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# MANAGEMENT OF NITRATE LEACHING IN PENNSYLVANIA: A FACTSHEET APPROACH

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## ABSTRACT

Nitrate leaching into subsurface waters continues to be a major problem in agricultural areas despite efforts undertaken to minimize nutrient loss. Recent updates to the Natural Resource Conservation Service's Conservation Practice Standard 590 have brought nitrate management to the national spotlight, requiring the problem to be addressed in state conservation practice standards through a nitrate leaching index or other method approved by that state Natural Resource Conservation Service (NRCS). In Pennsylvania, scientists and the NRCS have worked together to find that best management practices for high nitrate leaching are already recommended under Pennsylvania's Act 38 Nutrient Management Policy. In order to educate farmers on how to incorporate these best management practices, a factsheet was developed that will be available through Penn State Extension. This thesis examines the history of nutrient management policy to show how the modern version of the 590 standard was developed and explains the process of meeting the 590 revision requirements through the development of a factsheet.

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# Chapter 1

## Introduction

Since the development of agriculture, animal manures and legumes have been important components of providing critical nutrients to crops, allowing the closed cycling of nutrients in the soil. Within this cycle, plants took up the nutrients added and used them in creating biomass; little of the nutrient content of the manure was lost to the environment. This system worked economically and environmentally. Farmers collected the manure produced by the animals and applied it to the fields that were growing the feed for the animals. At that time, there was no need for outside expenditures on fertilizer or animal feed. As the agricultural industry increasingly specialized into the monoculture setup we have today, this system failed. Most animal feed (in the form of corn and soybeans) is now grown in the Midwest, while Pennsylvania has become a heavy producer of animals fed on the Midwestern grain (Beegle, 2010). In the animal operations of Pennsylvania, manure is continuously produced, but land for spreading manure is limited without subjecting the nutrients to environmental losses. Economically, sending the manure to the inorganically fertilized cornfields in the Midwest is currently not feasible. For these reasons, nutrient pollution in Pennsylvania has become an important topic for farmers, environmentalists, and politicians alike.

Pennsylvania's agriculture remains a strong focus for environmentalists because of its impact on the health of the Chesapeake Bay. The Susquehanna River drains a large portion of the state, flowing directly into the Bay. Nitrogen, phosphorous, and sediment are the three main pollutants affecting the quality of life for organisms in the Bay, leading to algal blooms and dead zones with an absence of oxygen. Some of the more specific issues facing the Chesapeake Bay will be given more attention in the next section.

National and state standards and regulations limit the amounts of nutrients and sediment in the Bay, and researchers and politicians consistently work together to write and revise these documents. The Natural Resource Conservation Service (NRCS), a branch of the US Department of Agriculture, developed a voluntary program that allows farmers to develop nutrient management plans on their farms and be qualified to receive technical and financial assistance (CEAP Croplands Modeling Team, 2011). This program sets a national Conservation Practice Standard (Code 590) that is used for determining whether farmers are actively managing their nutrient loads. This national standard sets the minimum requirements for state regulations. In Pennsylvania, the Nutrient Management Law is Act 38 (Beegle, 2010). Nutrient management plans written under this law have been the core for all nutrient management planning efforts in PA, including plans written under the 590 standard and the federal Concentrated Animal Feeding Operations (CAFO) regulations. This provides consistency across programs and ensures that a farmer will not have to write several different nutrient management plans to meet the requirements of different state and federal programs (Beegle, personal communication). Revisions to the national 590 standard occur every few years, and the state version of the 590 standard must meet the minimum requirements set forth in the national standard, while also remaining consistent with Pennsylvania’s Act 38. In 2012, the national 590 standard was revised to include a nitrate leaching index to manage nitrogen loss through subsurface drainage (USDA, 2012). The specific wording is as follows:

> "The NRCS-approved nutrient risk assessment for nitrogen must be completed on all sites unless the State NRCS, with the concurrence of State water quality control authorities, has determined specific conditions where nitrogen leaching is not a risk to water quality, including drinking water."

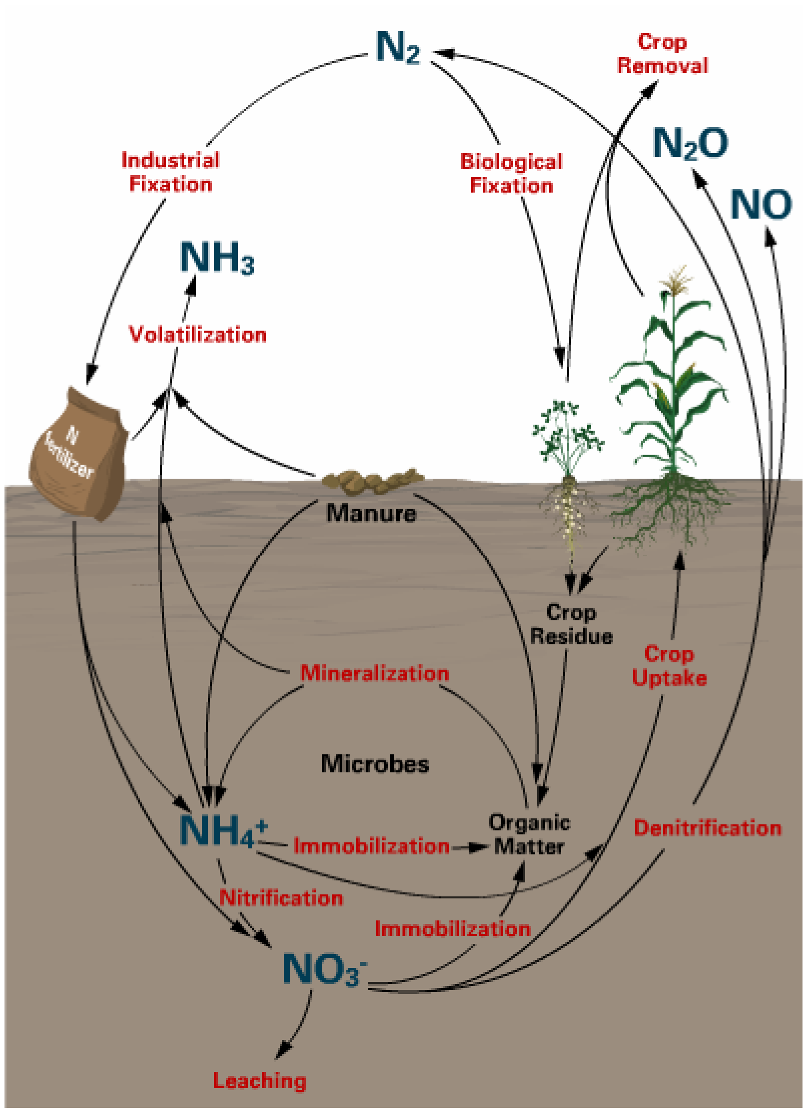
This new requirement poses a difficulty for Pennsylvania's nutrient management programs because Act 38 does not require a nitrate leaching index. It is important to keep the state 590 standard and Act 38 consistent, allowing one nutrient management plan for a farm to meet the needs for both state law and the voluntary standard. Incorporating a nitrate leaching index into Act 38 would be a difficult and expensive legislative process that would most likely take many years. However, as stated in the national standard quoted above, state authorities can determine specific situations where nitrate leaching does not impact water quality. Pennsylvania's current regulations already recommend or require several best management practices for reducing nitrate leaching, although they do not specifically state that they target nitrate leaching in the regulatory language (PA Dept. of Agriculture, 2005). An analysis of the nitrate leaching index shows that if a nitrate leaching index were to be used, the recommendations for high leaching soils would be to incorporate these same best management practices (BMPs). Because these BMPs are already being required for Pennsylvania nutrient management plans, it can be assumed that nitrate leaching is being adequately managed and the use of an actual index would be redundant. Some method of showing that these BMPs are explicitly targeting nitrate leaching would be necessary to meet the requirements of the national 590 standard. Upon further consideration and discussion with scientists and regulatory agencies, it was determined that an educational factsheet detailing the BMPs farmers should use for nitrate leaching would be the best approach.

