Pennsylvania Department of Environmental Protection

# FIELD APPLICATION OF MANURE

**A supplement to Manure Management for Environmental Protection**

Commonwealth of Pennsylvania, Harrisburg, Pennsylvania
Department of Environmental Protection

**DEPARTMENT OF ENVIRONMENTAL PROTECTION**
**BUREAU OF WATERSHED MANAGEMENT**

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| **APPLICABILITY:** | Provides technical guidance for all livestock and poultry operations in Pennsylvania. |
| **IMPACT:** | This section of the Manure Management Manual describes practices to minimize water quality impacts from manure application and provides accepted practices for use in DEP or related programs. |
| **DISCLAMER:** | The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. There is not intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant. |
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## FIELD APPLICATION SUPPLEMENT AUTHORS


**Dr. Doug Beegle**
Penn State Cooperative Extension
**Dr. Les Lanyon**
Penn State University
**Joel Myers**
USDA Natural Resources Conservation Service


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# PREFACE

This publication supersedes all previous *Field Application of Manure* supplements to the *Manure Management for Environmental Protection* published by the Pennsylvania Department of Environmental Protection (DEP). Due to changes in recommendations and practices, copies of the previous manuals should be discarded. The current publication consists of a booklet entitled *Manure Management for Environmental Protection,* as well as seven technical supplements. A complete list of titles and where they may be obtained is given at the back of this publication.

This manual was developed by technical specialists of the US Department of Agriculture, Natural Resources Conservation Service and the Cooperative Extension of the Pennsylvania State University. Additional input and review were provided by many individuals including DEP personnel, legislators, members of state farm organizations, and representatives of conservation districts.

*The Manure Manual for Environmental Protection and its supplements provide guidelines that comply with DEP regulations concerning animal manures. Some farmers may have operations that are Concentrated Animal Operations under the Nutrient Management Act Regulations, or Concentrated Animal Feeding Operations under the Pennsylvania's Strategy for meeting federal requirements. These farmers would follow requirements in addition to those found in this manual. Farmers who do not follow the practices in this publication are required to obtain DEP approval or a water quality permit.* Farmers who do not follow these requirements or do not have a permit from DEP may be in violation of state or federal water pollution control laws.

**Prepared under the direction of the Agriculture Advisory Board to the Pennsylvania Department of Environmental Protection.**

**Commonwealth of Pennsylvania**
**Department of Environmental Protection**
**Office of Water Management**
**Harrisburg, Pennsylvania**
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# INTRODUCTION TO NUTRIENT MANAGEMENT

NOTE: This supplement describes the approved manure management practices, which if implemented, allow application of animal manure to land for the purposes of agronomic crop production without first obtaining a permit or other approval from the Pennsylvania Department of Environmental Protection (DEP). There are, however, permit requirements applicable to Concentrated Animal Feeding Operations. The underlying principle for manure application is to apply only the rate to cropland that will supply the amount of nutrients required to achieve realistic expected crop yields in accordance with a written plan. Because animal manure contains several plant nutrients at various concentrations, manure should be applied at rates which will result in no more than high soil test nutrient levels over the entire crop rotation.

Moderate amounts of manure when properly applied can provide plant nutrients for plant growth and improve the tilth, aeration and water holding capacity of soils. In practice, manure is not always applied to optimize plant nutrient use. Historically, a common practice has been to apply commercial fertilizer without giving credit for nutrients already applied in manure. In some situations where there is excess manure on the farm, the practice has been to field apply the manure simply as a disposal method. Applying manure in excess of plant needs, or at the wrong time, or handling it improperly may release nutrients into air and water, where they can become pollutants. Leaching of N through the soil can raise groundwater nitrate levels above the EPA drinking water limit, which can adversely affect the health of young children and livestock. Surface movement of nitrogen and phosphorus in runoff increases levels of these nutrients in surface waters. There are other consequences of surface water pollution which can lead to eutrophication and death of fish or other aquatic life.

## PLANT NUTRIENT MANAGEMENT PROCESS

Nutrient management generally involves decision-making about a wide range of farm operations. The decisions in this process are made as frequently as several times a day to as seldom as once every five years or more. These decisions include day-to-day details of farm operations, such as spreading manure on a specific field on a particular day, or deal with the long-range future of an entire farm, such as building a manure storage. Nutrient management is an ongoing process including assessment, option selection, planning and implementation (Figure 1). This process is repeated as necessary, but at least annually or when conditions change.

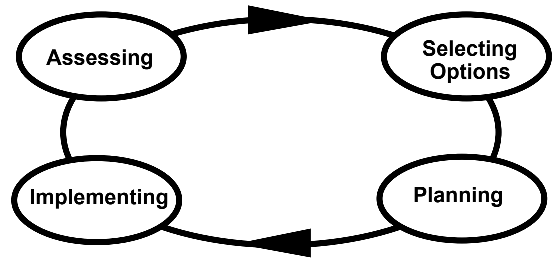



Figure 1. A schematic of the nutrient management process illustrating the four activities.

An initial assessment of the farm and the potential environmental impacts of the existing farm operations is an effective starting place in many situations. In the assessment activity the approximate nutrient balance of individual fields, groups of fields that are treated similarly, or even the whole farm can be determined depending on the purpose of the assessment. The outcome of the assessment can be used to determine what options should be considered for farm nutrient management to protect the environment while producing crops and animals. The nutrient management assistance required to change a farm operation will also be influenced by the type and extent of the practices to be incorporated.

The nutrient management options can be specific practices, such as incorporating field-applied manure soon after application, identifying other landowners who may be interested in having manure spread on their fields, or more far-reaching possibilities, such as postponing a planned expansion of the livestock housing facilities on the farm. The assessment and the options selected can be the basis for many decisions that will be made in the development of a farm nutrient management plan to allocate the manure and to determine any supplemental fertilizer requirements.

Implementation of a nutrient management plan involves the actual activities called for in the plan plus the appropriate recording of those activities so that the effectiveness of plan implementation can be assessed. Because of factors beyond the farmer's control, such as the weather, and because of changes in management, even the best nutrient management plan may not be implemented exactly as prepared. Thus record keeping and assessment to evaluate where the implementation deviated from the plan are critical for improving the plan for the following year.

Changes in management generally involve a transition period. This period could involve the adoption of new practices or new financial arrangements to deal with new costs of farm operation. The transition period can be of different lengths depending upon the nature and the extent of the changes required in the farm operation. After the transition period is completed, following nutrient management guidelines for crop production and environmental protection may simply become a part of normal farm operations.

## ASSESSMENT OF PLANT NUTRIENT FLOW ON FARMS

Plant nutrient management decisions deal largely with the flow of plant nutrients to, from and within farms. The organization of farms will lead to different patterns of materials, such as crops, fertilizers and manure, to be moved in the managed pathways of the farm operation. Understanding the various types of farm organization can be helpful in practically all activities associated with the nutrient management process for crop production and environmental protection. This is especially true in evaluating the nutrient management situation on farms. A major goal of nutrient management for crop production and for protecting the environment is to balance agronomic crop requirements and the supply of nutrients from all sources. Based on the movement of farm materials, and the nutrients contained in those materials, nutrient management should be sensitive to specific farm situations and existing strategies of farm management.

### Cash Crop Farm

Nutrient movement to, from and within a farm can be introduced most easily by looking at the patterns of material movement that are managed by a modern cash-crop farmer (Figure 2).

Nutrients enter this farm in fertilizers and other materials that are applied directly to the fields. Crops harvested from the fields take a fraction of the applied nutrients with them. When the crops are sold, the nutrients the crops contain leave the farm. There is a direct connection between the flow of nutrients and the agronomic or economic performance of the farm. Traditional economic and agronomic incentives can be effective in guiding nutrient use by these farmers both for crop production and for environmental protection. Nutrients generally are not applied unless a profitable response is expected. There is little reason to apply excess nutrients which might cause pollution. However, if nutrients are over-applied or allowed to be lost from the fields with runoff or leaching water, significant losses can occur. Cost of management actions that reduce nutrient losses on a cash-crop farm can be at least partially offset by decreased costs in purchased fertilizer.

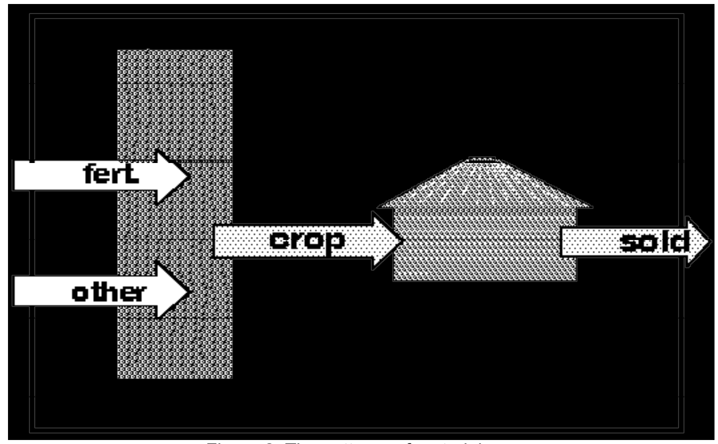


Figure 2. The patterns of material movement as managed on a cash-crop farm.

### "Traditional" Crop and Livestock Farms

Traditionally, crop and livestock farms have been viewed as producing outputs primarily from on-farm resources. The pattern of material movement (Figure 3) is significantly different from a modern cash-crop farm.

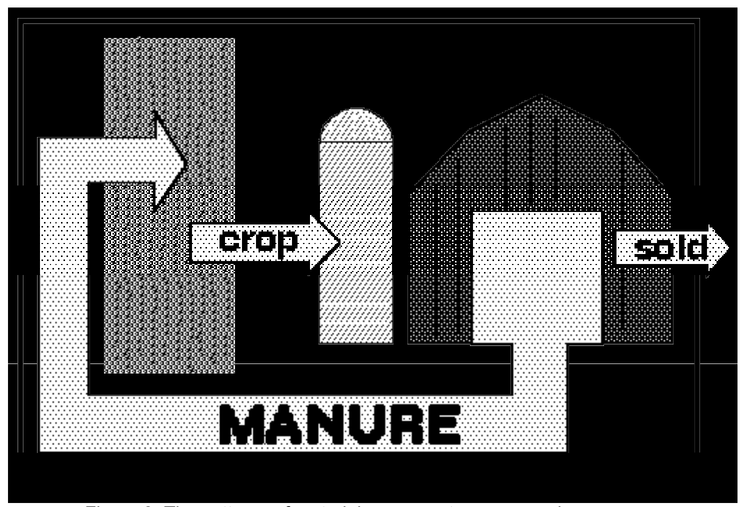


Figure 3. The patterns of material movement as managed on a "traditional" crop and livestock farm.

Plant nutrients contained in crops produced as feed for the animals are returned to the farm fields in manure. The output of this farm is animals or animal products. Fewer nutrients will be returned to the fields in the manure than were harvested in the crop due to the sale of the animal products and nutrient losses in manure handling. So, the efficient return of nutrients to the fields is critical to maintain crop production on the farm. A farm such as this is unlikely to lose nutrients to the environment. Likewise, changes in management may not be needed to protect the environment, because there is a direct benefit to the farmer from minimizing nutrient loss by efficiently utilizing the nutrients.

The ready availability of fertilizers since the 1950s meant that losses of plant nutrients in animal production and manure handling from a traditional "self-sufficient" farm could be offset (Figure 4). Not only could fertilizer offset the losses of nutrients from the farm due to the animal outputs and handling losses, it could build soil fertility to achieve potential crop productivity**.** This increase in crop yield is the familiar nutrient response to fertilization that was so important to the widespread adoption of fertilizer by farmers.

Neither crop production or fertilizer use are directly connected to the output of these crop and livestock farms. The marketing of animals or animal products such as milk depends on the animal husbandry skills of the farmer, not just success in crop production. Because of this, the decisions about plant nutrient use in the fields are not as sensitive to the economic or agronomic criteria of crop production as on the modern cash-crop farm.

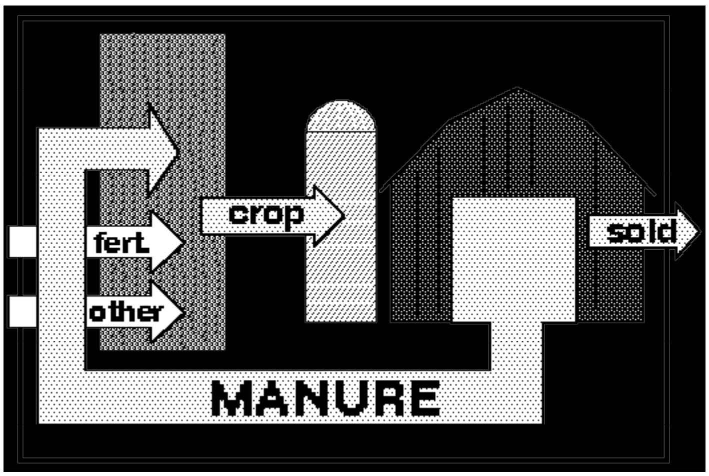



Figure 4. The patterns of material movement as managed on a “traditional” crop and livestock farm that is supplemented by off-farm fertilizers.

## Modern Crop and Livestock Farms

The feasibility of supplementing on-farm crop production with off-farm feeds and other inputs for animal production also came about with abundant and inexpensive fertilizer (Figure 5).

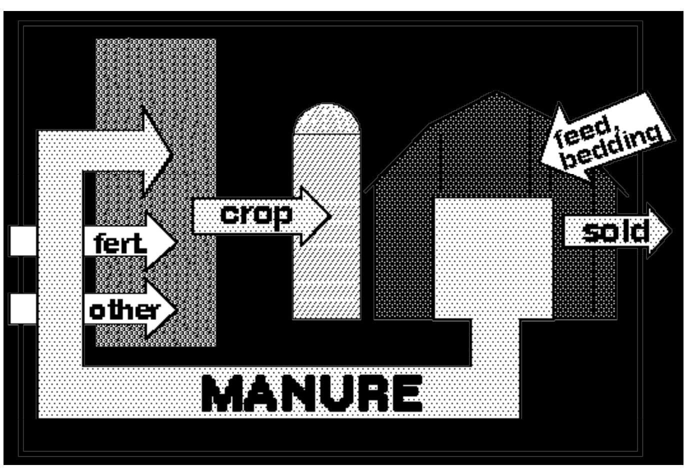



Figure 5. The patterns of material movement as managed on a "traditional" crop and livestock farm that is supplemented by off-farm fertilizers.

Off-farms feeds can either be produced on another nearby farm and transported to the farm where the animals are housed, or be purchased commercially from a distant farm through a feed company and delivered to the farm. The key factor is that **the manure produced by the animals is no longer spread on all the fields where the crops were produced.** Accounting for all sources of plant nutrients being applied to fields on the modern crop and livestock farm becomes an important management activity to protect the environment from negative impacts of nutrient over-application.

