Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects

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List of common acronyms used throughout the text:

BMP	Best Management Practices
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CBWM	Chesapeake Bay Watershed Model
GIS	Geographic Information Systems
GPS	Global Positioning System
ICPRB	Interstate Commission on the Potomac River Basin
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
RR	Runoff Reduction
RT VM	Reporting, Tracking, Verification and Monitoring
ST	Stormwater Treatment
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WIP	Watershed Implementation Plan
WQGIT	Water Quality Group Implementation Team
WTM	Watershed Treatment Model

Note: text in blue denotes additional language added by Watershed Technical Work Group or Water Quality Goal Implementation Team

Summary of Panel Recommendations

Over the last two decades, the Chesapeake Bay states have pioneered new techniques for finding, designing and delivering retrofits to remove pollutants, improve stream health and maintain natural hydrology in developed watersheds. Several important regulatory drivers are likely to increase the amount of future stormwater retrofit implementation across the Chesapeake Bay watershed. Some communities need to install retrofits to meet pollutant reduction targets under recently issued municipal stormwater permits or meet local TMDLs. In addition, each of the seven Bay states are considering greater use of urban stormwater retrofits as part of an overall strategy to meet nutrient and sediment load reduction targets for existing urban development under the Chesapeake Bay TMDL.

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. The Panel classified retrofits into two broad project categories -- new retrofit facilities and retrofits of existing BMPs. These two categories encompass a broad range of potential local retrofit options and applications including new constructed wetlands, green streets or rain gardens, as well as conversion, enhancements or restoration of older BMPs to boost their performance.

Given the diversity of possible retrofit applications, the Panel decided that assigning a single universal removal rate was not practical or scientifically defensible. Every retrofit is unique, depending on the drainage area it treats, the treatment mechanism employed, its volume or size and the antecedent degree of stormwater treatment, if any.

Instead, the Panel elected to develop a protocol whereby the removal rate for each individual retrofit project is determined based on the amount of runoff it treats and the degree of runoff reduction it provides. The Panel conducted an extensive review of recent BMP performance research and developed a series of retrofit removal adjustor curves to define sediment, nitrogen and phosphorus removal rates. The Panel then developed specific calculation methods tailored for different retrofit categories. To assist users, the Panel has included numerous design examples to illustrate how retrofit removal rates are calculated.

The Panel recommended simple retrofit reporting criteria to reduce the administrative burden on local and state agencies. The Panel also stressed that verification of retrofit installation and subsequent performance is critical to ensure that pollutant reductions are actually achieved and maintained across the watershed. To this end, the Panel recommends that the retrofit removal rate be limited to 10 years, although it can be renewed based on a field inspection that verifies the retrofit still exists, is adequately maintained and operating as designed. To prevent double counting, removal rates cannot be granted if the retrofit project is built to offset, compensate or otherwise mitigate for a lack of compliance with new development stormwater performance standards elsewhere in the jurisdiction.

Section 1
The Expert Panel and its Charge

EXPERT BMP REVIEW PANEL Stormwater Retrofits	
Panelist	Affiliation
Ray Bahr	Maryland Department of the Environment
Steve Stewart	Baltimore County
Ted Brown	Biohabitats, Inc.
LJ Hansen	City of Suffolk, VA
Jason Papacosma	Arlington, VA
Bill Stack	Center for Watershed Protection
Rebecca Stack	District Department of the Environment
Joe Kelly	Pennsylvania Department of Environmental Protection
Virginia Snead	Virginia Department of Conservation and Recreation
Jeff Sweeney	U.S. Environmental Protection Agency, Chesapeake Bay Program Office
Tom Schueler	Chesapeake Stormwater Network (facilitator)
The Panel would like to acknowledge the following additional people for their contribution: Norm Goulet, Chair Urban Stormwater Workgroup Lucinda Power, U.S. Environmental Protection Agency, Chesapeake Bay Program Office Chris Brosch formerly of University of Maryland and the Chesapeake Bay Program Office modeling team	

The charge of the Panel was to review all of the available science on the pollutant removal performance and runoff reduction capability of BMPs that can be used to derive methods or protocols to derive nutrient and sediment removal rates for individual retrofits.

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Removal rates will need to be inferred from other known BMP pollutant removal and runoff reduction data. Every retrofit is unique, depending on the drainage area treated, BMP treatment mechanisms, volume or sizing and the antecedent degree of stormwater treatment, if any.

Stormwater retrofits can be classified into two broad project categories, as shown below:

a. New retrofit facilities
b. BMP conversions, enhancements, or restoration

The Panel was specifically requested to:

- Provide a specific definition for each class of retrofits and the qualifying conditions under which a locality can receive a nutrient/sediment removal rate.

- Assess whether the retrofit class can be addressed by using existing CBP-approved BMP removal rates, or whether new methods or protocols need to be developed to define improved rates.

- Evaluate which load estimation methods are best suited to characterize the baseline pre-retrofit for the drainage area to each class of retrofit.

- Define the proper units that local governments will report retrofit implementation to the state to incorporate into the Watershed Model.

Beyond this specific charge, the Panel was asked to:

- Determine whether to recommend if an interim BMP rate should be established for one or more classes of retrofits prior to the conclusion of the Panel for WIP planning purposes.

- Recommend procedures for reporting, tracking and verifying the recommended retrofit removal rates. The Panel also will look at the potential to develop regional monitoring consortium to devise strategies for future collaborative monitoring to better define the performance of various retrofit projects.

- Critically analyze any unintended consequence associated with the removal rates and any potential for double or over-counting of the load reduction achieved.

While conducting its review, the Panel followed the procedures and process outlined in the WQGIT BMP review protocol (WQGIT, 2010). The process begins with BMP expert panels that evaluate existing research and make initial recommendations on removal rates. These, in turn, are reviewed by the Urban Stormwater Workgroup, and other Chesapeake Bay Program (CBP) management committees, to ensure they are accurate and consistent with the Chesapeake Bay Watershed Model (CBWM) framework.

Appendix C documents the process by which the expert panel reached consensus, in the form of a series of five meeting minutes that summarize their deliberations. Appendix D documents how the Panel satisfied the requirements of the BMP review panel protocol.

Section 2
Background on Retrofitting in the Bay

Over the last two decades, communities across the Chesapeake Bay have pioneered new techniques for finding, designing and delivering retrofits to remove pollutants, improve stream health and maintain natural hydrology in developed watersheds (Schueler, 2007). Several important regulatory drivers are likely to increase the amount of future stormwater retrofit implementation across the Chesapeake Bay watershed.

For example, some communities need to install retrofits to meet pollutant reduction targets under recently issued muuicipal stormwater permits. Other communities are employing retrofits to control pollutants to meet local TMDLs. Each of the seven Bay states are considering greater use of urban stormwater retrofits as part of an overall strategy to remove nutrients and sediment loads, to meet reduction targets for existing urban development under the Chesapeake Bay TMDL. This section provides highlights about these retrofit strategies, which differ from state to state. More detail on individual state retrofitting strategies can be found in the stormwater sector section of their Phase 1 and Phase 2 Watershed Implementation Plans, the links to which can be found in Table 1.

PA DEP indicated that most of the retrofit activity in the Pennsylvania portion of the watershed to this point has involved various demonstration projects, many of which were funded under the Growing Greener program. The scope of retrofit activity will expand in the coming years as communities implement their new PAG-13 MS4 permits which require localities to develop strategies in the form of a local Chesapeake Bay Pollutant Reduction Plan by 2013.

VA DCR indicated that most of the retrofit activity in the Commonwealth included demonstration projects under state grants and revolving funds, although some suburban counties have also supported strong retrofit programs employing their own capital budgets. VA DCR intends to issue new Phase 1 MS4 permits during 2012 that will require as much as 40% pollutant reduction for existing development over a 15 year period. The pollutant reductions from existing development may be achieved by a variety of urban restoration practices, including stormwater retrofits. During the first permit cycle, communities are encouraged to conduct local watershed assessments to identify the most cost effective combinations of retrofits and other restoration practices.

MDE noted that Maryland has had a long retrofitting history. For more than a decade, Phase 1 MS4 communities have needed to treat 10% of their impervious cover in each five year permit cycle. Most communities have elected to meet that target through stormwater retrofits. Over the years, MDE has offered several grant programs to defray local retrofit project costs, but most communities have relied on their local capital budgets to finance the majority of their retrofits. MDE intends to issue new Phase 1 permits during 2012 that will expand the retrofit requirement to as much as 20% of untreated impervious cover during each permit cycle, and may also institute numerical retrofitting requirements for Phase 2 MS4 permits.

The District of Columbia has also had a long history of retrofitting, particularly in the Anacostia watershed. The focus of retrofitting in DC has evolved over the years to reflect the challenges and opportunities within their highly urban watersheds. DDOE currently relies on several residential and business incentive programs to build on-site LID retrofits, such as bioretention, rain barrels, green roofs or permeable pavers. The District is also implementing an extensive green street retrofit program on municipal streets. DDOE tracks these retrofits over time using a GIS tracking tool to record the aggregate acreage treated, and generally assumes a five year removal rate duration for on-site retrofits, which can be renewed based on inspection.

While Delaware has been involved in numerous retrofits over the years, they are not relying heavily on them in the small portion of their state that actually drains to the Chesapeake Bay. This part of the watershed area is primarily rural, and most of their urban restoration activity will involve septic system upgrades rather than retrofitting.

Similarly, the other upstream states (West Virginia and New York) are not expecting a great deal of stormwater retrofit activity in the coming years, and are focusing on other pollutant source sectors (e.g., agricultural, wastewater, abandoned mines) to achieve the bulk of their pollutant reductions. Both states, however, are expanding stormwater treatment requirements on new and redevelopment projects to prevent increased urban loading.

Stormwater retrofits have been uncommon at federal facilities until quite recently. The President's Executive Order on the Chesapeake Bay directed federal agencies to lead by example and demonstrate more pollution prevention and stormwater retrofits at the many federal properties in the watershed. Numerous federal agencies are now condncting retrofit and site benchmarking investigations at their facilities and it is likely that much more federal retrofit implementation will occur in the coming years.

Table 1 Key Web links for State and Federal Bay TMDL and WIP Guidance[1]

EPA	http://www.epa.gov/chesapeakebaytmdl/
DC	http://ddoe.dc.gov/service/total-maximum-daily-load-tmdl-chesapeake-bay
DE	http://www.dnrec.delaware.gov/wr/Information/Pages/Chesapeake_WIP.aspx
MD	http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/PhaseIIBayWIPDev.aspx
NY	http://www.dec.ny.gov/lands/33279.html
PA	http://www.depweb.state.pa.us/portal/server.pt/community/chesapeake_bay_program/10513
VA	http://www.dcr.virginia.gov/vabaytmdl/index.shtml
WV	http://www.dep.wv.gov/WWE/watershed/wqmonitoring/Pages/ChesapeakeBay.aspx

1 links current as of 3.16.2012

Section 3
Retrofit Definitions and Qualifying Conditions

Definition: Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Stormwater retrofits can be classified into two broad project categories, as shown below:

1. New retrofit facilities
2. Existing BMP retrofits

<u>1. New retrofit facilities:</u> This category includes new retrofit projects that create storage to reduce nutrients from existing developed land that is not currently receiving any stormwater treatment. Common examples of new retrofit facilities include creating new storage:

(a) Near existing stormwater outfalls
(b) Within the existing stormwater conveyance system
(c) Adjacent to large parking lots
(d) Green street retrofits
(e) On-site LID retrofits

With the exception of (e), many new retrofit facilities are typically located on public land, and utilize a range of stormwater treatment and runoff reduction mechanisms. Due to site constraints, new retrofits may not always meet past or future performance standards for BMP sizing that applies to new development.

<u>2. Existing BMP retrofits:</u> are a fairly common approach where an existing BMP is either:

(a) Converted into a different BMP that employs more effective treatment mechanism(s).
(b) Enhanced by increasing its treatment volume and/or increasing its hydraulic retention time.
(c) Restored to renew its performance through major sediment cleanouts, vegetative harvesting, filter media upgrades, or full-scale replacement.

Most ***BMP conversions*** involve retrofits of older existing stormwater ponds, such as converting a dry pond into a coustructed wetland or wet pond, although many other types of BMP conversions are also possible. BMP conversions can be located within existing BMPs located on public land, or at privately-owned BMPs. BMP conversions can utilize a wide range of stormwater treatment mechanisms.

BMP enhancements utilize the original stormwater treatment mechanism, but improve removal by increasing storage volume or hydraulic residence time. An example of a BMP enhancement is an upgrade to an older stormwater pond built under less stringent sizing and design standards. These upgrades may increase treatment volume, prevent short circuiting, extend flow path or hydraulic residence time, or add internal design features to enhance overall nutrient and/or sediment reduction. BMP enhancements typically occur within existing BMPs located on public land, or at privately-owned BMPs.

BMP restoration applies to major maintenance upgrades to existing BMPs that have either failed or lost their original stormwater treatment capacity. The method to calculate the removal rate increase depends on whether or not the BMP has previously been reported to EPA.

If the BMP has been previously reported, a lower removal rate is calculated using the curves that reflects the existing level of treatment, and this value must be reported for at least one progress reporting cycle. After the qualifying BMP restoration is completed, the curves are used to derive a higher rate for the increased treatment volume in subsequent years. If the BMP was not previously reported to EPA, it is considered a new retrofit, and the curves are used to define the removal rate based on the total treatment volume provided.

