WORLD RESOURCES INSTITUTE

WORKING PAPER

How Nutrient Trading Could Help Restore the Chesapeake Bay

CY JONES, EVAN BRANOSKY, MINDY SELMAN, MICHELLE PEREZ

World Resources Institute Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.

Suggested citation: Jones, Cy, et al. 2010. "How Nutrient Trading Could Help Restore the Chesapeake Bay." WRI Working Paper. World Resources Institute, Washington DC. Available online at http://www.wri.org/stories/2009/12/how-nutrient-trading-can-help-restore-chesapeake-bay.

CONTENTS

February 2010

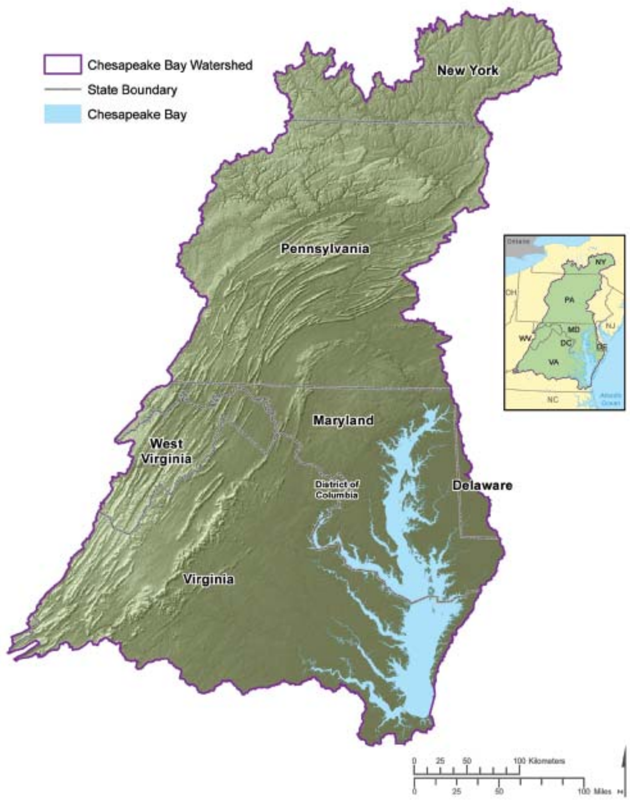
SUMMARY

The largest estuary in the United States, the Chesapeake Bay is a vital economic, cultural, and ecological resource for the region and the nation. Excess runoff and discharges of nutrients—particularly nitrogen and phosphorus—from farms, pavement, wastewater treatment plants (WWTPs), and other sources have placed the bay on the Environmental Protection Agency's (EPA's) List of Impaired Waters. This nutrient pollution is responsible for creating large algal blooms that lead to "dead zones" in the bay (Chesapeake Bay Program, 2009b). Despite decades of restoration efforts, progress has been slow, and the rivers and streams that drain into the Bay remain polluted (Chesapeake Bay Program, 2009b).

The proposed "Chesapeake Clean Water and Ecosystem Restoration Act of 2009" (H.R. 3852/S. 1816) would provide significant new resources and new approaches to help restore the bay. Nutrient trading is one such approach. In a nutrient trading market, sources that reduce their nutrient runoff or discharges below target levels can sell their surplus reductions or "credits" to other sources. This approach allows those that can reduce nutrients at low cost to sell credits to those facing higher-cost nutrient reduction options. Nutrient trading, therefore, could allow sources of pollution such as WWTPs and municipal stormwater programs to meet their pollution targets in a cost-effective manner and could create new revenue opportunities for farmers, entrepreneurs, and others who implement low-cost pollution reduction practices.

The bill would establish a baywide nutrient trading market for the Chesapeake Bay watershed (Figure 1), allowing credits to be exchanged across state lines and among the watershed's nine major river basins. A baywide nutrient trading market would build on the existing and pending state-level nutrient trading programs in Maryland, Pennsylvania, Virginia, and West

Figure 1 | **A Baywide Nutrient Trading Market Would Involve the Entire Chesapeake Bay Watershed**



Source: Chesapeake Bay Program

Virginia. A baywide nutrient trading market could help states and sectors more cost-effectively achieve court-ordered nutrient pollution limits called Total Maximum Daily Loads (TMDLs) that are being developed by the EPA. These TMDLs will set limits on nutrient loads to the bay and its tributaries for the agricultural, wastewater, municipal stormwater, and other sectors.

Preliminary analyses indicate that the economic benefits of a baywide nutrient trading market for nitrogen could be significant for the agricultural, wastewater, and municipal stormwater sectors in the Chesapeake Bay watershed. Depending on credit prices, trading potentially could:

- Generate new revenue for the agricultural sector and other credit generators at an amount comparable to current levels of annual public funding for agriculture conservation cost-share programs for the bay;
- Reduce nitrogen removal costs for some in the wastewater sector by as much as 60 percent; and
- Save the municipal stormwater sector hundreds of millions of dollars per year.

RATIONALE FOR NUTRIENT TRADING

A number of features and benefits make nutrient trading an attractive approach for helping restore the Chesapeake Bay.

