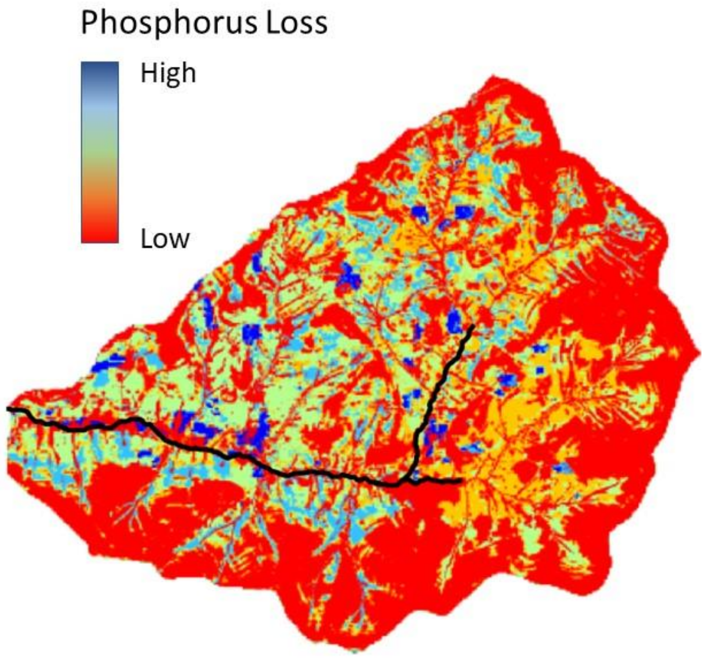
Increasing Effectiveness and Reducing the Cost of Nonpoint Source Best Management Practice (BMP) Implementation: Is Targeting the Answer?



STAC Workshop Report
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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at http://www.chesapeake.org/stac.

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Contents

Executive Summary

As the Chesapeake Bay Program (CBP) passes the mid-point assessment, major point source discharges will have achieved (or nearly achieved) their final Total Maximum Daily Load (TMDL) nitrogen (N) and phosphorus (P) waste load allocations. Jurisdictions, however, still need to achieve substantial nutrient and sediment reductions from agricultural and urban non-point sources (NPS). Based on current understanding and modeling, the CBP estimates that agriculture and urban NPS need to achieve an additional 35 million and 12 million pounds of N reductions, 1.3 and 0.6 million pounds of P reductions, and 941 and 594 million pounds of sediment, respectively to meet TMDL goals. State and local governments are poised to spend hundreds of millions of additional dollars to meet these goals, primarily by installing agricultural and urban nonpoint source best management practices (BMPs). Thus, BMP implementation stands at the center of CBP efforts to meet TMDL requirements. Yet, water quality monitoring suggests that the link between BMP implementation and load reductions is tenuous. In a recent STAC review, Keisman et al (2018) state "current research suggests that the estimated effects of conservation practices have not been linked to water quality improvements in most streams." The Chesapeake Bay Watershed Model estimates substantial reductions in NPS loads, but monitoring data suggests little to no change in these loads between 1992-2012 (Keisman et al, 2018). A critical question is why? Potential explanatory factors include inadequate BMP coverage, poor implementation/maintenance, lag times between implementation and pollutant load reductions, pollutant transport and transformation processes that are incompletely understood, and inability to target BMPs to critical pollutant source areas. The purpose of this workshop was to make recommendations as to how the CBP can develop and integrate mechanisms to target BMPs to areas of the watershed producing disproportionate nutrient and sediment loads.

Through this report, the workshop participants make several recommendations for developing and integrating BMP targeting programs into the CBP BMP protocol. These include recommendations that the Chesapeake Bay Program partnership take measures to:

1. Improve the spatial prediction capability of the CBP TMDL accounting system by:
    a. *Develop finer scale modeling capacity to guide and inform targeting*
    b. *Continue to improve spatial resolution of datasets that drive the CBP models and increase sharing and development of remote sensing and high resolution data that can inform the location of NPS loads and BMP removal effectiveness.*
    c. *Allow for differential crediting of NPS BMPs*

2. Develop and test alternative incentive systems for targeting programs:
    a. *Develop and support small testbed watersheds to pilot and test targeting incentive designs and assessment of outcomes*
    b. *Support development and testing of nonfinancial approaches to encourage wider program participation and improved land manager identification of NPS hotspots through behavioral "nudges", communication strategies, and feedback on NPS management performance.*

Introduction and Workshop Objectives

To achieve the nutrient and sediment reduction goals of the Chesapeake Bay, jurisdictions need to reduce annual pollutant loads from agriculture and urban non-point sources (NPS) by an additional 35 million and 12 million pounds of nitrogen (N), 1.3 and 0.6 million pounds of phosphorus (P), and 941 and 594 million pounds of sediment, respectively to meet the Total Maximum Daily Load (TMDL) goals. These load reductions must come largely from agricultural and urban nonpoint sources. State and local governments primarily rely on the installation of best management practices (BMPs) to achieve these reductions. This workshop, organized by the Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program (CBP), focused on developing mechanisms (both technical and policy) to target BMPs to areas of the landscape producing disproportionate nutrient and sediment loads.

The CBP utilizes a partnership-approved expert panel process for estimating the nitrogen, phosphorus, and sediment reduction effectiveness of nonpoint source BMPs. In the process, panels of experts review scientific evidence and provide point estimates of the nutrient and sediment removal effectiveness for individual BMPs. For most BMPs, nutrient reductions are estimated by applying removal efficiencies to load estimates from land uses within a land-river segment (approximately 100 km^2) These estimates are used in different ways; the CBP uses them in modeling efforts to track progress toward meeting water quality objectives, and state and local governments use them to calculate progress toward meeting TMDL requirements. From a policy perspective, states generally encourage the voluntary adoption of BMPs based on state and/or federal cost-sharing, which pays a portion of BMP installation costs.

Opportunities exist to improve the performance and cost-effectiveness of nonpoint source management by targeting BMPs in high nutrient and sediment loss areas. Many studies suggest that between 5-20% of the land area generates 50-90% or more of runoff and nonpoint source loads, particularly for pollutants such as phosphorus and sediment (Heathwaite et al. 2000; White et al. 2009; Qui, 2009; Wagena and Easton, 2018; Rao et al. 2009; Yu et al. 2019). Within fields, nutrient losses may be confined to relatively small areas (Easton et al. 2008), that with the correct targeting and incentives may be easily treated. Numerous studies have found that targeting BMPs to sites with higher pollution potential can improve cost effectiveness of pollution reduction efforts (Khanna et al. 2003; Yang and Weersink 2004; Giri et al. 2012; Xu et al. 2019). Studies have shown that targeting BMPs or a land retirement payment scheme using flow paths, specifically identified sub-catchments, soil erodibility, or other land and soil characteristics as criteria instead of applying BMPs randomly or uniformly can reduce costs of meeting a given water quality goal (Yang and Weersink 2004). Multiple policy designs could be pursued to better target cost effective nonpoint source reduction investments, each with different strengths and limitations (Ribaudo 2015).

Currently, the CBP has limited capacity for finer scale BMP targeting in its modeling and management frameworks. However, BMP targeting has important implications for the cost and risk of achieving water quality goals; and the CBP conducts reviews of its modeling policy allowing for the inclusion of emerging scientific understanding and providing the opportunity to potentially incorporate CBP targeting. Within this context, the workshop had four goals:

1) Review effectiveness of existing BMP implementation practices to produce observed improvements in water quality in programs
2) Review the evidence of effectiveness of targeting to improve water quality outcomes and lower costs (both modelled and measured outcomes), e.g. to what degree can targeting incrementally move the needle and buy more reductions with the same fixed budget
3) Identify the approaches to targeting (conceptually and program implementation) including incentives and barriers.
4) Apply targeting approaches to the Chesapeake Bay.
    a. Near and long-term recommendations for improving water quality response to BMPs
    b. What is required from CBP to accomplish this with respect to both policy and modeling

Workshop Summary

Workshop participants (Appendix B) included experts on the CBP BMP process, CBP BMP modeling tools, Watershed Implementation Plans (WIP), BMP implementation, risk and uncertainty modeling, and policy design.

On the morning of the first day, workshop participants were provided a brief overview of the workshop objectives, a summary of existing NPS control efforts in the CBP, salient points from the targeting synthesis (Appendix C), and an overview of the CBP Watershed Model and how it currently handles BMPs. These three presentations were provided to ensure all participants understood the current state of BMP targeting in the CBP and set the stage for discussions and recommendations. Workshop participants were then provided information on three pilot programs that employed BMP targeting to improve water quality outcomes. A brief synopsis of these presentations is provided below.

Overview of NPS Control Efforts in the CBP—James Davis-Martin (VA DEQ)

James Davis-Martin summarized the current and historic state of the TMDL and WIP processes. He noted that approximately 82% of all needed nutrient reductions are allocated to the agricultural sector. This allocation presents both opportunities, because treating agricultural NPS pollution is far less expensive than Wastewater Treatment Plant (WWTP) upgrades or urban BMPs, and barriers, because implementation of agricultural BMPs is voluntary. However, he was optimistic that by targeting, implementation costs may be reduced because practices would be concentrated in high risk areas, requiring fewer practices overall and less administration to implement. Davis-Martin presented that in addition to evaluating targeting efforts on cost effectiveness and water quality improvements, the co-benefits of practices for human and environmental health should be considered to increase participation.

Salient Points from Synthesis — Kurt Stephenson (VT), Zach Easton (VT)

Kurt Stephenson and Zach Easton presented an overview of relevant points from the targeting synthesis document produced by the steering committee and shared with workshop participants prior to the workshop. They began by reviewing a schematic of the CB system and causal linkages, in particular, where and how BMPs interact with various system components (Figure 1). Effective targeting of nonpoint source investments requires identifying the appropriate location (source of nutrients), people (land managers responsible for nutrient-related decisions) and treatment options (reduce nutrients). Key points from the presentation included

1. The impact of funding constraints; absent significant new funding, the only mechanism to increase reductions in NPS pollution is to get more NPS reductions per dollar expended,
2. There is a tremendous amount of variability in NPS load generation across the landscape, and thus BMP effectiveness will vary across the landscape,
3. The scale at which these variations occur is critical to capture in order to design effective NPS control measures,
4. Land managers tasked with implementing BMPs vary in their attitudes, abilities and willingness to adopt BMPs, and
5. Multiple incentive designs exist to motivate land managers to identify and treat NPS losses.

Presenters also noted that targeting of BMPs will differ based on the pollutant of concern and the pollutants fate and transport characteristics. For instance, P and sediment tend to be mobilized and transported via surface flow paths, while N moves via mix of surface and subsurface pathways, with subsurface flow being more difficult to treat with BMPs. For surface flow pathway pollutants, flow connectivity or terrain models (that incorporate landscape connectivity, hydrologic distance, and soil depth) can identify hydrologically sensitive areas, and when intersected with land use can provide estimates of where critical pollutant source areas occur. For groundwater pathway pollutants, identifying where recharge areas occur (perhaps from soil drainage class and restricting capacity, or geomorphic surveys) and intersecting these with land use data can provide an estimate of where critical pollutant source areas occur. BMPs that are appropriate for treating surface or subsurface pathways differ as well; subsurface flow paths may be more responsive to BMPs that reduce the source of the nutrient entering the system (e.g., nutrient management plans, or cover crops) or those that enhance natural attenuation (e.g., denitrifying bioreactors), while surface flow paths may be better treated by BMPs that can both reduce the source (e.g., nutrient management plans, cover crops), and reduce the mobilization and/or transport of the pollutant (e.g., no-till, riparian buffers). Participants discussed multiple tools that could be used in a targeting program, including process-based models, indexes, remotely sensed data, and/or physical measurements/indicators.

Easton and Stephenson discussed incentive structures, means of engaging more landowners, and information needed to encourage effective targeting of NPS management actions. Similar to the variation in the landscape, land managers exhibit significant variation in attitudes, motivations, and behavior related to conservation decision-making. BMP targeting incentive systems designs must address what actions or outcomes are incentivized, what type and level of financial reward for NPS reductions are used. Various pilot programs around the country have experimented with creating financial incentives that reward land managers for improvements in outcomes (e.g. pollutant removal) rather than (or in addition to) payment to install practices. A key question is what measure of ‘performance’ to use. Options include modeled pounds of reduction achieved, observable indirect indicators of nutrient reduction (e.g., change in soil P levels), or ambient outcomes (see discussion below). Such targeting programs alter the type and level of technical support needed to support land manager decision-making.

