OPTIONS TO ADDRESS NUTRIENT POLLUTION FROM AGRICULTURAL DRAINAGE

Lara Bryant and Jan Goldman-Carter, National Wildlife Federation

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Author's Note

Mid-August of 2014, National Wildlife Federation convened the Summer Roundtable on Agricultural Drainage in Minneapolis, Minnesota. The meeting was funded by the Walton Family Foundation and the McKnight Foundation provided facilities to host the meeting.

Invitees were expressly selected for their expertise in agriculture, water policy and best management practices for tile-drained systems. The goal of the event was to discuss practices that best addressed pollution from agricultural drainage, as well as the best regulatory and non-regulatory legal and policy mechanisms to maximize pollution reduction through the use of these practices. Meeting attendees provided valuable insight into the status and impact of these practices and policies. Their expert knowledge and opinions laid the foundation for this paper; many of the opinions, recommendations and conclusions are influenced by statements from meeting attendees, all of whom are listed in the Appendix.

Authorship of and conclusions reached in this white paper are those of the National Wildlife Federation staff authors and contributors. While **this paper is not a consensus document and is not meant to reflect the opinion of meeting guests**, there was a consensus from the participants on some of the high level insights that we would like to share. Attendees were asked to vote on policies that they felt had the most potential for further development, and they selected the following as the **top policies**:

1. Performance-based regulation
2. Agricultural certification
3. Practice-based regulation
4. Water quality trading

The following **list of insights** was also produced during the roundtable discussion:

1. There is a need to track discontinued conservation practices.
2. There is a need to track surface and new tile drainage practices installed without cost share assistance.
3. We need to be able to measure nutrient pollution reduction so that we know we are moving in the right direction with conservation practices (measurements that tell us when conservation

practices are sufficiently reducing nutrient pollution, and when additional or modified conservation practices are needed to reduce nutrient pollution).

4. Local water quality problems may be more likely to drive action (e.g., there is often more political will to take action to reduce nutrient pollution to better protect local drinking water supplies than to address the very serious down river problem of Gulf hypoxia).
5. Significant nutrient pollution reduction will likely require a shift toward more diverse and perennial cropping systems.

As you review our document, you will see many of the insights listed above reflected in our recommendations and analysis. We would like to again express our thanks to the experts who contributed to the discussion, and without whom this white paper would not be possible.

List of Acronyms and Abbreviations

APEX – Agricultural Policy Environmental Extender

ARS – Agricultural Research Service

BMP – Best Management Practice

CEAP – Conservation Effects Assessment Project

DRP – Dissolved reactive phosphorus

DWM – Drainage Water Management

EPA – Environmental Protection Agency

EQIP – Environmental Quality Incentives Program

ERS – Economic Research Service

FSA – Farm Service Agency

GIS – Geographic Information Systems

MAWQCP – Minnesota Agricultural Water Quality Certification Program

MRB – Mississippi River Basin

N – Nitrogen

NGO – Non-government organization

NPS – Nonpoint source

NRCS – Natural Resources Conservation Service

NRD – Natural Resource District

OIG – Office of Internal Governance

P – Phosphorus

PPR – Prairie Pothole Region

SARE- Sustainable Agriculture Research and Education

TMDL – Total Maximum Daily Load

UMRB – Upper Mississippi River Basin

USDA – United States Department of Agriculture

USFWS – United States Fish & Wildlife Service

USGS – United States Geological Survey

WIP – Watershed Implementation Plan

WRI – World Resources Institute

Executive Summary

Artificial drainage, commonly referred to as tile drainage or surface ditch drainage, has intensified in the Midwest in the latter half of the 20^{th} century. Drainage allows for higher yield and productivity on wet soils, serving as an incentive to convert land and wetlands that were considered marginal into cropland, and to expand tile drainage on already productive land for earlier planting and improved yields in wet years. While drainage has been a profitable practice for farmers, studies show that it can be a major factor allowing increased levels of nutrient pollution to waterways. Its contribution to freshwater and saltwater eutrophication and hypoxia is especially problematic in the highly-agricultural Mississippi River Basin (MRB). Reducing the nutrient pollution associated with agricultural drainage is the focus of this white paper.

The 2012 Agricultural Census revealed that nationally, more than 48 million acres are tile-drained and 42 million are artificially-drained by ditches. Within Upper MRB states, approximately 34% of cropland is tile-drained and 13% is artificially drained by ditches; a total of 60 million acres of cropland are drained within the Upper MRB. Studies show that increased tile drainage increases nitrate-N loads downstream. Increased drainage generally, including surface drains, increases stream flow volume, in-stream sediment erosion, and phosphorus and nitrogen loads downstream. Essentially, the extent of artificial drainage is so great that, unless its negative impacts are intentionally countered by best management practices (BMPs) through large scale initiatives, water quality in the MRB will continue to decline.

This paper discusses in detail these practices and their potential to reduce nutrient pollution. While BMPs can be very effective, they are not being implemented to their full potential. Current approaches that rely entirely on voluntary conservation are clearly not going far enough to increase BMP adoption, but there are numerous political, cultural, and economic barriers to achieving the necessary level of conservation. Tile and surface water drainage systems are pathways for nutrient pollution to enter America's waters. Nutrient pollution reduction solutions must drive significant, measurable nutrient pollution reductions while accommodating the variability and complexity of conditions, including geography, climate, cropping systems, and farm ownership and operations. We will examine this problem from different angles and recommend some high-level pathways to counter the negative effects of artificial drainage.

First, we examine a number of BMPs recognized as being effective at nutrient pollution reduction in a tile-drained system. We discuss each in terms of their adoption status, cost, water quality impact, advantages, and disadvantages. The practices we examined for their impact on tile drainage pollution include:

- Drainage water management
- Bioreactors
- Constructed Wetlands
- Cover crops
- Nutrient management
- Reduced tillage
- Saturated buffers

Since none of these practices are currently being used as broadly as they could be, we examined various options to increase adoption. We recommend the following general approaches:

1. The Hypoxia Task Force, USDA, and state agencies implementing nutrient reduction strategies should set a goal of installing at least one structural practice on every drainage outlet reaching streams, which could be a bioreactor, a control structure for drainage water management, a saturated buffer, or in some circumstances, a constructed wetland.
2. USDA, state agencies, conservation districts, and non-governmental organizations should continue and expand the current approach of outreach and education on cover crops and nutrient management (both of which are beneficial to farmers and to water quality), with an expanded focus on the benefits to farm profitability.
3. Since constructed wetlands are expensive to install but are highly beneficial to water quality (and have many other environmental benefits), USDA, EPA, and state governments should support development of partnership projects between local conservation groups and municipalities to carefully plan and install treatment wetlands where they will yield the greatest benefits.

While these BMPs have the potential to reduce pollution from tile drainage, implementation of conservation practices remains below the level necessary to protect water quality. Policy changes may bring us closer to achieving clean water goals, but certain barriers must be addressed and current approaches should be examined and remodeled in order to increase adoption.

The current approach has relied mainly on voluntary incentive-based conservation. While conservation programs have played a valuable role in preventing much greater environmental degradation than is currently occurring, it is increasingly clear that continuing to rely on an entirely voluntary approach of BMP implementation will not produce the desired results.

The large scale success of a basin-wide regulatory approach, such as the Chesapeake Bay Total Maximum Daily Load (TMDL), faces tremendous political barriers to adoption of enforceable nutrient pollution reduction limits within and across local and state governments within the same basin. The time, expense and difficulty of developing the monitoring, scientific data and modeling to support enforceable pollution reduction limits; developing and executing conservation practices and pollution controls to meet the pollution limits; and monitoring and enforcing compliance with the pollution reduction limits to achieve overall basin-wide pollution reduction, are also major barriers to success. However, TMDLs and similar basin-wide regulatory or quasi-regulatory approaches may be necessary for tackling basin-wide nutrient pollution from agricultural drainage systems. There may be greater potential for implementing a quasi-regulatory approach to nutrient pollution reduction on a smaller watershed scale, with a focus on localized water pollution concerns. For example, a quasi-regulatory approach might be considered for reducing nutrient pollution threats to drinking water sources in the Raccoon River Watershed near Des Moines, Iowa.

The current approach of the Gulf Hypoxia Task Force, coordinated by a committee of state and federal agencies, emphasizes nutrient reduction strategies for each state in the MRB, which would encourage ownership of the problem and flexibility to meet goals at the state level. In 2008, the Task Force charged each member state to develop a nutrient reduction strategy by 2013. By late 2015, most of the mainstem MRB states have completed strategies, while Arkansas, Kentucky,and Tennessee have completed draft strategies.

If states follow the framework recommended by EPA, these nutrient reduction strategies can serve as a platform for improved education, communication, and governance at the watershed level, as well as pollution reduction coordination among states and watersheds within the MRB. However, these strategies must be tied to nutrient pollution reduction goals and, almost certainly, to binding water quality standards if they are to achieve meaningful nutrient pollution reduction in the Mississippi River Basin.

Policies aimed at reducing nonpoint source pollution from agricultural operations have usually been practice-based, meaning that they focus on the practices installed, rather than the pollution-reduction outcome. Performance-based policies (i.e., policies based on meeting a specific pollution reduction outcome) may be a more effective way to reach water quality goals, but so far very few of them have been implemented for nutrient pollution reduction. Effluent limits, pollution taxes, and performance-based incentive payments are potential performance-based policies. Incentive payments are the most politically feasible, but given funding limitations they are unlikely to be sufficient on their own. Pollution taxes and effluent limits could also be implemented in the MRB with the necessary policy drivers, governance structures, and authority to regulate nonpoint sources. All performance-based policies have additional challenges for monitoring and measurement.

We compare several policies aimed at reducing nutrient pollution for their advantages and disadvantages, and possible applicability to tile-drained systems:

- Minnesota's Agricultural Certification Program
- TMDLs
- Wisconsin's Phosphorus Rule
- Water Quality Trading

We found several promising ideas worthy of further development that will help put the best policies in place to drive significant nutrient pollution reduction from tile drainage.

1. We need to advocate for more publicly-available information on the status of conservation practices on tile-drained acres, the extent and location of tile drainage in target watersheds (i.e., those with the highest nutrient pollution loads), the amount of nitrogen and phosphorus being discharged from private drainage systems to community drainage systems and downstream waters, and tools that assess phosphorus pathways and loss in tile-drained systems.
2. Decision makers need a tool that can accurately model both nitrogen and phosphorus reduction for every beneficial BMP, and it must be versatile enough to be used by practitioners at the field level in various drained systems throughout the Midwest. We should encourage development of this tool by USGS, NRCS, EPA, or another appropriate agency with the ability to also disseminate it for widespread use.
3. Because performance-based policies may be the most efficient way to achieve water quality goals, we should encourage implementation of performance-based pilot programs with monitoring that allows for measuring nutrient pollution reduction at a small watershed scale.
4. At the same time, we need to encourage more research comparing performance-based and practice-based policies in the MRB, preferably through paired watershed studies.
5. Agricultural certification programs are a prime opportunity to increase private sector investment in nutrient pollution-reducing conservation practices, and to raise consumer awareness of soil and water stewardship that improves water quality. We recommend raising

awareness of the most effective certification programs with the sustainability programs of corporations in the food supply chain.

6. We recommend further development of a policy model which would set quantitative nutrient reduction goals and binding water quality standards at larger watershed scales in the MRB, but allow smaller watersheds, ideally through smaller watershed governance, the flexibility to find the best approach to achieve those goals and standards through a combination of regulations, performance-based policies, and voluntary incentives.

Given the scope of the problem and the variability and complexity of conditions, including geography, climate, cropping systems, and farm ownership and operations, it is important to consider all options with proven efficacy and pursue strategies that encourage significant pollution reduction through increased education, technical assistance, and performance-based policies such as performance-based incentives, taxes on nutrient pollution, and, if necessary, enforceable effluent limits.

We recommend moving away from reliance on current, strictly voluntary measures, and moving toward practices tied to performance-based standards. We also recommend promoting more diverse cropping systems and markets for their products. We believe a policy model worthy of further development would set quantitative nutrient pollution reduction goals and binding water quality standards at larger watershed scales in the MRB, but allow smaller watershed-level governing bodies the flexibility to find the best approaches to achieve those goals and standards through a combination of regulations performance-based policies, and voluntary incentives.

Introduction: Tile Drainage and Water Pollution in the Mississippi River Basin

For more than 30 years, scientists and policy makers have studied hypoxia in the Gulf of Mexico, and have reached the consensus that polluted runoff from agriculture is the leading cause of the problem. Yet, as a nonpoint source of pollution, row crop agriculture is not regulated by the Clean Water Act and there has been no significant progress in addressing this major source of freshwater eutrophication and hypoxia related water quality problems in the Mississippi River Basin, the Chesapeake Bay, and the Great Lakes. The size of the annual oxygen-deprived 'Dead Zone' in the Gulf has not decreased significantly since the 1990s.[1] Current voluntary and piecemeal approaches may have reduced some negative impacts of agricultural intensification in recent years, but they have not produced much, if any, significant water quality improvement. The agricultural industry has shown tremendous resistance to any policies even perceived to be regulatory in nature. The time is ripe to ramp up nutrient pollution reduction in watersheds with heavy nutrient loading. This paper will present **options to address nutrient pollution from tile drainage**, a significant contributor to increased nitrate loading to Mississippi River Basin streams and to the Gulf of Mexico. While this paper focuses on tile drainage and nitrate loading, it also addresses more broadly tile-surface drainage systems and their loadings of both phosphorus and nitrogen with the goal of innovating practice and policy to achieve actual and significant water quality improvements in the Mississippi River Basin (MRB).