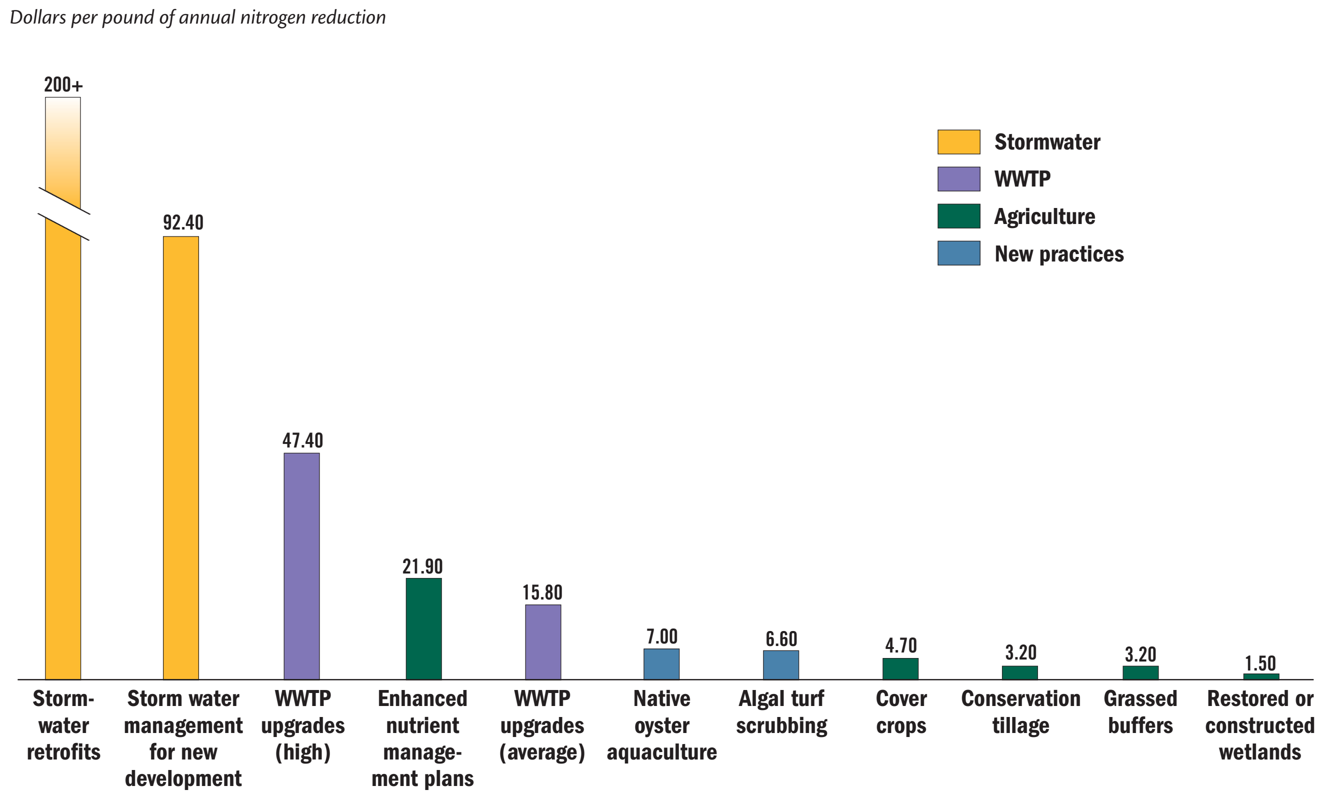
Trading could create revenue opportunities and reduce costs. The opportunity for nutrient trading arises because large differences in the cost to reduce a pound of nitrogen exist among various sectors and practices (Figure 2). In a trading market, sources that can reduce nutrients at low cost have an economic incentive to make reductions below target levels and then sell the credits to those facing higher costs. Trading therefore creates new revenue opportunities for farmers, entrepreneurs, and others who can generate nutrient credits. At the same time, trading allows those WWTPs and municipal stormwater programs that face higher nutrient reduction costs to save money by purchasing credits to meet a portion of their nutrient reduction obligations. As a result, trading could help achieve overall nutrient reductions in the Chesapeake Bay watershed in a more cost-effective manner.

Note that Figure 2 does not show credit prices in a nutrient trading market but, rather, current average costs to reduce a pound of nitrogen based on a number of studies. Prices are determined by the market dynamics of supply and demand. The costs in Figure 2 do not take into account the baseline or minimum practices that agriculture will have to implement prior to selling credits. Subsequent analyses in this working paper take baselines into account.

Trading could accelerate nutrient load reductions.

Nutrient trading encourages identification and adoption of the least expensive nutrient reduction practices, many of

Figure 2 | **Nitrogen Reduction Costs Differ Among Sectors and Practices, Creating Economic Opportunities for Credit Trading**



Source: U.S. EPA and Abt Associates, 2009; Wieland, et al., 2009; MDNR, 2008; Stewart, E. A., 2006; WRI analysis using WWTP upgrade costs from MDE and VDEQ.

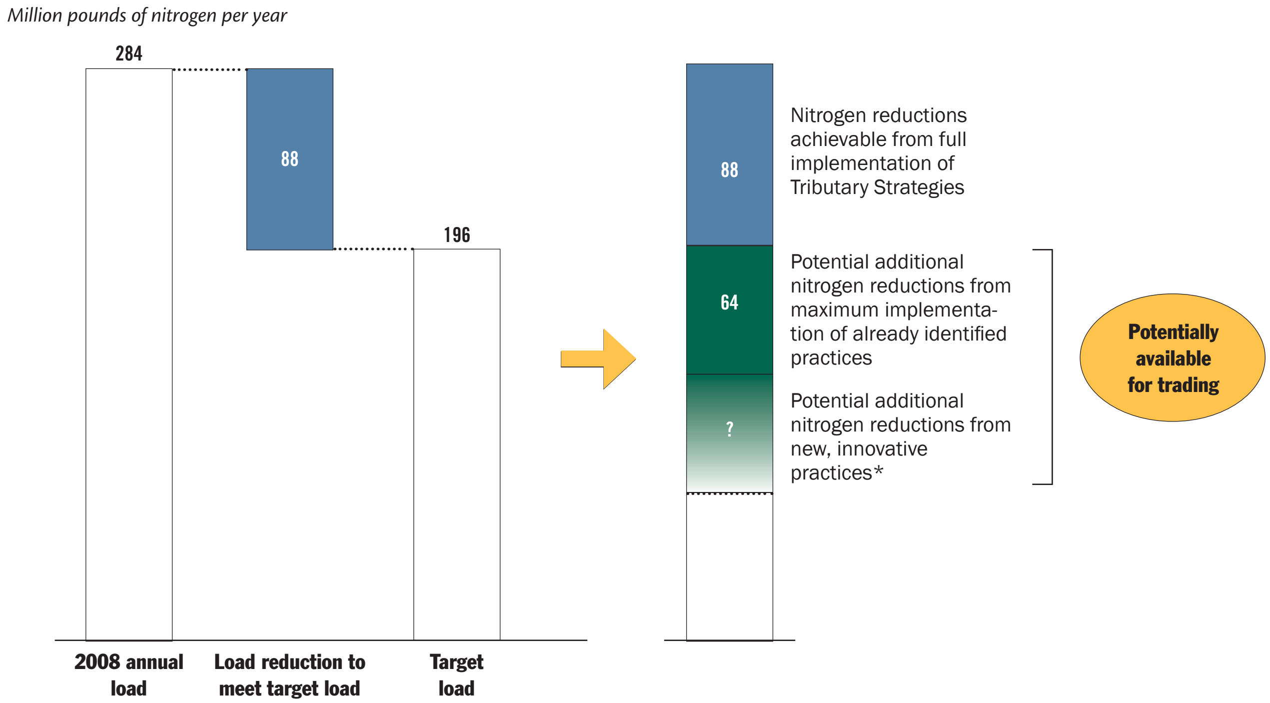
which are frequently faster and easier to implement. By achieving the most efficient, readily available nutrient reductions, trading can accelerate progress toward achieving clean water goals.