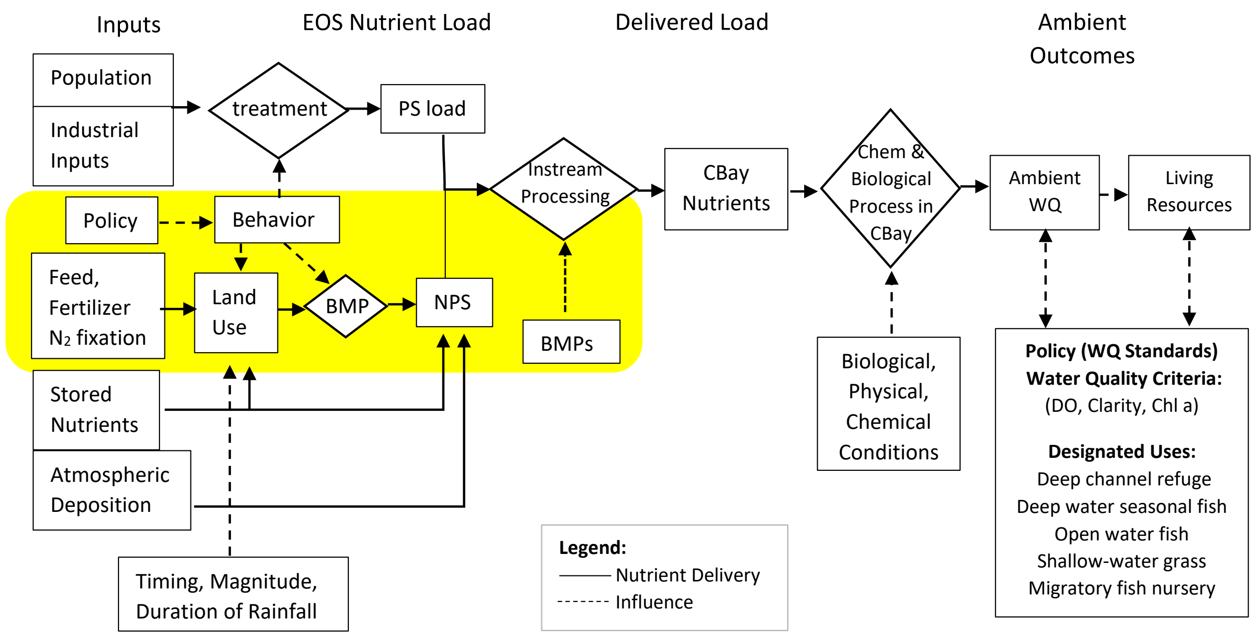

Figure 1. CB system and causal linkages between components. Highlighted in yellow is how BMPs interact with the system.

Overview of CBP Watershed Model — Gary Shenk (USGS CBP)

Gary Shenk presented an overview of the CBP structure, the current structure of the CBP Phase 6 Watershed Model and Chesapeake Assessment Scenario Tool (CAST), and how the model is used to track TMDL progress. He started by explaining how the nutrient and sediment allocations are made at the state-basin level (major river basin located within each state), followed by the current guidelines used for determining planning targets, which states that those areas (at the land-river segment level) that have more impact on bay water quality must do more at the jurisdictional level to improve water quality. He then discussed how CAST is used in the planning process to develop and analyze BMP scenarios and to document and track jurisdictions' progress towards their WIPs.

Innovative Pilot Programs

Jonathan Winsten (Winrock): Pay for performance programs

Jonathan Winsten began by contrasting typical BMP cost share programs i.e., 'pay-for-practice' vs 'pay-for-performance' programs. Pay-for-performance programs pay landowners to achieve quantified nutrient/sediment reductions, as opposed to paying cost share for a BMP to be installed (pay-for-practice). Winsten recommended that pay-for-performance programs should model nutrient load reductions at the farm level and measure ambient outcomes at the watershed level. Incentive payments have been designed for both levels: compensation paid based on $/lb of modeled pollutant reductions and secondary bonus incentive payments for achieving specific observable outcome/thresholds. Since farm-level models incorporate field specific information, landowners are incentivized to select and site BMPs in areas that generate the greatest reduction per dollar (based on the modeled BMP performance), increasing program cost effectiveness. Thus, the pay-for-performance system necessarily incorporates outcome-based incentives, paying for estimated NPS reductions rather than the installation of practices. He provided several examples of pilot pay-for-performance programs in Iowa, Vermont, Wisconsin, and Ohio. To highlight the importance of being able to identify and select cost effective BMP investments, Winsten presented case study evidence of the large range in unit costs ($/lb) to achieve reductions (modeled) within even small watersheds. Winsten also noted that soliciting enough participation to achieve overall target reductions can be challenging in any voluntary program, regardless of incentive. However, the pay-for-performance system represents a method to bring in a group of farmers and landowners who are concerned about getting feedback on the outcomes of their efforts. More information on Winrock's pay-for-performance program can be found at https://www.winrock.org/wp-content/uploads/2016/02/PfP-How-To-Guide-Final.pdf.

Joe Sweeney (Water Science Institute): Identification of stream bank erosion hot spots

Joe Sweeney discussed identifying legacy sediment impairments that result from a history of mill dams or other stream obstructions. Using change detection via digital elevation model (DEM) or point cloud differencing, streambank erosion hot spots are identified where wetland and stream restoration opportunities may be prioritized. Sweeney described how a combination of remote sensing, including drone photogrammetry and high-resolution data (LiDAR) analyses are utilized to develop heatmaps of stream and near stream areas with the disproportionate potential to contribute sediment to reaches. Analytical results indicated that treating stream reaches with large legacy sediment loads through integrated stream and wetland restoration was far more cost-effective ($/lb reduction) than typical BMPs (i.e.g., riparian buffers and cover crops) for phosphorus and sediment and had a similar cost-effectiveness for nitrogen. Based on the LiDAR differencing measurement technologies highlighted, 18 legacy sediment stream bank erosion hot spots identified in the Mill Creek watershed in Lancaster County, PA, contribute the equivalent sediment load as 9,500 acres cropland according to CAST. Treatment of these sediment hotspots with restoration would reduce loads equivalent to approximately 4,800 acres of forested riparian buffer plantings and at substantially lower annual costs. In addition, similar treatment of the 18 hotspots would reduce loads equivalent to ~99 acres of traditional wetland restoration at a substantially lower cost. More information on the Water Science Institute (WSI) applied technologies to identify and target legacy sediment hotspots can be found at www.waterscienceinstitute.org. Allyson Gibson, director of the Lancaster Clean Water partners discussed how the WSI data was incorporated into the Partners Collaborative Watershed Mapping Tool developed by the Chesapeake Conservancy. The tool allows partners and other watershed organizations to target priority sub watersheds through an app that incorporates national, regional, and local data.

Alan Collins (WVU): Payment by distribution of source areas

Alan Collins described a pilot program that paid a group of landowners based on prior ambient nitrate concentrations in a small West Virginia watershed (Cullers Run). The decision of landowners to join the group was voluntary. Group participants were responsible for determining how funds provided to the group were spent on BMPs to improve water quality (reduce N) and distributed among group members. Group members decided that performing a series of watershed-wide sampling campaigns was warranted to assist in identifying areas contributing disproportionate N loads. This sampling effort identified a distinct location in the watershed where instream nitrate concentrations spiked. Collins described how the group members helped persuade the farmer with land delivering the high N load to allow construction of a constructed wetland to intercept the high N load. This single action ultimately resulted in a 17% decrease in growing season N concentrations in the stream.

Barriers and Opportunities

On the afternoon of day one, technical and policy issues related to BMP targeting were discussed by a panel of experts, who were tasked with responding to and expanding on several questions developed by the workshop committee:

1. What was the most compelling outcome (positive or negative) that has been achieved in a targeting-like NPS effort?
    a. The pay for performance program was able to motivate farmers, and also bring in a new group of farmers. The monitoring/modeling tools served also as a form of outreach (Winsten).
    b. Unlike some other examples of pilot programs, the pay for services program in Florida continues to operate. One of the reasons is that there is an active buyer (water management district) willing to purchase water retention (Shabman).
2. What were the most important changes from conventional programs you were able to make (or observed others making)?
    a. The pay for performance program in Florida does not measure performance/service provision directly but is able to verify contract compliance through the use of stage recorders and occasional farm visits. Contract compliance is tied (closely enough to) service provision that buyers find credible. Change was facilitated by having a buyer initially interested in payment for outcomes (Shabman).
    b. In pay for performance programs, landowner motivation matters – 'productivist' vs. 'conservationist. (Ribaudo). Information (nutrient loss reduction estimates, costs, and profit/loss margins) is critical to support farmer decision making on appropriate NPS reduction strategies (Winsten).
3. What are the top two or three barriers in improving effectiveness and cost effectiveness of outcomes?
    a. More water quality monitoring is needed (Winsten). Monitoring should be done more frequently and with finer spatial resolution, before and after BMP implementation, even at the cost of accuracy or precision (e.g., perhaps by harnessing citizen science-based principles) (Shabman).
    b. Shabman noted numerous challenges and barriers to implementation that were often not technical but institutional in nature (e.g., existing administrative procurement procedures) and creating a viable and sustainable competitive bidding process that allows suppliers to compete on price (i.e., low bids)
    c. Tradeoff between certainty of payment and uncertainty of environmental result (Winsten).

4. What emerging developments/tools/policies are out there that offer the biggest opportunities for improving NPS targeting program efforts?
    a. Remote sensing data and other emerging tools to monitor or measure performance/service provision present a new opportunity for NPS targeting efforts. This includes indirect measures that can be collected at a landscape scale at a lower cost than in-stream monitoring, as long as these indirect measures are tied (closely enough to) service provision to be credible for buyers or other agencies interested in monitoring performance. Examples of these indirect measures include change detection (DEM or point cloud differencing) for stream bank loss, soil P levels, and/or tissue nutrient tests. For nitrate, robust portable optical sensors can be used either for continuous monitoring at fixed sites, or for rapid spatial surveys to locate source areas within small watersheds.

Day one concluded with breakout groups identifying barriers and opportunities for incorporating BMP targeting mechanisms into the CBP. Participants self-selected into a breakout group discussing policy and adoption issues, or a group discussing technical and modeling issues, after which participants regrouped and synthesized results:

1. Opportunities
    a. More effective communication about sources and variation in loads
    b. More use/novel use of existing data
    c. Refined monitoring
    d. Creating space to test incentive designs
    e. Incentivize group achievement: more competition, including ‘peer pressure’ on less compliant members, and performance based metrics for compensation
    f. Use of proxy models, indirect measurements, or indices for hotspots identification
2. Barriers
    a. Recognition of disproportionate loads
    b. Any new tools need to be consistent with CAST
    c. Measuring success/lack of monitoring at the scale needed
    d. Lack of flexibility in BMP implementation
    e. Uncertainty in hydrologic response and BMP performance
    f. Nutrient mass imbalances in areas of the watershed that cannot be fixed with traditional BMP application
    g. Equity and fairness considerations
    h. Time frame for implementation (e.g., 5 years to meet TMDL targets)
    i. Inherent difficulty of detecting post-BMP trends in highly variable monitoring data.

Workshop participants were instructed to keep these points in mind for day-two as the workshop moved into developing recommendations.

Day-two began by summarizing the discussion from day-one and gauging the level of agreement among attendees on the potential of BMP targeting to improve nonpoint source program outcomes. An initial set of four workshop premises were presented to the group. Workshop attendees were asked whether they “agreed”, “could live with”, or “disagreed” with each statement. Each statement was discussed and debated. Statements were edited for clarity and to generate broader agreement. The following statements were produced in which no participant “disagreed,” and a majority of the group agreed.

1. There are opportunities to increase the amount of NPS reductions we can achieve for every dollar spent.
2. There is recognition that some areas produce disproportionate NPS loads and that BMP effectiveness varies across the landscape.
3. Methods for identifying spatial variation in pollutant source areas and BMP effectiveness will increase the effectiveness of programs.
4. Increasing flexibility in how we incentivize land managers (e.g., cost share for practice versus pay for outcomes) can improve NPS program effectiveness (more load reduction per program dollar spent, less uncertainty).

The remainder of day-two was spent in breakout groups and whole group discussion to develop recommendations on improving BMP targeting in the CBP. The following are the recommendations that emerged from the workshop.

Recommendations from the BMP Targeting Workshop

1. Improve the spatial prediction capability of the CBP TMDL accounting system

To encourage improvements in nonpoint source targeting, the CBP should explore and develop opportunities and options for the identification and recognition of treatment of high loss areas. While the CBP program already recognizes that certain areas (land river segments) produce differential loads, other options (see discussion below) exist for more spatially refined identification of high loss areas and differential treatment effectiveness of those areas. Furthermore, to encourage further targeting NPS investments, the CBP should also explore different ways jurisdiction and implementation partners can be credited with reductions in high loss areas within the TMDL accounting framework. Recommendations and suggestions for how this can be accomplished is described below.

a. *Develop finer scale modeling capacity to guide and inform BMP targeting*

Development of finer scale modeling tools to estimate effectiveness of BMPs based on spatial variation in loading and removal effectiveness.

<u>Short-term:</u>
Explore options for developing or incorporating measures for recognizing spatial variation within the existing CBP modeling framework. This could build on the indexing approach, similar to the sediment connectivity index that the CBP is already using.

Using a risk indexing approach, such as a Topographic Wetness Index/flow path model overlaid with land use and/or soils to determine areas of higher relative risk of transport may also be an option. Risk index values could then be averaged across a land-river segment, in a manner similar to the sediment connectivity index, to determine which segments pose a greater relative risk of transport. Implementers/jurisdictions could use the index values at the native sub-field resolution (perhaps 10m) to target those areas of the landscape within a land-river segment for BMP implementation.[1]

Once hotspots are identified, the most effective BMPs will need to be selected, and given that they are to be applied to areas producing disproportionate loads, design considerations may need to reflect this (e.g., some BMP designs might differ from the minimum recommended design standards). Use of local expert knowledge would be critical here.