In order to develop this factsheet, literature on the use of factsheets in extension programs was examined. Additionally, the nitrate leaching policies and recommendations of several different states were examined for comparison and to see if they actually use a leaching index or not. A summary of these findings is included in the Solutions chapter. In order to establish the need for nitrate leaching management, an introduction to the process of nitrate leaching is covered in the next sections. A history of nutrient management policy and the significance of the revisions are also included to build the background for the current situation.

## A. What is nitrate leaching?

Nitrogen is a macronutrient critical to all life. The invention of an industrial pathway for nitrogen fertilizer creation in the early 20$^{th}$ century allowed for increased food production and a huge human population expansion across the world. Nitrogen is notoriously difficult to make plant-available for crop uptake (Follett and Delgado, 2002). Prior to the widespread use of inorganic nitrogen fertilizer, animal manures and legumes were the predominant sources of nitrogen in agricultural settings. Nitrogen is ubiquitous throughout the soil and the atmosphere, but a very small percentage of that nitrogen is plant-available. Naturally, some nitrogen is made plant-available every year through microbial processes, resulting in around 60-80 lbs N/acre/yr (Durst and Beegle, 1999). The rest of the crop requirement comes from fertilizer, manure or growing legumes in the crop rotation. Nitrogen has many forms that are continuously cycling, and many of these forms have negative environmental impacts. Figure 1-1 shows the details of this complex cycle.

Figure 1. An Overview of the Nitrogen Cycle (Johnson, et al., 2005)



Nitrate and ammonium are the only two forms that can be taken up by plants. Ammonium is a positive cation and easily adsorbs to negatively-charged soil colloids. Plants can then exchange other cations for those ammonium ions and take them up for use. Nitrate is a negative anion and cannot adsorb to the negative soil particles. Nitrate is held in the soil solution, where it is easy for plant roots to take it up, but it is also easy for excessive rainfall or irrigation to leach the nitrate through the soil profile (van Es, et al., 2002). If the water table is shallow or the soil is excessively well-drained, the nitrate can easily leach into the groundwater. In some fields, tile drainage systems may prevent leaching into the groundwater, but these drains often provide nitrate a direct access to surface water instead (Williams and Kissel, 1991).

Applying nitrogen in the ammonium form does not always prevent nitrate leaching. Nitrification is the process of converting ammonium into nitrate, making the nitrogen more vulnerable to loss. Microbes are responsible for this process that occurs rapidly under the optimum conditions of field capacity moisture level, aerated soil, and a temperature beginning above 50°F and peaking in the range of 75-95°F (Follett and Delgado, 2002). Nitrification also results in the acidification of soil, which can be costly to fix. Nitrification inhibitors are commercially available, but the best response is to apply nitrogen as close to crop uptake as possible so that the N is quickly taken up by plants, thus avoiding the process entirely (Mosier, et al., 2002).

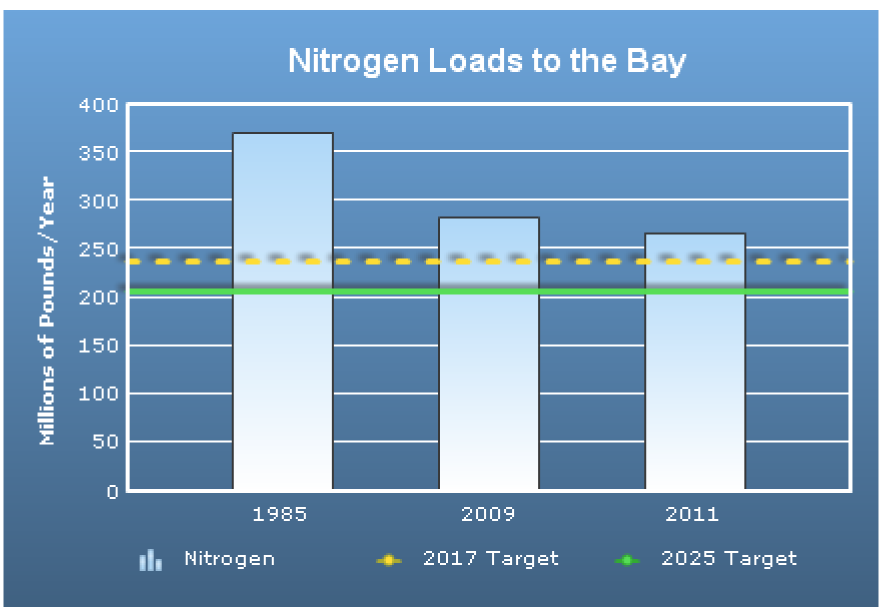
As mentioned previously, nitrate leaching allows nitrate to enter both groundwater and surface water, where it can cause many negative side effects. Nitrate in drinking water has received a great deal of attention due to its human health implications. Nitrate affects infants most strongly, inducing a condition called methemoglobinemia, otherwise known as blue-baby syndrome (Burkhart and Stoner, 2008). This illness occurs when nitrate is converted to nitrite, which then interferes with oxygen uptake in the blood. Babies appear to have a bluish tint to their skin, especially around the nose and mouth. There have also been several studies linking nitrate levels in drinking water to diseases in adults, including non-Hodgkin's lymphoma and bladder cancer (Rao and Puttanna, 2006).

In addition to these negative health implications, nitrate in the environment also serves as one of agriculture's main contaminants. While phosphorous is limiting in freshwater ecosystems, nitrogen is generally the limiting factor in saltwater systems such as estuaries. Nitrate often ends up in surface water and is transported to estuaries, where it may cause dead zones. High nitrate levels allow algal blooms to occur, and the decaying of the algae consumes much of the oxygen in the water, essentially suffocating all other species. This is a huge problem in both the Gulf of Mexico and the Chesapeake Bay (van Es, et al., 2002). Much of Pennsylvania drains into the Chesapeake Bay, making this an important topic of consideration when it comes to discussing nitrate leaching that will be expanded upon in the next section.

## B. Issues in the Chesapeake Bay

Environmentalists have been fighting to reduce pollution to the Chesapeake Bay for decades with mixed results. While significant progress has been made, pollution levels are still high, and aquatic life is still limited in oxygen-depleted zones caused by nutrient loading. The three significant pollutants in the Chesapeake are nitrogen, phosphorous, and sediment. Cultivated cropland makes up only 10% of the total land in the Chesapeake Bay watershed, but it contributes almost 31% of the total nitrogen load to the Bay (Chesapeake Bay Program, 2010)). According to a recent Conservation Easement Assessment Program study, it was found that nitrogen lost through subsurface drainage decreased by 31% during the period of 1985 to 2006, but increased conservation practices could reduce this nitrogen loss by an additional 20% (CEAP Cropland Modeling Team, 2011). The numbers have likely decreased even more since the end of the study period because there has been heavy emphasis on education and encouragement of conservation practices. The study also found that there is a high level of need for additional conservation practices on 810,000 acres of cropland. Significant progress has been made since 1985, but there is still a lot of work to be done, as is seen in Figure 1-1.

