INNOVATION IN AGRICULTURAL CONSERVATION FOR THE CHESAPEAKE BAY: EVALUATING PROGRESS & ADDRESSING FUTURE CHALLENGES

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CHESAPEAKE BAY PROGRAM

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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 on measures to restore and protect the Chesapeake Bay. As an advisory committee, STAC reports quarterly to the Implementation Committee and annually to the Executive Council

STAC members come primarily from universities, research institutions, and federal agencies. Members are selected on the basis of their disciplines, perspectives, and information resources needed by the Chesapeake Bay Program.

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PREFACE

The Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program (CBP), in cooperation with the U.S. Department of Agriculture, Agricultural Research Service and the Cooperative State Research, Education and Extension Service, Mid-Atlantic Water Quality Program, convened a forum on innovation in agricultural conservation on May 5-6, 2003. Leading experts on various aspects of agricultural nutrient pollution control from the Bay region and beyond discussed current, emerging, and future practices, technologies, and policies that can help to achieve needed nutrient reduction goals within a sustainable agricultural system. Twenty-eight speakers and discussion leaders provided their vision for innovation, while discussion among scientists, engineers, economists, and practitioners broadened and diversified the vision. The forum included factors that influence the adoption of innovation and policies and approaches to implementing innovation.

This White Paper identifies emerging science-based practices, programs, and policies that can be implemented within three years as well as develop efforts that will aid nutrient reduction within a 10-year timeframe, including the research and education necessary for that implementation. The White Paper draws upon the presentations and discussion among experts at the Forum with considerable input from the editing and review panel. Interpretations of the information presented rest principally with the authors. We would like to thank all of the participants at the Forum, both the presenters and those who took part in the discussion. The paper, titled "Innovation in Agricultural Conservation for the Chesapeake Bay: Evaluating Progress, Addressing Future Challenges," is available on line at http://www.chesapeake.org/stac/workshop.html.

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SUMMARY RECOMMENDATIONS FOR INNOVATIONS IN AGRICULTURAL RESEARCH CONSERVATION FOR THE CHESAPEAKE BAY WATERSHED

These recommendations are the result of a two-day forum on innovation in agricultural conservation sponsored by the Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program (CBP). Leading agricultural scientists and practitioners from the Mid-Atlantic and beyond gathered to discuss research needs and opportunities to reduce the amount of nutrients delivered to the Chesapeake Bay. The authors drew upon the discussions and interpretations of data presented at the forum and reviewed by a STAC panel of science experts.

Significant nutrient reductions have been achieved in the last decade but there is a need to better quantify the effectiveness of existing strategies and to develop new strategies to meet the challenge of new, more aggressive nutrient reduction goals while maintaining and enhancing farm profitability.

The major summary recommendations presented here are designed to advance discussions on improvements and, ultimately, system changes to agricultural best management practices in the watershed, with the objective of overcoming water quality impairments while sustaining production agriculture.

The recommendations, unless otherwise stated, pertain equally to animal and crop agriculture and include research needs, management/policy directions, and implementation steps. They address the continuum of short-term revisions of current practices to new tools, systems changes, and funding alignments.

These summary recommendations are discussed in greater depth in the Forum White Paper (available at http://www.chesapeake.org/stac/workshop.html) which provides descriptions of both near-term adjustments and long-term changes in greater detail.

The major summary recommendations presented here are designed to advance discussions on improvements and, ultimately, system changes to agricultural best management practices in the watershed, with the objective of overcoming water quality impairments while sustaining production agriculture.

Research Initiatives

Modifications to Existing Program/Practices

Research on Best Management Practices must establish the magnitude of actual nutrient loss reduction from agricultural production systems—crop and animal—under real world applications. There is a critical need for comprehensive long-term small watershed BMP research, with concurrent plot research, to determine watershed efficiencies and longevity for current BMPs under varying climate, physical, and cultural conditions

New Tools

New BMPs must go beyond tactical controls (e.g., erosion, storage sheds) in addressing nutrient balances at the farm gate and watershed level that will result in improved water quality and enhanced BMP performance.

Research is needed to provide novel strategies for balancing nutrients. Emerging or expanding industries such as horticulture, aquaculture, organic farming, and the expansion of the swine industry should incorporate nutrient balancing criteria in BMPs to minimize water quality impacts.

Systems Change

Research to address major nutrient imbalances associated with intensive animal production and nutrient-rich crop specialization at the watershed scale must consider a systems approach that incorporates alternative crops and/or production management and meaningful incentives to balance nutrient flow and acceptable nutrient stocks.

Funding Alignments

State and federal support for agricultural research and education funding in the Chesapeake Bay should prioritize links between water quality improvement and agricultural profitability as well as identify areas of innovation.

Management/Policy Initiatives

Modifications

Farming operations actively participating in nutrient balancing and continuous water quality monitoring should be considered a high priority for on-farm research support and technical assistance as well as assistance in developing marketable nutrient credits. These operations would have the opportunity for greater flexibility in how they reduce nutrient loadings and be considered low priority for regulatory compliance monitoring.

New Tools

Existing incentive programs should be restructured toward programs that fund performance-based pollution prevention, (e.g., waste management solutions to nutrient inputs or alternative crops instead of correcting poor performance or addressing the results of excessive nutrients).

Chesapeake Bay states should reorder cost-share support and petition federal agencies to prioritize in-state farm grants and subsidies to operations in impaired watersheds participating in performance-based farming systems. This support would also prioritize cost-share funding and the level of funding to practices and watersheds that provide the greatest nutrient reduction for the cost and are consistent with CBP goals.

System Changes

Chesapeake Bay states should pursue aligning environmental regulatory authority and state agricultural loans and grants toward research and technical assistance supporting a restructuring of agricultural operations in nutrient-impaired watersheds that may include incentive payments or alternative crop research for operations more compatible with maintaining good water quality, alternative energy sources, food security, and multiple profit channels.

Implementation Initiatives

Modifications to Current Practices

Current approaches to BMP efficiency estimates in the Chesapeake Bay watershed should continue but undertake a major revision of BMP efficiency assumptions, data reporting, operation, and maintenance.

New Tools

Current BMP model "average practice" efficiencies need to be reduced from ideal, research plot-based estimates to those that better reflect broad watershed applications and variability in implementation.

STAC should provide leadership in developing a strategic plan for university and public programs to structure consistent coordinated research on agricultural BMP systems and CB water quality.

System Changes

Extension education must engage private sector participants (e.g., dealers, feed industry, integrators, distributors, contract holders) in the implementation of nutrient balances through diet inputs, integrated farming, etc. to allow for more strategic versus tactical watershed-based decisions.

Funding

Existing water quality monitoring programs need to be funded and reorganized to target priority nutrient-impaired subwatersheds and allow for the continuous monitoring of BMPs as part of a systems approach to farm management. There is a need to identify opportunities to pursue partnerships with industry and producer organizations for nutrient balance assessments, as well as comprehensive public/private funding programs, for integrating systems farming research with increased profitability.

Introduction

Restoring the Chesapeake Bay will require nutrient—nitrogen and phosphorus—reductions far beyond those already achieved. In April 2003, Maryland, Virginia, Pennsylvania, New York, Delaware, West Virginia, the District of Columbia, and the U.S. Environmental Protection Agency agreed to an unprecedented partnership to reduce nutrient loads delivered to the Bay by nearly 50 percent from 1985 levels. The new goals of 175 million pounds per year of delivered nitrogen and 12.8 million pounds per year of delivered phosphorus represent estimated levels that must be attained to remove nutrient impairments to water quality in the Bay and its tidal tributaries. That, in turn, will ensure the protection of living resources and critical habitats: migratory and open water fish, Bay grasses, shellfish, and deep channel refuges.

Watershed farmers have made significant progress implementing conservation and nutrient management plans as well as traditional conservation practices in the last two decades. But with the Chesapeake Bay Program's Watershed Model estimating that 41 percent of the nutrients delivered to the Bay still originate from agriculture, it is clear that this sector—along with urban, suburban, and other sources—will need to make additional major reductions while ensuring that past progress is maintained.

Developing effective strategies to meet these goals requires a scientific assessment of current, emerging, and potential practices, programs, and policies to ensure that all opportunities for reduction are realized. Experts at the May 2003 Scientific Forum on Innovation in Agricultural Conservation for the Chesapeake Bay discussed how much more can be achieved with current approaches; what new technologies have a sufficient research base that could lead to implementation in the near future; and what areas of research look promising for advancing nutrient reduction efforts within 10 years. An overarching theme of the discussions was the need to pursue performance-based research, conservation practices, and policies that link water quality enhancement with the sustainability of agriculture.

With the Chesapeake Bay Program's Watershed Model estimating that 41 percent of the nutrients delivered to the Bay still originate from agriculture, it is clear that this sector—along with urban, suburban and other sources—will need to make additional major reductions while ensuring that past progress is maintained.

