Introduction to the Clean Water Optimization Tool: Calculate Pollutant Removal Capabilities and Costs of Stormwater Best Management Practices

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Abstract

The Center for Watershed Protection, Inc. developed a cost-optimization tool for stormwater management practices associated with reducing nitrogen, phosphorus, and sediment in the Chesapeake Bay. This planning-level tool will help communities struggling with identification and selection of cost-effective best management practices and provide them with initial guidance, as well as side-by-side comparisons for cost per unit of pollutant reduction strategies. Inputs are largely user customizable and results are geographically tailored. Several case studies are summarized and show the potential for substantial cost savings on pollutant reduction (sometimes more than 50%) when the most cost-effective practices are implemented to the maximum extent practical.

Introduction

Although the Chesapeake Bay is heralded as a national treasure, pollution from various sources still plagues the Bay, and years of action to protect and restore it have not yet yielded the desired results. In response to pressure for more effective measures to meet the total maximum daily load (TMDL) for nutrients and sediment, state-wide Watershed Implementation Plans (WIPs) (EPA n.d.) were developed to determine specific actions and the corollary costs and pollution-reduction potentials of these actions. For many communities that developed their WIPs without the benefit of a tool incorporating practice cost-effectiveness, the resulting cost estimates for the WIPs were enormous and raised questions about the utility and implementation capability of the WIPs. The Center for Watershed Protection, Inc. developed the Clean Water Optimization Tool (CWOT) (Center for Watershed Protection, Inc. 2015) as a publicly accessible tool for communities to enter various best management practices (BMPs) into different scenarios and visualize output in terms of nitrogen, phosphorous, and total suspended solids, along with the associated implementation costs.

The CWOT is a free, publicly accessible spreadsheet that incorporates a full range of BMPs, including those for which credits are not yet available through the U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program (CBP). Some of the unique features of the tool include (1) adjustments for different geographic regions; (2) optional user inputs for BMP costs, reduction goals, and specific pollutants to consider; and (3) inclusion of nontraditional BMPs such as ditch enhancements, urban cover crops, soil augmentation, pet waste programs, outfall netting systems, and other user-defined BMPs. Additionally, the CWOT offers preset data, but most options can be customized by the user.

Those familiar with the Center's Watershed Treatment Model (WTM) (Center for Watershed Protection, Inc. n.d.) may ask if this is just an update to the WTM or whether there really is some difference between WTM and the CWOT. The CWOT offers different scale options (Municipal Separate Storm Sewer System, watershed or county-level) and incorporates cost data, whereas the WTM is more appropriate for the smaller subwatershed scale and community use. Practitioners may find that using both models can help refine and/or broaden the appropriate scale at which they are estimating the effectiveness of various practices. Also, the WTM could be used as a follow up to the planning level results of the CWOT.

Utility of the CWOT

The Chesapeake Assessment Scenario Tool (CAST) (including the Maryland version, MAST, and the Virginia version, VAST) (Devereaux and Rigelman n.d.) was developed to "compare among scenarios to select the practices that reduce the most pollution, are most cost-effective, and target these practices to the highest impact areas," (Devereaux and Rigelman n.d.). This model is generally used for official record-keeping across the different waste load sectors (e.g., agriculture, septic, urban) by Chesapeake Bay jurisdictions. The CWOT is not intended to replace the CAST family;

rather, it should be seen as a potential precursor planning tool focusing on urban or urban transitional stormwater. The tool offers the opportunity to add location-specific cost data "on the fly" and plan for future BMP implementation using practices not yet approved by the CBP while using the latest information from the EPA CBP BMP expert panel recommendations. The tool also lets the user quickly test "what-if" scenarios, which may allow synergy between stormwater management and other green infrastructure or habitat-related programs.

The CWOT compares the suite of urban practices on the basis of dollars per pound of pollutant removed, which for most BMPs is calculated using the estimated cost and pollutant removal per runoff equivalent impervious acre (i.e. 1.00 acre of urban pervious may count for 0.22 acres of urban impervious in terms of runoff volume)[1]. This is a strength because costs can be substantially higher when one factors in the need to hydraulically treat runoff from both impervious and pervious cover. The preset cost data are presented as an average annual cost per unit treated and include maintenance, design, and construction costs amortized over a default of 20 years (based on King and Hagan 2011). However, the user can change the cost data to be more representative of local conditions, as well as the amortization planning timeline. The optimization routine assures that the least expensive practices (in terms of cost per unit of reduction) will be maximized to the extent practical, based on user estimates of available land on which to install BMPs.