Figure 2 Current and target nitrogen loads to the Chesapeake Bay (Chesapeake*Stat,* 2013).



## C. A Brief History of Policy

The Chesapeake Bay is the largest estuary in the United States and its watershed is home to 17 million people (Chesapeake Bay Program, 2010). Unfortunately, the Chesapeake Bay has also proven to be the main indicator of nutrient and sediment pollution in the Mid-Atlantic region, which has prompted a series of regulations beginning in the early 1980's. With the Clean Water Act of 1972 enacted, attention turned to the declining state of the Chesapeake Bay in the mid 1970's. In 1976, the Environmental Protection Agency was charged with a seven year intensive study of the state of the Bay (Flanagan, 1984). The results of this research allowed for the development of a Framework for Action to be published in 1983 with a corresponding conference of seven hundred scientists, politicians, and administrators to discuss and agree on the plan (Chesapeake Bay Program, 1983). It was during this conference that the Chesapeake Executive Council was established, representing the states of Maryland, Virginia, and Pennsylvania, the District of Columbia, and the Environmental Protection Agency. This Council would be in charge of meeting twice a year to discuss the implementation of plans to improve the health of the Bay. This 1983 plan was instrumental in establishing the need for collaboration among states and making recommendations for improving the Bay, but it did not include specific numeric goals for reducing pollution loads (Chesapeake Bay Program, 1987).

In 1987, more specific goals were introduced as the need for a plan to guide cooperative efforts was realized. The Chesapeake Executive Council set the ambitious goal of "at least a 40% reduction of nitrogen and phosphorous entering the main stem of the Chesapeake Bay" by the year 2000 (Chesapeake Bay Program, 1987). This specific goal set the beginning of funding for nutrient management and allowed money for use in developing best management practices and other conservation measures. During this time, most of the funding went to the development of structural BMPs and expensive manure storage facilities rather than cheaper, lower profile BMPs that would have likely made a bigger difference if widely implemented. Amendments in 1992 reaffirmed the 40% reduction goal by 2000, although it was acknowledged that this goal challenged the limits of technology (Chesapeake Bay Program, 1992). Additionally, these amendments expanded protection to the tributaries of the Bay, as well as the Bay itself. The Natural Resource Conservation Service developed the Nutrient Management Standard Code 590 in the early 1990's to address nutrient pollution nationally, and it was enacted in 1993 (Stangel, 2002). The 590 standard set basic minimum requirements for nutrient management that states must follow, but left the details up to the states.

In response to the concerns for managing nutrient pollution, Pennsylvania passed Act 6 in 1993, the Pennsylvania Nutrient Management Act (Beegle, 2010). At this time, most of the focus on agriculture centered on nitrogen management, while phosphorous was more associated with point sources such as wastewater treatment plants. Agricultural phosphorous was managed primarily through erosion control, as phosphorous tends to bind to soil particles. Act 6 required Concentrated Animal Operations (CAOs) to develop comprehensive nutrient management plans that address all manure produced and applied on the farm, as well as best management practices to be implemented. This plan must be written by a certified nutrient management plan writer, or the farmer may become certified to write it. These nutrient management plans had to be approved by the local conservation district and implemented to be in compliance with the law. Act 6 did not actually go into effect until October 1, 1997. During the mid-to-late 1990’s, much more research emphasis was placed on the study of phosphorous. In 2002, Act 38 replaced Act 6 as the PA nutrient management law. The majority of the information in Act 6 carried over, but more regulations related to phosphorous management were included (Beegle, 2010). It was during this time that the Phosphorous Index began to be used regularly. There were no significant changes related to nitrogen management in Act 38 as the N provisions of Act 6 had been challenged in court and found to be valid. Both Act 6 and Act 38 were consistent with the requirements of NRCS Standard 590 which allowed these regulatory plans to meet the requirements of the NRCS Standard 590.

Throughout this time, improving the quality of the Chesapeake Bay remained a priority. In 2000, the Chesapeake 2000 agreement was written which reaffirmed the previous goals and set a deadline of 2010 for attaining them (Chesapeake Bay Program, 2000). This agreement also acknowledged the increasing challenges of a growing population. As 2010 approached, it became clear these goals would not be attained and that a stricter and more defined program was needed in order to make the significant changes required. The Chesapeake Bay Total Maximum Daily Load (TMDL) was developed in 2009 to achieve set reductions on nutrient loads by 2025 (Chesapeake Bay Program, 2010). In order to ensure that adequate progress is being made throughout the watershed, the watershed has been divided into jurisdictions that must each submit two-year Watershed Implementation Plans. Jurisdictions must also submit progress reports every two years, and they must complete 60% of the reductions by 2017. In this way, hopefully the goals of cleaning up the Bay can be achieved. Table 1-1 gives a summary of the various policies enacted since 1972.

Table 1-1 A History of Nutrient Management Policies in Pennsylvania

| Year | Policy Implemented/Historical event |
|---|---|
| 1972 | Clean Water Act |
| 1976 | EPA charged with researching Chesapeake Bay |
| 1983 | EPA's Chesapeake Bay Program founded |
| 1987 | Chesapeake Executive Council set goal of 40% nutrient load reduction by 2000 |
| 1992 | 1992 Amendments to the Chesapeake Bay Agreement |
| 1993 | NRCS Nutrient Management Standard 590 in effect |
| 1993 | Pennsylvania Nutrient Management Act 6 written |
| 1997 | Act 6 went into effect |
| 2000 | Chesapeake 2000 agreement |
| 2005 | PA Act 38 replaced Act 6 |
| 2009 | Chesapeake Bay TMDL |
| 2012 | NRCS Nutrient Management standard 590 REVISED |

### D. Background Information: What the 590 standard is and why we have it

The NRCS wrote the first Conservation Practice Standard 590 in the early 1990's, and the standard is revised every 4-5 years to maintain relevance and stay up to date with technology (Stangel, 2002). To be clear, the 590 standard is *not* a law or regulation, and the NRCS is not a regulatory agency. The NRCS exists to further agricultural research and provide farmers with technical and financial assistance in ensuring the practices on their farms are environmentally sound. The Conservation Practice Standard (590) is part of a voluntary, incentives-based program that encourages farmers to reduce pollution and preserve the nutrients on their farms (CEAP Croplands Modeling Team, 2011). In order to receive technical and financial assistance, farmers must develop nutrient management plans based on the 590 standard. In PA, plans developed in accordance with Pennsylvania's Act 38 meet this requirement. Act 38 nutrient management plans are required for Concentrated Animal Operations with more than 8 Animal Equivalent Units (AEUs) and/or more than 2 AEUs per acre, but all farms with animals are strongly encouraged to develop these plans (Beegle, 2010). The NRCS 590 standard is critical in that it sets the national minimum standards for nutrient management, and each state must develop a standard that must be no less restrictive than it. In Pennsylvania, it has been determined that Act 38 regulations meet all the requirements of the national 590 standard.

