand Filter	GS+BR+WD+WL+RB	84	89
WD=Wet Detention	SF+GS+BR+WD+WL+RB	90	94
WL=Wetland			

Exhibits 35 and 36 present the results of this analysis and summarize the compliance and pro forma credit implications. The results are similar for both watersheds since the same land use and BMP series examples are used. They differ with respect to the Upper New Hope’s lower loading target, beyond which extra credits may be generated, and its higher land costs.

EXHIBIT 35

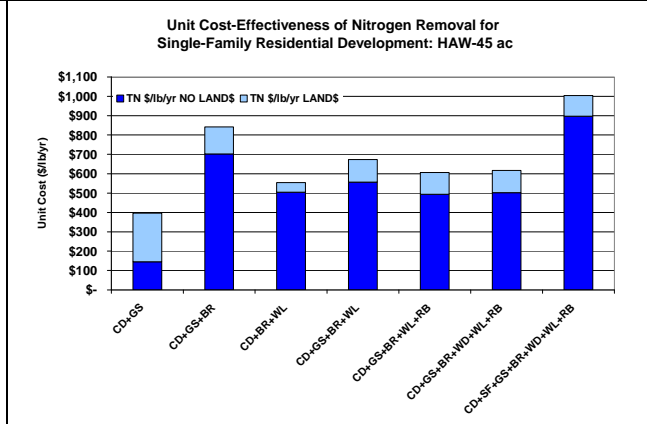
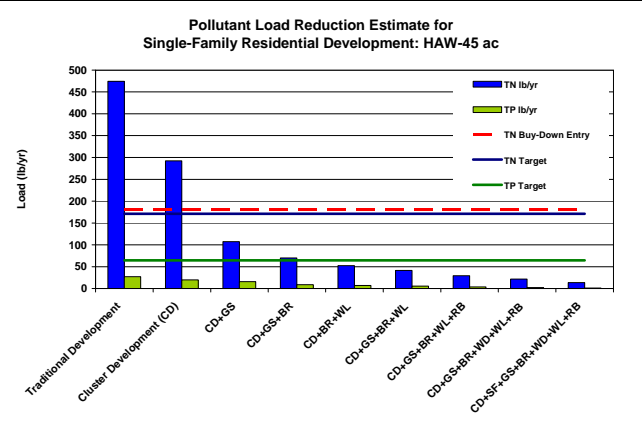
Assessment of the Compliance and Credit-Generating Capabilities of BMPs in Series: HAW WATERSHED

Note that scales on the pollutant load reduction graphs are land use-specific. Unit costs for phosphorus are not shown because this and other analyses documented under this project indicate there is unlikely to be a significant market for phosphorus credits. This allows for presentation of nitrogen unit costs at a finer level of detail, as the phosphorus unit control costs are substantially higher.

BMP Key: BR=Bioretention CD=Cluster Development GS=Grassed Swale RB=Riparian Buffer SF= Sand Filter WD=Wet Detention WL=Wetland

Single Family Residential

The graphs show that the developer must employ cluster development and at least the GS BMP to reach the buy-down threshold, which also meets the loading target. Because the effective nitrogen buy-down threshold and target are so close together for this example, 180 versus 171 lbs/yr, there is little opportunity to reach the buy-down without reaching the target. Once the target is met, the BMP packages could generate nitrogen credits, in the range of 64 to 158 lbs/yr. Unit costs range from \$195/\$400 to \$900/\$1000, and average \$540/\$670 without/with land costs included.



Multi-Family Residential

On this site, three alternatives, including no BMPs, meet the buy-down threshold. For these options, credits in the amount of 2 to 32 lbs/yr would be needed for compliance with the target. Five BMP packages meet the target, and would generate credits in the range of 7 to 25 lbs/yr. Nitrogen unit costs range from \$100/\$450 to \$660/\$820, and average \$400/\$590 without/with land costs included.

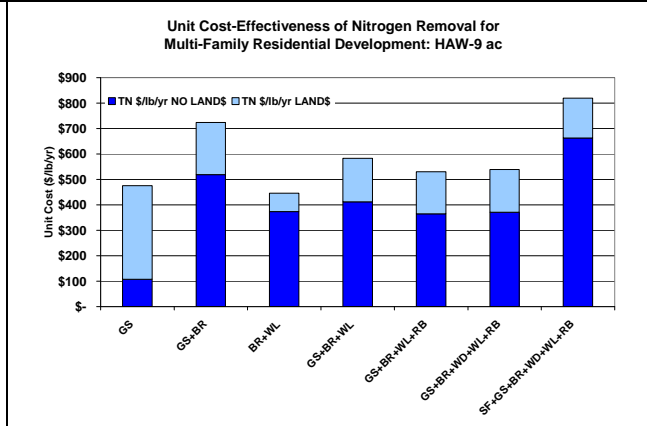
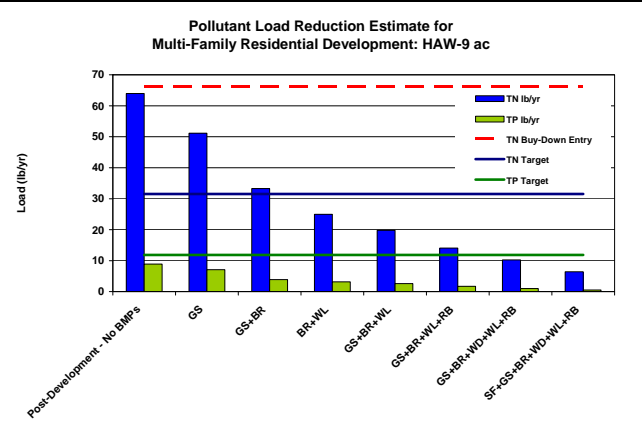