Background

The Chesapeake Bay is the nation's largest and, historically, most productive estuary. It has been in some stage of decline for more than 200 years with sedimentation, the loss of wetlands, overfishing, and toxicant and pathogen pollution being the principle causes of its decline prior to 1950. Congress authorized a major research effort in the mid-1970s to determine the cause of the accelerated decline of the Bay's habitat and living resources since the 1950s. It became evident during the research that nutrient overenrichment was the principal cause of the more recent systemic decline. The Chesapeake Bay Program (CBP), formed in 1983 to restore the estuary, is a voluntary partnership comprising Maryland, Virginia, Pennsylvania, the District of Columbia, and the U.S. Environmental Protection Agency.

Nutrient overenrichment causes excessive algal growth which can result in areas of low to no oxygen in most deep waters and some shallow creeks and rivers from May through September (See: *The Role of Nutrient Runoff in Algae Growth* on page 7). This effectively eliminates the cooler, deeper waters as warm weather habitat for finfish and shellfish, and makes it difficult for bottom-dwelling organisms to survive. In shallow tidal rivers and creeks, low oxygen is responsible for many reported fish kills, particularly in late spring and early summer. Excessive algal concentrations also impair clarity in shallow water and, in tandem with sediments, are responsible for the loss of most of the underwater grasses in the tidal shallows (0.5-2.0 meter depths). These grasses are critical habitat for many finfish and crab species. They also improve water quality and clarity by buffering shorelines from wave action, filtering sediment, and absorbing nutrients (Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis, Maryland; Region 3 Water Protection Division, Philadelphia, Pennsylvania, in coordination with Office of Water, Office of Science and Technology, Washington, D.C., April 2003. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries*, EPA 903-R-03-002).

Nutrient reduction steps began in 1987, when the Chesapeake Bay Program adopted a goal calling for a 40 percent nutrient reduction. The goal was later modified to cover only the portion of nutrient loadings considered "controllable" at that time, excluding such sources as septic systems, air pollution, and others. As a result, the 40 percent goal effectively became a 20 percent reduction for nitrogen and a 31 percent reduction for phosphorus. Nonetheless, significant progress toward the goal was made by 2000 through the implementation of agricultural best management practices (BMPs) and urban point source controls, largely wastewater treatment plants. Progress has been estimated by entering reported practice implementation and associated nutrient reduction efficiencies into the state-of-the-art Chesapeake Bay Watershed computer model. The model projected that while phosphorus loadings were reduced from 27 million pounds to 19 millions pounds, nearly achieving the goal, nitrogen loadings were reduced from 337 million to 285 million, more than 25 percent short of the goal. Actual monitoring data at the fall line on major rivers (the free-flowing area of the river immediately above the reach of the tide) showed some progress, but not as much as the watershed model projected. Meanwhile, observed data in the tidal portions of the same rivers and main part of the Bay showed little impact from implementation efforts. While the discrepancies are not completely understood, factors such as lag times from groundwater, instream and tidal nutrient processes, model limitations, and overly optimistic assumptions regarding BMP performance are widely considered to be the principle causes of the model's inability to reproduce observed conditions. This document will examine the BMP performance assumptions at length.

When the Chesapeake 2000 agreement was signed in June 2000, it contained more than 100 commitments on a wide range of topics. The most significant commitment was to remove the Bay from the Clean Water Act's list of impaired waters by 2010. The last three years have been spent determining the nutrient and, to a lesser extent, sediment reductions needed to restore dissolved oxygen, chlorophyll a, and clarity to unimpaired levels. If, at a minimum, strategies to remove these impairments are not in place and being actively implemented by 2010, a regulatory TMDL (total maximum daily load—a pollution loading cap placed on an impaired water body to return its water quality to the state where it supports designated uses) may be initiated for the Chesapeake Bay and its tidal tributaries. Thus, the new nutrient loading goals and associated tributary-specific nutrient and sediment control strategies are an effort to accomplish the regulatory objectives in a cooperative, voluntary/regulatory program. This creates an even greater need for scientifically based goals and implementation strategies that can withstand scrutiny by regulators, stakeholders and, in all likelihood, the judicial system.

Current BMP Definitions, Efficiencies & Implementation Assumptions

Much of the modeled progress toward the 2000 nutrient reduction goals came from state reports detailing implementation of agricultural BMPs between 1993 and 2000. Both structural BMPs, (e.g., lagoons, waste storage sheds) and agronomic management practices (e.g., cover crops, nutrient management) are included in the strategies states developed to reduce nutrient loads in 16 major Bay watersheds. The BMP definitions are coordinated and generally consistent among states because of CBP efforts. Each practice has an approved definition, reduction efficiency, and tracking/reporting procedure (M. Palace, J. Hannawald, L. Linker, G. Shenk, J. Storrick, and M. Clipper, 1998. *"Appendix H: Tracking Best Management Practice Nutrient Reductions in the Chesapeake Bay Program"* in *"Chesapeake Bay Watershed Model Application and Calculation of Nutrient and Sediment Loadings"*. EPA 903-R-98-009, CBP/TRS 201/98. Chesapeake Bay Program Office, Annapolis, Maryland). The CBP appears to be the only program in the nation to have developed such a sophisticated quantitative BMP tracking and crediting system (i.e., assigning numerical load reduction efficiencies to various practices for nitrogen and phosphorus). The fact that it has been in existence for 10 years, has undergone two self-imposed internal re-evaluations, and has openly identified a list of weaknesses and needed improvements, is laudable. *The scientific community remains somewhat skeptical of the quantitative use of model-based results such as Baywide nutrient reductions based on reported BMP implementation and efficiency assumptions when they are used to shape policy. Progress is likely to be overestimated as evidenced by the overprediction of observed nutrient reductions by the watershed model.*

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BMP Definitions & Efficiencies

An evaluation of the BMP crediting system reveals both strengths and weaknesses in the model. While the definitions of specific practices appear to be consistent among states in the watershed, the model itself is limited in its capacity to simulate different land uses and crops to which any individual practice is applied. The watershed model simulates a "composite crop" for each of the watershed segments, which range in size from hundreds to thousands of square kilometers. Developing a meaningful and accurate approach for determining the appropriate Baywide efficiency rating of a BMP is challenging. The CBP has tried to improve accuracy by compensating for the overestimation of nutrient reduction efficiencies caused by

The Role of Nutrient Run-Off in Algae Growth

At the base of the marine food chain are the microscopic algae that serve as the ultimate source of food for all marine life. The typical drop of water is teeming with thousands of cells of many different species.

The growth of microscopic algae is controlled by the rate at which nutrients are supplied. Microscopic algae require many of the same nutrients that are used as fertilizers to grow crops, gardens, and lawns. Plants, including microscopic cells, grow better when there are more nutrients available, and can attain higher abundance in the water. Microscopic cells have a huge range of diversity, and it is for this reason that certain species grow only under certain environmental conditions. As the quantities of nutrients have increased in many regions, the type of nutrients entering the waters has changed also. These changes may have profound consequences for the microorganisms. Among the thousands of species of microscopic algae, or phytoplankton, that provide food for marine life, there are a few dozen species that can cause fish kills, contaminate seafood with toxins, cause serious human health impacts, and alter marine ecosystems in ways that are harmful. Under certain conditions, these algae may grow to extremely dense conditions and form what we call "blooms." Under other conditions, some species of algae may produce compounds that are toxic to either shellfish, fish, or, in some cases, humans.

There is growing evidence that these harmful algal species are increasing in frequency of occurrence in the Bay and in many other parts of the world. Although much press was given to the outbreaks of *Pfiesteria* in the late 1990s, *Pfiesteria* is only one of many harmful algal species present. Just as one may use different fertilizer formulas depending on whether one is growing grass, roses, or tomatoes, different proportions of nitrogen and phosphorus may be selectively stimulating those species in the water that are harmful. Many of the harmful species have fascinating, and very effective, mechanisms for scavenging nutrients from a range of sources and outcompeting the algae that would otherwise grow and lead to healthy waterways.

The classic example of differences in absolute nutrient requirements by specific species groups is diatoms. Diatoms are the foodstock of the Bay, and are readily filtered by zooplankton, oysters and other consumers. Because of their cell wall, they have a requirement for silicon, whereas others such as dinoflagellates do not. Thus, if nutrient loading leads to a proportional enrichment of nitrogen or phosphorus relative to silicon, then a proportional shift away from a diatom-dominated community might be expected along with a shift toward harmful algal species.

While some species, such as diatoms, have an absolute requirement for a particular nutrient, other species have seemingly lost the ability to acquire specific nutrients. For example, the brown tide species that blooms from Long Island to the Coastal Bays has very little capability for the uptake of nitrate. This species must obtain its nitrogen from another source, in this case, urea. Other harmful species, including many dinoflagellates that cause "mahogany tides" in the Chesapeake Bay, have also been found to preferentially use nitrogen in the form of urea, other organic compounds, or ammonium instead of nitrate.