The cost-effectiveness of pollution-credit trading has been demonstrated. Trading has lowered the cost for achieving several air and water pollution goals. The 1990 Clean Air Act Amendments established an interstate trading program for sulfur dioxide emissions that allows power plants facing higher pollution reduction costs to purchase reductions from power plants facing lower pollution reduction costs. The program has reduced the cost of compliance by 43 to 55 percent compared to achieving the required reductions without trading (California Market Advisory Committee, 2007).

The state of Connecticut established a nitrogen trading program among 79 WWTPs to reduce pollution in the western end of Long Island Sound. Trading began in 2001. The program is projected to reduce the ultimate cost for the WWTPs to meet their waste load allocations under the Long Island Sound nitrogen TMDL by approximately 33 percent (CT DEP, 2009).

There are sufficient potential nitrogen reductions to restore the bay and support nutrient trading. The Chesapeake Bay Watershed Model estimates that the bay received 284 million pounds of nitrogen from all sources in 2008 (Figure 3). This load will have to be reduced by 88 million pounds in order to achieve the target load of 196 million pounds per year. This target load is the

Figure 3 | **Sufficient Nitrogen Reduction Opportunities Exist to Support Trading**



*** Innovative practices such as algal turf scrubbing and new manure management technologies are not currently listed in state Tributary Strategy implementation plans and their possible nutrient reductions are not yet quantified.**
Source: Chesapeake Bay Watershed Model Phase 5.2, 2009a.

Tributary Strategy load in the Chesapeake Bay Watershed Model Phase 5.2.

The Chesapeake Bay Watershed Model indicates that the needed 88 million pounds of reduction are available, as well as up to an additional 64 million pounds per year if all of the practices that have been identified in bay state cleanup plans are implemented (Koroncai and Shenk, 2009). These additional reductions could be sold as credits. Although not all of the 64 million pounds in additional reductions may be realized, a portion large enough to support the trading market is likely to be achievable. Further nitrogen credits could be generated by implementing new, innovative practices such as algal turf scrubbing, native oyster aquaculture, and new manure management technologies that are not yet included in bay state cleanup plans.

ESTIMATING THE ECONOMIC BENEFITS OF BAYWIDE NUTRIENT TRADING

What could be a potential range of economic benefits of baywide nutrient trading to the agricultural, wastewater, and municipal stormwater sectors? To answer this question and provide preliminary figures to get a sense of possible “scale,” the World Resources Institute (WRI) modeled three scenarios of a mature market. These scenarios are not intended to be predictive but rather to identify possible low and high ends of a range. Focusing solely on nitrogen, these scenarios combine estimated average credit prices, estimated credit supply, and estimated credit demand. All scenarios reflect nitrogen loads that are delivered to the mainstem of the Chesapeake Bay. The scenarios use the Chesapeake Bay Program’s Chesapeake Bay Watershed Model, available nutrient reduction cost information from a range of studies, expert interviews, and other data sources.

Table 1 | **Estimated Average Nitrogen Credit Prices Used in the Scenarios**

Scenario	Credit price	Description	Source
1	$8/lb	Represents a price within the price range of historical nitrogen credit transactions in the nascent Pennsylvania pre-TMDL nutrient credit market between 2006 and 2009. Credit prices in a mature baywide nitrogen trading market would likely be higher since demand for credits would be higher under a TMDL and growth pressure.	PA DEP, 2010
2	$20/lb	Represents an estimated minimum price at which farmers may be willing to sell credits. This estimate is based on annualized implementation, operations and maintenance, and opportunity costs for four agricultural practices (i.e., early cover crops, forest buffers, riparian grass buffers, constructed wetlands) that are implemented after a farm's baseline has been met. This estimate reflects the average of these costs and practices across five bay states.	MDNR, 2008; PA DEP, 2004; VDEQ, 2006; Wainger and King, 2007; Wieland et al., 2009
3	$50/lb	Represents a scenario where municipal separate storm sewer systems (MS4s) can buy credits and therefore greatly increase demand because of the high costs they are seeking to avoid. The WWTPs in the market are those facing high upgrade costs ($47/lb), and the $50/lb credit price exceeds their willingness to pay. The MS4s in the market are facing retrofit costs of $200+/lb and would be willing to pay the credit price of $50/lb. If credit supply were short of demand, MS4s could generally outbid WWTPs for most available credits.	MDE, 2009; VDEQ, 2006

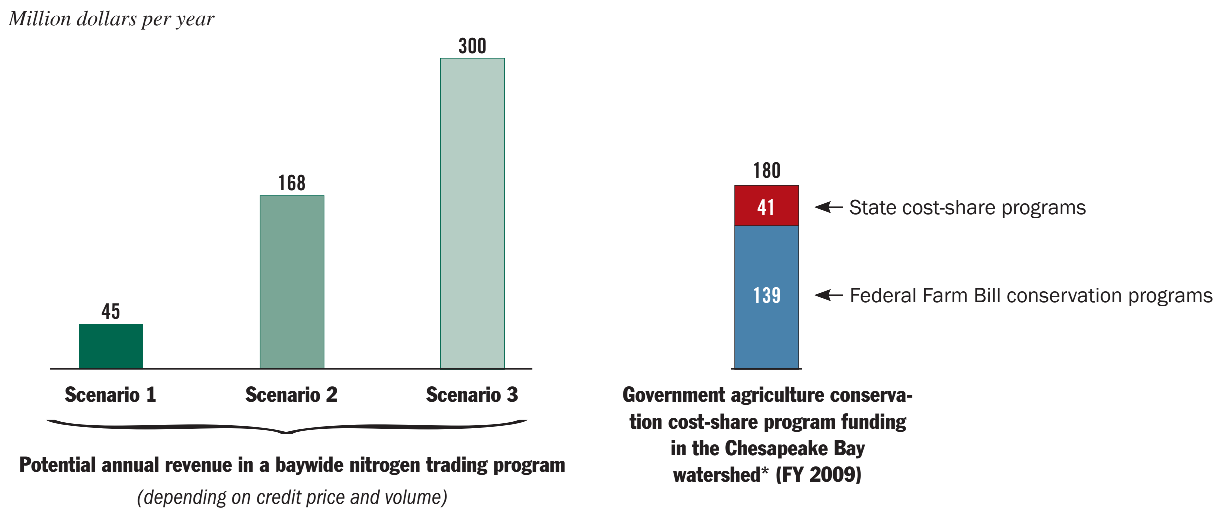
Table 1 summarizes the three credit prices while the appendix provides background information on assumed credit supply and credit demand. The estimated credit prices in Table 1 are the average for the scenario's credit sales, recognizing that prices in an operational market would fluctuate over time in response to the forces of supply and demand. The appendix also discusses the approach for handling trading ratios (uncertainty, reserve, and retirement ratios) in this analysis.