EXHIBIT 35

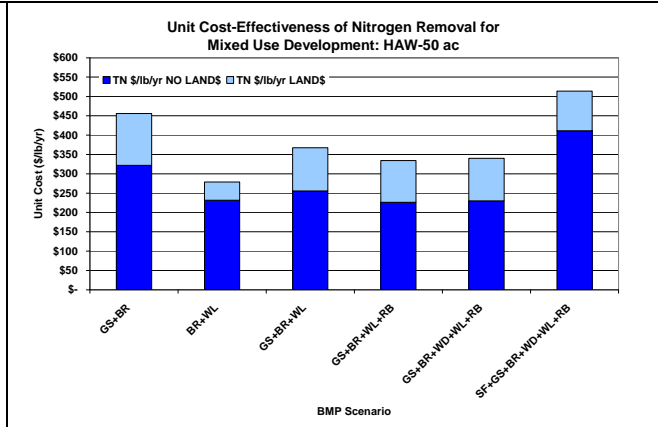
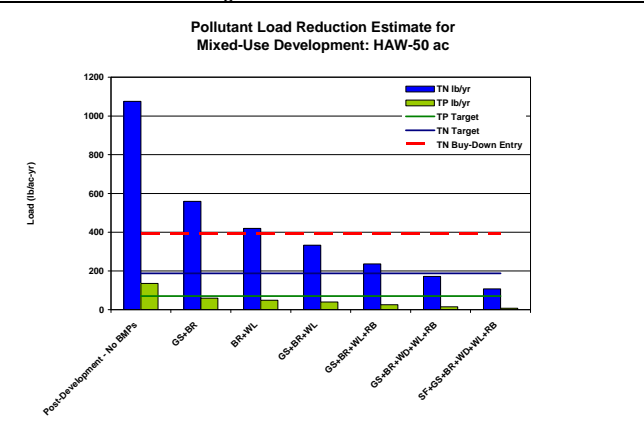
Assessment of the Compliance and Credit-Generating Capabilities of BMPs in Series: HAW WATERSHED

Note that scales on the pollutant load reduction graphs are land use-specific. Unit costs for phosphorus are not shown because this and other analyses documented under this project indicate there is unlikely to be a significant market for phosphorus credits. This allows for presentation of nitrogen unit costs at a finer level of detail, as the phosphorus unit control costs are substantially higher.

BMP Key: BR=Bioretention CD=Cluster Development GS=Grassed Swale RB=Riparian Buffer SF= Sand Filter WD=Wet Detention WL=Wetland

Mixed-Use Residential

At this site, the developer would have to use at least three BMPs—GS+BR+WL—before the buy-down threshold for nitrogen would be met. With that package, and even with an additional RB, nitrogen offsets in the amount of approximately 49 to 146 lbs/yr would be needed. Only two packages would produce credits, in the amounts of 16-80 lbs/yr. Nitrogen unit costs range from \$230/\$410 to \$450/\$510, and average \$280/\$380 without/with land costs included.



Commercial

On this commercial site, at least three BMPs—GS+BR+WL—are needed to meet the buy-down threshold for nitrogen. With this package and an additional RB, offsets/credits would be needed for compliance, in the range of 22 to 55 lbs/yr. With an additional WD, the loading target is met, if the estimates are rounded to the nearest whole pound (the calculations actually show it is just short by 0.41 lb/yr). It is not until six BMPs are applied in series that the loading limit for nitrogen can completely be met on-site with additional credits to spare, in the amount of approximately 21 lbs/yr. Unit costs range from \$60/\$390 to \$310/\$590, and average \$240/\$470 without/with land costs included.

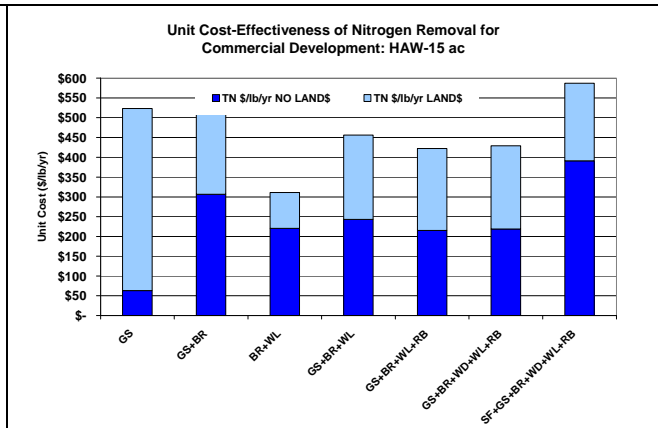
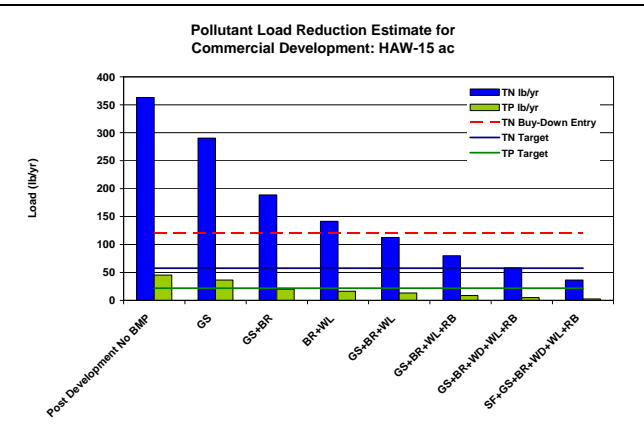