Some algae, particularly certain harmful dinoflagellates, also have the ability to obtain much of their nutrition by ingesting other organisms, such as bacteria, or other small algae. Some of these species have the ability to switch between "feeding" and "photosynthesis" as a lifestyle, depending on environmental conditions. For those species that feed, dissolved nutrients are also important, as they may stimulate growth of the preferred food, ultimately stimulating the harmful algae cells. Many other dinoflagellates have complex life cycles, and different nutritional strategies are used during different stages.

Different forms of nitrogen—such as nitrate, ammonia or urea—that reach the Bay or its tributaries generally have different sources. A common source of nitrate is groundwater. Urea may be delivered by direct surface runoff, as more and more urea is applied directly as a fertilizer. Urea is also a breakdown product from uric acid in chicken manure. Recent data confirm that concentrations of urea are significantly elevated in many of the tributaries of the Bay, but are much more dilute farther from land.

Understanding the role of nutrients in affecting species composition requires a fundamental understanding of both physiological differences and environmental conditions. The ultimate success of a given species will depend on its ability to exploit both the quantity and quality of available nutrients, the timing and intensity of the nutrient supply, and the interaction of other environmental factors and competitor or consumer species.

— Dr. Patricia M. Glibert, University of Maryland Center for Environmental Science, Horn Point Laboratory, September 2003

composites and averaging through such techniques as reducing the amount of acreage assumed under forest buffer management, or by limiting the nutrient loss potential for confined animal operations. Such efforts are useful, but compound the level of estimation in the model.

Nutrient reduction efficiencies are based on research results and field observations of what constitutes an individual practice or a management system that includes multiple practices. Research results are usually derived from plot scale data and typically, on a new and perfectly implemented practice. The efficiencies of practices newly implemented on a research plot scale are likely to be much higher than those implemented on a watershed scale. *As a result, it is difficult to extrapolate plot scale research results directly to field scale practice efficiency.* The CBP approach may be the best currently available, but some mechanism should be used to adjust efficiencies to better reflect field, farm, or watershed scales, as well as practices in place over time, *Reported progress is usually based on plans written or structures designed, not actual implementation.*

versus plot scale efficiencies. It is apparent that more long-term research on a range of watershed scales is needed to more realistically estimate actual reductions.

In addition, reduction efficiencies for a particular practice in one geographic area may not be the same as in another, as is assumed in the watershed model. There are substantial data indicating that BMP efficiencies are highly site specific and can vary widely under different cultural and physiographic conditions (Dillaha, T. A. 1990. "*Role of Best Management Practices in Restoring the Health of the Chesapeake Bay*." In: *Perspectives on the Chesapeake Bay,* 1990: Advances in Estuarine Sciences. Report CBP/TRS41/90. CBP, U.S. EPA, p.57-81). Some practices do vary in efficiency across watershed model segments or between different hydrogeomorphic regions within the watershed model. *While this may be the best that is currently possible, it must be recognized that "average" practice efficiencies do not properly represent the large variability in actual efficiency nor account for variation in the pre-implementation status of individual farms. Improved management models (based on physical and biological properties and processes) that allow for a more site-specific evaluation of practices under different conditions are needed.*

Implementation Assumptions

States are responsible for collecting and reporting levels of practice implementation on an annual basis. Implementation rates vary widely between states and from year to year within states. This may be related to differences in staff support between states, political emphasis on the need for reporting and the availability of cost-share funds for practice implementation from year to year. Methods for tracking and reporting to the Bay Program are consistent among the states although the collection of data varies within states. There is concern that the double-counting of certain practices may be occurring if cases of multiple activity on the same acreage or animal operation occur, particularly as part of Conservation Planning and Nutrient Management Plans. These plans generally recommend that more than one control practice is necessary for animal feedlot operations, for example. Because progress is based on reported implementation, there is also concern about the overly optimistic reporting of implementation. This is further complicated by the perceived need to always show progress. If a state were to find errors in previous reporting, it must reduce reported implementation and run the risk of being further from goals than previously reported. While the revised numbers would be more accurate, they may create problems with public and political perceptions. The CBP accepts state-reported implementation rates without question except when implementation in a model segment exceeds available acres. *More CBP or third party review of annual implementation progress should be conducted.*

Reported progress is usually based on plans written or structures designed, not on actual implementation. There is much concern that this results in the substantial overestimation of implementation. A Rural Clean Water Project study in Pennsylvania found an implementation rate as low as a 22 percent for some nutrient management plans and animal waste BMPs (*Pennsylvania-Conestoga Headwaters Project, 10 Year Report 1981-1991*, USDA/ASCS 1992). A 1998 statewide Maryland survey of nutrient management plan implementation found that, depending on definitions, only 40–70 percent of farmers reported "following the plan," and many of those had not reduced nutrient inputs, (e.g., fertilizer use) as much as had been assumed in nutrient management reduction efficiencies.

Another watershed model implementation assumption is that the practice is implemented as defined by the CBP. For example, cereal grain cover crops are an efficient post-harvest nitrogen management practice with very high reduction efficiencies. But these efficiencies assume timely fall planting (before October 1 in the Coastal Plain). In some cases, cost-sharing standards for cover crops allow planting until November 1 and even later. The same data on which the cereal grain nitrogen reduction efficiencies were based showed a major decline in nitrogen reduction efficiency after October 1. In one study, delaying planting from October 1 to October 30 resulted in a 90 percent reduction in the uptake of nitrogen by mid-December (R. Brinsfield, K. Staver, University of Maryland, *Role of Cover Crops in Reduction of Cropland, Nonpoint source Pollution*; November 1991; U.S. ASCS, SCS Cooperative Agreement #25087). There are numerous other cases where either state requirements or farmer practices are inconsistent with Chesapeake Bay Program BMP definitions.

The CBP should adjust the implementation rates of practices based on available data. Additional research should be conducted to refine actual rates of implementation and identify differences between practice definitions and what is being implemented.

Further, all practices are assumed to be implemented and maintained as prescribed and to function at design efficiency over time and in all types of storm events. *The CBP has identified BMP function, maintenance, and performance during major storm events as items of concern for future improvement, and these, along with optimistic efficiency and implementation assumptions, are likely to result in the substantial overestimation of nutrient reductions. BMP efficiencies used in the watershed model should reflect* *the quality of the BMPs as implemented, not the efficiencies of "ideal implementation." The "actual" progress to meet the nutrient reduction goals will not change nor will the substantial efforts already made by states and farmers. What will change is the progress "estimate" based on the watershed model outputs.*

Systems Approach to Conservation & Nutrient Balances

While the discussion above identifies specific actions that can improve estimates of progress from BMP implementation, there are broader issues related to the overall approach to reducing farm nutrient losses using BMPs. Most BMPs are selected to address current farm nutrient run-off problems based on existing crop and animal production systems. It may be important to address total farm nutrient imbalances and to look at feasible changes in production systems as part of a comprehensive planning process. *Despite efforts for more comprehensive planning, BMP practices are still frequently implemented individually without looking at how they work together to address whole farm water quality concerns.* Treating the current system to reduce impacts is tactical. Identifying potential changes in feed, animal numbers, types of crops, or rotations that result in less total impact is strategic. *The current focus is on tactical plans.*

Structural and pollution abatement practices are frequently considered equivalent to pollution prevention practices in terms of reduction efficiencies. But there is little research on the long-term effectiveness of the former. A more concentrated effort should be made through feeding, waste storage, crop system, and nutrient management to minimize the opportunities for nutrient losses before using pollution abatement practices to treat lost nutrients. Planning and implementation needs to be an ongoing repetitive process that continually reassesses crop and animal management options at the farm, watershed, and industry-wide levels to meet water quality objectives. *Keeping nutrients out of waterways will negate later abatement costs and impacts, and make a much greater contribution toward maintaining farm nutrient balances.*

The specialization, intensification, and concentration of agricultural production, particularly poultry and livestock, have created field, farm gate, and regional nutrient imbalances. Historically, farms producing animals and animal products depended heavily on farm crops to feed the animals. In the last half of the 20th century, as farms became more specialized and livestock and poultry production became more regionalized, the crops used to feed the animals are increasingly produced in other areas. As a result, crops are often not consumed on the farms where they are produced, but are exported to other farms and regions where intensive animal production is located. This new organization of production is typical for non-ruminant animals, such as poultry and hogs, and is becoming more important in the dairy industry. Although nutrients are removed from the farms where crops are produced, they are replaced with imported nutrients, primarily commercial fertilizer. In crop/feed importing regions, the flow of nutrients to individual farms in the form of animal feed may far exceed the removal of nutrients by the export of animals, animal products, and crops. This imbalance in flows results in short– or long-term accumulations of nutrients on farms that import feed, which then have a higher potential for nutrient losses to surface and ground waters.