Artificial drainage, commonly referred to as tile or surface drainage, has intensified in the Midwest in the latter half of the 20th century, and particularly in the last decade. Drainage allows for higher yield and productivity on wet soils, serving as an incentive to convert lands, including wetlands, which were considered marginal for farming into row crops. While drainage has been a profitable practice for farmers, it is now understood to be a major factor allowing increased levels of nitrogen, especially nitrate, and in some cases phosphorus, to reach water bodies, including eventually, the Gulf of Mexico.

Drainage can increase agricultural production by altering normal hydrological flow so that soils are well-drained and more suitable for growing high-yielding crops. Unfortunately, **drainage also allows water and nitrates to move quickly through the soil profile and the drainage system to reach streams and other surface waters**. In the past couple of decades, research has documented the impact of tile drainage on increased nitrate loading. For example, a 1999 United States Geological Survey (USGS) study noted that:

> *"The flux of nitrate to the Gulf has approximately tripled in the last 30 years with most of the increase occurring between 1970 and 1983…The principal source areas of N are basins in southern Minnesota, Iowa, Illinois, Indiana, and Ohio that drain agricultural land……. Agricultural drainage plays a major role in transporting nitrate from cropland to streams in the MRB."[2] - USGS*

A 2010 study by David et al used modelling to examine the sources of nitrate yields in the MRB and found that the "greatest nitrate N yields corresponded to the highly productive, tile-drained cornbelt from southwest Minnesota across Iowa, Illinois, Indiana, and Ohio."[3]

Excess nitrogen (N) is the primary pollutant of concern in coastal marine hypoxia, while excess phosphorus (P) causes eutrophication and algal blooms in freshwater lakes, leading to hypoxia. Both N and P can be contributing factors in both environments, depending on the relative amounts of biologically available N and P. While overland flow and increased flow in ditches and streams (triggering phosphorus-laden soil erosion) and surface water runoff is the primary transport pathway for P, studies have shown that **agricultural drainage is also an important contributor of dissolved reactive phosphorus (DRP)**,.[4,5] It was the increase in DRP which led to an outbreak of toxic algae in Lake Erie and shut down the water supply for the city of Toledo for several days in the summer of 2014.[6]

Artificial surface and tile drainage has also facilitated increased conversion of the MRB's remaining wetlands to row crops, to the detriment of biodiversity, fish and wildlife populations, flood storage, and water quality. A US Fish & Wildlife Service (USFWS) report found that 37,700 acres of wetlands were lost to upland agriculture in the Prairie Pothole Region (PPR) between 1997 and 2009.[7]

"Farmed wetlands were very vulnerable to drainage for agricultural crop production because they were usually small, in close proximity to existing farm field operations and could be easily drained, usually without penalty under existing regulations." - USFWS

Tile drainage has increased to a tremendous extent, particularly over the course of the past half century. The 2012 Agricultural Census revealed that more than 48 million acres are tile-drained and 42 million are artificially-drained by ditches.[8] Within Upper Mississippi River Basin states, approximately 34% of cropland is tile-drained and 13% is artificially drained by ditches; a total of 60 million acres are drained within the Upper MRB. (See Table 1 for the complete list of drained acres by MRB state.) These drainage figures do not include the tile and ditch drainage that is occurring in the James River, Big Sioux River, and Vermillion River watersheds of the Dakotas that also contribute flows and pollution to the MRB. Essentially, **the extent of artificial drainage is so great that, unless its negative impacts are intentionally countered by best management practices (BMPs) through large scale initiatives, water quality in the MRB will continue to decline.[9]**

Overview of Best Management Practices in an Artificially-Drained System

Artificial drainage is only part of the water quality problem in the MRB. The increase in tile drainage is driven by intensive row-crop production, which is driven by high crop prices and technology driving increased yields through drainage. This intensive crop production, in turn, fuels increased flows and in-stream soil erosion, as well as poorly-timed or excessive application of fertilizer and manure. Some of the solutions are the same in all cropping systems, tile-drained or not: follow a nutrient management plan, use conservation tillage on highly erodible land (or avoid planting such land), keep the land covered with a cover or perennial crop. However, this section will discuss these and other best management practices particularly in terms of their implementation in a tile-drained cropping system.

- Drainage management
- Bioreactors
- Constructed wetlands and restored wetlands
- Cover crops
- Nutrient management
- Reduced tillage
- Saturated buffers

We will discuss each of these practices in terms of their adoption status, cost, water quality impact, advantages, and disadvantages. See Table 2 for a quick comparison.

Drainage Water Management

Drainage water management (DWM) controls the flow of tile drainage water with in-field water control structures, and is meant to provide the farm options that conserve and store water on the land during winter, when drainage isn't necessary for crop production, or during the growing season, when more water needs to be conserved for the crop (well-drained soils are more critical during planting and harvest). Holding water on the land and in the soil and maintaining a higher water table reduces the volume of water reaching ditches and streams, and thus, can reduce total nitrate loading to streams. While these reductions vary by regional precipitation and temperature, a 2012 USDA study of drainage management in Iowa found that it **reduced tile flow by 21% and nitrate load leaching by 29%**.[10] A study by Kieser & Associates states that DWM could reduce nitrate losses by 16 pounds/acre.[11]

The practice **costs between $20-90/acre** to implement, although NRCS offers assistance for planning and installation.[12] Based on a 30% reduction in nitrates removed, Cooke et al. found that the practice costs $0.66-4.17/lb of N discharge avoided[13] Kieser & Associates distinguishes between the cost of retrofits and new installations, estimating retrofits to be more expensive at $93/acre while new installations are $88/acre.[14] DWM may result in increased yields and greater profits for the farmer, which could give farmers incentives to install systems at their own expense.

DWM won't work on all tile-drained acres; it is **best suited for flat land**, with less than 2% slope, and it may not be effective under prolonged wet or dry conditions.[15] Kieser & Associates found that 7.2 million acres of cropland in the Upper Mississippi and Tennessee-Ohio watershed are suitable for DWM, while USDA's Natural Resources Conservation Service (NRCS) estimates that 29 million acres are suitable.[16][17] As of 2013, **only 8,575 acres have been installed** through the NRCS cost-share program, so there is certainly room for a tremendous increase in the use of this practice.[18]

Expanded use of drainage water management will reduce water pollution from tile drainage, but it is not an across-the-board solution. Moving forward, **outreach efforts for DWM should be targeted to suitable acres.**

Bioreactors

Bioreactors are an edge-of-field device, but are specifically designed to reduce the amount of nitrate leaving the field. A typical bioreactor is a trench approximately 100 feet long by 10-15 feet wide and 2.5 feet deep, filled with wood chips or another carbon source.[19] The tile water is diverted through the bioreactor, where the carbon source and low-oxygen environment allow microorganisms to convert the nitrates in the tile water to nitrogen gas. Bioreactors can **remove 35-50% of nitrates from the water**, but there is no known impact on phosphorus or sediment.[20] Also, the nitrate removal effectiveness of bioreactors is compromised in high flow events when tile water is redirected around the bioreactor.

Bioreactors can treat drainage water from 40-80 acres and work well in existing filter strips, so the land use is not significant; there is little opportunity cost to the farmer.[21] There is little maintenance and operation required. After 10-15 years, the wood chips must be replaced, and the lifespan of the trench is approximately 40 years. [22]

Total cost, including installation and operation, varies; a 2013 study by Christianson, Tyndall, and Helmers estimates total cost over a 40 year lifespan to be between $308-637 per hectare **($708-$1573 per acre**), and Iowa Soybean Association estimates the average total cost of installation at $8000.[23][24] Environmental Quality Incentives Program (EQIP) funding, offered through NRCS, may be available to cover 50% of the cost of installation.

NRCS estimates that **at least 30 bioreactors have been installed in the states of Iowa, Illinois, and Minnesota**.[25] While there is great potential to expand use of bioreactors, the cost and lack of agronomic benefits to the farmer give little incentive for farmers to install them without a cost-share, a significant barrier to high levels of adoption.

Constructed and Restored Wetlands

Over half of America's historical natural wetlands (up to 90% in some states) have been drained, plowed under, or converted to other land uses, and their many ecological and water quality benefits have been lost. Constructed wetlands and restored natural wetlands reestablish some of the natural water filtration, flood mitigation, and habitat value that natural wetlands provided in the past. Wetlands, particularly emergent marshes, can be used for denitrification of nitrate and for trapping of particulate phosphorous loads from cultivated fields. Key considerations are the siting of wetlands to intercept a significant fraction of the nutrient load and whether the wetlands are sufficiently large to treat the loads they receive. While wetlands have been shown to efficiently trap phosphorus associated with suspended particles, their capacity to trap dissolved phosphorus is more variable. Wetlands are generally less effective at retaining dissolved phosphorous than at removing nitrate. There is widespread potential for restored wetlands to intercept agricultural drainage and reduce nutrient export to downstream waters in the MRB.[26]

Restored natural wetlands have been shown to reduce nitrates by about 50%.[27] While constructed wetlands are often smaller and less characteristic of natural wetlands, research by The Nature Conservancy (TNC) has shown that constructed wetlands in Illinois can reduce nitrates and total **nitrogen by 18-44%**, and **phosphorus by 57-68%**.[28] However, nutrient removal effectiveness depends upon proper siting, design, and maintenance, and long-term effectiveness may be affected by flooding or other disturbances over time.

TNC has found that its costs of construction, seeding, and tile work associated with building several Conservation Reserve Program (CRP) CP-39 wetlands is highly variable, but TNC estimates the average cost at about $14,500/acre.[29] While the Farm Services Agency (FSA) offers attractive federal incentives for establishing wetlands under the CP-39 program,[30] TNC has found significant gaps between these FSA reimbursements and the actual costs of the wetland construction. To increase the establishment of CP-39 wetlands, FSA reimbursement rates need to be updated to reflect current contractor rates.[31]

Recent studies of Iowa CREP wetlands designed and sited to reduce the N runoff they receive from tile drains shows that on average these wetlands reduce NO3 loads by about 50%, and do so at an average cost of $1.26 per lb. This analysis confirms that these wetlands are a cost-effective way to reduce NO3 loadings and should remain a tool for enhancing water quality even in the face of high cropland prices, and without any consideration of the additional environmental benefits these wetlands provide for wildlife habitat, carbon (C) sequestration, and flood water retention.[32] As of 2012, the FSA had enrolled over 300,000 acres in farmable wetlands, mostly in MRB states, if the Dakotas are included.[33] With assistance from federal and state programs as well as conservation organizations, there is potential to expand wetlands construction and restoration for nutrient removal in the MRB, but with limited financial resources, use of constructed wetlands must be planned carefully to maximize their effectiveness in improving water quality.

Cover Crops

Cover crops are a versatile practice that can be adapted to work in almost any climate and cropping system with water quality benefits. Cover crops are a non-cash crop included in usual crop rotations for conservation purposes or for soil health benefits. By holding the soil on the land and keeping more nutrients near the surface soils taking up nutrients, cover crops reduce the amount of nitrogen and phosphorus that reach surface and subsurface water. They also improve the ability of the soil to hold water, reducing overall flow to streams.

Cover crops reduce nitrogen and phosphorus loading, but the water quality impacts will vary along with the management and land characteristics. USDA Agricultural Research Service (ARS) research found that cover crops have the potential to **reduce nitrate losses from tile-drained fields by 43%**.[34] The Iowa State Nutrient Reduction strategy estimates that, if cover crops were planted on all corn-soybean and continuous corn acres in Iowa, they could reduce N loading by 28% and P by 50%.[35]

The cost of seed, planting, and terminating cover crops can be between **$30-50 per acre**.[36] However, a survey by USDA's Sustainable Agriculture Research and Education (SARE) revealed that many farmers report a 5-10% yield boost following cover crops.[37] The 2015 survey reports a statistically significant average 2-5% yield boost following cover crops.[38] SARE estimates that this yield increase could result in a $35 per acre return for corn and a $28 per acre return for soybeans, reducing the overall cost. Cover crops can also result in reduced input costs for fertilizer and weed or pest management, or provide forage for cattle. For these reasons, many farmers (at least 60% according to SARE) are willing to pay for cover crops out of their own pocket, without receiving a cost-share.

Due to these agronomic benefits, cover crops have become increasingly popular, and reports have shown that their use has doubled or even tripled in recent years.[39] However, changing farm practice to properly manage cover crops requires high initial investments of time, and cover crops are still perceived as a risk by many farmers. The 2012 Agricultural Census revealed that cover crop adoption in terms of total cropland acres is still low; **only 3.4 million acres, less than 3% of total cropland, are planted to cover crops in the Upper MRB states**.[40]

Increasing cover crop adoption has the potential to significantly improve water quality in the region, but even an exponential increase can only go so far toward reversing freshwater eutrophication and Gulf hypoxia. Cover crops, like most BMPs, have limited impact during increasingly frequent storms and floods, and can only do so much to reduce the tremendous amount of excess nutrients reaching streams and rivers.

Nutrient Management

Nutrient management is more difficult to define than other BMPs, but on row crops, the term is usually applied to choices made for fertilizer and manure application, including rate, timing, and method of nutrient application. The concept of nutrient management is sometimes used interchangeably in agricultural conservation as the "4 R's" principle; using the "**r**ight" source, right timing, right place and right rate of fertilizer and manure application. However, it can also refer to manure management on a livestock operation. Nutrient management is often practiced in combination with other practices, like cover crops, that benefit soil health. Drainage management can also complement nutrient management, as it controls the retention of nutrients in a field.