Only four types of BMP restoration are allowed:

(a) *Major Sediment Cleanouts* – Removal of sediment, muck and debris that is equal to or greater than 1/10 the volume of the facility. For wet ponds, the volume of the facility would be where the normal water elevation or invert of the outfall pipe is. For dry ponds or enhanced extended detention facilities, the volume would include the volume of any fore bays, to their overflows, and ½ the height of the dewatering structure.

(b) *Vegetative Harvesting* – Removal of excessive, non-planned vegetative growth with off-site sequestration or composting. Appropriate plant species shall be re-planted and re-established when the vegetative harvesting causes an erosive or denuded condition.

(c) *Filter Media Enhancements* – Removal and sequestration of contaminated material and replacement with a media that is superior to those originally proposed in the design specification (i.e., replacing sand with a sand/organic or sand/zeolite mixture).

(d) *Complete BMP Rehabilitation* – Complete rehabilitation of a failed BMP to restore its performance (e.g., converting a failed infiltration basin into a constructed wetland). This restoration option only applies to older BMPs that were not previously reported to EPA.

Figure 1. Examples of New Retrofit Facilities and their Potential Applications

New retrofit facilities provide stormwater treatment in places that treatment did not previously occur. There are many opportunities for new retrofit facilities in the urban landscape. Some common examples are listed below.

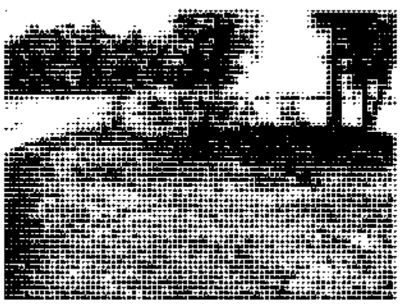
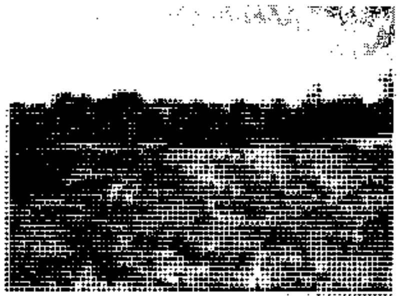
	
Near Existing Stormwater Outfalls	Within the Existing Stormwater Conveyance System
	
Adjacent to Large Parking Lots	Green Street Retrofits
	
On-Site LID Retrofits	

Figure 2. Examples of Existing BMP Retrofit Facilities and their Potential Applications




BMP Conversion: from a Dry Pond (left) to a Constructed Wetland (right) to allow for more effective treatment of stormwater.


BMP Enhancement: by adding a berm you can increase the flow path thereby extending the hydraulic retention time within the practice leading to better treatment.


BMP Restoration: increasing performance of a BMP by conducting major repairs or upgrades. In this example, an underperforming pond is dredged for sediment thereby restoring it to its full performance capacity.

Important Notes:

- No pollutant removal rates are given for routine maintenance of existing stormwater practices.
- Routine maintenance is essential to ensure the pollutant removal performance of any stormwater practice.

- The WTWG added a further qualifying condition that the proposed BMP restoration activities must be significant enough to achieve the intent of the original water quality design criteria in the era in which it was built (e.g., sediment cleanouts would, at a minimum, need to recover the original water quality storage capacity under the prevailing design standards at the time the BMP was constructed).

- Individual state stormwater agencies are encouraged to develop more detailed guidance on the qualifying conditions for acceptable BMP restoration.

- Applying more stringent stormwater requirements at redevelopment sites that had not previously treated stormwater runoff is functionally equivalent to a new retrofit facility. However, the Performance Standards Expert Panel recommended a protocol to compute load reductions at redevelopment projects.

Section 4
Protocol for Determining Retrofit Removal Rates

Basic Approach

Given the diversity of possible retrofit applications, the Panel decided that assigning a single universal removal rate was not practical or scientifically defensible. Instead, the Panel opted to develop a protocol whereby the removal rate for each individual retrofit project is determined based on the amount of runoff it treats and the degree of runoff reduction it provides. This approach is generally supported by a review of the recent pollutant removal and runoff reduction research, which is summarized in Appendix A.

The Panel initially developed a retrofit removal rate adjustor table that provides increasing sediment and nutrient removal rates for retrofits that treat more runoff and/or employ runoff reduction practices. For ease of use, the adjustor table was converted into a series of three curves, which are portrayed in Figures 3 to 5. Readers that wish to see the technical derivation for the adjustor curves should consult Appendix B.

In order to determine the runoff volume treated by a retrofit practice, the designer must first estimate the Runoff Storage volume (RS) in acre-feet. This, along with the Impervious Area (IA) in acres, is used in the standard retrofit equation to determine the amount of runoff volume in inches treated at the site:

$$= \frac{(RS)(12)}{IA}$$

Where:

RS = Runoff Storage Volume (acre-feet)
IA = Impervious Area (acres)

Once the amount of runoff captured by the practice is determined, the retrofit removal adjustor curves make it easy to determine pollutant removal rates for individual stormwater retrofits. The designer first defines the runoff depth treated by the project (on the x-axis), and then determines whether the project is classified as having runoff reduction (RR) or stormwater treatment (ST) capability (from Table 2). The designer then goes upward to intersect with the appropriate curve, and moves to the left to find the corresponding removal rate on the y-axis (see example in Figure 3).

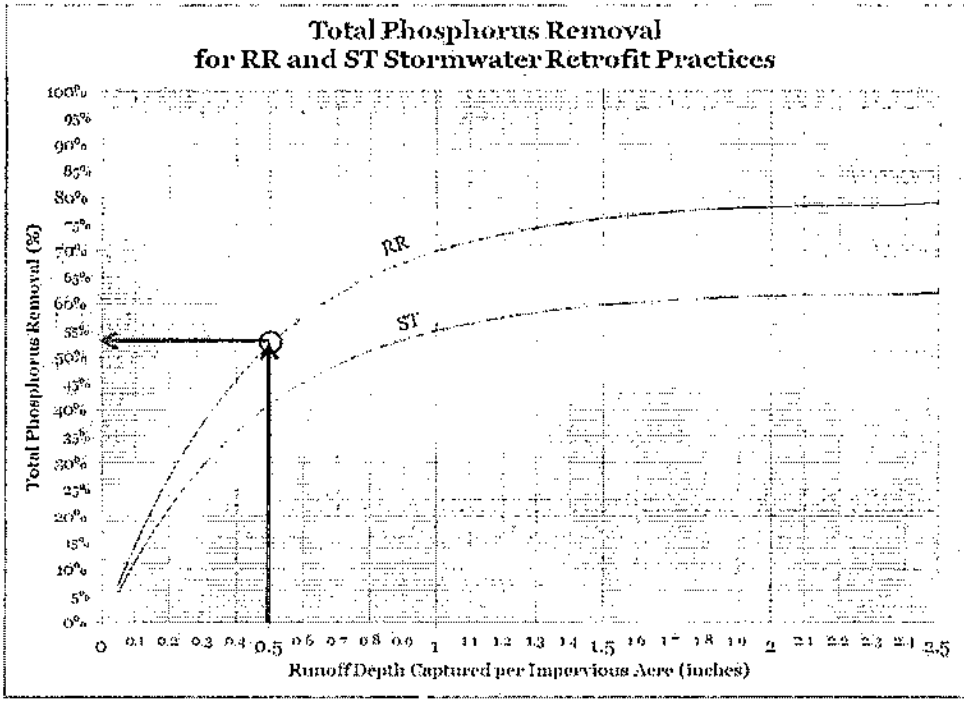


Figure 3. Retrofit Removal Adjustor Curve for Total Phosphorus

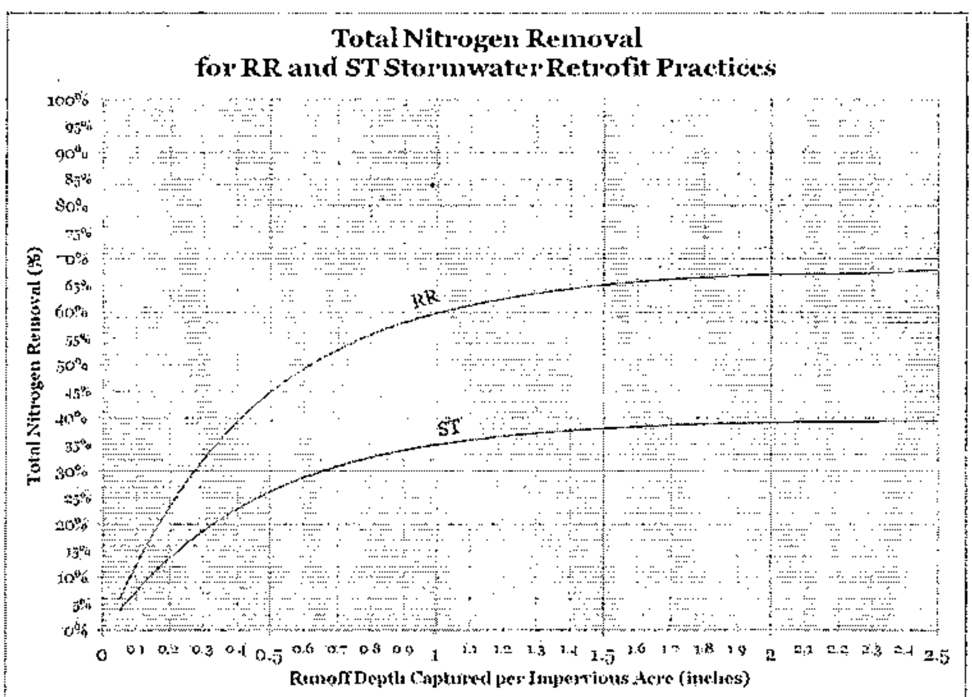


Figure 4. Retrofit Removal Adjustor Curve for Total Nitrogen

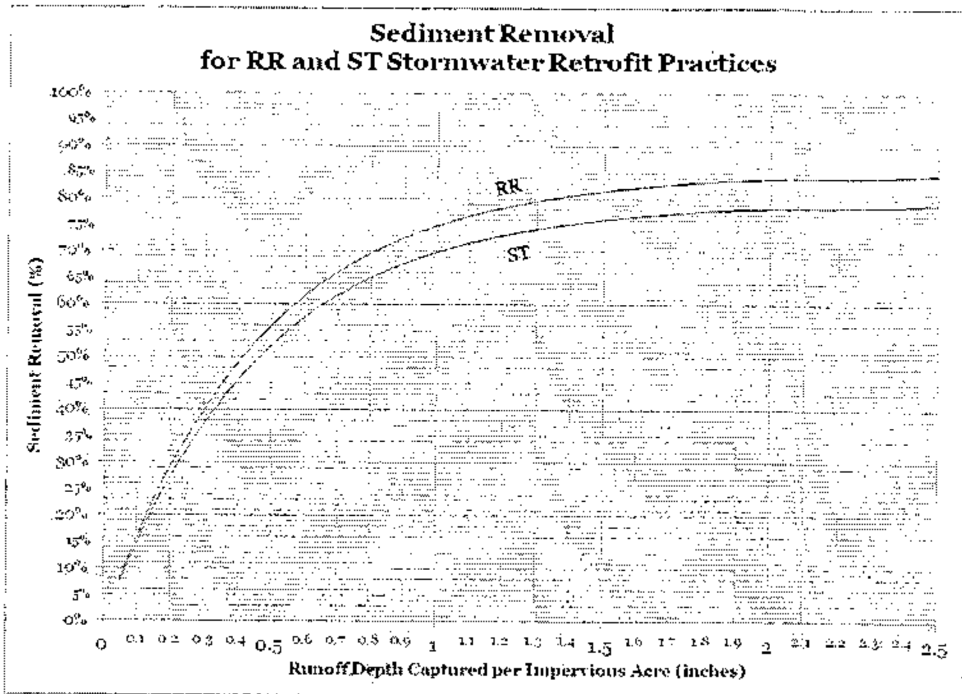


Figure 5. Retrofit Removal Adjustor Curve for Sediment

Runoff reduction is defined as the total post development runoff volume that is reduced through canopy interception, soil amendments, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapo-transpiration. Retrofit projects that achieve at least a 25% reduction of the annual runoff volume are classified as providing Runoff Reduction (RR), and therefore earu a higher net removal rate. Retrofit projects that employ a permanent pool, constructed wetlands or sand filters have less runoff reduction capability, and their removal rate is determined using the Stormwater Treatment (ST) curve.

Table 2 assigns all of the stormwater practices referenced in Bay State stormwater manuals into either the ST or RR category, so that designers can quickly determine which curve they should use based on the primary treatment practice employed by the retrofit. In situations where a mix of ST and RR practices are used within the same retrofit project, the designer should use the curve based on either the largest single practice used in the project or the ones that provide the majority of the retrofit treatment volume.

The removal rates determined from the retrofit removal rate adjustor curves are applied to the entire drainage area to the retrofit, and not just its impervious acres. Also, the retrofit reporting unit is the entire treated area, regardless of whether it is pervious or impervious.