This imbalance can be understood by a "stock and flow" analysis of nutrient pathways. The particular flows to be monitored depend on the goals, available resources, and in some cases, the specific nutrient. The analyses of fields, facilities, animals, and farms can be extended to regions defined as geopolitical jurisdictions and/or watersheds. Conceptually, when the managed nutrient flows in and out of a farm are similar, the nutrient stock is stable and opportunities for unintended nutrient losses are limited. However, if nutrient inputs greatly exceed outputs, the stock is likely to increase for "conserved" nutrients like phosphorus while losses of the less well-conserved nitrogen may eliminate any seasonal increase in stock.

As phosphorus stocks increase in fields, the potential for unintentional losses increases. Certain landscape areas, particular management practices, and the types and frequencies of runoff events across multiple growing seasons may all become important factors in water quality protection. Within-year depletions of supplemented nitrogen stocks in fields are often greatest from short-season annual crops that typically have nitrogen uptake efficiencies of only 40–60 percent. These losses increase greatly when the nitrogen applications exceed recommendations for agronomic production. In-season nitrogen management and post-season BMPs to manage residual nitrogen can reduce the loss of excess nitrogen. *The intent of many field management BMPs is water quality protection rather than an increase in production. Therefore, voluntary adoption and committed implementation by farmers may be difficult to achieve without sufficient incentives.*

Farm phosphorus stocks can also increase within the animal production unit rather than just the field area of the farm when phosphorus accumulates in the sludge layers that are not removed from manure storage

Despite efforts for more comprehensive planning, BMP practices are still frequently implemented individually without looking at how they work together to address whole farm water quality concerns.

Recommendations

Management

1. Continue to use current approaches to efficiency estimates in the Chesapeake Bay watershed but undertake a major revision of BMP efficiencies, reporting, and operation and maintenance;

2. Adjust current BMP model "average practice" efficiencies from ideal, research plot-based estimates to those that better reflect broad watershed applications and variability in implementation quality;

3. Adjust BMP performance efficiencies to reflect variable functions during major storm events;

4. Evaluate state reporting and tracking approaches; implement a Chesapeake Bay Program or third party review of state progress reporting;

5. Revise reported progress based on surveys of implementation rates and quality of implementation;

6. Develop and implement collaborative efforts on a subwatershed-wide basis for BMP implementation in priority or impaired watersheds. Plans should encompass integrated systems farming and nutrient balancing using BMPs assessed for the dual objectives of increased water quality abatement efficiency and reduced farm costs; and

7. Construct incentive programs and means of verification for improving field, farm, and regional nutrient balances.

Research

1. Conduct research to address major nutrient imbalances associated with intensive animal production and nutrient-rich crop specialization at the watershed scale. Research must focus on systems approach that considers alternative crops and/or production management that balances nutrient flow and acceptable nutrient stocks;

2. Conduct larger-scale research on BMPs to quantify actual reduction losses in agricultural production systems—both crop and animal—under real world applications. There is a critical need for comprehensive long-term small watershed BMP research, with concurrent plot research, to determine watershed efficiencies and longevity for current and new BMPs under varying climate, physical, and cultural conditions;

3. Direct new BMP research to go beyond tactical controls (e.g., erosion, storage sheds, feed rations) toward addressing nutrient balances at the farm gate and watershed level; and

4. Conduct research to determine BMP implementation rates, quality of implementation, operation and maintenance, and replacement for Bay Program BMPs.

As regional animal and nutrient stocks increase, risks to regional water quality increase correspondingly and reductions in feed nutrients or the transport of excess nutrient stocks are the primary alternatives to offset continuing nutrient imports.

facilities. Nitrogen stocks can be depleted before the nitrogen is field applied if the animal housing facilities or manure storage structures release ammonia to the atmosphere. Novel animal facility BMPs may reduce some of these losses, but their adoption will face challenges because of implications for animal management, animal health, and farm labor requirements.

Using off-farm feeds or supplements can increase the stock of phosphorus or nitrogen remaining in the animal waste. The overfeeding of phosphorus or nitrogen or the accumulation of nutrients on the farm can result in the imbalance between nutrient imports in feed and nutrient exports in farm products. The BMPs to reduce the nutrient density of the feeds or to improve the nutrient uptake efficiency of livestock will depend on cooperative research and management efforts by the animal production industry and other Bay Program stakeholders.

The number of animals on a farm or in a production region, even when fed the most efficient ration, will have a substantial impact on regional nutrient balances because animal physiology dictates that only a small fraction of the nutrients consumed in feed are retained by the animals. *As regional animal and nutrient stocks increase, risks to regional water quality increase correspondingly. Reductions in feed nutrients or the transport of excess nutrient stocks are the primary alternatives to offset continuing nutrient imports.* The economic incentives for farmers or the logistic advantages to businesses from concentrating animals on individual farms or regionally will be difficult to overcome unless farmers and businesses are required to manage manure based on regional nutrient balances.

For some farmers and businesses, importing feeds to support animal production beyond what can be produced locally may be very rational for cultural or economic reasons. Opportunities to intensify animal production may ensure that the next generation has an opportunity to remain on the land or that the net returns from farming can be increased compared to other options.

It is unlikely that the scale and organization of livestock producers will return to the point where most crops and manures produced on a farm are used on the farm. As a result, the only way to address major nutrient imbalances associated with intensive agricultural production may be to develop a strategic approach to production and animal waste management that achieves a balanced nutrient flow and acceptable nutrient stock within a production region. Nutrient management and other pollution control practices should be used where animal wastes are land applied, but these practices cannot address long-term nutrient imbalances where feed is imported. Obviously, the social and economic consequences of water quality goals for concentrated production regions must be addressed during any restructuring of the industry.

A strategic approach that improves farm, subwatershed, and watershed nutrient balances will require multidimensional approaches that balance the values of the farmer, rural society, landscape, and ecosystem with the economic return generated by the marketing of animals and animal products. For instance, high quality water will become a valued output of a well-functioning crop or animal production system just as the normally marketed products are valued. *Continuing production at the lowest per unit cost, while externalizing social and environmental impacts, will generate even greater nutrient imbalances and water quality problems in rural America and will have far-reaching consequences for water resource users, aquatic species, other wildlife, and future generations.*

Summary

It is apparent that BMP efficiencies and implementation assumptions result in the overestimation of nutrient reduction progress. The extent is likely substantial but difficult to quantify. The CBP should be recognized for being bold and innovative enough to create this system a decade ago. It has served well as a relative guide to progress. The system cannot be abandoned, but lessons learned in past decades should be used to refine progress estimation. It should be expected, and explained beforehand, that such refinement will almost certainly result in reduced progress estimates. However, the refined progress estimates will better reflect actual reductions in nutrient losses from agricultural activities to the Chesapeake Bay. They will facilitate the improved targeting of Bay resources to BMPs and farm systems that are most likely to result in actual improvements in Bay water quality.

Nutrient management plans and many other land-based BMPs may offer tactical approaches to offset nutrient imbalances, but strategic decisions dealing with animal enterprises, such as increased animal numbers, feed importing, or diet changes may exacerbate imbalances beyond the control capacity of the tactical BMPs. As a result, the only way to address major nutrient imbalances associated with intensive animal production may be to develop a strategic approach to farm management that balances nutrient flows and establishes acceptable nutrient stocks at the farm gate, watershed, and industrywide level.

Livestock & Poultry Production

Livestock and poultry production will remain a viable agricultural industry in the Chesapeake Bay watershed into the foreseeable future. Significant efforts have been made to address environmental impacts, especially nitrogen and phosphorous runoff, that result from manure, particularly in concentrated animal operations. Nonetheless, of the more than 2,000 watersheds in the lower United States reviewed by the U.S. Department of Agriculture, key watersheds in the Chesapeake Bay rank in the top 10 percent in terms of manure nitrogen runoff, leaching, and loadings from confined livestock and poultry operations. Although Chesapeake Bay farms are smaller than the U.S. average, poultry and hog farms are considered large when measured by the number of animals per farm and the number concentrated per acre (*Chesapeake Futures: Choices for the 21st Century*, edited by Donald F. Boesch and Jack Greer, January 2003, An Independent Report by the Scientific and Technical Advisory Committee, Chesapeake Bay Program, STAC, 2003, Edgewater, Maryland). As a result, there is a need to improve current practices to control the impact of manure on water quality. In addition, a number of practices in use may be modified to lessen nitrogen and phosphorus impacts on the environment. Also, new short– and long-term approaches are needed to meet recently developed goals for reducing nitrogen and phosphorus loading into the Chesapeake Bay. Livestock (dairy and beef) and poultry (broilers, layers, and turkeys) will be addressed separately. Not discussed in this paper is swine production which, while growing in certain areas of Pennsylvania, is not extensive in the Bay watershed.