### E. The implications of recent changes to 590 and why this is a challenge

In late 2011, the NRCS released a revised version of the national 590 Nutrient Management Standard for a brief public review period. Several of the revisions were rather drastic, including replacing the Phosphorus Index with a single soil test criterion. Multi-university efforts were focused on making sure the Phosphorous Index remained a part of the standard (Sharpley, et al., 2011). In early 2012, the final version of the 590 Standard was released, and states were given a year to develop a state 590 standard that complied with the new national standard. One such addition to the revised standard, the requirement of a nitrate leaching index, posed a problem for Pennsylvania. As mentioned previously, Pennsylvania's Nutrient Management Act (Act 38) had always been consistent with the national NRCS 590 Standard. The addition of a nitrate leaching index would make the requirements of the 590 standard inconsistent with Pennsylvania's Act 38, but changing the law would require legislative action and likely take several years and a great deal of taxpayer money. Additionally, the nitrate leaching index would need to be performed on farms, which would require extra time and money to accomplish.

## F. How to implement in PA?

The challenges posed by the revised 590 standard lead to the question: how should Pennsylvania implement the updates to the 590 standard while maintaining consistency in regulations for farmers across all programs? After an analysis of leaching indices and policies in other states, and current requirements in PA, it was determined that current management requirements in Pennsylvania's Act 38 would achieve the same management outcome that would be achieved by requiring the nitrogen leaching index according to the 590 standard. In fact, since all farms with an Act 38 nutrient management plan would have to meet these requirements, this approach goes beyond the 590 standard requirements; many farms would not have to implement these BMPs if the decision were based on a voluntary nitrate leaching index. Further, it was determined than an educational approach to assure that planners and farmers were aware of the requirements and that leaching is properly considered in nutrient management plans to be implemented on farms would be critical to meeting the requirement of both Act 38 and the NRCS 590 standard. Thus, the idea of a factsheet detailing the best management practices to prevent nitrate leaching became the focus. This thesis details how this factsheet came about and how it will work to reduce nitrate leaching in the commonwealth of Pennsylvania.

# Chapter 2

# Solutions

## A. Analysis of Nitrate Leaching Policy in other states

In order to determine the best method for addressing nitrate leaching in Pennsylvania, the policies and regulations of other states were examined to determine their current positions. While the required need to address nitrate leaching arose with the 2012 590 Standard Updates, the lack of information available to farmers about nitrate leaching in their fields was somewhat surprising. Some states require the use of a nitrate leaching index, but only New York State provided a fact sheet with information on the index and subsequent requirements for farmers. The states that were examined are Delaware, New Jersey, Wisconsin, Maryland, Wisconsin, Virginia, and New York. The findings have been grouped based on similarity in approaches.

Many of the states surveyed included little or no mention of nitrate leaching in either extension publications or regulations. In the available resources from the state of Delaware, no specific mention of nitrate leaching potential in soils was found. In order to prevent nitrogen leaching, the recommended best management practices are the use of the Corn Stalk Nitrate Test and the Pre-Side Dress Soil Nitrate Test, both of which will help to ensure that nitrogen is applied as close to uptake as possible and at rates that will be utilized by crops (Hansen, 2000). Using best management practices is a good way to reduce the possibility of nitrate leaching, but this information should be more readily available to farmers and also address current 590 regulations. However, further examination of other states began to show that this type of approach was very common. In the state of New Jersey, again there was no mention of a nitrate leaching index. Heavy emphasis was placed on the use of best management practices, although there was no specific reference to BMPs that reduce nitrate leaching (NJ Association of Conservation Districts, 2013). One of the listed BMPs was soil nitrate testing, which was recommended but listed as optional for Animal Waste Management Plans (Heckman, 2003). In the state of Maryland, the following requirements are stated for nutrient management plans: Any best management practices included to reduce risk of nutrient movement, and any methods (including the use of a risk analysis tool) indicating the potential for nutrients to move into surface or groundwater (Maryland Dept. of Agriculture, 2004). While unclear if referencing a nitrate leaching index, the implied requirement is that if these practices are used, they must be included in the plan, but if they are not used, they do not need to be included. This lack of clear definition is a problem both for farmers and nutrient management plan writers. They also state that consultants should consider recommending “split application of nitrogen on soils identified as having a high leaching potential”( Maryland Dept. of Agriculture, 2004). But how is this high leaching potential determined? As with previous states and in the case of Pennsylvania, it would be clearer to both the farmer and planner if there was a document specifying these BMPs and the criteria for using them, such as the fact sheet proposed for development in Pennsylvania.

The state of Wisconsin gives a slightly more concrete approach to the management of nitrate leaching (Shepard, 2000). In Wisconsin, the 2005 version of the 590 standard gives criteria to minimize entry of nutrients to groundwater (United States, 2005). These criteria (in the form of common best management practices) are to be applied in four scenarios: 1) high permeability soils, 2) soils with less than 20 inches to bedrock, 3) soils with less than 12 inches to apparent water table, and 4) soils within 1000 feet of a municipal well. A list of these soils with a stronger potential for nitrate leaching is provided in a technical note and should be referenced when completing a nutrient management plan. This list is likely not as complete as it could be, and a better method might be to recommend these criteria for reducing leaching on all soils, rather than just the ones in these four categories. Updates based on the 2012 590 standard should be made available, and address soils with high nitrate leaching values. Virginia uses a similar method in managing leaching potential. When leaching potential is high, split applications of nitrogen fertilizer are required (Virginia DCR, 2005). Fields considered "environmentally sensitive sites" should have nitrogen application programs that address concerns with fertilizer and manure applications. These environmentally sensitive sites include fields draining into sinkholes or containing 33% of land meeting any of the following criteria: 1) high leaching potential based on texture, 2) less than 41 inches deep over limestone bedrock, 3) subsurface tile drainage, 4) high potential for subsurface flow, 5) floodplains, or 6) slope greater than 15% (Virginia DCR, 2005). A major difference in Virginia as opposed to Wisconsin is the use of the Nitrate Leaching Index, which uses hydrologic soil group and county precipitation data to determine a leaching index for soils. While split nitrogen applications are always recommended, they are required by law for soils with high or very high leaching potential. While this nitrate leaching index is used in the development of nutrient management plans, there are no educational documents to help farmers understand what leaching is and how certain practices can reduce it. Also, the only requirement for mentioning high leaching potential is split nitrogen applications, but the use of other best management practices should be recommended as well.

Finally, New York has done a significant amount of work over the past few years in developing a unique nitrate leaching index along with educational documents that have been influential in the development of Pennsylvania's factsheet. The Cornell University Cooperative Extension uses the Nitrate Leaching Index developed using the Percolation Index and the Seasonal Index by Williams and Kissel, but takes the index a step further by using township-based precipitation data rather than county-based (Czymmek, et al., 2003). Calculations are not necessary as tables detailing all of the needed information for soils and townships are provided. New York has also developed a two-page extension factsheet to educate farmers about the leaching index. The bulk of the factsheet emphasizes the management implications for having high or moderate leaching potential (Czymmek, et al., 2003). In order to meet the 590 standard, best management practices should be in practice for high leaching potential fields, and these practices are recommended for moderate fields. The best management practices recommended in this factsheet are similar to those already recommended in Pennsylvania.

After investigating how other states are currently managing nitrate leaching, methods for Pennsylvania were developed and will be detailed in the next section.