Long-term:
Develop and evaluate finer scale models for use in BMP implementation programming. Finer scale models could allow improved targeting of cost effective BMPs at the farm scale (ex. allowing pay for performance incentives) and provide state and local implementers the ability and incentive to seek and identify high reduction opportunities.

b. Continue to improve spatial resolution of datasets that drive the CBP models, and increase sharing and development of remote sensing and other high-resolution data for determining locations of high NPS loads for BMP targeting

In particular, improve datasets related to field management, manure and fertilizer applications, geomorphology, and remote-sensing data. The CBP should support more fine-scale spatial analyses of stream concentrations, to identify local sources and/or non-sources of watershed loads. Ideally this would extend to dense sampling arrays in first and second order streams, sampled at appropriate times when major source signals are most likely to be observed (e.g., spring-time moderate base flow for nitrate, storm flow for sediment), and could include sensor deployment, sample collection and analysis, and/or visual inspection. The CBP should also recognize importance of subsurface geologic information that is not recoverable from remote sensing approaches. This can affect (1) groundwater flow paths connecting distant contaminant source areas to discharges in springs, seeps, and streams, (2) natural attenuation (reactivity) that could make some areas more or less problematic (more or less in need of BMPs), (3) 'lag times' between BMP implementation and full system response. This information will be critical to correctly identifying hotspots, siting BMPs and for CBP model development and testing

c. Allow for differential crediting of NPS BMPs

Providing differential NPS BMP crediting toward TMDL compliance can create further incentives to target high loss areas. Note that differential BMP crediting is already supported in the CBP, as cover crops have differing effectiveness across the Bay watershed, thus there are no policy impediments preventing differential crediting. Workshop participants generally agreed that short-term and long-term strategies/options are needed for recognizing the differential impact of BMP removal effectiveness across the landscape within the current TMDL accounting framework. Additional effort is needed to explore and develop these strategies/options. Note this recommendation applies to BMPs using removal efficiencies and undifferentiated load removal estimates. For some BMPs, differential removal effectiveness is reflected in options for measured load estimates (oysters, manure conversion, etc.).

Short-term: The CBP should develop and evaluate practical options for providing finer scale spatial resolution within the existing TMDL accounting framework. Ideas and suggestions for accomplishing this included, but were not limited to, the following:

- Allow differential credit within CAST for 'certified' plans of targeted BMP implementation; for example, plans with documented input/approval from professional advisors.
- Allow differential credit based on the BMPs implemented employing the rank distribution of risk index values recommended in the modeling section[1]
- Begin requiring all BMP expert panels to report explained variation in BMP removal efficiencies and identify the general causal factors thought to be the primary drivers in explaining the observed variation. Currently panels are instructed to provide a point estimate, which is often an average. Understanding causes of variation of BMP efficiencies will be more useful than simply assigning overall 'uncertainties.' Begin investigating the extent to which these variabilities can be incorporated into CAST.
- Allow differential credit for BMPs based on the improved capabilities to monitor stream bank loss (highlighted at the workshop) using remote sensing DEM and point cloud differencing. This would be specifically geared to practices designed to reduce stream bank loss (e.g. stream restoration, wetland restoration at legacy sediment hot spots, stream exclusion fencing for livestock).
- Allow differential credit based on monitored outcomes when available, including in-stream monitoring, based on approved and replicable monitoring procedures.
    - Any expected upward bias on load reductions (due to jurisdictions tending to choose the larger of the modeled vs. monitored outcome, or the 'Lake Woebegone' effect in which everyone is above average) is expected to be small due to the expense of monitoring NPS load. The ancillary benefits of more widespread monitoring data and improved monitoring technologies in the Bay watershed —which would be encouraged by the allowance of crediting based on monitored outcomes when available— should be weighed against potential risk of the Lake Woebegone effect.
    - In addition, for particular practices or projects, jurisdictions may opt to use monitored outcomes for crediting purposes, in which case there would be no possibility of choosing the larger of the modeled vs. monitored outcomes.

Long-term:
Development of finer scale modeling or monitoring approaches to credit BMPs

2. Develop and test alternative incentive systems for targeting programs

To be effective, nonpoint source targeting needs to provide landowners clear information and incentives to identify and effectively treat high loss areas. Existing NPS financial assistance and incentive programs (e.g., compensating landowners based on practice installation costs) have been the backbone of agricultural NPS policy for decades. Yet, new innovations in NPS implementation policy are needed to improve the results and cost effectiveness, particularly since financial resources are inadequate for treating all land. The CBP has explicit processes for incorporating innovative nutrient control technologies/practices into implementation but has no formal way to encourage the design and testing of institutional innovations (particularly as it applies to NPS controls). While workshop participants did not recommend any particular option, participants generally agreed that the development and testing of new financial and nonfinancial incentive programs for NPS targeting is warranted.

a. Develop and support testbed watersheds to pilot and test targeting incentive designs

The CBP should encourage and support the development of testbed watersheds to evaluate and promote innovations in NPS incentive and implementation programming. Additional financial incentive structures have promise in more directly rewarding treatment of high loss areas.

Testbed watershed programs should develop and refine financial incentive designs, targeting tools and engagement approaches (including the use of local expertise), and monitored assessments of outcomes. These testbed watersheds should be developed (or found if some already exist) to test BMP targeting effectiveness, participation, and program design using either a pre- and post-BMP implementation design or a treatment watershed and control watershed design.

These testbed watersheds would be provided funds and flexibility in how funds could be spent to create new incentives for land managers. This could include programs such as pay-for-performance systems that financially reward land managers directly on the quantity of a service provided (ex. reductions in pounds of a nutrient). Support should also be provided to organizations who provide the technical support for testbed program implementation. The following caveats or examples of innovative incentive systems in testbed watersheds are provided:

- Comparing methods for measuring and rewarding performance, which could include payments based upon finer-scale modeled outcomes, ambient measurements, indirect but observable measures of pollutant control performance, or remote sensing indicators. Rather than derail this important question by proposing/imposing a particular method to measure performance, it is advisable to encourage innovation among jurisdictions or subwatersheds to employ alternatives for measuring and rewarding outcomes – with the potential of utilizing these alternatives in a pay-for-performance system.

- Additional ambient water monitoring and field-scale or stream-reachreach scale indicators of change in pollutant loads are essential for improving and documenting the performance of NPS programs. Monitoring serves multiple purposes ranging from providing feedback to landowners and implementers on BMP performance, to providing data to inform finer-scale model development in general. Encourage use of ambient monitoring by allowing jurisdictions or watersheds groups to use ambient monitoring to target reductions and claim credit toward TMDL compliance. A critical component of any testbed implementation is ensuring that planning and resources are coordinated to guarantee long-term assessment of actual outcomes in stream loads and to compare those with "model" outcomes.

  - An example of a testbed application would include development and testing of financial reward payments for demonstrated achievement of observable benchmarks closely linked to water quality improvement (ex. reductions in soil P levels in critical source areas).
  - Targeting may require additional cognitive demands on land managers. Identification of high loss areas, site specific variation in loss pathways, and multiple treatment options with different costs add complexity to conservation choices. Test incentive designs should evaluate the most effective ways to engage land managers in the identification of nutrient loss areas and the evaluation of alternatives to treat those areas. These two activities may occur at different levels of involvement (community vs individual land manager).
  - Testbeds may be most useful if focused in very small areas where BMP compliance is high, local input data are available, and results are most likely to be interpretable, to increase likelihood that responses to specific BMPs can be resolved from responses to other factors and from system noise.

In the longer term, these testbed watersheds could be used to develop and test more site-specific approaches to estimating and crediting NPS control investments. This could include more mechanistic modeling, either explicit (predicting load and/or BMP effectiveness on a field-by-field basis) or using a "representative scenario" modeling exercise (non-spatially specific, although incorporating the distributions of controlling factors), with the latter providing a simple way to upscale across similar physiographic regions. Such approaches could also include testing and evaluation of how ambient monitoring can be used more effectively to improve spatial targeting and incentivized to reward spatial targeting for TMDL crediting purposes.

The CBP's federal and state partners can support these developments in a number of ways, including providing funding for implementation, monitoring, and technical support. Nonfinancial support could include providing flexibility to localities that are willing to host testbed watersheds, in terms of how these testbed watersheds can comply with TMDL requirements given demonstrated and innovative efforts at improving the targeting and effectiveness of nutrient reduction efforts.

- For example, jurisdictions/subwatershed groups may opt-out of the conventional modeling framework to use approved finer-scale modeled or monitored outcomes, for TMDL crediting purposes.
- Other jurisdictions/subwatershed groups, as well as the CAST modeling framework, could take lessons learned from these targeted accounting systems that are proven to work in the demonstration subwatersheds.

b. ***Support development and testing of nonfinancial approaches to encourage wider program participation and improved land manager identification of NPS hotspots***

through behavioral 'nudges,' communication strategies, and feedback on NPS management performance.

Case-study evidence provides a number of examples of how nonfinancial incentives have been used in motivating participants to address nutrient hotspots. For example, social referencing and public posting of indicators of improvements in nutrient removal efficiency (e.g., soil P levels) have been used to raise awareness and competition for improvement among land managers. Recent field studies have shown that information on stream bank erosion rates —provided by aerial LiDAR imagery at the parcel-level— substantially increases farmer willingness to undertake restoration efforts when farmers are located at targeted stream bank erosion hot spots. Intensive instream monitoring to identify high N source areas and farmer-led planning committees have been used in a West Virginia pilot to inform BMP investment decisions. Local watershed organizations are implementing a variety of engagement and communication strategies, including panels for farmer experience-sharing, watershed field days, and field management workshops.

The CBP should support and encourage the systematic design and evaluation of the effectiveness of such nonfinancial targeting approaches through financial support, in-kind support, unconventional crediting of demonstrated success, etc.

[1] In order to credit BMP implementation that uses an indexing approach, the CBP could develop a distributional efficiency multiplier from the index that modifies the CAST defined BMP efficiency. For example, if a BMP is targeted to areas on the landscape in the 90th percentile of risk index values, (e.g., 10 % of locations are "riskier") the CAST BMP efficiency would be multiplied by 1.9 (or any scalar value, 1.4, 1.6, etc.), and if the BMP is in the 10th percentile (e.g., 90 % of locations are "riskier'), then the CAST BMP efficiency is multiplied by 0.1 (or any scalar value, 0.2, 0.4, etc.). This could also easily incorporate the delivery ratio effect using a nested risk indexing. Land river segments with a high delivery ratio would have the ranking shifted towards the upper end of the multiplier distribution. For example, Lancaster County in Pennsylvania, would be designated a high delivery ratio and a high aggregate risk index score, so would have a higher BMP efficiency multiplier at the county/land river segment and at the field scale (note the field scale multiplier would still vary based on the field level risk). Another county/land river segment with a lower delivery ratio and or a lower aggregate risk index score would have a lower BMP efficiency multiplier at the county/land river segment, and at the field scale (Figure 2). We recognize that an approach like this needs to be constrained by a realistic range of BMP efficiencies; that is, the ultimate efficiency resulting from an approach like this should not be greater than (or less than) the maximum (or minimum) efficiency (if this value exists) defined by the expert panel process.

An approach like this has several benefits; it is consistent across scales (both county/land river segment and field), it fits within the CAST framework, and it keeps any model-based targeting program easily verifiable.

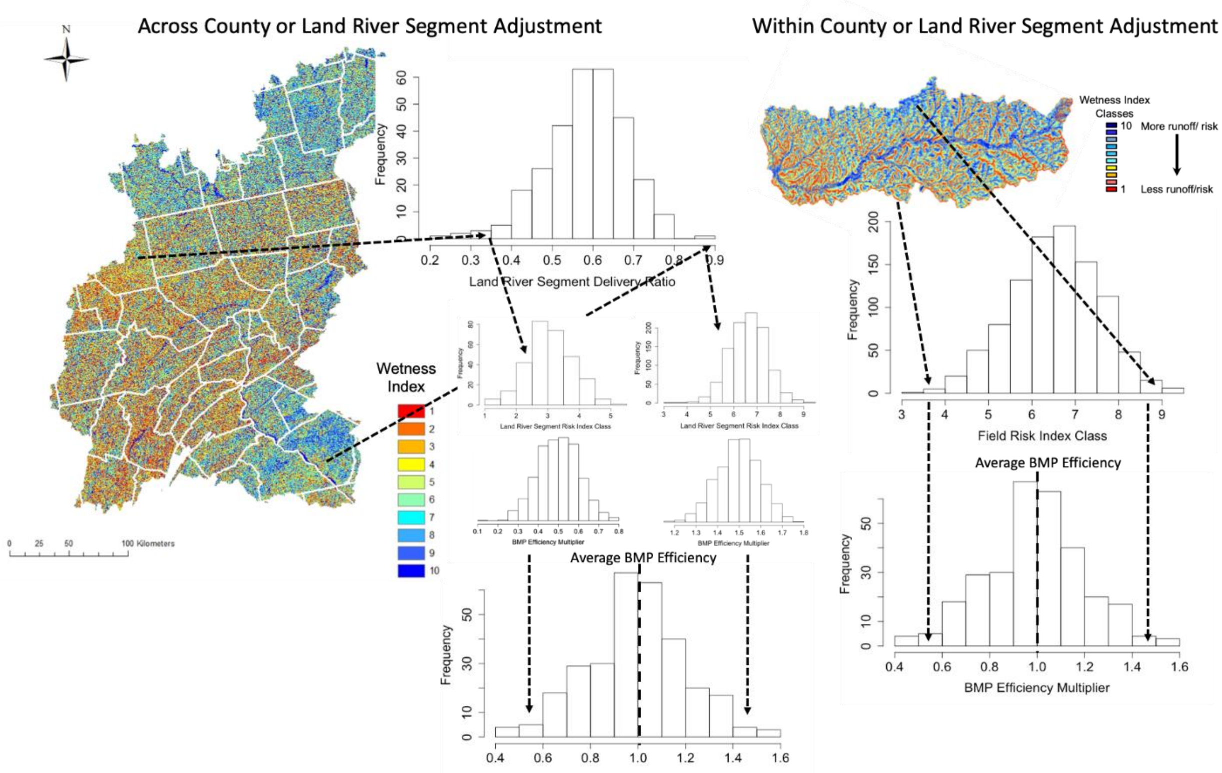

Figure 2: A conceptual framework for differential BMP crediting based on targeting.