POTENTIAL BENEFITS TO THE AGRICULTURAL SECTOR

A baywide nutrient trading market could generate economic benefits for the region's agricultural sector.

Nitrogen credit trading could generate $45-$300 million per year in revenue, an amount comparable to current agriculture conservation cost-share programs in the bay. Farmers could earn

Figure 4 | **Potential Annual Revenue from Baywide Trading of Nitrogen Credits Could Be Comparable to Current Agriculture Conservation Cost-Share Programs**



*Farm Bill programs include EQIP, AMA, FRPP, WRP, CRP, CREP, and the Chesapeake Bay Watershed Program. State cost-share includes funding for the Chesapeake Bay watershed portions of MD, NY, PA, and VA. Data for the bay portions of DE and WV are not available.

Source: U.S. Department of Agriculture, 2009; Chesapeake Bay Foundation, 2010; WRI analysis using data from the Chesapeake Bay Watershed Model Phase 5.2

additional revenue if they sell nutrient credits generated by implementing practices that reduce fertilizer or manure runoff beyond baseline levels (Box 1). Preliminary scenario analyses suggest that the potential annual revenue from selling nitrogen credits in a baywide nutrient trading market could be comparable to the amount of public funds for agriculture conservation cost-share programs in the Chesapeake Bay (Figure 4). A trading market could generate an estimated $45 million to $300 million per year, the amount varying with average credit price and the number of credits sold (see Tables 1 and 2 for details underlying the scenarios). In comparison, the combined state and federal cost-share funds for farms in the Chesapeake Bay watershed was approximately $180 million in fiscal year 2009.

Nitrogen reductions in these scenarios come from implementation of practices that have been identified in bay state cleanup plans. The scenarios do not assume maximum implementation of all agriculture practices identified as reducing nitrogen below the Tributary Strategy target in the Chesapeake Bay Watershed Model Phase 5.2. Rather, credits supplied and sold in scenarios 1, 2, and 3 equate to 22 percent, 33 percent, and 24 percent, respectively, of post-Tributary Strategy nitrogen reductions possible in the agricultural sector according to the bay model.

Nonpoint source credit-generation opportunities are likely to extend beyond “traditional” farm practices. A trading market might stimulate implementation of innovative nutrient removal approaches such as algal turf scrubbing and manure waste-to-energy technologies. Such approaches could involve the agricultural sector in the form of land leases, manure sales, and other activities.

Nutrient trading could complement public agriculture conservation cost-share funding. The financial incentives from cost-share programs and nutrient trading markets are complementary. Farmers could use state and federal agriculture conservation cost-share funds to help finance baseline practices that are to be implemented before farmers can participate in nutrient credit markets. Farmers then can earn revenue by selling nutrient credits generated by additional practices that yield further nutrient reductions.

Box 1 | What is a Baseline?

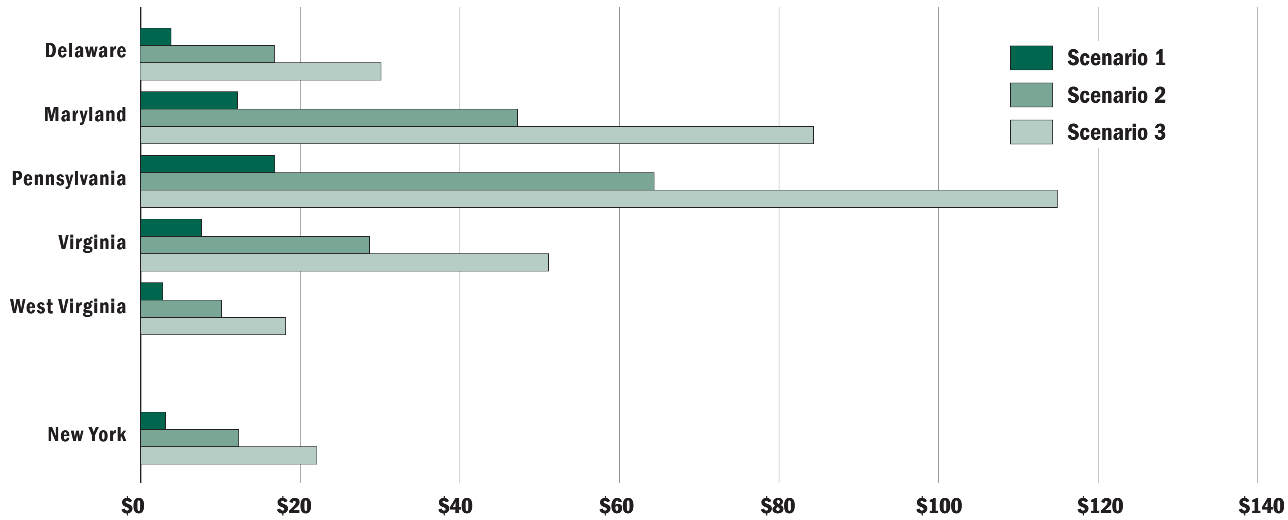
A baseline is a level of annual nutrient runoff or discharge that a source must meet before it is eligible to sell nutrient credits. Sources generate credits by reducing nutrient runoff or discharges below the baseline. For a WWTP, the baseline would be the annual waste load stipulated in its discharge permit. For a farm, the baseline could correspond to an individual farm’s share of the overall state reductions needed from the agricultural sector in order to achieve a water quality goal such as those specified in a state Tributary Strategy or TMDL. Baseline requirements may differ by state.

Farmers throughout the Chesapeake Bay watershed could benefit from baywide nutrient trading. The ability of a farm to generate credits will vary by farm type, soil, slope, location, best management practices implemented, and other factors. Preliminary analyses indicate that many farms (but not all) in each state and in each existing state trading basin could benefit from selling nitrogen credits. Figure 5 summarizes potential annual revenue per state from nitrogen credit sales in each of the three scenarios. Figure 6 summarizes potential annual revenue per basin in each of the three scenarios.

Figures 5 and 6 are based on the simplifying assumption that total revenue from credit sales is distributed in proportion to the state’s or river basin’s relative contribution to total potential nutrient reductions as provided by the Chesapeake Bay Watershed Model. To refine this assessment, further analysis is underway to account for potential differences in credit generation costs and abilities among basins and states.