Poultry

The poultry production industry in the Chesapeake Bay Watershed depends on the import of feeds from other regions and the import of fertilizer for grains grown locally. This evolution of the industry departs from the historic cycle of growing crops for animal feed and fertilizing those crops with animal manure from the same farm. This net import of nutrients (in feeds and fertilizers) has created a surplus of manure-borne nutrients. *Managing nitrogen—and especially phosphorus—in the poultry production process has become a major agricultural water quality issue in the Chesapeake Bay watershed.*

The role of diet and feed formulations as a way to manage overall phosphorus balancing is gaining increased scrutiny. The addi-

Managing nitrogen—and especially phosphorus—in the poultry production process has become a major agricultural water quality issue in the Chesapeake Bay watershed.

Poultry Short-Term Needs
Phosphorus & Nitrogen

__1.__ Studies on the best use of phytase alone as well as in combination with other feed ingredients are needed as well as a sufficient database on phosphorus reductions. These studies must also address any impacts on bird performance or processing losses;

__2.__ Studies should be undertaken to examine the effects of dietary minerals (calcium, etc.) on the use of phosphorus and phytase, as well as reducing inorganic phosphorus in feeds; and

__3.__ Farm level nutrient balance models and incentives are needed for farmers to monitor/manage nitrogen and phosphorus balances.

Recommended Phosphorus & Nitrogen Levels

__1.__ Further study is needed to determine nitrogen (protein) and phosphorus levels in feed at national, state, or industry levels, to determine opportunities to reduce fecal matter production while not reducing production efficiency;

__2.__ Studies should examine the nitrogen composition of manures and its effects on water quality;

__3.__ Studies are needed to link nitrogen nutrition and manure nitrogen generation; and

__4.__ There is a need to develop alternative uses or redistribute surplus manure nutrients (e.g., pelletization and composts), as well as to develop markets, reduce transport costs, and address liability issues.

Laying Hen, Turkey & Broiler Needs

__1.__ These production systems require additional research on the local impacts of changes to nitrogen and phosphorus in feeds.

Poultry Long-Term Research Needs
Phosphorus & Nitrogen

__1.__ Research should be conducted on gene and protein structures and marker-selected breeding to better understand nitrogen and phosphorus nutrition and excretion while enabling the industry to improve feed utilization.

Laying Hen, Turkey & Broiler Breeders

__1.__ There is a need to improve the dietary manipulation of nitrogen and phosphorus for these production systems.

Ammonia

__1.__ Research on the air and water quality impacts of ammonia losses from production facilities needs to be accelerated, along with the development of new technologies, (e.g., strategic facility design) to mitigate releases.

> *The target audience should begin with the nutritionist, not the farmer, because they control the phosphorus level in the feed. It is cheaper to not feed excess phosphorus than it is to manage excess phosphorus in the manure.*

tion of phytase to poultry feeds has been operationally proven to reduce total excreted phosphorus by about 18 percent. However, the incorrect use of phytase in the diet can increase soluble phosphorus in manures that more easily runs off the land. *Better implementation and the correct use of phytase can decrease total phosphorus by 20–30 percent. This is critical where litter is not marketed for commercial fertilizer use.* Recent research indicates that further reductions in feed phosphorus levels can be obtained without impacting chicken performance or quality. It is estimated that diet refinement, in combination with phytase use and other additives, can result in a nearly 40–50 percent reduction, compared with pre-phytase levels. It is critical, though, that these diet changes do not negatively impact performance or processing. Research is needed to identify the optimal use of phytase in poultry diets.

Research on nitrogen nutrition and consequent effects on manure concentrations have not kept pace with the research on phosphorus. Atmospheric ammonia losses from production facilities are substantial and need to be reduced for better water and air quality. Research in the United States is beginning to examine ways to reduce ammonia emissions from poultry houses and to stabilize manure nitrogen, but this work needs to be accelerated.

Research on nutrition and manure composition for laying hens, turkeys, and broiler breeders is minimal. *It is noteworthy that most cost-share and technical assistance programs today target hundreds of thousands of dollars for waste management structures and technologies, but do not provide incentives to reduce waste production through improved nutrition.*

Beef & Dairy

The total number of beef and dairy animals has not changed in the watershed although there are fewer farms with more animals per farm. As with poultry, these animals can be overfed both nitrogen and phosphorus. Overfeeding for nitrogen alone is estimated to cost the dairy industry approximately $18 million annually in the Chesapeake Bay watershed. Research shows that improving herd nutrient utilization efficiency by 50 percent can reduce nitrogen losses to water by up to 40 percent, but improving manure utilization efficiency by 100 percent only reduces nitrogen losses by 10-14 percent (J. S. Jonker, R.A. Kohn, and J. High,2002. J. *Dairy Science* 85:1218-1226. *Dairy Herd Management Practices that Impact Nitrogen Utilization Efficiency*). Variable feeding levels among farms and high phosphorus feeding recommendations by the National Research Council also contribute to substantial overfeeding. It also occurs because industry-formulated feed standards do not fit the specific ration needs of individual farms. Incentives are needed to promote better interaction between suppliers, formulators, and users to reduce overfeeding. *The target audience should begin with the nutritionist, not the farmer, because they control the phosphorus level in the feed. It is cheaper to not feed excess phosphorus than to manage excess phosphorus in the manure.* Farmers must now go to their nutritionists and ask them to remove phosphorus. Incentives are needed to monitor the phosphorus levels, and feed only optimal levels. Inexpensive technologies are also needed to monitor excess levels of phosphorus that already exist for urea nitrogen as well as incentives to use these technologies.

Unless nutrients going into the animal production system are reduced, manure management will continue to be problematic as the strategy remains one of handling materials with "end of pipe" fixes. Current practices reduce nutrient impacts somewhat except where inadequate land exists to apply the manure. Treatment, transport, and/or the off-farm application of dairy or beef manure are unlikely to be economically feasible under current market conditions without substantial subsidies. New facilities need to be designed to help balance nutrients. Some farmers need financial assistance; others have the capacity to use available systems; while others need worker/manager training on available systems to improve the recovery of nutrients and minimize nutrient losses to air and water.

In addition to manure, lot runoff, stream corridor management, silage runoff, and milking center impacts all need to be considered. *It is important to implement BMPs that are already known to reduce nutrient losses to water by targeting critical source areas first by using education and incentive programs, cost sharing, and/or regulation. Studies have shown that education alone is not sufficient to implement BMPs effectively although they can be used in combination with incentives or controls.*

A number of management factors need to be addressed with beef and dairy. Incentive programs (e.g., milk urea/nitrogen price support, fertilizer tax rebate, excess phosphorus in feeds tax) need to be evaluated. Simple management controls, such as fencing to separate loafing

Beef & Dairy Short-Term Needs

Phosphorus & Nitrogen Nutrition

1. *Diet formulation models are needed to identify minimal nitrogen and phosphorus feed concentrations to promote growth and reduce the overfeeding of these nutrients;*

2. *Farm level nutrient balance models and incentives are needed for farmers to monitor/manage nitrogen and phosphorus balances.*

3. *Research is needed on the nutritional quality of crops, their by-products, and efficiency/utilization by the animal to minimize excreted nitrogen and phosphorus; and*

4. *Analytical techniques that can cost-effectively analyze milk to predict manure composition of nitrogen and phosphorus should be explored with necessary incentives for adoption.*

Manure Management

1. *The atmospheric impacts from manure production in dairy and beef operations need to be more fully evaluated to control the flow of nitrogen;*

2. *Economic research is needed to evaluate value-added products (co-utilization of waste streams on– and off-farm) as well as to enhance waste handling/utilization;*

3. *Techniques to remove or immobilize phosphorus from manures need to be developed;*

4. *There is a need to investigate anaerobic digestion technology and its economics to facilitate evaluating electricity generation from methane and the full-cycle removal of nutrients; and*

5. *There is a need to redistribute or develop alternative uses for surplus manure, (e.g., pelletization, composts) as well as to develop markets, overcome transport costs, and address liability, safety, and nuisance issues.*

Beef & Dairy Long-Term Research Needs

Phosphorus & Nitrogen

1. *Research on the optimization of diets either through digestion trials for total amino acid requirements or the use of gene and protein markers through selected breeding should lead to an improved understanding of nitrogen and phosphorus nutrition and excretion as well as better feed utilization; and*

2. *Research on alternative feeds will contribute to lower nitrogen and phosphorus excretion in manures.*

Manure Management

1. *Economies-of-scale are cost-effective for current manure treatment technologies resulting in larger confined operations. Research should be conducted to adapt technologies to small– and medium-scale operations and to identify cooperative systems for neighboring farmers;*

2. *Other manure treatment systems, such as those developed for swine, should be examined for applicability to dairy manures;*

3. *Improved composting technologies should be developed to reduce the volume of manure and stabilize nitrogen and phosphorus;*

4. *New ways to use liquid waste (e.g., subsurface irrigation) should be developed;*

5. *Research on the use of manure solids as biofuels is needed; and*

6. *Research should be conducted at the systems level to include nutrient balances and budgets at the farm, watershed, and industrywide levels.*

Management Needs for Animal Operations

1. *Economic incentive programs to change management practices (e.g., reduce excess fertilizer use, nutrient content in feeds) need to be examined;*

2. *Farm and feedlot structural changes should be implemented to eliminate obvious contamination practices such as direct access to streambeds;*

3. *The industry should engage in cooperative ventures to reduce excess nitrogen and phosphorus in feed; and*

4. *Additional methods to measure performance success as part of BMP implementation should be designed.*

areas in dairies from surface water contact and remote watering, should be implemented for beef and dairy pastures. *There is a significant need to work with the industry to reduce excess nitrogen and phosphorus in premixed rations. Performance-based measures of success must accompany any new technology.* BMPs must also be cost-effective.