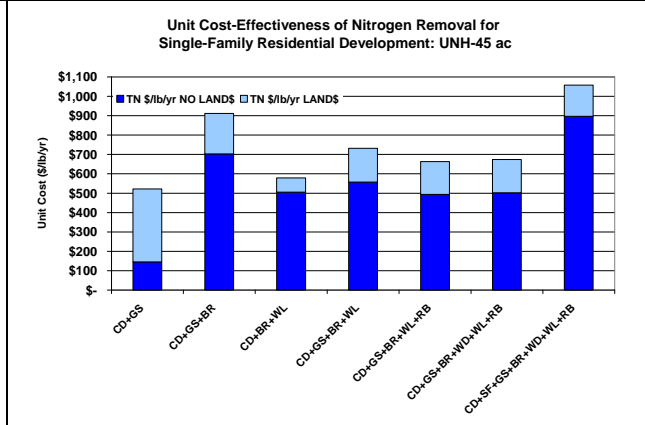
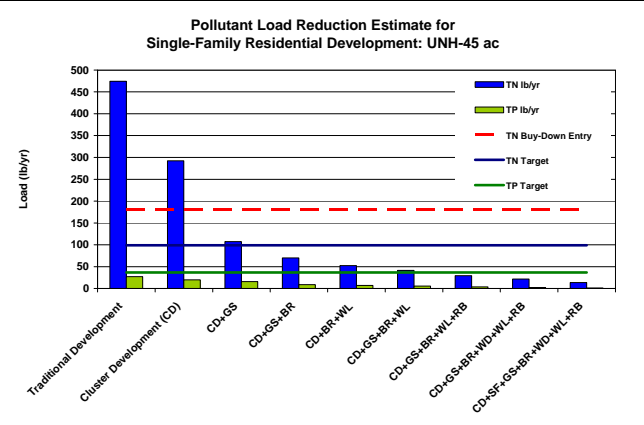
EXHIBIT 36

Assessment of the Compliance and Credit-Generating Capabilities of BMPs in Series: UPPER NEW HOPE WATERSHED Scales on the pollutant load reduction graphs are land use-specific. Unit costs for phosphorus are not shown because this and other analyses documented under this project indicate there is unlikely to be a significant market for phosphorus credits. This allows for presentation of nitrogen unit costs at a finer level of detail, as the phosphorus unit control costs are substantially higher.

BMP Key: BR=Bioretention CD=Cluster Development GS=Grassed Swale RB=Riparian Buffer SF= Sand Filter WD=Wet Detention WL=Wetland

Single Family Residential

The graphs show that the developer must employ cluster development and at least the GS BMP to reach the buy-down thresholds, at which 8.5 lbs/yr would still be needed for compliance with the loading target. Once the target is met with the CD+GS+BR BMP package, that and the other packages could generate nitrogen credits, in the range of 29 to 86 lbs/yr. Unit costs range from \$145/\$520 to \$900/\$1060, and average \$540/\$730 without/with land costs included.



Multi-Family Residential

On this site, five alternatives, including no BMPs meet the buy-down threshold. For these, credits in the amount of 2 to 46 lbs/yr would be needed for compliance with the target. Three BMP packages meet the target, and would generate credits in the range of 4 to 12 lbs/yr. Nitrogen unit costs range from \$110/\$520 to \$660/\$980, and average \$400/\$780 without/with land costs included.

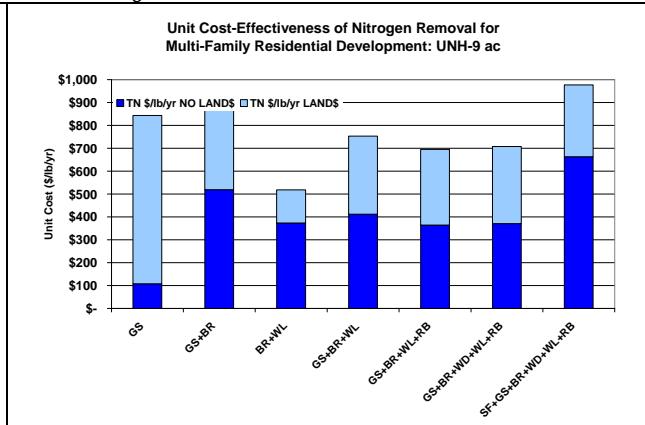
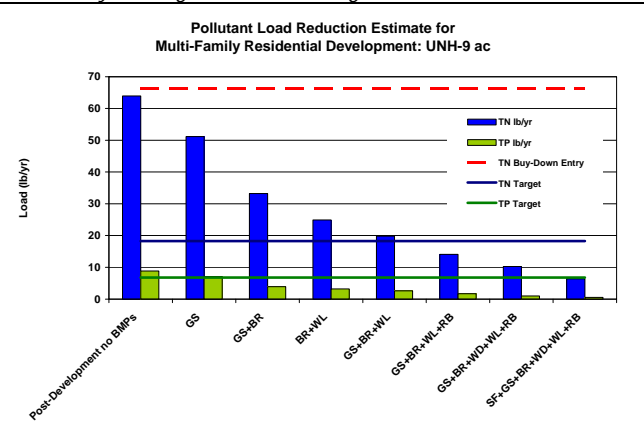