Due to the nebulous nature of the concept, field variability, and lack of monitoring data, it is difficult to assess the water quality impacts of nutrient management practices. For the purposes of this paper, we will refer to a science assessment of the Iowa Nutrient Reduction Strategy.[41] This assessment was based on a literature review and scenarios of nutrient load reduction potential from a baseline of estimated existing conditions, incorporating, for example, estimates of nutrient applications, crop rotation, and the extent of tile drainage in the baseline assessment. The assessment calculated the potential impact of N and P management practices on nutrient loading.

For nitrogen (N), the assessment found that alterations in timing of N application (changing from fall to spring application, for example) resulted in little reduction in nutrient loading, and in some years, an increase. The assessment states that **reduction in the rate of N applied** is more promising, with the potential to **reduce nitrates by 9%**.[42]

For phosphorus (P), the assessment mainly focused on erosion control practices to manage loss, including tillage and cover crops. The assessment found that P rate reduction in certain regions could **reduce phosphorus by 7%** from the baseline.[43]

We will not generalize the cost of nutrient management practices because they are so specific and variable. For example, a simple reduction in the rate of nutrients applied should result in cost savings for the farmer, and if calculated correctly, should not result in a decrease in yield. However, changing the timing of application from fall to spring could result in increased input costs to the farmer, due to the discounts offered for fall application.

The status of nutrient management implementation is similarly difficult to ascertain, but it is certainly far below optimum.[44, 45] The NRCS Conservation Effects Assessment Project (CEAP) found that while most MRB acres have some form of N or P management, **only about 13 percent of acres met full nutrient management criteria** for both, including consistent rates, timing, and method of application, and that **47% of acres needed additional management**.[46] According to a 2014 study by Osmond et al, "Farmers were found to be hesitant to apply N at university-recommended rates because they did not trust the recommendations, viewed abundant N as insurance, or used recommendations made by fertilizer dealers."[47] A Natural Resources Conservation Service (NRCS) report on barriers to adoption of nutrient management practices also found that farmers are skeptical of the science behind nutrient management and the role of "Big Government" in developing recommendations.[48] There is also resistance to limiting manure applications in excess of soil phosphorus requirements, at least in part due to the manure waste management needs of Concentrated Animal Feeding Operations (CAFOs).[49]

While nutrient management has significant barriers to adoption and variable impacts on water quality, it still must be part of the solution to excessive nutrient loading to tile drainage and surface water. **Reducing fertilizer and manure inputs in modern agricultural systems is not a solution to high nutrient loads, but it is an important first step in reducing nutrient loads from agricultural fields into streams and rivers.**

Reduced Tillage

Literature shows that no-till or reduced tillage systems may not have a significant impact on water quality in surface drainage and tile lines. A 1995 study by Randall and Iragavarapu compared no-till and conventional tillage systems in a tile-drained system in Minnesota over eleven years; the study concluded that tillage practices had minimal impact on nitrate losses to subsurface tile flow.[50] In Iowa, a study by Kanwar et al. assessed four different tillage practices and found that tillage had little influence on nitrate and pesticide losses to subsurface drainage water.[51] Coelho et al. studied phosphorus and sediment loading in overland and tile flow and found that less than 2% of DRP traveled through tile drains, and that minimum tillage reduced overland phosphorus and sediment load by 3-6 fold.[52] Finally, a paired watershed study in Illinois by Lemke et al. found that an increase in BMP implementation, including strip-tillage, resulted in no significant change in N, P, sediment, or hydrology within the treatment watershed, after seven years of monitoring.[53]

From this, we can conclude that, **while reduced tillage may be extremely effective at reducing erosion and surface runoff, it is less relevant to the discussion of addressing pollution from tile drainage**. In fact, a USDA report even cautions that treatment of erosion alone through tillage or other structural practices may actually increase nitrogen loss by rerouting it to subsurface flow.[54]

Saturated Buffers

Emerging practices like **saturated buffers** have a lot of potential and should also be considered in the mix of BMPs for tile drainage systems. Saturated buffers work on fields with riparian buffers; instead of discharging directly into streams, the tile flow is diverted into the soil profile beneath the buffer and filtered. Where tile water is discharged to the buffer (rather than bypassing it), early research has shown that saturated buffers can remove 35-59% of the N in tile flow, as well as some phosphorus, with fairly low implementation costs.[55]

Recommendations

BMPs are not being implemented to their full potential. After reviewing the practices, their status, cost, and water quality impact, we recommend the following general approaches to increase adoption of these BMPs.

1. **It should be a goal to install at least one structural practice on every drainage outlet reaching streams**, which could be a bioreactor, a control structure for drainage water management, or a saturated buffer.
2. **Cover crops and nutrient management (of fertilizer and manure)** are beneficial to farmers and to water quality on every field, not just tile-drained acres. The **current approach of outreach and education on these practices should continue** with a focus on the benefits to farm profitability. To support increased adoption of cover crops, increased technical support to farmers is necessary to assist in the transition to cover crops, including addressing potential risks to crop yields.
3. **Nutrient management recommendations for manure application should not exceed actual crop production requirements.**
4. Constructed wetlands are expensive to install but, like restored natural wetlands, they are highly beneficial to water quality and have many other environmental benefits. With assistance from federal and state programs as well as conservation organizations, there is potential to expand wetlands construction and restoration for nutrient removal in the MRB, but with limited financial resources, use of constructed wetlands must be planned carefully to maximize their effectiveness in improving water quality.

The Past, Present, and Future of Non-point Source Strategies

We have shown that several best management practices have the potential to reduce pollution from tile drainage. In fact, short of taking land out of production or giving modern production systems a complete makeover, there is no way to reduce agricultural pollution without the use of conservation practices. Unfortunately, BMP implementation is still low.

Is it possible to flip the status quo from low implementation of conservation practices to widespread adoption in the Midwest? After years of public and private investment in BMPs, can more be done to increase adoption? Policy changes may bring us closer to achieving clean water goals, but certain barriers must be addressed and current approaches to increase adoption should be examined, remodeled and better funded.

The Limits of Voluntary Incentive-Based Conservation

True water-quality success stories from entirely voluntary efforts to address non-point source pollution from agriculture are rare, if you measure success in real water quality outcomes – restored streams, de-listed lakes and rivers, or the disappearance of hypoxic zones and toxic algal blooms. Little progress has been made in more than 30 years of work to address Gulf hypoxia and implementing an overarching strategy for such a large region is an enormous challenge. The failure to achieve goals to reduce the size of the hypoxic zone heralds the need to try a new approach. **It is unlikely that continuing to rely on an entirely voluntary approach of BMP implementation will produce the desired results**.

Policy specialists have been questioning this dependency on a voluntary approach for years. In 1982, Ervin and Ervin pointed out that voluntary programs "have not effectively met their objectives to increase and maintain soil conservation on cropland, despite expenditures of over $20 billion since 1935."[56] More recently, USDA's Economic Research Service (ERS) stated that, in the Chesapeake Bay, "exclusive reliance on such [voluntary] policies has not been effective in improving water quality."[57]

This is not to say that voluntary conservation programs have not made a tremendous difference to the landscape and do not have a continuing role to play. Certainly, farm bill programs have provided a reward for good stewardship and have prevented much greater environmental degradation than is even now occurring. Voluntary conservation programs provide many public benefits in addition to water quality improvements and have provided a tremendous boost to wildlife habitat on working lands. The USDA's Conservation Effects Assessment Project (CEAP) report on conservation practices in the UMRB is very positive on the impacts of voluntary conservation practices, stating that farmers "have made significant progress in reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption."[58]

However, the CEAP assessment also makes it clear that **more than half of the 63 million acres in the UMRB still need additional conservation treatment**, and that **nitrogen loss through leaching is still a major source of concern**.[59] The CEAP modelling approach did not assess some practices specifically aimed at addressing nitrates in tile drainage, such as drainage water management or constructed wetlands, but suggests that **47% of cropped acres need additional nutrient management to address nitrogen loss from subsurface flow**.[60]

Despite extensive outreach efforts and financial incentives from cost-share programs, there is clearly still a lot of ground to cover in the UMRB. Meanwhile, federal funding for agricultural conservation programs declines each year. The 2014 Farm Bill reduced conservation funding by $4 billion from the 2008 bill, and it is unlikely that the next one will increase spending levels.[61] **Even if limitless amounts of conservation funding existed, many factors influence producer decisions on whether or not to implement a practice; cost-share funding alone cannot purchase the level of conservation needed.**

Nonpoint Source Regulation: Barriers and Limitations

There are tremendous political barriers to the large scale success of a basin-wide regulatory approach like the Chesapeake Bay Total Maximum Daily Load (TMDL) that includes adoption of enforceable pollution reduction limits within and across local and state governments. The time, expense and difficulty of developing the monitoring, scientific data and modeling to support enforceable pollution reduction limits, developing and executing conservation practices and pollution controls to meet the pollution limits, and monitoring and enforcing compliance with the pollution reduction limits to achieve overall basin-wide pollution reduction are also major barriers to success. Given these barriers, adoption of a one-size-fits-all regulatory approach on a scale as broad as the entire MRB seems particularly daunting.

On a smaller watershed scale, with a focus on localized water pollution concerns**, the potential for achieving water quality improvements following adoption of regulatory measures should be greater.** It may also be easier to adopt, implement, and enforce nutrient pollution limits and to measure progress toward achieving water quality goals. One example that has been successful is the approach taken on the Central Platte River Valley in Nebraska, which once had high levels of nitrate contamination in the groundwater. Nebraska passed a state law in 1981, the Groundwater Management and Protection Act, then revised that law in 1986 to authorize local Natural Resource Districts (NRDs) to form management areas and require implementation of best management practices.[62] In 1992, fall and winter nitrogen applications were banned, and the rate and application method of spring applications were also subject to regulation. The Central Platte Natural Resource District developed a groundwater quality management plan and used a phased approach, increasingly restrictive at each phase. Over time, the nitrate levels in the aquifer decreased.

There may be the potential and the need to implement similar strategies on the local level in the UMRB, especially when nutrient pollution threatens drinking water sources, as in the Raccoon River watershed near Des Moines. In 2015, the Des Moines Water Works filed suit against several Iowa drainage districts in an effort to force significant nitrate pollution reductions from drainage systems triggering excessive nitrates in the drinking water supply of some 500,000 citizens in the metro Des Moines area.[63]

Minnesota's experience with its 2015 Stream Buffer Law illustrates the resistance to requiring BMPs, even when requirements are flexible and come with taxpayer financial support. Minnesota passed a widely supported stream buffer bill in 2015 that identified about 110,000 acres of Minnesota land for water quality buffer strips, required new perennial vegetation buffers of up to 50 feet along rivers, streams, and ditches to filter out phosphorus, nitrogen, and sediment, provided flexibility and financial support for landowners to install and maintain buffers, and was designed to boost compliance with existing buffer laws across Minnesota.[64] Less than one year after passage, agricultural groups reneged on the agreement to buffer private ditches and lobbied hard against the buffer requirements for them. The state resource agencies were forced to back off of these buffer requirements all the while acknowledging the need to buffer these ditches to reduce their nutrient pollution discharges to Minnesota waters.[65]

Statewide Nutrient Reduction Strategies

The current approach of the Gulf Hypoxia Task Force, coordinated by a committee of state and federal agencies, emphasizes nutrient reduction strategies for each state in the MRB, which would encourage ownership of the problem and flexibility to meet goals at the state level. In 2008, the Task Force charged each member state with developing a nutrient reduction strategy by 2013. In early 2014, EPA's Office of Internal Governance (OIG) audited this approach and found that **most of the MRB states had not yet completed a strategy**.[66] By late 2015, most of the mainstem MRB states had completed strategies, while Arkansas, Kentucky and Tennessee have completed draft strategies.

EPA's OIG Report provided a basic framework to aid the states in developing the strategies, suggesting that each state prioritize watersheds for N and P loading, set load reduction goals, report implementation activities annually, and develop a work plan for developing numeric criteria.[67] The OIG report also recommended that the task force emphasize measurement systems for state strategies and augment the state's emphasis on local waterways with a focus on the larger watershed. State nutrient reduction strategies that incorporate and implement these important elements have the potential to significantly advance nutrient pollution reduction in the MRB. The state strategy development process in Iowa, for example, fostered healthy research and policy discussion and generated concrete state goals, objectives, and priorities. However, the Iowa state strategy is still based on voluntary conservation measures, lacks enforceable nutrient pollution reduction limits, and on its current implementation trajectory, there is no guarantee that Iowa will achieve sufficient nutrient pollution reduction from Iowa sources to solve local nutrient pollution problems or contribute to solving the Gulf Hypoxia problem. **Statewide nutrient pollution reduction strategies need to be strengthened and fully implemented to successfully trigger significant nutrient pollution reduction in the MRB.**

We will explore how these strategies can serve as a platform for improved communication, watershed governance, and coordination among states and watersheds, as well as pollution reduction within the MRB later in this paper.

The Future of Performance-Based Strategies

A performance-based strategy emphasizes results and outcomes, while a practice-based or design-based strategy focuses on management actions in service of the final result. According to a USDA Economic Research Service (ERS) report, **performance-based policies may be more efficient and provide more flexibility to farmers than a practice-based approach**.[68] Some examples of performance-based policies are:

- **Effluent limits**,
- **Pollution taxes**, and
- **Payments for pollution reductions or water quality improvements**.[69]

Very few performance-based policies have been implemented for nutrient reduction so far, but there could be an increase of these strategies in the future. California's nonpoint source program is one of the few state-level performance-based policies, designed to **limit nutrient pollution discharges**.