Long-term, non-research factors that need to be addressed include the development of new policies and practices among farmers, suppliers, and the public to provide a more holistic understanding of nitrogen and phosphorus issues associated with dairy and beef. New practices need to anticipate emerging problems rather than react to inadequate operations.

Conservation Innovation in Crop Production

Horticultural/Nursery Industry

The horticultural industry is the fastest growing sector of agriculture in the region and will continue to expand in the Chesapeake Bay watershed. Maryland alone has about 1,000 nursery/greenhouse operations, which cover about 10,000 acres and grow 400 to 500 plant species. There are indications that greenhouses and nurseries could be a potential alternative to chicken houses for some farmers on the Eastern Shore. These operations are heavily fertilizer dependent. At present, greenhouses and container nurseries are covered largely by out-of-ground nutrient management plans, under the premise that nitrogen and phosphorus move with the water in a soil-less substrate. The challenge is to keep the nutrients in the potting media and capture and recycle run-off or leachate. There is a lack of knowledge on the nutrient uptake for these plants, given the diversity of operations, species, varieties, and the wide range of water and nutrient needs. This leads to an overall lack of nutrient mass balancing. Also, there is a significant lack of monitoring information to determine the effectiveness of horticultural BMPs.

Research shows that once yields are near optimum levels, a high rate of leaching may occur.

Working with this industry as it grows will help to ensure that BMPs are identified and implemented before impacts occur. This may represent a near-term opportunity to effectively and cost-efficiently work with an industry as it matures and expands. Real nutrient loss reductions can be achieved by such technologies as drip irrigation. Both short– and long-term research needs can help to make this a model for an environmentally friendly agricultural industry.

Horticulture/Nursery Industry

Research Needs

__1.__ Develop nutrient balancing criteria in BMPs to minimize water quality impacts for emerging or expanding industries;

__2.__ Establish appropriate monitoring procedures for horticultural operations so that BMPs can be implemented and their effectiveness quantified;

__3.__ Develop and expand the number of water and nutrient use efficiencies by establishing a database of nutrient/water needs by crop species and their growing method (pot, in-ground);

__4.__ Conduct studies on delivery technologies and the fate, recovery, and recycling of nutrients;

__5.__ Research agricultural by-products as growth media and a nutrients source; and

__6.__ Develop site-specific crop simulation models for managing nitrogen utilization and leaching to facilitate better management practices.

Management Needs

__1.__ Establish nutrient budgets and performance goals for greenhouses and container nurseries;

__2.__ Conduct education and outreach programs for growers;

__3.__ Develop management principals for integrators and contractors; and

__4.__ Provide siting and production assistance to minimize water quality impacts.

Grains & Oilseeds Production

Corn, wheat, and soybeans are the predominant field crops grown in the Bay region, particularly on the coastal plains. They are the dominant tradable crop commodities from the region, both nationally and internationally. Overall, watersheds in southeast Pennsylvania and southern Virginia coastal areas rank in the upper 10 percent of watersheds nationally with respect to commercial nitrogen applications (Chesapeake Futures: Choices for the 21st Century, 2003, Science and Technical Advisory Committee, Chesapeake Bay Program).

Corn, wheat, and soybeans are not efficient users of nutrients, typically taking up only 40–60 percent of applied nutrients, resulting in high nutrient losses per acre compared to hay and/or perennial grasses. Up to half of the remaining nutrients can be recovered before they are lost to groundwater through the timely planting of a cereal cover crop after corn is harvested. Timing is critical, as the later the planting in the season, the less the benefit. This still leaves 20 percent or more of the applied nitrogen that may be lost to surface or groundwater and eventually reach the Bay. Nitrogen losses from small grains are similar. Very little, if any, nitrogen fertilizer is needed for soybeans as they meet their needs by fixing nitrogen directly from the atmosphere. Some of the fixed nitrogen from the soybean crop carries over to the following year and substantial amounts, almost as much as from corn, may leach to groundwater. Farmers can account for some of this carried-over nitrogen and do not have to add as much nitrogen to grow subsequent crops.

Leguminous cover crops (e.g., hairy vetch or crimson clover) grown during the fall and early spring can supply all or most of the nitrogen needed for corn and some horticultural crops. Some of this naturally fixed nitrogen also ends up in groundwater. The physical properties of soil can play a large role in determining how much is lost into the environment. The natural fixation of nitrogen by legumes does not mean that this fixed nitrogen will not contribute to the contamination of Bay waters.

The principles of managing nitrogen in these systems are well studied (e.g., soil-crop-hydrologic cycle, proper nitrogen application rates; and the timing and placement of nitrogen applications in nutrient management) and cover crops are considered a key tool in helping to manage nitrogen. Cereal cover crops planted after row crops are a successful tool in sequestering unused nitrogen if planted in a timely manner. However, planting cereal cover crops after soybeans may be impractical as soybeans are generally harvested too late to plant the cereal that will adequately take up leachable nitrogen. Other known management practices include limited-till and no-till to reduce erosion, which also increase carbon sequestration and enhance infiltration.

To effectively manage nutrients, farmers need to rigorously implement nutrient management systems that take into consideration the timing, rate, and placement of farm-applied nutrients. It is critical to know, for example, the leaching rates relative to yield over the long term. *Research shows that once yields are near optimum levels, a high rate of leaching may occur* (Sandra S. Batie et al, *Soil and Water Quality: An Agenda for Agriculture.* National Research Council, National Academy Press. 1993).

Tools currently exist that can be used to improve nutrient management and reduce losses of both nitrogen and phosphorus. Expansion of the use of fall cereal grain cover crops, planted in a timely fashion, could significantly reduce nitrogen losses as well as provide some phosphorus loss reductions. The incorporation of manures through subsurface injection, chisel plowing, or disking immediately after application can greatly reduce ammonia volatilization and subsequent redeposition. When manures are incorporated as part of a Nutrient Management Plan, it is important that it is done in a way that does not increase soil erosion, especially on highly erodable lands. It is also necessary to address soil remediation through new technologies for lands high in nutrients, such as phosphorous, so that no more be added. Regionally developed and implemented nutrient management plans for a subwatershed can enhance nutrient use efficiency by prescribing timing, rate, and method of nutrient application. New technologies, including variable rate application within a field and real time sensors, can further improve nutrient use efficiency and reduce the tendency to overfertilize for insurance against yield losses.

Crop models can be used to enhance the adoption of practices contributing to efficiency and yields. *Research is needed to enhance and improve crop models to maintain profitability and reduce nutrient loss during production.* This includes making models user-friendly and available.

Research on practices to reduce nutrient losses from the corn-wheat-soybean production system that dominates mid-Atlantic commodity crop production needs to continue. It must be acknowledged, though, that this system has an inherently high potential for water quality impacts. Current government subsidies based on acres planted and crop yields exacerbate the problem. Incentive or subsidies to reduce nutrient inputs to levels even nominally below current nutrient management recommendations would substantially reduce losses with minimal increases in profit risk. Over the long term, changes in rotations and cropping systems should be explored. Longer rotations that include perennials will have less environmental impact than the current corn-wheat-soybean rotation.

Crops or cropping systems that could provide multiple revenue streams for the farmer with much lower water quality impacts should be developed. Warm-season native grasses show substantial promise. Their top-growth could be used to produce renewable energy while their root system sequesters carbon in the soil that could produce marketable carbon credits for Canadian and European markets. Major reductions in nutrient losses that would occur could generate marketable nutrient credits. Soil quality credits may also accrue. Research into market-based solutions to agro-environmental issues could provide viable alternatives to production subsidies for income stabilization.

Such a shift clearly requires long-term research, infrastructure and market development, economic analyses, and the examination of secondary consequences. One consequence could be the need to import more nutrients in feedstock for poultry and livestock production. But the mid-Atlantic animal production region already has severe nutrient imbalances that require transportation and alternative uses to overcome. Low-impact crops may use fewer

Research is needed to enhance and improve crop models to maintain profitability and reduce nutrient loss during production.

nutrients, which could increase the need for transport or alternative uses of manures to achieve or maintain that balance. The long-term movement to lower impact cropping systems, many of which provide a domestic, renewable energy resource, needs to be considered in light of current heavy subsidies, declining profitability, and water quality impacts of grain and oilseed production in the Chesapeake Bay region.

