Draft for USWG Review

4-10-19

Recommendations for Crediting Outfall Restoration Projects

Stream Restoration Group 2:
Crediting Outfall Restoration Practices

Ray Bahr, Aaron Blair, Ted Brown, Karen Coffman, Ryan Cole, Tracey Harmon, Erik Michelsen, Nick Noss, Elizabeth Ottinger, Brock Reggi, Stephen Reiling, Allison Santoro, Chris Stone, Carrie Traver and Neil Weinstein

Date: April 10, 2019

A group of experts was formed in 2018 to recommend methods to credit pollutant removal achieved by individual outfall restoration practices built to meet the Chesapeake Bay TMDL (USWG, 2018). The experts were asked to adapt the existing crediting protocols contained in the original stream restoration expert panel report (CBP, 2014). The group met five times and developed the consensus recommendations that are outlined in this technical memo. The memo is organized as follows:

1. Group Charge and Roster
2. Background on Outfall Stabilization and Restoration Practices
3. Definitions and Qualifying Conditions
4. Protocol 5 Alternative Prevented Sediment for Outfalls
5. Technical Rationale for New Protocol
6. Environmental Assessment for Outfall Projects
7. Reporting and Record Keeping Requirements
8. Verifying Outfall Restoration Projects
9. References
10. Glossary

Technical Appendices
A: The Three Step Method to Calculate Watershed Sediment Delivery
B: Example Outfall Restoration Projects (MDOT SHA)
C. New Site Screening Appendix

Section 1: Charge and Roster of the Working Group

Table 1 profiles the team of experts who evaluated the feasibility of an alternative stream restoration crediting protocol for outfall restoration projects and agreed on the consensus recommendations outlined in this memo.

Table 1: Outfall Restoration Crediting Team

Name	Affiliation	E-mail Address
Ray Bahr	MDE	Rbahr@mde.state.md.us
Stephen Reiling	DOEE	Stephen.reiling@dc.gov
Tracey Harmon	VDOT	tracey.harmon@vdot.virginia.gov
Brock Reggi	VADEQ	Brock.reggi@deq.virginia.gov
Karen Coffman	MDOT SHA	KCoffman@sha.state.md.us
Ryan Cole	MDOT SHA (alternate)	rcole@sha.state.md.us
Elizabeth Ottinger	US EPA Region 3	Ottinger.elizabeth@epa.gov
Carrie Traver/Aaron Blair	US EPA Region 3	Traver.carrie@epa.gov
Alison Santoro	MD DNR	Alisona.santoro@maryland.gov
Ted Brown	Biohabitats	Tbrown@biohabitats.com
Chris Stone	Loudoun County, VA	Chris.Stone@loudoun.gov
Erik Michelsen	Anne Arundel County	pwmich20@aacounty.org
Neil Weinstein	LID Center	nweinstein@lidcenter.org
Nick Noss	PA Turnpike Commission	Nnoss@paturnpike.com
Jeremy Hanson (VA Tech), David Wood (CSN) and Tom Schueler (CSN) facilitated the team. Several consultants provided valuable technical support to the group on how to apply the new protocol to real world outfall erosion problems. The contributions of Kelly Lennon, Scott Lowe, Megan McCollough and Cory Anderson are gratefully acknowledged.		

Charge for the Group:

The group was asked to review the MDOT SHA (2018) outfall crediting proposal to determine if it could be adapted to calculate sediment and nutrient reduction associated with this class of projects. In particular, the team was asked to:

- Provide clear definitions of the specific channel conditions that apply to the new protocol (i.e., zero order streams) and whether any of these channels are potentially jurisdictional and subject to further environmental review and permitting
- Outline any other conditions that must be satisfied to receive credit, and justify whether the existing "100 foot" minimum project length condition (used for other stream restoration practices) can be relaxed for this class of projects.
- Work with the CBPO modeling team to determine the appropriate land use/stream segment in the Phase 6 model to credit the load reductions.
- Decide whether the prevented sediment calculations should be adjusted to (a) exclude coarse grained sediment particles that would not be delivered to the Bay or (b) exclude some fraction of the sediment mass that might never have been eroded had the stabilization project not been built (c) and/or apply the same 50% restoration efficiency rate utilized in Protocol 1.
- Determine whether soil samples need to be collected to define key parameters for the prevented sediment calculations, and if so, the specific methods for collecting and analyzing them
- Evaluate any unintended consequences associated with the practice, with an emphasis on the quality of downstream ecosystems, and issues regarding iron flocculation.
- Determine the extent to which functional uplift will be measured and achieved by the practice.

The working group met five times from September, 2018 to March, 2019, as it developed its consensus recommendations.

Section 2: Background on Outfall Stabilization and Restoration

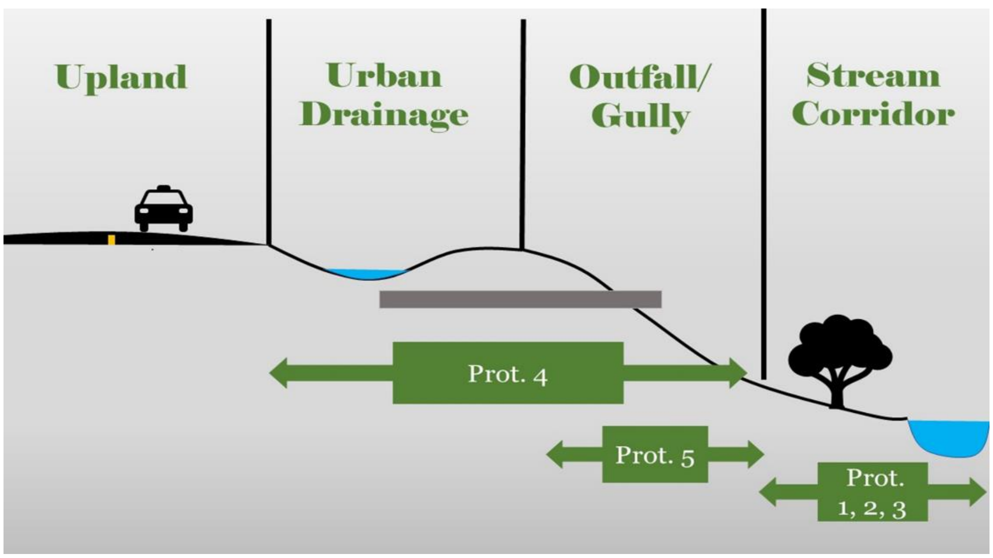
This section introduces the problem of outfall erosion, how they deliver high sediment loads to urban streams and how they can be fixed to reduce that sediment load.

The headwater transition zone

At the outset, it is important to define the term "headwater transition zone". It represents the transition zone from upland land uses into altered urban drainage (swales, ditches and storm drain pipes) that stormwater discharges into the beginning of the urban stream network. These zones experience higher rates of both vertical and lateral erosion and are responsible for high sediment delivery to downstream reaches.

A schematic showing the key features of the headwater transition zone can be found in Figure 1.