Today, intensive animal production supported by off-farm feed is possible. This changes the amounts of nutrients flowing to, from and within the farms. More manure in limited areas can result. The distance and amount of manure to be hauled can increase substantially to spread the nutrients uniformly over potentially suitable crop areas. Also, since ruminant animals often spend part of their time outside of buildings, the larger number of animals in barnyards and holding areas can result in the areas around farmsteads being degraded by the increased animal traffic and becoming sources of nutrient losses from the farm directly to the environment.

The concentration of animals on farms is most intense for non-ruminant animals, such as hogs and poultry. Most, if not all, of the feed necessary for these animals can be economically transported to where the animals are housed. Even though these farms may produce some crops for off-farm sale, the land areas involved in crop production can be quite limited since the management focus is on animal production (Figure 6).

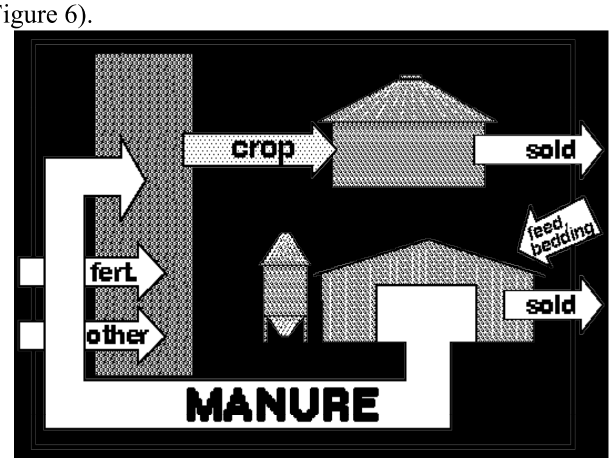



Figure 6. The patterns of material movement as managed on a modern crop and livestock on a farm with primarily non-ruminant animals.

Because of the small land area on these farms, field-based agronomic practices may be of limited effectiveness in treating the total quantity of manure. It is unlikely that plant nutrient management to protect environmental quality can be accomplished solely on the farm where the livestock or poultry are housed. Successful management of nutrients to protect the environment will depend on support from off-farm people and organizations. Neighbors with land for manure application could cooperate by providing land for manure distribution. Off-farm organizations may deal with manure hauling to locations where the manure can be used directly or transformed into another product such as compost.

## PLANT NUTRIENT MANAGEMENT OPTION SELECTION

Since nutrient management is a continuous process that is part of many farm operations, the decisions in the process and the level of nutrient management assistance that will be required will depend on the farmer and the organization of the farm. To aid nutrient management options selection, farms can be classified into management categories (Figure 7). Classification categories are based on nitrogen as the most important nutrient for nutrient management to protect environmental quality.

This is a simplified classification. Questions about individual farm classification should be resolved with more comprehensive, specific information. This classification is not intended as the basis for regulatory action, but demonstrates the implications of different nutrient management situations for nutrient management assistance. Individual farms in each category will not necessarily fit all the characteristics described for the category. When there is inadequate information available, a Category 2 classification can be assumed. Since agriculture is changing rapidly, farm classifications may change with time. Therefore, nutrient management status will need to be evaluated periodically.

**FARM CATEGORY**

| Nitrogen fertilizer on corn (lb/A) | | | |
|---|---|---|---|
| >150 | 2 | 3 | 3 |
| 50 to 150 | 1 | 2 | 3 |
| <50 | 1 | 2 | 3 |
| External feed (% total) | <50 | 50 to 80 | >80 |
| Animal density (AU/A manured) | <1.25 | 1.25 to 2.25 | >2.25 |

Figure 7. A farm classification when environmental quality protection is based on the potential for available soil nitrogen balance.

***Category 1*** **-** The manure available on these farms is generally not adequate to meet total crop nutrient needs and the purchased nutrients are within balance. An initial assessment of the current nutrient management practices can be adequate to confirm that environmental protection criteria are being met. A well planned nutrient management program on these farms emphasizing economic and agronomic efficiency could benefit the farmer. Practices designed to maximize nutrient efficiency will be emphasized.

***Category 2*** **-** The manure available on these farms could meet a significant part, if not all, of the nutrient requirements for crop production. Nutrient management changes on these farms may offer potential environmental benefits, but the economic impact may be either positive or negative depending upon the situation. It is very likely that intensive management assistance will be needed on these farms to adequately implement the nutrient management plan for crop production and environmental protection. The financial or management resources required to balance all nutrient sources and utilization may be only partially offset by reductions in fertilizer purchases. Practices which maximize the safe utilization of manure, rather than nutrient efficiency, will be emphasized.

***Category 3*** **-** The manure on these farms will generally exceed the nutrient requirements for crop production. It is unlikely that there is any way that all of the manure can be safely utilized on these farms. Nutrient management programming will most likely result in environmental benefits as excesses on the farm are reduced. Only part of the nutrient management program will be field-based. A significant component of nutrient management will involve off-farm cooperation for acceptable off-farm uses of the excess manure. Additional cost will be involved when implementing environmentally-sensitive nutrient management programming on these farms.

Typical characteristics of farms in each category are summarized in more detail in Table 1. The characteristics reflect the nutrient flow based on the farm organizational pattern and the amount of land commonly involved in these types of operations in Pennsylvania. Possible management considerations for the various categories of farms are listed in Table 2. These considerations can be included in the nutrient management decision-making process in order to adapt nutrient management to specific conditions on particular farms. Estimates of non-point source pollution potential are based on interpretations of the fertilizer use and manure nutrients that would produced. However, these descriptions are made to suggest the importance of considering the implications of farm management for environmental protection, not to assign responsibility for pollution to these farms.

Based on this farm-level classification, an appropriate approach for nutrient management on a farm can be developed. More detailed evaluation of fields and practices may be necessary to identify specific management options for each individual situation. The following section provides a detailed discussion of management options when field application of manure is the appropriate nutrient management tactic. This discussion will provide the basis for developing a field by field nutrient management plan.

Table 1. Characteristics of farms based on an assessment of the pattern of farm material flow with available soil nitrogen balance as the performance criterion.

| | Farm Category | | |
|---|---|---|---|
| **Assessment Criterion** | **1** | **2** | **3** |
| **Animal density**<br>(Animal units/ acre routinely manured) | Low<br>(<1.25/A) | Medium to high<br>(1.25-2.25/A) | Very high<br>(>2.25/A) |
| **Feed source**<br>(% Off-farm)* | On-farm<br>(<50%) | Combination<br>(50-80%) | Off-farm<br>(>80%) |
| **Nitrogen fertilizer use**<br>(lb/A on corn) | Low to moderate<br>(<50 to 150) | Low to high<br>(<50 to >150) | Low to high<br>(<50 to >150) |

*Feed purchased or grown on land that is not routinely manured.

Table 2. Management considerations for environmental quality protection for farms based on an assessment of the pattern of farm material flow with available soil nitrogen balance as the performance criterion.

| | Farm Category | | |
|---|---|---|---|
| **Management Consideration** | **1** | **2** | **3** |
| **Land for manure spreading** | Adequate | Limited | Inadequate |
| **Manure nutrient balance** | Deficit | Balanced | Excess |
| **Non-point source pollution potential** | Low | Low to High | Very high |
| **Assistance Required for:** | | | |
| **Field-by-field nutrient management planning** | Low to moderate | Moderate to high | Low |
| **Nutrient management implementation** | Low to moderate | Moderate to high | High |
| **Source of nutrient management options** | On-farm | On-farm | Off-farm |
| **Manure management strategy** | On-farm efficiency | On-farm safe utilization | Off-farm excess distribution |
| **Economics of Manure Management** | + | **+ or -** | **-** |

# FIELD APPLICATION OF MANURE

In order to optimize crop yields and protect the environment, each farmer planning to use animal manure on fields should develop and follow a written plan for managing manure. The written plan details how all nutrients will be managed for agronomic crop production and environmental protection. It takes into account nutrient needs throughout the crop rotation, realistic expected crop yields, liming requirements, existing soil nutrient levels, and timing, placement, amounts of additional nutrients applied to the soil and site limitations based on potential environmental impact. Information required to develop these plans will vary among farms. It will likely include: crop acreage determination, crop field histories, measured harvest or crop yield checks, livestock or poultry numbers and average weights, amount and kind of manure applied per acre, amount of purchased fertilizer applied per acre, soil testing and analysis, animal manure testing and analysis, and manure spreader calibration. The plan should be reviewed annually and updated as necessary to reflect new information and conditions as determined by an assessment of the farm nutrient status and implementation of the plan.

## Behavior of Nutrients in the Soil

Under normal conditions, nitrogen (N), phosphorus (P) and potassium (K) will move through cycles on a farm. They will go from a feed crop, to the animals, to the soil, and back again to another crop. As nutrients move through the farm system they undergo biochemical processes which affect their retention, use and loss. When the cycles are disturbed, the nutrients may be lost from the system. Following is a brief discussion of the behavior of N, P and K in the soil.

### Nitrogen

Of the three nutrients, nitrogen (N) has the most complex behavior. A diagram of nitrogen behavior is pictured in Figure 8.

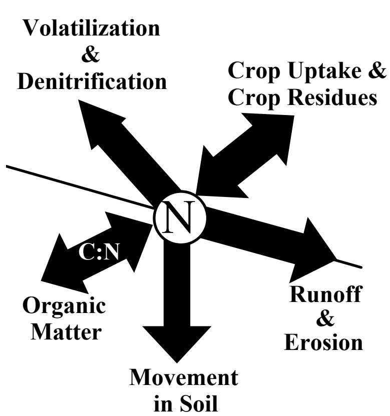



Figure 8. Summary of Nitrogen Behavior in Soil

In soil, organic nitrogen is broken down, or mineralized, into ammonium-nitrogen ($NH_4^+$), the form of nitrogen contained in ammonium fertilizers. Ammonium-nitrogen may be retained in the soil as an exchangeable cation and taken up by crops. Ammonium-nitrogen can also be converted to ammonia gas ($NH_3$) and lost by volatilization. This process occurs readily with urea nitrogen either from fertilizer or manure. Soil bacteria can convert the ammonium-nitrogen to nitrate-nitrogen ($NO_3^-$). This is the major form of nitrogen taken up by plants. Nitrates, because they are readily dissolved in water and are not adsorbed to the soil, can be lost to surface or groundwater. This loss is called leaching and is most likely to occur in well-drained soils. It is a significant source of surface and groundwater pollution. Nitrates can be changed to nitrogen gases ($N_2$ and $N_2O$). This process, called denitrification, occurs when oxygen is limited in soils because they are saturated with water. It is caused by anaerobic microbes that use the oxygen present in the nitrate, and in the process, convert the nitrate-nitrogen into nitrogen gases that are lost to the atmosphere. Manure provides an excellent energy and nitrate source for the microbes, and denitrification occurs rapidly soon after soil is saturated with water and normal oxygen is no longer available to the microbes. Denitrification is most common in heavy, poorly drained soils, but will occur in any soil that becomes saturated with water. Unlike nitrate-nitrogen, organic nitrogen and ammonium-nitrogen are both relatively immobile compounds, but they can be lost when soil is eroded.

Like higher plants microbes require nitrogen for growth, thus they compete with plants for the supply of mineral nitrogen in the soil. In this process, called immobilization, nitrogen is assimilated into soil organic matter by the microbes. The amount of immobilization that occurs depends on the relative amount of energy and nitrogen available to the microbes. If there is a large amount of energy in the form of organic carbon available in the soil, microbial populations will increase and so will the demand for nitrogen. This process is especially important when an organic material is added to the soil. If the added material has a relatively high amount nitrogen relative to its carbon content (a low carbon to nitrogen ratio), the microbes will be able to get adequate nitrogen to meet their demands as they breakdown the carbon. However, if the added material has a high amount of carbon relative to its nitrogen content (a high carbon to nitrogen ratio), there will not be enough nitrogen from the material to support the microbes. In this situation the microbes will utilize mineral nitrogen already in the soil and thus compete with the crop for the available nitrogen. If a large amount of high carbon, low nitrogen material is added to a soil this can result in a severe nitrogen deficiency in the crop. Generally materials with a carbon to nitrogen ratio (C:N) less than 20 will result in a net release of mineral nitrogen. Materials with a C:N ratio greater than 30 will usually result in net immobilization of N. Between 20 and 30 there will be little net change in mineral nitrogen in the soil. Examples of typical carbon to nitrogen ratios are given in Table 3. Note from Table 3 that manure itself has a relatively low C:N ratio and thus should result in release of available nitrogen. Nitrogen tie-up by immobilization is a temporary process. As the carbon source is depleted, the microbes will die and the nitrogen they have assimilated will be released in mineral form and become available in time for most crops to effectively utilize it. A common practical concern with immobilization is the effect of bedding in the manure. Note that most of the materials commonly used for bedding have a high C:N ratio. In most cases this is not a significant problem because the amount of bedding is small compared to the amount of manure and thus the C:N ratio of the combined manure and bedding will be relatively low. In some cases where there is excess mineral nitrogen in the soil, high rates of a high C:N ratio material have been added to sequester some of this excess nitrogen and then release it slowly over time to improve the utilization of the nitrogen by plants. This technique should only be considered in a remedial program to deal with a high nitrogen situation. Because of the temporary nature of the immobilization, it should not be considered as a management option to allow excess nitrogen to be applied in the first place.

Table 3. Typical carbon to nitrogen ratios for some common organic materials.

| Source | C:N Ratio |
|---|---|
| Soil | 10:1 |
| Fresh legume residue | 15:1 |
| Manure | 20:1 |
| Fresh non-legume residue | 30:1 |
| Corn stover | 60:1 |
| Straw | 80:1 |
| Sawdust | >200:1 |

Since most of the reactions of nitrogen in the soil are microbial they are very sensitive to environmental conditions such as moisture and temperature, i.e., the weather. Under saturated or air-dry conditions most microbial activity is limited. Likewise at temperatures below 50 degrees Fahrenheit or above 100 degrees Fahrenheit activity is also limited. Our inability to predict the weather is a major factor in our difficulties in predicting nitrogen behavior in the soil and thus making nitrogen management recommendations and determinations about the fate of nitrogen.

## Phosphorus

The general behavior of phosphorus is illustrated in Figure 9. In the soil, phosphorus is the least mobile of the macro nutrients. Especially under very acidic or very alkaline conditions, phosphorus may become fixed in insoluble compounds with iron and aluminum or calcium, respectively. This fixation reduces the amount of phosphorus available to plants and also allows phosphorus to build up in the soil. This buildup could have detrimental effects on plant growth such as phosphorus induced zinc deficiency. Fortunately, this is rarely a problem in soils where the high levels of phosphorus come from manure because the manure also supplies zinc. Where high levels of phosphorus come strictly from fertilizer however this can be a problem. Soil pH is an important management factor for phosphorus availability to crops. Maintaining soil pH between six and seven will usually result in optimum phosphorus availability.