Appendix A: Workshop Agenda

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Targeting BMPs Workshop – November 12-13, 2019

Location: Northern Virginia Regional Commission (NVRC), Fairfax, VA
Meeting Room: --

Workshop Webpage: https://www.chesapeake.org/stac/events/increasing-effectiveness-and-reducing-the-cost-of-non-point-source-best-management-practice-bmp-implementation-is-targeting-the-answer/

Tuesday, November 12

Webinar Website:
https://chesapeakeresearch.webex.com/chesapeakeresearch/onstage/g.php?MTID=e229774ccd9944a214ab4058f5a1df7d9 **Password:** day1
Toll-Free Number: 1-877-668-4493 **Access Code:** 730 449 396

****Exact Times Are Subject to Change****

8:00 am **Coffee & Light Breakfast (Provided)**

8:30 am **Introduction**
- Introductions: Expertise in the room
- Objectives of the workshop – *Zach Easton (VT), Kurt Stephenson (VT)*

8:50 am **Overview of NPS Control Efforts/Programs in the CBP** — *James Martin (VA DEP)*

9:20 am **Salient Points from Synthesis** — *Zach Easton (VT), Kurt Stephenson (VT)*
Modeling tools, monitoring options, changing behavior, and policy

9:50 am **Overview of CBP Watershed Model** — *Gary Shenk (USGS)*
The CBP partnership's watershed model used for the Chesapeake Bay TMDL is built for use at the large scale. The level of targeting possible with the current will be discussed

10:20 am **Break**

10:30 am **Examples of Putting the Pieces Together: Innovative pilot programs**
- *Jonathan Winsten (Winrock)*: Pay for Performance Programs
- *Joe Sweeney (Water Science Institute)*: Big spring run, Identification of stream bank erosion (and associated nutrient) hot spots; How this information is being incorporated into Lancaster County's WIP.
- *Alan Collins (WVU)*: Payment by Ambient Outcomes

12:00 pm **Lunch (Provided)**

12:40 pm **Facilitated Panel Discussion: Technical and policy**
— *Jonathan Winsten (Winrock), Marc Ribaudo, Leonard Shabman (RFF)*
- What was the most compelling outcome *(positive or negative)* that has been achieved in a targeting-like NPS effort.

- What were the most important changes from conventional programs you were able to make (or observed others making)
- What are the top 2 or 3 barriers in improving effectiveness and cost effectiveness of outcomes?
- What emerging developments/tools/policies are out there that offer the biggest opportunities for improving NPS targeting program efforts? (Game Changers?)

2:30 pm **Break**

2:50 pm **Breakout Discussions: Identifying opportunities and barriers**

4:30 pm **Regroup and synthesize**

5:00 pm **Recess**

Wednesday, November 13

Webinar Website:
https://chesapeakeresearch.webex.com/chesapeakeresearch/onstage/g.php?MTID=e18a4cc48bbf94892d70004ddbd0d2ff4 **Password:** day2
Toll-Free Number: 1-877-668-4493 **Access Code:** 734 710 295

8:00 am **Coffee & Light Breakfast (Provided)**

8:30 am **Synthesize and Overview of Day 1**
Next steps for improving NPS Control effectiveness in the Chesapeake Bay

8:50 am **Group-based Discussion**
Develop a roadmap for the Chesapeake Bay Program (CBP) based on short-term and long-term BMP targeting goals.

10:50 am **Whole Group Discussion**
Synthesize results and recommendations.

12:00 pm **Workshop Adjourns**

Appendix B: Workshop Participants

Name	Affiliation	Email
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* Bold indicates steering committee member

Appendix C: Workshop Background Document

Increasing Effectiveness and Reducing the Cost of Non-Point Source Best Management Practice Implementation: Is Targeting the Answer?

I. Introduction

As the Chesapeake Bay Program (CBP) passes the mid-point assessment, point source discharges will have achieved (or nearly achieved) their final Total Maximum Daily Load (TMDL) nitrogen (N) and phosphorus (P) wasteload allocations. Jurisdictions, however, still need to achieve substantial nutrient and sediment reductions from agricultural and urban nonpoint sources. Based on current understanding and modeling, the CBP estimates that agriculture and urban nonpoint sources need to achieve an additional 35 million and 12 million pounds of N reductions, 1.3 and 0.6 million pounds of P reductions, and 941 and 594 million pounds of sediment, respectively, to meet TMDL goals. State and local governments are poised to spend hundreds of millions of additional dollars to meet these goals, primarily by installing nonpoint source best management practices (BMPs).

Thus, BMP implementation stands at the center of efforts to meet TMDL requirements. Yet, water quality monitoring suggests that the link between BMP implementation and load reductions is tenuous at best. The CB watershed model estimates substantial reductions in agricultural loads, but monitoring data suggests little to no change in these loads between 1992-2012 (Keisman et al. 2018). In a recent STAC review, Keisman et al. (2018) state "current research suggests that the estimated effects of conservation practices have not been linked to water quality improvements in most streams." This is a familiar outcome. In general detecting observed changes in ambient conditions from nonpoint source control efforts is a challenge common across the country (Osmond et al 2012; Perez 2017).

A critical question is why? Potential explanatory factors include inadequate BMP coverage, poor implementation/maintenance, lag times between implementation and water quality response, inadequate participation, and inability to target BMPs to critical pollutant source areas (Easton et al. 2017). Improved targeting of nonpoint source controls to areas with high pollutant loss rates (both at the field and watershed level) is often proposed as a way to produce better outcomes (Shortle et al. 2012; Perez 2017; Osmond et al 2012).

Many studies have noted that areas of high nutrient loss are site specific and highly localized. If BMPs tend to get applied in lower risk areas rather than targeted to areas where nutrient loads are more likely to originate, nutrient load reduction effectiveness will be overestimated. Many studies suggest that between 5 - 20% of the land area generates 50-90% or more of the nonpoint source loads (NPS), particularly for pollutants such as P and sediment (Heathwaite et al. 2000; White et al. 2009; Qui, 2009; Wagena and Easton, 2018; Rao et al. 2009; Yu et al. 2019).In the Chesapeake Bay watershed, 80% of cropland loses less than 40 lbs/acre of N per year, while the remaining 20% loses up to 300 lbs/acre (USDA, NRCS, 2011a). Losses may also originate from a disproportionate share of farms that lack effective nutrient management. Within fields, nutrient losses may be confined to relatively small areas (Easton et al. 2008a), that with the correct targeting and incentives may be treated at relatively low cost. Yet few NPS implementation programs have been designed to identify and treat high pollutant loss areas, including those in the Chesapeake Bay watershed. NPS implementation programs typically apply BMPs and other treatment measures based on factors including the willingness of landowners to participate, access to sites, and distribution of financial incentives. In addition, some programs cannot or do not identify and credit treatment of high impact areas. For instance, modeling capacities may not be spatially or analytically refined enough to identify localized areas of high loss and by extension areas that would be critical to target with BMPs.

Numerous studies have found that targeting NPS reduction projects to sites with higher pollution potential and low implementation costs has the potential to improve cost effectiveness of pollution reduction efforts (Carpentier et al 1998; Khanna et al. 2003; Yang and Weersink 2004; Giri et al. 2012; Perez 2017; Xu et al. 2019; Fleming et al. 2019). Studies have shown that targeting BMPs or a land retirement payment scheme by flow paths, sub-catchment, soil erodibility, or other land and soil characteristics instead of applying BMPs randomly or uniformly can reduce costs of meeting a given water quality goal (Yang and Weersink 2004). Multiple policy designs could be pursued to better target cost-effective nonpoint source reduction investments, each with different strengths and limitations (Ribaudo 2015).

Can targeting of nonpoint source controls be improved to get more pollutant reductions for less cost in the Chesapeake Bay region? In general, targeting programs must answer two basic questions: how pollutant loads are identified/quantified and how are stakeholders motivated to cost-effectively identify and reduce NPS loads? There is a multitude of ways these two simple questions can be answered. Selecting among the wide range of possible answers to these two questions is a critical challenge and one in which this workshop will attempt to provide insight.

The objectives of this synthesis are1) to summarize the range of options available for identifying high loss areas and measuring the effectiveness of nonpoint source control measures; 2) to identify and summarize incentive and behavioral approaches to encourage decision-makers to adopt cost-effective treatment options; 3) to summarize the criteria that define success of such programs, and 4) to describe the design and outcomes of several targeting programs that have been piloted or implemented. This document is intended to provide background information and resources and serve to facilitate discussion and consideration of targeting at the workshop.

II. What is Targeting?

“Targeting” in voluntary nonpoint source control programs is a widely used term that can describe a diverse range of program designs. For the purposes of this workshop/synthesis targeting is defined in three dimensions, 1) targeting landscape NPS areas that produce disproportionate loads, 2) incentivizing people to treat those loads with NPS control measures, and 3) selecting the most cost-effective NPS control measures to treat those areas. Targeting may occur at different spatial scales, ranging from the watershed, field level, or subfield level. Targeting may also mean identifying land managers whose managed lands produce disproportionately high loads and providing additional assistance and incentives to successfully manage those loads.

In general targeting is undertaken to improve the effectiveness of nonpoint source control investments and to reduce the costs of achieving any given amount of pollutant abatement (cost effectiveness). Targeting most frequently occurs at the watershed and subwatershed levels. Geographic targeting of impaired, high pollutant loss, or environmentally risky/sensitive subwatersheds to address water quality issues has been used in several USDA conservation efforts over the years and is used in the CBP to prioritize high loss land river segments. The

Rural Clean Waters Program (1980s) and the President's Water Quality Initiative (1990s) are two examples. The USDA Environmental Quality Incentives Program (EQIP) targets ecologically important areas (e.g., Chesapeake Bay and western Lake Erie) and incorporates ranking criteria in selecting contracts at the local level. However, other programs may merely prioritize the implementation of particular practices thought to be particularly effective in reducing pollutants. For example, Maryland emphasizes the implementation of cover crops. Virginia has adjusted cost-share arrangement to prioritize stream fencing. Pennsylvania is currently focusing on forest riparian buffers through the Keystone Ten Million Trees partnership (http://www.tenmilliontrees. org/). While these are laudable goals and aimed at trying to reduce the cost of NPS control, they are not in a strict sense targeting.

Within the confines of the existing Chesapeake Bay Program modeling and accounting system, targeting is essentially limited to the land river segment level. Differential pollutant losses and nutrient reduction credit at the field and subfield level are not currently recognized. Furthermore, it is difficult to identify and receive credit for working with land managers that contribute disproportionate loads. The questions confronting nonpoint source water quality managers are, can more refined targeting improve program outcomes (load reductions, cost savings, etc) and if so, how can this be accomplished in the Chesapeake Bay region?

III. Defining Success in Targeting Programs

The criteria for evaluating the success of a targeting program represents an important consideration, regardless of the particular program design. In the context of NPS load reductions, the primary objective of a targeting program is to secure more pollutant reductions for any given amount of effort or resources. Given the primary objective, examples of useful evaluative criteria include achievement of stated objectives, cost effectiveness, participation, certainty, administrative costs and burdens, and equity and fairness.

Achieving Nonpoint Source Load Reductions/Water Quality Objectives. While it is perhaps obvious, the overriding goal of targeting is to secure reductions in nutrient and sediment loads. As stated in the introduction, achieving demonstrative results in this area of NPS control is a vexing policy challenge. A premise of targeting is that identifying, managing, and treating high loss areas will generate greater reductions. If effective, these efforts should produce observable changes in ambient outcomes.

When considering the overall effectiveness of a targeting program in achieving load reductions it is necessary to consider the total system changes stimulated by the policy. Water quality managers must consider unintended behavioral consequences of focusing on high loss areas. For example, will such a focus inadvertently reduce effort in less critical areas? Similarly, how will larger incentive payments targeted to high loss areas affect behavior within those areas?[2] .

[2] Slippage or leakage is a concern of any voluntary incentive program. In the context of NPS pollution, this refers to the tendency of incentive payments for practices that reduce load on high loss areas (e.g. no-till or manure storage) to make intensive production models relatively more profitable within those areas, in comparison to alternative land uses. For example, payments for practices that reduce erosion and nutrient loss on marginal land will make intensive crop production on that land relatively more attractive, in comparison to more environmentally benign land uses like perennial hay or pasture (Lichtenberg and Smith-Ramirez 2011). Because intensive crop production produces greater NPS runoff in comparison to perennial grasses--even when it is treated with conservation practices--slippage will lead to worse environmental outcomes when it occurs (Fleming et al. 2018). The consequences of targeting programs on the entire system should be considered, in order to secure the actual load reductions that are intended.

Cost Effectiveness. Cost effectiveness can broadly be defined as the total cost per unit of pollutant reduced (e.g. dollars spent per kg of N, P, or sediment), and a policy that improves cost effectiveness is one that will achieve the most pollutant load reduction for a given budget. Costs include not only expenditures to install or construct a pollutant control practice but also other opportunity costs to private citizens such as reduced production, forgone land use, etc. Decision-makers must have the ability and knowledge to select combinations of BMPs that match perceptions of stakeholders and reduce the most pollutants at the lowest possible cost. Cost effectiveness also requires the identification and participation of stakeholders within a watershed who can reduce the largest pollutant load at the lowest possible cost.