Figure 1. Schematic of the Headwater Transition Zone



Importance of headwater streams

Kaplan et al (2010) provide a compelling literature synthesis on the value of headwater streams in maintaining the structure, function and diversity of larger stream and river ecosystems. Despite their short lengths, headwater streams comprise a majority of the length of the entire drainage network of major rivers.

Streambank erosion and urban sediment yield.

Recent research has confirmed the importance of bank erosion in urban sediment yield. For example, Donovan et al (2015) found that bank erosion accounted for an average of 70% of annual sediment yield in 18 small watersheds sampled in Baltimore County, MD.

The headwater stream network was the source of most of the measured erosion, a majority of which were derived from legacy sediments.

Their findings are generally consistent with other recent geomorphic research conducted across much of the Bay watershed (Gellis et al 2017, Allemendiger et al 2007, Bergman and Clausen 2011, Fraley et al 2009, Merritts et al 2010, Miller and Kochel 2010, Alexander et al, 2007, Smith and Wilcock, 2015 and Pizzutto et al, 2018). The research also reinforces the notion that stream bank erosion represents a major fraction of the sediment yield from urban watersheds, especially those with extensive legacy sediment deposits in their floodplains.

The headwater transition zone as an urban sediment erosion hotspot

The headwater transition zone acts as a watershed "hotspot" for sediment erosion and downstream delivery (Lowe, 2018). The headwater transition zone has many characteristics that promote high rates of erosion and sediment delivery (see Figure 2). These include:

- Erosive force of flows discharged from storm drain outfalls
- High channel slopes and energy conditions
- Exposed and non-cohesive soils
- Poor vegetative cover
- Floodplains that are narrow or absent

Consequently, outfall erosion is a major problem in the headwater transition zone, which usually caused by a combination of the following:

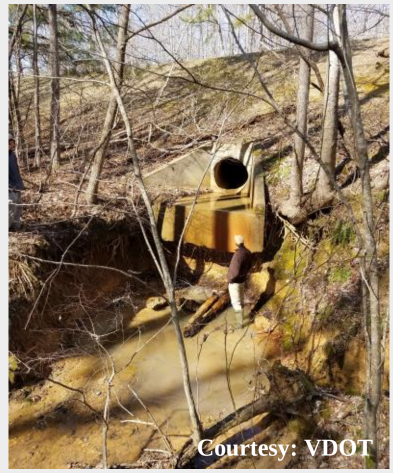
- Uncontrolled stormwater runoff from upstream development
- Inadequate energy dissipation structures below the outfall
- Nick points migrating upstream that reach the outfall
- Poor slope stabilization or fill spoils presents below the outfall
- Extreme storm events that exceed design capacity of the channel.

While the group analyzed many engineering calculations showing very high potential sediment delivery from the headwater transition zone, they were only able to find two watershed monitoring studies that measured erosion rates in this zone (Smith and Wilcox, 2015 and Downs et al, 2018).

Figure 2. Examples of Severe Outfall Erosion in the Headwater Transition Zone

1.

2.



3.

4.

1. Extremely incised vertical walls with failed outfall structure.
2. Eroding channel and threatened outfall structure caused by migrating knickpoint.
3. Highly incised and widened outfall channel caused by migrating headcut.
4. Eroding roadway embankment with severe incision and threatened infrastructure.

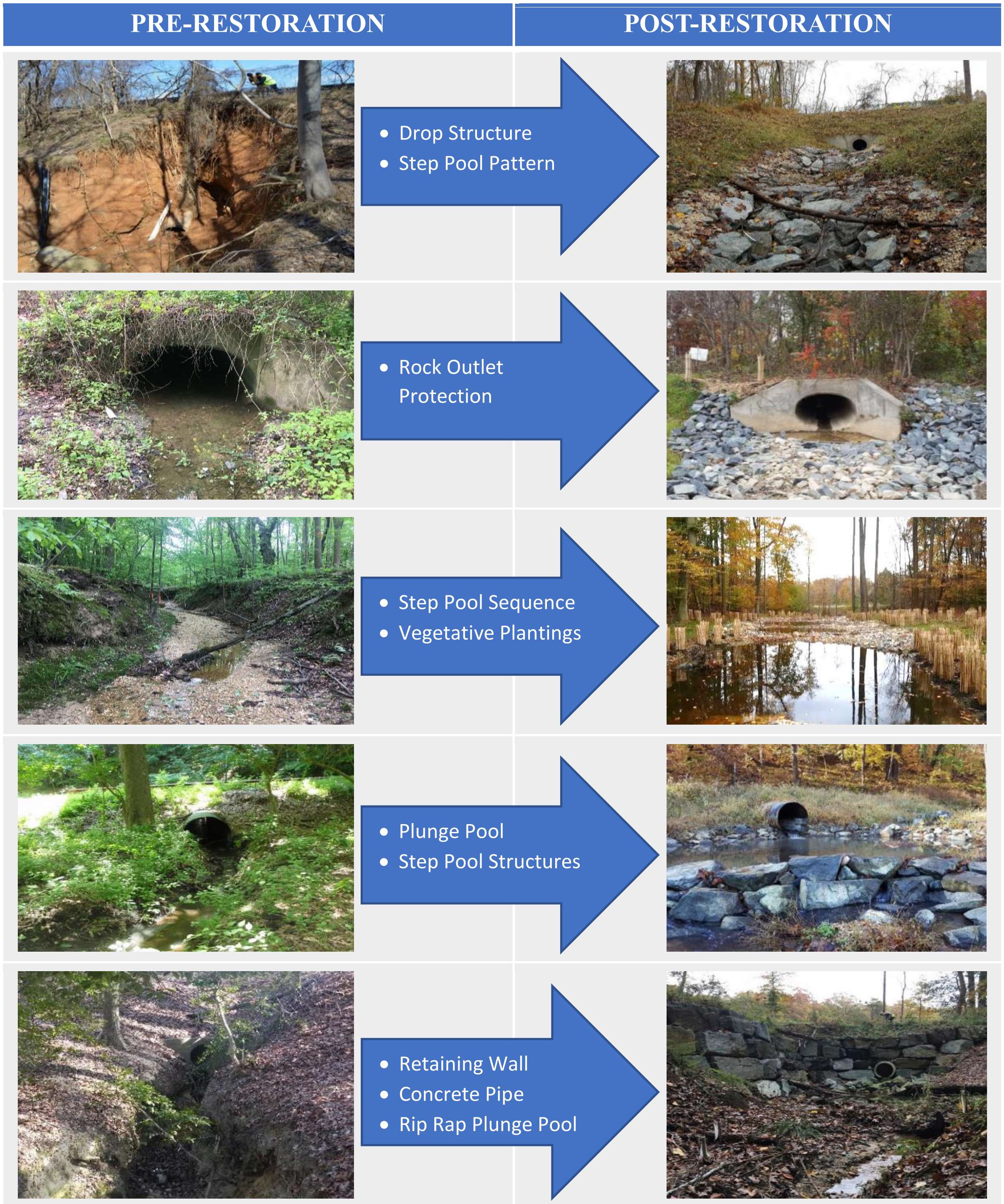
Outfall stabilization vs. outfall restoration practices

When outfall erosion begins to threaten public infrastructure, such as roads and sewers, the traditional response has been to fill the gully by dumping large rock (known as rip-rap) down the slope to create a more stable channel. These traditional measures are known as **outfall stabilization practices.** They are usually temporary and must be repeated frequently, since they do not fix the underlying problems at eroding outfall sites.