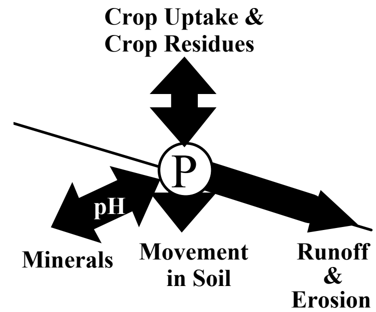



Figure 9. Summary of Phosphorus Behavior in Soil

Because the soluble forms of phosphorus are rapidly converted to insoluble forms, phosphorus is not generally leached from the soil. However, phosphorus, especially in soils with high phosphorus levels or freshly fertilized or manured soils, particularly on steep slopes, may be lost due to erosion and runoff. The phosphorus carried into surface waters attached to soil that is eroded can eventually dissolve and can be a significant source of water pollution. Properly designed, installed and maintained soil and water conservation practices are critical for minimizing phosphorus losses associated with erosion. Although phosphorus is not very soluble, when it is present at high levels in the soil, especially at the surface where it is in contact with runoff water, loss of soluble phosphorous is possible. Thus phosphorus loss can occur even if there is little or no erosion. The main characteristics of a site that should be evaluated to determine the potential for phosphorus loss include: soil erosion of the site, water runoff at the site, soil test phosphorus level, phosphorus fertilizer rate and method of fertilizer application, organic phosphorus application rate, method of application and proximity to a vulnerable water body. All of these factors must be integrated to evaluate a site for phosphorus loss. For example, a higher soil test level or application rate of phosphorus could likely be tolerated with little potential for loss on a site with little erosion or runoff. Conversely, on a site with a high erosion and/or runoff potential, extreme care would be required in planning and implementing phosphorus applications.

## Potassium

The general behavior of potassium is illustrated in Figure 10. Potassium is intermediate in mobility among the macro nutrients. Being a cation in the soil, potassium is held in available form on the soil cation exchange capacity (CEC). Thus, it accumulates in the soil, which is generally desirable because it helps supply plant needs. Like phosphorus, however, potassium can accumulate to excessive levels and have detrimental effects on plant growth. Small amounts of potassium may be leached from soil, especially sandy soil, but it is not considered a pollution problem. The main loss mechanism for potassium is through soil erosion. As the soil clay, which is the site of the soil CEC, is eroded away the potassium is lost with the sediment.

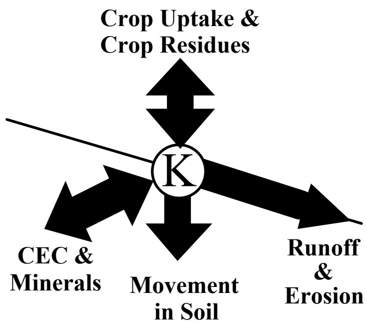



Figure 10. Summary of Potassium Behavior in Soil

## PROPERTIES OF MANURE

### Manure Nutrient Analysis

The amount of manure available for field application and the nutrients in that manure varies with the type and management of the animal; the animal's age, ration, and feed consumption; and the way the manure is handled prior to and during field application. Table 4 lists the average daily manure production for various livestock and the average amounts of nutrients in the manure. The extent of nitrogen losses as a result of various manure handling and storage systems prior to field application are accounted for in the nutrient values in Table 4. Table 4 also lists the average amounts of nutrients in paunch (digestive tract) manure, which is the material removed from the stomachs of animals being slaughtered. It is considered acceptable for agricultural use provided it is free of flesh, fat and blood.

Table 4. Estimates of manure production and of chemical and physical characteristics for stored manure.

| **Animal** | **Animal size (lb)** | **Daily manure production per 1,000 lb live weight (lb)** | **(cu ft)** | **(gal)** | **Dry matter (percent)** | **Approx. total nutrient content[a] (lb/ton** **N** | **$P_2O5$** | **$K_2O$** |
|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 150-1500 | 82 | 1.4 | 10 | 13 | 10 | 4 | 8 |
| Dairy cattle - liquid | | - | - | - | - | 28 | 13 | 25[b] |
| Veal | 100-350 | 63 | 1.0 | 7.5 | 1.6 | 8.0 | 2.4 | 10.7 |
| Beef cattle | 400-1400 | 60 | 1 | 7.5 | 12 | 11 | 7 | 10 |
| Paunch | - | - | - | - | 28 | 10 | 5 | 1 |
| Sheep | 100 | 40 | 0.6 | 4.6 | 25 | 23 | 8 | 20 |
| Horse | 1000 | 45 | 0.7 | 5.6 | 20 | 12 | 5 | 9 |
| Aquaculture/Fish[c] | 0.1-1.0 | 9 | _ | _ | 6.5 | 66 | 82 | 9 |
| Swine (Liquid) | | | | | | | - - - lb/1000 gal - - - | |
| Gestating sow | 275 | 27 | 0.5 | 4.0 | 9 | 25 | 10 | 17 |
| Sow & 8 pigs | 375 | 106 | 1.4 | 10.6 | 10 | 40 | 13 | 13 |
| Grower Pigs | 35-200 | 63 | 1.1 | 7.5 | 10 | 52 | 23 | 18 |
| Anaerobic Lagoon | | | | | | | | |
| Supernatant | - | - | - | - | .25 | 2.9 | 0.6 | 3.2 |
| Sludge | - | - | - | - | 7.6 | 25 | 23 | 63 |
| Poultry | | | | | | | | |

| | | Calculate manure production using one or the other of the following approaches:[2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Calculations based on average weight | | | Calculations based on final weight | | | | | | |
| | Typical Production period (days) | Average wt (lb) | Avg. manure prod. per day[d] (lb/1000 lb average wt) | Manure prod. per period (lb/1000 lb average wt) | Final wt (lb) | Avg. manure prod. per day[d] (lb/1000 lb final wt) | Manure prod. per period (lb/1000 lb final wt) | Manure % dry matter | N | $P_2O_5$ (lb/T) | $K_2O$ |
| Layer | 364 | 3.3 | 26.2 | 9,537 | 3.7 | 23.4 | 8,535 | 41 | 37 | 55 | 31 |
| Pullet | 126 | 1.5 | 48.4 | 6,108 | 2.9 | 24.2 | 3,054 | 35 | 43 | 46 | 26 |
| Light Broiler | 44 | 2.2 | 22.2 | 977 | 4.4 | 11.1 | 488 | 34 | 79 | 62 | 42 |
| Heavy Broiler | 57 | 2.9 | 19.9 | 1,134 | 5.9 | 9.8 | 559 | 25 | 66 | 63 | 47 |
| Turkey (tom) | 123 | 14.3 | 12.6 | 1,554 | 28.6 | 6.3 | 777 | 40 | 52 | 76 | 42 |
| Turkey (hen) | 88 | 7.4 | 11.2 | 990 | 14.7 | 5.6 | 495 | 35 | 73 | 88 | 46 |

Sources: The Pennsylvania State University, U.S.D.A. Natural Resources Conservation Service, University of Maryland

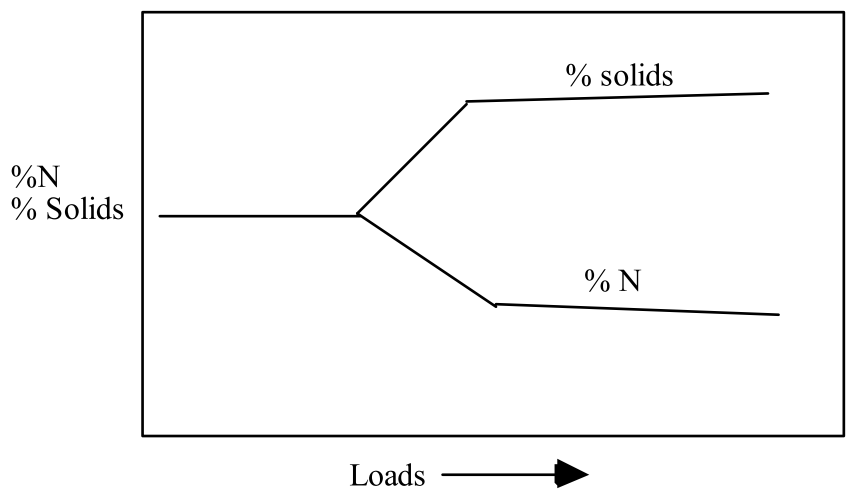
[a] Nutrient content accounts for typical losses in storage and handling, but does not include adjustments for dilution. Use this table for daily spreading also.

[b] Analysis in lbs. /1000 gal. for reference

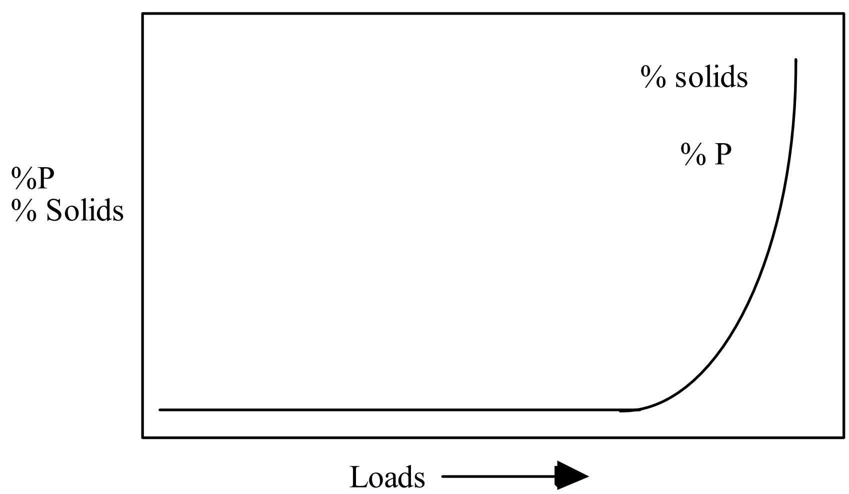
[c] Dewatered - Fish wastes are excreted into water, thus the manure has a high moisture content. Waste in this form can easily be sprayed onto agricultural land. If the waste is dewatered and dried it can be applied in the same manner as any other dry manure.

[d] For poultry manure the manure production can be estimated either based on average weight of growing animals. This is the method used to calculate AEUs under the PA Nutrient Management Act . Or you can calculate manure production for poultry based on the final weight of the birds. The final weight is a more well known number than the average weight. Both methods are valid, use the one that is most convenient.

Data from the Extension Manure Analysis program at Penn State indicate that actual manure characteristics can easily range almost 100 percent above or below the values listed in Table 4, and the volume that a handling system must accommodate may be much larger due to the addition of water and bedding. Because the figures listed in the table are approximate, each livestock farm should have its manure analyzed, at least once for each manure group, and following any change in feed or ration. In a storage where the manure cannot be completely homogenized separate samples should be taken as differences in the manure are observed. Ideally a storage, especially a new storage, should be subject to at least one intensive sampling program to characterize the variation in analysis within that storage and handling system. An example of the variation in % solids and nitrogen analysis of dairy manure as a storage is unloaded is shown in figure 11a. Note the abrupt change in both % solids and % nitrogen that occurs when the crust, that typically forms on a liquid dairy storage, breaks up. In a liquid swine storage (Figure 11b) the solids tend to settle out on the bottom of the storage. Since much of the phosphorus in swine manure is in the solids the liquid that is pumped out of the storage early in the emptying process is low in phosphorus. However, when the solids in the bottom of the storage are removed the phosphorus analysis increases dramatically.




a. Dairy Manure Nitrogen.




b. Swine Manure Phosphorus

Figure 11. Examples of the variation in manure analysis as a manure storage is unloaded.

It is important to know the composition of the manure at the time it is spread on the fields. Although animals can be studied and their manure production linked to the production of similar animals on a particular farm, manure as it is spread on fields is subject to many management actions that influence its composition. Therefore, good sampling procedures at the time of spreading are necessary to accurately manage the nutrients in each situation. Manure analysis is available from many commercial testing laboratories. Contact the nearest Penn State Cooperative Extension office for a list of manure analysis labs.

### Collecting Manure Samples for Nutrient Management

Manure sampling procedures will depend on the level of management of other components of the manure management process. If the rest of the process is closely managed, including manure spreader calibration, good yield measurements, and accurate records of manure applications to the fields, then more sophisticated sampling procedures will be justified. If approximations are used in other aspects of manure management, then very simple manure sampling procedures will be adequate. Manure sampling procedures can be changed as the overall level of nutrient management sophistication increases. Contact the nearest cooperative extension agent, conservation district or NRCS office for assistance in determining the proper sampling procedure.

### Availability of Manure Nitrogen

The availability of nitrogen in manure varies depending upon whether the nitrogen is contained in the urine or in the feces (see Figure 12). The nitrogen in urine breaks down and becomes available very rapidly. In urine, the nitrogen is in the form of urea, the same compound that makes up urea fertilizers. Urea is unstable, and as the manure dries and the urea breaks down into ammonium nitrogen on a barn floor, in a manure pile or in the soil, it creates the high pH, alkaline conditions, that favor ammonia production. If the urea is exposed to the air as it dries, the nitrogen in the ammonia gas will be lost to the air. When properly handled and incorporated into soil, however, the unstable nitrogen in manure is as effective as commercial fertilizers for providing nitrogen to crops.

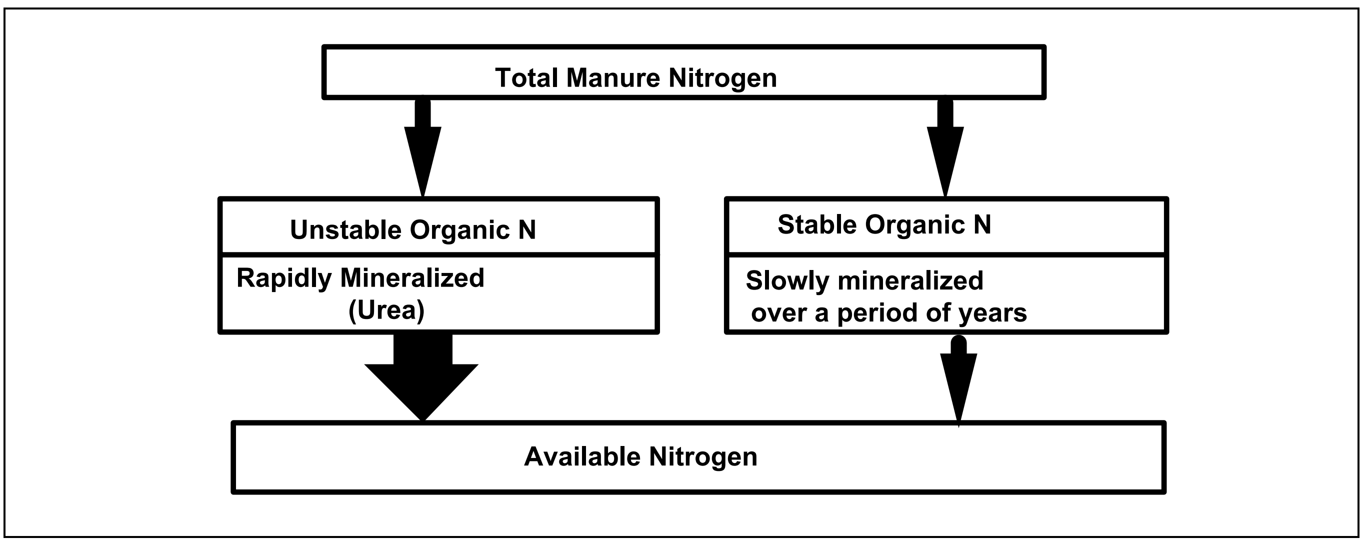



Figure 12. The relative stability of nitrogen in urine and feces

Nitrogen availability factors for estimating the available nitrogen in manure are given in Table 5. Note that the factors are different for poultry manure. The appropriate factor in Table 5 is multiplied times the total manure nitrogen from the manure analysis to estimate the nitrogen available in the year the manure is spread.