Figure 5 | **Farmers in Each Bay State Could Earn Revenue From Selling Nitrogen Credits in a Baywide Trading Market**

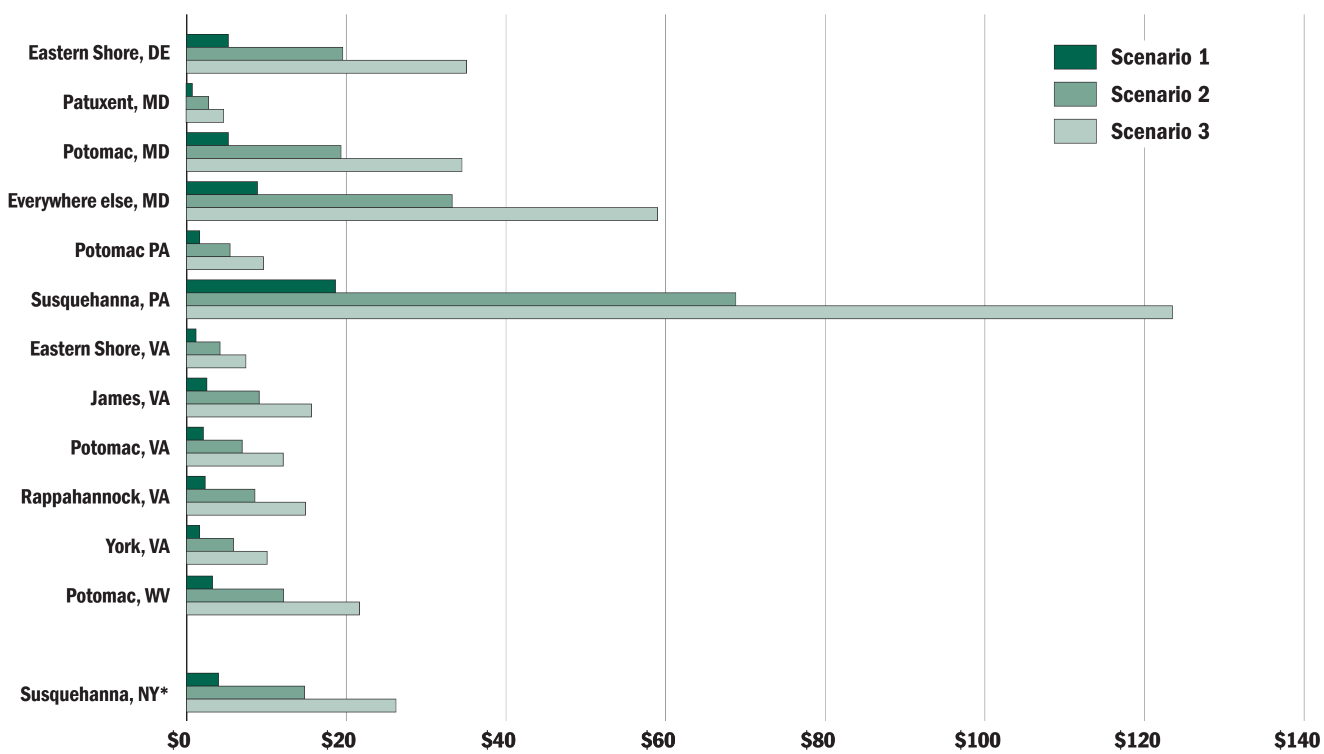
Estimated potential revenue, million dollars per year



*** Estimates for all states except New York are based on the Chesapeake Bay Watershed Model phase 5.2. Projections for New York are being revised in this model phase, thus this analysis uses phase 4.3 for New York.**
Source: Chesapeake Bay Watershed Model Phase 5.2 (for DE, MD, PA, VA, and WV), 2009a; Chesapeake Bay Watershed Model Phase 4.3 (for NY), 2008.

Figure 6 | **Farmers in Each Existing Bay Trading Basin Could Earn Revenue From Selling Nitrogen Credits in a Baywide Trading Market**

Estimated potential revenue, million dollars per year



*** Estimates for all states except New York are based on the Chesapeake Bay Watershed Model Phase 5.2. Projections for New York are being revised in this model phase, thus this analysis utilizes Phase 4.3 for New York.**
Source: Chesapeake Bay Watershed Model Phase 5.2 (for DE, MD, PA, VA, and WV), 2009a; Chesapeake Bay Watershed Model Phase 4.3 (for NY), 2008.

POTENTIAL BENEFITS TO THE WASTEWATER SECTOR

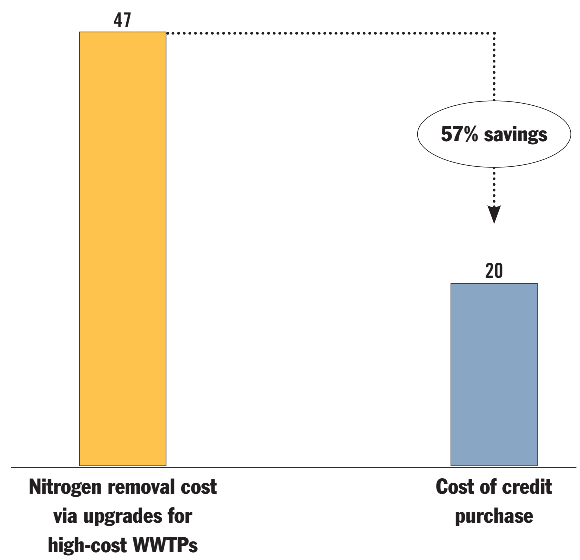
A baywide nutrient trading program could yield a number of benefits to WWTPs that face obligations to reduce their nutrient discharges.

Nutrient trading could yield nearly 60 percent cost savings for those WWTPs facing expensive upgrades. WWTPs within the bay watershed face a range of costs to remove nitrogen through treatment process upgrades. Some plants face low costs, some high. WWTPs facing high costs could meet some or all of their obligations less expensively and more rapidly by purchasing credits from farms, entrepreneurs, or other WWTPs that have lower nutrient reduction costs.

A WRI analysis of 109 WWTPs in Maryland and Virginia (comparable data from other states was not available) ranging in design capacity from 0.1 to 180 million gallons per day found that 40 plants face treatment process upgrade costs greater than an assumed credit price of $20 per pound of nitrogen (scenario 2). The weighted average annualized upgrade cost of these 40 plants is $47 per pound. Thus, if the credit price were $20 per pound, then purchasing credits would save WWTPs facing similar upgrade costs 57 percent relative to implementing treatment process upgrades (Figure 7). To the degree that the Maryland and Virginia WWTPs are reasonably representative of WWTPs in the bay states in terms of planning, design, and construction costs, this savings rate is indicative of the potential size of savings for other, similarly high-cost WWTPs in the region.