Outfall restoration practices are a newer engineering approach to design a stable channel to dissipate energy that extends from the storm drain outfall to the stream channel. The new channel is re-constructed and armored to achieve an equilibrium state where future sediment loss is minimized or eliminated altogether.

Acceptable outfall restoration practices can include elements such as drop structures, storm drain enclosure, natural channel design, channel grading, step pools, boulder revetments, rock cascades, root wads and bioengineering techniques. The specific practices that are applied depend on site conditions and the need to effectively dissipate energy at the site. Some examples of different outfall restoration practices are provided in Figure 3 and more detail on ORP applications can be found in the example projects found in Appendix B.

Figure 3. Examples of Outfall Restoration Projects



Summary of Protocol 1: Prevented Sediment Credit

Since the proposed protocol is an alternative to the prevented sediment protocol, it is worth describing how Protocol 1 is applied to stream restoration projects, and some of its key technical assumptions.

Protocol 1 calculates an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream. The three key steps for applying the protocol are provided in Table 2.

Table 2: Summary of Protocol 1: The Prevented Sediment Credit
Step 1: Estimate stream sediment erosion rates The most common technique to estimate bank erosion rate is the BANCS Method (Rosgen, 2001), where field surveys are used to calculate BEHI and NBS scores, which in turn, are entered into regional bank erosion curves to determine the annual rate of streambank retreat. Designers also have the option to actually measure the rate of bank retreat in the project reach using bank pins and cross section surveys. The final option employs LIDAR surveys and hydraulic engineering models to calculate expected bank retreat over time. The specific methods allowed for this option are now being developed by Group 3 (2019). The pre-restoration erosion rate for the project reach is then entered into the following equation to determine its potential prevented sediment load: $$S = \frac{\sum(cAR)}{2{,}000} \quad \text{(Eq. 1)}$$ where: S = sediment load (ton/year) for reach or stream c = bulk density of soil (lbs/ft^3) R = bank erosion rate (ft/year) (from regional curve) A = eroding bank area (ft^2) 2,000 = conversion from pounds to tons **Step 2: Convert erosion rates to nitrogen and phosphorus loadings**. In this step, the nutrient load associated with the prevented sediments are calculated using a unit conversion, based on the measured or default estimate of its sediment nutrient content. The current default values are provided below for reference, but it is likely that they will either be reduced or required to be measured later this year (Group 3, 2019). 1.05 pounds P per ton of sediment. 2.28 pounds N per ton of sediment **Step 3: Estimate restoration reduction efficiency.** In the last step, sediment and nutrient load reductions are conservatively reduced by 50% to account for the presumed efficiency of stream restoration practices.

Note on Sediment Delivery from the Stream to Head of Bay

Some fraction of the sediment load is deposited on downstream channels and floodplains, where they may be stored for decades or more. Sediment storage complicates the issue how sediments travel from the headwaters to the head of the bay estuary. The original expert panel recommended a fixed sediment delivery ratio, depending on whether a stream was located in the coastal plain or not. After some significant improvements in sediment modeling were adopted, the Phase 6 Chesapeake Watershed Model (CBP, 2018) now explicitly calculates sediment delivery for individual stream reaches.

If you know the geographic address of your project, its specific sediment delivery ratio from the stream reach to the Bay can be quickly determined using the Chesapeake Assessment and Scenario Tool (CAST - EPA, CBP, 2018). Some guidance on a step by step method to estimate the unique sediment delivery factor for the land-river segment in which a project resides can be found in Appendix A.

Section 3: Definitions and Qualifying Conditions

Definitions: The group established the following definitions to assist the reader in understanding the terminology relating to outfall stabilization. For the reader's convenience, additional technical, engineering or design terms are defined in the glossary presented in Section 10.

Base-level control: Base-level control features consist of channel features, such as bedrock and existing infrastructure that are anticipated to withstand expected channel erosion processes. Confluence locations, an existing stable condition downstream, or the downstream limits of proposed bed stabilization features can be used as base level controls in cases where no hard point controls are present within the channel**.**

Channel conditions: the current or future potential for erosion of the channel bed or banks to subsequently deliver sediment and other pollutants downstream.

Dry channel regenerative stormwater conveyance (RSC) involves restoration of ephemeral streams or eroding gullies using a combination of step pools, sand seepage wetlands, and native plants (see An, 2018). The receiving channels are located above the water table and only carry water during and immediately after storms. Protocol 4 is used to define pollutant reduction achieved by this stormwater retrofit treatment practice.

Equilibrium slope is the ground surface slope wherein channel bed and bank slopes within the hydrologic regime and erosion substantially decreases or ceases. Based on slope stability analysis.

Equilibrium bank angle is the angle at which a channel or stream bank reaches a stable condition, thereby minimizing or eliminating bank erosion within the hydrological regime.

Headwater channels are stream segments connected to open or closed channel segments within zero to first order channels where water first originates in a stream system. These channels can be ephemeral, intermittent, or perennial and often adjust to storm flows through gully and rill formation and therefore can produce significant vertical and lateral rates of erosion.

Headwater transition zone: The slope or channel that extends from a storm drain outfall to the perennial stream network. This zone has an exceptionally high potential for sediment erosion and is the focus of outfall restoration practices

Outfalls are the outlets, conveyances and discharge points from storm drain networks, often located at headwater stream systems or are direct connections to closed storm drain networks. Does not include outfalls that produce overflows from separate or combined sewer systems

Outfall stabilization projects (OSP) refers to traditional methods to repair erosion problems at or near outfalls that typically involve regrading and placement of stone rip-rap to stabilize the eroding channel and temporarily protect the outfall.

Outfall restoration projects (ORP) refers to newer methods that seek to restore an eroding outfall channel to an equilibrium or near-equilibrium state, such that future sediment loss is minimal or eliminated altogether. These can include structural and non-structural energy dissipation techniques. For the purposes of this protocol, ORPs utilize bank height, equilibrium slope and equilibrium bank angle to compute sediment and nutrient load reductions.

Pipe Conditions: the current or future status of the discharge pipe associated with the given outfall and channel.

Project reach refers to the length of an individual outfall restoration project as measured by the restored channel length (expressed in units of feet). The project reach is defined as the specific work areas where outfall restoration practices are installed.

Stream restoration (SR) refers to any natural channel design (NCD), regenerative stormwater conveyance (RSC), legacy sediment removal (LSR) or other restoration project that meets the qualifying conditions for pollutant removal crediting as described by the Stream Restoration Expert Panel (CBP, 2014).