**B. Why a factsheet and education are the best method at this time**

As discussed previously, the revised national 590 standard states "the NRCS-approved nutrient risk assessment for nitrogen must be completed on all sites unless the State NRCS, with the concurrence of State water quality control authorities, has determined specific conditions where nitrogen leaching is not a risk to water quality, including drinking water" (United States, 2012). Pennsylvania needs to respond by creating a state 590 standard that is no less restrictive than the national standard. Currently, the nutrient management plan required by the 590 standard meets the requirements of both Pennsylvania's Act 38 and the CAFO regulations, which allows farmers to have one nutrient management plan meeting all of these requirements. The addition of a nitrate leaching index to the 590 standard would differentiate that plan from the others already required. Traditionally, Pennsylvania has tried to maintain consistency between these regulations for ease of management and to reduce the time and money spent by farmers to meet them. With the new nitrate leaching index, Act 38 and CAFO plan regulations would need to be modified, which in the field of environmental policy would be a multi-year, very costly experience. The national 590 standard does state that a nitrate leaching index is not required under "*specific conditions where nitrogen leaching is not a risk to water quality, including drinking water*" (United States, 2012). Using this piece of information, discussions between Penn State Extension and Pennsylvania's NRCS state office led to the idea that best management practices could create the specific conditions where nitrate leaching is not a risk to water quality.

There are several best management practices already recommended for farms used to prevent nitrate leaching, although they are not specifically listed as BMPs for nitrate leaching (PA Dept. of Agriculture, 2005). In studying New York's factsheet on the Nitrate Leaching Index, most of the best management practices recommended for high leaching areas are already recommended under Act 38 regulations, although they are not mentioned in association with nitrate leaching specifically. For example, the following BMPs are found in Act 38: Never exceed nitrogen-based manure rates, time manure and fertilizer applications as close to crop uptake as practical, cover crops should be planted for fall and winter applied manures, manure may not be applied within 100 feet of a stream, the Pre-Sidedress Nitrogen Test should be used to determine supplemental nitrogen needs, and manure should be incorporated as soon after application as practical or use low disturbance manure injection (PA Dept. of Agriculture, 2005). In order to explicitly state how to manage nitrate leaching, the idea for an educational factsheet was proposed as the solution.

Education and voluntary incentives are hotly debated in terms of effectiveness in environmental protection.  Studies have shown that farmers implement conservation practices only when there is a clear economic incentive (Daberkow, et al., 2008). While there is an economic incentive to managing fertilizers and manures more efficiently, farmers often have an overabundance of manure that must be managed somehow, with spreading being the preferred method of disposal. However, in the case of nitrate leaching in Pennsylvania, there is little information about its management available to either farmers or nutrient management plan writers.  The purpose of a factsheet would be to draw specific attention to this issue so that more people are aware of it and farmers should be able to see how the best management practices they are often already using can impact water quality or see additional reasons to consider implementing a BMP. Additionally, a factsheet can be published in a timely manner and made available to a wider audience than other means of publication. A factsheet will answer the requirements of the national 590 standard in an affordable and ultimately more efficient way than adjusting current regulations.

**C. Development of Nitrate leaching factsheet for PA**

After reviewing current information available on nitrate leaching and seeing the format of New York's factsheet, the Pennsylvania Nitrate Leaching factsheet was created to introduce the concept of leaching, explain current regulations, and detail practices that specifically address with leaching management. This factsheet is written for a widely ranging audience of farmers, nutrient management plan writers, and PA and national legislators and government agencies. Additionally, the factsheet will be an important educational resource for the nutrient management certification training program in Pennsylvania. Highlights of the factsheet will be discussed in this section, but the full version of the factsheet is available in Appendix A.

Overviews of the nitrogen cycle are available in other Penn State factsheets, so the process was covered briefly in this factsheet. Specifically, more focus was placed on detailing the conditions required for nitrate leaching to occur, from soil types to specific drainage schemes. Emphasis was placed on the reasons nitrate leaching should be avoided, particularly human health issues, water quality in the Chesapeake Bay, and regulatory compliance. This introduction was followed with an explanation of how Pennsylvania's Act 38 addresses the issue of nitrate leaching with best management practices. Each of the practices was detailed with a brief explanation to show the relation to nitrate leaching.

The bulk of the factsheet focuses on the nitrogen management practices that farmers can undertake to minimize leaching. These practices include ensuring that the appropriate nitrogen application rate is used, applying nitrogen as close to crop uptake as possible, using appropriate application methods, and planning for environmentally sensitive areas. In order to better illustrate these concepts for farm managers and nutrient management plan writers, a matrix was developed in a similar design to other extension publications. This matrix helps them to look at specific management categories and select the practice most appropriate for the specific conditions on the farm. For each management category, best, good, fair, and unacceptable options for management are listed. This matrix summarizes the main points from the written portion of the factsheet. The matrix can be viewed in Appendix A.

The creation of this factsheet brings to light information on nitrate leaching that was otherwise unavailable through Penn State extension and fills the need of educating the agricultural community about the importance of this issue. Nitrate leaching remains a serious problem in many areas, and hopefully this factsheet will illustrate the seriousness of the problem and why the management practices are so critical.

# Chapter 3

## Conclusions and Implications for Further Study

For decades, environmentalist and legislators have worked together towards goals of clean water available to every citizen and high quality in every environment, but these goals have yet to be attained. The conflict between the need to produce food and the nonpoint pollution source of agriculture leads to many debates among special interest groups. There is no clear answer for solving this issue. We can only continue to work towards our goals, specifically those relating to nutrient loads to the Chesapeake Bay. Nitrate leaching gains more attention because of its potentially damaging impact on human health, but it is also a major pathway of nitrogen loss from agricultural fields. The hope is that educational materials such as the nitrate leaching factsheet will make farmers aware of practices they can implement on their farms to minimize their impact.

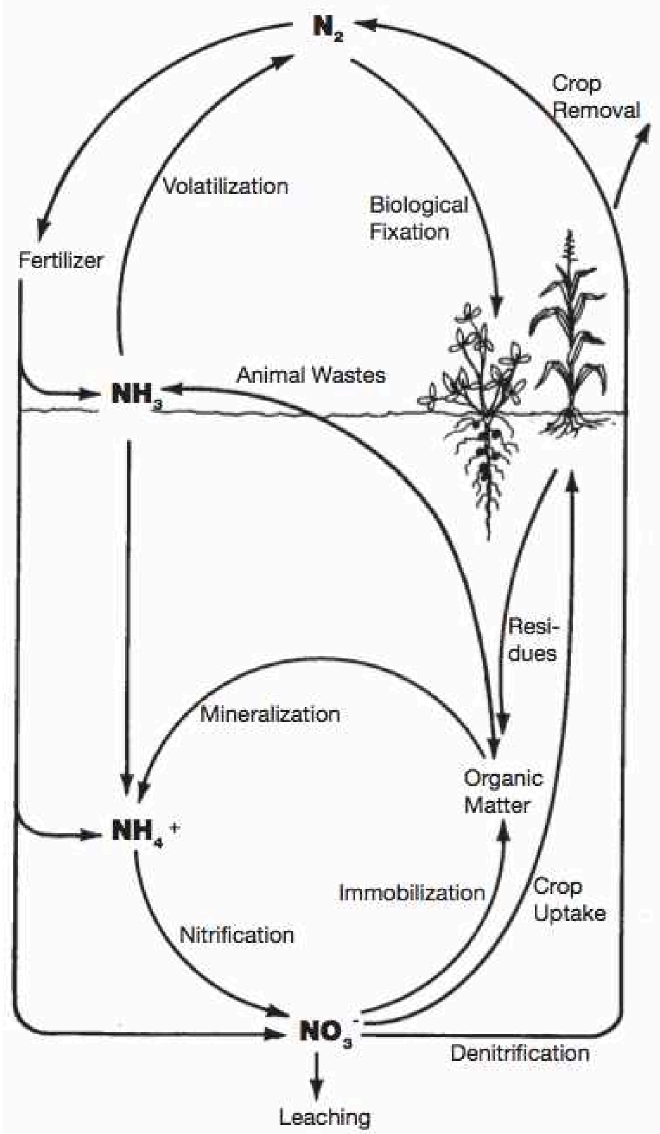
For further study, actual measurements of the effects of best management practices on nitrate leaching would be useful.  It would also be interesting to see how many farmers implement BMPs and which ones they use. Furthermore, it would be useful to see what the effect of each BMP is on nitrate leaching to determine the optimum amount of leaching that can be prevented.  Little research on nitrate leaching in Pennsylvania has been done to date, so any or all of these studies would be helpful in making future recommendations on nitrate leaching and could potentially show the need for a stronger approach than education.  Analysis of the effectiveness of the factsheet approach in farmer education would also be interesting, and a survey of farmers on their knowledge of nitrate leaching on their farms could help to develop a stronger plan for the future. Until then, this nitrate leaching factsheet will hopefully bring a greater awareness to the issue and influence farmers to better steward their lands, waters, and sources of nutrients to ensure the health and safety of the people and natural resources of Pennsylvania and the Chesapeake Bay area.