Since targeting necessarily includes some criteria of improved efficiency--i.e. more load reductions per unit of effort, per project implemented, per land area treated, and so forth--improved cost effectiveness can be considered an overarching goal of targeting programs by definition. Moreover, absent large increases in funding levels, the only way to achieve more NPS reductions is to get more out of the nonpoint source programs currently available. Thus, cost effectiveness is critical to overall program success.

Participation. For voluntary conservation programs, landowner participation is critical. Even when the best targeting program is devised, cost-effectiveness may be limited when farmers or landowners do not participate in conservation programs (non-participation) or stop using practices after the end of a conservation program contract or the life of the practice (dis-adoption) (Claassen et al. 2008; Just and Horowitz 2013). The level and type of participation both matter to program effectiveness. Not only does the level of participation matter (ex. # landowners), *who* participates also matters to program success. Just as there is spatial variability of loads across the watershed, there is variability in the effort and motivation of land managers. A nonpoint source control policy that solicits high levels of participation from the same set of conservation-minded landowners may not produce large or inexpensive reductions because each added BMP is treating a smaller and smaller remaining load. However, a nonpoint source program that can involve land managers of operations with particularly large pollutant loads, or those that have little experience adopting conservation practices, may be able to produce larger and less costly reductions.

A critical challenge in voluntary incentive programs is ensuring that funds induce *more* participation. When landowners receive payments for practices that they would have adopted without a payment (non-additionality), no new participation in conservation activities is achieved. This problem has been shown empirically to have substantial effects on both the changes in water quality that can be attributed to a program, as well as the program's cost-effectiveness (Chabe-Ferret and Subervie 2013; Mezzatesta et al. 2013). However, the size and scope of non-additional payments vary across different NPS practices (Claassen et al. 2018).

To address the challenges related to landowner participation, there are often trade-offs between program goals. For example, increasing incentive payments to encourage greater participation rates will also increase the profitability of existing production models, thereby encouraging slippage (Fleming et al. 2018). Setting stricter baseline requirements for conservation behavior on a farm as a condition for program participation--in order to reduce non-additional adoption--will also tend to reduce participation rates (Just and Horowitz 2013). Moreover, landowners may be able to shift baseline levels of practice adoption on their farms to take advantage of payment programs (Bosch et al. 2013).

Certainty. The degree of certainty with which water quality improvements are achieved is another necessary consideration when evaluating the success of targeting programs. In general, NPS actions that improve certainty of outcomes are preferred. NPS control efforts are often modeled rather than measured, since many types of NPS losses (e.g., sediment and nutrient runoff from agricultural fields, N leaching to groundwater) are difficult, costly, or even impossible to measure. Modeling introduces a considerable amount of uncertainty in the estimates (e.g., uncertainty related to input parameters, model processes, and system variability). Thus, estimates of cost and NPS control effectiveness can vary widely based on the assumptions used. To allow for meaningful comparisons of pollutant control effectiveness across programs and practices, analyses of NPS control cost-effectiveness should provide greater transparency in the assumptions and sources of uncertainty underlying the estimates (Wieland et al. 2009; Chesapeake Assessment Scenario Tool (CAST) 2019; Fleming 2019).

While uncertainty exists in estimating nonpoint source loads and control effectiveness, can targeting programs increase the level of certainty in pollutant control performance over outcomes that would be achieved under the status quo policy? Targeting programs may result in greater confidence in outcomes, given their emphasis on identifying and, to the extent possible, measuring and monitoring water quality effects.

Administrative Costs & Burdens. Another critical aspect of targeting is administrative cost. Participation and outcomes are improved when participants can identify reduction opportunities and adjust management at modest costs. In general, better targeting requires landowner outreach, resources to predict and measure outcomes, time to consider and evaluate options, and technical support. Yet, effort comes at a cost. Tradeoffs may exist between increasing targeting complexity and the time and compliance costs to participate.

Equity & Fairness. All else equal, programs perceived as fair generate more interest, participation and support. Different targeting program designs will produce different distributions of resources and benefits. Targeting of an impaired sub-watershed may involve higher payment rates to landowners in that watershed, reflecting the greater potential benefits to be achieved in that area. However, differential payment rates to landowners in different areas may lead to political push-back from those receiving the lower payment rates, thus jeopardizing public support for the program. For example, the USDA's Water Quality Incentives Program (WQIP) targeted specific watersheds for funding, and the program was discontinued in part due to political resistance to these differential payments. Targeting programs should be designed and evaluated in consideration of their fairness and distributional impacts, which will ultimately impact the viability of these programs.

IV. Elements of Targeting Programs

Section III outlined the primary goals for designing nonpoint source programs. This section will outline the tools and targeting design options available to achieve these outcomes. This will include both technical options for identifying and measuring the effectiveness of controls to reduce high NPS pollution loads (IV.A) and policy design options for reducing these loads within a framework of voluntary landowner participation (IV.B).

A. Targeting/Identification of Pollutant Source Areas

i. Introduction/Challenge

The need for identification and spatial targeting of landscape areas generating disproportionate NPS pollution losses is driven by the heterogeneity of pollution sources and transport pathways. Figure 1 illustrates that differences in pollution generation over orders of magnitude can occur across small spatial domains and are driven by hydrology (Fig. 1a), land use/soils (Fig. 1b,e), terrain (Fig. 1c), and morphometric features (Fig. 1d) . Approaches to identify these NPS pollution "hot spots" or "critical source areas" (CSAs) can depend on the pollutant, its transport pathway, and the geographical scale of targeting. We define CSAs broadly to include all source/pathway combinations generating disproportionately high NPS pollution loads. We describe available approaches for targeting CSAs (IV.A.ii), how their applicable spatial scales and data requirements differ (IV.A.iii), and how BMP performance variability can affect targeting strategies (IV.A.iv).

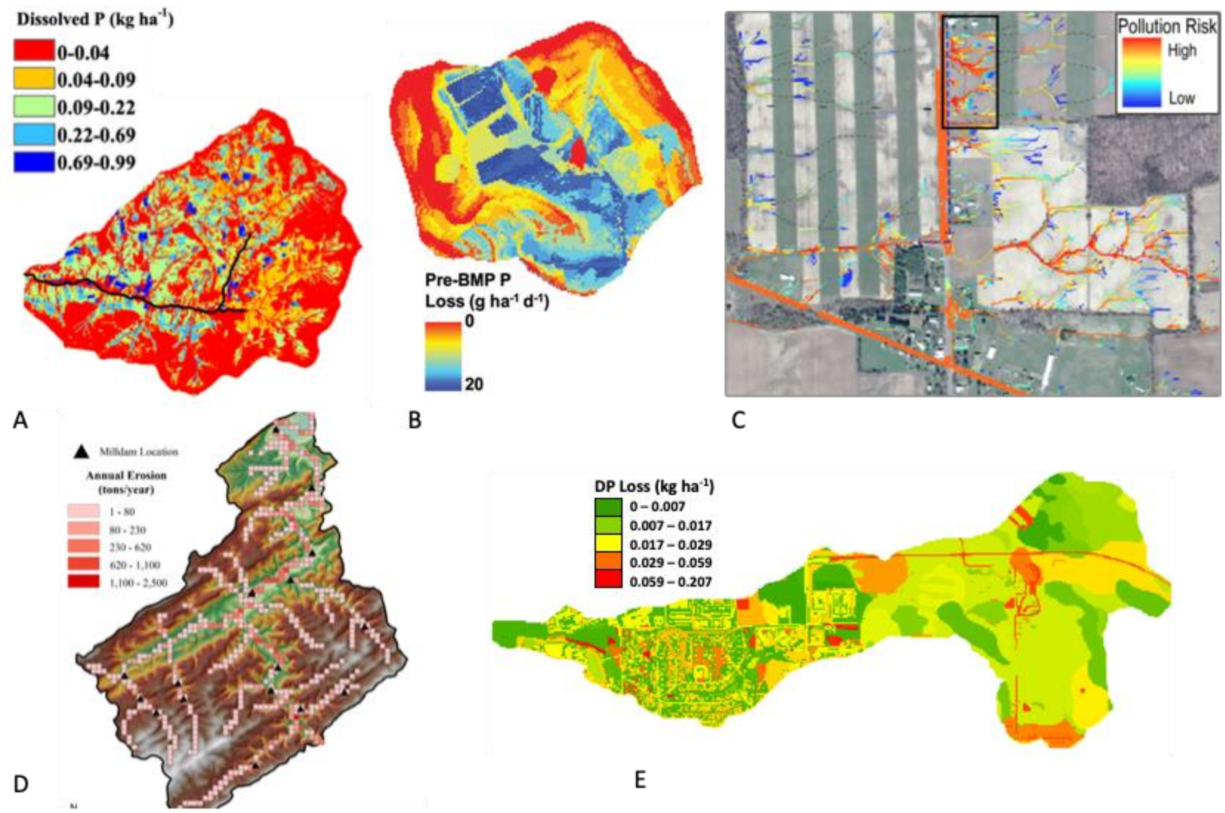

Figure 1. Examples of spatial heterogeneity and different targeting approaches at various scales: landscape hotspots of phosphorus (P) loss from agricultural watersheds at 37 km^2 (A) and 1.6 km^2 (B) scales, variable landscape connectivity over several farm fields of ~5 ha (C), streambank erosion heat map across a ~40 km^2 watershed (D), and dissolved P loss in a 3.3 km^2 urban watershed (E).

ii. Modeled or Measured Approaches to Determining Target Areas

Ecohydrological models are the most comprehensive but most computationally intensive approaches to characterizing NPS pollution generation and transport. Depending on the geographical area of interest, these process-based models can identify priority subbasins (Rabotyagov et al. 2010), hydrologic response units (coincidence of land use/management, slope, and soil properties, Rodriguez et al. 2011), or even areas within an individual farm fields (Easton et al. 2008a). Examples of such models include the Agricultural Policy / Environmental eXtender (APEX), SPAtially Referenced Regression On Watershed attributes (SPARROW), Soil and Water Assessment Tool (SWAT), and extensions of SWAT including SWAT-VSA (variable source area) and SWAT/HUMUS (Hydrologic Unit Model of the United States) or other integrated modeling approaches. One advantage of ecohydrological models is that they can be used to identify CSAs of N, P, and sediment simultaneously. Additionally, the effects of BMP implementation on pollutant loading to target water bodies can be simulated, and the impacts of climate change or landuse change on water quality and the efficacy of BMPs can be evaluated. However, some limitations of these models include their inability to adequately capture stream bank erosion, which is an important source of sediment, lag times between BMP implementation and water quality improvements, and groundwater processes that can deliver substantial amounts of N in baseflow but with substantial variability in lag times and/or natural attenuation. Furthermore, Osmond et al. (2012) emphasize that most models consistently overestimate control effectiveness. There is also the need for sufficient data to calibrate and evaluate the models and potentially significant degrees of uncertainty to consider.

Less computationally intensive approaches tend to rely on terrain metrics derived from Digital Elevation Models (DEMs) overlaid with land use and management information and sometimes combined with soils data. Targeting CSAs by Topographic Index (TI) has produced promising results and improved prediction of pollutant delivery (see Figure 1 A & B) from diffuse sources compared to approaches that do not consider topography, such as water body proximity (Buchanan et al., 2014; Hahn et al., 2014; Easton et al., 2007a,b; 2008a,b; 2011; Schneiderman et al., 2007). For example, Wagena and Easton (2018) demonstrated that 30% of agricultural land in the Susquehanna River Basin, about 42% of the Chesapeake Bay watershed (71,000 km^2), generated the majority of the agricultural NPS pollution. This conclusion was evidenced by simulations with SWAT-VSA predicting nearly the same N, P, and sediment load reductions to the Bay with BMP implementation on 30% of the agricultural land compared to 100% of the agricultural land. In a study explicitly evaluating cost, Xu et al. (2019) found that targeting hydrologically active areas, as defined by a terrain model, reduced the cost of achieving N load reductions by 30-40% in a 7.3 km^2 watershed in Pennsylvania under current and future climate scenarios.

Beyond simulation studies, the identification of CSAs may be accomplished using observable indicators. Identification through observable indicators has historically been limited in geographic scope and feasibility for NPS pollutants; however ,improvements in the quality of airborne light detection and ranging (LiDAR) data have made it possible to locate and quantify stream bank erosion rates at watershed-scales and target CSAs with precision (Walter et al. 2017; Fleming et al. 2019). Stream bank erosion may now be the one NPS pollutant pathway for which landscape-scale measurement data can be collected at reasonable costs. The measurement of vertical and horizontal changes at fine levels of detail (sub-meter) is available both through point cloud and digital elevation model (DEM) differencing in an approach referred to as change detection (http://gcd.riverscapes.xyz/). Improved methodologies exist to account for uncertainty and the presence of vegetation during leaf-season or in high-density wooded areas (Wheaton et al. 2010, James et al. 2019). In addition to being scalable, change detection can be done over long periods of time if LiDAR data are acquired during different years. Practitioners and government agencies have a need for additional LiDAR data within key watersheds to allow for comparisons across time.