Qualifying Conditions for the Practice:

The Expert Panel also outlined a series of qualifying conditions that must be met for a project to be eligible for Chesapeake Bay TMDL reductions. To be consistent with the report, the group agreed that outfall restoration projects should meet the following qualifying conditions:

- The channel or gully slope below the outfall must exhibit predictive indicators for severe erosion or hill-slope failure and be actively enlarging or degrading as demonstrated through equilibrium slope analysis or comparable method.
- The project should utilize a comprehensive approach to stream channel design, addressing long-term stability of the channel, banks, and floodplain.
- Each project must comply with all state and federal permitting requirements, including 404 and 401 permits, which usually contain conditions for pre-and post-project assessment and post construction monitoring
- Before credits are granted, outfall restoration projects will need to meet post-construction stability criteria and successfully establish needed vegetation. Projects should maintain or improve existing native riparian vegetation in the headwater stream corridor to the extent possible. Projects should follow regulatory agency guidance regarding compensation for any losses of forest, wetlands and sensitive habitats within project work areas.

In addition, the group felt that some of the qualifying conditions that apply to other stream restoration practices could be relaxed due to the unique conditions and locations of outfall restoration projects. For example,

- Practices that armor or harden the outfall channel ARE eligible for credit if they are needed to sustain channel stability and do not adversely impact ecological functions below the project reach.
- Projects do not need to meet the minimum project reach length that applies to downstream restoration practices (100 feet). Actual project length for outfall restoration practices is typically determined by equilibrium slope analysis, but usually are less than 500 feet in length.
  - Projects are typically restricted to zero order stream channels that lack perennial or seasonal flow (where traditional stream restoration practices are seldom applied).
- ORPs do not require special project monitoring to assess stream function because these functions are usually minimal or absent in the headwater transition zone prior to any restoration.

- A visual inspection of downstream perennial streams should occur after construction to ensure that upstream ORP projects contribute to their function and stability.

In addition, Protocol 5 is restricted in how it applies to, or is combined with, stream restoration practices constructed under the other four crediting protocols.

Protocol 5 cannot be combined with Protocol 1 (Prevented Sediment) within the same project reach. Protocol 5 can be combined with Protocols 2 and 3 in the same project reach, if it meets the conditions for hyporheic exchange and/or floodplain reconnection, which is exceedingly unlikely.

Wet-channel RSC practices installed on perennial or intermittent stream channels may be credited using either Protocol 1 or 5 but the two credits c*annot* be combined together in the same project reach.

Dry-channel RSC practices installed in ephemeral stream channels can be credited as both a stormwater retrofit (Protocol 4) and an outfall restoration practice (Protocol 5). Protocol 4 reductions are subtracted from the pollutant load generated from upland impervious cover, whereas the Protocol 5 reductions are subtracted from the urban stream bank load.

The pollutant reduction impact of outfall restoration projects is *independent* of any reduction achieved by upstream retrofits or other approved urban practices in the contributing drainage area.

The group did not suggest that any single design approach was superior to others, as any outfall restoration project can fail if it is inappropriately located, assessed, designed, constructed, or maintained.

Section 4: Protocol 5 -- Alternative Prevented Sediment for Outfalls

This protocol, originally developed by MDOT SHA, uses a 5-step process to define the equilibrium headwater channel condition as a means of estimating prevented sediment loss from restoration (MDOT SHA 2018). The alternate SHA protocol is based on the assumptions that bed and bank incision will cease once the channel reaches equilibrium slope and bank angle based on physical characteristics of the soil material. This approach accounts for sediment loss through vertical incision that is common at stormwater outfalls, but is not fully captured by Protocol 1.

The group developed the following process for practitioners in other Bay states. The simplified process involves 5-steps, as follows:

1. Define the Existing Channel Conditions
2. Define the Equilibrium Channel Conditions
3. Calculate Total Volume of Prevented Sediment Erosion
4. Convert Total Sediment Volume to Annual Prevented Sediment Load
5. Determine Annual Prevented Nutrient Loads

It is recommended that practitioners in Maryland continue to use the more detailed MDOT SHA alternate method to perform their computations.

Step 1: Define the Existing Channel Conditions

The following measurements need to be collected from the existing headwater channel:

- Length of Proposed Project Reach (ft)
- Channel Slope (ft/ft)
- Bank Height (ft)
- Bottom Width (ft)
- Top Width (ft)
- Bulk Density (lb/ft^3)

The channel slope, bank height and top and bottom width should be taken at three representative cross-sections within the project reach prior to construction. The average of the three cross sections will be used for the calculations. Bulk density samples should be taken roughly every 200 ft along the project reach. For sites shorter than 200 ft, one sample is sufficient.

Step 2: Define the Equilibrium Channel Conditions

There are four components of an equilibrium channel that must be defined:

- Base Level Control
- Equilibrium Bed Slope (ft/ft)
- Equilibrium Bank Slope (ft/ft)
- Future Channel Width (ft)

Base Level Control:

Base level controls are the site constraints that bound the upstream and downstream extent of the equilibrium channel design and define the maximum extent of vertical scour at the project site in the absence of restoration. Determine if the prospective project reach contains any of the following base level controls:

- Hard Point Control (ex. bedrock or existing infrastructure)
- Confluence (elevation of larger, stable, receiving stream)
- Channel at equilibrium (existing slope is within 5% of the equilibrium slope)
- Upstream Limit of Erosion (pipe outfall or other defining infrastructure)
- Downstream limits of equilibrium slope must be set at the downstream limits of project bed stabilization features

If no pipe outfall or other defining infrastructure is present upstream of the restoration site, the upstream limit is determined by the equation:

$$L_{max}=153A_d^{0.6}$$

Where L_{max} is the maximum upstream channel length (ft) from a given point, and A_d is the drainage area (acres). Upstream limits of erosion should be field verified.

Equilibrium Bed Slope:

To calculate the equilibrium bed slope, use the equation(s) in Table 3 for the applicable bed conditions at the project site. The equilibrium slope analysis is based on methods from Technical Supplement 14B (TS14B)— Scour Calculations—of Part 654 of the National Engineering Handbook—Stream Restoration Design (Natural Resource Conservation Service (NRCS), 2007).

Table 3. Equilibrium Bed Slope Equations	
Cohesive Bed	$S_{eq} = 0.0028A^{-0.33}$
Sand and Fine Gravel (0.1-5mm particle size)	$S_{eq}= 0.06 / (y * 62.43)$
Beds Coarser than Sand (>5mm particle size)	Average of 4 Equations Details can be found in 2.1.3 of Appendix A.
S_{eq} is equilibrium slope (m/m or ft/ft), A is drainage area (km^2), and y is mean flow depth (ft). When estimating the critical shear stress, a 10-year recurrence interval can be used for the design discharge, and intermediate suspended sediment concentration (1,000 to 2,000 ppm) can be assumed.	

Equilibrium Bank Slope

The equilibrium bank slope for this analysis has been defined as 1.76:1. According to methods from Technical Supplement 14A (NRCS 2007), it has been shown that equilibrium bank slopes range from 1.4:1 to 2.1:1 in the absence of the influence of seepage. Utilizing the equilibrium bank slope for medium dense sand of 1.76:1 provides a conservative estimate for this analysis.