Long Rotations With Forage Crop Production

Long rotations (four to seven years) that include perennial forages are economically important to farmers in some areas of the Chesapeake Bay watershed, particularly on dairy farms. These rotations usually have one to three years of annual row crops with three to six years of a perennial forage. Typically, much of the grain, silage, and hay produced on long-rotation fields is consumed by ruminate animals on the farm. Manure nutrients can then be returned to these fields for subsequent crop production. These production systems provide greater opportunity for achieving farmgate nutrient balances and for maintaining soil phosphorus at agronomically optimum levels than when farm animals are supported primarily by off-farm feed sources.

A long rotation corn-hay system can reduce the

Grain & Oilseeds

Short-Term Research Needs – Nitrogen

1. *Conduct studies on the fate of nitrogen from natural and applied sources (e.g., leachates as well as ammonia and NOx emissions). This will become more important as the total balance of nitrogen in the Chesapeake Bay watershed is realized;*

2. *Develop better methods for the placement of nitrogen, especially fertilizers and manure;*

3. *Improve the use of cereal and leguminous cover crops to reduce leaching losses. It is predicted that nitrogen leaching could be reduced by up to 50 percent with cereal cover crops in certain situations; and*

4. *Accelerate the development of real-time sensors for on-farm monitoring to determine nitrogen efficiency and sprayer-mounted sensors for better timing and rate of nitrogen application for crop needs.*

Long-Term Research Needs – Nitrogen

1. *Systems research is needed to develop technologies that will combine manure use with fertilizer supplementation and result in more effective nitrogen utilization;*

2. *Improve the systems for nitrogen use, placement, timing, and the use of cover crops in nutrient management as it relates to water/irrigation use and water quality issues to reduce nitrogen leaching and runoff;*

3*. Site-specific research using crop simulation models for managing nitrogen utilization and leaching should lead to better management practices;*

4. *The development of financially viable rotations involving perennials could greatly reduce nitrogen loss to the environment;*

5. *An evaluation of the potential for government programs, such as the Conservation Reserve Program and various riparian buffer strip programs, to reduce nitrogen loss to runoff and to groundwater is needed; and*

6. *Strategies are needed to remediate "high" phosphorus soils via phytoremediation, chemical remediation, deep soil plowing, and wetland reconstruction.*

Management Needs

1. *Develop a watershed pilot and demonstration program that insures against profit/loss risk for farmers who apply nominally less nitrogen (15-25 percent), based on research studies, than the agronomic optimum;*

2. *Implement, on a larger scale, existing tools that reduce both nitrogen and phosphorus:*

3. *Expand the use of fall cereal crops, planted in a timely fashion, to reduce nitrogen losses and provide some phosphorus loss reductions;*

4. *Incorporate manures where appropriate by chisel plowing or disking immediately after application to reduce ammonia volatilization and subsequent redeposition;*

5. *Develop and implement nutrient management plans regionally to maximize nutrient use efficiency by optimizing timing, rate, and method of nutrient application; and*

6. *Implement new technologies, including variable rate application within a field and real time sensors, to further improve nutrient use efficiency.*

Research Needs – Phosphorous

1. *Develop cropping systems that lower soil phosphorus levels while maintaining farm income; and*

2. *Develop grains that have higher levels of available phosphorus, yet maintain good grain and nutrition.*

Long Rotations & Alternative Cropping Systems

1. *Conduct research to develop longer term rotations that include perennials and winter biennials, which could be as profitable (with comparable subsidies) and have lower water quality impacts than current corn-wheat-soybean two– to three-year rotations;*

2. *Conduct research and develop a regional prototype/demonstration program to grow warm season grasses for bioenergy production through direct combustion and/or ethanol production;*

3. *Identify low-impact cropping systems that can provide multiple revenue streams to farmers, such as warm season grasses in conjunction with a bioenergy program, with revenues provided to the farmer through bioenergy commodities, soil carbon credits, nutrient credits, renewable energy production credits, or subsidies;*

4. *Accelerate research to develop moderate-yield perennial small grains with alternative, market-based revenues; and*

5. *Investigate the potential of grass-based dairies for profitability and reduction of nutrient surpluses.*

average annual application of phosphorus in excess of crop removal from nearly 30 kg/ha to less than 10 kg/ha when compared to continuous corn receiving rates of manure to meet the nitrogen needs of the crop. Leguminous or grass hay in rotation that receives limited nutrient applications can reduce high phosphorus levels in soil that may occur as a result of the application of manure at nitrogen-based rates for preceding corn crops.

Long rotations that include modestly fertilized perennial hay average less annual nitrogen and phosphorus losses to water than heavily fertilized short rotations with annual row crops. Hay has a more extensive root system, better ground cover and much longer growing season than annual row crops that combine to result in substantially lower nutrient losses, when properly managed. Accounting for residual nitrogen from legume forage crops in the fertilization of subsequent non-legume crops, like corn, can also reduce nitrogen losses.

Research should be conducted to optimize the effectiveness of hay and row crop production in different animal production systems that are characteristic of many areas in the Chesapeake Bay region to achieve nutrient balances and manage soil phosphorus levels. Research is also needed on extending the use of perennial hay in the rotation while meeting feed production objectives. This will enhance nutrient balances and reduce average annual nutrient losses, but may require transport or alternative uses of excess manures. Perennial hay, greater use of pasture, and less reliance on grain/silage by dairies can reduce nutrient losses if manures are properly managed and pastures conservatively fertilized. Some dairies are finding that grass-based production systems are in their economic self-interest and, when carefully managed, provide substantial local and distant water quality benefits. More research is needed on the management, economic, and environmental aspects of grass-based dairy production systems, as well as other opportunities to increase the use of perennial forages in long rotations.

Research into market-based solutions to agro-environmental issues could provide viable alternatives to production subsidies for income stabilization.

Implementation/Incentives

Agriculture is responsible for 13 percent of the gross domestic product in the Chesapeake Bay watershed and about 4 percent of the labor force. Even as both numbers are declining, agriculture remains critically important for many local economies for its open space, critical wildlife habitat, and recreational values, as well as water quality protection where environmentally sound practices are used. Agricultural land covers about 23 percent of the Chesapeake Bay watershed; contributing 41 percent of the anthropogenic nitrogen to the Bay and 49 percent of the phosphorus in 2000 (Chesapeake Futures Report: Choices for the 21st Century; Scientific and Technical Advisory Committee, Chesapeake Bay Program; 2003). Unlike farms in the rest of the nation, Chesapeake Bay farms are relatively small, averaging 180 acres versus 500 acres nationally, although confined animal operations are quite large when measured by the density of animals per acre. While there is a wide diversity of crop production among farms including small grains, vegetables, hay, mushrooms, berries, and orchards, crops of economic influence outside of the region are limited to only a few. Newer agricultural activities, such as greenhouses and nurseries, are growing but are dispersed widely in the watershed.

Chesapeake Bay Farming

The average Chesapeake Bay farm family makes the vast majority of its income from non-farm sources. On average, only 12 percent of farm family income nationwide is related to farm production. The small farms in the Chesapeake Bay region are operated largely by “lifestyle” farmers, many of whom lose money on farming operations. The motivations of such farmers may not be the same as those who receive most of their income from farming.

According to surveys by the U.S. Department of Agriculture, it takes a minimum of $250,000 in annual farm sales to generate more than 50 percent of family income from farming. The majority of farm sales are concentrated in a small number of farms. Nationwide, 10 percent of farms produce 85 percent of farm receipts. In the Chesapeake Bay region, livestock and poultry farms and large-scale crop farms produce most of the agricultural income. Poultry farms are typically independently managed, but produce poultry or eggs on contract with large agribusiness integrators and processors.

There are a number of “historic” opportunities to do innovative work in the various programs of the 2002 Federal Farm Bill, such as the Conservation Security Program, Conservation Corridor Program, Conservation Reserve Program, and Conservation Innovation Grants. Each program, though, has specific limitations and objectives, limited flexibility for systems management, and is not always directly linked with other programs.

Farmer Perspective on Water Quality Goals

Chesapeake Bay farmers are concerned about the productive capacity of their land and believe that they are protecting resource quality to the best of their ability. Farmers recognize that agricultural practices can contribute to severe local or on-farm pollution but are less likely to accept that their practices could be a primary cause of such pollution.

To many farmers in the Chesapeake Bay watershed, farming is seen as a "moral" occupation. They have economic and utilitarian views of nature, including the view that nature cannot be fully understood. Although livestock and poultry farmers regard resource protection as important, they do not view livestock wastes as resources and feel forced by economic considerations to dispose of animal waste as inexpensively as possible. There is a strong belief in established practices that outweighs the attractions of new technology, especially when the risks and total costs of BMPs are not well understood. Farmers may also be reluctant to implement established practices because of perceived financial and production risks.