The CWOT generates county- or watershed-wide strategies for pollution removal, compares BMPs on the basis of cost-effectiveness, and tracks progress toward water quality goals as actions are implemented. By estimating both pollutant removal and costs, the user can focus on specific pollutants of concern or specific budgetary requirements—both essential in the world of regulatory mandates.
Currently, the CWOT incorporates Chesapeake Bay guidelines for counties within Maryland. In addition to the specific county of interest, the user must enter the WIP milestone year (2017 or 2025) to populate predefined reduction goals (Figure 1). If

[1] English units are used in association with this work, as they are the customary tracking and reporting units in this subject.

developing a scenario for a town or a watershed, the user can enter custom reduction goals, which are used in the optimization routine. To facilitate the BMP selection process, a budgetary section is included on the setup page for users who are new to stormwater planning. Overall, with some developer judgment, the flexibility of the CWOT provides communities with quick and appropriate data for planning-level analysis.

Clean Water Optimization Tool Scenario Setup

Required User Input
Optional Input Cells
Results Cells

1. Community Information:

Enter the required inputs in the yellow cells below. Required pollutant load reductions for urban areas will be calculated automatically based on the County selected. Optionally, specific pollutant reductions goals may be entered in the blue cells if the scenario is being run for a municipality or at the watershed scale.

County of Interest	Allegany County
Are you an NPDES regulated community?	No
Scenario Starting Year *(Use 2009 for WIP scenarios)*	2013
Scenario Endpoint	2025

Required Pollutant Load Reductions:

Pollutant	Total County Urban Load (lbs/yr)	County Reduction Goal (lbs reduced/yr)	Reduction Goal (lbs/yr) for scale other than county
TN	76,023	8,514	
TP	23,201	3,899	
TSS	48,025,081,112	#N/A	

2. Best Management Practices:

For each BMP below, enter the maximum practical number of units that can be treated in the jurisdiction or watershed of interest.
If you do not want to include a particular BMP in the scenario, enter a ZERO in the Maximum Practical Units Treated column.
For some BMPs, you must also estimate the average percent imperviousness in the drainage area.
You may also enter the % agricultural land in the drainage area for certain BMPs if applicable. There is currenlty no mechanism for counting these reductions towards the urban sector targets but the Tool will track these reductions separately so that opportunities to receive credit or trade with other sectors can be further explored.
See the User Guide for instructions on deriving estimates of maximum practical number of units and impervious area treated.

****Not sure where to begin? Try this.****
Enter your budget for stormwater BMP implementation: ______ per year *Select Nutrient:* TN

Figure 1. Screen shot of the CWOT Setup Sheet where the user enters a county, custom reduction goals, and, optionally, an annual stormwater budget.

A Word About BMPs Not Yet Approved By EPA CBP

Currently, there is a list of BMPs approved by EPA CBP that can be implemented for pollutant removal credit. Innovation in stormwater treatment is occurring regularly; however, these innovative practices cannot be used for credit without review and approval by EPA CBP. Approval of BMPs by EPA CBP is conducted in several ways, but the process for approval requires documented proof of research and findings. Part of the challenge of obtaining approval is that research on some of these BMPs is very limited. For example, pet waste, seen traditionally as a nuisance issue rather than a water quality issue, lacks research on documented methods for effective abatement or removal. Although corollary research on trash documents the effectiveness of education and receptacles on trash reduction, similar research for pet waste is practically nonexistent. The lack of research may be in part a result of the social aspects of pet waste, which requires studying the behaviors of people rather than just designing a BMP.

The list of innovative practices includes more than these examples. Communities looking for credits can submit their own research on these or other practices, so long as they are backed up with scientific research and findings. Regardless of whether or not the user decides to implement not-yet-approved practices, the CWOT allows practitioners to think beyond traditional methods to determine what combination of nutrient and sediment reduction methods are most appropriate for their community. The following case studies touch on potential cost savings using new and/or evolving uncredited technologies as well as highlighting some of the challenges a few Maryland counties are facing.