Table 2 Classification of BMPs based on Runoff reduction capability[1]

Runoff Reduction Practices (RR)	*Stormwater Treatment Practices (ST)* [2]
Site Design/Non-Structural Practices	
Landscape Restoration/Reforestation	
Riparian Buffer Restoration	Constructed Wetlands
Rooftop Disconnection (aka Simple Disconnection to Amended Soils, to a Conservation Area, to a Pervious Area, Non-Rooftop Disconnection)	Filtering Practices (aka Constructed Filters, Sand Filters, Stormwater Filtering Systems)
Sheetflow to Filter/Open Space* (aka Sheetflow to Conservation Area, Vegetated Filter Strip)	Proprietary Practices (aka Manufactured BMPs)
All Non-structural BMPS – Chapter 5 of the 2006 Pennsylvania Stormwater BMP Manual	Wet Ponds (aka Retention Basin)
Practices	Wet Swale
All ESD practices in MD 2007	
Bioretention or Rain Garden (Standard or Enhanced)	
Dry Channel Regenerative Stormwater Conveyance (aka Step Pool Storm Conveyance)	
Dry Swale	
Expanded Tree Pits	
Grass Channels (w/ Soil Amendments, aka Bioswale, Vegetated Swale)	
Green Roof (aka Vegetated Roof)	
Green Streets	
Infiltration (aka Infiltration Basin, Infiltration Bed, Infiltration Trench, Dry Well/Seepage Pit, Landscape Infiltration)	
Permeable Pavement (aka Porous Pavement)	
Rainwater Harvesting (aka Capture and Re-use)	

*May include a berm or a level spreader

[1]Refer to DC, MD, PA, VA or WV State Stormwater Manuals for more information

[2] Dry ED ponds have limited removal capability , their efficiency is calculated using rates in Table A-4, Appendix A

Protocol for New Retrofit Facilities

To determine the sediment and nutrient removal rate for an individual new retrofit project, the designer should go the appropriate curve and find the unique rate for the combination of runoff depth captured and runoff reduction/stormwater treatment that is achieved. The designer should also estimate the total contributing drainage area to the retrofit. Several examples are provided in the next section to illustrate how the protocol is applied.

Protocol for Existing BMP Retrofit Facilities

The method used to define removal rates differs slightly for each of the three classes in this category, as follows:

BMP Conversion: The specific method for defining the removal rate depends on the type and age of the BMP being converted:

- *If the BMP being converted is a dry detention pond or flood control structure that currently is providing no effective water quality treatment*, then the existing BMP will have a zero removal rate. A higher CBP-approved BMP rate that reflects the improved stormwater treatment mechanism associated with the conversion can be taken directly from Table A-5 of Appendix A (i.e., dry ED, wet pond, constructed wetland or bioretention)

- *If the BMP being converted involves a significant increase in runoff capture volume and/or an increase in runoff reduction, than an incremental rate is used.* The removal rate for the existing BMP should be determined from the adjustor curve. A higher removal for the converted BMP will reflect the higher degree of runoff treatment and/or runoff reduction associated with the retrofit, as determined from the retrofit removal adjustor curves (Figure 3 to 5). This method will generally be the most applicable to the majority of conversion retrofits.

In all cases, the designer should also estimate the total contributing drainage area to the retrofit. Examples are provided in the next section, that illustrate how both of these methods are applied to conversion retrofits.

BMP Enhancement: The sediment and nutrient removal rates for individual BMP enhancement retrofits are also expressed as an incremental removal rate (enhanced BMP - existing BMP).

- The rate for the existing BMP is defined based on its combination of runoff treatment and runoff reduction using the retrofit removal adjustor curves. Designers may reduce the actual amount of runoff treatment in the existing BMP that is not effective (e.g., treatment volume that is ineffective because of short-circuiting or other design problems that reduce the hydraulic retention time).

- The enhanced BMP will have either a greater runoff treatment volume and/or achieve a better runoff reduction rate. Designers can determine the higher rate for the enhanced BMP using the retrofit removal adjustor curves.

- The removal rate for the BMP enhancement is then defined as the difference between the enhanced rate and the existing rate. An example of how to apply this protocol for BMP enhancements is provided in the next section.

BMP Restoration: The removal rate for BMP restoration depends on whether the existing BMP has been previously reported to EPA.

- If the BMP has not been previously reported, it is considered to be a new retrofit facility and the removal rate is determined by the retrofit removal adjustor curves for the drainage area contributing to the BMP.

- If the BMP was previously reported to EPA, then the removal rate for a restored BMP is expressed as an incremental removal rate (restored BMP - existing BMP). The existing BMP removal rate is defined using the curves based on the original BMP sizing and design criteria. The restored BMP rate is defined using the retrofit removal rate adjustor curve for the runoff treatment volume "restored" (i.e., by sediment cleanouts, vegetative harvesting or practice rehabilitation) and/or shifting to RR runoff reduction (i.e., media replacement).

  To prevent double counting, the removal rate credit is reported to EPA by the jurisdiction in a two step process. First, it must be reported at the degraded condition (lower removal rate) for at least one annual progress run. Second, the incremental rate improvement associated with the BMP restoration is then reported the next progress year.

Other Key Issues:

What Data to Report

To be eligible for the removal rates in the model, localities need to check with their state stormwater agency on the specific data to report individual retrofit projects, and must meet the BMP reporting and tracking procedures established by their state. The Panel recommended that the following information be reported:

a. Retrofit class (i.e., new retrofit facility or existing BMP retrofit)
b. GPS coordinates
c. Year of installation (and expected rate duration)
d. 12 digit watershed in which it is located
e. Total drainage area and impervious cover area treated
f. Runoff volume treated and identify "type" of BMP
g. Projected sediment, nitrogen and phosphorus removal rates

Jurisdictions will also be responsible for other tracking and verification procedures as outlined in Section 6 of this memo.

The Baseline Load Issue

The protocol developed by the Panel does not require jurisdictions to define a pre-retrofit baseline load. The Panel acknowledges, however, that many jurisdictions may want to estimate pre-retrofit baseline loads when it comes to finding the most cost-effective combination of retrofit projects to pursue in their subwatershed retrofit investigations.

Analyzing Retrofit Options in the Context of CAST/MAST/VAST

The Panel acknowledges that its retrofit assessment protocol does not fit easily within the context of assessment and scenario builder tools that have been recently developed to assist states and localities to evaluate BMP options to develop watershed implementation plans (i.e., each retrofit has a unique rate and consequent load reduction, while the CAST tools apply a universal rate for all retrofits).

The CBPO modeling team has expressed a willingness to incorporate the adjustor curves into the CAST modeling framework in the next year or so. Until these refinements are made, the Panel felt that it was reasonable, for planning purposes, for each state to assign a single removal rate to characterize the performance of a generic type of retrofit to evaluate alternate BMP scenarios.

As an example, a state might assume a generic stormwater retrofit that is a 50/50 blend of RR and ST practices and treat 1 inch of runoff from impervious area. This generic retrofit rate could be used in the context of CAST to compare load reductions for different levels of local drainage area treated by retrofits. As noted, each state would elect to develop its own scenarios to be consistent with their unique scenario assessment tools.

Section 5
Retrofit Examples

The following examples have been created in order to demonstrate the proper application of the retrofit removal adjustor curves for the purpose of determining the nutrient and sediment removal rates of retrofits.

New Retrofit Facilities

Constructed Wetland. A Bay County has discovered an un-utilized parcel of parkland where it is feasible to build a constructed wetland. The engineer has estimated that the retrofit storage in the constructed wetland is 1.67 acre-feet. The proposed retrofit will treat the runoff from a 50 acre residential neighborhood with 40% impervious cover. The engineer determines the number of inches that the retrofit will treat using the standard retrofit eqnation:

$$\frac{(RS)(12)}{IA} = x \text{ inches} \qquad \frac{(1.67)(12)}{20} = 1.0 \text{ inch}$$

The constructed wetland retrofit will capture and treat 1.0 inch of rainfall. Table 2 informs that constructed wetlands are considered to be a ST practice.

By referring to Figures 3-5, we can see that this proposed retrofit will have the following pollutant removal rates:

TP	TN	TSS
55%	35%	70%

Green Street. A Bay City is considering a plan to construct green streets as part of a revitalization project for the downtown commercial area. Their engineering consultant plans to employ permeable pavement, expanded tree pits and street bioretention to treat runoff and she estimates the runoff storage volume for the combined practices to be 0.27 acre-feet. Since the 4.3 acres of 100% impervious urban land that drain to the existing street have not provided stormwater management in the past, the new green street project is classified as a new retrofit. The engineer determines the number of inches that the retrofit will treat using standard retrofit equation:

$$\frac{(0.27)(12)}{4.3} = 0.75\ inches$$

Collectively, the new LID practices will treat 0.75 inches of runoff and fall under the RR practice category. Based on this information, the City uses the retrofit removal adjustor curves (Figures 3 to 5) to determine the following removal rates for the green street retrofit project:

TP	TN	TSS
64%	54%	70%

On-Site LID Retrofits. A Bay Township creates an incentive program for residential homeowners to install rain gardens on their property and would like to determine the pollutant removal rates associated with such a program. Each homeowner has an average roof size of 500 ft^2 and if 100 homeowners participate in the program, treatment can occur for a combined drainage area of 1.15 acres, at 100% impervious. The runoff storage volume associated with the combined retrofits is estimated to be 0.05 acre-feet. The amount of runoff volume treated by the rain gardens is calculated using standard retrofit equation:

$$\frac{(0.05)(12)}{1.15} = 0.5\ inches$$

Each rain garden is assumed to treat 0.5 inches of rainfall and is classified as a RR practice. The township engineer uses the curves to estimate the projected removal rates associated with the rain garden incentive program:

TP	TN	TSS
52%	45%	56%

In all three of the above examples, the information that needs to be reported is the retrofit removal rates and the total contributing drainage area to the practices.

Existing BMP Retrofits

BMP Conversion. A dry pond was built in 1985 in Maryland which was designed to provide flood control only. The designer is able to create new water quality storage using a combination of a forebay with a permanent pool, a submerged gravel wetland cell and a final bioretention polishing cell. As a result, the facility now provides a runoff storage volume of 1.3 acre-feet for its 65 acre urban drainage area that is 40% impervious. The amount of runoff volume treated by the converted BMP is calculated using the standard retrofit equation:

$$\frac{(1.3)(12)}{26} = 0.6\ inches$$

Because the project is a dry pond conversion, the designer evaluated both methods to assess pollutant removal rates. The designer rejected the use of existing CBP-approved rates because the conversion involved three different stormwater treatment mechanisms. Instead the designer opted to use the retrofit removal adjustor curves, since the retrofit conversion produced a large increase in runoff treatment volume and a modest increase in runoff reduction. The comparative removal rate projections are shown below:

	TP	TN	TSS
CBP approved rates	N/A	N/A	N/A
Adjustor removal rates	58%	49%	62%

BMP Enhancement. A dry extended detention pond was built in a Bay County in 1995 that served a 10 acre commercial property. The facility was originally designed to under older standards that only required that the "first flush" of stormwater runoff be treated. Analysis of drainage area characteristics indicated that the dry ED pond was sized to capture only 0.3 inches of runoff per impervious acre. In addition, field investigations showed that the pond had a major short-circuiting problem, such that half of its storage volume was hydraulically ineffective.

The Bay County engineer realized that this site was a good candidate for a BMP enhancement retrofit, and modified the configuration of the pond to increase its hydraulic retention time, provide missing pretreatment and excavate several shallow wetland cells in the bottom of the pond to improve treatment.

Collectively, these design enhancements created an additional 0.3 inches of new runoff treatment volume per impervious acre, for a total runoff of 0.6 inches. For BMP enhancement retrofits, the removal rate is defined as the incremental difference between the new removal rate and the original removal rate. The engineer analyzed the retrofit removal adjustor curves, and computed the net effect of the BMP design enhancements, as follows:

	TP	TN	TSS
Enhanced Rate	45%	29%	58%
Original Rate	29%	19%	37%
Incremental Removal Rate	16%	10%	21%

BMP Restoration. A wet pond was installed in Bay City in 1980, which captured 0.5 inches of runoff from the impervious cover of its contributing watershed. Bay City had previously reported the pond to Bay State. Over time, however, the storage capacity of the wet pond was seriously diminished due to sedimentation and growth of invasive plants. The maintenance crew noted that 60% of the pond's storage capacity had been lost, resulting in an actual capacity of a mere 0.2 inches of runoff treatment.

Bay City DPW conducted a major dredging effort to clean out the sediments and replanted the pond with native species. As a result of the pond restoration, 0.3 inches of storage were recovered, increasing the total storage in the pond to its original design volume of 0.5 inches of runoff depth captured. Bay County employed the retrofit removal adjustor curves for ST practices to determine the incremental pollutant removal rates associated with the pond restoration, as follows:

	TP	TN	TSS
Restored Rate (0.5)	41%	26%	52%
Existing Rate (0.2)	21%	14%	27%
Incremental Removal Rate	20%	12%	25%

Consequently, Bay City would report the existing rate to the state in the first year, and then submit the additional incremental rate for the restoration in subsequent years after the BMP is restored.

BMP Restoration (Non-Reported BMP). A sand filter was built in Bay City in 1998 and was sized to capture 0.5 inches of runoff from a municipal parking garage. Due to poor design, the sand filter had clogged over time and is no longer functioning as a BMP. Because the sand filter had never been reported to the state, it was eligible to get the full BMP pollutant reduction rate.