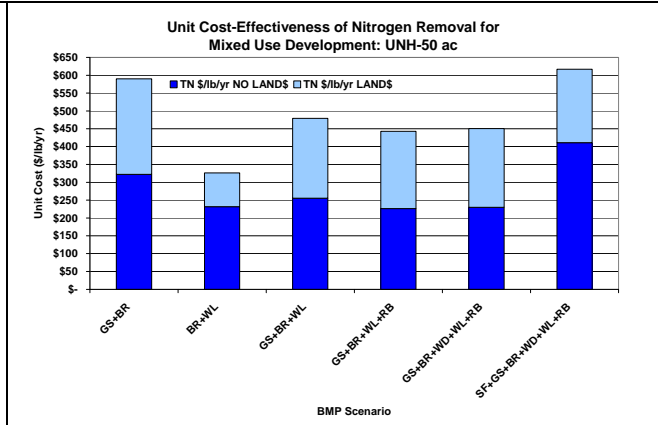
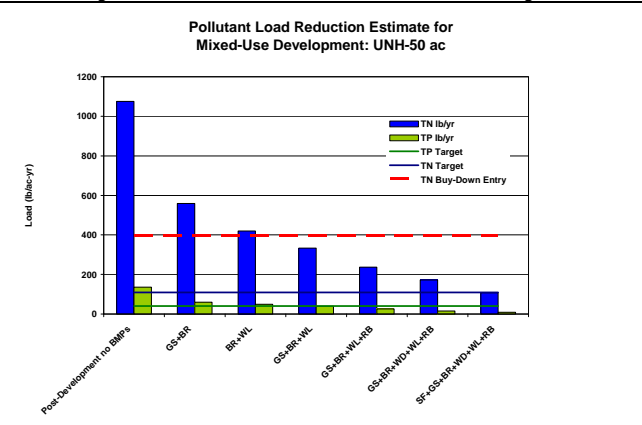
EXHIBIT 36

Assessment of the Compliance and Credit-Generating Capabilities of BMPs in Series: UPPER NEW HOPE WATERSHED Scales on the pollutant load reduction graphs are land use-specific. Unit costs for phosphorus are not shown because this and other analyses documented under this project indicate there is unlikely to be a significant market for phosphorus credits. This allows for presentation of nitrogen unit costs at a finer level of detail, as the phosphorus unit control costs are substantially higher.

BMP Key: BR=Bioretention CD=Cluster Development GS=Grassed Swale RB=Riparian Buffer SF= Sand Filter WD=Wet Detention WL=Wetland

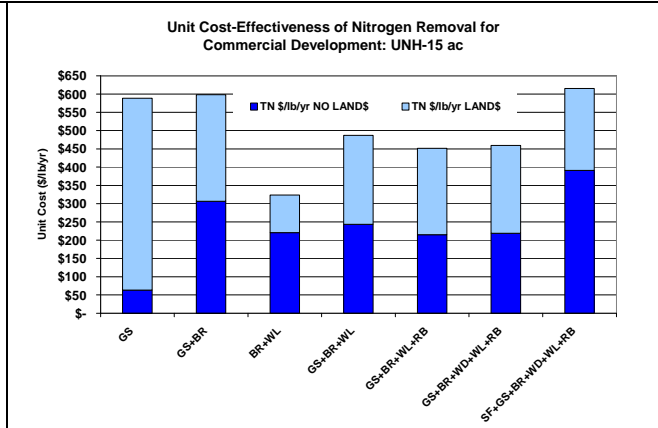
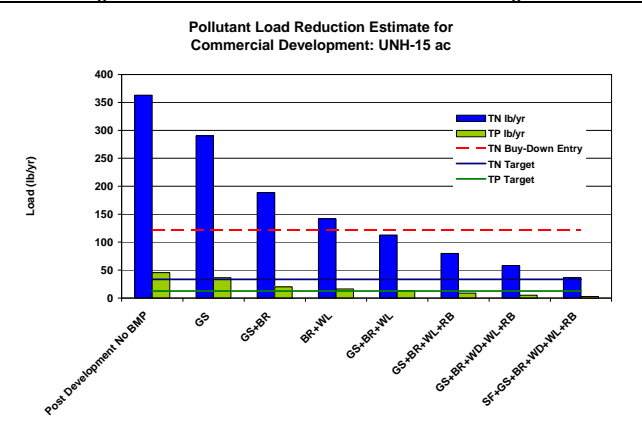
Mixed-Use Residential

At this site, the developer would have to use at least three BMPs—GS+BR+WL—before the buy-down threshold for nitrogen would be met. With the three packages that meet the buy-down threshold, but not the target, nitrogen offsets in the amount of approximately 63 to 225 lbs/yr would be needed. To meet the loading target, the developer would have to use at least six BMPs—SF+GS+BR+WD+WL+RB— with one pound to spare! So, the credit-generation potential appears very low to non-existent. Unit costs range from \$230/\$330 to \$330/\$620, and average \$280/\$480 without/with land costs included.