If farmers are considering the adoption of water quality protection practices, they need consistent science-based information from all providers, site-specific performance monitoring of environmental results, and clear connections between practices and economic impacts. In addition, the cost-effectiveness of water quality protection programs is likely to be optimal when program activities are targeted at the principal sources of water impairment, such as livestock operations and/or environmentally critical areas within watersheds.

Farmers are less likely to respond to perceived risk or impacts that cannot be observed locally, especially if the response affects investments, labor and management inputs, or profitability.

Major Obstacles to Implementation

Most large crop farmers lease a large proportion of cropland that is owned by other farmers or non-farm landowners. *Farm operators have less incentive to install structural practices for water quality protection on rented land and may be restricted by those agreements from adopting certain conservation practices not required by regulation.* Contract operations such as poultry farms may have limited managerial flexibility for changes in practice, such as those necessary for nutrient balancing. Farm businesses have very little margin for any financial problems that may be created by resource protection practices or structures. It may take years to recover from short-term losses, and seemingly minor financial risks may significantly impact their ability to stay in business.

To function properly, BMPs require education, upfront investment, operation and maintenance, and additional labor, none of which contributes directly to the short-term profit margin. Information on the economics of BMPs to profit margin (e.g., yield, expense reductions) is limited. *Little research has been conducted to examine the whole-farm financial impact of BMPs over time. This research is critical, especially as it addresses farm systems management.*

The farmer's planning horizon is short; decisions are often made for the short term based on the annual profit margin. This is necessitated by the generally low profit margin for farming, especially crops, where survivability is measured on a year-to-year basis. Animal production planning horizons can be longer, especially as housing and structural facilities must be amortized, although market prices still influence short-term decision-making. In addition, some of the beneficial qualities of farming operations most highly regarded by the public do not generate any farmer income, such as open space, water quality protection, and rural ambiance. *Decisions to adopt or change practices are generally tactical, (e.g., what to adopt, where, and when), require some form of cost sharing, and must be proven. Farm information to support new practices or change is frequently inconsistent among information sources, especially as those changes affect an individual's farm operations.* Sources include university researchers, cooperative extension personnel, USDA Natural Resources Conservation Service personnel, contract obligations (either through leased lands or product sales [e.g., to poultry integrators]), animal nutritionists, sales distributors, fertilizer dealers, farm cooperatives, national and local agricultural associations, public interest associations, neighboring operations, and federal and state agencies. With so many sources of information, it is common to hear conflicting messages or to have a wide range of messages from which to choose.

What is more, there is growing evidence, as mentioned earlier, that education alone may not be sufficient to ensure adoption and implementation. Results from the Rural Clean Water Project in Pennsylvania, for example, show that even with intensive one-on-one support, only 22 percent of the farms implemented 70 percent of the nutrient management plans and 57 percent implemented just 30 percent (USDA/ASC, 1992). Recent efforts to assess the degree of BMP implementation under the three-year review cycle of Pennsylvania's Nutrient Management Act is hindered by the lack of good on-farm recordkeeping. This type of recordkeeping is one of the major objections of Maryland farmers in their criticism of Maryland's Water Quality Improvement Act.

Incentive Programs

Most state and federal incentive programs

Management Recommendations

Widespread farmer participation in either a regulatory or non-regulatory program to improve water quality on a scale the size of the Chesapeake Bay will not succeed unless it simultaneously improves agricultural production operations. The performance results for both must be measured and communicated. Incentive programs must address performance and behavioral change.

Short-Term Actions

1. *Chesapeake Bay states should reorder cost-share support and petition federal agencies to prioritize in-state farm grants and subsidies to farm operations in impaired watersheds participating in performance-based farming systems. This support would also prioritize cost-share funding and the level of funding to practices and watersheds that provide the greatest nutrient reduction for the cost and are consistent with Chesapeake Bay Program goals. Funding should be graduated and based on the amount of nutrient reduction achieved and maintained from a three-year baseline or over a three– to five-year period.*

2. *While recognizing that not all funding is directed toward water quality improvement, STAC should provide leadership in developing a strategic plan for university and public programs to structure consistent, coordinated research on agricultural BMP systems and Chesapeake Bay water quality. Chesapeake Bay states should reorder state funding to support that plan.*

3. *Existing water quality monitoring programs need to be funded and organized to target priority nutrient-impaired subwatersheds allowing for the continuous monitoring of BMPs as part of a systems approach to farm management.*

4. *Chesapeake Bay states should petition for special funding from USDA incentive programs, Federal Clean Water Act grant programs, and corporate contributions (e.g., compliance settlement funds, partnerships) to support continuous monitoring, performance measurements of water quality, or of near-term outcome surrogates.*

5. *Extension education and outreach must engage private sector participants (e.g., dealers, integrators, feed industry, distributors, contract holders) in the implementation of nutrient balances through methods such as diet inputs or integrated farming, etc. to allow for more strategic versus tactical watershed-based decisions.*

6. *Researchers and the CBP should provide continuous monitoring and feedback on BMP effectiveness and water quality impacts to farmer participants.*

7. *Farming operations actively participating in nutrient balancing and water quality monitoring should be considered a high priority for on-farm research support, technical assistance, and help in developing marketable nutrient credits. These operations would have the opportunity for greater flexibility and should be considered low priority for regulatory compliance monitoring.*

8. *Federal support programs for the Chesapeake Bay region such as the Conservation Security Program should be focused on water quality.*

Long-Term Incentives

1. *Chesapeake Bay states should align environmental regulatory authority and state agriculture loans and grants toward research and technical assistance supporting a restructuring of agricultural operations in impaired watersheds, including incentive payments for alternative cropping systems and animal production systems more compatible with maintaining good water quality, alternative energy sources, food security, and multiple profit channels.*

2. *Revenue-generating opportunities should be examined to identify support for continuous water quality monitoring, (e.g., tax check-off, license plates), especially in local tributaries;*

3. *Production subsidy programs need to be converted to conservation subsidies that provide a comparable safety net and income stability for farmers and are also consistent with World Trade Organization rules.*

4. *Existing incentive programs should be restructured to prioritize funding operations focused on performance-based pollution prevention (e.g., diet refinements, alternative crop/animal systems, etc.) in place of correcting poor performance.*

are not performance-based, are varied and piecemeal, and do not mutually support societal goals of sustainable working lands and water quality protection. The government has used three generic approaches to support agriculture and agricultural conservation. The first is to remove land from farming. This results in protected water quality but a loss of agricultural land; and unless that "preserved" land is also protected from future urban development, water quality can eventually suffer. The second is to heavily subsidize crops to make them competitive and profitable. These commodity programs focus solely on acres planted and greater yields; they do not encourage the efficient use of nutrients. Subsidies ensure price and income support for named crops but there is

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no mechanism for integrating water protection costs into production costs, nor for allowing the flexibility to produce alternative, more nutrient-efficient crops that are unsubsidized. The third approach is government cost-share programs for BMPs. The result is generally generic plans with a tactical BMP "activities list" without sufficient implementation and maintenance incentives. For example, most cost-share standards set the maximum storage period of animal waste at six months. This necessitates a fall application just prior to the period of most intense runoff and leaching. Care must be taken to assure that the practices designed and cost shared do not just reduce losses from one pathway while transferring them to another These tactical activities are not targeted to areas or operations most in need of improvement or where outcome beyond yield performance can be measured. This approach does not improve agriculture or water quality. *There are several new federal incentive programs that are beginning to address performance but they are more resource-intensive to implement.* Funding directed toward targeted, critical source areas is scarce and fragmented.

The measurements of success for some of these programs are not performance-oriented but use surrogates that poorly correlate with water quality improvements. Examples include the number of acres of "preserved" lands, the number of BMP implementation plans written, and the number of specific BMPs implemented, usually measured in acres (cover crops) or miles (buffers). Without the critical link to priority impaired watersheds, continual water quality monitoring, and nutrient balancing, these efforts will remain insufficient to meet the water quality goals of the Chesapeake Bay.

Research Recommendations

1. *Assess land use, management practices, and nutrient applications in priority subwatershed areas identified as critical for water quality protection.*

2. *Evaluate the economic cost of BMP implementation necessary to correct nutrient imbalances.*

3. *Research in reducing BMP costs, determining their impact on farm production, and increasing farm profits—including the cost of pollution abatement in the cost of production—should be included in the study of individual nutrient loss abatement efficiencies. Integrated efforts with applied research disciplines (engineering, economics, soils) should be put in place.*

4. Identify opportunities to pursue partnerships with producer organizations for nutrient balance assessments, as well as comprehensive public-private funding programs for integrating systems farming research with increased profitability.

5. Provide state and federal funding for agricultural research in the Chesapeake Bay watershed that prioritizes linkages of water quality improvement and agricultural profitability.

6. Conduct research to examine the whole farm financial impact of BMPs necessary to correct nutrient imbalances over time.

The measurements of success for some of these programs are not performance-oriented but use surrogates that poorly correlate with water quality improvements.