Bay City DPW upgraded the original sand filter to improve its retention time and replace the old media with a more effective bioretention mix. The removal rates are calculated from the retrofit removal adjustor curves:

TP	TN	TSS
52%	45%	56%

Non Eligible Restoration Example. Bay County inspectors concluded that it was time to clean out sediments trapped within the pre-treatment cell of a large bioretention facility. The facility was originally sized to capture 1.0 inch of runoff volume and achieves a 70% TP removal rate. This routine maintenance operation recovered 0.05

inches of runoff volume capacity in the bioretention area. Because this cleanout did not meet the 10% recovery threshold, it does not qualify for BMP restoration and no additional removal rate credit is given.

Section 6
Accountability Procedures

The Panel concurs with the conclusion of the National Research Council (NRC, 2011) that verification of BMP installation and subsequent performance is a critical element to ensure that pollutant reductions are actually achieved and sustained across the watershed. The Panel also concurred with the broad principles for urban BMP reporting, tracking and verification contained in the draft memo to the Urban Stormwater Workgroup. The Panel recommends that CBP adopt the following reporting, tracking and verification protocols for stormwater retrofit projects:

1. *Duration of Retrofit Removal Rate.* The maximum duration for the removal rate will be 10 years, although it can be renewed based on a field performance inspection that verifies the retrofit still exists, is adequately maintained and operating as designed. The duration of the removal rate will be 5 years for on-site retrofits installed on private property, and can only be renewed based on visual inspection that the on-site retrofit still exists.

2. *No Double Counting.* A removal rate cannot be granted if the retrofit project is built to offset, compensate or otherwise mitigate for a lack of compliance with new development stormwater performance standards elsewhere in the jurisdiction. Instead, the removal rate can only be applied as an offset (i.e., the acres of new development that will now fully meet the state stormwater performance standard). The Panel also recommends more frequent inspection and verification process for any retrofit built for the purpose of stormwater mitigation, offsets, trading or banking, in order to assure the project(s) is meeting its nutrient or sediment reduction design objectives.

3. *Initial Verification of Performance.* Jurisdictions will need to provide a post-construction certification that the urban retrofit was installed properly, meets or exceeds the design standards under its retrofit classification and is achieving its hydrologic function prior to submitting the retrofit removal rate to the state tracking database. This initial verification is provided either by the retrofit designer or a local inspector as a condition of retrofit acceptance, as part of the normal municipal retrofit design and review process. From a reporting standpoint, the MS4 community would simply indicate in its annual report whether or not it has retrofit review and inspection procedures in place and adequate staff to implement them.

4. *Retrofit Reporting Units.* Localities will submit documentation to the state stormwater or TMDL agency to document the nutrient/sediment reduction claimed for each individual urban retrofit project that is actually installed. Localities should check with their state stormwater agency on the specific data to report for individual retrofit projects. The Panel recommends that the following reporting data be submitted:

a. Retrofit class
b. GPS coordinates
c. Year of installation (and expected duration)
d. 12 digit watershed in which it is located
e. Total drainage area and impervious cover area treated
f. Runoff volume treated and identify "type" of BMP
g. Projected sediment, nitrogen and phosphorus removal rates

5. *Retrofit Recordkeeping*. The agency that installs the retrofit should maintain a more extensive project file for each urban retrofit project installed (i.e., construction drawings, as-built survey, digital photos, inspection records, and maintenance agreement, etc). The file should be maintained for the lifetime for which the retrofit removal rate will be claimed.

6. *Ongoing Field Verification of BMP Performance*. Inspectors need to look at visual and other indicators every 10 years to ensure that individual retrofit projects are still capable of removing nutrients/sediments. If the field inspection indicates that a retrofit is not performing to its original design, the jurisdiction has up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, the pollutant reduction rate for the retrofit would be eliminated, and the jurisdiction would report this in its annual MS4 report. The retrofit removal rate can be renewed, however, if evidence is provided that corrective maintenance actions have restored retrofit performance.

Collaborative Monitoring of Retrofit Performance

The Panel agreed on the continuing need to monitor the effectiveness of retrofits at both the project and watershed scale to provide greater certainty in the removal rate estimates. The Panel also noted the importance of monitoring both innovative and traditional retrofit techniques in varied applications, terrain and climatic conditions.

The Panel indicated the best route to acquire such monitoring data was through retrofit monitoring programs undertaken as part of municipal MS4 stormwater permit programs.

The Panel recommended that localities pool their scarce local MS4 monitoring resources together to create a monitoring consortium that could fund selected retrofit monitoring projects to be performed by monitoring experts (i.e., universities and qualified consulting firms).

In the interim, the Panel recommended that any local retrofit monitoring be conducted under a standard quality assurance project plan (QAPP) developed under the auspices of the USWG to ensure the performance data is reliable and accurate. Since several communities may be interested retrofit monitoring, USWG might not have the capacity to review all of the designs. The Panel therefore recommended that the CBP retain a consultant with expertise in "applied" monitoring to develop basic QAPP guidelines and make suggestions to monitoring plans. A possible model might be the 3-tiered QA certification process that increases in rigor with the increased need for data accuracy employed by the city of Suffolk and other Virginia communities (Details can be found at http://www.deq.virginia.gov/cmonitor/guidance.html).

The consultant would also be charged with identifying synergies among research to avoid duplication of effort and also prioritize monitoring needs. The initial guidelines would be fairly generic cutting across retrofit types and would be flexible to account for local site conditions. Ultimately, the Panel recommended that a standard methodology be established for each type of retrofit practice as long as it allows for local site variability.

The Panel also discussed the timeframe by which new retrofit monitoring data would be considered in adjusting future retrofit efficiencies, and recommended the Panel be reconvened at every two year WIP milestone, which fits in nicely with the "adaptive management" approach that is advocated by NRC (2011). One of the chief considerations should be whether the efficiency changes would be adjusted locally or applied globally across the Bay watershed.

Appendix A Evolution of Stormwater BMP Removal Rates

The Panel agreed that the performance of stormwater retrofits could only be inferred by analyzing previous studies that have looked at pollutant removal and runoff reduction data for groups of stormwater BMPs.

Over the past three decades, considerable research has been undertaken to understand the nutrient removal dynamics of urban stormwater practices and translate these into generic removal rates that can be used by watershed managers. This appendix begins with a brief review of how our understanding about BMP performance has evolved in response to new monitoring data and shifts in stormwater technology. This background is needed to interpret the many different (and sometimes conflicting) removal rates that have been assigned to BMPs over time, and to support the retrofit analysis approach.

Evolution of the Science of Stormwater BMPs

Stormwater managers have been grappling to define nutrient removal rates for stormwater practices, with at least ten different sets of rates published in the last 25 years (Schueler, 1987, Schueler, 1992, Brown and Schueler, 1997, Winer, 2000, Baldwin et al, 2003, CWP, 2007, CWP and CSN, 2008, Simpson and Weammert, 2009, ISBD, 2010, and CSN, 2011). It is no small wonder that managers are confused given that the nutrient removal rates change so frequently.

Each new installment of published BMP removal rates reflects more research studies, newer treatment technologies, more stringent practice design criteria and more sophisticated meta-analysis procedures.

For example, the first review involved only 25 research studies and was exclusively confined to stormwater ponds and wetlands, most of which were under-sized by today's design standards. The monitoring design for this era of BMP assessment evaluated the change in nutrient concentration as storms passed through individual practices. Analysis of individual performance studies showed considerable variability in nutrient removal efficiency from storm to storm (negative to 100%), and among different practices in the same BMP category.

The variability in removal rates was damped by computing a median removal rate for each individual practice and then computing a group mean for all the practices within the same group. This enabled managers to develop a unique "percent removal rate" for each group of BMPs.

By the turn of the century, about 80 research studies were available to define BMP performance, which expanded to include new practices such as grass swales, sand filters and a few infiltration practices. The number of BMP research studies available for analysis had climbed to nearly 175 by 2007. Table A-1 portrays the percent removal rates for nutrients for different groups of stormwater practices. The percent removal approach provides general insights into the comparative nutrient capability of different BMP groups, both in terms of total and soluble nutrient removal. For example, wet ponds and filtering systems are clearly superior to dry ponds when it comes to TN and TP removal, but wet ponds do a much better job than filtering systems in removing soluble N and P.

Table A-1
Typical Percent Removal Rates for Total and Dissolved Fractions of Phosphorus and Nitrogen (N=175)

Practice Group	TP (%)	Sol P (%)	TN (%)	Nitrate-N(%)
Dry Ponds	20	-3	24	9
Wet Ponds	52	64	31	45
Wetlands	48	24	24	67
Infiltration	70	85	42	0
Filtering Systems	59	3	32	-14
Water Quality Swales	24	-38	56	39
Source: CWP, 2007				

At about the same time, researchers began to recognize the limits of the percent removal approach. First, percent removal is a black box approach that provides general performance data, but little or no insight into the practice design features that enhance or detract from nutrient removal rates (Jones et al, 2008). Second, new data analysis showed that there were clear limits on how much any BMP could change nutrient concentrations as they passed through a practice. Extensive analysis of the nutrient levels in BMP effluent indicated that there appeared to be a treatment threshold below which nutrient concentrations could not be lowered.

This threshold has been termed the "irreducible concentration". The nutrient concentration limits for each group of practices is shown in Table A-2, and are caused by pass-thru of fine particles, internal re-packaging of nutrients, biological activity and nutrient leaching and/or release from sediments.

The third critique of the percent removal approach was that the population of monitoring studies upon which it is based is biased towards newly installed and generally well-designed practices. Very few monitoring studies have been performed on older practices or practices that have been poorly installed or maintained. The clear implication is that the ideal percent removal rate may need to be discounted to reflect these real world concerns, and several BMP reviews (Baldwin et al, 2003 and Simpson and Weammert, 2009) have derived more conservative rates in order to account for them.

Table A-2 "Irreducible" Nutrient Concentrations Discharged from Stormwater Practices				
Stormwater Practice Group	Total Phosphorus	Soluble Phosphorus	Total Nitrogen	Nitrate Nitrogen
	mg/l			
Dry Ponds	0.19	0.13	ND	ND
Wet Ponds	0.13	0.06	1.3	0.26
Wetlands	0.17	0.09	1.7	0.36
Filtering Practices	0.16	0.06	1.1	0.55
Water Quality Swales	0.21	0.09	1.1	0.35
Untreated Runoff	0.30	0.16	2.0	0.6
Source: Winer (2000)				

The most serious critique, however, of the percent removal approach is that it focuses exclusively on nutrient concentrations and not flow reductions. This was not much of an issue with the first generation of BMPs (ponds, wetlands, and sand filters) since they had little or no capability to reduce runoff as it passed through a practice (ISBD, 2010). With the emergence of new research on LID practices, however, the importance of runoff reduction in increasing the mass nutrient removal rate became readily apparent.

Nearly 50 new performance studies on the pollutant and runoff reduction capability of LID practices have been published in the last five years. Collectively, this new research has had a profound impact on how nutrient reduction rates are calculated, and in particular, isolating the critical practice design and site variables that can enhance rates. CWP and CSN (2008) synthesized the runoff reduction research and calculated new (and higher) mass nutrient removal rates for both traditional and LID stormwater practices.

A key element of the new runoff reduction approach is that it prescribes two design levels for each practice that have a different nutrient removal rate. An example of the two level design approach for bioretention is shown in Table A-3. The table reflects recent research that indicates which design features, soil conditions and performance standards can boost TN and TP removal. Some of these include:

- Increased depth of filter media
- No more than 3-5% carbon source in media
- Create an anoxic bottom layer to promote denitrification
- Increased hydraulic residence time through media (1-2 in/hr)
- Test media to ensure soils have a low phosphorus leaching risk

- Designers that meet or exceed the Level 2 design requirements are rewarded with a higher nutrient mass reduction rate.

Table A-3 Example of Two Level Design Approach for Bioretention	
LEVEL 1 DESIGN	**LEVEL 2 DESIGN**
RR = 40% TP = 55% TN = 64%	RR= 80% TP= 90% TN = 90%
Treats the 90% storm	Treats the 95% storm
HSG C and D soils and/or under drain	HSG A and B soils OR has 12 inch stone sump below under drain invert
Filter media at least 24" deep	Filter media at least 36" deep
One cell design	Two cell design
Both: Maximum organic material in media of 5% and hydraulic residence time of 1 inch per hour through media	

The basics of the runoff reduction method and/or design level approach are now being incorporated into stormwater design manuals and compliance tools in Virginia, West Virginia, District of Columbia, Delaware and the Maryland Critical Area. Table A-4 summarizes the mass nutrient removal rates developed to implement the new Virginia stormwater regulations.

The runoff reduction method enables designers to achieve high removal rates when a mix of site design and LID practices and conventional stormwater practices are combined together to meet a specific phosphorus performance standard. In many cases, the aggregate nutrient reduction achieved by a mix of LID practices at a site exceeds the existing CBP approved rate for the individual practices (which reflects the higher treatment volume, better soil conditions and more stringent design criteria). In summary, urban BMP nutrient removal rates have constantly evolved over time in response to new performance research, changing stormwater practices and paradigms, and more stringent design criteria and regulations.

Approved Removal Rates for Urban BMPs in the Chesapeake Bay

Given the proliferation of removal rates described in the preceding section, the Chesapeake Bay Program has established a peer-review process to derive standard and consistent removal rates for a wide range of urban BMPs. These rates are used for the purpose of definiug the aggregate uutrient and sediment reduction associated with BMP implementation in the context of the Chesapeake Bay Watershed Model. Since 2003, about 20 urban BMP rates have been established, with the supporting documentation provided in Baldwin et al (2003) and Simpson and Weammert (2009). The most current CBP-approved efficiency rates that relate to retrofitting are provided in Table A-5.