California's Porter-Cologne Water Quality Control Act of 1969 authorizes the regulation of nonpoint source pollution, giving California the authority to issue permits and require dischargers to follow implementation programs (NPS plans).[70] Nitrogen and phosphorus discharges are regulated through this nonpoint source program, as well as pesticides and some other pollutants. Permits and plans are enforced through regional boards and a system is in place to deal with violations, which could result in fines if the violation is not addressed. Environmental Law & Policy Center evaluated the program in a 2010 report, in which they praised the design of the program but also pointed out the need for improvements in enforcement and documentation of results.[71]

Similar programs could be implemented in the MRB, but they would depend on the authority to regulate nonpoint sources. Their adoption, acceptance, and enforcement also depend on monitoring, measurement, and sound modeling of nutrient pollution loads and load reductions in order to support and enforce the discharge limits imposed, and to demonstrate effective long-term nutrient pollution reduction. Without reliable monitoring and accountability systems in place, regulatory programs such as these may not achieve the desired water quality results. There are tremendous political barriers to passing state laws like the Porter-Cologne Act in the Midwest. Nevertheless, if drinking water supplies are threatened, public attitudes will likely shift in favor of such regulations.

Even where state laws are enacted, when states share a water resource like the Mississippi River and its tributaries, it is important that the states each "pull their weight" in terms of nutrient pollution reduction if water quality improvements are to be achieved. This basic premise is at the heart of the Clean Water Act, which sets basic uniform minimum water quality standards across the states. While the Clean Water Act does not require permits for non-point source pollution, it does authorize the establishment of Total Maximum Daily Load (TMDL) watershed cleanup plans for waters that are not meeting water quality standards, and these TMDLs can be adapted to set performance-based standards for non-point sources as part of a watershed cleanup plan. Once again, monitoring, measurement, and sound modeling of nutrient pollution loads and load reductions is essential in order to support and enforce the discharge limits imposed, and to demonstrate effective long-term nutrient pollution reduction. *See* TMDL discussion below.

Ideally, a performance-based **pollution tax** would be based on a calculation of surplus nutrients leaving the farm, which is not the same as an input tax - on fertilizer, for example. While similar taxes have been applied to urban stormwater, we cannot point to an adequate example of a tax on agricultural sources, perhaps due to political barriers and difficulty of implementation.[72] The Dutch government briefly tried an approach called the Mineral Accounting System (MINAS), which was targeted to nitrates but based on amount of nutrient inputs minus outputs, in the form of crops and livestock.[73] The approach failed in 2006; it was deemed ineffective to protecting water quality, unfair to farmers, and it required enforcing strict manure application standards. Despite the lack of success with pollution taxes, some policy experts still point out the advantages of such an approach, as it is a market-based solution that requires the polluter to pay, rather than the taxpayer.[74][75]

Tile and surface drainage systems are defined water conveyance systems with discrete outlets at which nutrient concentrations in water flows could be measured and taxed directly. Despite the tremendous political barriers in most areas, a shift in public sentiment due to concern over a threatened drinking water supply could create opportunities to test the effectiveness of a pollution tax on tile and surface drains in some MRB watersheds where drinking water is threatened, such as the Raccoon River in Des Moines. If such a tax were tested, it would also be important to monitor at least a representative subset of both tile drain and surface drain outlets to tributary streams and lakes.

Performance-based payments remain more politically feasible, as they are voluntary. Winrock International has a pilot program in the UMRB that pays farmers per pound of nutrient reduced, rather than directly for practices.[76] While the program does make use of in-stream and edge-of-field monitoring, the payments for phosphorus reductions are based on estimates. Nitrogen management is tested with an end-of-year cornstalk nitrate test. The program is designed to be more flexible and cost-effective than paying for practices. The project showed that when farmers are involved in calculating their nutrient loss from various practices, they learn new things about their farms and are able to save money while improving water quality. This approach could be very useful in managing nutrient loss through tile-drainage, as BMP effectiveness could vary greatly at the field level. So far there is not sufficient research comparing pay-for-performance to pay-for-practice incentive programs. For example, would the cost and effort of monitoring and implementing the program on every field be translatable to larger watersheds? **A paired watershed study that monitors water quality, transaction costs, costs per pound of nutrient reduction, and adoption rates between traditional pay-for-practice and pay-for-performance approaches would be very valuable in deciding the future of this approach.**

A Comparison of Existing Policy Tools

We have given an overview of current broad policy approaches to addressing fresh water eutrophication and Gulf hypoxia and some of the major barriers to creating effective public policy that will address the negative impacts of tile drainage. However, these barriers can be overcome or circumvented. Here we will discuss policy tools with the potential to tackle nutrient pollution in the MRB, and the advantages and disadvantages of each. See Table 3 for a side-by-side comparison of each policy.

Minnesota Agricultural Certification Program

"Certainty programs" are so-called because they offer producers certification of compliance in advance of any state or federal water quality laws. The programs are entirely voluntary, but would not exist without the threat of future regulation. Several states offer certification programs, including Maryland, Michigan, New York, Louisiana, and Texas, but we will focus on the recently-developed Minnesota Agricultural Water Quality Certification Program (MAWQCP).

Enrollment in the Minnesota program requires a 10-year commitment to implement a suite of conservation practices on the whole farm.[77] Each field and each crop that may be in the field is assessed using a computer model that evaluates field physical characteristics, nutrient management, tillage management, pesticide management, irrigation management, drainage management, and conservation practices, and **scores each field/crop on an index of 1-10**, a higher number indicating a lower risk to water quality. All fields/crops must score higher than 8.5 to receive certification, and each farm is verified by a licensed certifier for the final step of the certification process. Tile drainage is included in the assessment, and will reduce the overall score if tile drains are present and left untreated. Scores on tile-drained farms may be boosted if drains are treated with drainage water management or similarly effective conservation practices. In Minnesota, agricultural certification began on a pilot basis in a few Minnesota watersheds in June 2014. By May 2015, 41 farms had been certified, establishing 145 new conservation practices on about 23,000 acres.[78] Minnesota's Department of Agriculture expanded eligibility for certification statewide in 2015.[79]

The program has the advantage of identifying and tailoring water quality practices to reduce water quality risks, taking into account unique agricultural systems and physical characteristics on a parcel-by-parcel and crop-by-crop basis. The program is appealing to farmers because it rewards them not only with regulatory certainty, but also with recognition for good stewardship. It also offers technical assistance and guidance on implementing specific conservation practices.

While this technical assistance is valuable, to the producers and potentially to the level of water quality benefits, these customized certifications are also very time and labor intensive – at taxpayer expense. Furthermore, a late 2015 assessment of the water quality potential of the Minnesota certification program concluded that the program "does not currently protect water quality standards for nitrate." The study found that "every location with tile monitoring significantly exceeded the safe drinking water standard for nitrate (ranging from 1 ½ to 5 times the standard) and several of these locations scored high enough to certify." The study recommends numerous specific actions to improve the nutrient reduction effectiveness of the Minnesota Certification Program, including tightening up the scoring of nutrient reduction best management practices, stepping up monitoring and modeling to estimate the pollution reduction potential of certification efforts in targeted watersheds, and improving transparency and accountability.[80]

While implementation is still low and pollution reduction effectiveness is uncertain, **certification programs have great potential to enlist farm operations in effective nutrient reduction practices,** if nutrient reduction standards are set high and nutrient reduction practices are deployed and maintained where they will be most effective. **These programs will likely be more successful if they can be coupled with private sector investment through the supply chain.** As consumers express preferences for food products grown, harvested, prepared, and packaged in an environmentally sustainable manner that protects soil and water resources, food industry corporations should be motivated to invest in certification for producers in their supply chain. For example, purchasers in the food industry wishing to boost their own corporate sustainability image and practices could offer incentives or require their producers to receive certification, driving greater farm-level investment in soil and water stewardship. Because the Minnesota program has a systems-approach focused on water quality, it is likely to drive improvements in water quality if certification standards can be strengthened and the program is implemented on a broad scale.

Total Maximum Daily Load (TMDLs)

The Clean Water Act requires states to set standards for local water bodies, make a list of impaired waters that fail to meet those standards, and then develop a Total Maximum Daily Load (TMDL) cleanup plan for impaired waters. The TMDL sets the maximum amount of a particular pollutant that a water body can receive in order to meet its water quality standards. For example, the Chesapeake Bay TMDL sets a Bay watershed-wide limit of:

- 185.9 million pounds of nitrogen (25% reduction),
- 12.5 million pounds of phosphorus (24% reduction), and

- 6.45 billion pounds of sediment per year (20% reduction).[81]

While TMDLs are regulatory in nature, the Clean Water Act does not require enforcement of TMDL nonpoint source controls. However, a state may choose to implement a TMDL through state implementation plans that regulate or otherwise limit the amount of nutrient pollution that can reach a water body from nonpoint sources as well as point sources. This watershed-based accountability framework for non-point source pollution is a primary strength of TMDLs, but it is also a major reason for the tremendous political opposition to TMDLs from the agricultural community.

After the TMDL has been developed, the next step is development of a Watershed Implementation Plan (WIP) to meet the TMDL goals. These plans are often referred to as TMDL projects. There is no TMDL for the entire Mississippi River Basin, although there are many TMDLs for water bodies within the MRB and for watershed sections of the Mississippi.[82]

Development of TMDL plans can take years and their implementation is historically inconsistent. Some TMDL plans, like that for the Chesapeake Bay, are pursued aggressively, backed by strong scientific analysis and modeling and setting and achieving timelines and milestones, while others are left on the shelf.[83] Even TMDLs with solid accountability frameworks can fall short of achieving nutrient pollution reduction goals, largely due to the challenging nature of reducing significant nutrient loads from agricultural run-off. A recent study of Chesapeake Bay TMDL implementation data finds that the failure to significantly curb nitrogen loading from agricultural sources in Pennsylvania could threaten the success of the TMDL cleanup plan Baywide.[84]

TMDLs can also be costly. One 2001 EPA report estimated **the average cost of TMDL development alone to be $52,000, with TMDL development costs ranging between $26,000-500,000**.[85] TMDL development costs for more effective TMDLs will likely exceed this estimate, but the environmental benefits of effective TMDLs will likely increase as well.

Another barrier to developing adequate TMDLs to address nutrient pollution is that many states do not have EPA-approved numeric criteria for nutrients. Within the UMRB, only Wisconsin and Minnesota have developed statewide phosphorus criteria. Illinois and Missouri have partial statewide phosphorus or nitrogen criteria for lakes and reservoirs. Iowa, Indiana, and Ohio do not have any nutrient criteria.[86] Despite the lack of numeric criteria, many TMDLs have been developed in the MRB for excessive nutrients. Some watersheds have been listed for nitrates based on drinking water standards. For example, in Iowa, the South Skunk watershed is listed as impaired for nitrates, though no TMDL has been developed yet.[87] In Illinois, the North Fork of the Vermilion River and Lake Vermilion are used for drinking water; consequently, a TMDL has been developed for nitrates due to exceedance of the drinking water standard of 10 mg/L.[88] The same is true for the Sangamon River above Lake Decatur, Illinois.[89]

Despite these limitations, **TMDLs provide value by offering a framework for watershed-scale nutrient pollution reduction planning and quantitative goals that, if achieved, could result in real nutrient pollution control outcomes**. The TMDL and state implementation planning process can be a great resource and an opportunity to involve watershed stakeholders in pollution reduction, drinking water supply protection, and aquatic resource restoration. The creation of TMDLs can also open up funding opportunities with the EPA's Clean Water Act section 319 program, which offers funding for watershed projects in listed, impaired waters.[90] A TMDL watershed-based accountability framework is among the tools being considered to curb excessive nutrient pollution in the West Lake Erie watershed that is threatening drinking water and aquatic life in the Maumee River and West Lake Erie.[91]

Wisconsin Phosphorus Rule

Wisconsin's Phosphorus Rule, created in 2002 and updated in 2010, applies to both point and non-point sources. The following rules apply to crop production:

- All cropland must maintain a soil erosion rate less than or equal to the "tolerable" T rate,
- No tillage can be conducted within 5 feet of surface waters,
- All crop producers must average no more than 6 and not exceed 12 on the Wisconsin Phosphorus Index, a tool that measures phosphorus runoff based on a field conditions, crops, tillage, and nutrient management, and
- All crop producers must comply with a nutrient management plan.[92]

The rule does not address drainage practices, and the P index only calculates overland flow.[93] Still, the rule might serve as a model for states or regions to regulate nitrates in tile drainage. It combines regulation of practices, like the tillage setbacks, with a performance-based standard, the P index, which would allow producers to choose their own mix of practices to meet the standard.

For difficult practices and for producers with financial need, the law requires that the state provide up to a 70% cost-share. Total cost of implementing the non-point source portion of the rule is not available. However, Wisconsin's adaptive management approach is meant to combine regulation of point sources and nonpoint sources for the least-cost option; its actual cost-effectiveness should and most likely will be assessed in the next few years.

Water Quality Trading

If they are designed to significantly reduce overall nutrient pollution loads in a watershed, then **water quality trading programs offer a means to reduce nonpoint source pollution by providing a market-based funding mechanism for enhanced application of BMPs.** If water utilities and other point sources face burdensome costs for treatment upgrades that provide only marginal nutrient pollution reduction, it may be less expensive and equally or more effective to reduce nutrient loading through additional targeted BMPs paid for by regulated point-sources, as long as trade ratios are designed to achieve real net nutrient pollution reduction through more than a one-to-one trade. For example, one effective mechanism might be a trade ratio that requires the purchaser (treatment plants) to buy credits from farmers for three times the amount of nutrient reductions than is required by the nutrient criteria.[94]

Water quality trading is being tried in Ohio where utilities in the Great Miami River Watershed were facing $422 million in upgrades to treatment plants to meet pending nutrient criteria.[95] These upgrades would have resulted in significantly higher consumer prices and still would not have addressed nutrient pollution coming from non-point sources upstream. The cost to achieve the necessary reductions through conservation practices was estimated to be $50 million.[96] In order to achieve the pollution reductions for a much lower cost, the Miami River Conservancy District developed a pilot water quality credit trading program to pay farmers for conservation practices. The program has achieved 572 tons of nutrient reductions.[97]

The program is still in the pilot phase and nutrient criteria are still pending. It's overall impact and longevity is uncertain, as the trading program relies on EPA and USDA grant funding for administration. Other trading programs in the United States are in similar phases of early development and with uncertain futures with the trading markets not being fully established. Their ultimate success may depend on the setting of numeric nutrient criteria and clear regulations governing trading. A 2009 World Resources Institute (WRI) report identified **23 active trading programs in the United States; only 5 were located in UMRB states**.[98] The next 5-10 years could be a critical window for water quality trading programs to find their footing.