In small watersheds, specific farmers or fields can be identified as CSAs using in-stream water quality monitoring or field-level data collection. Field-level data collection can support calculations of sediment loss or the P Indices. Nearly every state in the US has developed and use P Indices to improve nutrient management by indicating agricultural fields with the highest risk of P loss (Sharpley et al., 2003, 2008). P Indices are primarily based on P source characteristics (fertilizer and manure composition, rate, timing and method of application) and surface transport factors. In one example, targeting farms with the highest soil P Index values in a 50 km^2 watershed resulted in a 55% reduction of in-stream storm flow P loads within four years of practice adoption (Perez, 2017). In another case, specific fields were targeted by collecting in-stream N measurements, moving sequentially upstream until high concentrations were detected, and implementing riparian buffers on the adjacent farmland (Maille et al., 2009). Other studies have also demonstrated the value of spatially intensive "synoptic" stream analyses to identify variation of N inputs to streams in small watersheds using both discrete sampling and mobile sensors (e.g., Lindsey et al., 2003; Hyer et al., 2016).

The difficulty in identifying the small percentage of land contributing disproportionately high NPS loads has been emphasized in the Conservation Effects Assessment Project (CEAP) reports. The Lake Erie CEAP report raised the issue that while soils are very heterogeneous and occur as a mosaic in the landscape, many farms/fields are managed according to the dominant soil type. In a case study of a field that is managed appropriately for the three soil types that comprise 98% of the area, the remaining 2% of the land had high vulnerability to N, P, and/or sediment loss that required additional control measures (NRCS, 2016). These vulnerable soils would only be detected with strategic soil sampling (according to a grid or zone) and would likely require precision agricultural practices to address their loss vulnerability (NRCS, 2016). The report highlighted field-scale mapping of soil properties and variable rate nutrient application technology as important components of managing small, discrete CSAs in the landscape, particularly for addressing subsurface and soluble P losses (NRCS, 2016). An analogous conclusion can be drawn with respect to site hydrology. Although hydrologically active areas can often be identified within fields using terrain models, on the ground site assessment is critical to detect unmapped artificial drainage features.

It is also important to recognize that subsurface hydraulic and geologic features that are not directly observable by surface mapping or remote sensing can have important effects on groundwater flow paths, residence times, and persistence of contaminants, including N (e.g., Böhlke, 2002; Lindsey et al., 2003). Improvements in subsurface physical and chemical datasets will be important for assessing the distribution of source areas, lag times, and natural attenuation of N between recharge areas and discharge areas.

iii. Effectiveness of Approaches

1. Criteria

In the context of the Bay, targeting programs should focus on areas of the watershed that deliver the greatest loads of a pollutant to the Bay, and not necessarily on where the largest edge-of-field loads are generated. In the Chesapeake Bay watershed, water quality improvement may be observable in some regions of the Bay watershed and attributable to targeted conservation efforts. However, lag times between practice implementation and measurable improvements in water quality in receiving water bodies can vary widely and make detecting changes difficult within short time frames. Partial responses may be detectable within a few years, whereas full responses may take decades or longer. Perez (2017) provides an approximate time frame of 4-8 years for achieving measurable and attributable water quality improvements in response to conservation efforts for watersheds up to about 400 km^2, based on an analysis of six “water quality targeting success stories” that were part of the NRCS Regional Conservation Partnership Program. Therefore, it may take years for water quality improvements to be realized from even the most scientifically robust targeting programs. Improved strategies for monitoring and trend analysis might detect early BMP responses in receiving waters by focusing on specific flow conditions, seasons, or multi-constituent ratios (Hyer et al., 2016).

2. Strengths and Weaknesses

Comparing the efficacy of methods to identify CSAs for treatment is complicated by several factors. The accuracy of CSA identification using a particular approach depends on how well the dominant pollutant sources and loss pathways are represented, the heterogeneity of the watershed, data availability, and scale. Different identification approaches are more appropriate in different scenarios. For example, collecting in-stream water chemistry measurements in a small watershed may pinpoint specific farmland with high NPS contributions, but this approach becomes increasingly costly and labor intensive as the watershed size increases. In contrast, model-based approaches can be applied to much larger watersheds. Some models (e.g., SWAT) require extensive watershed data, including detailed information about existing land use and management practices, while others, like terrain models, have relatively low data needs. There are also differences in model complexity, data needs, and utility at the field scale. For example, the soil P index has relatively modest data needs compared to process-based models, like APEX, but cannot be used for identifying N or sediment losses. While a number of modeling tools are geared toward identifying NPS pollution generated by surface processes, there is increasing technological capacity to measure and identify streambank-derived pollution using change detection tools such as point cloud or DEM differencing. Tool selection will depend on which pollutants and loss pathways are prioritized. Table 1 summarizes tools available for CSA targeting and indicates their relative cost, relevance to different target pollutants, and data needs.

Table 1. Summary of modeling and physical options to guide targeting.

Options	**Effort to Accomplish (H, M, L)**	**WQ Concern Addressed**	**Data Needs (H, M, L)**	**Scale**
<u>Models</u>				
APEX	H	Hydro, WQ	H	Field
SWAT	H	Hydro, CSA, WQ	H	Sub-Field to watershed

P Index	L (conducted as part of NRCS 590 regs)	Primarily WQ (P)	M	Field
CB Model	H	Hydro, WQ	H	Watershed to region
Terrain models	L	Hydro, CSA, WQ	L	Sub-Field to watershed
Distributed models	H	Hydro, CSA, WQ	H	Pixel to watershed
<u>Physical</u>				
WQ measurements	H	Hydro, WQ	H	Various
Soil/tissue	H	nutrient mass balance	M	Sub-Field to field
Wet boot/eye test	L (although time intensive)	Hydro, CSA	L	Sub-Field to field

In the WQ Concern Addressed column, Hydro refers to hydrology, WQ refers to water quality in terms of N, P, and sediment loading, and CSA refers to identification of critical pollution source areas, and H, M, and L as High, Medium, and Low.

A few studies have explicitly compared different approaches to spatial targeting. One compared genetic optimization to simpler approaches previously applied in CEAP where target areas were defined by areas of moderate to high conservation need and projected that the former could reduce the cost of intervention by half (Rabotyagov et al., 2014). Another compared four CSA identification approaches based on targeting the highest pollutant concentrations in sub-watershed reaches, total pollutant load from the reach, pollutant load per subbasin, or average pollutant load per unit area (Giri et al., 2012). Notably, the most effective approach for reducing sediment loads (targeting the highest load per subbasin) differed from that for reducing nutrient loads (targeting land adjacent to stream reaches with the highest N and P concentrations), and, somewhat surprisingly, targeting the highest pollutant load per unit area was not the best approach. Identification and prioritization of lands for BMP implementation can be based on the pollutants, such as P and sediment (by considering predominantly surface or overland flow pathways) or N, which moves via a mix of surface and subsurface pathways, with subsurface flow being more difficult to treat, such that source reductions are better. Or they can be based on source area. For surface pathway pollutants, flow path or terrain models (that incorporate landscape connectivity, hydrologic distance, and soil depth) can identify hydrologically sensitive areas, and when intersected with land use can provide an estimate of where critical pollutant source areas occur. This approach is simple in terms of both data and effort required but could provide some valuable insight into pollutant sources. For groundwater pathway pollutants, identifying where recharge areas occur (perhaps from soil drainage class and restricting capacity) and intersecting these with land use data can provide an estimate of where critical pollutant source areas occur.

Apart from the accuracy of targeting tools, their utility to watershed managers must be considered with respect to the technical capacity of targeting program administrators. The degree of sophistication necessary in targeting methodologies or tools to identify CSAs across spatial scales remains an open research question. Targeting is most effective as a staged approach in the conservation planning process, at the watershed scale to drive regional prioritization or resource allocation, and down to the field scale to select and implement appropriate BMPs.

iv. Modeled and Measured Effectiveness of BMP Implementation

1. Technical Aspects

Landowner BMPs options can be divided into several different classes. Numerous methods for organizing BMP types have been utilized, and these include source vs. transport BMPs, structural vs management BMPs, and typologies based on pollutant transport pathways. The usefulness of these different organizing typologies largely depends on the context in which they are applied. Source BMPs are those that aim to reduce the amount of nutrients introduced into the system, while transport BMPs attempt to reduce the mobilization of nutrients or sediment by altering hydrologic production. Structural BMPs are those that attempt to prevent or reduce the discharge of pollutants in stormwater; many urban BMPs are structural, such as infiltration basins and bioretention. Management BMPs, as the name suggests, are BMPs that alter some form of management to prevent or reduce pollutant mobilization or transport; BMPs, such as no-till and nutrient management plans (NMPs), are management BMPs.

BMPs can also be differentiated by the pollutant transport pathways that they address. This allows landowner management options to be matched with the CSA identification tools mentioned above. BMPs that address surface-pathway NPS pollution (runoff, erosion) include conservation tillage, contour-strip farming, riparian buffers, and cover crops, as well as production models that reduce erosion (e.g. grass-fed vs. feeding of commodity crops). BMPs that address subsurface-pathways (leaching to groundwater) include cover crops, well-established buffers, nutrient management plans, as well as changing inputs to reduce nutrient application / deposition (e.g. fertilizer use, animal feed options). Finally, BMPs that address mobilization of NPS pollutants in stream banks (sediment and associated nutrients) include stream restoration, off-stream fencing for livestock, and legacy sediment stream or wetland restorations. Finally, some BMPs promote or enhance natural attenuation processes (such as denitrification for nitrogen) and could be leveraged to provide permanent N removal; some of these practices include bioreactors, wetlands, or drainage control.

Accounting for site-specific BMP performance is necessary to predict the impact of CSA targeting and to compare the potential environmental outcomes of different targeting approaches. For example, two locations may generate equivalent pollutant loads but have different load reduction potentials due to their suitability for treatment with BMPs or greater effectiveness of a particular BMP at one of the sites. Without predicting the effects of BMP implementation at the two sites, they would be treated as equivalent in a targeting program though the latter would provide an opportunity for more cost-effective treatment. Practice effectiveness can be related to landscape characteristics and hydrology and is affected by the conditions under which the practices are tested, including temporal features of seasonality, climate patterns, and climate change (Ahmadi et al., 2014). Site-specific practice effectiveness can be simulated using biophysical models (e.g., APEX, SWAT) and provide insight into which practices or suite of practices perform better for a particular area or under particular conditions (e.g., climate change projections). However, the lack of descriptive data for practices relating to other factors affecting performance, namely design, implementation, and maintenance, is a significant constraint.

2. Assumptions

Data needs stand at the center of targeting approaches. In order to effectively target, data-- either model derived or, ideally, measured--must provide contextual evidence of pollution generating areas. The data required to develop and inform a targeting program must address issues of source, scale, timing, and delivery. Spatial targeting by identification of CSAs using landscape metrics (e.g., soil wetness index), high resolution digital elevation models or point clouds (to determine streambank erosion rates), or ecohydrological models relies on the availability and accuracy of data, such as soil characteristics, land use, LiDAR (light detecting and ranging), and the location of existing BMPs. The latter has proven a perpetual challenge in the absence of disaggregated and spatially explicit data for BMPs implemented with federal cost-share (Kurklova et al. 2015). Having reliable baseline data--knowledge of the location and operational status of existing BMPs--is essential for any targeting strategy. Spatial targeting decisions based on biophysical simulations can only be as good as the data used to parameterize such models and are dependent on the accuracy of pollutant generation, transport, storage, and transformation processes. Strengths and weaknesses in these representations differ across models, suggesting the value in pursuing multiple lines of evidence or model ensemble approaches. One notable limitation shared across models predictive of water quality is the representation of pollutant storage and resultant lag times in pollutant delivery to target water bodies, which is discussed subsequently as a critical issue that needs to be considered for targeting strategies (4.A.iv.3). All models are subject to the constraints of incomplete data regarding land use and land management practices. In addition, properties of the subsurface (hydraulics, biogeochemistry), which affect lag times and natural attenuation processes for solutes such as nitrate, are not well characterized at watershed scale. Thus, sensitivity analysis and explicit examination of model uncertainty must inform decision-making. Data tend to be the most incomplete at farm or field scales, the scales at which critical targeting decisions are made, and this has been identified as a major hurdle to spatial targeting (NRCS 2016; Wardropper et al., 2015).

3. Problematic Issues in Targeting Programs

Several issues exist that could be problematic for any targeting program; specifically, the nutrient mass balance in many regions of the watershed and the impact of lag-times in pollutant delivery yielding legacy impacts. Efforts to address these two issues must be made in order for a targeting program to be effective.

Nutrient Mass Balance. Large mass balance issues exist in many agricultural dominated regions of the Bay (inputs of feed and fertilizer exceeding local assimilative capacity). Continued growth in intensive animal agriculture has and will continue to compound this issue (Yagow et al., 2016). However, targeted feed management has been shown to significantly reduce nutrient excretions in manure and is thus a potential option for mitigating nutrient mass imbalances, particularly in livestock intensive operations. In the New York City watershed, Ghebremichael et al. (2009) demonstrated significant reductions in P excretions of 5.5 kg/cow/year (about 23%) when using a precision feed management strategy, with no reduction in herd productivity. Targeting with respect to animal agriculture nutrient mass balances should focus on those herds with excessive nutrient excretions as determined by nutrient content in the manure. More generally, mass imbalance, at the field, farm or watershed scale, are difficult to control with targeted BMPs, as there are very few that reduce nutrient input into the system. Conversely, improved understanding of the distribution of natural attenuation processes (e.g., groundwater nitrate reduction) could be used to identify areas where additional BMPs may not improve water quality considerably (Böhlke, 2002).