Table A-4 Mass Nutrient Removal Rates for Stormwater Practices			
Practice	**Design Level[1]**	**TN Load Removal[4]**	**TP Load Removal[4]**
Rooftop Disconnect [5]	*1*	*25 to 50*	*25 to 50*
	2 [6]	*50*	*50*
Filter Strips [5]	*1*	*25 to 50*	*25 to 50*
	2 [6]	*50 to 75*	*50 to 75*
Green Roof	*1*	*45*	*45*
	2	*60*	*60*
Rain Tanks & Cisterns [7]	*1*	*15 to 60*	*15 to 60*
	2	*45 to 90*	*45 to 90*
Permeable Pavers	*1*	*59*	*59*
	2	*81*	*81*
Infiltration Practices	*1*	*57*	*63*
	2	*92*	*93*
Bioretention Practices	*1*	*64*	*55*
	2	*90*	*90*
Dry Swales	*1*	*55*	*52*
	2	*74*	*76*
Wet Swales	*1*	*25*	*20*
	2	*35*	*40*
Filtering Practices	*1*	*30*	*60*
	2	*45*	*65*
Constructed Wetlands	*1*	*25*	*50*
	2	*55*	*75*
Wet Ponds [8]	*1*	*30 (20)*	*50 (45)*
	2	*40 (30)*	*75 (65)*
ED Ponds	*1*	*10*	*15*
	2	*24*	*31*

Notes

[1] See specific level 1 and 2 design requirements within each practice specification
[2] Annual runoff reduction rate (%) as defined in CWP and CSN (2008)
[3] Change in nutrient event mean concentration in and out of practice, as defined in CWP and CSN (2008)
[4] Load removed is the product of annual runoff reduction rate and change in nutrient EMC
[5] Lower rate is for HSG soils C and D, Higher rate is for HSG soils A and B
[6] Level 2 design involves soil compost amendments, may be higher if combined with secondary runoff reduction practices
[7] Range in RR depends on whether harvested rainwater is used for indoor, outdoor or discharged to secondary runoff reduction practice. Actual results will be based on spreadsheet
[8] lower nutrient removal parentheses apply to ponds in coastal plain terrain

Table A-5 Approved CBP BMP Efficiency Rates for Retrofit Analysis [1,2,3]				
URBAN BMP		**Total Nitrogen**	**Total Phosphorus**	**TSS**
		MASS LOAD REDUCTION (%)		
Wet Ponds and Constructed Wetlands		20	45	60
Dry Detention Ponds		5	10	10
Dry Extended Detention Ponds		20	20	60
Infiltration		80 (85) [4]	85	95
Filtering Practices (Sand Filters)		40	60	80
Bioretention	C & D w/UD	25	45	55
	A & B w/ UD	70	75	80
	A & B w/o UD	80	85	90
Permeable Pavement	C & D w/UD	10 (20)	20	55
	A & B w/ UD	45 (50)	50	70
	A & B w/o UD	75 (80)	80	85
Grass Channels	C & D w/o UD	10	10	50
	A & B w/o UD	45	45	70
Bioswale	aka dry swale	70	75	80

[1] In many cases, removal rates have been discounted from published rates to account for poor design, maintenance and age, and apply to generally practices built prior to 2008
[2] Current Practices are designed to more stringent design and volumetric criteria, and may achieve higher rates –see Table A-4
[3] Some practices, such as forest conservation, impervious cover reduction, tree planting are modeled as a land use change. Urban stream restoration is modeled based on a reduction per linear foot of qualifying stream restoration project
[4] Numbers in parentheses reflect design variation with a stone sump to improve long term infiltration rates

A quick glance at Table A-5 reveals that the rates for ponds and wetlands tend to be fairly conservative, which reflects the concern that ideal or initial removal rates should be discounted due to real world implementation issues such as poor design, installation and maintenance, or simply the age of the practice. The removal rates for newer LID practices, by contrast, is not discounted.

Appendix B Documentation of How the Retrofit Removal Adjustor Table/Curve Was Derived

The Panel started by noting the strong relationship between the runoff volume treated and the degree to which runoff reduction is achieved at individual BMPs. The primary source was a comprehensive analysis of runoff reduction and pollutant event mean concentration reduction data for a wide range of BMPs that are typically applied in retrofitting (CWP and CSN, 2008).

CSN (2011) developed a general table to determine nutrient removal rates for all classes of retrofits, and this approach was used as a starting point. The basic technical approach defines an "anchor" rate for composite stormwater treatment (ST) and runoff reduction (RR) practices for one inch of runoff treatment (see Table B-1). The RR practices included six different LID practices including bioretention, dry swales, infiltration, permeable pavement and green roofs/rain tanks.

The composite for ST practices included wet ponds, constructed wetlands, sand filters, and wet swales. Dry ponds and Dry ED pond were omitted from the ST category since they have such low removal rates that they are typically not targets of retrofitting. The annual mass nutrient removal rates associated with each practice presented in Table A-4 was averaged for the composite practices, as shown in Table B-1 below.

Table B-1 Composite Approach to Derive Nutrient Mass Load Reductions for RR ad ST Practices [1, 2]

PRACTICE	TP Mass Reduction (%)	TN Mass Reduction (%)
Bioretention	73	77
Dry Swale	66	63
Infiltration	75	78
Permeable Pavers	70	70
Green Roof/Rain Tank	55	55
Average RR	**70**	**70[2]**
Wet Ponds	63	35
Constructed Wetlands	63	40
Filtering Practice	63	38
Wet Swale	30	30
Average ST	**55**	**35**

[1] Source: Table A-4, nutrient rates computed using the average mass reduction for both Design Level 1 and Level 2.
[2] This value was subsequently discounted by 18% to reflect the impact of nitrate migration from runoff reduction practices described later in this appendix.

The next step involved using a rainfall frequency spreadsheet analysis from Washington, DC to estimate how the anchor removal rate would change based on different levels of runoff capture by the composite practice. The percent of the annual rainfall that would be captured by a retrofit designed for a specific control depth was estimated by summing the precipitation for all of the storms less than the control depth, plus the product of the number of storm events greater than the control depth multiplied by the control depth. This sum was then divided by the sum of the total precipitation. A visual representation of this may be helpful and can be seen as follows:

$$\%\,Annual\,Rainfall = \frac{(SUM\ P_{<CD} + CD(in) * (\#\ of\ Storms\ P_{>CD}))}{Sum\ of\ Total\ Precipitation\ (inches)}$$

Where:

$P_{<CD}$ = Precipitation of Storms less than Control Depth (inches)
$P_{>CD}$ = Precipitation of Storms greater than Control Depth (inches)
CD = Control Depth (inches): the depth of rainfall controlled by the practice

Once the percent annual rainfall has been determined for a specific control depth, we can use this along with the anchor pollutant removal rates to determine the pollutant removal values associated with a specific control depth. For example:

$$Pollutant\ Removal_{CD} = \frac{(Pollutant\ Removal\ Value_{AR} * \%\,Annual\ Rainfall_{CD})}{\%\,Annual\ Rainfall_{AR}}$$

Where:

Pollutant Removal Value $_{AR}$ = The anchor rates for N, P or TSS and ST or RR practices per 1.0" of Control Depth (~88% Annual Rainfall)

Phosphorus		Nitrogen		Sediment	
ST	RR	ST	RR	ST	RR
55%	70%	35%	60%	70%	75%

% Annual Rainfall $_{CD}$ = The % Annual Rainfall for a specific Control Depth as determined by the previous equation

% Annual Rainfall $_{AR}$ = This will always be 88%

The same basic approach was used to define maximum mass nutrient reduction rates for storms above the anchor rate, up to the 2.5 inch storm event. In general, no BMP performance monitoring data is available in the literature to evaluate removal for runoff treatment depths beyond 1.5 inches, so this conservative approach was used for the extrapolation. The Panel had limited confidence in removal rates in the 1.5 to 2.5 inch range, although it was not overly concerned with this limitation, since few of any retrofits are sized to capture that much runoff. A spreadsheet that defines how the anchor rates and bypass adjustments were derived can be obtained from CSN.

The tabular data was converted into a series of curves to make it easier for users to define a rate for the unique combination of runoff capture volume and degree of runoff reduction. This was done by fitting a 5^{th} order polynomial curve to the tabular data points, which came within a few percentage points of the tabular values for a wide range of runoff capture depths and removal rates.

A 0.05 inch runoff capture volume was established as the cut-off point for getting any retrofit removal rate, since this roughly corresponds to the depth of initial abstraction that occurs on impervious surface. It should be noted that retrofits in this small size range will require very frequent maintenance to maintain their performance over time.

The Panel concluded that the generalized retrofit removal adjustor curves were a suitable tool for estimating the aggregate pollutant load reductions associated with hundreds or even thousands of future retrofit projects at the scale of the Bay watershed and the context of the Chesapeake Bay Watershed Model.

Notes on the Standard Retrofit Equation

The specific retrofit storage volume achieved at an individual site is usually "discovered" and is measured or estimated by an engineer based on site constraints. The retrofit storage volume (usually reported in acre-feet) needs to be converted into the appropriate unit on the X-axis of the curves (i.e., depth of runoff captured by retrofit per impervious acre).

The basic rationale is that the Rainfall Frequency Analysis method used to derive the adjustor curve (above and below the anchor points) is based on the assumption that the runoff delivered to a practice is generated from a unit impervious acre. By contrast, the retrofit storage volume available at each retrofit is unique, based on the upstream land cover, soils and the drainage area. Consequently, the retrofit storage volume must be adjusted to get a standard depth of runoff treatment per unit impervious cover to get the correct depth to use on the x-axis of the retrofit adjustor curves.

This is done by using standard retrofit equation which multiplies the retrofit storage volume by 12 to get acre-inches, and then is divided by the impervious acres to get the desired unit for the retrofit adjustor curves. Numerically, the standard retrofit equation is:

$$= \frac{(RS)(12)}{IA}$$

The removal rates determined from the retrofit removal adjustor curves are applied to the <u>entire</u> drainage area of the retrofit, and not just its impervious acres. Also, the retrofit reporting unit is the <u>entire</u> treated area, regardless of whether it is pervious or impervious.

Notes on the Derivation of Sediment Removal Rates

The original retrofit removal rate adjustor table (CSN, 2011) did not include estimates for sediment removal. They were derived in January of 2012 after a detailed analysis of BMP sediment removal rates drawn from the following sources --Brown and Schueler, (1997), Winer (2000), Baldwin et al, (2003), CWP (2007), Simpson and Weammert, (2009), and ISBD (2011a). Collectively, these BMP performance research reviews analyzed more than 200 individual urban BMP performance studies conducted both within and outside of the Chesapeake Bay watershed. The following general conclusions were drawn from the analysis.

Sediment removal by both traditional BMPs and LID practices was consistently higher and less variable than nutrient removal. This is attributed to the particulate nature of sediment which makes it easier to achieve reductions through settling, trapping, filtering and other physical mechanisms.

The analysis began with an examination of existing CBP-approved rates (see Table A-5). Two important trends were noted. First, TSS removal always exceeded TP and TN rates for every category of urban BMP. Second, nearly all the rates were within a fairly narrow range of 60 to 90%.

The same composite BMP method was employed using the CBP-approved rates to define sediment removal rates for RR and ST practices. The ST practice category included wet ponds, constructed wetlands and sand filters, which collectively had a TSS removal rate of 70%. The RR category included all design variations of bioretention, permeable pavement, infiltration and bio-swales in Table A-5, and had a slightly higher composite TSS removal rate of 75%.

Other BMP performance reviews have also noted that TSS removal rates exceed TP or TN removal rates for all individual studies of traditional urban BMPs (up to 1.0 inch of runoff treated, Winer, 2000 and CWP, 2007).

The sediment removal rate for traditional BMPs is ultimately limited by particle size considerations. Studies have shown that there is an irreducible concentration associated with the outflow from traditional BMPs (Winer, 2000 and NRC, 2008) around 15 to 20 mg/l which reflects the limits of settling for the most fine-grained particles. In practical terms, this sets an upper limit on maximum sediment removal around 70 to 80% for the range of monitored BMPs (i.e., sized to capture 0.5 to 1.5 inches of runoff).

Additional analysis was done to examine whether sediment removal rates for LID practices (i.e., runoff reduction practices) would achieve high rates of runoff reduction. Recent sediment mass removal rates were reviewed for bioretention, permeable pavers, green roofs, rain tanks, rooftop disconnection and bioswales (Simpson and Weammert, 2009, ISBD, 2011a, and a re-analysis of individual studies contained in CWP and CSN, 2008). The following general conclusions about LID sediment removal rates were drawn from the analysis:

- Most LID practices had lower TSS loadings than traditional BMPs, primarily because there was no major up-gradient sediment source area (e.g., green roofs, rain tanks, permeable pavers, rooftop disconnection) or a small contributing drainage area (bioretention, bio-swales).

- In general, LID practices had a slightly lower outflow sediment concentration than their traditional BMP counterparts (around 10 mg/l-- ISBD, 2011a).