A WRI study by Perez et al used the CEAP APEX model to assess the potential for large-scale interstate nutrient trading programs in the MRB. The study assumed the Hypoxia Task Force goal of a 45% nutrient reduction, and that all point and nonpoint sources had first met their individual requirements to meet that goal.[99] The model included conservation practices that would address pollution from tile drainage: drainage water management, nutrient management, and cover crops, among others. In two different hypothetical training scenarios in Chicago and northern Kentucky, the average cost of reducing **nitrogen** through BMPs was **$4.50 and $11.89 per pound**, and **phosphorus cost $30.35 and $26.07 per pound**, respectively.[100] WRI determined that "large-scale interstate nutrient trading in the MRB could be an economically and environmentally feasible tool for helping to reduce hypoxia in the Gulf of Mexico."[101]

Can trading programs actually improve water quality, or do they simply allow point-sources to avoid important upgrades for uncertain gains in nonpoint-source pollution reduction? This is a legitimate question and there is certainly risk in this approach. A recent WRI report by Walker and Selman classifies the uncertainties and risks of water quality trading:

- Biophysical and scientific (do BMPs actually achieve the calculated reductions?);
- Extreme events (a flood or a drought could render the implemented BMPs ineffective);
- Behavioral (a default on the trade agreement on the part of the farmer);
- Regulatory (if regulations change, so does the market, and also maybe the value of previously purchased credits); and
- Market (unknown supply and demand).[102]

Another water quality trading concern is the generation of nutrient pollution hotspots, where nutrient pollution is allowed to persist in some parts of the watershed while being ameliorated in others, raising issues of fairness and justice for communities burdened by these persistently polluted areas.[103]

Some of these uncertainties can be addressed through built-in mechanisms to ensure that programs achieve reductions above and beyond the business-as-usual approach, incorporating a margin of error, and trade ratios that require the purchaser (treatment plants) to buy credits from farmers for several times the amount of nutrient reductions required by the nutrient criteria.[104]

A 2015 report involving the National Network on Water Quality Trading provides important guidance for building a successful water quality trading program. [105] This report concludes that programs should be consistent with the 2003 EPA Trading Policy and the Clean Water Act[106] and with guiding principles that include: accomplishing regulatory and environmental goals, being based on sound science, providing "sufficient accountability, transparency, accessibility, and public participation to ensure that promised water quality improvements are delivered," producing no localized water quality problems, and including compliance and enforcement provisions to ensure long-term success.

The report further concludes that growth in trading programs and their success in improving water quality, will depend on the following actions, quoted below:

- Clear and consistent documentation of assumptions and decisions underlying trading program development and operations;
- Serious consideration of watershed science and goals in guiding the practical workings of trading programs;
- Incorporation of WQT into a suite of water quality protection goals and tools; and
- Regular, informative communications to the public to build confidence that progress is being made toward clean water goals in a timely way.

Drainage Districts

The installation of tile and surface drainage systems is largely governed by drainage districts – local boards authorized by state law to manage the location of tile drainage outlets on the land and to maintain district-wide surface drainage systems that collect flows from tile drainage outlets. To understand them better, we will compare the governance of drainage districts in Iowa and Illinois.

Iowa Drainage Districts

- **Authorization**: A constitutional provision added to Iowa law in 1908, authorizing the organization of drainage districts with the power to "construct and maintain levees, drains and ditches and to keep in repair all drains, ditches and levees heretofore constructed under the laws of the state…"[107]
- **Status:** Over 3000 drainage districts in Iowa
- **Generation:** Formed when two or more contiguous landowners petition the county Board of Supervisors
- **Funding:** Paid for by property tax on land within the district
- **Management:** Most districts managed by county board

Illinois Drainage Districts

- **Authorization:** Governance began with a state law passed in 1870, and has been modified multiple times over the years, most recently in 1955[108]
- **Status:** Approximately 1700 drainage districts in Illinois[109]
- **Generation:** Created by petition to the County Court
- **Funding:** Paid for by property tax on land within the district
- **Management:** Managed by three district commissioners who serve three-year terms; commissioners are elected or appointed and must be landowners within the district

While the drainage districts are responsible for permitting and overseeing the construction and maintenance of tile drainage outlets in their boundaries, they appear to have no responsibilities for impacts of tile drainage on local water quality, except perhaps for flood control.

Drainage districts could be valuable partners in mitigating the negative impacts of tile drainage, but it could be extremely difficult to enlist their support in this endeavor. Public statements by the Iowa and Illinois drainage district associations make it clear that drainage is perceived to be a right, a public good, and also to be beneficial. For example, the Illinois Association of Drainage Districts brochure states that "our ancestors understood that drainage is an essential utility."[110] The Iowa Drainage District Association website quotes state law from Chapter 468, Section 2, Code of Iowa: "The Drainage of surface waters from agricultural lands and all other lands or the protection of such lands from overflow shall be presumed to be a public benefit and conducive to the public health, convenience and welfare." The role of tile and surface drainage in nutrient pollution is not acknowledged publicly.

Areas for Further Exploration

Overview of Monitoring and Information Needs

One of the major barriers to implementing a large-scale strategy in the MRB is the lack of information on practices going in and being taken off of the landscape. USDA collects information at the state and sometimes the county level on some conservation practices, but that information is not always available to the public and to watershed managers. Furthermore, even when data on installed conservation practices is available, data on removed conservation practices is not. As funding decreases or when land managers decide to discontinue a practice, this information on removed conservation practices is not collected.

Mapping of tile lines is also largely incomplete or unavailable. While the latest agricultural census did collect data on tile drainage, that data is not currently publicly available at the county level. The last county-level map of tile drainage was created with GIS by World Resources Institute in 2007, and based on data from the 1992 National Resources Inventory.[111] Local drainage districts oversee construction of tile lines and govern district drainage systems, and may have detailed tile line maps, but these are not publicly available. (See sidebar on drainage districts.)

Farm operations data is also needed to better assess pollution loads with and without conservation practices. Farm nutrient application rates are difficult to come by and vary from site to site. [112]

Monitoring data of tile and surface drainage outlet flows and pollution loads is incomplete or unavailable. The United States Geological Survey (USGS) has at least 40 in-stream monitoring stations that measure nitrogen and phosphorus loading throughout the MRB, thus the status of water quality in larger tributaries is well-documented and publicly available.[113] However, monitoring of subsurface flow and tile lines is dispersed and usually connected with specific research projects; there is no public clearing house of available data. While some farmers may be willing to install monitoring equipment on their land, the cost of monitoring for extended periods of time on an adequate number of farms may be prohibitively expensive. At the same time, monitoring sensor technology is advancing and should lower the cost barrier to expanding drainage outlet monitoring.

Given the expense of monitoring drainage outlet flows and pollution loads, the need for monitoring and the cost per acre of this monitoring should be considered in evaluating the pros and cons of particular BMPs and implementation approaches. For example, the need for monitoring is high for a water quality trading approach which depends on reliable demonstrations of significant non-point source nutrient pollution reductions. The cost per acre of monitoring will likely vary between BMPs based in part of the size of the area treated. Compare, for example, constructed or restored wetlands and bioreactors.

Good field data is essential to the accuracy of any model, but in the absence of good data, models can still be used to determine the impact of conservation practice implementation on water quality.[114] While researchers place a high value on accuracy, policy makers and resource managers may be willing to sacrifice a level of certainty to make necessary decisions. Watershed resource managers merely need a tool to determine the level of pollution reduction needed and the best combination of practices on the landscape to meet those water quality goals, so that they can target policies accordingly. Field level planners need a tool like Wisconsin's Snap Plus or EPA's Region 5 STEP L model to determine the likely nutrient pollution reductions from a suite of conservation practices in a given tile-drained field.

While there are a number of water quality models that assess the impact of conservation practices on surface water, few of them apply to subsurface flow and tile drainage. Table 4 lists a few of these. Each has advantages and disadvantages, and **none of these models can be adequately refined to measure phosphorus loss and transport**. However, most of them can be adapted to serve as a compass for creating a science-based nitrate reduction strategy.

Tools for assessing the impact of conservation practices on tile-drained fields can be adapted and put to good use, but more data needs to be collected and made publicly available for the best conservation planning. **The greatest information needs are the status of conservation practices on tile-drained acres, the extent and location of tile drainage in target watersheds (i.e., those with the highest nutrient pollution loads), and tools that assess phosphorus pathways and loss in tile-drained systems.**

Our recommended model includes an emphasis on performance-based strategies. However, performance-based policies are still rarely applied to agricultural pollution reduction; **further research would be instructive in comparing performance-based to practice-based approaches through paired watershed studies in the MRB.** These studies should monitor water quality, transaction costs of programs, costs per pound of nutrient reduction, and BMP adoption rates across BMPs and between practice-based and performance-based approaches.

Improved Watershed Governance

Improved governance of watersheds across the MRB would serve many purposes, including improving the pool of resources and information and the sharing of those resources and information among stakeholders in the watershed. If and when the state nutrient reduction strategies are completed in accordance with the EPA framework, they can serve as a platform to better integrate the MRB approach to reducing freshwater eutrophication in smaller watersheds as well as addressing Gulf hypoxia. Federal agencies and states can use the strategies to get a bird's eye view of the targets and milestones each state is working to achieve, and the needs that need to be met. **After they are completed, the strategies can be analyzed for gaps and opportunities to strengthen the MRB approach and make it more consistent and more effective.**

If the nutrient reduction strategies follow the EPA recommended framework and list priority watersheds, each state can focus attention on getting necessary resources to the leading sources of N and P loading. This may include **creating nutrient criteria and reduction goals, as with the Chesapeake Bay TMDL model, which would be enforced at the state level**. These drivers should set targets, but not prescribe specific conservation practices to achieve their goals. With the necessary motivation and support from the state, **watershed managers and other local authorities can come up with their own implementation plans to reach quantitative water quality goals**. For example, stakeholders in a priority watershed may find that their watershed has a large number of acres suitable for drainage water management, and that it is possible to reach their goals by installing DWM on every eligible tiled field. Local authorities can decide from there whether and how to make DWM a requirement, or to fund installation through a cost-share program. Layering cover crops and nutrient management with DWM might achieve additional gains.

State and watershed-level authorities can work together to determine the best approach to monitor results, but monitoring will be more effective if it is consistent and planned in advance of program implementation. Ideally, nutrient reduction strategies will help establish a framework for management that is consistently implemented in every MRB state, recognizing some potential regional differences (e.g., between the Upper MRB and the Lower MRB). If EPA takes the lead as a coordinator for state level implementation of strategies to achieve MRB goals, states can in turn coordinate watershed management to achieve statewide nutrient reduction goals by setting targets for each watershed. At each level, leaders can establish a framework for communication, including meetings and milestones to keep all players invested and accountable in the process. While some states already have established watershed district governance, many have not. Some states have single mission drainage districts as mentioned previously. Many states have soil and water conservation districts that have relevant expertise and work at the watershed scale. Worthy of further exploration are initiatives to enlist soil and water conservation districts as well as watershed districts to take on watershed governance to reduce nutrient pollution reduction in concert with state and federal resource managers.

Even though some states have completed their strategies, these can and should be evaluated, modified and amended over time to increase pollution reduction effectiveness and to make overall nutrient pollution reduction frameworks consistent across the MRB.

In summary, our recommended model (as shown in Figure 1) **would set quantitative nutrient reduction goals and binding water quality standards at larger watershed scales, and give local watersheds the flexibility to reach those goals and standards with their choice of practice-based or performance-based nutrient pollution reduction policies.** Of course, both approaches entail the application of one or more BMPs at the field level.

This approach of watershed implementation and governance to meet federal and state-level drainage basin water quality goals does have its own barriers and it is a major challenge to coordinate all of the state and watershed level governments and stakeholders. Implementing this approach is very time consuming and resource intensive, and requires sustained political commitment. Lack of secure funding on the state, federal, and local level to implement such programs is a significant barrier, but may be overcome in part through a redirection of resources.

Increase Private Sector Investment in Conservation for Water Quality

Funding from other sectors besides state and federal government will be essential to success in the MRB. Non-profits like The Nature Conservancy, the Sand County Foundation, and the National Wildlife Federation are heavily invested in promoting BMP use in the MRB, but non-profit resources are insufficient to effectively achieve large scale pollution reduction through conservation practices on the ground, even when leveraging taxpayer funded programs like the Resource Conservation Partnership Program (RCPP). It is the private sector driving production agriculture that has the most power to influence conservation and land use change on a scale sufficient to significantly reduce nutrient pollution in the MRB.