Lag-times in Nutrient and Sediment Delivery. Legacy nutrients result from excess input of anthropogenic nutrients and their subsequent accumulation and storage in soil, sediment, or groundwater. Notably, nutrients leached through soils into groundwater may take decades to eventually be discharged to surface waters. For example, groundwater discharging into surface water in the Chesapeake Bay watershed has been identified as a significant nitrate source and can be characterized by travel times ranging from less than a year to more than 50 years (Focazio et al., 1999; Easton et al., 2017; Lindsey et al., 2003; Phillips and Lindsey, 2003; Sanford and Pope, 2013; Meals et al., 2010). Because discharge can include various mixtures of groundwater ages, nitrate responses in streams to changes in nitrate recharge beneath the landscape can include various combinations of partial rapid responses, delays, dilution or attenuation factors, and lengthy flushing times, all of which must be incorporated in the meaning and assessment of "lag times" for BMP responses. Sediment delivery can take even longer, largely due to storage of sediment behind stream impediments, such as the numerous historic mill dams that exist in the Chesapeake watershed (Walter and Merritts 2008; Yagow et al., 2013). Understanding the impact of lag times is critical to setting expectations for water quality responses to BMP targeting, because failing to account for these pollution sources can mask the outcomes of targeting and cause a delay in their detection. Targeting areas with shorter lag times could improve water quality more quickly, though it may sacrifice some cost efficiency in the long term. Targeting shorter lag-times may also be justified on environmental grounds, as areas with longer lag times may provide more opportunities for natural attenuation and ultimately require less treatment.

B. Decision Making

A major challenge confronting voluntary targeting programs is motivating participants to put the right control actions in the right place to achieve maximum water quality benefit. This challenge is compounded by the physical reality of NPS pollution, which is extensive and heterogeneous (Nowak, Bowen, and Cabot, 2006). Furthermore, farmers and landowners hold a variety of different motivations and interests. Some participants may be strongly motivated by a conservation ethic while others maybe more focused on financial returns (Ribaudo 2015). Different incentive program designs can significantly impact who participates and is engaged in pollution control efforts. For instance, financial incentive programs premised on sharing costs of BMP installation may not motivate a subset of land managers to participate. Adding resources to such a program may face diminishing results if new participants (potentially those with high pollutant losses) are not motivated to act.

This section describes different targeting program design choices that structure and incentivize landowners' choices to select and participate in nonpoint source reduction measures. This discussion will assume questions related to how NPS outcomes can be identified and quantified (see discussion above) have been addressed, and we will now focus on how program participants' conservation choices can be structured.

IV. B.1. Farmer/Landowner Choices Over NPS Control Options

An important dimension for the cost effectiveness of targeting programs is degree of choice over NPS control options given to decision-participants. Other factors equal, the more options a participant has on how NPS can be controlled, the more cost effective the result. For instance, if a landowner is offered only a few BMPs that may be used to control, more effective and lower cost alternatives better tailored to the specific site or farm operation could be foregone. For a targeting program, choice flexibility extends also to decisions about where control activities are applied. For instance, targeting a few critical source areas of a farm operation may generate large reductions in pollutant loads at relatively low costs. Requirements to treat all areas in the farm operation, regardless of the pollutant contribution of these areas, would limit choice, and reduce cost effectiveness.

However, offering more NPS control choices is not without tradeoffs. As the number of control options increase, so do the cognitive demands on decision-participants. The time required to consider and evaluate choices increases, thus increasing costs to participate.

IV.B.2. Structure of Financial Incentives/Subsidies

Financial assistance or cost-share programs are a key policy mechanism to induce the voluntary adoption of NPS management practices in the Chesapeake Bay region. Such programs are the primary methods to incentivize landowners and decision makers in the agricultural sector to change management practices and reduce NPS loads. Similar financial assistance programs are used in urban stormwater programs to encourage households and stormwater managers to implement stormwater controls (Ando and Netusil 2013; Gonzalez et al. 2018). Such financial incentive programs can be structured in a myriad of ways (Engel 2016). In general, all must answer a few basic questions: 1) what is paid for, 2) how is the level of compensation determined, 3) how are people selected to receive the funds (or conversely, how do program administrators ration limited program funds)?

Pay-for-Practice Programs. Traditional financial assistance programs generally answer these questions in similar ways. First, these programs pay participants to adopt specific practices. In other words, participants' financial payment is conditioned on the implementation of a particular activity or practice, called "pay for practice". Second, the amount of compensation is typically based on a percentage of the actual or estimated costs of installing//adopting the practice. Finally, while financial assistance funds may be targeted to particular areas, the funds are generally distributed based on a first come, first serve basis.

A variety of incentive designs can be employed to direct funds and focus pollution controls and efforts in a pay for practice program. For example, pay-for-practice type program may be modified to vary the amount of financial assistance based on the location or type of practice. For example, the Honey Creek Project (Oklahoma) adjusted the relative financial assistance rates for selected practices based on categorical assessments of the environmental benefit of the project and the likelihood of adoption. Practices that were unlikely to be adopted without financial assistance (high potential additionality) carried more financial assistance (Perez 2017). Similarly, the Maryland Agricultural and Water Quality Cost Share (MACS) program offered higher payment rates to farmers within certain targeted watersheds, including the Eastern Shore of the Chesapeake Bay. (However, these differential payments were subsequently discontinued, in part due to perceptions of fairness and equity.) In general, water quality managers adjust cost-share rates based on spatial targeting of high loss fields using modelled outcomes (e.g. SWAT, CBP water quality model). For programs such as the Honey Creek Project, the ability to establish and maintain variable compensation rates was possible because program managers were able to secure non-traditional funding sources that granted flexibility in how funds were spent.

Pay-for-Performance Programs. A more direct targeting approach could pay recipients directly for the level of predicted or demonstrated pollutant removal services provided (e.g. paying directly for the outcome desired), called pay-for-performance (Ribaudo et al. 1999; Ferraro and Simpson 2002; Shortle et al 2012; Savage and Ribaudo 2016). Pay-for-performance programs could also be called pay for services because payments are conditioned on the level of service provided (e.g. pollutant reduction) rather than the installation of a practice that generates the service. Participants who generate greater levels of the service receive more compensation. Conceptually, participants have an incentive to undertake actions that generate the greatest reductions per dollar of practice implementation cost. If performance metrics are appropriately scaled, then pay-for-performance systems provide direct incentives to treat high loss areas.

To calculate removal services, program rules typically define a starting point (baseline or reference point) from which to quantify the level of service provided. Total compensation paid would not be based on costs incurred by the landowner, but on the quality of service provided (e.g. the pounds of nutrients reduced) multiplied by the price or value of the service (e.g. $/lb). In such a system, the landowner or advisor must evaluate various options to reduce nutrient loads (BMPs and NPS control options described above), the reduction achieved for each option, and what must be given up (costs) to achieve them. In such a program, compensation received can exceed observed financial costs of practice implementation, resulting in a potentially new profit-making option for landowners. The policy does not presume knowledge of a participant's opportunity costs. Rather, it relies on participants to determine whether the payment provides sufficient compensation to provide the reductions or services requested.

A purported advantage of a pay for performance program for targeting is that it directly identifies and pays for the desired water quality change. Conceptually, such an approach incentivizes consideration of a wider array of pollutant control strategies and allows participants to select the type and location of activities that generate the most reductions for the least cost. Choice flexibility is essential since individual circumstances, costs, and physical conditions vary among landowners (Fisher et al. 2016). Importantly, those who can provide the most abatement at the lowest cost have the largest economic incentive to act. This means that landowners who may not have traditionally participated in conservation programs might have a strong incentive to do so. Such an approach is "self-targeting" in that those who can provide the most environmental benefit at least cost stand to gain the greatest economic benefit. Another advantage of a pay for performance program is that it will reveal information about the location and costs of available abatement options. Yet, to be effective, the method of predicting or measuring outcomes must be refined enough to capture the heterogeneity described in the previous section, accurate enough to be build trust among different stakeholders, and straight-forward enough to be accessible and manageable for the program participants.

How is Compensation Determined? - Design Considerations of Pay-for-Performance Programs. Obviously, the choice of the definition and measure of service change (performance measures) is critical. Pay-for-performance targeting programs could quantify pollution removal services based on predicted performance (pay-for-modeled performance) or observed (pay-for-demonstrated performance) (Winsten et al 2011). If multiple outcomes/services are desired, compensation could be based on an index of predicted environmental outcomes.

The most common approach is to base payments on modeled changes in nutrient loads (Fales et al. 2016; Winsten and Hunter 2011; Fisher et al 2016). For instance, a pay for performance program in Michigan afforded farmers a flat payment ($225) for every ton of sediment reduced based on a model that translated specific actions and BMPs into reductions of sediment load (Fales et al. 2016; Wickerham 2019). Winrock International has piloted several programs in the Midwest and Vermont that compensated landowners based on the pounds of P removed and not on the number of BMPs installed (Fisher et al. 2016; Winrock 2010). Maryland's recently revised nutrient trading program allows farmers and municipalities to receive payment for NPS pollution reductions based on outcomes modeled in the Maryland Nutrient Trading/Tracking Tool (MNTT) (Maryland Dept. of Environment 2017). Obviously, the NPS control options that participants may select is limited to BMPs explicitly included in the model. Moreover, credible field-scale models also have intensive data requirements (Muenich et al 2017), highlighting a tradeoff between complexity/accessibility, accuracy/uncertainty, and cost.

Performance-based incentive programs, however, could condition payments based on actual outcomes rather than predicted/modeled outcomes. Given the cost of direct monitoring and the stochastic nature of nonpoint source loads, direct measurement of changes in pollutant reduction poses a challenge, particularly for surface-flow and groundwater pathway pollutants. However, the ability to measure/monitor stream bank erosion introduces new opportunities in relation to pay for performance programs. Along with direct measurement, pay for performance programs may base compensation on some other observable outcome that could be used as an indicator of service provision. For instance, pilot programs have paid landowners based on soil nutrient levels or nutrient levels in post-harvest plant tissue (Winrock 2010). Note that compensation does not necessarily need to be based on a specific quantity of load reduction, but on whether a particular target indicator is achieved. Program designers must be reasonably confident that the performance metric provides a reliable indicator of the final outcome being sought (pollutant reductions). Some pay for performance schemes pay a "performance bonus" based on achievement of some benchmark indicator.

A pilot program in West Virginia developed a group payment scheme predicated on anticipated achievement of outcomes based on prior N concentration data at a subwatershed level (Maille et al 2009). A group of landowners in a small watershed (Culler's Run) received lump sum payments based on the flow-weighted metric of N at the outlet of the watershed. The group then used these resources to help install N reduction practices in the watershed.

Pay-for-performance programs must also consider the method for setting the price paid for the service change (e.g. price per lb. of pollution reduction). Price per unit can be fixed or negotiated (Engel 2016). Fixed price systems offer a single price for the service, though the price may need to be adjusted based on how participants respond. For example, one pay for performance program in Michigan's Saginaw Bay Watershed initially estimated the price per ton of sediment reduced to be less than $100/ton but had to increase the payment rate to $225/ton to induce higher levels of participation (Fales et al. 2016; Wickerham 2019). In contrast, if the price is negotiated among participants, the landowner/farmer (service provider) must be willing and able to develop an estimate of an acceptable price (Claassen et al 2008). Requiring the participant to develop plans for both the pollution control strategies and bid price can complicate the decision process and create significant disincentives to participate (Palm-Forster et al 2016).

The timing of financial incentive payments is another issue to address. In a traditional cost-share program, participants typically receive financial assistance when the practice is installed. Thus, financial assistance is provided before the service is actually delivered. However, in pay for performance programs, the program sponsor/funder may wish to see some evidence that the service is provided in order to make a payment. A pay for services program in the Northern Everglades paid landowners annual payments only after the demonstration of service provision (i.e. retaining water in designated wetland) (Lynch and Shabman 2011; Shabman et al. 2013). To reduce uncertainty and risk from the landowner's perspective, the annual service payment was coupled with a more conventional financial assistance program that reimbursed participants for upfront installation costs. In general, initial funding is more likely to be based on predicted outcomes, whereas continued payments can be based on proven outcomes, which may be difficult to document in many cases.

Who Receives Funds? - Further Design Considerations. Targeting programs that rely on financial incentives for landowners must also determine who receives funds. How are recipients and projects selected? Moving beyond a first-come, first-serve model, some programs rely on a ranking process to prioritize projects. The ranking system could be based on a number of factors including estimated water quality impact or previous participation. Other programs may use competitive processes to select projects and recipients of funding (Claassen et al., 2008). Competitive bidding processes would require potential recipients to compete to deliver the NPS pollution reduction service at the lowest possible cost, as in reverse auction designs. Such processes have been used in Florida to reduce P (Shabman et al. 2013). Maryland has implemented a bid process to solicit and identify cost effective restoration projects. Competitive bidding processes, however, require additional costs and effort on the part of participants. In some cases, the effort required to formulate bids may dramatically dampen participation (Palm-Forster et al 2016).

IV.B.3. Support, Outreach and Nudges for Decision-Making in Targeting Programs

Like all voluntary nonpoint source control programs, targeting programs requires effective technical support, communication, and persuasion to induce behavioral change. In targeting programs, such support takes on critical importance because of the additional attention and intellectual resources needed to identify critical source areas, evaluate nutrient reduction options, or work with land managers with particularly high loss rates. Building and maintaining trust between water quality managers and landowners, a commonly accepted condition for a successful program, is universally cited as essential when developing new information and incentives that might be required under a targeting program. The challenge is designing and implementing programs that build that trust and social relationships.