- The ability of LID practices to change the event mean concentration of sediment as it passed through a practice differed among the major classes of LID practices. For example, nearly a dozen studies showed that bioretention and bioswales could achieve significant reduction in sediment concentrations. On the other hand, permeable pavers and green roofs generally produced low or negative changes in sediment concentrations through the practice. This finding was not deemed to be that important given how low the sediment inflow concentrations were.

Based on these conclusions, the Panel took a conservative approach and did not assign higher sediment removal rates for LID practices that achieved a high rate of runoff reduction, at least for facilities designed to capture less than an inch or more of runoff.

Beyond that point, the Panel did assign a modest increase in sediment removal rate for LID practices under the assumption that the combination of high runoff capture and reduction would work to reduce or prevent accelerated downstream channel erosion. The Panel notes that the extra sediment removal rate for this range of LID practices is an untested hypothesis that merits further research.

Notes on Revising TN Adjustor Curve to Reflect Nitrate Migration from BMPs to Groundwater

The adjustor curves are used to define a removal rate that applies to both the pervious and impervious areas in the contributing drainage areas for the stormwater treatment practices. The removal rates properly apply to surface runoff and some portion of the interflow delivered to the stream, but may not properly apply to groundwater export of nitrate-nitrogen from the urban landscape. The "missing" nitrate may be nitrate that exits a runoff reduction practice via infiltration into soil, or slowly released through an under drain (e.g., bioretention).

Once stormwater runoff is diverted to groundwater, the overall load is reduced by using the ground as a filtering medium, but not eliminated. Therefore, the WTWG concluded that the original TN adjustor curves developed by the expert panel may over-estimate TN removal rates, and should be discounted to reflect the movement of untreated nitrate from runoff reduction BMPs. This discounting is not needed for TKN, TP or TSS as these pollutants are not mobile in urban groundwater.

The USWG concurred with this approach and developed the following procedure to derive a new TN adjustor curve to account for groundwater nitrate migration from runoff reduction practices.

This discount factor is fairly straight forward to calculate and is simply based on the ratio of nitrate in relation to total nitrogen found in urban stormwater runoff. Stormwater runoff event mean concentration data from the National Stormwater Quality Database (Pitt et al, 2006) was analyzed for more than 3000 storm events, and the nitrate:TN fraction was consistently around 0.3. This sets an upper boundary on the fraction of the inflow nitrate concentration to the BMP which could be lost to groundwater or under drains at about 30%.

The next step is to account for any nitrate loss within the BMP due the combination of either plant uptake and storage and/or any de-nitrification within the BMP. Most runoff reduction practices employ vegetation to promote ET and nutrient uptake, whereas the de-nitrification process is variable in both space and time.

Over 70 performance studies have measured nitrate removal within runoff reduction BMPs. A summary of the national research is shown in Table B-2. Clearly, there is a great deal of variability in nitrate reductions ranging from nearly 100% to negative 100% (the negative removal occurs when organic forms of nitrogen are mineralized/nitrified into nitrate within the BMP).

Some well studied runoff reduction practices, such as bioretention and bioswales, have a median nitrate removal ranging from 25 to 45%, presumably due to plant uptake. Initial results for green roofs indicate moderate nitrate reduction as well. Non-vegetative practices, such as permeable pavers and a few infiltration practices, show zero or even negative nitrate removal capability (Table B-2). Submerged gravel wetlands that create an aerobic/anaerobic boundary that promotes denitrification appear capable of almost complete nitrate reduction.

Therefore, it is recommended that maximum nitrate removal within runoff BMPs be assumed to be no more than 40%. Although this value may seem generous, it should be noted that some additional nitrate reduction occurs as the nitrate moves down-gradient through soils on the way to the stream. Under this conservative approach, no additional nitrate reduction is assumed after it exits the BMP and migrates into groundwater.

Given the nitrate inflow concentrations, the potential groundwater/under drain nitrate loss would be (0.3)(0.60) = 0.18, or a discount factor of 0.82

The discount factor is then applied to the anchor rates used to derive a new N adjustor curve. The anchor rate for RR practices would be adjusted downward from the current 70% to 57%, and the existing runoff frequency spectrum equation would be used to develop a new, lower curve for TN removal. An example of the how this discount influences the existing N adjustor curve is shown in Figure B-1.

Table B-2 Nitrate Removal by Runoff Reduction Practices [1]				
Practice	Median Removal Rate	No. of Sites	Range	Source
Bioretention [2]	43%	9	0 to 75	CWP, 2007
Bioretention [2]	44%	1	NA	UNH, 2009
Bioretention [2]	24%	10	NA	ISBD, 2010
Bioswales	39%	14	-25 to 98	CWP, 2007
Bioswales	7%	18	NA	ISBD, 2010
Infiltration [3]	0	5	-100 to 100	CWP,2007
Permeable Pavers	-50% [4]	6	NA	IBSD, 2010
Permeable Pavers	0	4		Collins, 2007
Green Roof [5]	Positive	4	NA	Long et al 2006
Gravel Wetland	98%	1	NA	UNH, 2009

Notes:

[1] As measured by change of event mean concentration (EMC) entering device and final exfiltrated EMC, and involves either or plant uptake or denitrification

[2] For "conventional" runoff reduction practices only, i.e., no specific design features or media enhancements to boost nitrate removal

[3] Category includes several permeable paver sites

[4] A negative removal rate occurs when organic forms of nitrogen are nitrified to produce additional nitrate which is

[5] Test column study

It is also noted that no nitrate loss parameter needs to be defined for stormwater treatment (ST) practices, since inlet and outlet monitoring of these larger facilities already takes this into account (and is a major reason why the ST curve is so much lower than the RR curve).

The de-nitrification process can be enhanced through certain design features (inverted under drain elbows, IWS, enhanced media). Several good research reviews indicate that these design features show promise in enhancing nitrate removal (Kim et al, 2003, NCSU, 2009, Weiss et al, 2010), these features are not currently required in Bay state stormwater manuals. Should future research confirm that these features can reliably increase nitrate removal through denitrification and/or plant uptake, it is recommended that a future expert panel revisit the existing nitrogen adjustor curve.

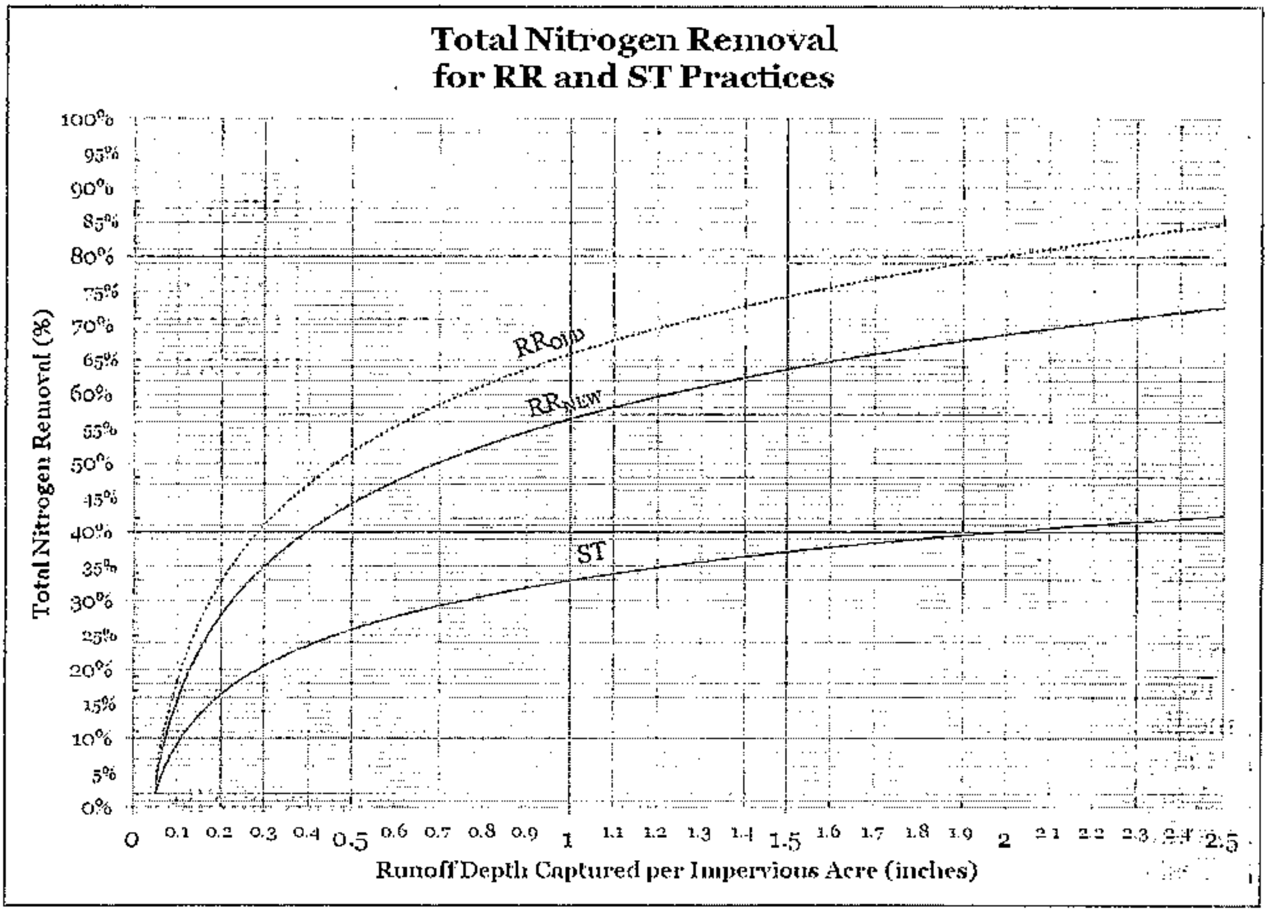


Figure B-1. Revised TN Adjustor Curve

Appendix C Panel Meeting Minutes

First Meeting Minutes
Stormwater Retrofit Review Panel
Thursday October 28, 2011

Members Present

Panelist	**Affiliation**	**Present ?**
Ray Bahr (Cappucitti)	MDE	Yes
Steve Stewart	Baltimore County	Yes
Ted Brown	Biohabitats	Briefed
LJ Hansen	City of Suffolk, VA	Yes
Jason Papacosma	Arlington, VA	Yes
Bill Stack	CWP	Yes
Rebecca Stack	DDOE	briefed
Joe Kelly	PA DEP	Yes
Jeff Sweeney	EPA, CBP	Yes
Facilitator: Tom Schueler	CSN	Yes
Non-panelists		
Norm Goulet, chair USWG; Lucinda Power, EPA CBP		

Attachments distributed in advance of call: (1) Performance standard excerpts from Technical Bulletin #9; (2) MDE document; and (3) CBP BMP Protocol Process.

Proposed next call date: It was agreed that the next teleconference would be a 2-hour call on November 21st from 10 AM to Noon, pending verification from the two panelists who could not make today's meeting

Action: the Panel amended the charge to add discussion of future retrofit monitoring protocols in the reporting, tracking and verification area. The Panel endorsed the amended charge, but it was agreed that the Panel would have an additional week to provide comments or revisions to the charge. Any comments received will be distributed to the Panel and discussed at the next teleconference.

Action: Panelists are requested to provide any additional research studies, performance data or reports to Tom Schueler by November 10, who will send them to the entire Panel. If no further data is provided by then, the Section 5 summary will be considered the core research on retrofits.

Action: The Panel was asked to provide a thorough review of the retrofit excerpts from Technical Bulletin #9 and the MDE document to Tom Schueler by the second week of November. All comments received will be distributed to the Panel.

Action: Jeff Sweeney (EPA) will provide a summary of CBP annual urban runoff loads per acre following the general format shown in Table 1 of MDE (2011) for CBWM version 5.3.2.

Action: Several panelists indicated the need to get better information on each state's unique retrofit, maintenance and inspection issues. Tom and the states will provide a brief profile of these issues at the next meeting.

Action: *Norm and Tom will confer on getting an official VA DCR rep to serve on the panel, and Tom will work with Lucinda and Jeff Sweeney on whether other states (NY, DE, and WV) should be invited as well.*

Call to Order and Panelist Introductions

Each of the panelists introduced themselves and explained their background in retrofit analysis and implementation in their jurisdiction. Tom briefly outlined the WQGIT BMP review panel protocol by which the Panel would conduct its business, and asked the Panel whether they understood their role and had any questions about the protocol

Tom then outlined his role was to facilitate the Panel, organize the research and methods, and document its progress, but not be involved in the decision-making process.

Review of the Charge for the Panel, the BMP Panel Review Process and Panel Member Responsibilities

Tom proposed a draft charge for the Panel to ensure that it has reviewed all of the available science on the pollutant removal performance of different retrofit classes.

The initial charge of the Panel is to review all of the available science on the pollutant removal performance and runoff reduction capability of BMPs that can be used to derive methods or protocols to derive nutrient and sediment removal rates for individual retrofits:

Stormwater retrofits are a diverse group of projects that provide nutrient and sediment reduction on existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. Removal rates will need to be inferred from other known BMP pollutant removal and runoff rednction data. Every retrofit is unique, depending on the drainage area treated, BMP treatment mechanisms, volume or sizing and the antecedent degree of stormwater treatment, if any.