Agricultural corporations are becoming increasingly sensitive to consumer concern over sustainability, but most consumer awareness is centered on the corporations' carbon footprint or treatment of animals in production. This seems so despite poll after poll demonstrating that public concern for clean drinking water, and clean water more broadly, tops the list of environmental concerns. Increasing consumer awareness of conservation stewardship on agricultural land and its relationship to water quality could drive more pollution-reducing conservation practices on the ground if the private sector gets involved. Agricultural certification programs are a prime opportunity for private-sector investment**. If the market requires or encourages agricultural certification for water quality, more producers will enroll and these programs can expand in the MRB.** Agricultural corporations would benefit by improving their public image.

The crop insurance program, though largely federally subsidized, provides another opportunity to create additional incentives for stewardship. The Farm Bill's conservation title currently requires basic soil and wetland conservation measures in order to receive federal crop insurance premium subsidies. These basic conservation compliance requirements could be expanded to include additional soil and water quality best management practices. In addition, many in the agricultural and environmental community have proposed the idea of a "good-driver discount" for practices like cover crops that improve soil health and minimize long-term risk to farm profitability. There is a lot of potential in linking crop insurance subsidies and discounts to soil and water quality best management practices, but these ideas are still new and untested.

Summary of Key Findings

We found several promising approaches worthy of further development that will help put the best policies in place to drive significant nutrient pollution reduction from tile drainage.

1. **We need to advocate for more publicly-available information on the status of conservation practices on tile-drained acres, the extent and location of tile drainage in target watersheds (i.e., those with the highest nutrient pollution loads), the amount of nitrogen and phosphorus being discharged from private drainage systems to community drainage systems and downstream waters, and tools that assess phosphorus pathways and loss in tile-drained systems.**

To create effective policy, decision makers need to know which lands in which watersheds to target, what actions to take, and where to direct attention in order to maximize nutrient pollution reduction. The National Agricultural Statistics Service (NASS) collects data on conservation and on the number of tile-drained acres, but their location and the status of conservation on those acres is unavailable to the public. Drainage districts may have tile line maps, but may not be willing to share that information. Satellite photos and other technology may be helpful in mapping artificial drainage. Monitoring data and sound modeling of nutrient pollution loads and load reductions is essential to effective long-term nutrient pollution reduction. However, monitoring data of tile and surface drainage outlet flows and pollution loads is incomplete or unavailable, particularly for subsurface flow and tile line effluent and there is no public clearing house of available data. Monitoring sensor technology is advancing and should lower the cost barrier to expanding drainage outlet monitoring.

While nitrate is still the primary pollutant of concern in subsurface drainage, it has become clear that we need more research about phosphorus pathways in drained systems and BMPs to mitigate negative impacts of both.

2. **Decision makers need tools that can accurately model both nitrate and phosphorus reduction for every beneficial BMP to reduce drainage pollution, and it must be versatile enough to be used by practitioners at the field level in various drained systems throughout the Midwest. We should encourage development of this tool by USDA's Agricultural Research Service (ARS), USGS, NRCS, EPA, or another appropriate agency with the ability to also disseminate it for widespread use.**

A number of models and tools are available to predict nitrate reductions from conservation in drained systems. However, none of them are easily accessible for decision makers at the watershed and field level, and none of these tools are well-suited for predicting phosphorus reductions. Decision makers at the state and watershed level need a tool that will predict the impact of increased use of BMPs on nutrient pollution. Farmers and technical experts need field-level tools that will predict nutrient reductions from installing conservation practices in a drained system.

3. **Because performance-based policies may be the most efficient way to achieve water quality goals, we should encourage implementation of performance-based pilot programs with monitoring that allows for measuring nutrient pollution reduction at a small watershed scale.**

Performance-based policies focus on measurable pollution reduction results, and may be more effective than practice-based policies that focus on requiring certain types and amounts of conservation practices. As long as the necessary pollution reductions occur, it doesn't matter precisely which conservation practices are installed to make that happen. Flexibility is more appealing to farmers; the focus on results creates buy-in and makes producers aware of how their decisions impact water quality.

4. **At the same time, we need to encourage more research comparing performance-based and practice-based policies in the MRB, preferably through paired watershed studies.**

Nevertheless, there are few existing examples of truly performance-based programs for pollution reduction on agricultural land; most conservation is voluntary and focused on practices, not results. Performance-based approaches may be more difficult to implement and monitor than practice-based approaches. However, we know that practice-based approaches do not go far enough to improve water quality, so it is time to try something new. More research will help, but there is no reason not to proceed with increased use of performance-based programs and measure progress along the way.

5. **Agricultural certification programs are a prime opportunity to increase private sector investment in nutrient pollution-reducing conservation practices, and to raise consumer awareness of soil and water stewardship that improves water quality. We recommend increasing the effectiveness of certification programs and raising awareness of the most effective certification programs with the sustainability programs of corporations in the food supply chain.**

Government support for conservation programs and water quality efforts can be better utilized, but available funds are unlikely to increase in the next few years. We need other drivers and sources of funding. Agricultural production and land use is market-driven; pollution-reducing conservation on cropland can also be driven by the market and the private sector. Agricultural certification programs have a lot of potential to improve the level of soil and water stewardship on cropland. If agribusiness offers incentives for farmers to enroll in certification programs, or even requires enrollment as a corporate sustainability measure, the level of nutrient pollution-reducing conservation will certainly increase.

6. **We recommend further development of a policy model which would set quantitative nutrient reduction goals and binding water quality standards at larger watershed scales in the MRB, but allow smaller watersheds, ideally through smaller watershed governance, the flexibility to find the best approach to achieve those goals and standards through a combination of regulations, performance-based standards, and voluntary incentives.**

Quantitative goals and standards do not necessarily have to be regulatory in nature, but they do need to create enough impetus to drive the creation of watershed-level plans that will be implemented and will achieve significant nutrient pollution reduction, and to direct resources where they are most needed. For example, TMDLs do not necessarily regulate non-point source discharges, but can set water quality goals and standards that create a driver for nonpoint source pollution reduction. As a practical matter, state-mandated, binding pollution reductions, determined in concert with EPA and other states in the watershed, will likely be necessary in many cases to provide the impetus for significant and lasting nutrient pollution reductions. Decisions on how to reach those goals and standards are ideally made at the smaller watershed level, and could be either voluntary or regulatory in nature. Local leaders need to be invested in improving water quality in their watershed, and the EPA or state-level authorities can encourage this by offering incentives, disincentives, coordinating frameworks, and technical and financial support.

Conclusion

Tile drainage, surface ditch drainage, and tile-to-surface water drainage systems are a significant pathway for nutrient pollution to America's waters. Given the scope of the problem and the variability and complexity of conditions, including geography, climate, cropping systems, and farm ownership and operation, it is important to consider all options with proven efficacy and pursue strategies that encourage significant pollution reduction through increased education, technical assistance, and performance-based policies such as performance-based incentives, taxes on nutrient pollution, and, if necessary, enforceable effluent limits.

It is clear that past and present voluntary approaches are not having the necessary level of impact. There is a growing opinion that voluntary BMP adoption, alone, will not go far enough to clean up severe nutrient pollution from agricultural sources and make U.S. agriculture sustainable. Some have recommended taking more land out of crop production or, at the least, shifting more acres away from intense row crop production. Research shows that water quality would benefit from more diverse cropping systems and more perennials on the landscape. **Increasing planting of cover crops and diverse perennial crops and decreasing corn-soybean crop systems will hold more water in the soil, improve soil health and reduce fertilizer and manure applications and pollution loadings.** These cropping systems should be encouraged through enhanced technical assistance to farmers as well as increased private and public financing

In the meantime, we have provided some promising ideas worthy of further development and have noted some additional research and data needed to support implementation of these approaches.

We strongly recommend moving away from reliance on current, strictly voluntary measures, and moving toward promoting more diverse cropping systems and markets for their products as well as practices tied to performance-based policies. We believe a policy model worthy of further development would set quantitative nutrient pollution reduction goals and standards at larger watershed scales in the MRB, but allow smaller watershed-level governing bodies the flexibility to find the best approaches to achieve those goals and standards through a combination of regulations, performance-based policies, and voluntary incentives.

Appendix

Attendees to Summer Roundtable on Agricultural Drainage

Todd Ambs, National Wildlife Federation, Campaign Director for Healing Our Waters-Great Lakes Coalition

Lara Bryant, National Wildlife Federation, Agriculture Program Coordinator

Les Everett, University of Minnesota Water Resources Center, Education Coordinator

Jan Goldman-Carter, National Wildlife Federation, Senior Manager, Wetlands and Water Resources

Jim Gulliford, Soil and Water Conservation Society, Executive Director

Matthew Helmers, Iowa State University, Associate Professor of Agriculture & Biosystems Engineering

Dan Jaynes, USDA-Agricultural Research Service, Soil Scientist

Krista Kirkham, The Nature Conservancy, Assistant Aquatic Ecologist for Mackinaw River Program

Linda Kinman, Des Moines Water Works, Public Policy Analyst and Watershed Coordinator

James Klang, Kieser & Associates, Senior Project Engineer

Keegan Kult, Iowa Soybean Association, Environmental Project Manager

Greg McIsaac, representing Agricultural Watershed Institute, Associate Professor at University of Illinois

Mark Muller, McKnight Foundation, Mississippi River Program Officer

Brad Redlin, Minnesota Department of Agriculture, Water Quality Certification Program Manager

Keith Schilling, Iowa Geological Survey and Adjunct Assistant Professor at the University of Iowa

Matt Schwarz, Environmental Contaminations Specialist, US Fish and Wildlife Service

Kris Sigford, Minnesota Center for Environmental Advocacy, Water Quality Program Director

Ryan Stockwell, National Wildlife Federation, Senior Agriculture Program Manager

Table 1. Tile and Ditch Drainage Acreage in the Mississippi River Basin, from 2012 Agricultural Census Data

State	Total Cropland	Tile-Drained Land, Acres	% Tile-Drained Cropland	Land Drained by Ditches, Acres	% Cropland Drained by Ditches	Tile + Ditch, Acres	% Cropland Drained, Tile + Ditch
Us Total	389,690,414	48,566,201	12%	42,175,207	11%	90,741,408	23%
Iowa	26,256,347	12,631,135	48%	1,669,073	6%	14,300,208	54%
Illinois	23,752,778	8,900,026	37%	3,701,001	16%	12,601,027	53%
Minnesota	21,597,136	6,461,173	30%	4,548,977	21%	11,010,150	51%
Indiana	12,590,633	5,672,188	45%	1,894,351	15%	7,566,539	60%
Ohio	10,748,553	4,997,908	46%	1,278,406	12%	6,276,314	58%
Michigan	7,669,071	2,583,727	34%	1,212,253	16%	3,795,980	49%
Missouri	15,259,319	884,110	6%	2,058,741	13%	2,942,851	19%
Wisconsin	9,910,991	805,846	8%	805,846	8%	1,611,692	16%
Total UMRB	**127,784,828**	**42,936,113**	**34%**	**17,168,648**	**13%**	**60,104,761**	**47%**

Note: These drainage figures do not include the tile and ditch drainage that is occurring in the James River, Big Sioux River, and Vermillion River watersheds of the Dakotas that also contribute flows and pollution to the MRB.

Table 2. Comparison of Impacts, Status, Costs, Advantages and Disadvantages of Best Management Practices

Practice	Status	% reduction in N or P	Cost	Advantages	Disadvantages
Drainage Management	Low implementation; 8,575 acres out of 29 million possible in UMRB.	N – 29	$20-90/acre	Potentially high nitrate load reductions with proper installation and monitoring.	Effective mostly on flat land and not during prolonged drought or wet conditions.
Bioreactors	Low implementation; at least 30 have been installed in UMRB.	N - 35-50	$(**$708-$1573**/treated acre lifetime total cost; $8000 average installation cost	High nitrate load reduction; little maintenance required after installation.	High cost, no agronomic benefits to encourage farmers to adopt without a cost-share.
Restored and Constructed Wetlands	Low implementation; at least 126,460 acres enrolled in Conservation Reserve Program's farmable wetlands in UMRB states.	N – 18-44 (up to 50% for restored wetlands) P – 57-68	up to $14,500/acre treated (constructed wetlands); $1.26 lb–1 N treated for restored wetlands	High nitrate and phosphorus load reduction; co-benefits for ecological value and flood-reduction.	High cost for constructed wetlands, no agronomic benefits to encourage farmers to adopt without a cost-share.
Cover Crops	Implementation on the rise but still low; less than 3 million acres or 3% of UMRB cropland.	N – 28-43 P – 50	$30-50/acre	High nitrate and phosphorus load reduction; potential benefits to farm profitability; can be grown anywhere.	Perceived as a risk by many farmers; can be time and labor-intensive.
Nutrient Management	Low implementation	N- 9 P-7	$0-?	Potential cost savings in simple reduction of rate applied. Can be applied in any cropping system that uses nutrient inputs.	Farmer attitudes and reliance on fertilizer retailers for rate recommendations present significant barriers to adoption; Questionable nutrient reduction effectiveness
Saturated Buffers	Early Stages	N-35-59% Some P removal	?	Relatively low cost and high nitrogen load reduction	