Commercial

At this commercial site, at least three BMPs—GS+BR+WL—are needed to meet the buy-down threshold for nitrogen. No package meets the nitrogen loading target, so the developer will need between 3 and 79 lbs/yr of nitrogen offsets/credits in this example. Unit costs range from \$60/\$390 to \$320/\$620, and average \$240/\$500 without/with land costs included.



5.4 Summary of Pro Forma Results and Market Implications

To illustrate how a nitrogen credit market might work in the Haw and Upper New Hope basins, the debit/credit and cost-effectiveness results from the conceptual design BMPs and the BMP series are consolidated into two “mini” credit markets. Exhibits 37 and 39 present the range of debits and/or credits resulting from each site. This illustrates the maximum credit demand and supply from among the sites in the mini-market, and the possibilities to balance demand and supply. Exhibits 38 and 40 present the unit costs for each level of debit or credit possible from each site. Together with the demand/supply indications, the relative unit costs illustrate which landowner might be interested in buying from or selling to another landowner.

How to Read the Charts

- Exhibits 37 and 39 show the potential debit (below the red line) and credit (above the red line) position of each of the sites examined for the subwatersheds. For the BMP series sites, the debit/credit position provided by each series, or individual BMP (for any of the six conceptual design BMPs) is marked incrementally by the series colors. Note however that a given series segment may not represent the same BMP series for each site. Bar segments below the red line represent potential buying situations, while those above the red line represent potential selling situations.
- Exhibits 38 and 40 show the relative unit control costs in \$/lb/yr for each possible debit/credit position: unit costs to the left of the center red line represent potential debit positions, and those to the right represent potential credit positions. Two points are shown for each position – unit costs without and with land included: the “with land costs included” estimate will be immediately above its corresponding “without land costs included” estimate. Points to the left of the red line indicate potential buying situations, while those to the right of the red line indicate potential selling situations.

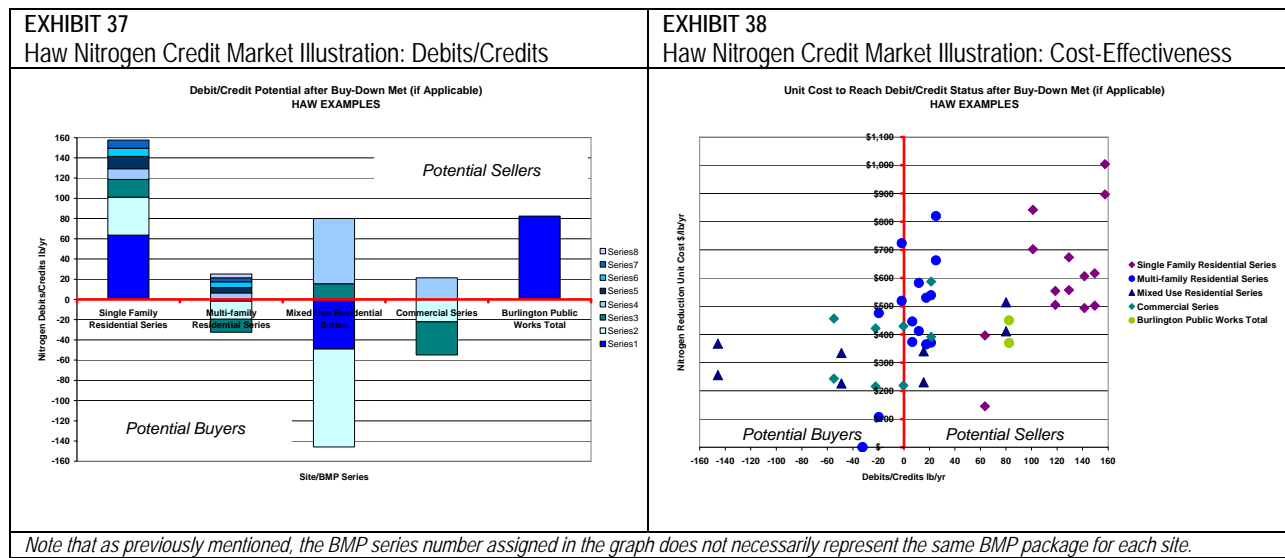
Haw Nitrogen Credit Market Illustration and Market Analysis

Exhibit 37 shows that there are three potential buyers and five potential sellers in this simulated market for the Haw. The maximum credit demand is 233 credit lbs/yr, if the multi-family, mixed use, and commercial sites all met their buy-down but then wanted to purchase credits to meet the loading target. Potential sellers under that scenario include the single family, and Burlington Public Works sites – see that their debit/credit positions are all positive, above the red line. These two potential sellers could provide as many as 232 credit lbs/yr, if they implemented BMP series to their maximum credit potential, which would not quite cover full demand from the other three sites. The maximum credit potential from all sites is 358 lbs/yr.

As to the question of whether buying credits is cost-effective, it may be less expensive for the mixed-use and commercial site landowners to meet the loading target on site than to buy credits from among this group. Exhibit 38 shows that the mixed use and commercial BMP series options to the left of the center red line and the one just to the right which meets the on-site loading target have lower unit costs than any potential seller, except for one single family residential option excluding land costs (see that the first three sets of blue triangles and turquoise diamonds from the left are all below most all other point estimates to the right of the red line).