A Summary of the Case Studies

The Center for Watershed Protection, Inc. used CWOT in a number of case studies throughout Maryland, including in Kent, Queen Anne's, Talbot, and Wicomico counties, all fairly rural areas. An earlier version of the tool was also applied in the City of Richmond, VA. Case studies consistently showed that these communities could reduce WIP costs from 25%–67% compared to the cost estimate of the original WIPs developed for these same jurisdictions (see the case study series associated with the Center for Watershed Protection, Inc. (2015) for specific information on the four Maryland communities). Of course, an important disclaimer needs to be added here—each case study took a different approach to produce the end number: the total cost to the community of meeting its pollutant reduction targets. For most of these communities, application of the CWOT included use of practices that are not currently approved for nutrient and sediment reduction credits in their WIP portfolio.

Kent, Queen Anne's, Talbot, and Wicomico counties are predominantly agricultural communities located on Maryland's Eastern Shore. The estimated cost of fully implementing the county WIPs as they were originally developed are presented in Table 1. These costs were estimated using the CWOT because, despite the fact that some counties provided cost estimates for their WIPs, significant changes in the CBP crediting protocols have been made since WIP development, which require standardization to compare results to those of the cost-optimized scenarios developed with the CWOT. Information for each WIP was queried from available documents (Maryland Department of the Environment 2012) and modified, where needed, to make them current. Table 1 also presents the results of the cost-optimized scenarios developed using the CWOT. As noted below in Table 1, in two cases the 2025 nutrient load goals were not met. This is important to note when comparing the costs of WIP versus cost-optimized scenarios for these counties. The primary reason for not meeting the nutrient load goals was the limited amount of publicly owned urban land on which to install practices. The annual county budget shown in Table 1 was based largely on public works department budgets or through publicly available information, as there is rarely a stormwater-specific budget for these rural jurisdictions.

Table 1. Costs associated with stormwater management to achieve pollution reduction goals (adapted from Center for Watershed Protection, Inc. 2015). The annual county stormwater budget is largely based on estimated budgets for public works departments.

County	Annual County Stormwater Budget	WIP BMPs via CWOT	Cost-Optimized BMPs
Kent*	N/A	N/A	$4.7 million/year
Queen Anne's*	$150,000	$42.8 million/year	$8.2 million/year
Talbot	$380,000	$44 million/year	$18.4 million/year
Wicomico	$200,000	$57.9 million/year	$27.3 million/year

*The scenarios developed for these counties did not meet the pollution reduction goals.

The nutrient load assigned to the stormwater sector of each county and the respective stormwater nutrient reduction goals are presented in Table 2. Reduction goals were calculated based on the Maryland BAYSTAT (n.d.) stormwater loads reported in 2013. For analysis purposes, nitrogen was the pollutant chosen for optimization. Table 2 also shows the county-specific findings of the CWOT case studies. In Kent County and Queen Anne's County, nitrogen reduction goals were not met with the CWOT scenario because of the limited public space to implement BMPs, as well as some discrepancies between WIP assumptions and real-world measurements (e.g., 6,831 acres of urban filtering practices were called out in the Queen Anne's County WIP, but this area is greater than the total impervious cover in the entire county). These counties will need to conduct on-the-ground assessments to further refine their estimates of feasible locations to install BMPs and may wish to further explore their options for accessing private lands to install BMPs and for cross-sector nutrient trading. In some cases, to achieve the required reductions for nitrogen, the county scenarios exceeded the phosphorus reduction goals. It should also be noted the reductions shown in Table 2 are associated with the cost-optimized BMP scenarios presented in Table 1. The target loads shown in Table 2 were provided by EPA CBP to the counties, and—as with all TMDLs—the reduction goals were derived by subtracting this target load from the current modeled pollutant load from the county.

Table 2. Maximum pollution target loads to meet the Chesapeake Bay TMDL, reduction goals by county (Maryland BAYSTAT n.d.), and portion of reduction met with CWOT scenarios.