## Appendix A

## The Developed Factsheet

Nitrogen continuously cycles in the environment, from plant-available to unavailable forms. Figure 1 details this cycle, and further information can be found in the next section on this factsheet.

**Figure 1. Nitrogen cycle: Transformations between N forms.**



## The Nitrogen Cycle: What you should know

Nitrogen (N) makes up 78% of the air we breathe in the form $N_2$, but this form is unable to be used by plants. In fact, there are 34,000 tons N/acre in the air above an acre of land, but none of it can be used by crops. Nitrogen must be fixed in order to become available, which is done through the process of making fertilizers industrially or through nitrogen-fixing bacteria associated with the roots of legumes. There is a lot of nitrogen in soil naturally (2000-4000 lb/A), but 98% of that nitrogen is in the organic form and cannot be used by plants either. This organic nitrogen is found in all the living and once living material in the soil. Nitrogen naturally becomes available in soil as organic matter is decomposed, which results in around 60-80 lb N/acre/year. There are two forms of inorganic nitrogen that are plant available: Ammonium N ($NH_4^+$) and Nitrate N ($NO_3^-$). Ammonium N is held on the soil particles and can be exchanged with other cations in order for plants to take it up, but it does not leach easily from the soil. Nitrate N, on the other hand, is found in the soil solution and can be leached from the profile. This leaching needs to be managed properly to ensure plants have access to the nitrate and minimize the nitrate pollution in waterways. Understanding the nitrogen cycle thoroughly allows us to do that. The processes involved in the cycle are summarized below.

The forms of N and the transformations that it undergoes in the soil are summarized in the N cycle shown in figure 1. Most of the transformations in the N cycle are the result of microbial activity. Because these are biological processes, they are very sensitive to the environment where they are occurring. Major factors influencing these processes are temperature and moisture and thus the weather. The challenge with managing N is manipulating the N cycle and/or managing inputs to achieve maximum N availability when crops need N but minimizing N in soluble forms when there is not crop uptake to reduce loss of N to the environment. The three main pathways of N loss are:

**Nitrate Leaching**

Nitrate is a negative anion, and does not hold onto the negatively-charged soil particle. Ammonium is a positive cation and does hold to the soil. Because nitrate is in the soil solution and not held to the soil, rainfall or irrigation can leach the nitrate through the soil profile. Nitrates are found naturally in drinking water in small amounts because nitrification occurs as microbes decompose ammonium. However, nitrate can enter water systems in much higher amounts in agricultural areas because of the nitrification that occurs when microbes break down fertilizer and manure. Nitrate is particularly dangerous when it comes to drinking water—babies can get very sick from “blue baby syndrome” when nitrate in the blood reduces the oxygen-carrying capacity. Because of this, a limit on the amount of nitrate in drinking water is set at 10 ppm nitrate-N. Exposure to nitrates over time could also impact the health of adults, as well.

Nitrate also impacts the environment negatively, particularly the Chesapeake Bay. In saltwater environments, nitrogen is the limiting factor. Excess levels of nitrate allow algae to flourish in harmful algal blooms that result in dead zones where little can live due to the low oxygen levels. These dead zones result in widespread death of oysters, blue crabs, and other important species for the fishing industry in the Chesapeake Bay, with a huge economic impact. With a large portion of Pennsylvania draining directly into the bay, it is critical to manage nitrate leaching on farms and improve the water quality.

### Denitrification

Denitrification occurs only in situations with anaerobic activity when soil is saturated with water. Microbes generally use oxygen in the soil when they decompose organic matter, but if $O_2$ is not available due to saturation or plant use of oxygen, they will use nitrate instead. They convert nitrate to gas forms of nitrogen which are released back into the atmosphere. Typical soils may lose up to 15% of nitrate in this manner. Denitrification thus results in a significant loss of available N for crop production. N can also be lost through denitrification as nitrous oxide $N_2O$. This is a major greenhouse gas which is 300 times more damaging than $CO_2$.

### Volatilization

Volatilization of ammonia is a huge problem in Pennsylvania. The urea form of N, found in urea-containing fertilizers and in animal manure, converts to ammonia gas, $NH_3$, and is lost to the atmosphere if exposed to air on the surface. If urea or manure is incorporated, the ammonia converts to ammonium N, which is adsorbed to the soil particles. As with leaching and denitrification, volatilization represents a significant loss of N for crop production and also represents a potential negative environmental effect. Ammonia in the atmosphere is a precursor for the development of potentially harmful microscopic particulate matter usually called $PM_{2.5}$. These small diameter particles are able to be respired deep into the lungs causing a respiratory problems such as coughing, bronchitis, asthma, etc. Also, a significant amount of the N volatilized as ammonia is redeposited out of the atmosphere back onto land or directly into water bodies resulting in N enrichment.

All of these losses potentially represent both a significant agronomic and economic loss of N for crop production and a significant environmental threat. The goal of reducing N loss can be met most practically through appropriate management of the source, rate, timing, and method of N application. Considerable efforts have been made through education and regulation to address the need for appropriate N management to reduce these losses.

## What are the regulatory requirements?

With the updated 2012 version of the NRCS Conservation Practice Standard Nutrient Management Code 590, nitrogen shall be managed for leaching risk on all fields by meeting criteria and guidance in the *Act 38 Regulations*, the *Act 38 Technical Manual*, and Penn State Extension guidance in the *Pennsylvania Agronomy Guide* and related technical fact sheet publications. What does this mean for you?

Under Act 38, concentrated animal operations (CAOs) are required to develop an approved nutrient management plan, and those plans need to address any potential nitrate leaching on the farm. CAOs are defined as having 8 or more animal equivalent units (AEU) and more than 2 AEUs per acre. For more information, see Agronomy Facts 54 Pennsylvania's Nutrient Management Act (Act 38): Who Is Affected? (http://pubs.cas.psu.edu/FreePubs/pdfs/uc149.pdf)and Agronomy Facts 40 Nutrient Management Legislation in Pennsylvania: A Summary of the 2006 Regulations (http://extension.psu.edu/cmeg/facts/agronomy-facts-40).