Stormwater retrofits can be classified into six broad project categories, as shown below:

a. New retrofit facilities
b. BMP conversions (e.g., a dry ED pond to a constructed wetland)

c. Enhanced design or volume of existing BMPs
d. Green street retrofits
e. On-site LID retrofits
f. Maintenance upgrades

The Panel is specifically requested to:

- Provide a specific definition for each class of retrofits and the qualifying conditions under which a locality can receive a nutrient/sediment reduction rate
- Assess whether the retrofit class can be addressed by using existing CBP-approved BMP removal rates, or whether new methods or protocols need to be developed to define improved rates
- Evaluate which load estimation methods are best suited to characterize the baseline pre-retrofit for the drainage area to each class of retrofit
- Define the proper units that local governments will report retrofit implementation to the state to incorporate into the Watershed Model

Beyond this specific charge, the Panel is asked to:

- Determine whether to recommend whether an interim BMP rate be established for one or more classes of retrofits prior to the conclusion of the panel for WIP planning purposes
- Recommend procedures for reporting, tracking and verifying the removal rates achieved by retrofit projects
- Critically analyze any unintended consequence associated with the removal rate and any potential for double or over-counting of the load reductions achieved

While conducting its review, the Panel shall follow the procedures and process outlined in the WQGIT BMP review protocol.

The Panel indicated that the charge should be amended to specifically recommend potential future retrofit monitoring protocols and regional monitoring consortia that could improve/refine our understanding of retrofit removal performance.

Second Meeting Minutes
Stormwater Retrofit Review Panel
Monday, November 21, 2011

Members Present

Panelist	Affiliation	Present?
Ray Bahr	MDE	X
Steve Stewart	Baltimore County	X
Ted Brown	Biohabitats	X
LJ Hansen	City of Suffolk, VA	X
Jason Papacosma	Arlington, VA	X
Bill Stack	CWP	X
Rebecca Stack	DDOE	
Joe Kelly	PA DEP	X
Jeff Sweeney	EPA, CBP	
Ginny Snead	VA DCR	X
Tom Schueler	CSN Facilitator:	X
Non-panelists		
Norm Goulet, chair USWG; Lucinda Power, EPA CBP		

Action items

- **Rebecca Stack** will provide an overview of DDOE retrofit activities at next meeting.
- **Tom** to revise the draft retrofit definitions in time for next panel call.
- **LJ and Tom** to work on more detailed draft of qualifying conditions of BMP maintenance upgrades for next panel call.
- **Bill Stack and Tom** to evaluate sediment removal rates for Table 23 for panel consideration at next meeting. Tom will also coordinate on the issue with the Performance Standards Panel.
- **Tom and Ray Bahr** to meet off-line to ensure that retrofit methods are integrated with existing MDE guidance.
- Tom requested the **Panel** provide any additional comments on the RT VM protocol in the next two weeks, and then he would revise the protocol in advance of the next meeting.
- **Bill Stack, Jason P and LJ Hansen** will coordinate on procedures for retrofit monitoring and present some recommendations at next meeting.

- The Panel agreed to reconvene for a third teleconference from **2 to 4 PM on Wednesday January 11th, 2012.**

Call to Order, Review of the Charge for the Retrofit Panel and Review of Meeting Minutes

Meeting called to order @ 10.04 AM. The meeting minutes and charge for the panel were approved. The Panel also confirmed that the summary of BMP performance research provided in the first meeting was adequate for their purposes.

State Perspectives on their Retrofitting Programs.

The state stormwater representatives discussed their ongoing retrofit activity.

Joe Kelly (PA DEP) indicated that most retrofit activity to this point was of the demonstration variety, although will change in the coming years as their new PAG-13 MS-4 permits are implemented, and localities developed their local Chesapeake Bay pollutant reduction plan.

Doug Fritz of VA DCR indicated that most of their retrofitting activity so far included demonstration projects under state grants and revolving funds. Their new Phase 1 permits may avoid the term retrofit and use the term existing pollutant reductions. Although the new permits are still being developed, Doug indicated that they may include numerical requirements for reducing existing pollutant loads, which would initially be low, but expanded in future permit cycles. The next permits would also likely include "retrofit" planning and assessment requirements.

Ray Bahr (MDE) noted that Maryland had a longer retrofitting history, and is writing new Phase 1 permits that will require retrofitting of up to 20% of untreated impervious cover in each permit cycle, and may institute retrofitting requirements for Phase 2 MS4 permittees. MDE has had several grant programs to defray local retrofit project costs, but these have not been fully funded in recent years.

Tom attempted to describe DDOE retrofit activities, which originally focused on Anacostia River restoration. The current effort relies heavily on green street and green roof retrofits, as well as on-site LID projects through residential and commercial stewardship incentive programs. Tom will contact **Rebecca Stack** about presenting more detail on DC retrofit situation at next teleconference

Review and Discussion of Retrofit Definitions

Consensus: The Panel had an extensive discussion on retrofit definitions and came to the following consensus.

The "lumpers" defeated the "splitters", such that the six retrofit classes were collapsed into two broad retrofit categories:

On-site LID retrofits and green streets should be classified as a new retrofit facility, and not as a separate category.

BMP conversions, enhancements and upgrades should all be classified within a single existing BMP category

The Panel felt that more information was needed on the qualifying conditions for BMP maintenance upgrades, and JL and Tom will work on a draft for our next meeting.

The Panel asked Tom to revise the draft definitions for their consideration at the next call

Discussion of Methods to Define Pre-Retrofit Baseline Loads

The Panel briefly discussed the issue of how to define pre-retrofit loads (simple method and/or CBWM unit loads). While there was some interest in recommending the Simple method, the discussion was deferred until the next meeting when **Jeff Sweeney** will hopefully provide unit area loading for all states using CBWM

The Panel had a much longer discussion of the issue of edge of stream, edge of field and delivered loads, and how the Panel should interpret these. **Steve Stewart** noted that the methods are best used to determine edge of stream loads for individual retrofits, but that localities should use tools like MAST/CAST/VAST to identify those areas in their jurisdiction that had the highest delivered loads (e.g., shortest distance/travel time to Bay and lack of impoundments) when conducting retrofit assessments at the watershed level. The **Panel** though this was a good idea, but wanted Tom to check in with Bay modelers to make sure this is the correct interpretation

Review of Methods for Defining Retrofit Removal Rates

Tom provided an overview of the various methods for defining retrofit removal rates, and the Panel provided the following feedback.

MDE design by era method is already established in Maryland as a default method, although localities can opt for a different method.

Method(s) should be consistent and not unduly complicated. The fewer the methods proposed the better to avoid multiple sets of differing numbers.

There was support for the retrofit adjustor table (Table 23), since it provided scale-able removal rates, based on rainfall capture and degree of runoff reduction. Several refinements were needed to make it a useful tool. 1) add sediment removal rates, 2) drop the reductions above 1.5 inch since few retrofits can achieve this degree of treatment, there is much less research to support these projections and the high removal rates for the 2.0 to 2.5 inch range provide counter intuitive results that nutrient loads from urban land could be lower than forest land

There was strong support to avoid use of past CBP approved BMP removal rates for the purpose of defining retrofit performance.

Bill Stack and Tom to evaluate sediment removal rates for Table 23 for Panel consideration at next meeting. Tom will also coordinate on the issue with the Performance Standards Panel

Tom and Ray Bahr to meet off-line to ensure that retrofit methods are integrated with existing MDE guidance

Protocols for Reporting, Tracking, Verifying and Monitoring Retrofits

The Panel discussed the proposed protocol for retrofit reporting, tracking, verification and monitoring. (Attachment D). The Panel indicated that the general framework was useful, but could be improved in several areas:

No need to require signed local certification for state reporting, but these records should be maintained in project file (e.g., as-built)

Ray Bahr wanted to see if CBPO could accept GIS files rather than spreadsheets, as this would make detection of double BMP accounting easier to do.

Support for limiting the duration of the removal rate for approx 5 to 10 years, with renewal based on local inspection. The shorter duration might apply to retrofits where there is only a limited maintenance pledge (e.g., homeowner BMPs) and the longer duration applies when there is a more formal maintenance agreement in place with a responsible authority.

Tom requested the Panel provide any additional comments on the protocol in the next two weeks, and then he would revise the protocol in advance of the next meeting

Set Next Meeting Date. The **Panel** agreed to reconvene for a third teleconference from 2 to 4 PM on Wednesday January 11th, 2012.

The call adjourned at 11:50 AM

Urban Stormwater Retrofit BMP Review Panel
Third Teleconference
Wednesday, January 11, 2012

Members Present

Panelist	Affiliation	Present?
Ray Bahr	MDE	X
Steve Stewart	Baltimore County	X
Ted Brown	Biohabitats	X
LJ Hansen	City of Suffolk, VA	X
Jason Papacosma	Arlington, VA	X
Bill Stack	CWP	X
Rebecca Stack	DDOE	X
Joe Kelly	PADEP	X
Jeff Sweeney	EPA, CBP	
Ginny Snead	VA DCR	X
Tom Schueler	CSN Facilitator:	X
Non-panelists		
Norm Goulet, chair USWG; Lucinda Power, EPA CBP		

Call to Order, Review of November Meeting Minutes and Action Items

Tom called the meeting to order @ 2.04 PM. Tom commended the Panel for all their hard work in completing all the assigned action items since the last teleconference. The Panel reviewed and approved the November meeting minutes.

DC Perspectives on Retrofitting. (10 mins)

***Rebecca Stack** (DDOE) gave a short presentation from DC about their current and future level of retrofit activity in their highly urban watersheds. She noted that they rely heavily on residential and business incentive programs to get on-site LID retrofits implemented (e.g., bioretention, rain barrels, green roofs, permeable pavers etc). In addition, DC is implementing an extensive green street retrofit program on municipal streets. **Jason Papacosma** asked how these retrofits were tracked and maintained over time. **Rebecca** noted that they use a GIS tracking tool to record the aggregate acreage treated, and generally assume a five year removal rate for on-site retrofits.*

The state perspectives on retrofitting from this and the last meeting will be incorporated into the final technical memo.

Consensus: Review and Adoption of Retrofit Definitions

Tom *reviewed the revised retrofit definitions provided in Attachment B.* ***LJ Hansen*** *described the proposed new definition for BMP restoration which replaces the previous category of maintenance upgrades. After discussion, the Panel concurred with the revised definitions for three classes of stormwater retrofits, with several edits and revisions, mostly to delete references to baseline loads. The Panel asked to have a last chance to provide review and comment on the final memo, prior to final acceptance.*

Consensus: Methods to Define Pre-Retrofit Baseline Loads

The Panel continued its discussions on the proper method(s) to define pre-retrofit baseline loads, including the Simple Method and generic CBWM urban unit loading rates (Attachment C). After considerable discussion, the Panel elected not to recommend a method for defining baseline loads to retrofit projects, when it comes to reporting individual retrofits to state TMDL agencies. Instead, localities would simply report the removal rates computed from the retrofit adjustor table and the contributing drainage area for each project. The Panel also indicated that states could decide whether to use the Simple Method, CBWM unit loads or other suitable methods when conducting local watershed analyses for retrofit investigation or MS4 permit reporting. They also indicated that both methods should be included as an appendix in the technical memo.

Consensus: Method to Define Retrofit Removal Rates

Tom presented a revised version of the retrofit removal adjustor table that includes new sediment removal rates, and incorporates other changes recommended, defines rates based on runoff reduction and runoff volume treated. The Panel asked to see more written documentation on the sediment removal rates. The Panel generally concurred with the revised retrofit adjustor table, but wanted to see examples for each of the retrofit classes in the final technical memo so that local users would be able to understand how it would be computed. They also indicated they wanted to see a table that defined which BMPs would be classified as RR or ST runoff reduction, and also be clear that the computed removal rate applies to the entire drainage area of the retrofit project, and not just the impervious acres.

Consensus: Protocol for Reporting, Tracking and Verifying Retrofits

The Panel discussed the revised general framework for RTV and adopted it subject to the following modifications:

Provide more specific guidance as to what constitutes "installed properly, meets or exceeds state design standards and is functioning hydrologically as defined" so that it can be physically defined in the field.

Change certification to verification

Simplify the local retrofit reporting requirements, and especially drop the baseline load calculation

Recap Consensus Achieved and Structure for Panel Report

The Panel indicated that they had achieved consensus on many items and approved the proposed outline for the documentation memo to be submitted to the Urban Stormwater Workgroup. The Panel directs Tom to prepare a draft of their memo for their final review by mid-February.

Combined Meeting Minutes
Urban Retrofit Expert Panel
Final Review Teleconferences

March 12, 2012
and
April 2, 2012

Panelist	**Affiliation**	**Present 3/12 ?**	**Present 4/2?**
Ray Bahr	MDE	X	X
Steve Stewart	Baltimore County	X	X
Ted Brown	Biohabitats	X	X
LJ Hansen	City of Suffolk, VA	X	X
Jason Papacosma	Arlington, VA	X	X
Bill Stack	CWP	X	C
Rebecca Stack	DDOE	X	
Joe Kelly	PADEP	X	X
Jeff Sweeney	EPA, CBP		
Ginny Snead/Fritz	VA DCR	X	X
Tom Schueler	CSN Facilitator:	X	X
Non-panelists			
Norm Goulet, chair USWG; Lucinda Power, EPA CBP			

The Panel held two calls and provided extensive written and verbal comments on the Feb 19 and March 12 drafts of the final panel memo. These minutes summarizes the key technical changes made to the method by CSN during this review period, as well as a providing a record for how the Panel resolved its more substantive comments. Based on this, the Panel voted 9-0 to tentatively adopt the final memo, subject to a two week period for errata and state-specific comments, and report out on its final recommendations at the April 30 USWG meeting.