In contrast, the multi-family site may have a few cost-effective buying options. Several sites generate credits at lower unit costs than some of the multi-family series, depending on how land costs might be included. For example, after the multi-family site meets the buy-down, its next series costs \$520-725/lb/yr and 20 credit lbs/yr are needed to meet the applicable loading target. The single family residential site could generate 63 credit lbs/yr at a cost of \$145-\$400/lb/yr, and the Burlington Public Works BMP could generate 87 credit lbs/yr at a cost of \$370-450 lb/yr (without/with land costs).

These observations presume that potential sellers would not sell credits for less than cost: theoretical scenarios exist where one or more might sell credits at sufficient enough discount to attract either the mixed use and/or commercial landowner as a buyer. Actual choices will also depend on the future price of EEP offsets compared to credits from other sources.



Upper New Hope Nitrogen Credit Market Illustration

Exhibit 39 shows that there are four potential buyers and seven potential sellers in this simulated market for the Upper New Hope. The maximum credit demand is 358 credit lb/yr, if the single family, multi-family, mixed use, and commercial sites each met the buy-down but then wanted to purchase credits to meet the loading target. Potential sellers under that scenario include the five conceptual design BMPs (see the blue bars above the red line). These five potential sellers could provide as many as 318 credit lbs/yr, if they implemented BMP series to their maximum credit potential. The single family, multi-family, and mixed use sites could be buyers or sellers. The maximum credit potential from all sites is 425 lbs/yr.

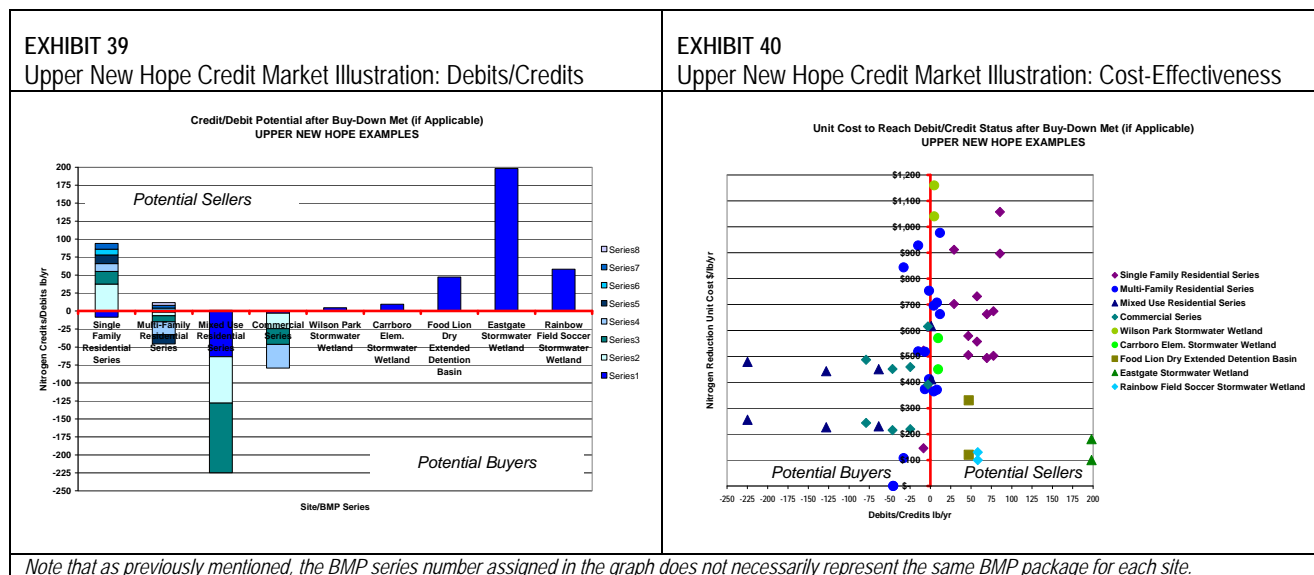
It appears all potential buyers could find more cost-effective credits than on-site compliance, if the sellers are willing. For example, depending on if/how land costs are accounted for:

- The Food Lion BMP generates 47 credit lbs/yr at a cost of \$120-\$330/lb/yr;
- The Eastgate BMP generates 198 credit lbs/yr at a cost of \$100-\$180/lb/yr; and
- The Rainbow Field BMP generates 58 credit lbs/yr at a cost of \$100-\$130/lb/yr.

See that the unit costs (y-axis values) for points representing these credits (olive squares, green triangles, and light blue diamonds) are below or roughly even with the points to the left of the red line representing the potential buyers' on-site compliance unit costs (mulberry diamonds, dark blue triangles, teal diamonds, and bright blue circles).

If the 304 credits/yr were available from the above three cited potential sellers sites at attractive prices, the buyers' demand of 294.6 lbs/yr could be met in this mini-market, with 9 credits/yr leftover, as follows: the single family site buys 8.5 credits/yr; the multi-family site buys 45.7 credits/yr, the mixed-use site landowner puts in one BMP series and buys 161.3 credits/yr; and the commercial site landowner buys 79 credits/yr.

These observations presume that potential sellers would not sell credits for less than cost: theoretical scenarios exist where one or more might sell credits at sufficient enough discount to attract either the mixed use and/or commercial landowner as a buyer. Actual choices will also depend on the future price of EEP offsets compared to credits from other sources.