Under the Pennsylvania Clean Streams Law, all farms that produce or utilize manure must have a written Manure Management Plan. Guidance for these plans is provided in the Pennsylvania Manure Management Manual (MMM) (http://panutrientmgmt.cas.psu.edu/pdf/mmp/Land%20Application%20of%20Manure%202011-10.pdf) Plans written to meet Act 38, CAFO, or NRCS 590 requirements satisfy this requirement. These plans can be farmer written and do not have to be approved but must be kept on the farm and fully implemented with records to document implementation.

Under the federal Clean Water Act, Concentrated Animal Feeding Operations (CAFO,) which are farms with large numbers of animals regardless of the land base, must have a National Pollutant Discharge Elimination Permit (NPDES) which also requires an approved nutrient management plan. In Pennsylvania, the nutrient management plan requirements for a CAFO NPDES permit are the same as the Pennsylvania Act 38 requirements (http://www.pabulletin.com/secure/data/vol35/35-43/1945.html).

The nutrient management programs in Pennsylvania have historically been highly coordinated to make it easier for farmers to comply with the different state and federal requirements and to minimize duplication of efforts. Consequently, the NRCS 590, PA CAO, and Federal CAFO programs all utilize the same core nutrient management plan. Thus all of these nutrient management plans use the same requirements for managing N.

The details of the nutrient management requirements for N as found in the Act 38 regulations follow [numbers in brackets indicate a reference in the regulations]. All of these requirements can found in Act 38 at http://panutrientmgmt.cas.psu.edu/pdf/lr_Act38_Regulations.pdf.

i) Never exceed nitrogen-based manure rates [83.293 (a)(1)]. N Based manure rates are developed by taking the nitrogen recommendation (based on the crop and expected yield) and subtracting factors such as starter fertilizer, leftover nitrogen from legumes, and previous manure applications. Then this number is divided by the available nitrogen in the manure. Nitrogen not taken up by plants is vulnerable to loss to the water supply, so it is critical not to apply any more N than the crop can take up.
ii) Time manure and fertilizer applications as close to crop uptake as practical [83.294(a & b)]. Nutrients, in particular nitrogen, should be applied to fields at the best possible times and under the best possible conditions, using any best management practices possible to minimize entry into ground or surface waters. Applications should also be timed to avoid times when high rainfall is expected.
iii) For fall and winter applied manures cover crops should be planted [83.294(f & g)]. For fall applications, this means that manure should only be applied if a cover crop will be planted and grow enough for nutrient uptake, or if the manure is injected (or other no-till incorporation methods) within 5 days. For winter applications, fields must have at least 25% cover by crop residue or an established cover crop.

iv) Setbacks and buffers [83.294 (f)]. There are several situations where manure may not be applied due to setbacks or buffers designed to protect the water from nutrient pollution. Manure may not be applied within 100 feet of a stream or intermittent streambed, unless a 35 foot vegetative buffer is established. It may not be applied within 100 feet of an open sinkhole (meaning there is direct access to the water table at the bottom) unless a 35 foot vegetative buffer is established. Manure also can't be applied within 100 feet of private wells or public drinking water sources.

v) Use the PSNT to determine supplemental nitrogen needs [83.293 (d)]. The Pre-Sidedress Nitrogen Test involves a soil test taken to a depth of 12 inches when the corn is 12 inches tall. It measures the amount of nitrate-N in the soil right before the large uptake of nitrogen by the corn. This shows whether the manure applied is providing an adequate amount of nitrate or if it needs to be supplemented with fertilizer N.

vi) Incorporate manure as soon after application as practical or use low disturbance manure injection [83.291 (d)]. This important practice reduces volatilization. Up to 60% of nitrogen could be lost if the manure isn't incorporated.

**Nitrogen Management Matrix**

The following Nitrogen Management Matrix can be use to assess current farm N nutrient management and provide guidance on appropriate management practices.   Following this matrix are more details on management practices that will improve N management for crop production on your farm and assure that you are meeting regulatory requirements to protect the environment.

| Management | Best | Good | Fair | Not Acceptable |
|---|---|---|---|---|
| N Fertilizer Rate | Rate does not exceed crop N recommendation or N removal by legumes and considers: previous legume crop, previous manure history, and planned manure application and PSNT or Chlorophyll meter used to adjust sidedress N rate | Rate does not exceed crop N recommendation or N removal by legumes and considers: previous legume crop, previous manure history, and planned manure application | NA | Rate exceeds crop N recommendation and does not consider: previous legume crop, previous manure history, and planned manure application |
| N Fertilizer Timing | Fertilizer applied in split applications in sync with crop uptake. eg. Apply by cutting to grass forages, sidedress N on corn, apply the bulk of N in the spring to winter grains, etc. | Fertilizer applied immediately (days) prior to planting annual crops<br>or<br>Applied earlier (weeks) to a growing cover crop<br>or<br>Applied earlier (weeks) with a nitrification inhibitor | Fertilizer applied well ahead (weeks) of planting annual crops with no cover crop or expected uptake by a perennial crop | Fertilizer applied a month or more before planting an annual crop or expected uptake by a perennial crop |
| N Fertilizer Incorporation Timing | Fertilizer placed or Injected directly into the soil | Fertilizer incorporated within 1 day | Fertilizer incorporated within 1 week | Fertilizer not Incorporated |

| | | | | |
|---|---|---|---|---|
| N Fertilizer Incorporation Method | Fertilizer placed or Injected directly into the soil with minimal soil disturbance | Fertilizer incorporated by conservation tillage methods<br>or<br>Not incorporated and a urease Inhibitor used with urea or UAN fertilizer<br>or<br>Not incorporated surface band application of UAN | Fertilizer not incorporated but applied immediately before a non-runoff producing rainfall event<br>or<br>Incorporated by conventional tillage methods | NA |
| Manure Location | Manure applied on level, well drained soils far from water with growing crop or 25% crop residue and conservation practices implemented | Manure applied on sloping well drained soils with growing crop or 25% crop residue and conservation practices implemented | Manure applied on steep slopes or in areas prone to flooding and excessively well drained or poorly drained soils | Manure applied within required application setbacks or where restricted by the P Index or on greater than 15% slope in the winter |
| Manure N Rate | Rate does not exceed crop N recommendation and considers: previous legume crop, previous manure history, and fertilizer N to be applied regardless of manure (eg. Starter N) | NA | NA | Rate exceeds crop N recommendation and does not consider: previous legume crop, previous manure history, and fertilizer N to be applied regardless of manure (eg. Starter N) |
| Manure Application Timing | Manure applied to growing crops (Primarily grass forage crops)<br>or<br>Manure applied immediately (days) prior to planting annual crops | Manure applied earlier (weeks) to a growing cover crop<br>or<br>Applied earlier (weeks) with a nitrification inhibitor | Manure applied well ahead (a month or more) of planting annual crops with a cover crop or at least 25% residue cover | Manure in the winter to frozen ground or applied well ahead (a month or more) of planting annual crops with no cover crop or less than 25% residue cover |
| Manure Incorporation Timing | Placed or Injected directly into the soil | Incorporated within 1 day | Incorporated within 1 week | Not Incorporated |

| | | | | |
|---|---|---|---|---|
| Manure Incorporation Method | Placed or Injected directly into the soil with minimal soil disturbance | Incorporated by conservation tillage methods | Not incorporated but applied immediately before a non-runoff producing rainfall event<br>or<br>Incorporated by conventional tillage methods | NA |

**REFERENCES**

Aisoa, Jennifer. 2004. New Federal CAFO Rules. CSREES Mid-Atlantic Water Quality Program. Accessed March 15, 2013. Available at: http://www.mawaterquality.org/publications/pubs/NewCAFOpub.pdf.