1. Key Technical Changes to the Method

Changes after First draft

1. *Dropped reference to the Original Retrofit Adjustor Table and replaced with curves.* The tabular data was converted into a series of curves to make it easier for users to define a rate for the unique combination of runoff capture volume and degree of runoff reduction. This was done by fitting a 5th order polynomial curve to the tabular data points, which came within a few percentage points of the tabular values for a wide range of runoff capture depths and removal rates.

2. *The technical basis for defining the anchor rates was provided in a new table in Appendix C.*

3. *More accurate estimates of runoff capture were derived using an explicit rainfall frequency spectrum equation, and this supplemental documentation was incorporated into Appendix C.* The new more accurate method has the result of flattening the removal curves for higher depths of runoff capture.

4. *The cut-off threshold for minimum retrofit capture volume was reduced.* A 0.05 inch runoff capture volume was established as the cut-off point for getting any retrofit removal rate, since this roughly corresponds to the depth of initial abstraction that occurs on impervious surface. It should be noted that retrofits in this small size range will require very frequent maintenance to maintain their performance over time.

5. *Suitability of method.* The Panel concluded that the generalized retrofit removal adjustor curves were a suitable tool for estimating the aggregate pollutant load reductions associated with hundreds or even thousands of future retrofit projects at the scale of the Bay watershed and the context of the Chesapeake Bay Watershed Model.

Changes after 2nd Draft

1. *Modify HI/LO Designation.* Change the HI runoff reduction designation to RR (runoff reduction) and the LO designation to ST (stormwater treatment). DE recommended this clarification as it is more consistent with how these practices are treated in state stormwater manuals. This would be reflected in the text and on the curve labels in the memo, however, there would be no change in how the current list of stormwater practices are categorized (i.e., Table 2).

2. *Make the following clarifications in the methods section:*

   - Clearly define the x-axis as being "depth of runoff captured by practice per impervious acre."

   - Clearly state that the retrofit storage volume for each site must be adjusted using a "unitization" equation that converts the storage volume into a unit depth per impervious acre at each site.

- Note that the corresponding removal rate determined from the appropriate curve applies to the entire drainage area of the retrofit.

3. *Change the retrofit storage equation to divide by impervious area rather than site area.* To ensure consistency in how the adjustor curves are used to define removal rates for retrofits, the standard retrofit storage equation needs to be modified. The current equation is:

$$= \frac{(RS)(12)}{SA}$$

   The specific retrofit storage volume achieved at an individual site is usually measured or estimated, and is a given (usually acre-feet). The user will need to interpret how this volume will be adjusted to use on the x-axis of the curves. This is done by using standard retrofit equation which multiplies the retrofit storage volume by 12 to get acre-inches, and then divides by the impervious acres to get the unit "depth of runoff captured by practice per impervious acre." This value is used with the curves to define the retrofit removal rates. The new version of the standard retrofit equation will be:

$$= \frac{(RS)(12)}{IA}$$

4. *Provide documentation on why the unitization equation is needed for retrofits in Appendix C.* Add a section in Appendix C that documents why the unitization for impervious area is needed to provide a common basis of comparison among states and drainage areas. The basic reason is that the Rainfall Frequency Analysis used to derive the curve above and below the anchor points is based on the assumption that the runoff delivered to a practice is generated from a unit impervious acre. The runoff storage volumes achieved for individual retrofits, however, are unique, based on the land cover, soils and hydrologic assumptions used in each state. Therefore, these volumes must be adjusted by a unitization equation to get the correct depth to use on the x-axis of the curves.

2. Resolving Key Comments From the Panel

General Comments: In general, the Bay states wanted to ensure that the memo would protect state prerogatives with respect to their existing and/or future BMP reporting and tracking systems.

Retrofit Definitions Section

Comment: PA DEP noted that applying more stringent stormwater requirements at redevelopment sites was functionally equivalent to a new retrofit facility.

Resolution: the Panel agreed, but noted that a specific BMP crediting system for redevelopment projects was being developed by the Performance Standards Expert Panel. The Panel indicated that the redevelopment should be cross-referenced in the text, so readers would be aware of that option.

Comment: PA DEP, MDE noted that the photo illustrating "Storage behind Roadway Crossings" appeared to show a retrofit in waters of the US and would not be allowed under state or federal wetland permits.

Resolution: The Panel agreed that the photo and the retrofit sub-category should be dropped.

Comments about BMP Restoration category:

- Concern that some localities may interpret this as a chance to claim additional nutrient reduction credit for routine BMP maintenance which is needed to sustain the performance of existing BMPs (for which they are already getting credit).

- For BMP restoration the protocol depends on whether or not the State has included the BMP in its pre 2006 input deck. Based on previous conversations with DCR, this does not seem possible in Virginia.

Resolution: The Panel noted that the definition of BMP restoration only applies to major BMP upgrades that produce a substantive recovery or expansion of stormwater treatment volume, as measured by at least a 10% increase. The Panel also recommended that the following text be added to drive home the point: "Important Note: No pollutant removal credit is given for routine maintenance of existing stormwater practices. Routine maintenance is essential to ensure the pollutant removal performance of any stormwater practice." The Panel noted that individual states may want to develop their own more detailed guidance on qualifying conditions for acceptable BMP restoration.

Methods Section

Comment: MDE requested the removal of the BMP by ERA option from the retrofit memo, for the sake of simplicity, and because the curve method tends to produce a higher removal rate for more retrofit categories.

Resolution: The Panel agreed that it should be dropped from the text and the appendices.

Comment: MDE and others noted that some runoff reduction practices take surface stormwater and shift it to groundwater, so that it is possible that some fraction of the nitrogen entering a runoff reduction practice may ultimately end up in a stream, and that the nitrogen removal rates shown on the curve may not be as high in the real world.

Resolution: The Panel acknowledged the potential for this, but did not have any data to confirm or refute that it exists. The Panel agreed that this issue should be a top retrofit research priority, and indicated that the following statement be added to the existing section on research collaboration: "The Panel expressed a particular interest in defining the fate of nitrogen in retrofits that rely heavily on infiltration or extended filtration to provide runoff reduction".

Accountability Section

Comment: Various states indicated that their BMP reporting systems are unique, and they did not want a "one-size fits all" approach to retrofit reporting.

Resolution: The Panel agreed that states will need to aggregate data on individual retrofit location, year installed, and removal rate for reporting them to EPA, and also have the capacity to remove retrofits that are no longer functioning. However, the Panel agreed the followiug language should be added to the memo:

"Localities must submit basic documentation to the state stormwater or TMDL agency to documeut the nutrient/sediment reduction claimed for each individual urban retrofit project that is actually installed. Localities should check with their state stormwater agency on the specific data to report for individual retrofit projects. Some *typical* information that may be reported includes...".

Comment: Several states and localities on the panel indicated concerns over the language on initial verification/certification of individual retrofit performance. The concerns ranged from effect on local resources, and that localities should be able to use the existing annual MS4 annual reports as an alternative.

Resolution: The Panel agreed and re-drafted the section as follows: This initial verification is provided either by the retrofit designer or a local inspector as a conditiou of retrofit acceptance, as part of the normal municipal retrofit desigu and review process. From a reporting standpoint, the MS4 community would simply indicate in its annual report whether or not it has retrofit review and inspection procedures in place and adequate staff to implement them.

Comment: Several panelists questioned the process for down-grading individual BMPs, noting that as long as a local jurisdiction has a regular inspection and maintenance program/procedures in place to correct under or non-performance of retrofits, then removal and replacement of credits should be rare. This requirement could be excessively burdensome and the subject of error and confusion not only at the local level, but also at the level of the Bay Program modelers.

Resolution: The Panel agreed that downgrading based on field inspection was an importaut component of retrofit verification. The Panel drafted language on a reasonable time frame for corrective action and that downgrades only need to be reported through MS4 permit annual reports, as follows: If the field inspection indicates that a retrofit is not performing to its original design, the locality would have up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, the pollutant reduction rate for the retrofit would be eliminated, and the locality would report this to the state in its annual MS4 report.

Comment: The Panel noted that the field inspection and verification procedures should be more rigorous when retrofits are built for stormwater offsets or load reduction credits are being banked or traded. The prescribed inspection cycle for this special case of retrofits should be shorter.

Resolution: The Panel agreed with this, and suggested that the issue be addressed with the trading and offsets workgroup, and recommended the following language be added to the text: The Panel also recommends more frequent inspection and verification process for any retrofit built for the purpose of stormwater mitigation, offsets, trading or banking, in order to assure the project(s) is meeting its nutrient or sediment reduction desigu objectives.

Comment: If these protocols are accepted by the CBP, then the CAST, MAST, VAST will need to be modified as well. There will be no utility to these programs if they don't effectively predict CBP model results. Coordination with CAST needs to be a priority that should happen in concert with the update of urban BMP removal rates and not as an afterthought.

Resolution: The Panel agreed with this, and instructed CSN to share the final memo with the CB Modeling Team to ensure procedures were in place to prior to USWG meeting to address these concerns, They also added the following language to the text: "The Panel acknowledges that its retrofit assessment protocol does not fit easily within the context of assessment and scenario builder tools that have been recently developed to assist states and localities to evaluate BMP options to develop watershed implementation plans (i.e., each retrofit has a unique rate and consequent load reduction, while the CAST tools apply a universal rate for all retrofits).

The Panel recommends that localities use the CAST tools to evaluate non-retrofit urban BMPs to determine how much nutrient and sediment load remains after these cost-effective practices are applied. The retrofit removal rate protocol developed by the Panel can then be used to assess the most cost-effective combination of individual retrofit practices to close the remaining gap. CSN will work with ICPRB and Bay Partners to make improvements to future versions of CAST to improve its ability to handle stormwater retrofits."

Appendix C

Comment: It was noted that a Table in Appendix C had incorrect units for sediment loading rate from CBWM.

Resolution: Table Corrected.

Comment: A locality noted that when it comes to defining baseline loads from which the removal rates are applied, the two methods in Appendix C can give different loads for the same scenario (e.g., Simple Method cs. CBWM unit loads). The main issues is that Simple Method computes load solely based on IC, where the CBWM unit load method has employs both IC and pervious cover to compute baseline loads. Depending on the method, this could result in an over-estimate of load removed.

Resolution: The Panel noted that the baseline loads are only done for the purpose of enabling localities identify the most cost-effective retrofits and track their load reductions over time in MS4 permits. The actual retrofit load reductions are calculated for each project based on the NEIN location on the CBWM. The Panel noted that each Bay state should provide guidance to their MS4 localities ou which of the two methods they prefer, to assure consistency in their MS4 permit reports.

Appendix D
Conformity of Report with BMP Review Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2010) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where panel addressed the requested protocol criteria.

1. Identity and expertise of panel members*:* Table in Section 1, p. 4

2. Practice name or title: Section 3, p. 8

3. Detailed definition of the practice*:* Section 3: p. 8-12

4. Recommended N, P and TSS loading or effectiveness estimates

Protocol provided in Section 4 p. 13-19

5. Justification of selected effectiveness estimates*:* Appendix A and B, p. 27-40

6. List of references used*:* p. 59-62

7. Detailed discussion on how each reference was considered*:*
Appendix A andB, p. 27-40

8. Land uses to which BMP is applied: All qualifying acres of urban land(pervious or impervious)

9. Load sources that the BMP will address and potential interactions with other practices: Stormwater loads from urban land.

10. Description of pre-BMP and post-BMP circumstances and individual practice baseline: The Protocol is used to provide a specific removal rate for each retrofit project, based on the drainage area treated and the degree of runoff reduction or stormwater treatment provided. The pre-BMP baseline is defined as no BMP treatment for new retrofit facilities, and an incremental rate for certain categories of existing BMP retrofits (see Section 4, p. 16 to 18). The design examples (Section 5) also illustrate how removal rates are determined pre and post project

11. Conditions under which the BMP works/not works

Qualifying conditions to be eligible for the credit depend on the retrofit category, and are described in Section 3, p.8 to 12.

12. Temporal performance of BMP including lag times between establishment and full functioning

Retrofits are assumed to be fully functioning once they have met the requirements for initial performance verification: Section 6, page 24.

The new state stormwater performance standards go into effect at different times, see Section 5, p. 19

13. Unit of measure: Project specific removal rate for the acres of urban pervious and impervious land treated by the qualifying retrofit (Section 3, p. 13 and Section 6, p.24-26).

14. Locations in CB watershed where the practice applies: Retrofits are applicable throughout the Bay watershed, subject to the normal feasibility limitations for retrofits.

15. Useful life of the BMP: 10 years, and renewable based on visual inspection of practice performance (Section 6, p.24-26)

16. Cumulative or annual practice: See # 15 above

17. Description of how BMP will be tracked and reported: Section 6, p, 24-26

18. Ancillary benefits, unintended consequences, double counting

See No double counting, Section 6, p. 24

19. Timeline for a re-evaluation of the panel recommendations

Panel feels the estimates should be reevaluated when warranted by future retrofit performance monitoring data

20. Outstanding Issues

See Section 3: Analyzing retrofit options in the context of CAST, SB and CBWM (p. 18-19) and Section 6: Collaborative monitoring of retrofit performance (p. 24 -26)

21. Pollutant relocation

See Appendix B, Notes on Revising TN adjustor curve to reflect nitrate migration from BMP to groundwater, p. 37-40.

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