Future Bottom Width:

Select a representative reach within the study reach (from the groundwater origin or outfall location to the selected base level control feature) and take the average of three reference cross sections. This average will represent the future bottom width.

Step 3: Calculate the Total Prevented Sediment

To calculate the total volume of prevented sediment, you must take the difference between the equilibrium channel condition and the existing channel condition. This can be done using 3D surface modeling programs, such as *InRoads* or *Geopak*. To run this analysis, you will need the information summarized in Table 4.

Table 4. Summary of Information Needed for 3D Surface Analysis

	Parameter	*Source*
Pre-Restoration Channel	Length of Project Reach	Measured
	Average Bank Height	3 measured cross sections
	Average Bottom Width	3 measured cross sections
	Average Top Width	3 measured cross sections
	Base Level Controls	Fixed start and end points determined by bedrock, existing infrastructure or downstream confluence
Equilibrium Channel	Equilibrium Bed Slope	Equations in Table 1
	Equilibrium Bank Slope	1.76 : 1
	Average Bottom Width	3 measured cross-sections from reference reach

Three-dimensional surface modeling can be a time and labor-intensive process. To aid local municipalities with initial site evaluation and project screening. Appendix C provides examples of good candidate sites for outfall restoration. Example calculations are also provided for select sites. Following a preliminary site inspection, municipalities can decide whether to pursue additional data collection and analysis.

Step 4: Convert the Total Sediment Volume to Annual Prevented Sediment Load

To convert the total volume of prevented sediment erosion to an annual timescale, divide the total volume by 30. Thirty years is recommended as a conservative estimate of the amount of time it would take an eroding outfall channel to export the total volume of sediment calculated in Step 3.

To maintain consistency with the Stream Restoration Expert Panel report, the mass load reductions should then be discounted to account for the fact that projects will not be 100% effective in preventing bed and bank erosion and that some sediment transport occurs naturally in a stable stream channel.

Consequently, a conservative approach assumes that projects will be 50% effective in reducing sediment and nutrients from the channel reach. Efficiencies greater than 50% should be allowed for projects that have shown through monitoring that the higher rates can be justified subject to approval by the states. This conservative factor should be multiplied by the annual prevented sediment load.

$$S_p = 0.5\,(S_v / 30)$$

Where S_p represents the annual volume of prevented sediment and S_v represents the total volume of prevented sediment calculated in Step 3.

The annual volume of prevented sediment must also be adjusted by the bulk density of the soil to determine the final annual prevented sediment load. Bulk density measurements can be highly variable and each project site should have one sample collected every 200 ft throughout the reach to determine a representative bulk density value. The NRCS Soil Series data (NRCS 2019) may be used to provide an estimate value for preliminary calculations. Multiply the annualized sediment volume by the bulk density to determine the annual prevented sediment load.

Step 5: Determine the Annual Prevented Nutrients

Pollutant load reduction credits are awarded based on the amount of pollutant—TN, TP, and sediment—reduction estimated to occur as a result of the proposed project. The amount of TN and TP present along a project reach is determined by applying TN and TP concentrations to the annual sediment loading rate. CBP (2014) provided two methods for estimating or measuring TN and TP concentrations in project soils. These methods are currently under review by Group 3, and are likely to be revised when they make their final recommendations (Group 3, 2019).

Planning for Sediment Delivery

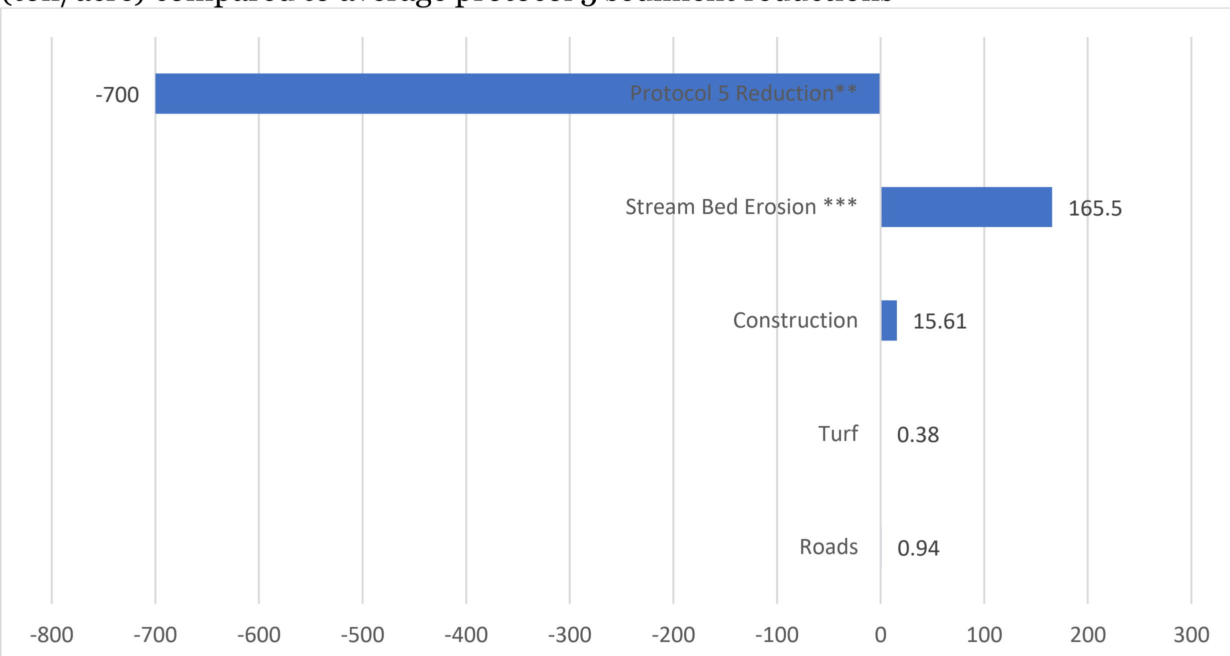
In the new Phase 6 Chesapeake Bay Watershed Model, calculated nutrient and sediment reductions are reported to the state without applying a sediment delivery factor. However, some practitioners and localities may wish to know the sediment delivery rate for a proposed site for planning purposes. Please use the 3-step guide in Appendix A to determine the sediment delivery rate for your project reach.

Section 5: Technical Rationale for New Protocol

This section documents why Protocol 5 is consistent with, but different from, Protocol 1. It describes the technical analyses the group conducted to support its conclusions that a new protocol is merited within the headwater transition zone, and why the method presented in MDOT SHA (2018) is technically supportable.

Figure 4 compares the unit area sediment loads for upland urban land uses and downstream urban channels, as simulated in the calibrated Phase 6 watershed model. Upland sediment loads tend to be much lower than those generated by the network of urban stream channels, even when under active construction. Even higher sediment loading rates are inferred for the headwater transition zone, based on the engineering calculations that Lennon and Lowe (2018) and McCollough and Andersen (2018) provided to the group.