Beegle, D.B. 2010. Nutrient management legislation in Pennsylvania: A summary of the 2006 regulations. Agronomy Facts 40. The Pennsylvania State University. University Park, PA.

Burkhart, M.R., and J.D. Stoner. 2008. Nitrogen in groundwater associated with agricultural systems. Chapter 7. *Nitrogen in the Environment: Sources, Problems, and Management.* (http://www.sciencedirect.com/science/article/pii/B978012374347300007X).

CEAP Croplands Modeling Team. 2011. Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region. USDA, NRCS. Accessed March 15, 2013. Available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042076.pdf.

Chesapeake Bay Program. 1983. 1983 Chesapeake Bay Agreement. Accessed March 15, 2013. Available at: http://www.chesapeakebay.net/content/publications/cbp_12512.pdf.

Chesapeake Bay Program. 1987. 1987 Chesapeake Bay Agreement. Accessed March 15, 2013. Available at: http://www.chesapeakebay.net/content/publications/cbp_12510.pdf.

Chesapeake Bay Program. 1992. Chesapeake Bay Agreement: 1992 amendments. Accessed March 15, 2013. Available at: http://www.chesapeakebay.net/content/publications/cbp_12507.pdf.

Chesapeake Bay Program. 2000. Chesapeake 2000. Accessed March 15, 2013. Available at: http://www.chesapeakebay.net/documents/cbp_12081.pdf.

Chesapeake Bay Program. 2010. Chesapeake Bay Total Maximum Daily Load. Accessed March 15, 2013. Available at: http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/BayTMDLFactSheet8_6.pdf.

Czymmek, K., Q. Ketterings, H. van Es, and S. DeGloria. 2003. Fact Sheet 11: The New York Nitrate Leaching Index. CSS Extension Publication E03-2. 34 pages.

Daberkow, S., M Ribaudo, and O. Doering. 2008. Economic Implications of public policies to change agricultural nitrogen use and management. In: Schepers, J.S. and W.R. Raun, editors, *Nitrogen in Agricultural Systems.* Agronomy Monograph 49. ASA/CSSA/SSSA Madison, WI. p. 883-910.

Delgado, J., C. Cox, H. van Es, and W. Reeves. 2002. Nutrient management in the United States. Journal of Soil And Water Conservation 57(6):388.

Delgado, J.A. 2002. Quantifying the loss mechanisms of nitrogen. Journal of Soil and Water Conservation 57(6):389-398.

Durst, P.T. and D.B. Beegle. 1999. Nitrogen fertilization of corn. Agronomy Facts 12. The Pennsylvania State University. University Park, PA.

Flanagan, Frances, ed. 1984. Choices for the Chesapeake: an action agenda. The Citizen's Program for the Chesapeake Bay, Inc. Accessed March 15, 2013. Available at http://www.chesapeakebay.net/content/publications/cbp_13266.pdf.

Follett, R.F., and J.A. Delgado. 2002. Nitrogen fate and transport in agricultural systems. Journal of Soil and Water Conservation 57(6): 402-408.

Hansen, D. 2000. Nitrogen Management. Delaware Nutrient Management Notes. 2000 Volume 1, number 4. Delaware Cooperative Extension System, DE.

Heckman, J.R. 2003. Soil Nitrate Testing as a Guide to Nitrogen Management for Vegetable Crops. FS 285, Rutgers NJAES Cooperative Extension, New Brunswick, NJ. 6 pages.

Maryland Department of Agriculture. 2004. Title 15 Department of Agriculture, Subtitle 20 Soil and Water Conservation, Chapter 08 Content and Criteria for a Nutrient Management Plan Developed for an Agricultural Operation. Maryland Dept. of Agriculture, Annapolis, MD.

Mosier, A.R., J. W. Doran, and J.R. Freney. 2002. Managing soil denitrification. Journal of Soil and Water Conservation 57(6):505-512.

NJ Association of Conservation Districts. *On-Farm Strategies to Protect Water Quality: An Assessment and Planning Tool for Best Management Practices on New Jersey Farms*. Publication. New Brunswick: Rutgers University, n.d. Web. 15 Mar. 2013. <http://www.nj.gov/agriculture/divisions/anr/pdf/BMPManual.pdf>.

Pennsylvania Department of Agriculture. 2005. Act 38 Pennsylvania's Nutrient Management Law. PA Dept. of Agriculture, Harrisburg, PA.

US Department of Agriculture. NRCS, NHCP. 2012. Conservation Practice Standard Nutrient Management Code 590. Accessed March 15, 2013.

< ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/590.pdf>.

Randall, G.W., J.A. Delgado, and J.S. Schepers. 2008. Nitrogen management to protect water resources. In: Schepers, J.S. and W.R. Raun, editors, *Nitrogen in Agricultural Systems.* Agronomy Monograph 49. ASA/CSSA/SSSA Madison, WI. p. 911-945.

Rao, E. V. S. P., and K. Puttanna. "Strategies for combating nitrate pollution." *Current science* 91.10 (2006): 1335-1339.

Sharpley A., Beegle D., Bolster C., Good L., Joern B., Ketterings Q., Lory J., Mikkelsen R., Osmond D. and Vadas P. 2011. Revision of the 590 nutrient management standard: SERA-17 supporting documentation. Rep. Southern Cooperative Series Bulletin No. 413. Virginia Tech University, Blacksburg, VA.

Shepard, R. 2000. Nitrogen and phosphorous management on Wisconsin farms: Lessons learned for agricultural water quality programs. Journal of Soil and Water Conservation 55(1): 63-68.

United States. USDA. Ohio Natural Resources Conservation Service. *Electronic-Field Office Technical Guide*. N.p., June 2003. Web. 15 Mar. 2013. < http://oema.osu.edu/publications/NRCSPracticeStandard590-NutrientMgt.pdf>.

United States. USDA. Ohio Natural Resources Conservation Service. *Electronic-Field Office Technical Guide*. N.p., Nov. 2012. Web. 15 Mar. 2013. <http://efotg.sc.egov.usda.gov/references/public/OH/11-01-2012_Ohio_590_Standard.pdf>.

United States. USDA. Wisconsin Natural Resources Conservation Service. Conservation Practice Standard Code 590. Sept. 2005. Web accessed: March 15, 2013. <http://datcp.wi.gov/uploads/Farms/pdf/590_final.pdf>.

US Environmental Protection Agency Chesapeake Bay Program. 1983. Chesapeake Bay: A framework for action. Accessed March 15, 2013. Available at http://www.chesapeakebay.net/content/publications/cbp_12405.pdf.

van Es, H.M., K.J. Czymmek, and Q.M. Ketterings. 2002. Management effects on nitrogen leaching and guidelines for a nitrate leaching index in New York. Journal of Soil and Water Conservation 57(6):499-504.

Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation. 2005. Virginia Nutrient Management Standards and Criteria. VA Dept. of Conservation and Recreation, Richmond, VA.

Williams, J.R. and D.E. Kissel. 1991. Water percolation: an indicator of nitrogen-leaching potential. Chapter 4. *Managing Nitrogen for Groundwater Quality and Farm Profitability.* Soil Science Society of America, Madison, WI.

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**Research Interests**

I am interested in soil fertility and nutrient management, particularly in nitrogen and phosphorous management within the Chesapeake Bay watershed. Specifically, I am interested in how scientific research can be communicated to farmers in order to help them reduce negative environmental impacts.