6.0 The In-Lieu Fee Program Offered through EEP

Overview

The In-Lieu Fee program for nitrogen and phosphorus provides one benchmark against which to compare the results of the cost-effectiveness estimates presented in this TM. These “credits” are available as offsets for stormwater BMPs once the required minimum on-site levels are met. Currently, under this program, “unadjusted” credits for the two nutrients, nitrogen and phosphorus, are available for \$28.35 for nitrogen in the Neuse Basin,²⁰ \$21.67 for nitrogen in the Tar-Pamlico Basin and \$286.20 for phosphorus in the Tar-Pamlico Basin per pound per year, respectively. Such credits will also be available to buyers in the Jordan Lake watersheds, however unit prices have not yet been set for those watersheds.

The in-lieu fee program concept essentially consists of a “bank” of credits that may be purchased by individuals to offset the responsibilities of meeting specific requirements for nitrogen and phosphorus on site. While there are many complexities to various types of trading and banking programs, the in-lieu fee program for NC EEP has simplified the payments to offset nutrient loading into an equation.

Payments to offset nitrogen loading are calculated by using the following equation with an example:

$$\text{N Payment} = \left[\left(\frac{\$}{\text{lb}} \right) \times (\# \text{ of lbs/acre/year to be offset}) \times (\text{acres in development}) \times (30 \text{ years}) \right]$$

An example for Neuse Basin follows: [\$28.35 x 1.0 lbs. nitrogen/acre/year x 3 acres x 30 years]= \$2,551.50 nitrogen offset payment required

The variables are defined as follows:

- **\$/lb** = The cost of mitigation in dollars per pound of nitrogen mitigation. This value is currently established at \$28.35/lb of nitrogen in the Neuse Basin and \$21.67/lb of nitrogen in the Tar-Pamlico Basin;
- **# of lbs/acre/year to be offset**= The number of pounds of nitrogen exported or discharged each year for which mitigation is being requested; in above example is 1.0 lb/ac-yr;
- **Acres in development** = The overall size of the development, for which the mitigation is requested, in acres; in above example is 3 acres; and
- **30 years** = The time period required for offset payments.

A similar equation is applied for phosphorus, with a cost of \$28.62 per tenth of a pound of phosphorous in the Tar-Pamlico Basin. In the Tar-Pamlico basin, if a development project has both nitrogen and phosphorus reduction requirements, the offset-requirement and payment-amount calculations are performed for both nutrients, and only the higher amount is required to be paid.

²⁰ There are no phosphorus offset prices established for the Neuse River Basin because there are no phosphorus requirements.

Current Challenges of Comparing EEP Offset Prices to Results of this Study

As described above, EEP nitrogen credit prices as of the date of this TM are \$22/lb and \$28/lb in the Tar Pamlico and Neuse basin offset programs, respectively. A recent study found that prices between about \$40 and \$100/lb may be needed to sustain the offset programs for these basins, depending on the proportion of riparian buffers and stormwater wetlands in the offset portfolio.²¹ This same study also estimated mean expenditures for four BMP cost categories at between \$16.80 and \$574.30 \$/lb-N (in 2006 Dollars).²²

In general, unit cost estimates presented in this study appear somewhat higher in range and average than current EEP nitrogen offset prices and potential future prices that may be needed to sustain the program. However, EEP's prices cannot be directly compared to the estimates presented in this TM without further analysis that is outside the scope of this project, due to differences in methodology. A preliminary review conducted by the project team for this study attributes apparent differences in unit costs/prices to a combination of the factors that collectively all appear to be working in the same direction to result in lower EEP prices compared to the unit costs estimates developed in this study, including:

- Differences in present value calculations, including differences in assumptions about discount rates, and BMP/credit life;
- Differences in calculation methods for capital costs, including assumptions about interest rates, O&M costs, and future inflation;
- Differences in the proportion of specific BMPs included in the costing basis; and
- Differences in assumed loading rates by land use and/or BMP removal efficiencies.

For example, these effects can be illustrated using a very rough comparison made after multiplying the EEP prices by 30 (the number of years of credits which must be purchased) and dividing by 20 (the credit life assumed for unit cost calculations presented in this study). Using that approach, EEP prices presented above translate as follows: \$33/lb and \$42/lb respectively for current prices in the Tar Pamlico and Neuse Basins; an estimated \$60/lb to \$150/lb to sustain the program; and an estimated \$24/lb to \$861/lb in mean expenditures to date.

The Pro Forma trading program recommended in *Jordan Lake Watersheds Trading Project: Proposed Nutrient Credit Trading Framework for the Haw and Upper New Hope Watersheds* (CH2M HILL, 2008a) would be a good opportunity to compare EEP pricing and other unit costing methods to provide a clearer picture of the real relative cost-effectiveness between EEP offsets and alternative compliance strategies, including on-site BMPs and non-EEP credits.

²¹ See *A Study of the Costs Associated with Providing Nutrient Controls that are Adequate to Offset Point Source and Nonpoint Source Discharges of Nitrogen and Other Nutrients*, RTI and CWP, 2007, pages ES-2, 4-16, 4-17.

²² See RTI and CWP, page 3-11.

7.0 Summary Conclusions

Overview

The screening results and pro forma analyses presented in Sections 4 and 5, respectively, demonstrate that some BMP-land use (imperviousness) combinations are more cost-effective than others. These results confirm the importance of optimizing BMP selection for on-site compliance with applicable nutrient control requirements and the financial merit in looking for alternative compliance opportunities through existing and potential future credit markets.