Table 3: Comparison of Existing Policy Mechanisms

Policy Tool	Status	Pros	Cons
Minnesota Agricultural Certification Program	2014 pilot phase. By May 2015, 41 farms certified, establishing 145 new conservation practices on more than 23, 000 acres. Eligibility extended statewide in 2015.	• Assessment tool based on water quality benefits • Systems approach • Practices are tailored to farm; • Practices verified • Offers producers regulatory certainty from future regulations and recognition for stewardship	• Time and labor-intensive • Regulatory certainty may not offer enough of an incentive for participation • Not implemented on a watershed scale • Certification practices may not be consistently protecting nitrate water quality standards.
Total Maximum Daily Load (TMDLs)	Many TMDL plans have been developed in the MRB, but with varied implementation.	• Sets a quantitative, science-based goal • Watershed implementation plans a valuable resource • Create funding and partnership opportunities that may drive better implementation	• Expensive • Nitrates are not adequately addressed • No enforcement required
Wisconsin Phosphorus Rule	Enacted in 2010 and applicable to all producers in the state of Wisconsin.	• Required by all producers • Combines practice-based and performance-based approach • Could serve as a model for other states and for nitrates in tile drainage.	• Wisconsin must pay up to 70% cost-share for some practices. • Puts county conservation agents in difficult position of enforcement • Still faces political opposition • Does not consider or address P in subsurface flow from tile drainage.
Water Quality Trading	Only a few pilot programs operating in MRB.	• Cost-effective • Offers a unique funding mechanism to reach more farmers on more acres • Rules can be built in to address uncertainties • Can be targeted to specific pollutant	• Depends on drivers – nutrient criteria, regulations • Need more monitoring and verification to address uncertainties • Markets still emerging

Table 4: Water Quality Models for Simulating Tile-Drainage Systems

Model	Description	Advantages	Disadvantages
Agricultural Policy Environmental Extender and Soil and Water Assessment Tool (APEX-SWAT)	Combined models assess the field-level effects of conservation practices and in-stream loads from the field level and extrapolate to the larger watershed (Wang)	• Flexible, many applicable uses. Simulates weather, erosion, soil carbon, crop yields • Has a tile drainage component • Can be used for watershed level assessments	• Uncertainties in the model (Wang)
The Nitrogen Simulation Model, DRAINMOD-N II	Simulates dynamics of hydrology and nitrogen in tile-drained fields (Thorp). Designed for a pattern drain system	• Specifically designed for tile-drained fields • Can find nitrate loss from tile-drained field • Tillage and management practices can be incorporated • Similar to RZWQM but will estimate surface water storage	• Does not assess phosphorus
Root Zone Water Quality Model (RZWQM)	Developed by USDA-ARS to model the movement of water and nutrients vertically through the soil profile and within the crop root zone. (Tetra tech) Purpose is to assess the effect of BMPs on nitrate and pesticide loading.	• Tile drainage can be simulated • Conservation practices can be incorporated • Hybrid models can be created to simulate drainage water management (Jaynes)	• Limited to corn, soybean and wheat fields • Not good for estimating runoff • Does not assess phosphorus
Nitrogen Loss and Environmental Assessment Package (NLEAP)	Simulates infiltration and transport of soil water and nitrates through surface flow and through the soil profile. Can be used as a management tool to assess effectiveness of BMPs (Delgado et al)	• Models surface and subsurface flow • Incorporates tile drainage • Can use to assess BMPs	• Does not assess phosphorus

Figure 1: Model Framework for Mississippi River Basin Governance

EPA and Hypoxia Task Force

- Set reduction goals for each state
- Use nutrient reduction strategies as platform for governance and communication
- Guide and support states in achieving goals

States

- Set reduction goals for watersheds
- Create a structure for monitoring, reporting, and accountability

Watershed

- Preferably watershed districts with water quality mission, possibly in conjunction with counties or municipalities;
- Develop implementation plan and set policies in place to achieve targets within the watershed
- Monitor pollution loads, reductions, report pollution loads and reduction progress back to state

Sources

[1] U.S. EPA Office of Inspector General. 2014. Nutrient Pollution: EPA Needs to Work with States to Develop Strategies for Monitoring the Impact of State Activities on the Gulf of Mexico Hypoxic Zone (Report #14-P-0348). Accessed March 7, 2016 at: http://www.epa.gov/office-inspector-general/report-nutrient-pollution-epa-needs-work-states-develop-strategies
[2] Goolsby, D. S., Battaglin, W. A., & Aulenbach, B. T. 1999. Nitrogen Flux and Sources in the Mississippi River Basin. Retrieved from United States Geological Survey. Accessed March 7, 2016 at: http://toxics.usgs.gov/pubs/wri99-4018/Volume2/sectionC/2401_Goolsby/pdf/2401_Goolsby.pdf
[3] David, M., Drinkwater, L. & McIsaac, G. 2010. Sources of Nitrate Yields in the Mississippi River Basin. *Journal of Environmental Quality*, 1657-1667.
[4] Gentry, L.E., David, M.B., Royer, T.V., Mitchell, C.A. & Starks, K.M. 2007. Phosphorus Transport Pathways to Streams in Tile-Drained Agricultural Watersheds. *Journal of Environmental Quality*, 408-415.
[5] Sims, J.T., Simard, R.R., & Joern, B.C. 1998. Phosphorus Loss in Agricultural Drainage: Historical Perspective and Current Research. *Journal of Environmental Quality*. 27: 277-293
[6] See CBS News. August 5, 2014. Toxic Algae in Lake Erie: What You Need to Know. Accessed December 14, 2015 from: http://www.cbsnews.com/news/toxic-algae-in-lake-erie-what-you-need-to-know/.
[7] Dahl, T.E. 2014. Status and trends of prairie wetlands in the United States 1997 to 2009.U.S. Department of the Interior; Fish and Wildlife Service, Ecological Services, Washington, D.C.
[8] USDA, National Agricultural Statistics Service. 2012 Census of Agriculture, Table 50: Land Use Practices by Size of Farm.
[9] See NRCS. 2012. "Assessment of the Effect of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin." pp. 162-171 and Table 69. Accessed January 25, 2016: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042093.pdf.
[10] Jaynes, D.B. 2012. Changes in yield and nitrate losses from using drainage water management in central Iowa, United States. *Journal of Soil and Water Conservation*. 67: 485-494.
[11] Allerhand, Joanna E.; Klang, James A.; and Kieser, Mark S. 2012. "Drainage Water Management Implementation Costs." Kieser & Associates Environmental Science & Engineering. Kalamazoo, MI.
[12] Cooke, Richard A., Sands, Gary R., and Brown, Larry C. 2006. "Drainage Water Management: A Practice for Reducing Nitrate Loads from Subsurface Drainage Systems." Accessed from http://water.epa.gov/type/watersheds/named/msbasin/upload/2006_8_24_msbasin_symposia_ia_session2.pdf
[13] See Cooke, et al., 2006.
[14] See Allerhand et al., 2012.
[15] See Cooke, et al., 2006.
[16] See Allerhand et al., 2012.
[17] NRCS. 2012. "Cropland Suitable for Drainage Water Management." Map 2012-41. Accessed from: http://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1046708.jpg
[18] NRCS. 2013. Ag Drainage Water Management, Fiscal Year 2013 Progress Report. Can be accessed from: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/manage/
[19] Iowa Soybean Association, Sand County Foundation, and Agriculture's Clean Water Alliance. 2014. "Bioreactors". Ankeny, IA.
[20] See Iowa Soybean Association, 2014. There is some indication that these bioreactors may reduce selenium, another contaminant of concern in tile drains in South Dakota. See Partheeban, Cynthuja and Kjaersgaard, Jeppe. 2014. The Effectiveness of Wood Chip Bioreactors to Remove Selenium from Tile Drain Water in Eastern South Dakota. Accessed January 27, 2016: https://scisoc.confex.com/scisoc/2014am/webprogram/Paper87830.html.
[21] See Iowa Soybean Association, 2014.
[22] Christianson, Laura; Tyndall, John; and Helmers, Matthew. 2013. Financial comparison of seven nitrate reduction strategies for Midwestern agricultural drainage. *Water Resources and Economics*. 2-3:30-56.
[23] See Christianson, Tyndall, and Helmers, 2013.
[24] See Iowa Soybean Association, 2014.

[25] Willey, Patrick H. 2012. "Wood Chip Bioreactors." Presentation for 2012 Land Grant/Sea Grant National Water Conference. Accessed October 29, 2014: http://www.usawaterquality.org/conferences/2012/Workshops/pdf/W6_workshop/10_Willey.pdf

[26] Crumpton, William G. 2013. Potential of Restored and Constructed Wetlands to Reduce Nutrient Export from Agricultural Watersheds in the Corn Belt. Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop, Chapter 3. Published by American Society of Agricultural and Biological Engineers (doi:10.13031/2013.24242). Accessed January 29, 2016 at: http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/umrshnc.pdf

[27] See Jordan, T.E., Whigham, D. F., Hofmokel, K.H., and Pittek, M.A. 2003. Nutrient and Sediment Removal by a Restored Wetland Receiving Agricultural Runoff. J. Environ. Qual.32:1534–1547; Mitsch, W. J., Day, J.W., Zhang, Li, and Lane, R.R. 2005. Nitrate-nitrogen retention in wetlands in the Mississippi River Basin. Ecological Engineering 24(4): 267-278.

[28] The Nature Conservancy. 2014. "Fact Sheet: Constructed Wetlands (Mackinaw River watershed, Illinois)".

[29] Personal Communication, Krista Kirkham, The Nature Conservancy, 2015; see also, Betts, Lynn. February 2015. Field Filters. The Progressive Farmer at 16-20. Accessed January 29, 2016 at: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/iowa/placesweprotect/progressive-farmers-field-filters.pdf

[30] Farm Service Agency. 2011. "Fact Sheet, Constructed Wetland CP-39." Accessed October 29, 2014 from http://www.epa.gov/region5/agriculture/pdfs/nutrientworkshop/constructed-wetland-practice-usda-fsa-201106.pdf; Betts, Lynn. Field Filters, 2015.

[31]Personal Communication, Krista Kirkham, The Nature Conservancy, 2015.

[32] Hyberg, Skip, Iovanna, Rich, Crumpton, William and Richmond, Shawn. 2015. The cost effectiveness of wetlands designed and sited for nitrate removal: The effect of increased efficiency, rising easement costs, and lower interest rates. *Journal of Soil and Water Conservation.* 70 (2): 30A-32A, Table 2.

[33] Farm Service Agency. 2012. "Conservation Reserve Program Annual Summary and Enrollment Statistics." Accessed October 28, 2014 from http://www.fsa.usda.gov/Internet/FSA_File/summary12.pdf

[34] Malone, R.M.; Jaynes, D.B.; Kaspar, T.C.; Thorp, K.R., Kladivko, E.; L Ma; James, D.E.; Singer, J.; Morin, X.K.; and Searchinger, T.. 2014. "Cover Crops in the Upper Midwestern United States: Simulated effect on nitrate leaching with artificial drainage. J. Soil and Water Conservation 2014 69(4):292-305 last accessed February 19, 2016 at: http://www.ars.usda.gov/SP2UserFiles/Place/20200500/Malone2014%20-%20RZWQM%20cover%20crops%20Midwest.pdf

[35] Iowa State University. 2013. Iowa Nutrient Reduction Strategy. Section 2.1 Executive Summary – Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River Basin. Table 4, pg 8, and Table 6, pg 10.

[36] Myers, Rob. 2014. "The Case for Cover Crops." Presentation to the National Conference on Cover Crops & Soil Health. February, 2014.

[37] See Myers, Rob, 2014.

[38] Conservation Technology Information Center (CTIC) et al. 2014-2015 Annual Report: Cover Crop Survey. July 2015. Accessed February 2, 2016 at: http://www.sare.org/Learning-Center/From-the-Field/North-Central-SARE-From-the-Field/2015-Cover-Crop-Survey-Analysis.

[39] Bryant, Lara; Stockwell, Ryan; and White, Trisha. 2013. "Counting Cover Crops." National Wildlife Federation

[40] USDA, National Agricultural Statistics Service. 2012 Census of Agriculture. Data retrieved from Quick Stats.

[41] Iowa State University. 2013. Iowa Nutrient Reduction Strategy. Section 2.1 Executive Summary – Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River Basin. 2014 updated version accessed February 2, 2016 at http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2-141001.pdf

[42] Iowa Nutrient Reduction Strategy, Table 4, pg 8.

[43] Iowa Nutrient Reduction Strategy, Table 6, pg 10.

[44] Osmond, D., Hoag, D., Luloff, A., Meals, D., and Neas, K. 2014. Farmers' Use of Nutrient Management: Lessons from Watershed Case Studies. *Journal of Environmental Quality*.