County	Nitrogen			Phosphorus		
	Current Chesapeake Bay TMDL Target Load (lbs/yr)	WIP Reduction Goal (lbs/yr)	% of Reductions Met by CWOT	Current Chesapeake Bay TMDL Target Load (lbs/yr)	WIP Reduction Goal (lbs/yr)	% of Reductions Met by CWOT
Kent	73,920	41,066	14.0%	3,455	2,444	28.0%
Queen Anne's	132,484	62,984	26.3%	6,786	3,412	213.2%
Talbot	126,792	68,667	100.1%	6,119	4,234	294.8%
Wicomico	206,105	52,340	101.0%	11,122	4,677	213.0%

Although potential significant cost reductions might be realized when compared to the original WIP estimates in each of the counties, the costs to achieve reduction goals were still far in excess of estimated county budgets. Unlike highly urban areas, the drivers to implement these practices are largely absent in these communities. Although water quality trading is a feature of the tool, it was not used as a primary offset technique, as the future of trading programs and potential ramifications is not fully understood in the state at this time. Financing options for these communities may be part of the solution, but without a dedicated source of funding, achieving these goals is a continuing challenge.

There is additional potential to further reduce costs by developing standard designs (i.e., efficiency through standardization) for those BMPs that might be broadly implemented in the Maryland Eastern Shore counties. For example, implementing a retrofit in ditches along county roads (Figure 2) may provide opportunities to achieve pollutant reduction goals because of the sheer number of miles available for practice implementation. Taking advantage of even moderate efficiencies in a case like this could allow for substantial savings.

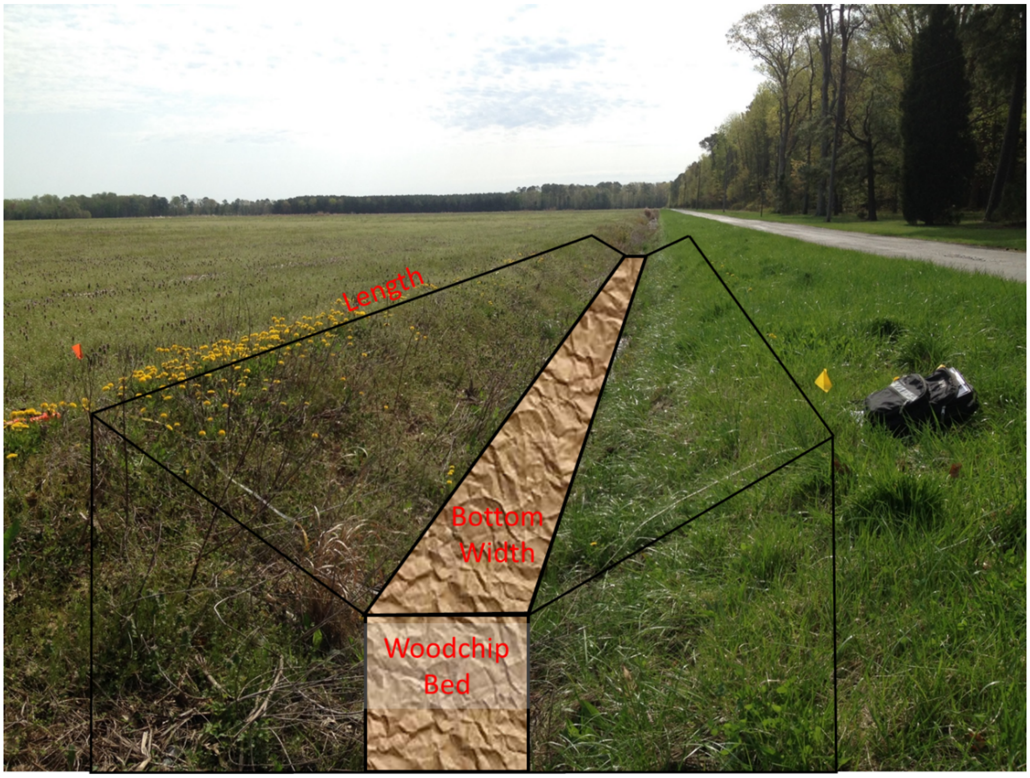

Figure 2. Potential to use woodchips to provide denitrification in ditches with minimal grade or with periodic connection to shallow groundwater.