Figure 4. Comparison of upland and stream channel sediment loading rates* (ton/acre) compared to average protocol 5 sediment reductions



*Average loading rates are for MS4 land uses in the Phase 6 Chesapeake Bay Watershed Model
** Average reduction at edge of stream, based on 81 Maryland sites, with 50% reduction efficiency.
*** Average Chesapeake Floodplain Network sediment flux (62.69 lb/ft/yr) where 1 mile = 1 acre

The group also analyzed a series of example projects to determine how the sediment reductions achieved under the new credit compare to those calculated under the prevented sediment protocol.

The comparison is shown in Table 5. As can be seen, the proposed Protocol 5 credit earns about an order of magnitude higher sediment reduction compared to Protocol 1, although most ORPs are installed on shorter project reaches.

Table 5. Comparison of Sediment Reduction Potential for the Three Protocols

Sediment Reduction Protocol	Typical Reach Length	Default	Min	Mean	Max
	ft	lbs of sediment per linear ft restored [1]			
Protocol 1 [2]	1000 to 4000	248	3	375	3,750
Protocol 4 [3]	100 to 300	NA	5	7	8
Protocol 5 [4]	50 to 500	NA	40	1,060	17,300

Notes:
[1] Estimate is at edge of stream with no efficiency factor applied.
[2] Using Hickey Run Curve where bulk density=75lb/ft^3 over a 2500 ft reach. Min uses Low/Low (NBS/BEHI) with 2ft average bank heights. Mean uses High/High with 5ft average bank heights. Max uses Extreme/Extreme with 10ft average bank heights.
[3] Using RR adjustor curve. Min treats 0.5 in, Mean treats 1 in, and Max treats 2 in. All scenarios calculated as 200ft project treating 1 acre of "average" MS4 Roads land use.
[4] Estimates based on 81 sites in Maryland analyzed by MD SHA.

Section 6: Environmental Assessment for Outfall Projects

Defining the origin of headwater streams has been a matter of debate for scientists and regulators for many decades, and this group does not plan to wade into this controversy except to note that:

(a) Headwater streams are extremely important to downstream ecosystems (see Kaplan et al, 2010 for a concise review), and,

(b) All Bay states currently regulate construction activity within the certain headwater streams zones, which usually require some form of stream, wetland or forest field assessment to delineate if projects are subject to general or individual permits

The original expert panel strongly endorsed the need to show functional uplift for stream projects primarily built for pollutant reduction credit (USR EP, 2013). They also recommended that stream function assessment resources developed by Harman et al (2011), and subsequently Davis et al (2014) and Starr and Harman (2016) be used to assess stream response to restoration efforts.

This group concluded its recommendations should be descriptive rather than prescriptive and should reinforce ongoing environmental assessment efforts by state and federal permitting agencies. The group offers some general guiding principles for the environmental assessment of ORPs and their future management:

- Drop structures, storm drain enclosures or hard armoring techniques should never be used within jurisdictional waters, as determined by the appropriate permitting agency. Projects should be assessed to ensure no adverse impacts on passage of aquatic or semi-aquatic life, and any crediting of projects in jurisdictional waters is subject to the armoring limits established by Group 3 (Group 3, 2019).

- The primary purpose of ORPs is to prevent excess sediment delivery and flow velocities from impairing habitat and ecosystem function in downstream reaches.

- Better opportunities for instream habitat creation will normally exist further downstream.

- Designers should focus on demarcating two "tie in zones" – the first extends from the storm drain outfall to the beginning of the ORP, whereas the second runs from the terminus of the ORP and the perennial stream channel.

- Each project should show how future vegetation will be managed within the project right of way to promote enhanced forest cover in the headwater transition zone, while allowing for limited tree-cutting to ensure stability of the restored channel over time.

Section 7: ORP Reporting and Record-keeping Requirements

The information that is required to be reported to the Chesapeake Bay Program to earn credit for stream restoration practices has been streamlined since the expert panel report was first published in 2013. The current reporting criteria for stream restoration practices are outlined in Wood et al (2018) and includes:

- *BMP Name:* Stream Restoration
- *Length Restored:* (ft)
- *Protocol(s) Name and associated unit amount* (lbs):
    - Protocol 1 TN; Protocol 1 TP; Protocol 1 TSS;
    - Protocol 2 TN;
    - Protocol 3 TN; Protocol 3 TP; Protocol 3 TSS
    - Protocol 5 TN: Protocol 5 TP: Protocol 5 TSS
- *Land Use:* The default land use is Stream Bed and Bank
- *Geographic Location:* (see NEIEN for details)
- *Date of Implementation*: year the project was completed

In addition, the group recommends that the following additional information be collected for ORP projects:

- Outfall pipe diameter (in)
- Drainage area (acres) and its impervious cover (%) [MD only]

- Primary outfall restoration technique using the armoring definitions developed by Group 3.
    - Non-creditable armoring
    - Creditable armoring, with limitations
    - Creditable armoring

The current record-keeping requirements for stream restoration practices were outlined in the original EPR report, and stipulated that:

> "the installing agency should maintain an extensive project file for each stream restoration project installed (i.e., construction drawings, credit calculations, digital photos, any post-construction monitoring, inspection records, and maintenance agreement). The file should be maintained for the lifetime for which the load reduction will be claimed"

This group concurs with the need for good project documentation, especially to support the future inspection needed to verify the long-term performance of ORPs. Some good examples of ORP project documentation can be found in Lennon and Lowe (2018).

In addition, the verification group is recommending better industry standards for post-construction project drawings/surveys (Group 1, 2019). Specifically, post-construction redlines, surveys or as-builts should identify fixed photo stations or cross-sections along the project reach to determine future sediment stability. If possible, specific control sections should be monumented at reach locations that are most vulnerable to erosion and high shear stress.

Section 8: Verifying Outfall Restoration Projects

The original expert panel outlined general requirements to verify stream restoration practices that are submitted for TMDL credit (CBP, 2014). These requirements preceded the partnership's broader decisions to establish more detailed guidance on how to verify BMPs (USWG, 2014 and CBP, 2014b). A working group was established in 2018 to provide more specific guidance on how to verify stream restoration practices (USWG, 2018) and it has recently made its recommendations to the CBP partnership (Group 1, 2019).

The general verification requirements outlined by the original expert panel are excerpted below:

- The installing agency needs to conduct visual inspections once every 5 years (after the original permit conditions expire) to ensure that individual projects are still capable of removing nutrients and sediments.

- Duration of the credit (5 years) is shorter than other urban BMPs, as these projects are:

  - subject to catastrophic damage from extreme flood events
  - have requirements for 3 to 5 years of post-construction monitoring to satisfy permit conditions

- If a project does not pass inspection, there is 1 year to take corrective action prior to loss of credit

Recommended field verification methods

This section builds on the basic verification methods for stream restoration practices developed by Group 1 (2019) and assumes that the same two-stage inspection process used for Protocol 1 projects would also be applied to outfall restoration projects.