Table 5. Manure nitrogen remaining available to crops as affected by field management.

| Time of application and incorporation | N availability factor: Poultry manure | N availability factor: Other manure |
|---|---|---|
| Manure applied for CORN or SUMMER ANNUALS in the coming year: | | |
| Applied in the spring | | |
| incorporation the same day | 0.75 | 0.50 |
| incorporation within 1 day | 0.50 | 0.40 |
| incorporation within 2-4 days | 0.45 | 0.35 |
| incorporation within 5-6 days | 0.30 | 0.30 |
| incorporation after 7 days or no incorporation | 0.15 | 0.20 |
| Applied previous fall or winter with no cover crop | 0.15 | 0.20 |
| Applied the previous fall or winter with cover crop harvested for silage[a] | 0.15 | 0.20 |
| Applied previous fall or winter with a cover crop not harvested[b] | 0.50 | 0.40 |
| Applied previous fall or winter to a perennial forage crop[b] | 0.50 | 0.40 |
| Manure applied for SMALL GRAINS: | | |
| Applied in spring or previous fall or winter | 0.50 | 0.40 |

[a] These low availability factors in this category do not indicate a net loss of N. A large amount of N is removed in the cover crop silage. This N will be recycled in the manure when the silage is fed.
[b] Assumes that the weather is cold and that there is frequent enough rain to incorporate the manure

For example, if a sample of poultry manure contains 60 pounds total nitrogen per ton and it is incorporated within 4 days the available nitrogen per ton of manure would be 27 pounds nitrogen per ton, calculated as follows:

<u>Example: Calculating N available from manure based on total N and time to incorporation</u>

60 lbs. N/ton x .45 (availability factor for 2-4 days incorporation) = 27 lbs. avail. N/ton

The organic nitrogen in the solid fraction of the manure decomposes into ammonium nitrogen more slowly, so the nitrogen is more likely to be used by the crop before it is lost. In soil, the decomposition is greatest during the first year after manure is applied. Residual nitrogen also becomes available for plants during succeeding years. Factors for estimating the availability of this residual nitrogen are given in Table 6. The appropriate factor from Table 6 is multiplied by the amount of total nitrogen typically applied annually to the field. This provides an estimate of the amount of residual nitrogen that will be available in the current year.

Table 6. Factors for estimating residual manure nitrogen.

| Frequency | Residual N Availability Factor Poultry Manure | Residual N Availability Factor Other Manure |
|---|---|---|
| Rarely received manure in the past | 0 | 0 |
| Frequently received manure (4-8 out of 10 yrs) | 0.07 | 0.15 |
| Continuously received manure (>8 out of 10 yrs) | 0.12 | 0.25 |

For example, if a field typically received 20 tons/acre of dairy manure containing 10 lbs. of nitrogen per ton, five out of the last ten years ("Frequent" category in Table 6) the residual nitrogen from this history of manure applications would be 30 lbs. N/acre, calculated as follows:

Example: Calculating residual N based on typical rate and field manure history

20 ton/acre x 10 lbs. N/ton = 200 lbs. total N /acre (typical annual manure N)

200 lbs. N/acre x 0.15 (factor for history of frequent applications) = 30 lbs. N/acre

This would be deducted from the nitrogen recommendation for the crop before the current manure or fertilizer rate is calculated. An example of the calculation of appropriate manure application rate using the above method is given later in the section on "Manure Application Rates".

The approach outlined above is good for “typical” manure. However, when the manure has been handled atypically or it has been treated or composted or for less common types of manure or biosolids a better estimate of available nitrogen is possible if the manure is also analyzed for ammonium nitrogen in addition to total nitrogen. With this addition of ammonium nitrogen analysis the method outlined in Figure 13 is used to calculate available nitrogen. In this approach the availability of the ammonium nitrogen is adjusted for volatilization losses based on the time to incorporation. The organic nitrogen, which is the difference between the total nitrogen and the ammonium nitrogen, is used to estimate the current release of organic nitrogen and the residual nitrogen. An example of the calculation of appropriate manure application rate using this method is given later in the section on "Manure Application Rates".

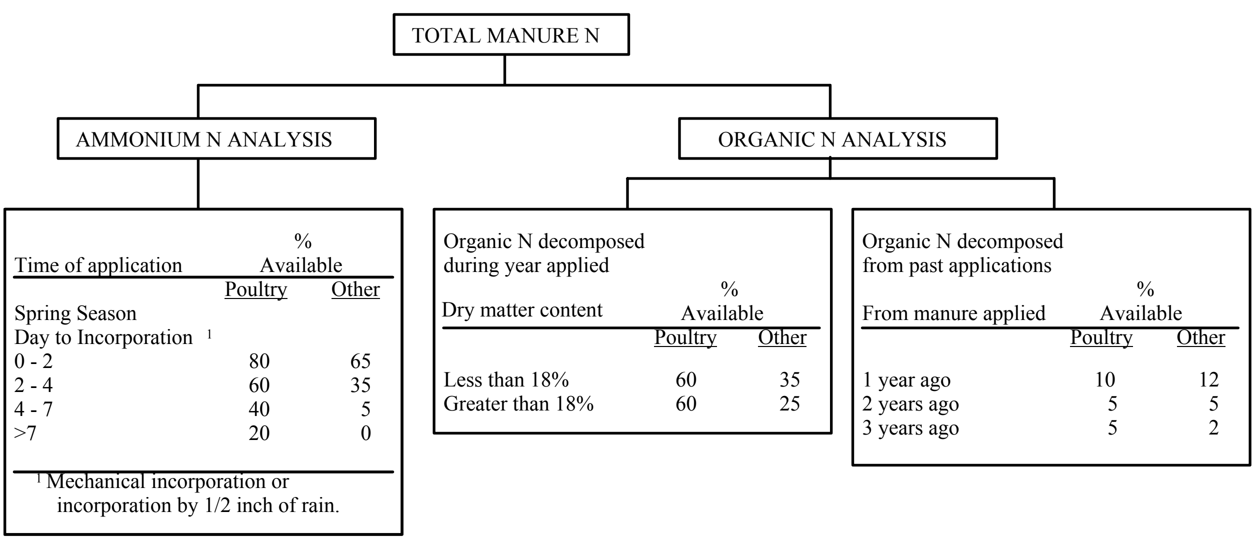



Figure 13. Factors for calculating manure nitrogen availability based on time of application, incorporation, field history, and manure analysis with ammonium and organic nitrogen fractions. Recommended for all manures but required for atypical or treated manures. (Adapted from: Klausner and Bouldin, Cornell University, & Sims, University of Delaware)

## Availability of Manure Phosphorus

In manure, phosphorus is present chiefly in feces in both insoluble organic and inorganic forms. Like nitrogen, organic phosphorus becomes soluble and available to plants when the organic matter is broken down. Over time, phosphorus from manure is as efficiently used by plants as phosphorus from broadcast fertilizer. Thus, for building soil phosphorus levels, manure phosphorus can be substituted on a one for one basis for broadcast fertilizer phosphorus in meeting crop requirements. However, because it breaks down slowly, the phosphorus in manure is not a substitute for starter fertilizer where starter fertilizer is recommended.

## Availability of Manure Potassium

Manure potassium, chiefly present in the urine fraction of manure, is readily available and is equivalent to fertilizer potassium on a one-for-one basis and is thus available for plant growth in the year that it is applied.

## Recommended Manure Application Methods, Timing, and Rates

Certain farming practices will help prevent the loss of nutrients from manure and manured fields, thus reducing both fertilizer expenses and water pollution. One important way to conserve manure nitrogen, phosphorus and potassium is to reduce erosion and runoff from fields. This is one of the reasons why farmers are required to develop and implement a farm conservation plan. Conserving manure nitrogen also requires proper handling, storage, treatment and timing of manure applications, and incorporation of manure into the soil. Overall, the most crucial factors in preventing the loss of nutrients are the method and timing of field application.

## Application Methods

Manure should always be spread uniformly on fields at appropriate rates. Nutrient losses, pollution and odor are reduced if manure is spread as near as possible to the time when plants will use the nutrients and incorporated into the soil as soon as possible after it is spread.

*Surface Applied/Unincorporated Manure*
Manure applied to the surface without incorporation will lose available nitrogen through the volatilization of ammonia gas and runoff loss. Volatilization losses will increase with time, temperature, wind and low humidity. Surface applied manure will be less likely to volatilize during early spring, when temperatures are lower and rainfall may be more frequent; one half inch of soaking rainfall without significant runoff is comparable to incorporation of surface applied manure. Gentle rainfall increases the likelihood of ammonia being washed into the soil. However, intense rainfall increases the potential for water pollution from surface runoff. Generally, surface loss of nutrients and, to a lesser extent, volatilization losses will be reduced as the amount of bedding increases.

Surface losses of manure may also be related to land cover. Close growing crops such as hay, small grains and cover crops are most effective in reducing both surface losses and leaching, especially if the crop is actively growing. Also, high amounts of surface residue associated with conservation tillage (especially no-till) can indirectly reduce surface losses and may also help to retain some nutrients which are subject to leaching. However, if an excess of a mobile nutrient like nitrogen is applied, the increased infiltration and percolation associated with reduced runoff can result in increased leaching. Therefore, maintaining nutrient balance so that no excess nitrogen is applied, is especially critical.

The combination of manure applied on the surface and no-till farming requires consideration of the benefits of no-till versus the reduction of nitrogen available for crop utilization. This evaluation must be made specifically for each farm operation and requires integration of soil erosion considerations as well as factors relating to the surface application of manure. Currently livestock operations in Pennsylvania utilize no-till systems in livestock operations in which manure is utilized on a substantial part of the cropland.

*Incorporated Manure*
Incorporating manure into the soil, either by tillage, subsurface injection or rainfall increases the amount of manure nitrogen available for use by the crop as discussed earlier under the behavior of manure nitrogen. If the rate of application is adjusted to match available nitrogen to optimum crop utilization, then incorporation can reduce pollution potential. Table 5 relates nitrogen loss to time until incorporation.

Injection is probably the best method for incorporating liquid manure in reduced or no-till cropping systems because it causes less disturbance to the soil surface and leaves crop residues on the surface to act as a mulch. Injection requires a liquid manure spreader and equipment to deposit manure below the soil surface. To be effective, the openings made by the injectors must be closed over the manure after it is applied. In no-till systems spreaders must be equipped with injectors that do not significantly disturb the soil surface residues. It may be possible to inject manure in a growing row crop to supply nutrients nearer to the time when the crop needs them. Injection, while it may be the most effective method of subsurface application from a nutrient management standpoint, represents the largest investment in equipment for the farmer. Injecting manure also has practical difficulties. It is generally limited to liquid-manure handling systems that require the addition of significant amounts of water to the manure. This increases the amount of material to handle and apply. Injection is usually slower than broadcasting, requires more energy, and may not be practical on many shallow, stony soils in Pennsylvania. New technology is being developed that may enable shallow injection of liquid manure using a coulter system similar to a no-till drill may reduce the cost of injection, work on stony, shallow soils and maximize the retention of surface residue.

Rainfall can also incorporate manure in no-till systems. One half inch of soaking rainfall without significant runoff is comparable to incorporation of surface applied manure. There are, however, several important considerations when depending on rain to incorporate manure. As noted earlier under surface application, runoff can result in significant loss of nutrients from surface applied manure. A second consideration is that it is difficult to predict when it will rain, therefore determining the appropriate nitrogen availability to use in calculating the correct rate of application is subject to considerable error. For example, if one assumes that it isn't going to rain for seven days and applies manure based on the appropriate availability factor for seven days until incorporation, 20 percent available (Table 5), but it rains within one day, when the availability factor is 40 percent, there will be twice as much available nitrogen in the soil as was estimated. The excess could represent a significant environmental threat. This is a common error in calculating manure application rates, especially early in the spring when rain is fairly frequent. Generally in Pennsylvania in April when a large proportion of our manure is spread, it is unlikely to be rain free for seven days. Also, considering that you one should wait a day or so after a rain until the soil dries out so that manure can be spread, manure rates should be calculated with a shorter incorporation time such as two to four days during this time of the year. A similar consideration may be important at other times of the year.

Generally, because manure is often applied when the soil is not fit to till, manure application has been implicated as a major cause of soil compaction on many farms. Deep compaction from heavy axle loads may be very difficult to remediate and will likely take a long time to correct.

*Irrigation of Manure.*
Irrigation can be an economical and labor saving application method, especially where large volumes must be handled. Irrigation allows more flexibility in the application schedule, by permitting application of liquid and slurry manure during the growing season. A properly designed and operated irrigation system will provide uniform manure application, and will incorporate the ammonia nitrogen in the soil with the irrigation water. Irrigation of manure should be on vegetated ground, for two reasons: (1) vegetated soils have higher infiltration rates than bare soils, and (2) the nutrients can be utilized by the vegetation.

Irrigation of manure has the same types of surface water pollution potential as surface spreading, with the additional consideration of hydraulic loading. Surface and groundwater pollution potential can be greater with irrigation than with either surface or subsurface spreading depending on the volume and rate of liquid applied to the land. The same types of management considerations used for other application methods apply to irrigation, in addition to good water management. In addition to calculating proper application rates based on crop requirements and nutrient availability, the rates and total amount must be based on the soil hydraulic loading and infiltration capabilities.

The solids content of the manure, in terms of both total solids concentration and the type of solid material in the manure, is the major factor in determining if manure can be irrigated and what type of equipment to use. Manure with up to 4 percent solids content can be handled with conventional irrigation equipment. With solids content between four and twelve percent, chopper-agitator pumps are needed. For irrigating semi-solid manure, open impeller centrifugal and screw-type pumps are typically used with big gun sprinklers having 3/4 inch and larger nozzles. Bedding can make irrigation more difficult, since straw can clog nozzles, and sand can be abrasive to most irrigation system components. When manure solids and liquids are separated to facilitate irrigation, the C:N ratio of the liquid fraction will be low resulting in higher availability of the nitrogen in the irrigated manure. The method of estimating manure nitrogen availability shown in Figure 13 should be used for separated manure.