This need for increasing cost-effectiveness is what the CWOT attempts to address. A separate cost-effectiveness analysis for the City of Richmond, VA showed substantially reduced costs for pollutant load reduction when focusing on the most cost-effective practices (Center for Watershed Protection, Inc. 2013). When rated by cost-effectiveness according to the three pollutants of concern in the Chesapeake Bay—nitrogen, phosphorus, and sediment—the results were surprising. Pet waste programs, sewer repairs, elimination of cross-connections, forest buffers, urban stream restoration, urban growth reduction, and vegetated open channels were among the most cost-effective practices (Table 3). Though these are not all creditable under the Chesapeake Bay TMDL (or credits may have changed since the publication of this work), this may change in the future. Additionally, nutrient reductions may be applicable (creditable) for local TMDLs or other water quality efforts. Table 3 provides a summary of these practices and how they ranked relative to the pollutants of concern.

Table 3. Top three BMPs by pollutant and cost-effectiveness in the James River Basin (adapted from Center for Watershed Protection, Inc. 2013).

Pollutant	**Most Cost-Effective BMPs for Pollutant Removal (Considering all BMPs; based on $/lb)**	**Most Cost-Effective BMPs for Pollutant Removal (Considering EPA CBP-approved BMPs only; based on $/lb)**
Total Nitrogen (TN)	1. Pet waste program 2. Sewer repair 3. Cross connection correction **Average cost = $18/pound of nitrogen removed**	1. Forest buffers 2. Urban growth reduction 3. Urban stream restoration **Average cost = $265/pound of nitrogen removed**
Total Phosphorous (TP)	1. Pet waste program 2. Sewer repair 3. Cross connection correction **Average cost = $72/pound of phosphorus removed**	1. Urban stream restoration 2. Urban growth reduction 3. Forest buffers **Average cost = $1,806/pound of phosphorus removed**
Total Suspended Solids (TSS)	1. Sewer repair 2. Urban stream restoration 3. Urban growth reduction **Average cost = $3/pound of TSS removed**	1. Urban stream restoration 2. Urban growth reduction 3. Vegetated open channels **Average cost = $4/pound of TSS removed**

Most surprisingly, the City of Richmond had estimated $305 million to meet its regulatory requirements (City of Richmond, VA 2013), but by developing different scenarios using a precursor to the CWOT, the costs were substantially reduced to as low as $62 million over 16 years (the city's analysis timeline)—an 80% reduction in cost—by focusing on the lowest cost BMPs first (Center for Watershed Protection, Inc. 2013). The lowest-cost scenarios for the City of Richmond maximized the use of the cost-effective BMPs shown in Table 3. This analysis highlights two issues: (1) There is a need for research on and approval of lower cost BMPs. (2) Sometimes thinking beyond "traditional" stormwater management practices may lead to an overall reduction in cost or greater improvements in water quality given a static budget.

The City of Richmond, with a stormwater utility budget of approximately $61 million from 2016-2020 (City of Richmond 2016-2020 Adopted Capital Improvement

Budget,
http://www.ci.richmond.va.us/Budget/documents/CapitalImprovementPlans/2016-2020_AdoptedCapitolImprovementProgram.pdf), provides a contrast to the smaller budgets of nonregulated communities that often do not have the budgets or regulatory drive to invest substantially in pollution reduction. Although the CWOT is useful for any jurisdiction conducting a gross-scale analysis of the most cost-effective practices, the Maryland case studies illustrate that when available land to install BMPs is limited, there is little room for optimization because each and every practice is needed. Accessing private lands for BMP implementation could also provide a huge cost savings to urbanized jurisdictions, which is something that the CWOT can clearly demonstrate. In both regulated and unregulated communities, a follow-up step is to perform actual site assessments for each jurisdiction to determine whether there are additional efficiencies that can be associated with their efforts.

Limitations of the CWOT

As with any tool, the CWOT has its limitations. The tool focuses solely on maximizing results within the urban sector, and the results rely heavily on user-input estimates of the maximum area that can practically be treated with BMPs. Other areas that could be further developed include agricultural BMPs and septic practices. The developers also note that preparing highly realistic scenarios is more easily done with input from stakeholders (e.g., local government employees, GIS specialists, watershed planners), as they are aware of local issues and opportunities affecting practice implementation, including community acceptance.