Studies implementing targeting programs have noted some common themes for effective engagement and trust building with land managers/program participants. For example, multiple targeting efforts have noted the benefits of directly involving farmers and other land managers directly into planning and implementation of conservation programs (Mailles et al 2009; Winrock International 2010; Perez 2018). Pilot programs have experimented with involving landowners in multiple ways, ranging from designing of ranking schemes to facilitate implementation. In a West Virginia pilot, a group of farmers assumed leadership in identifying and prioritizing implementation of BMPs in their subwatershed. Based on extensive in-stream monitoring, these farmers identified N hot spots. In one case these landowners were able to convince a neighboring landowner to allow the installation of a constructed wetland, which produced ambient reductions in summer nitrate levels (Collins and Gilles 2014).

Nudges. There is increasing evidence of the effects of different behavioral nudges on landowner participation in NPS programs and water quality management (Ferraro et al. 2017; Palm-Forster et al. 2019). Some of the most promising behavioral interventions in this area include feedback on outcomes, salience, and information provision coupled with peer comparisons. These insights can be applied to improve the design and outreach efforts of targeting programs.

Feedback. A common theme in the conservation literature is the value of visible feedback of outcomes for increasing program interest, commitment, and participation. In short, participation and willingness to engage in targeting programs is improved if participants can see observable and positive outcomes produced by their efforts (Wilson et al. 2014; Perez 2017) This may occur from observing biological improvements in local streams (e.g. increased fish abundance) or in-stream monitoring of ambient outcomes (Miao et al. 2016). On-field indicators could include reduced sedimentation of ditches, decreasing levels of surplus nutrients in soil tests, and decreased undermining of riparian areas due to stream bank erosion / retreat. Arguably, targeting programs contain more design features that potentially offer such feedback to landowners and program managers. Indirect feedback and encouragement also can be obtained from compiled examples of "demonstration projects", where extra monitoring and experimentation could be done at extra cost. Such examples could be highlighted in simplified form online.

Salience. Increasing the salience of issues related to NPS runoff can be another important method that may increase landowner participation in targeting programs, particularly given that farmers' attention is divided among numerous competing priorities. For example, reminder letters were found to significantly increase re-enrollment in the USDA's Conservation Reserve Program (CRP), at a relatively modest cost to the program. Reminders coupled with public disclosure of other landowners' interest in re-enrollment also led to higher re-enrollments in the CRP, but no higher than the simple reminder itself (Wallander et al. 2017).

Information Provision and Peer Comparisons. Targeting programs can potentially induce participation and behavior change through social referencing and peer comparison. For example, farmers have long referenced their farming skills by comparing their crop yield with neighbors. And in other environmental contexts--such as household energy and water use--information provision and social comparisons have been shown to significantly increase household willingness to engage in conservation behavior (Allcott 2011; Ferraro and Price 2013). The same appears to hold true in the context of NPS pollution. In an Iowa pay for performance pilot, field level P and soil index results were posted on the local watershed council's webpage. This public information (coded for confidentiality) created competitive behavior from farmers to meet a benchmark level of performance (Winrock 2010; Perez 2018). Information provision at the farm-level on stream bank erosion rates led to substantially larger landowner investments in stream restoration when paired with peer comparisons (Goodkin et al. 2019). Farm- or parcel-level information provision and peer comparisons has historically been difficult to provide for NPS pollution--given the challenges of identification and measurement mentioned above (4.A). However, improved NPS monitoring tools, such as the aerial imagery and mapping technology for stream bank erosion, provide an opportunity to implement such parcel-level informational targeting in practice.

V. Targeting Programs: Promise and Challenges

A. Putting the Pieces Together: Illustrations of Targeting Programs

As described in Section IV, nonpoint source targeting programs can take on a variety of designs or forms. A sample of the diversity of targeting program designs that have been implemented or piloted is summarized in Table 2. These programs demonstrate diversity in the approaches used to identify and target nonpoint source loads, as well as program designs used to induce NPS reductions. Table 3 summarizes the targeting tools applied in several BMP targeting projects and how the monitoring was used to link water quality outcomes to practice implementation. These tables are intended to summarize in succinct form the numerous examples of targeting efforts to date that were described in Section IV.

Table 2. Nonpoint Source Targeting Programs

Program	**Targeting Method /Tools**	**Level of Targeting**	**Incentive Payments**	**Payment Rate**
Saginaw Bay Pay-for Performance	GLWMS	Field and watershed level	Pay for performance ($/ton of sediment)	Flat payment ($225/ton)
Milwaukee River Pay-for-Performance		Field and watershed level		
Hewitt Creek, Iowa	P & soil condition indices, corn stalk NO_3 test	Field and watershed level	Pay for performance + performance bonus payments for achieving benchmarks	
Cullers Run WVa	Ambient monitoring	Watershed	Group payment	Based on ambient outcomes (N) and allocated based on group decision-making
Honey Creek Oklahoma.	SWAT	Field and watershed level	Cost-share for practices	Differential cost share rates

Table 3. Measured/modeled outcomes of nonpoint source targeting programs.

Study	**Targeting Approach**	**Monitoring/Attribution**	**Outcomes**

Bishop et al. 2005 Delaware River Basin	Detailed farm survey , CSA identification	Paired watershed (Farm and forested watersheds), 2 yrs pre BMP, 5 yrs post BMP	- reduced dissolved P in stormflow by 43% (95% confidence interval is 36% to 49%) and particulate P in storm flow by 29% (15% to 41%)
Easton et al. 2008b, Delaware River Basin	Used soil topographic index in VSLF mode	-measured TP at watershed outlet (164 ha farm) -modeled paired watershed to isolate BMP impacts	- 36% reduction in dissolved P, 47% reduction in TP - Simulated and measured load reductions were equivalent
Rao et al. 2012, Delaware River Basin	Used results from Easton at al. 2008, above	-measured TP at watershed outlet (164 ha farm) -modeled paired watershed to isolate BMP impacts	-targeting buffers to the 50% of the land producing the most runoff resulted in a 73% cost reduction
Fleming et al. 2019, Mill Creek watershed, PA	Identified streambank erosion hotspots with DEM differencing using LiDAR data	-before/after restoration monitoring (15 yrs)	-restoration at 18 sites reduced sediment loads ~8,524 tn along with bound nutrients with very high cost-effectiveness, $0.03, $19, and $14 per pound for sediment, P, and N, respectively
Perez 2017 Honey Creek, OK	Identified P hotspots with SWAT and verified with site inspections	-upstream/downstream -paired watershed - 320 km^2 project design	- 28% P reduction, 35% NO3-N reduction - Participation of nearly half of priority farmers
Perez 2017 Hewitt Creek, IA	Collected field data for soil P index, soil conditioning index, and corn stalk nitrate test	- in-stream chemical monitoring, design insufficient to attribute reductions to BMPs -93 km^2 watershed	- Downward trends in turbidity and TP attributable to BMPs because independent of rainfall - impact on suspend solids unclear -N loads not reduced
Perez 2017 Pleasant Valley, WI	-Previously identified as priority subwatershed	- before/after fisheries and quantitative habitat assessment	- 24,750 ft stream restoration for $10/ft - median storm load TP reduced by 55%

	- riparian site assessments - inventoried 90% of ag land to calculate soil P index and sediment loss (RUSLE2)	- before/after instream P monitoring, paired watershed - 50 km^2 watershed	

B. Remaining Challenges/Barriers

A review of targeting programs reveals a number of challenges confronting successful implementation. This includes issues over distributional consequences of targeting, funding & regulatory constraints, technical support and costs, and the ability to scale-up or replicate findings from pilot programs.

Distributional Consequences. Voluntary targeting incentive programs are premised on the notion that financial incentive payments go to areas that are able to achieve the greatest reductions for the lowest cost. Consequently, financial payments will necessarily be distributed unevenly across a watershed and decision participants. In some cases, land managers long considered "good stewards" may realize few financial opportunities from a targeting program, while others with high loss rates may be poised to receive a large share of funding. Establishment of baselines can help address this issue, but these will reduce incentives for some high impact/low cost landowners to participate (Ribaudo et al 2014). Targeting pilot programs frequently confront the tradeoffs between building participant support and distribution of program benefits.

Funding Constraints. Federal and state financial assistance programs intended to incentivize NPS reduction actions often have requirements and restrictions concerning the distribution of funding within districts or regions, the total level of individual award levels, and how the funds are spent. These restrictions can significantly limit the effectiveness of a targeting program by limiting the choices and incentives of land managers. Political considerations and individual award caps limit the amount of funds that may be devoted to addressing high loss regions or projects. Finally, financial assistance may only cover certain types of practices or costs, limiting or distorting choices of the most cost effective treatment options. Given the need for flexibility in targeting financial assistance, it is unsurprising that targeting program administrators note the critical importance of securing funding that is relatively unencumbered by formula or administrative restrictions (Fales et al. 2016, Lynch and Shabman 2011; Perez 2017).

Administrative and Technical Challenges. Nonpoint source pollution is field and farm specific. Pollutant loading and the effectiveness of control actions can vary tremendously between watersheds and farms, and even within farms. Are technical tools and indicators available to effectively capture these differences and convey them in a way that is accessible for landowner participants and program managers? Furthermore, can the treatment of these high loss areas be acknowledged and rewarded within established TMDL accounting frameworks? More work is needed to better understand the administrative costs of targeting programs, particularly relative to conventional programs.

Scaling-Up/Replication. There is little experience in scaling up incentive-based targeting programs. Most success stories are focused on efforts at relatively small scales. Program administrators often note that success depended on personal relationships that fostered the trust and credibility necessary for successful implementation. How and whether these dynamics can be replicated and sustained on larger scales is a largely unanswered question.

Most of the evidence on targeting program outcomes have been case-specific observations. Very few formal evaluations of pilot programs have been conducted in a way that allows for rigorous evaluation of program effects in comparison to what would have been achieved without targeting. Similarly, the relatively limited number of pilot programs, and the variability of program design, limits the ability to draw inferences on targeting program effects based on design features. The heterogeneity across watersheds, large differences in program administrative costs, and a lack of consistency regarding which expenditures are counted toward pollutant unit reduction costs (i.e. practice maintenance costs, program monitoring costs, regulatory and permitting costs) collectively limit the conclusions that can be drawn about the cost-effectiveness of a targeting program by comparing unit removal costs under different program structures.

C. Targeting Outcomes - Opportunities and Promise

Despite the real challenges that exist, the evidence synthesized above on technical tools for targeting and program design features suggests there are also real opportunities for improving the outcomes of conventional programs through targeting.

In several instances, targeting programs/efforts have been able to produce demonstrative reductions in ambient (in stream) nutrient levels. For example, according to paired-watershed comparisons, the Wisconsin Pleasant Valley and Oklahoma's Honey Creek targeting pilot projects produced detectable reductions in ambient P loads (Perez 2017). Effective targeting of attention and control efforts is a noted element in CEAP projects that produced observable improvements in ambient pollution levels (Osmond et al 2012; Kurkalova 2015; NRCS 2016). However, whether these reductions will be sufficient to overcome water quality impairments in those watersheds is a question that merits further research.

Researchers consistently find large potential cost savings from NPS targeting. The potential magnitude of cost savings appears to be significant, typically 30 to 50% based on modeling studies (Carpentier et al 1998; Rabotyagov et al., 2014; Xu et al., 2019; Geng et al. 2019). Savage and Ribaudo (2016) estimated that pay for performance programs in the Chesapeake Bay Watershed would achieve a water quality goal at a much lower cost than payments based on practice costs, even with targeting. However, such projections of cost savings typically do not attempt to account for constraints imposed by the regulatory environment and actual behavioral response of participants (Wardropper et al. 2015).

Behavioral and cost evidence from pilot programs do suggest significant promise. For instance, administrators of the Saginaw sediment pay for performance program estimate that paying directly for sediment reductions using a model that estimates sediment losses at the subfield level can purchase 4 times the amount sediment reductions than the conventional financial incentive program operating in the same watershed (Winkerham and Fales 2019). Program administrators attribute this increase in cost effectiveness primarily to the ability to devote funds specifically toward areas experiencing high sediment losses. This is consistent with findings in the Mill

Creek watershed of Lancaster County, Pennsylvania, where newly available tools to identify stream bank erosion hotspots have been piloted, and substantial reductions of sediment and P can be achieved at a fraction of the land area, number of landowner contracts, and overall cost required by other control practices (Fleming et al. 2019). The ability to devote not only funds but also administrative outreach to a few high-loss areas presents a major opportunity to improve the efficiency of existing NPS programs.

The extent to which targeting changes participation rates or reaches landowners who typically do not participate in conservation programs is another area needing further study. However, common themes emerge from reported behavior and participation rates in successful applications of targeting programs. A shift in participant mindsets due to increased attention on outcomes (lbs. reduced) and observable results heightened interest in conservation activities. Pilot programs provide numerous examples of participants working collaboratively and productively to identify and treat high loss areas. The flexibility to target funds to high needs areas is consistently noted as essential to targeting program success. A pilot program in Ohio (Alpine Cheese) documented how farmers who never participated in conservation assistance programs were willing to address observable and highly farm specific nutrient loss areas because funding and effort was explicitly directed to those specific problem areas, and the time and administrative costs for the landowner were minimal.

VI. Next Steps

Targeting programs offer one avenue to secure additional nonpoint source reduction with greater certainty in outcomes without necessarily relying on additional revenue streams. The questions confronting water quality managers in the Chesapeake Bay are:

Is the potential for more effective nonpoint source targeting worth further time and effort to pursue?

What efforts are needed to improve nonpoint source targeting in the Chesapeake Bay and what form should improved targeting take?

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