The irrigation system must be matched to the topography, cropping patterns on the farm, the nutrient and moisture needs of the crops, and the infiltration and water holding capacity of the soils. Stationary, hand moved and traveling irrigation equipment can be used, depending on the specific situation. The irrigation system must be designed specifically for the intended use, and all components must be compatible with that use and the available power source. The best way to assure a workable system is to purchase all of it at the same time from one supplier. Odors can be a problem when irrigating manure. Complaints can be minimized by selecting locations away from neighbors and heavily traveled roads, and avoiding weekends, holidays and days when the wind is blowing toward neighbors or the weather is hot and humid.

Grasses in grass/legume mixtures that are irrigated with manure must be cut and removed to allow new growth and to remove nutrients. Vegetation left to decompose on the surface will release nitrogen back to the soil resulting in no net removal of nitrogen. This nitrogen could convert to nitrate and leach into ground water. In addition to matching the application rate to the crop nutrient needs, irrigated manure must be applied in a manner that prevents runoff or deep percolation of the nutrients. The hydraulic loading will often control the amount of manure that can be applied at one time. The hydraulic loading must consider both the rate of application in inches per hour, and the total amount applied at one irrigation setting in inches. To avoid surface water pollution, the maximum application rate must be less than the infiltration rate of the soil. To avoid groundwater pollution, no more liquid should be applied than the amount necessary to fill the soil profile within the crop rooting depth to field capacity. Hydraulic loading can be calculated using the methods in standard irrigation references. The "Pennsylvania Irrigation Guide", prepared by the Natural Resources Conservation Service, is a good reference for crop rooting depths and recommended application rates, field capacity, and application amounts for various soil groupings. The effects of manure on infiltration should also be considered in designing a system. In the short term, manure solids may temporarily clog the soil pores and reduce infiltration. On a long term basis, application of manure increases the soil organic content, improves soil structure, and allows higher infiltration rates. To compensate for the short term effects, an infiltration rate less than published values should be used in design.

## Application Timing

The longer manure is in the soil before crops use its nutrients, the more those nutrients, especially nitrogen, can be lost through volatilization, denitrification, leaching and erosion. The season in which manure is applied will affect the nutrient availability for crops as follows:

*Spring*
Nutrients are best conserved by applying manure in the spring as close as possible to the time when plants can use the nutrients. Soil conditions that will allow manure application without causing compaction are an important consideration for spring manure application.

*Summer*
Summer application of manure is suitable for pure grass stands or to old grass-legume mixtures, summer annual grasses, small-grain stubble, non-crop fields where vegetation exists or pastures where nutrients are needed. However, if possible, manure should not be spread on young stands of legume forage, because legumes do not need nitrogen and the nitrogen may stimulate competitive grasses and may introduce weeds.

If manure must be applied to a forage legume, the legume can effectively utilize the nutrients from the manure, including nitrogen (See Table 10). However, care must be taken that the nutrients applied, especially nitrogen and phosphorus, do not exceed the crop requirements. If manure is applied at a rate based on utilizing the nitrogen from the manure, excess phosphorus will likely be applied. This can be a problem when attempting to balance phosphorus over a crop rotation containing manured and unmanured crops, as will be discussed in the following section on determining appropriate manure application rates. Thus it is best to use phosphorus to determine the limiting rate when applying manure to these forage legumes. Weed control is also important if manure is applied to alfalfa and care must be taken to not physically damage the stand with heavy manure spreaders or by applying too much manure and smothering the crop.

Liquid and Slurry manure can be irrigated on growing crops, but flushing of the leaf surfaces with clear water may be needed to avoid problems with leaf burn and impaired photosynthesis. Corn should not be irrigated with manure when the plants are very young or during silking.

*Fall*
Nitrogen loss from fall application of manure is generally greater than loss from spring application. If manure is incorporated immediately, the soil will stabilize some of the nutrients, especially at soil temperatures below 50 degrees Fahrenheit. In the fall, manure is best applied to fields that will be planted in winter grains or cover crops. The improved recovery of nitrogen when a cover crop is utilized is illustrated by the greater nitrogen availability factor for this practice in Table 5. If winter crops will not be planted, manure should be applied to fields containing vegetation or crop residues. Sod fields to be planted to corn the next spring would be acceptable, while fields where corn silage was removed and a cover crop was not planted would usually be unsuitable. Because of the long residence time before crop use and thus the greater vulnerability for loss, manure applications in the fall should be made as far away as possible from environmentally sensitive areas. For example, steep slopes and areas near bodies of water should be avoided if possible in the fall.

*Winter*
Winter application of manure is the least desirable, from both a nutrient utilization and a pollution point of view. The major problem is that frozen soil offers a relatively impervious surface that prevents rain and melting snow from carrying nutrients into the soil. The result is nutrient loss and pollution through runoff. If daily winter spreading is necessary, manure should be applied to fields having a vegetative cover or crop residue with the least runoff potential. It should be applied to distant or limited-access fields in early winter, then to nearer fields later in the season, when mud and snow make spreading more difficult. The use of conservation practices which reduce or slow runoff will help reduce the adverse effects of winter applied manure. All applications manure applications in the winter should be made as far away from environmentally sensitive areas as possible. For example, steep slopes and areas near to bodies of water should be avoided in the winter, if possible.

## Manure Management on Environmentally Sensitive Areas

The farmer should bear in mind that he is responsible for any pollution caused by the spreading of manure. Some special environmental considerations for field application of manure which are specified in the Nutrient Management Act regulations include:

1. Do not spread manure within 100 feet of an open sinkhole where surface water flow is toward the sinkhole, unless the manure is mechanically incorporated within 24 hours of application.

2. Do not spread manure within 100 feet of active private drinking water sources such as wells and springs where surface flow is toward the water source, unless the manure is mechanically incorporated within 24 hours of application.
3. Do not spread manure within 100 feet of an active public drinking water source, unless other state or federal laws or regulations require a greater isolation distance.
4. Do not spread manure within concentrated water flow areas in which vegetation is maintained, such as ditches, waterways, gullies and swales, during times when soil is frozen, snow covered or saturated.
5. Do not spread manure within concentrated water flow areas in which vegetation is not maintained, such as intermittent streams, gullies and ditches.
6. Do not spread manure within 100 feet of streams, springs, lakes, ponds, intakes to agricultural drainage systems (such as in-field catch basins, and pipe outlet terraces), or other types of surface water conveyance, where surface flow is toward the identified area when soil is frozen, snow covered or saturated.
7. Do not spread manure within 200 feet of streams, springs, lakes, ponds, intakes to agricultural drainage systems (such as in-field catch basins, and pipe outlet terraces), or other types of surface water conveyance, where surface flow is toward the identified area and where the slope is greater than eight percent as measured within the 200 feet, during times when soil is frozen, snow covered or saturated.

Otherwise, if it is necessary to spread manure on frozen ground, manure should be applied to fields having a vegetative cover or crop residue with the lowest runoff potential. It should be applied to distant or limited-access fields in early winter, then to nearer fields later in the season, when mud and snow make access and spreading more difficult. The use of conservation practices which reduce or slow runoff will help reduce the adverse effects of winter applied manure. On highly erodible land (HEL) as determined by NRCS or on any soils with high runoff potential, practices such as using a cover crop or crop residue management and as well as contour strip-cropping, contour farming, cropland terraces, diversions, grassed waterways and filter strips can effectively reduce the surface loss of soil and manure nutrients. If it is necessary to spread manure on soils subject to flooding, manure applications should be made only at times when flooding is least likely to occur.

However, this does not preclude the farmer operator from obligations covered by other state and federal laws, such as the Clean Streams Law. These isolation distances may not, by themselves, prevent surface water and groundwater pollution. Good judgement must be used in planning and implementing nutrient management plans. If not carefully managed, manure or any fertilizer can cause an unnecessary threat to both surface water and groundwater. Any nutrient management practices that cause pollution could result in penalties and damage costs.

## Manure Application in Relation to Soil Nutrient Levels and Crop Needs

Manure should be applied to fields at a rate which does not exceed the annual nitrogen needs of the crop or the phosphorus needs of the crop rotation. Supplying too few nutrients will, of course, decrease yields unless the manure nutrients are supplemented with fertilizer nutrients. Supplying an excess of nutrients is a waste of valuable resources, can result in pollution, and may even depress yields. Determining the rate at which nutrients, including manure, should be applied requires careful calculation of a crop's need, based on actual yield performance information and on the amount of residual nutrients already present in the soil.

*Soil Testing*
The rate at which manure should be applied depends on the amount of nutrients already present in the soil and available to the crop and on the actual requirements of the crop. Soil testing is an excellent method for estimating the fertility status of a soil and provides valuable information for developing a sound fertility management program. Because the fertility status of a soil cannot be determined visually, a good soil test is essential. The soil test is no better than the care given to taking samples. Follow the guidelines provided by your soil testing lab for taking soil samples.

Soil tests are essential for indicating the levels of available phosphorus and potassium in the soil. They will show where phosphorus and potassium are deficient and thus where applying manure will have a profitable effect on yields. Soil tests will also show where nutrients are present in excess of crop needs. The relationship between the soil test level and crop yield is usually represented as a diminishing response curve. As soil test levels increase from very low levels, the yield will increase until it reaches a "yield plateau" - the point at which yield no longer increases as soil test level increases. The optimum soil-test level lies just above that point. Eventually, if soil test levels continue to increase, there is the potential for yield reduction. Once the response curve has been determined by extensive field research in the area where the soil test will be used, the interpretation levels for the soil test can be established as follows:

*LOW:* A low soil test level indicates that the nutrient is probably deficient and that the deficiency will likely limit crop growth. There is a high probability of a profitable return from correcting a low level by adding fertilizer or manure. In fact, the greatest economic return per dollar invested in fertility is usually obtained through medium application rates to low-testing soils. However, the maximum profit per acre and the lowest cost per unit of crop produced is achieved as the rate is increased to near the level needed for maximum yield. The recommendation for a low testing soil is designed to gradually build up the nutrient level to optimum and to maintain it at that level.

*OPTIMUM:* An optimum soil test level indicates that the nutrient is probably adequate and will likely not limit crop growth in a typical growing season. There is a low probability of a profitable return from increasing the soil test level from optimum to high. The recommendation for an optimum-testing soil is designed to offset crop removal in order to maintain the nutrient in the optimum range. The crop nutrient removal per unit of yield used to calculate these maintenance recommendations is given in Table 7.

*HIGH:* A high soil test level indicates that the nutrient is more than adequate and will not limit crop growth. There is a very low probability of a profitable return from application of a nutrient to a high-testing soil. Any recommendation made for a high-testing soil is designed to offset crop removal in order to maintain the nutrient in the optimum range.

*EXCESSIVE:* An excessive soil test level indicates that the nutrient is greater than the crop needs and the requirement to maintain soil levels. Too much of a plant nutrient may cause a nutrient imbalance in the soil and, as a result, in the plant. While the excessive category is defined <u>only</u> in terms of crop needs and soil supply it has no direct relationship to environmental impact. However, a negative effect on environmental quality is more likely on soils with excessive soil test levels.

*Nitrogen Soil Testing:*
Estimating available nitrogen in the soil is much more difficult. A rough estimate of the amount of residual nitrogen available from previous manure applications can be made using the factors in Table 6 as discussed earlier in the section on behavior of manure nitrogen. Nitrogen supplied by previous legume crops (see Table 8), and any fertilizer applications must also be accounted for in estimating residual nitrogen. There has been considerable research activity recently on developing tests for nitrogen particularly for corn and winter grains. The ones that have been used appear to be most useful in implementing nutrient management plans because they are very good at confirming when applied manure nitrogen will be adequate to meet the needs of the corn crop. This removes some of the uncertainty associated with relying on manure nitrogen to grow the crop and replaces the perceived need for applying some insurance nitrogen.

Table 7. Phosphate, and potash removal from soil by various crops.

| | | Pounds removed per unit production | |
|---|---|---|---|
| **Crop** | **Units** | **$P_2O_5$** | **$K_2O$** |
| Corn, grain | bu | 0.4 | 0.3 |
| Corn, stover | ton | 8 | 37 |
| Corn, silage (65% Moist.) | ton | 5 | 11 |
| Sorghum, grain | bu | .6 | .8 |
| Sorghum, silage (65% Moist.) | ton | 3 | 10 |
| Soybeans, grain | bu | 1.0 | 1.4 |
| Soybean, residue | ton | 7 | 16 |
| Wheat, grain | bu | 0.5 | 0.3 |
| Wheat, straw | ton | 4 | 25 |
| Wheat, grain + straw | bu | 1 | 1.8 |
| Oats, grain | bu | 0.3 | 0.2 |
| Oat, straw | ton | 5 | 33 |
| Oats, grain + straw | bu | 0.9 | 1.5 |
| Barley, grain | bu | 0.4 | 0.3 |
| Barley, straw | ton | 5 | 31 |
| Barley, grain + straw | bu | 0.6 | 1.5 |
| Rye, grain | bu | 0.5 | 0.3 |
| Rye, straw | ton | 6 | 17 |
| Rye, grain + straw | bu | 0.8 | 1.0 |
| Alfalfa | ton[a] | 15 | 50 |
| Alfalfa-grass | ton[a] | 15 | 50 |
| Orchard grass | ton[a] | 17 | 63 |
| Brome grass | ton[a] | 13 | 51 |
| Tall fescue | ton[a] | 19 | 53 |
| Blue grass | ton[a] | 18 | 60 |
| Clover-grass | ton[a] | 15 | 40 |
| Trefoil | ton[a] | 15 | 40 |
| Timothy | ton[a] | 14 | 63 |
| Sorghum-Sudangrass | ton[a] | 15 | 60 |
| Sorghum-Sudangrass (65% Moist.) | ton | 7 | 7 |
| Small Grain Silage (55% Moist.) | ton | 4.5 | 27 |

Sources: Six sources listing nutrient removal for a given yield were averaged to estimate removal for a unit of production.

[a] Yields given as dry hay

Table 8. Residual nitrogen contributions from legumes for corn production.[1]

| Previous crop | % Stand | Soil Productivity Group[2] Group 1 | Groups 2 & 3 | Groups 4 & 5 |
|---|---|---|---|---|
| **Alfalfa** | | | Nitrogen Credit (lb/A) | |
| First year after alfalfa | | | | |
| | >50% stand | 120 | 110 | 80 |
| | 25%-49% stand | 80 | 70 | 60 |
| | <25% stand | 40 | 40 | 40 |
| Second year after alfalfa | | | | |
| | >50% stand | 60 | 60 | 60 |
| **Red clover and trefoil** | | | | |
| First year after clover or trefoil | | | | |
| | >50% stand | 90 | 80 | 60 |
| | 25%-49% stand | 60 | 60 | 50 |
| | <25% stand | 40 | 40 | 40 |
| **Soybeans** | | | | |
| First year after soybeans harvested for grain | | - - - - - - - - - - 1 lb N/bu soybeans - - - - - - - - | | |

[1] When a previous legume crop is checked on the Penn State Soil Test Information Sheet, the residual nitrogen for the first year after a legume is taken into account in the recommendation. This is noted on the soil test report, therefore, no further adjustment is necessary. There is no credit for the second year after a good stand of alfalfa taken into account in the recommendation.