[45] Beegle, D.B., Carton, O.T., and Baile, J.S. 2000. Nutrient Management Planning: Justification, Theory, Practice. *Journal of Environmental Quality*. 29: 72-79.
[46] NRCS. 2012. "Assessment of the Effect of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin." Executive Summary, pg 7. Accessed on October 31, 2014 from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042093.pdf
[47] Osmond et al, 2014.
[48] NRCS. 2003. Barriers and Strategies Influencing the Adoption of Nutrient Management Practices. Technical Report 13.1.
[49] See, e.g., Maryland's Proposed Phosphorus Management Tool regulation, including statement of purpose and economic analysis, 41 Maryland Register at 1425 (December 1, 2014) *available at:* http://www.dsd.state.md.us/MDRegister/4124.pdf; Bruce Hotchkiss, "Agriculture industry reacts to election," Delmarva Farmer, November 11, 2014 *available at:* http://www.americanfarm.com/publications/the-delmarva-farmer (Governor-Elect Logan's stated opposition to the Phosphorus Management Tool).
[50] Randall, G.W., and Iragavarapu, T.K. 1995. "Impact of Long-Term Tillage Systems for Continuous Corn on Nitrate Leaching to Tile Drainage." *Journal of Environmental Quality*. 24 (2): 360-366.
[51] Kanwar, R.S.; Colvin, T.S.; and Karlen, D.L. 2013. "Ridge, Moldboard, Chisel, and No-Till Effects on Tile Water Quality beneath Two Cropping Systems." *Journal of Production Agriculture*. 10 (2): 227-234.
[52] Ball Coelho, B.; Murray R.; Lapen, D.; Topp, E.; and Bruin, A. 2012. "Phosphorus and sediment loading to surface waters from liquid swine manure application under different drainage and tillage practices." *Agriculture Water Management* 104: 51-61.
[53] Lemke, A.M.; Kirkham, K.G.; Lindenbaum, T.T.; Herbert, M.E.; Tear, T.H.; Perry, W.L.; and Herkert, J.R. 2011 "Evaluating Agricultural Best Management Practices in Tile-Drained Subwatersheds of the Mackinaw River, Illinois." *Journal of Environmental Quality*. 40 (4): 1215-1228.
[54] See NRCS. 2012. Pg 9.
[55] Jaynes, D.B. and T. M. Isenhart. 2014. Reconnecting Tile Drainage to Riparian Buffer Hydrology for Enhanced Nitrogen Removal, J. Environ. Qual. 43 (2): 631-638. See also, South Dakota State University. 2013. "Proposal: Conservation Drainage Practices to Improve Drainage Water Quality." Accessed November 7, 2014 from https://www.sdstate.edu/abe/wri/research-projects/upload/SaturatedBuffer_ControlledDrainage_Proposal_v4.pdf
[56] Ervin, Christine A, and Ervin, David A. 1982. "Factors Affecting the Use of Soil Conservation Practices: Hypotheses, Evidence, and Policy Implications." *Land Economics* 58 (3): 277-292.
[57] Ribaudo, Marc; Savage, Jeffrey; and Aillery, Marcel. 2014. "An Economic Assessment of Policy Options to Reduce Agricultural Pollutants in the Chesapeake Bay." USDA Economic Research Service Report Number 166.
[58] See NRCS, 2012. Pg. 7.
[59] See NRCS, 2012. Pg. 8.
[60] See NRCS, 2012. Pg. 9.
[61] Lubben, Bradley, and Pease, James. 2014. Conservation and the Agricultural Act of 2013. *Choices*. Accessed on October 31, 2014 from http://www.choicesmagazine.org/choices-magazine/theme-articles/deciphering-key-provisions-of-the-agricultural-act-of-2014/conservation-and-the-agricultural-act-of-2014
[62] Spalding, Mary Exner; Perea-Estrada, Hugo; and Spalding, Roy F. 2010. "Long-Term Response of Groundwater Nitrate Concentrations to Management Regulations in Nebraska's Central Platte Valley." *Papers in Natural Resources*. Paper 323 http://digitalcommons.unl.edu/natrespapers/323
[63] See Eller, Donnelle. Des Moines Water Quality Suit Slated for Trial in 2016 (July 15, 2015) at: http://www.desmoinesregister.com/story/money/agriculture/2015/07/15/des-moines-water-works-lawsuit-buena-vista-calhoun-sac-counties-water-quality/30191169/; see also Hamilton, Neil. March 2015. Sixteen Things to Know about the Proposed Des Moines Water Works Lawsuit. Accessed February 19, 2016 at: http://aglaw.blogspot.com/2015/03/sixteen-things-to-know-about-des-moines.html
[64] See Minnesota Board of Water and Soil Resources Buffer Law. Accessed February 19, 2016 at http://www.bwsr.state.mn.us/buffers/

[65] See CBS Minnesota. Gov. Dayton Scales Back Buffer Law After GOP Objections (January 29, 2016). Accessed February 19, 2016 at: http://minnesota.cbslocal.com/2016/01/29/gov-dayton-scales-back-buffer-law-after-gop-objections/
[66] See EPA Office of the Inspector General, 2014.
[67] See EPA Office of the Inspector General, 2014.
[68] Ribaudo, Marc; Savage, Jeff; and Aillery, Marcel. 2014. An Economic Assessment of Policy Options to Reduce Agricultural Pollutants in the Chesapeake Bay. USDA Economic Research Service. ERR-166.
[69] See Ribaudo et al., 2014.
[70] Dexter, Jessica; Ettinger, Albert; Dixon, Kathrine; Roggenkamp, Ed; Pakenham, Caroline; Madden, Dana; Hladik, Johnathan; Snapper, Joseph; and Lewis, Heather. 2010. *Cultivating Clean Water: State-Based Regulation of Agricultural Runoff Pollution*. Environmental Law & Policy Center and the Mississippi River Collaborative.
[71] See Dexter et al., 2010.
[72] Anne Arundel County. 2008. "Watershed Protection Restoration Fees." Accessed November 25, 2014 through http://www.aacounty.org/DPW/Stormwater/WPRF.cfm#.VHSxOYvF-Sp
[73] Lankoski, J. and M. Ollikainen. 2013. "Innovations in Nonpoint Source Pollution Policy-European Perspectives." *Choices.* Quarter 3. Available at: http://choicesmagazine.org/choices-magazine/theme-articles/innovations-in-nonpoint-source-pollution-policy/ innovations-in-nonpoint-source-pollution-policyeuropean-perspectives
[74] Boyd, James. 2003. "Water Pollution Taxes: A Good Idea Doomed to Failure?" Resources For the Future. Discussion paper 03-20. http://rff.org/rff/Documents/RFF-DP-03-20.pdf
[75] Ribaudo, Marc; Horan, Richard, and Smith, Mark E. 1999. Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice. USDA Economic Research Service Report No. 782. http://www.ers.usda.gov/media/1385896/aer782.pdf
[76] Muirhead, Sarah. 2011. "Pay-for-results concept tested." May 13, 2011. Feedstuffs FoodLink. Accessed November 14, 2014 from http://feedstuffsfoodlink.com/story-payforresults-concept-tested-71-66345
[77] Redlin, Brad. August 12, 2014. "Minnesota Agricultural Water Quality Certification Program." Presentation to National Wildlife Federation Summit on Tile Drainage in Minneapolis, Minnesota.
[78] Brad Redlin, 2014 Presentation; Brad Redlin, personal communication by email, May 2015. See also Minnesota Agriculture Water Quality Certification Program (MAWQCP), at http://www.mda.state.mn.us/awqcp.
[79] Minnesota Center for Environmental Advocacy. December 2015. Minnesota Agricultural Certainty Program: Is it Working for Water Quality? Accessed February 2, 2016 at http://mncenter.org/issues/water/mn-agricultural-certainty-program-review.aspx
[80] Minnesota Center for Environmental Advocacy. December 2015.
[81] EPA. 2015. "Fact Sheet: Chesapeake Bay Total Maximum Daily Load (TMDL)." Accessed on February 8, 2016 from http://www.epa.gov/chesapeake-bay-tmdl/chesapeake-bay-tmdl-fact-sheet
[82] See e.g., the Crow Wing River Watershed TMDL, accessed February 8, 2016 at: http://www.epa.gov/sites/production/files/2015-10/documents/crow_wing_river_mn.pdf
[83] See, EPA Oversight of TMDL Watershed Implementation Plans and Milestones. Accessed February 8, 2016 at: http://www.epa.gov/chesapeake-bay-tmdl/epa-oversight-watershed-implementation-plans-wips-and-milestones-chesapeake-bay; EPA. 2014. "EPA Credits States for Making Progress in Bay Cleanup; Says More Effort Needed to Get Back on Track for a Restored Bay." Accessed November 25, 2014 through http://yosemite.epa.gov/opa/admpress.nsf/90829d899627a1d98525735900400c2b/d6fc92040ef8cc4585257d03005d7199!OpenDocument
[84] Steinzor, R. and Isaacson, E. Center for Progressive Reform. February 2016. Countdown to 2017: Five Years In, Chesapeake Bay TMDL at Risk Without EPA Enforcement. Accessed February 8, 2016 at: http://progressivereform.org/articles/Chesbay2017Countdown1601.pdf.
[85] EPA. 2001. "Fact Sheet on the National Costs of the Total Maximum Daily Load Program (Draft Report), EPA 841-F-01-004." Water: Total Maximum Daily Loads (303d). Accessed on November 5, 2014 from http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/costfact.cfm
[86] EPA. 2015. "State Development of Numeric Criteria for Nitrogen and Phosphorus Pollution." Nutrient Pollution Policy and Data. Accessed February 8, 2016 from http://cfpub.epa.gov/wqsits/nnc-development

[87] See EPA Watershed Quality Assessment Report, Iowa, South Skunk Watershed. Accessed February 8, 2016 at http://epadev.induscorp.com/waters10/attains_watershed.control?p_huc=07080105&p_state=IA&p_cycle=2004&p_report_type=T#pollutant
[88] Illinois Environmental Protection Agency. 2009. North Fork Vermilion River/Lake Vermilion Watershed TMDL Report. IEPA/BOW/. Accessed February 8, 2016 at: http://www.epa.state.il.us/water/tmdl/report/north-fork-vermilion/north-fork-vermilion.pdf
[89] Illinois Environmental Protection Agency. 2008. Sangamon River Lake Decatur Watershed TMDL Report. IPA/BOW/07-017. Accessed February 8. 2016 at http://www.ecologyactioncenter.org/mCLEANwater/wp-content/uploads/2012/03/Sangamon_River_Lake_Decatur_Watershed.pdf
[90] See EPA Non-point Source Success Stories accessed February 8, 2016 at http://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-success-stories
[91] See, e.g., http://www.cleveland.com/metro/index.ssf/2015/10/conservation_groups_call_on_us.html; http://www.nwf.org/News-and-Magazines/Media-Center/News-by-Topic/Wildlife/2015/10-22-15-Groups-to-EPA-Put-Lake-Erie-on-Pollution-Diet.aspx
[92] Wisconsin Administrative Code NR 151.02,03,04,07. See also, http://dnr.wi.gov/topic/surfacewater/phosphorus.html. http://docs.legis.wisconsin.gov/code/admin_code/nr/100/151/II/01
[93] Good, Laura Ward; Panuska, John, and Vadas, Peter. 2010. "Current Calculations in the Wisconsin P Index." Accessed November 5, 2014 from http://wpindex.soils.wisc.edu/wp-content/uploads/2011/10/PIndexdocumentforwebNov-182010final.pdf
[94] Faeth, Paul. 2000. Fertile Ground: Nutrient Trading's Potential to Cost-Effectively Improve Water Quality. World Resources Institute. Washington, DC. http://www.wri.org/sites/default/files/pdf/fertile_ground.pdf
[95] Bryant, Lara. 2013. *Clean Water Grows*. National Wildlife Federation. Washington, DC. www.nwf.org/cleanwatergrows
[96] Bryant, 2013. *Clean Water Grows*.
[97] Bryant, 2013. *Clean Water Grows*.
[98] Selman, Mindy; Greenhalgh, Suzie; Branosky, Evan; Jones, Cy; and Guiling, Jenny. 2009. *Water Quality Trading: An International Overview*. World Resources Institute. Washington, DC. http://www.wri.org/sites/default/files/pdf/water_trading_quality_programs_international_overview.pdf
[99] Perez, Michelle; Walker, Sara; and Jones, Cy. 2013. Nutrient Trading in the MRB. World Resources Institute. Washington, DC. http://pdf.wri.org/nutrient_trading_in_mrb_feasibility_study.pdf
[100] See Perez et al., 2013.
[101] See Perez et al., 2013.
[102] Walker, Sara, and Selman, Mindy. 2014. Addressing Risk and Uncertainty in Water Quality Trading Markets. World Resources Institute. Washington, DC. http://www.wri.org/sites/default/files/wri_issuebrief_uncertainty_3-9_final.pdf
[103] Steinzor et al., 2012. Fairness in the Bay: Environmental Justice and Nutrient Trading. Briefing Paper No. 1208. Center for Progressive Reform. Washington, D.C. *available at:* http://www.abell.org/pubsitems/ce_fairness_in_bay812.pdf
[104] Faeth, Paul. 2000. Fertile Ground: Nutrient Trading's Potential to Cost-Effectively Improve Water Quality. World Resources Institute. Washington, DC. http://www.wri.org/sites/default/files/pdf/fertile_ground.pdf
[105] Willamette Partnership, World Resources Institute, and the National Network on Water Quality Trading, 2015. *Building a Water Quality Trading Program: Options and Considerations.* http://willamettepartnership.org/wp-content/uploads/2015/06/
[106] *See* U.S. Environmental Protection Agency, *Water Quality Trading Policy*, 68 Fed. Reg. 1608, p. 1610, ("*CWA Requirements*. Water quality trading and other market-based programs must be consistent with the CWA.") (Jan. 13, 2003) accessed at: https://www.federalregister.gov/articles/2003/01/13/03-620/water-quality-trading-policy-issuance-of-final-policy
[107] Iowa State Constitution, Article I, Sec. 18, as amended in 1908, accessed at http://publications.iowa.gov/9883/1/CONSTITUTION_OF_THE_STATE_OF_IOWA.pdf.

[108] Illinois Drainage Code, 70 ILCS 605, accessed February 8, 2016 at http://www.ilga.gov/legislation/ilcs/ilcs5.asp?ActID=869

[109] Illinois Association of Drainage Districts Brochure accessed February 8, 2016 at http://iadd.info/wp-content/uploads/2012/02/2005iaddbrochure.pdf

[110] Illinois Association of Drainage Districts Brochure.

[111] Sugg, Zachary. 2007. *Assessing U.S. Farm Drainage: Can GIS Lead to Better Estimates of Subsurface Drainage Extent?* World Resources Institute.

[112] Klang, James email communication (February 2015).

[113] USGS. 2013. "Water-Quality Monitoring and Modeling in the Mississippi and Atchafalaya River Basin." Accessed November 7, 2014 from http://water.usgs.gov/nasqan/docs/marb.information.sheet.2pager.pdf

[114] Schaffer, M.J. 1995. "Fate and Transport of Nitrogen – What Models Can and Cannot Do." USDA Agricultural Research Service Working Paper No. 11. Accessed November 7, 2014 from http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_014205