The first stage involves a rapid inspection of the project reach to assess its condition, preferably at predefined photo stations or cross-sections, relying on simple visual indicators, as shown in Table 6. An example of Protocol 1 indicators that also apply to ORPs can be found in Figure 5. The guiding rule is that inspectors are looking for severe departures from the intended design that are clearly compromising its pollutant reduction functions.

The basic approach is to walk the entire project reach to assess the dominant restoration crediting protocol. The rapid initial inspection is intended to look for any potential loss of pollutant reduction function in some or all of the project reach. In some cases, observations or measurements may be made at predefined photo stations or cross-sections shown on the post construction project drawings. More details on the inspection fieldwork can be found in 2019 recommendations of Group 1.

Table 6. Defining Loss of Pollutant Reduction Function for Protocol 1 (Prevented Sediment)

Criteria for Loss	**Key Visual Indicators**
Evidence of bank or bed instability such that the project delivers more sediment downstream than designed, as defined by exposed soils/fresh rootlets	• Severe bank erosion (bare earth exposed or extreme undercutting) • Departure of more than 20% from average post-construction design bank height • Incising bed (bed erosion resulting in the loss of defined pools and riffles and active head cuts • Flanking or scour of in-channel structures • Failure or collapse of allowable bank protection practices

In the second stage, each project is graded on a pass/fail basis, based on the proportion of the reach deemed to be seriously compromised or failing. Inspectors rapidly inspect the project reach using the visual indicators. The reach is analyzed to compute the percentage of each reach that is:

- Functioning or showing minor compromise
- Showing major compromise
- Project failure

More details on how stream projects are managed based on their assessed function can be found in Group 1 (2019).

Figure 5. Visual Indicators Showing Failures in the Field for Protocol 1

	
Exposed Soil on Banks	*Extreme Undercutting*
	
Outflanking of Instream Structures	*Bank Armoring Collapse*

Source: (Group 1 2019)

Section 9: References

Allmendinger, N., J. Pizzuto, G. Moglen and M. Lewicki. 2007. A sediment budget for an urbanizing watershed 1951-1996.Montgomery County, Maryland, USA. *JAWRA*. 43(6):1483-1497.

An, D. 2018. Regenerative stream conveyance: Construction guidance. First Edition. Maryland Department of Natural Resources and Alliance for the Chesapeake Bay. Annapolis, MD.

Bergmann, K. and A. Clauser. 2011. Using bank erosion and deposition protocol to determine sediment load reductions achieved for streambank erosion. Brandywine Valley Association, West Chester, PA.

Chesapeake Bay Program (CBP). 2014a. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. Chesapeake Stormwater Network and Center for Watershed Protection, Ellicott City, MD.

CBP. 2014b. Strengthening Verification of Best Management Practices Implemented in the Chesapeake Bay Watershed: A Basin-wide Framework. report and documentation from the Chesapeake Bay Program Water Quality Goal Team's BMP verification committee. Chesapeake Bay Program Office, Annapolis, MD.

CSN. 2018a. Stream Restoration Forum: Notes from June 4th 2018 meeting. Held at Chesapeake Bay Program Office, Annapolis, MD.

CSN 2018b. Proposed Charge and Team to Define and Outfall Restoration Credit. Technical Memo. August 29, 2018.

Davis, S., R. Starr and C. Eng. 2014. Rapid stream restoration monitoring protocol. CBPO-S14-01. Chesapeake Bay Field Office. U.S. Fish and Wildlife Service. Annapolis, MD.

Donovan, M., A. Miller, M. Baker and A. Gellis. 2015. Sediment contributions from floodplain and legacy sediments in piedmont streams of Baltimore County, Maryland. *Geomorphology*. 235: 88-105.

Downs, P., S. Dusterhoff and G. Leverich. 2018. Fluvial system dynamics derived from distributed sediment budgets: perspectives from an uncertainty-bounded application. *Earth Surface Processes and Landforms, 43*(6), 1335-1354.

Fraley, L., A. Miller and C. Welty. 2009. Contribution of in-channel processes to sediment yield in an urbanizing watershed. *Journal of American Water Resources Association*. 45(3):748-766.

Gellis, A., M. Meyers, G. Noe, C. Hupp, E. Schenk and L. Myers. 2017. Storms, channel changes and a sediment budget for an urban-suburban stream, Difficult Run, Virginia. USA. *Geomorphology*. 278: 128-148.

Group 1. 2019. Recommended methods to verify stream restoration practices built for pollutant crediting in the Chesapeake Bay watershed. Technical memo submitted to Urban Stormwater Workgroup 2/15/2019.

Group 3. 2019. Recommended modifications to the prevented sediment protocol used to credit stream restoration in the Chesapeake Bay watershed. Technical memo submitted to Urban Stormwater Workgroup. In preparation.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs and C. Miller. 2011. A function-based framework for developing stream assessments, restoration, performance standards and standard operating procedures. U.S. Environmental Protection Agency. Office of Wetlands, Oceans and Watersheds. Washington, D.C.

Kaplan, L. T. Bott, J. Jackson, J. Newbold and B. Sweeney. 2010. Protecting headwater streams: the scientific basis for safeguarding stream and river ecosystems. A research synthesis of the Stroud Water Research Center.

Langland, M. and S. Cronin. 2003. A summary report of sediment processes in the Chesapeake Bay and watershed. U.S. Geological Survey Water Resources Investigations Report.

Lennon, K. and S. Lowe. 2018. Alternative headwater channel and outfall crediting: SHA and Howard County example projects. Presentation to group on 11/20/2018.

Lowe, S. 2018. Summaries of the references from the MDOT SHA Alternative headwater channel and outfall crediting protocol.

Maryland State Highway Administration (SHA). 2018. Alternative Headwater Channel and Outfall Crediting Protocol. Maryland Dept of Transportation.

McCollough, M. and C. Andersen. 2018. Preliminary review of four VDOT projects applying the Maryland protocol. 12/14/2018 Memo to Tracey Harmon, VDOT. Prepared by Stantec, Inc.

Merritts, D. R. Walter and M. Rahnis. 2010. Sediment and nutrient loads from stream corridor erosion along breached mill ponds. Franklin and Marshall University.

Miller, J. and R. Kochel. 2010. Assessment of channel dynamics, instream structures, and post-project channel adjustments in North Carolina and its implications to effective stream restoration. *Environmental Earth Science*. 59:1681-1692.

Natural Resources Conservation Service. 2007. Stream Restoration Design. National Engineering Handbook, Part 654. U.S. Department of Agriculture, Natural Resources Conservation Service.

Smith, S. and P. Wilcock. 2015. Upland sediment supply and its relation to watershed sediment delivery in the contemporary mid-Atlantic piedmont. *Geomorphology*. 232: 33-46.

Stack, W., L. Fraley McNeal and J. Fox. 2018. Crediting water quality benefits from stream restoration: implementation case studies and potential for crediting guidance application. Water Research Foundation and the Center for Watershed Protection

Starr, R. and W. Harman. 2016. Function-based stream restoration project process guidelines. CBPO-S16-03. Chesapeake Bay Field Office. U.S. Fish and Wildlife Service. Annapolis, MD.