[2] See table 2-1 in the Penn State Agronomy Guide for information on soil productivity groups

*Crop Nutrient Needs.*
The nutrient needs of a crop are determined by the expected yield. A crucial factor in setting realistic yield expectations is the yield potential of the soil. This is a function of soil depth and drainage independent of manure or fertilizer application. Expected yields should be adjusted to account for factors other than soil productivity, such as climatic conditions, management and economics. Records of yields produced in the past are a good starting point for determining realistic yield expectations for the future. The amount of phosphate and potash ($P_2O_5$, and $K_2O$) per unit of yield taken up by various crops is shown in Table 7. The amount of nitrogen utilized by non-legume crops is shown in Table 9, and legume crops are shown in Table 10. The tables can be used with the expected yield to estimate crop nutrient removal per acre.

Table 9. Nitrogen recommendations for agronomic crops. These are base recommendations. They should be adjusted for manure applications (See Manure Nutrient Management Section).

| Crop (Typical yield /A) | Recommendation lb N/unit of expected yield | Recommendation for typical yield lb N / acre | Comments |
|---|---|---|---|
| Corn grain (125 bu/A) | 1 – 1.1 | 130 | For better N efficiency delay application of the nitrogen until the corn is between 10 and 20 in. tall. If there is a history of manure and/or legumes in the field all of the N can be delayed. If there is no history of manure and/or legumes split the N, 1/3 near to planting and the balance delayed. The PSNT can be used to refine N recommendations for corn especially where manure is a major nutrient source. This recommendation should be adjusted for any previous legume in the rotation (See Table 8) |
| Corn silage (21 ton/A) | 7 | 150 | For better N efficiency delay application of the nitrogen until the corn is between 10 and 20 in. tall. If there is a history of manure and/or legumes in the field all of the N can be delayed. If there is no history of manure and/or legumes split the N, 1/3 near to planting and the balance delayed. The PSNT can be used to refine N recommendations for corn especially where manure is a major nutrient source. This recommendation should be adjusted for any previous legume in the rotation (See Table 8) |
| Grain sorghum (125 bu/A)<br>[1] Basic N requirement. Actual recommendations depends on manure history | 0.75 [1] | 0-30 | Field receives manure every 1-2 years. Use the higher rate for higher yield potential and/or lower rates of manure. |
| | | 30-60 | Field receives manure every 3-4 years. Use the higher rate for higher yield potential and/or lower rates of manure. |
| | | 60-90 | No recent manure applications. Use the higher rate for higher yield potential. |
| Forage sorghum (21 ton/A) | 7 | 150 | This recommendation should be adjusted for any previous legume in the rotation (See Table 8) |
| Oats (80 bu/A)<br>[1] Basic N requirement. Actual recommendations depends on manure history | 1.1 [1] | 0-30 | Field receives manure every 1-2 years. Use the higher rate for higher yield potential and/or lower rates of manure. |
| | | 30-60 | Field receives manure every 3-4 years. Use the higher rate for higher yield potential and/or lower rates of manure. |
| | | 60-90 | No recent manure applications. Use the higher rate for higher yield potential. |
| Wheat/Rye (60 bu/A)<br>[1] Basic N requirement. Actual recommendations depends on manure history | 1.5 [1] | 0-30 | Field receives manure every 1-2 years. Use the higher rate for higher yield potential and/or lower rates of manure. If plants did not tiller well apply N by mid-March otherwise, apply anytime up to growth stage 5. |
| | | 30-60 | Field receives manure every 3-4 years. Use the higher rate for higher yield potential and/or lower rates of manure. If plants did not tiller well apply N by mid-March otherwise, apply anytime up to growth stage 5. |
| | | 60-90 | No recent manure applications. Use the higher rate for higher yield potential. If plants did not tiller well apply N by mid-March otherwise, apply anytime up to growth stage 5. |

| | | | |
|---|---|---|---|
| Barley (75 bu/A)<br><br>[1] Basic N requirement. Actual recommendations depends on manure history | 1.4 [1] | 0-30 | Field receives manure every 1-2 years. Use the higher rate for higher yield potential and/or lower rates of manure. If plants did not tiller well apply N by mid-March otherwise, apply anytime up to growth stage 5. |
| | | 30-60 | Field receives manure every 3-4 years. Use the higher rate for higher yield potential and/or lower rates of manure. If plants did not tiller well apply N by mid-March otherwise, apply anytime up to growth stage 5. |
| | | 60-90 | No recent manure applications. Use the higher rate for higher yield potential. If plants did not tiller well apply N by mid-March otherwise, apply anytime up to growth stage 5. |
| Grass (4 ton/A) | 40 | 160 | Split the nitrogen recommendation and apply it based on the expected yield for each cutting. For grass-legume mixtures, if the legume is more than 50% of the stand, the field should be managed as a legume, thus no nitrogen is recommended. |

Table 10. Nitrogen removal by legumes.

| Legumes<br><br>No nitrogen application is recommended for these crops | lb N removed/unit of yield | lb N removed/A | Comments |
|---|---|---|---|
| Alfalfa (5 ton./A) | 50 | 250 | While legumes will utilize N from manure and other sources, applying N may increase the competition from weeds and grasses. If manure is applied it should be limited to an application rate that balances the P requirement of the crop. |
| Clover (3.5 ton/A) | 40 | 140 | While legumes will utilize N from manure and other sources, applying N may increase the competition from weeds and grasses. If manure is applied it should be limited to an application rate that balances the P requirement of the crop. |
| Trefoil (3.5 ton/A) | 50 | 175 | While legumes will utilize N from manure and other sources, applying N may increase the competition from weeds and grasses. If manure is applied it should be limited to an application rate that balances the P requirement of the crop. |
| Soybeans<br><br>(40 bu/A) | 3.2 | 130 | While legumes will utilize N from manure and other sources, applying N may increase the competition from weeds and grasses. If manure is applied it should be limited to an application rate that balances the P requirement of the crop. |

Manure nutrients, especially nitrogen, are used more efficiently by corn and cereal grains than by legumes. But, in general, if manure is applied to meet the nitrogen needs of a continuous grain crop, phosphorus and potassium will likely be applied in excess of crop needs and eventually build up to excessive levels in the soil. Forage crops, to which manure is not applied, planted in rotation with grain crops receiving manure will help remove the excess phosphorus and potassium and keep the three nutrients in balance over the rotation. This is illustrated in Figure 14. In each example in Figure 14 manure was applied to totally meet the nitrogen needs of the corn crop. With continuous corn (Figure 14a.), note the large excess of phosphorus and potassium that are applied. In the rotation example (Figure 14b), when manure is applied to meet the nitrogen needs of the corn, the unmanured forage crop in the rotation uses the excess phosphorus and potassium and some fertilizer phosphorus and potassium will probably be required to meet the needs of the forage crop. This effect will vary with different rotations but the concept will be the same.

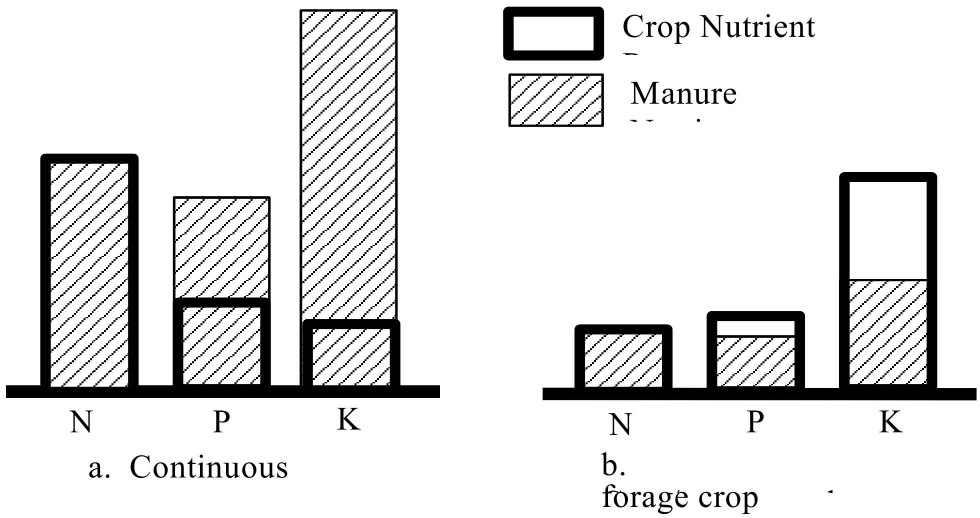



Figure 14. Crop nutrient requirement vs. manure nutrients for continuous corn and for a corn/unmanured forage crop rotation.

Regular soil testing is helpful to monitor the balance of phosphorus and potassium over the crop rotation. The ideal pattern of soil test levels for phosphorus or potassium is illustrated in Figure 15. Note the buildup of nutrients in the corn part of the rotation and then the subsequent draw-down in these levels in the unmanured forage part of the rotation. The bottom line is that over the rotation the trend in soil test levels is level in the optimum to high range.

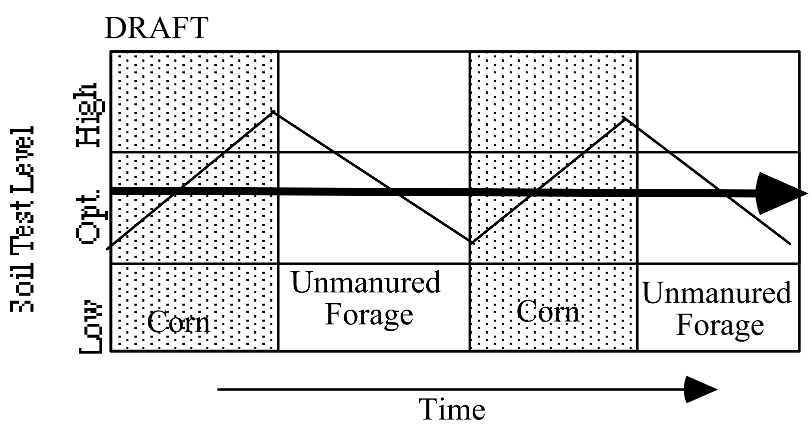



Figure 15. Trend in soil P or K levels over a crop rotation with corn and an unmanured forage crop.

If manure is also applied to the forage crop in the rotation, for example, to utilize excess nitrogen present on the farm, this rotational balance will be disturbed. Figure 16 is the same rotation as in Figure 14b except that it illustrates what would happen if in addition to the manure applied to the corn, manure is also applied to the forage crop at a rate to equal the nitrogen removal by the forage crop. When this management program is followed, the nitrogen remains in balance but now the rotation balance for phosphorus and potassium discussed earlier no longer hold. Large excesses of phosphorus and potassium will now be applied and soil test levels will continue to increase as illustrated in Figure 17. This raises serious environmental concerns because of the excess phosphorus. If manure is to be applied to the forage crops in the rotation it should be applied at a rate based on the phosphorus needs of the forage crop.

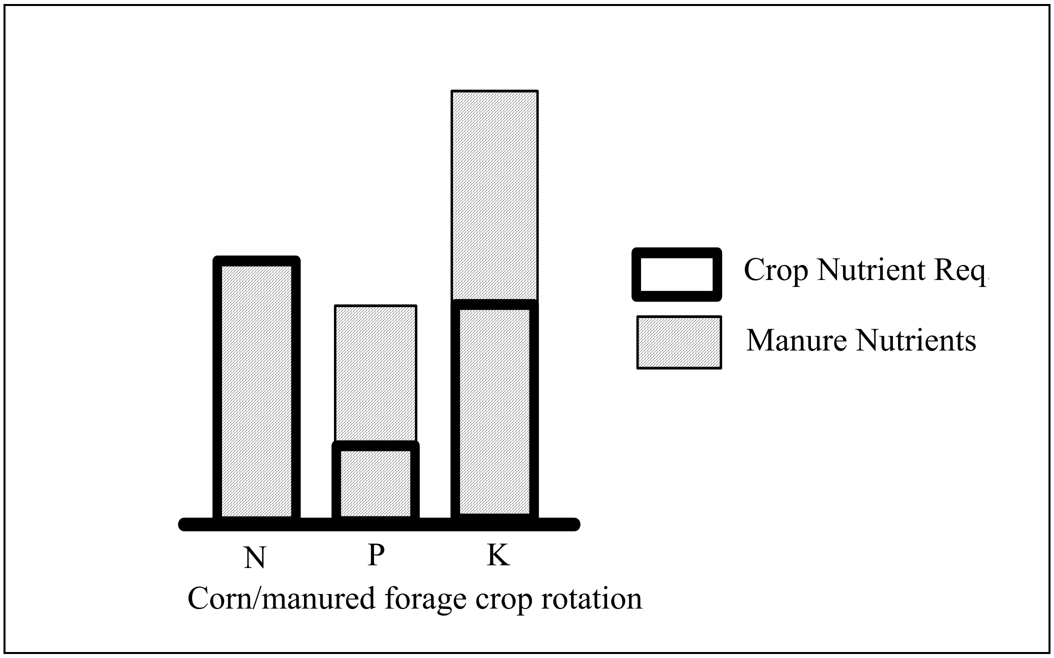



Figure 16. Crop Requirement vs. manure nutrients for a corn/manured forage crop rotation with manure applied to meet the nitrogen needs of both the corn and the legume.

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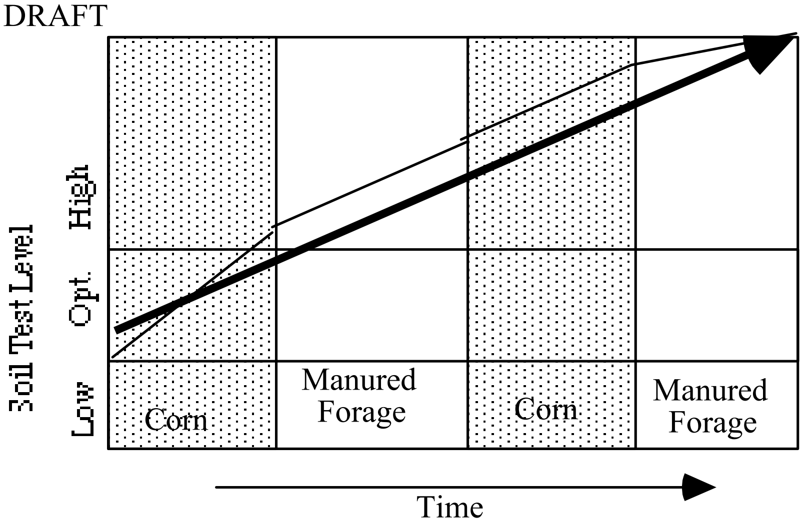


Figure 17. Trend in soil test P or K levels over a crop rotation with corn and a manured forage crop.

In monoculture where it is necessary to apply manure on a continuous basis phosphorus and potassium levels can be expected to increase if the manure is applied to meet the nitrogen needs of the corn as was illustrated in Figure 14a. To avoid this buildup of phosphorus in the soil, manure rates can be based on not exceeding the crop removal of phosphorus as given in Table 7. The balance of nutrients for poultry manure applied to corn based on balancing the phosphorus is illustrated in Figure 18. Generally, as shown in Figure 18, supplemental nitrogen will be required if manure is applied to meet the phosphorus needs of the corn. Also, a considerably larger acreage will be required to spread the manure on the basis of phosphorus compared to nitrogen.