Implications of Relative Cost-Effectiveness Results for Agricultural and Urban BMPs

Intra-Agricultural Credit Trading

If the agricultural sector has difficulty meeting its collective reduction target through on-site BMPs, the relative cost-effectiveness of the BMPs examined indicate a potentially sufficient cost-differential that an intra-sector nitrogen credit trading program could help meet the collective target less-expensively than exclusively through on-site BMPs. It was noted in the Framework TM, that agricultural stakeholders currently do not anticipate any interest or need in such an intra-sector market.

Agricultural Credit Sales to Urban Sources

After the agricultural sector meets its collective target, its members could become credit sellers to the urban sector – assuming sufficient capacity for additional nutrient reductions remained. Most of the agricultural BMPs examined are relatively less expensive than most of the urban BMPs, on a unit cost basis, and so they could be attractive credits to new development after the buy-down is met. In particular, it is possible agricultural credits could be less expensive than EEP offsets, depending on the costing and pricing methodology employed.

Urban Sector Credit Demand and Supply

A wide range of unit control costs was observed within the urban sector BMP-land use combinations examined. As illustrated in the pro forma analyses (see summary below), new development's need for offsets will occur when the buy-down is met but the loading target is not, and its ability to create credits will only occur after the on-site loading target is met. The combination of the relative cost results and the regulatory framework established by the Rules means that landowners will certainly want to examine their on-site compliance options and costs and carefully compare them to off-site options they might themselves implement or otherwise access through EEP and any future credit market.

Implications of the Pro Forma Analyses

Six Conceptual Design BMPs: Existing Development Retrofits

These BMPs illustrate how retrofits of existing sites could generate creditable nutrient reductions. The exact level of credits (number generated as a percent of total reduction) will depend on how the aggregate requirement for nutrient reductions from the “existing development” sector is ultimately implemented. If applied on a site by site basis, the examples show how credits might be generated after meeting the 8%/5% and 35%/5% reduction requirements for nitrogen/phosphorus in the Haw and Upper New Hope watersheds, respectively. The unit control costs calculated for these BMP projects are generally consistent

with the screening analysis and illustrate that retrofits may not always be more expensive, on a \$/lb reduced basis than BMPs for new development.

BMPs in Series Scenarios

The BMP series “packages” examined show the relative ease or difficulty of complying with the buy-down requirements and meeting the on-site loading target on four types of development subject to the Haw and Upper New Hope requirements for new development. It appears that single family and multi-family developments will be able to meet the buy-down and the target and create credits with several different BMP series packages in both watersheds. Mixed-use residential and commercial properties in the Haw appear to have some ability to create credits with selected BMP series packages, but with others they meet the buy-down but will still need offsets to comply with applicable targets. In the Upper New Hope, even with BMPs in series, it appears mixed-use and commercial properties will have difficulty ever meeting the on-site target completely, and will have some demand for offsets.

Illustrated Nitrogen Credit Markets in the Haw and Upper New Hope

The “mini-markets” developed using the five pro forma sites examined for the Haw and the nine examined for the Upper New Hope illustrate how a nitrogen credit market could play out with just those participants. Mathematically, sufficient credit supply exists in each watershed to meet the maximum potential demand. However, an examination of relative unit control costs shows that some site owners would be better off implementing their own set of BMPs in series on-site than seeking credits from others – unless those credits would be offered at a sufficient (sometimes substantial) discount to cost. In cases where some site owners will have to buy some number of credits (e.g., the mixed-use and commercial examples in the Upper New Hope) an illustration of a limited number of less expensive credits shows that the order and timing of entry to the credit market could well determine compliance costs.

Factors Affecting Estimated and (Future) Observed Relative Cost-Effectiveness

A variety of factors affect the results presented in this TM and the summary conclusions drawn with respect to specific comparisons of BMP-land use combinations. These include assumptions about: pre-BMP nutrient loading rates; water quality volumes; removal efficiencies; land consumption of BMPs and whether/how land costs are included; interest rates on capital expenditures and inflation for operation and maintenance; and discount rate and term for present value calculations.

Many of these same factors, and some additional ones will influence site-specific estimates for BMP implementation and actual compliance costs, including: site-specific conditions, limitations, and opportunities; non-cost factors and preferences (e.g., aesthetic); actual loading, removal efficiencies, and land costs.

Additionally, other requirements than those examined in this TM may affect the relative cost-effectiveness of certain options and the ability to generate reductions and create credits. For example TSS reduction requirements for BMPs installed as part of an NPDES Phase II requirement have to meet 85 percent TSS removal. This requirement could impact the level of additional reductions needed to meet the Jordan Lake nutrient reductions.

DWQ also allows only two BMPs with the same removal mechanism to be placed in series (DWQ, 2007). This limitation may impact the ability to comply on-site may become more limited and/or costly, increasing the demand for offsets.

Finally, the interest in a credit market that supplements and co-exists the offset program offered by EEP, as described in the Framework TM, will depend in large part on the future prices of EEP offsets. At current prices, and at some examined future prices, EEP offsets appear to be less expensive than on-site compliance with the loading target, and less expensive than other public and private credit options examined in Sections 4 and 5 of this TM. Some of this apparent difference may be attributed to differences in costing and pricing methodologies. As such, it is recommended that the pro forma trading program proposed in the Framework TM for the 2008-2011 include an initiative to examine on-site control costs and future EEP offset prices using a consistent methodology to make a more accurate determination as to whether credit options besides EEP offsets can be price-competitive and if EEP could satisfy expected demand at those comparative costs/prices.

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