Figure 7 | **Wastewater Treatment Plants Facing Expensive Upgrades Could Realize Significant Savings By Purchasing Nitrogen Credits**

Dollars per pound of annual nitrogen reduction



Source: WRI analysis based on data from MDE, 2009, and VDEQ, 2006.

Trading could generate revenue for some WWTPs. WWTPs with low nutrient reduction costs could earn revenue by reducing discharges below target levels and then selling the surplus reductions as credits to other WWTPS, municipal separate storm sewer systems (MS4s), or others.

Trading could help accommodate growth. Maryland, Pennsylvania, Virginia, and West Virginia adopted policies that provide no nutrient allocations to new or expanding WWTPs. Without the availability of nutrient credits to offset their discharges, these new and expanded plants could not be built and population growth could not be accommodated. Trading would allow growth to continue without increasing the amount of nutrients delivered to the bay.

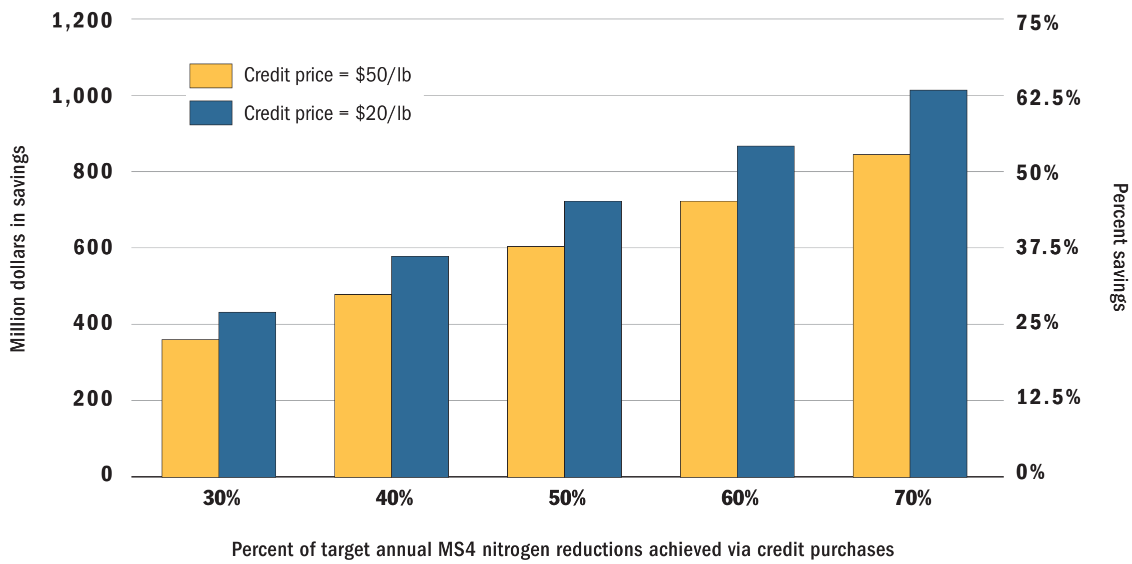
Trading could benefit water utility ratepayers. Ratepayers would save money on their utility bills when public-owned WWTPs meet nutrient reduction obligations at lower cost through nutrient trading.

POTENTIAL BENEFITS TO THE STORMWATER SECTOR

The cost to reduce nitrogen from stormwater systems through retrofits is among the most expensive measures in the Tributary Strategies (Figure 2). A baywide nutrient trading program could significantly lower costs for municipal stormwater programs throughout the Chesapeake Bay to achieve their target nutrient reductions.

Figure 8 | **MS4s Could Realize Significant Savings By Purchasing Nitrogen Credits Instead of Solely Relying on Stormwater Retrofits**

Annual savings relative to "no trading" when stormwater management practices cost $200/lb



Source: Chesapeake Bay Program, 2004b; WRI analysis using data from the Chesapeake Bay Watershed Model Phase 5.2.

Trading could complement existing approaches for meeting stormwater nutrient reduction targets. Trading can be an additional tool to help achieve target stormwater nutrient reductions. It can augment local stormwater programs in the following way. Most, if not all stormwater projects are done for local flood control, water quality, and stream restoration purposes. The need to reduce nutrient loadings to the bay is an additional goal or requirement that local jurisdictions must consider. The projects done for local purposes may or may not achieve enough reductions in delivered nutrient loads to the bay to meet these goals or requirements. Trading can come into play if they do not. If local jurisdictions have the option of covering their load reduction "shortfalls " by purchasing credits in the baywide nutrient market, they could save significant amounts of money compared to installing additional stormwater system retrofits solely for the purpose of reducing loads to the bay.

Nutrient trading could save MS4s hundreds of millions of dollars per year. Figure 8 summarizes potential savings to the Chesapeake Bay's MS4s of trading relative to no trading. In a "no trading" scenario, MS4s implement stormwater retrofits to meet 100 percent of their targets. The estimated average stormwater retrofit cost in this analysis is $200 per pound of nitrogen. This cost reflects the annualized capital, maintenance, and operation costs of stormwater practices such as urban filtration, urban filtering, and wet ponds (Chesapeake Bay Program, 2004a and 2004b), adjusted for inflation and the latest stormwater practice efficiencies. There is little present literature on the cost per pound of nutrient removal from stormwater retrofits. This cost is most likely at the low end of the range for stormwater and therefore the total estimated savings may be conservative.

In a "trading" scenario, MS4s are assumed to purchase nitrogen credits to meet 30, 40, 50, 60, or 70 percent of their nitrogen reduction targets and implement stormwater retrofits for the remainder. The analysis assumes that MS4s would not purchase credits to meet 100 percent of reduction targets since MS4s will implement stormwater retrofits to address local water runoff and quality issues in accordance with local stormwater needs and priorities.

Figure 8 highlights several points. First, MS4s could save hundreds of millions of dollars per year if they purchase credits in lieu of implementing retrofits to meet at least a portion of their nitrogen reduction targets. Second, the relative total savings would be on the order of 25 percent to 63 percent. Third, the amount and percent of savings would increase with increasing "credit utilization"—the use of credits to meet MS4 nitrogen reduction targets.

Increasing credit utilization is central to reducing MS4 costs. Sensitivity analyses indicate that an increase in credit utilization has a much greater impact on total savings than does a proportional change in credit price. Therefore, a baywide nutrient trading market that facilitates participation of MS4s would maximize potential cost savings and help achieve bay restoration in the most cost-effective manner.