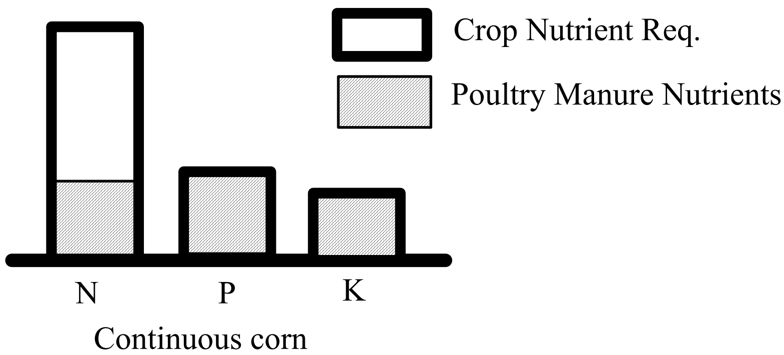


Figure 18. Crop nutrient requirement for corn grain vs. poultry manure nutrients, for manure applied to meet the phosphorus needs of a continuous corn crop.

## Manure Management System Considerations

### Initial Assessment and Evaluation

Management techniques will vary with each specific farm operation. An in depth assessment of the total farm operation is needed to develop a comprehensive manure management system. Information needed for the assessment should include, but not be limited to: total animal units and manure production; available nutrients from all manure sources; identification of all other nutrient sources for the farm; identification of soils and associated soil properties; record of crops grown with yields achieved; historical nutrient application; analysis of present manure handling system including storage and equipment, labor and other resources; identification of any existing problems or situations where changes should be made; and documentation of the desires and needs of the farm operator or manager.

After completing the initial assessment it is appropriate to evaluate alternatives that will most efficiently and effectively utilize available nutrients. Those alternatives should be related as closely as possible to the existing system, if adequate and desired by the farmer. Alternatives which require the most significant changes in the operation should only be selected if practical for the operation and desired by the farmer. In addition, economic and environmental impacts as well as agronomic suitability should be considered.

### Considerations in System Selection

1. Is land available for daily spreading?
2. How do nutrients produced compare with crop nutrient needs?
3. What system(s) is desired by the farmer for handling manure?
4. Could pasture management, including intensive grazing, be utilized to reduce the total volume of manure to be handled and/or stored?
5. Can crop rotation or crop sequences be modified to provide a better nutrient balance?
6. Can concentrated livestock areas, including feed and exercise lots, be managed to eliminate the loss of nutrients and potential off site pollution?

### Considerations for Daily Spreading

1. Is daily spreading desirable for the operation?
2. If land is not currently available for daily spreading, can the cropping system be adjusted to allow for daily spreading?
3. Could livestock be primarily kept on pasture during the time land is not available for manure application?
4. Is crop cover or surface residue available on the land where late fall and winter spreading is desired?
5. Can objectives in the Manure Management Manual and the Pennsylvania FOTG Standard and Specification for Nutrient Management PA590 be met with daily spreading?

### Considerations for Selecting Appropriate Storage Facilities

1. Is storage economically feasible and practical?
2. Are management resources available?
3. Is storage the only method available to solve an existing problem?
4. Could short term storage be used?
5. Has minimum length of storage, based on crop utilization and appropriate application time of manure been developed?
6. Could intensive grazing be a cost-effective method of manure nutrient utilization and reduce storage costs and labor required for manure handling?

7. Could a roof keep surface water from areas with concentrations of manure?

## Manure Management Planning

The nutrient management process, which includes assessment of nutrient status, selection of appropriate management options, developing a nutrient management plan and implementing the plan, was presented in the introduction to nutrient management in the first section of this publication. The following section provides details for developing a nutrient management plan for field application of manure when field application is the appropriate management option for a farm.

Developing a written plan to manage nutrients requires use of soil test results, manure analysis (if manure can be adequately sampled), the form of the manure when spread, projected total amount of manure available, cropping and manure application history including accurate estimates of expected crop yield, planned crop rotations including acres of each crop, tillage systems and manure incorporation practices, and soil survey information. Much of this information will already be part of the farm conservation plan. From this information a plan is developed which includes the following for each field or group of fields on the farm:

Which fields will receive manure?
How much manure will be applied?
When the manure will be applied?
How the manure will be applied, including incorporation, if any?
What supplemental nutrients if any will be required?
Are there special considerations such as proximity to environmentally sensitive areas?

### Manure Production

A first step in developing a plan is to estimate the manure nutrient resources on the farm. If there is a manure storage on the farm, the best way to estimate the amount of manure to be managed is to directly determine the amount of manure in the storage. If this is not possible the amount of manure on the farm can be estimated from the "daily manure production" figures in Table 4. To use these figures you need to determine the number of 1000 pound animal units that are on the farm and then multiply this times the production figure and the number of days this particular animal group is on the farm.

For example, a 1,300 pound dairy cow will produce approximately 19.5 tons of manure in a year. This is calculated as follows:

**Example: Dairy Cow**

**1300 lb./cow ÷ 1000 lb/AU = 1.3 AU/cow**

**1.3 AU x 82 lb. manure/AU/day x 365 days/yr ÷ 2000 lb./ton = 19.5 tons/cow/yr**

This calculation would be repeated, for example for the bred heifers, open heifers, calves, etc. on the farm. These groups would be summed to estimate the total manure production for the farm. This is a relatively simple calculation for a dairy cow because the cow is on the farm all year and the weight is relatively constant.

The calculation becomes more difficult with growing animals such as beef, hogs or broilers and when there are multiple flocks or herds with varying numbers of animals present for varying amounts of time during the year. With growing animals there are two common approaches. First you can use an average weight. For example with swine you might use a weight of 120 pounds as the average weight as the hogs grow from weaning to market weight.

**Example: Swine**

**500 pigs x 120 lb./pig ÷ 1000 lb/AU = 60 AU**

**60 AU x 65 lb. manure/AU/day x 365 days/yr ÷ 2000 lb./ton = 712 tons /yr**

The second approach is to divide the animals into different groups. For example with swine, the herd might be divided into gestating sows, lactating sows with litters, weaned pigs and grower pigs. If there were a relatively constant mix of these three animal groups on the farm throughout the year, that is the actual animals in each group will change over the year but the average number in a group at any point in time is constant, manure production would be calculated using the average weight for each group times the average number of animals in that group. An example using these figures follows:

**Example: Swine Farm, 120 Sow Farrow to Finish**

| | |
|---|---|
| **Gestating sows:** | **98 sows x 400 lb./sow ÷1000 = 39.2 AU** |
| | **39.2 AU x 32 lb. manure/AU/day x 365 days ÷ 2000lb./ton = 229 tons** |
| **Lactating sows:** | **22 sows x 470 lb./sow + litter ÷ 1000 = 10.3 AU** |
| | **10.3 AU x 88 lb. manure/AU/day x 365 days ÷ 2000 lb./ton = 165 tons** |
| **Weaned Pigs:** | **220 pigs x 30 lb./pig ÷ 1000 = 6.6 AU** |
| | **6.6 AU x 65 lb. manure/AU/day x 365 days ÷ 2000 lb./ton = 78 tons** |
| **Grower Pigs:** | **200 pigs x 145 lb./pig ÷ 1000 = 29 AU** |
| | **29 AU x 65 lb. manure/AU/day x 365 days ÷ 2000 lb./ton = 344 tons** |

**Total Manure Production = 229 + 165 + 78 + 344 = 816 tons manure per year**

An alternative is to calculate the manure production for a single animal as it moves through the groups. For example, for a beef animal you would calculate the manure production by the calves growing from 100 to 500 pounds over seven months, add to that the production by the stockers growing from 500 to 800 pounds over eight months and finally that from the finishing cattle growing from 800 to 1000 pounds over three months. This would give the total manure produced by an animal over its life.

**Example: Beef animal lifetime production**

**300 lb./calf ÷ 1000 lb/AU = .3 AU/calf x 60 lb/AU/day x 210 days ÷2000 = 1.9 ton/calf**

**650 lb./stocker ÷ 1000 lb/AU = .65 AU/stocker x 60 lb/AU/day x 240 days ÷2000 = 4.7 ton/stocker**

**900 lb./mature ÷ 1000 lb/AU = .9 AU/mature x 60 lb/AU/day x 90 days ÷2000 = 2.4 ton/mature**

**Lifetime total = 1.9 + 2.7 + 2.4 = 7 ton/animal**

With broilers, factors have been developed based on the final weight of the birds. (bottom of Table 4) These factors can be used to estimate the manure produced per day or for each production period. With broilers there are multiple flocks on the farm with a certain amount of down time between them. For example, if there are six flocks of broilers each on the farm for seven weeks, manure is only being produced for 294 days (6 flocks x 7 wks./flock x 7 days/wk. = 294 days). For this broiler example the calculation of annual manure production for 1000 broilers would be as follows:

**Example: 1000 broilers, market weight 5.2 lb**

**1000 broilers x 5.2 lb mkt. weight ÷ 1000 = 5.2 AU**

**Manure per produced per production period:**

**5.2 AU x 595 lb / AU ÷ 2000 = 1.5 tons/1000 broilers/prod. period**

**Manure produced by 6 flocks per year:**

**1.5 tons/1000 broilers/prod. period x 6 production periods = 9 tons /1000 broilers/year**

In estimating the manure production, particularly for cattle, it should be recognized that not all of the manure produced may be available for collection and spreading on crop fields. Significant amounts of manure may be deposited in exercise lots or on pastures. In developing a nutrient management plan, this uncollected manure should be accounted for in the plan. Often, especially in the case of exercise lots, this uncollected manure is resulting in a very high nutrient application rate on the exercise lot. This can be an environmental concern because many exercise lots are sited near water and have little or no vegetative cover to remove nutrients or to protect the site from nutrient losses by runoff or erosion.

## Prioritizing Fields for Manure Application

Fields or crop groups should be prioritized for manure applications. The highest priority fields to receive manure should be those determined to have the lowest residual nutrient concentrations, those in which the crop to be grown has the greatest nutrient needs, and those in which detrimental environmental effects will be minimized (no sinkholes, not a floodplain, gentle slopes, soils with low leaching potential, etc). The remaining fields are then ranked in descending order. Figure 19 summarizes the factors that should be considered during the field prioritization process.

| **CATEGORIZED BY PRIORITY NUTRIENT:** | **HIGH PRIORITY FOR MANURE** | **LOW PRIORITY FOR MANURE** |
|---|---|---|
| Crop **N** Needs | N-requiring Crops | Non-N Requiring Crops |
| **N** Requirement | Highest N Requirement | Lowest N Requirement |
| & Residual **N** | Lowest Residual N | Highest Residual N |
| **P** Soil Test Level | Lowest P Level | Highest P Level |
| & **K** Soil Test Level | Lowest K Level | Highest K Level |

**AND BY THE FOLLOWING <u>ENVIRONMENTAL CONSIDERATIONS</u>:**

| | |
|---|---|
| **PROXIMITY TO:** | Water Bodies |
| | Sinkholes |
| | Flood Plains |
| | Drinking water sources |
| **SOIL LIMITATIONS:** | Leaching Potential |
| (See your local NRCS) | Erodibility and Runoff |
| **LAND COVER:** | Presence of a Growing Crop, Crop Residue or Cover Crop |
| **OTHER CONSIDERATIONS:** | Distance, neighbors, etc. |

Figure 19. Field prioritization of manure applications

After fields have been prioritized, available manure is allocated to fields based on the priority. This priority does not determine the actual order that manure is spread on the fields. This decision is based on such factors as cropping plans, soil conditions, weather, time available and environmental sensitivity etc. at the time the manure is being spread. The priorities on the fields simply indicate that when possible fields with high priorities will receive manure instead of fields with low priorities.

## Manure Application Rates

Manure application rates are calculated based on the priority nutrient (usually nitrogen or phosphorus). Generally, maximum manure application rates are based on nitrogen because nitrogen has been identified as a major pollution concern both to ground water and to surface water. Soils have a low capacity to hold excess nitrate-nitrogen, so there is a large potential for loss of excess nitrogen. As discussed earlier in the section on phosphorus behavior, phosphorus is primarily a pollution threat to surface water. Therefore, properly designed, installed and maintained soil and water conservation practices should minimize phosphorus loss from cropland since these losses are generally only through runoff and erosion. Such practices will also reduce nitrogen losses to surface water but may actually increase nitrogen losses to groundwater if nitrogen has been applied in excess of crop needs. Thus it is more critical that excess nitrogen not be applied in any given year. However, even with good conservation practices, phosphorus should not be applied in excess of the rotation phosphorus requirements.

A practical approach is that the annual maximum manure rates is determined based on the nitrogen requirements of the crop, but total manure application is limited by the phosphorus requirement of the crop rotation. If the rate is based on nitrogen, the manure nitrogen content must be adjusted for nitrogen availability and the crop nitrogen requirement adjusted for residual nitrogen from previous manure applications and legume crops. The timing of manure applications and the incorporation intended will affect nitrogen availability and must be considered in determining manure application rates. Examples of approaches used to calculate the maximum manure application rate based on nitrogen are given in the examples on pages 37 and 38.

Calculated maximum rates may not be practical as an operational spreading rate. For example, the calculated maximum rates for a group of fields on a farm might be as shown in the second column of Table 11. It is not likely that these maximum rates would be the actual rates that are spread. The actual rates must be less than or equal to maximum rates. Suggested actual practical rates might be like those shown in the third and fourth columns of the table. The number of different rates and the amount of adjustment required in making the rates practical is an operational decision based on the physical and management capabilities of individual farmers. In the example in Table 11, the scenario labeled "Actual Rate I") with two rates comes very close to matching the nutrient requirements of the crops, if only one rate is desired it would be as illustrated in column 4 labeled "Actual Rate II"). Other management scenarios would be possible. Determining this *practical rate* will be critical to enabling the successful implementation of the nutrient management plan.

Table 11. Example of using the calculated maximum manure application rates to determine actual practical application rates.

| Field ID | Max. Rate (ton./acre) | Actual Rate I (ton./acre) | Actual Rate II (ton./acre) |
|---|---|---|---|
| 1 | 24.6 | 25 | 15 + |
| 2 | 25.2 | 25 | 15 + |
| 3 | 14.6 | 15 | 15 |
| 4 | 24.8 | 25 | 15 + |
| 5 | 25.1 | 25 | 15 + |
| 6 | 30.2 | 25 + | 15 + |
| 7 | 16.3 | 15 | 15 |
| 8 | 15.2 | 15 | 15 |
| 9 | 26.5 | 25 | 15 + |
| 10 | 14.6 | 15 | 15 |

+ Significant fertilizer application will be required to meet crop needs.