Thompson et al. 2018. The multi-scale effects of stream restoration on water quality. *Ecological Engineering*. 124:7-18

Urban Stormwater Working Group (USWG). 2014. Final recommended guidance for verification of urban stormwater BMPs. Chesapeake Bay Program (CBP) Partnership. Annapolis, MD.

USWG. 2016. Process for Handling Urban BMP Decision Requests. USWG Memo Approved February 2016.

USWG. 2018. Formation of technical groups to improve stream restoration protocols. Memo approved September 28, 2018 by USWG and Stream Health Work Group

Urban Stream Restoration Expert Panel (USR EP, 2013). Recommendations of the Expert Panel to Define Removal Rates for Individual Urban Stream Restoration Practices. Approved by the CBP WQGIT. March 2013.

Walter, R., D. Merritts, and M. Rahnis. 2007. Estimating volume, nutrient content, and rates of stream bank erosion of legacy sediment in the piedmont and valley and ridge physiographic provinces, southeastern and central, PA. A report to the Pennsylvania Department of Environmental Protection.

Water Quality Goal Implementation Team (WQGIT). 2016. Revised protocol for the development, review and approval of loading and effectiveness estimates for nutrient and sediment controls in the Chesapeake Bay Watershed Model. US EPA Chesapeake Bay Program. Annapolis, MD.

Weil, R. and N. Brady. 2016. *The Nature and Properties of Soils*. Pearson; 15th edition.

Wood, D., L. Fraley-McNeal and B. Stack. 2018. Frequently Asked Questions: Urban Stream Restoration BMP. Approved by Urban Stormwater Work Group in February 2018. Chesapeake Bay Program Office.

Section 10 Glossary

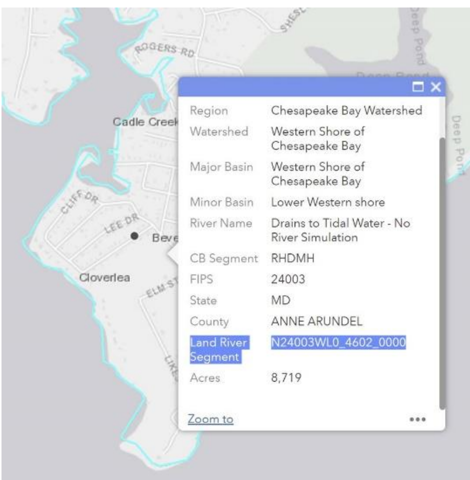
Glossary of Engineering Terms	
Term	*Description*
Channel bottom width	Width of the channel at the downstream section.
Critical shear stress	The minimum amount of shear stress exerted by stream currents or erosive forces to initiate soil particle motion or erosion. *See shear stress*
Hydraulic radius	The ratio of the cross-sectional area of a channel or pipe in which a fluid is flowing to the wetted perimeter of the conduit.
Internal friction angle (of soil)	The ability of a unit of rock or soil to withstand shear stress; the measure of shear strength of soils due to friction. The internal friction angles for different soil particles or soil types are available in technical reference sources, e.g., NRCS (2007), Technical Supplement 14A.
Kinematic viscosity	The ratio between the dynamic viscosity and the density of a fluid, often expressed in m^2/s or Stoke (St) units.
Particle settling velocity	Basically, the rate at which a particle will settle downward in a fluid (water) under gravity. Expressed in units of velocity, e.g., meters per second (m/s).
Particle size (or grain size)	Diameter or a soil particle (or grain of soil material).
Particle size distribution	The amounts of the various soil separates (silt, clay, sand) in a soil sample, usually expressed as weight percentages (Weil and Brady, 15th ed.). The distribution can be determined through particle size analysis. The median particle size (D_{50}) is the midpoint of the distribution.
Slope stability	The potential of soil-covered slopes to withstand and undergo movement, i.e. the resistance of an inclined surface to failure by sliding or collapsing. Stability is determined by the balance of shear stress and shear strength.
Shear strength	The capacity of an object or surface to resist shear.
Shear stress	The force acting on an object or surface parallel to the slope or plane in which that object or surface lies; this force produces shear. Represented by Greek character τ (tau) and typically expressed in Pascal units (Pa).

Soil consistence	Combination of soil properties that determine its resistance to crushing and its ability to be molded or changed in shape. Terms such as loose, friable, firm, soft, plastic and sticky are used to describe soil consistence. (Weil and Brady, 15^{th} ed.)
Soil plasticity	A plastic soil is capable of being molded or deformed continuously and permanently, by relatively moderate pressure, into various shapes. (Weil and Brady, 15^{th} ed.) Soil plasticity is measured by the plasticity index (PI) of a soil. The PI is the difference between the liquid limit and plastic limit of a soil. Soils with a high PI tend to be clay; those with lower PI tend to be silt. Soils with PI <7 are considered slightly plastic; PI between 7 and 17 is considered medium plastic; PI >17 is highly plastic.

Appendix A: Three Step Method

Step 1: Determine the total load reduction from the protocols.

Step 2: Visit https://gis.chesapeakebay.net/mpa/scenarioviewer/, and enter the nearest physical address or the practice. Once entered, click the identify button on the upper-left-hand corner of the screen, and click on the land surrounding your physical address. This will open a window that contains the land-river segment within which your practice is located. See highlighted land-river segment in screen shot included below.



Step 3: Download CAST Source Data at https://s3.amazonaws.com/cast-reports.chesapeakebay.net/public/SourceData.xlsx, and click on the "Delivery Factors" worksheet. Once there, you can filter the spreadsheet for your land-river segment and you load source. In the case of stream restoration, your load source would be Stream Bed and Bank. See the screen shot below. Here, I have a delivery factor from the stream to the river for sediment of 0.44 and from the river to the Bay of 1. Multiply those two factors together to determine a combined delivery factor from the stream to the Bay of 0.44.

LandRiverSegment	LoadSource	Lan	Lan	L	StreamToRiver_TN_Factor	StreamToRiver_TP_Factor	StreamToRiver_SED_Factor	RiverToBay_TN_Factor	RiverToBay_TP_Factor	RiverToBay_SED_Factor
N24003WL0_4602_0000	Stream Bed and Bank				0.88	0.74	0.44	1.00	1.00	1.00

Step 4: Multiply reduction found in Step 1 by combined delivery factor found in Step 3 to determine pounds of sediment reduced to the Bay from your stream restoration project.

Example:
Step 1: Edge-of-Stream Reduction = 1,000 lbs sediment
Step 2: BMP located within LRSEG N24003WL0_4602_0000
Step 3: Combined Delivery factor = 0.44 X 1.0 = 0.44
Step 4: Edge-of-Tide Reduction = 1,000 lbs sediment X 0.44 = 440 lbs sediment

Appendix B: Examples of Projects from MDOT SHA

Appendix C. Guidance for Screening Potential ORP Sites