SOME ISSUES TO BE ADDRESSED

Recent discussions about Chesapeake Bay nutrient trading highlight questions about how trading would work, as well as some concerns. All such questions and concerns need to be addressed as trading program development moves forward. The state trading programs are relatively new and will evolve and improve as the states gain experience with them. Design of a baywide trading program has not yet begun. As program development goes forward, there will be ample opportunity to answer all such questions and fully consider all issues and concerns that arise.

The following preliminary responses address some key questions that have been raised:

How can water quality trading deal with uncertainty? Nutrient trading programs must address the scientific uncertainties associated with the discharge of nonpoint source nutrient loads. The nonpoint source uncertainty can be dealt with in a number of ways such as monitoring to verify actual loads, applying discounts to calculated nutrient reductions to ensure environmental integrity, using approved loading rates, applying nutrient removal rates on land management practices (i.e., rates and efficiencies based on peer-reviewed scientific analyses), and directly measuring mass loads removed from the water body. Whatever the source of the uncertainty, the trading program design should incorporate measures to address it. The measures chosen will depend on the nature of the nonpoint sources involved. Uncertainty ratios, in which more credits are required than can be used by the buyer, are one method of accounting for uncertainty. In general, proposed trades involving innovative or "unproven" credit generation methods will require greater attention to the uncertainty issues in the credit certification, trade approval, and annual verification processes.

How can trading programs ensure that local water quality is protected? When a WWTP buys nutrient credits, it can then discharge a higher nutrient load to its receiving water than if it had upgraded its facility to achieve additional nutrient removal. There is concern that these local discharges could result in local water quality impairment (i.e., violation of a water quality standard).

To protect against local impairments, both EPA's nutrient trading policy and the Clean Water Act prohibit trades that would result in the violation of water quality standards. Existing permitting requirements for point sources—including WWTPs, municipal stormwater discharges, and concentrated animal feeding operations (CAFOs)—should ensure that impairments do not result from trades. For example, a WWTP buying credits will have the trade incorporated into its discharge permit by the state regulatory agency. A required component of this process is an evaluation by the permit-issuing agency of the water quality impact of the proposed discharge. Regulatory agencies typically use water quality modeling to make this assessment, and if the modeling shows that the proposed discharge would result in violations of a water quality standard, the proposed discharge would not be permitted. The Clean Water Act forbids the permitting authority from issuing a permit that would result in violations of a water quality standard. Therefore, an impairment would not occur as long as the required permitting procedures are followed.

How can compliance risk be reduced for regulated credit buyers? Some regulated credit buyers might be hesitant to buy nutrient credits out of concern that if the credits do not materialize, they will be in violation of their discharge permit and face a federal or state enforcement action under the Clean Water Act. While this legal liability cannot be transferred to the supplier of the credits, there are market design features that can significantly reduce this risk for credit buyers. For instance, the buyer could be given a reconciliation period after the end of the year during which it could acquire credits (generated in the same year) from other sources if necessary to cover any shortfall. If this reconciliation period were coupled with a reliable insurance pool of credits maintained for just such a purpose, then the risk of noncompliance is almost negligible.

Credit buyers may not want to interact with many small, individual credit sellers. How can this be avoided? Many buyers would find it unattractive to contract with many small credit suppliers because it would increase administrative and transaction costs, increase the likelihood of contract defaults, and create large demands on staff resources. An alternative would be to contract with a single supplier that essentially functions as a credit retailer. Such entities exist. Commonly known as "credit aggregators," they can provide a number of important functions and benefits including:

- Acquiring credits from farmers and landowners;
- Providing technical assistance and financing to credit generators;
- Ensuring that all federal, state, and local requirements are met; and
- Assuming risks and liabilities for credit supply.

CONCLUSION

Establishing a baywide nutrient trading market could help reduce nutrient pollution in the Chesapeake Bay in the most cost-effective, timely manner. It could allow sources of pollution such as WWTPs and municipal stormwater programs to inexpensively meet their pollution targets and could create new revenue opportunities for farmers, entrepreneurs, and others who implement low-cost pollution reduction practices.

Preliminary analyses indicate that the economic benefits of a baywide nutrient trading market for nitrogen could be significant. Municipalities could save hundreds of millions of dollars each year on stormwater nutrient reductions. Wastewater treatment plants could see nitrogen reduction costs lowered by as much as 60 percent in some cases. The agricultural sector could earn $45 million to $300 million per year in new revenue, an amount comparable to current levels of annual public funding for agriculture conservation cost-share programs for the bay. In short, nutrient trading could harness market forces to help save the bay.

APPENDIX

Estimated annual credit supply

In the three scenarios, credits are nitrogen reductions generated by a variety of agriculture practices after a farm's baseline has been met. Based on the Chesapeake Bay Watershed Model, the number of possible credits reflects nitrogen reductions from agriculture beyond the level required to meet the Chesapeake Bay Tributary Strategy. These reductions come from implementation of practices that have been identified in bay state cleanup plans. Nonpoint source credit-generation opportunities are likely to extend beyond "traditional" farm practices, too. A trading market might stimulate implementation of innovative nutrient removal approaches such as algal turf scrubbing and manure waste-to-energy technologies. Such approaches could involve agriculture in the form of land leases, manure sales, and other activities.

The scenarios do not assume maximum implementation of all agriculture practices identified as reducing nitrogen below the Tributary Strategy target in the Chesapeake Bay Watershed Model Phase 5.2. Rather, credits supplied and sold in scenarios 1, 2, and 3 equate to 22 percent, 33 percent, and 24 percent, respectively, of post Tributary Strategy nitrogen reductions possible in the agricultural sector according to the bay model.

Estimated annual credit demand

The scenarios assume that WWTPs and MS4s are the major buyers of nitrogen credits. Table 2 outlines three possible amounts of credits purchased per year. These estimates are conservative in that possible credit demand by MS4s due to urban/suburban growth and expanded development is not included due to insufficient data at the time of publication. Likewise, the scenarios do not include possible demand by WWTPs if policies were to change in Maryland and Virginia to allow WWTPs to purchase credits in lieu of implementing upgrades.