Future extension of the tool to include more agricultural practices is possible if the demand for this is apparent. Currently, the CWOT incorporates the treatment of agricultural runoff by urban BMPs in a simple manner that may be worth revising in the future. For example, a tally is done for those BMPs with a portion of their drainage areas in agriculture (e.g., roadside ditches where installed bioswales capture both road runoff and runoff from adjacent farms). This tally is reported at the end as potential reduction that could be sold on the water quality trading market. Note that this tally is different than the option of buying pounds of total nitrogen, total phosphorous, or total suspended solids. For buying pounds, the user must enter how much the jurisdiction is willing to pay ($/pound and total $), which is then added to the cost comparison calculations. Agricultural practices tend to be much less expensive, with the Chesapeake Bay Commission showing costs at around $140/pound of total nitrogen (after factoring in transaction and miscellaneous costs of 38%) as opposed to urban practices like bioretention, which are around $550/pound total nitrogen without transaction costs (Van Houtven et al. 2012).

Lastly, the tool focuses on pollutants and dollars but not ancillary value such as creating habitat corridors and providing social benefits. These important components can make or break a project, so some accounting of other benefits is necessary to make fully informed spending decisions.

Future of the CWOT

The Center for Watershed Protection, Inc. is in the process of making the CWOT more accessible for other states and geographic regions outside the Chesapeake Bay. The setup page and overall structure of the CWOT makes potential modifications by the user in different geographic regions feasible with some adjustments of land-use loading rates and BMP efficiencies (or efficiency calculations). The challenge will be in determining the appropriate loading rates for the impervious and pervious land cover types in other regions. As a precursor, the U.S. Geological Survey SPARROW model (2009) may be a starting point to develop relative land-use loading rates (i.e., pounds of total nitrogen per acre) for other states/regions.

Adding other research and practice elements to CWOT is also possible. For instance, some communities have used outfall downsizing (i.e., extended detention) to reduce discharge rates to mitigate stream bank erosion by providing temporary storage, and this stormwater management practice has been considered for inclusion in the tool. Further, credit for elimination of illicit discharges (sewer breaks and cross connections) (Figure 3) require pre- and post-correction monitoring data be collected to verify reduction in pollutant loads resulting from the correction; however, this makes predicting the benefits—and therefore cost-effectiveness— of these techniques difficult at this stage. That being said, the Center plans to include correction of illicit discharges as a strategy in the CWOT in the near future.

Figure 3. Illicit discharge detection in the City of Baltimore.

Conclusion

The CWOT was developed to address a gap in stormwater planning in the Chesapeake Bay watershed: the need for a tool that allows users to develop strategies that factor in both the cost and pollutant-removal effectiveness of the suite of urban practices. The CWOT goes a step further and automates the process of optimizing scenarios based on cost-effectiveness. The case study applications of the CWOT and its precursor show that—by maximizing the use of the most cost-effective BMPs and including those practices not yet approved by regulatory authorities—the costs of achieving compliance with the Bay TMDL can be reduced by at least 25% and by as much as 80%.

Another unique feature of the CWOT—the ability to base scenarios on actual estimates of available space for BMPs—ensures that the strategies are grounded in reality. This is important because in the urban landscape there is often limited space in the public sector to install practices, and site constraints such as poor soils and utility conflicts are quite common. In Kent County and Queen Anne's County, the ability to estimate the maximum practical acres treated with BMPs highlighted the difficulties of achieving such ambitious pollutant load reductions in a relatively rural area. For these communities, it will be important to refine their CWOT results in conjunction with a careful examination of other options (e.g., pollutant trading), improving technologies to increase nutrient reduction effectiveness, and/or developing programs and incentives to encourage widespread adoption of BMPs on private land. Talbot County is forging ahead with a pilot program to standardize designs for ditch retrofits, which based on their CWOT results, could further reduce annual costs by $12.4 million with the increased efficiency that comes with standardization.

Although the impetus for the CWOT was the Chesapeake Bay TMDL, its structure is flexible enough to be applied for different purposes (e.g., local TMDLs) and at different scales. With some modifications, the tool can be adapted to meet the unique requirements of a given state or region and can be populated with region-specific data. Users can optimize their experience by understanding how to use the CWOT to fit their needs.

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