Handling of trading ratios in the economic analysis

The analysis of potential credit prices and revenue associated with credit sales does not reflect the potential impact of the uncertainty, retirement, and reserve ratios that are required by the current state trading programs. One reason

Table 2 | **Estimated Nitrogen Credit Demand Used in the Three Scenarios**

Scenario	Number of Credits Purchased Per Year	Description	Source
1	5.6 million	WWTPs: WWTPs in Pennsylvania and West Virginia that are projected to exceed their waste load allocations over the coming decade buy credits from nonpoint sources after exhausting credit supply from other WWTPs. WWTPs in Maryland do not purchase credits since current state policy requires WWTPs to upgrade to best available technology. Virginia WWTPs trade with other WWTPs and do not purchase nonpoint source credits in accordance with current regulatory restrictions. MS4s: MS4s throughout the bay watershed buy credits to meet 40 percent of their load reductions needed to meet Tributary Strategy goals.	Selman et. al., 2009 Chesapeake Bay Watershed Model Phase 5.2
2	8.4 million	WWTPs: Same as above but in addition new and expanding WWTPs in all bay states buy credits to offset expansion. Estimated expansion is based on WWTP capacity by river basin, projected population growth, and 100 gallons/day/person. MS4s: MS4s throughout the bay watershed buy credits to meet 70 percent of their load reductions needed to meet Tributary Strategy goals.	Selman et. al., 2009 Chesapeake Bay Watershed Model Phase 5.2
3	6.0 million	WWTPs: Only new and expanding facilities purchase credits. WWTPs with existing waste load allocations choose to implement upgrades instead of buying credits. MS4s: MS4s throughout the bay watershed buy credits to meet 70 percent of their load reductions needed to meet Tributary Strategy goals.	MDE, 2009; VDEQ, 2006 Chesapeake Bay Watershed Model Phase 5.2

is that the states vary widely in the ratios they have adopted. For instance, Virginia requires an uncertainty ratio of 2:1 (a regulated buyer must purchase 2 credits (or "offsets") for every 1 pound of discharged nitrogen it needs to offset) for all trades involving nonpoint sources, and West Virginia has proposed a ratio of 1.2:1. Pennsylvania does not require an uncertainty ratio but establishes a credit reserve ratio of 1.1:1. Maryland requires no uncertainty ratio if the best management practice or practice that is certified to generate the credits is one for which the Chesapeake Bay Program has established long-term average efficiencies that have been incorporated into the Bay Watershed Model. These efficiencies are the result of a rigorous scientific peer-review process that also considered the uncertainty associated with each practice and set the efficiencies in a conservative manner based on the uncertainty. Hence, uncertainty has already been addressed for these BMPs and uncertainty ratios applied to individual trades involving them may not be warranted. If a baywide trading program were in operation in the future, Virginia, Pennsylvania, and West Virginia could potentially decide to eliminate the universal requirement for an uncertainty ratio.

Likewise, reserve and retirement ratios vary among states. Pennsylvania requires a 10 percent reserve/retirement ratio, Maryland 10 percent (retirement only), and West Virginia 20 percent. Virginia does not require one. As with uncertainty ratios, the states may choose to modify their existing requirements in light of a baywide trading program.

Uncertainty, reserve, and retirement ratios will likely have some impact on the economics of nutrient trading under a baywide program. This analysis does not currently address these impacts because of the wide variability of state requirements and uncertainty about the retention of such requirements by the states if a baywide program were in place and perhaps altered or eliminated the need for some of them.

SOURCES

California Market Advisory Committee. 2007. "Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California." Recommendations to the California Air Resources Board, June 30, 2007.

Chesapeake Bay Foundation. 2010. Personal communication, January 21, 2010.

Chesapeake Bay Program. 2004a. "Chesapeake Bay Watershed BMP Potential Load Reductions and Cost-effectiveness Study." Annapolis, MD: Chesapeake Bay Program.

Chesapeake Bay Program. 2004b. "Preliminary Tributary Strategy Cost by State - Revised 10/26/04." Annapolis, MD: Chesapeake Bay Program.

Chesapeake Bay Program. 2008. Chesapeake Bay Watershed Model Phase 4.3.

Chesapeake Bay Program. 2009a. Chesapeake Bay Watershed Model Phase 5.2.

Chesapeake Bay Program. 2009b. "Bay Barometer: A Health and Restoration Assessment of the Chesapeake Bay and Watershed in 2008." Annapolis, MD: Chesapeake Bay Program.

Connecticut Department of Environmental Protection (CT DEP), Bureau of Water Protection and Land Reuse. September 2009. *Connecticut's Nitrogen Credit Exchange – An Incentive-based Water Quality Trading Program*. Hartford, CT: CT DEP.

Koroncai, B., and G. Shenk. October 23, 2009. "Methodology to Distribute Target Loads," Fall Principals' Staff Committee Meeting, Washington, DC. Available online at http://archive.chesapeakebay.net/calendar.cfm?eventdetails=10431, attachment D, slide 4.

Maryland Department of Natural Resources (MDNR), Fisheries Service, Oyster Advisory Commission. 2008. December 20, 2008 conference proceedings: Oyster restoration economic and ecologic cost offsets. Available online at http://www.dnr.state.md.us/fisheries/oysters/mtgs/122007/meeting122007.html.

Maryland Department of the Environment (MDE). 2009. "Bay Restoration Fund Enhanced Nutrient Removal Program."

Pennsylvania Department of Environmental Protection (PA DEP). December 2004. *Pennsylvania's Chesapeake Bay Tributary Strategy*.

Pennsylvania Department of Environmental Protection (PA DEP). January 2010. "PA Nutrient Trading." Available online at http://www.dep.state.pa.us/river/Nutrient%20trading.htm.

Selman, M., et. al. 2009. *Nutrient Trading in the Chesapeake Bay Region: An Analysis of Supply and Demand.* Washington, DC.: Pinchot Institute for Conservation.

Stewart, E. A. 2006. Preliminary Engineering Assessment for a Comprehensive Algal Turf Scrubber - Based Nutrient Control Program for the Suwannee River in Florida. Hydromentia, Inc, Ocala, Florida, for the Suwannee River Water Management District, Live Oak, Florida.

U.S. Environmental Protection Agency (US EPA) and Abt Associates Inc. 2009. *Preliminary*, *Chesapeake Bay: Next Generation of Tools and Actions to Restore the Bay: Preliminary Economic Analysis of Options*. Washington, DC.: U.S. Environmental Protection Agency.

Virginia Department of Environmental Quality (VDEQ). 2006. "Water Quality Improvement Fund Point Source Program FY06 Grant Application Review Worksheet."

Commonwealth of Virginia. 2005. *Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy*.

Wainger, L., and D. King. 2007. *Establishing Trading Ratios for Point – Non-Point Source Water Quality Trades*. University of Maryland Center for Environmental Science Technical Report No. TS-523-07.

Wieland, R., et al. 2009. *Costs and Cost Efficiencies for Some Nutrient Reduction Practices in Maryland*. Maryland Department of Natural Resources Coastal Program.