The nutrients applied in the manure must be compared to the nutrients required by the crops. Deficiencies need to be corrected with additional nutrients and annual excesses should be compared to the rotational needs as discussed earlier (Figure 14). If the nutrient content of the available manure exceeds the rotation nutrient needs, the excess manure should be utilized properly on other suitable land.

*Example calculations of maximum rate of manure based on crop nitrogen requirements.*

*Calculations with total N analysis for typical Pennsylvania non-treated dairy, swine, other livestock, and poultry manure.*

Situation: Recommendations from the soil test report were 130 -50 -100 lb of N, $P_2O_5$, and $K_2O$, respectively. The manure analysis, is 10 lb Total N , 3 lb $P_2O_5$, and 7 lb $K_2O$ per ton. Manure is to be incorporated three days after application. Manure with the same analysis has been applied to this field at the rate of 20 tons/A frequently in the past (five or six out of the last ten years). The starter fertilizer program is 100 lbs./A of 10-20-10.

*Residual N = Total N x Residual N availability factor (Table 6).*

Based on previous manure applications (frequent in this example) -
Residual N availability factor = .15
Residual N = 20 T/A x 10 lb N/T x 0.15 = 30 lb N/A

*Net N Required = Soil test rec. - Residual N - Starter N*
Residual N = 130 lb N/A - 30 lb N/A - 10 lb N/A = 90 lb N/A

*Available N per ton = Total N x N availability factor (Table 5).*
Based on the time until incorporation (4 days in this example) -
N availability factor = 0.35
Available N per ton = 10 lb N/T x 0.35 = 3.5 lb N/ton

*Maximum rate per acre = Net N req. ÷ Available manure N*
Maximum rate per acre = 90 lb. N/A ÷ 3.5 lb N/ton = 26 ton/A

*Phosphorus or potash applied at the maximum rate = Max. rate x P or K Analysis*
Phosphorus applied at the max. rate = 26 ton/A x 3 lb $P_2O_5$/A = 78 lb $P_2O_5$ /A

Potash applied at the max. rate = 26 ton/A x 7 lb $K_2O$/A = <u>182 lb $K_2O$ /A</u>

*Net Recommendation @ Max. Rate:*

| | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Soil Test Recommendation | 130 | 50 | 100 |
| - Residual N | 30 | | |
| - Starter Nutrients | 10 | 20 | 10 |
| - Manure Nutrients @ 26 ton/A | 90 | 78 | 182 |
| Net Requirement | 0 | -48 | -82 |

(Negative number indicates an excess)

Because of the natural variation in soils and manures and because of the assumptions required in making the calculations illustrated above, the rate calculated above should be considered as a guideline for determining the actual rate. Actual rates should be close to or less than the maximum rate calculated here. If a rate less than the maximum is applied it will need to be supplemented with fertilizer nutrients. The supplemental fertilization rate is determined by subtracting the nutrients applied in the manure from the crop requirement. In this example, applying the maximum rate would apply more phosphorus and potash than is recommended on the soil test. When there is an excess it is important to check whether this excess will be utilized by other unmanured crops in the crop rotation. If not, a lower rate would be more appropriate. If a lower rate is selected it will need to be supplemented with nitrogen fertilizer and possibly phosphate and/or potash fertilizer depending on the rate used.

*Example calculations of maximum rate of manure based on crop nitrogen requirements.*

*Calculations with total N + $NH_4$-N and dry matter analysis. Can be used for all manure but required for atypical and/or treated manures or other organic wastes*

Situation: Recommendations from the soil test report were 130 -50 -100 lb of N, $P_2O_5$, and $K_2O$, respectively. This poultry manure was composted and has an analysis of 50 lb Total N, 10 lb $NH_4$-N, 40 lb $P_2O_5$, 30 lb $K_2O$ per ton and 40% moisture. Manure is to be incorporated three days after application. Manure with the same analysis has been applied to this field at the rate of 5 tons/A each of the last three years. The starter fertilizer program is 100 lb/A of 10-20-10.

*<u>Residual N equals the sum of the following. All factors are from Figure 13:</u>*

| Formula | Calculation |
|---|---|
| *Organic N* x previous year of application factor x rate* | 40 x 0.12 x 5 = 24 |
| *+ Organic N x 2 years ago application factor x rate* | 40 x 0.05 x 5 = 10 |
| *+ Organic N x 3 years ago application factor x rate* | 40 x 0.02 x 5 = 4 |
| *Total Residual N (lb/A)* | = 38 |

* Organic N=Total N - $NH_4$-N

*<u>Net N Required = Soil test rec. - Residual N - Starter N</u>*

Residual N = 130 lb N/A - 38 lb N/A - 10 lb N/A = <u>82 lb N/A</u>

*<u>Available N equals the sum of the following. All factors are from Figure 13:</u>*

| Formula | Calculation |
|---|---|
| *$NH_4$-N x "$NH_4$-N factor" Adjusted for incorporation)* | 10 x 0.60 = 6 |
| *+ Organic N*x readily decomposable N factor (for given dm %)* | 40 x 0.60 = 24 |
| *Total Available N (lb/ton)* | = 30 |

* Organic N=Total N - $NH_4$-N

*<u>Maximum rate per acre based on crop requirement = Net N required ÷ Available manure N</u>*

Maximum rate per acre = 82 lb. N/A ÷ 30 lb N/ton = <u>2.7 ton/A</u>

*<u>Phosphorus or potash applied at the maximum rate = Max. rate x P or K Analysis</u>*

Phosphorus applied at the max. rate =2.7 ton/A x 40 lb $P_2O_5$ /ton = <u>108 lb $P_2O_5$ /A</u>

Potash applied at the max. rate = 2.7 ton/A x 30 lb $K_2O$ /ton = <u>81 lb $K_2O$ /A</u>

*<u>Net Recommendation @ Max. Rate:</u>*

| | *N* | *P2O5* | $K_2O$ |
|---|---|---|---|
| Soil Test Recommendation | 130 | 50 | 100 |
| - Residual N | 38 | | |
| - Starter Nutrients | 10 | 20 | 10 |
| - Manure Nutrients @ 6.8 ton/A | 82 | 108 | 81 |
| Net Requirement | 0 | -78 | 9 |

(Negative number indicates an excess)

Because of the natural variation in soils and manures and because of the assumptions required in making the calculations illustrated above, the rate calculated above should be considered as a guideline for determining the actual rate. Actual rates should close to or less than the maximum rate calculated here. If a rate less than the maximum is applied it will need to be supplemented with fertilizer nutrients. The supplemental fertilization rate is determined by subtracting the nutrients applied in the manure from the crop requirement. In this example, applying the maximum rate would apply more phosphorus and potash than is recommended on the soil test. When there is an excess it is important to check whether this excess will be utilized by other unmanured crops in the crop rotation. If not a lower rate would be more appropriate. If a lower rate is selected it will need to be supplemented with nitrogen fertilizer and possibly phosphate and/or potash fertilizer depending on the rate used.

## Spreader calibration

Finally the plan for utilizing the manure must be implemented. This means the manure must be spread uniformly at a known rate. Two methods for spreader calibration are explained below. Method 1 is best for solid or semisolid manure. Method 2 can be used for any type of manure but is best for liquid spreaders.

*Method 1 - Best for solid manure*

Equipment required: a plastic sheet (6 ft x 6 ft or 10 ft x 10 ft), a scale (milk or bathroom scale), and a bucket.

1. Weigh the sheet with the bucket on the scale.
2. Lay the sheet in the field where manure will be spread. Place the sheet far enough in the field to get enough distance to put the spreader in gear and bring the tractor up to speed. Most spreaders apply less at the beginning and at the end of the load.
3. Drive the tractor and spreader over the sheet.
4. Fold the sheet so that no manure is spilled. Put the sheet in the bucket and weigh both on the scale.
5. Subtract the weight of the empty bucket and the sheet in Step 1 from the weight of the sheet and bucket filled with manure. This number is the weight of the manure collected on the sheet.
6. Repeat the procedure and determine an average for the weights.
7. From Table 12 (under Sheet size and Manure on sheet) determine tons of manure applied per acre.
8. If the size of the sheet is different or the pounds of manure collected is not in the table, use the following formula to calculate tons per acre:

   lb manure x 21.8 = T manure/A
   Sheet size, sq ft

*Method 2- Best for liquid manure*

Equipment required: yard stick or tape measure and a string or rope.

1. Determine the manure spreader capacity.
2. Measure the distance traveled to unload the load. This can be measured directly with a measuring tape or as follows:
   - Tie a string around the tractor tire at the top of the tire. Mark the ground directly below the string where the tire rests on the ground. Pull the tractor forward until the string is again at the top of the tire. Mark the ground again, as before, and measure the distance between the two marks on the ground. This is the distance the tractor moves with one revolution of the tire.
   - Spread the load of manure, counting the number of times the rope comes to the top of the tire. Multiply the number of revolutions the tire made to spread the load by the number of feet the tractor moved in the one revolution (Step 2). This is the distance traveled to spread the load.
3. Measure the width that the spreader is covering with manure.
4. Multiply the distance traveled (Step 3) by the width that the spreader is covering with manure (Step 4) and divide by 43,560 (the square feet in an acre). This is the number of acres covered by one load.
5. Divide gallons or tons of manure applied (the Spreader capacity from Step 1) by the number of acres covered (Step 5). The result is the tons or gallons applied per acre.

An alternative to this method is to count the number of loads of a known size applied to a known acreage.

Table 12. Manure spreader rate calibration.

| Manure on sheet, lb | Manure, T/acre Sheet size 6 ft x 6 ft | Sheet size 10 ft x 10 ft |
|---|---|---|
| 5 | 3.0 | 1.1 |
| 6 | 3.6 | 1.3 |
| 7 | 4.2 | 1.5 |
| 8 | 4.8 | 1.7 |
| 9 | 5.4 | 2.0 |
| 10 | 6.1 | 2.2 |
| 11 | 6.7 | 2.4 |
| 12 | 7.3 | 2.6 |
| 13 | 7.9 | 2.8 |
| 14 | 8.5 | 3.1 |
| 15 | 9.1 | 3.3 |
| 16 | 9.7 | 3.5 |
| 17 | 10.3 | 3.7 |
| 18 | 10.9 | 3.9 |
| 19 | 11.5 | 4.1 |
| 20 | 12.1 | 4.4 |
| 21 | 12.7 | 4.6 |
| 22 | 13.3 | 4.8 |
| 23 | 13.9 | 5.0 |
| 24 | 14.5 | 5.2 |
| 25 | 15.1 | 5.4 |
| 26 | 15.7 | 5.7 |
| 27 | 16.3 | 5.9 |
| 28 | 16.9 | 6.1 |
| 29 | 17.5 | 6.3 |
| 30 | 18.2 | 6.5 |
| 31 | 18.8 | 6.8 |
| 32 | 19.4 | 7.0 |
| 33 | 20.0 | 7.2 |
| 34 | 20.6 | 7.4 |
| 35 | 21.2 | 7.6 |

Once the rate being spread has been determined, adjustments in either tractor speed or spreader settings may have to be made to get the desired rate. After any change is made the spreader should be recalibrated. It may take several tries to get the proper adjustments for the desired rate.

## MANAGING EXCESS MANURE

On some farms, livestock and poultry may produce more manure than can be utilized by the crops grown on that farm. Land applying this excess manure on the farm is not an acceptable practice and may lead to off-site pollution as well as depressed crop yields. In these situations, it is the farmer's responsibility to find an acceptable alternative use for the manure.

Probably the most obvious and cost-effective option is to transport the manure to a neighboring farm having cropland that can utilize the additional nutrients contained in the manure. Custom manure haulers may be useful in those situations where a farmer does not have the equipment or the time necessary to transport the manure off the farm.

To avoid future manure excess problems, farmers should consider carefully the carrying capacity of their land base as well as available alternatives to land application before they expand the size of their herd or flock. Additional alternatives to land application are described in the pamphlet "Alternatives to On-Farm Land Application of Manure", produced by Penn State Cooperative Extension.

## Nutrient Management Data Collection and Plan Summary

The nutrient management process is very dependent on having good data to assess the nutrient status of the farm and for use in developing a farm nutrient management plan. Standard worksheets have been developed to provide uniformity in data collection as well as a suggested format to follow in developing a farm nutrient management plan. These worksheets may be obtained from local Conservation Districts, the DEP - Bureau of Watershed Management, the Natural Resources Conservation Service or Cooperative Extension. There are also several computer programs that may provide assistance in developing and implementing an improved nutrient management program. A farm nutrient management plan needs to be comprehensive, yet simple and easy to use. Although alternative methods are available for developing a nutrient management plan, the following worksheets are provided as a suggested standard format. This plan is actually a summary of the detailed calculations and may be supplemented by additional material at the planner's discretion.

## NMP-8 AND NMP-9

A more detailed description of these nutrient management planning worksheets is available under Standard 590 of the Pennsylvania Soil and Water Conservation Technical Guide published by the USDA Natural Resources Conservation Service.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATERSHED MANAGEMENT

# FARM NUTRIENT MANAGEMENT PLAN
# FARM OPERATOR'S SUMMARY

Owner/Operator ______________________________ Tract No. ____________

Concurrence ______________________________ Date ______________

Prepared By ______________________________

Totals: Animal Units (AU) ______________________ Acres Available __________

Storage Capacity ______________________

Time to Empty Structure ______________________

This Nutrient Application Schedule is based on:

______ Daily Spreading Only
______ Daily Spreading Plus Storage for ________ days
______ Daily Spreading with a Modified Cropping System
______ Daily Spreading with Considerations to Soil Limitations
______ Seasonal Spreading in Conjunction with Storage for _________ days

Legend:

Scale:

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATERSHED MANAGEMENT

# INSTRUCTIONS FOR THE COMPLETION OF 3900-FM-WM0459

This sheet is designed to aid you in allocating your manure to the appropriate crop groups.

| | |
|---|---|
| **Crop Group** | What crop will utilize the manure being spread.<br>(Example: "1st year corn after alfalfa" is the same as "corn (after legume)") |
| **Spread Period** | Month(s) to spread manure. (Example: April) |
| **Field Description (optional)** | Designate field(s) according to the spreading plan map. If fields are in strips, you may want to denote strips with letters. (Example: 1A, 2B, 4D) |
| **Acres** | List the number of acres in the crop group. |
| **Manure Group** | Animal producing the manure/description. (Example: dairy cows/slurry) |
| **Application Rate/Acre** | This is the recommended application rate. Take the rate from 3600-FM-WQ0457 (Example: 7,500 gal/acre) |
| **Load Size (T or Ga.)** | This is the spreader capacity in tons or gallons. (Example: 3,500 gal.) |
| **Loads/Acre** | Application Rate divided by Load Size |
| **Total Applied** | The total amount to be applied. (Example: 6 ac. x 7,500 gal/ac. = 45,000 gal. on strips 1A, 2B, 4D) |
| **Incorporation Time** | Days between spreading and incorporation. (Example: 4) |
| **Fertilizer/Starter/Other** | Amount of fertilizer (lb/acre) recommended for use. (Example: 7-34-7 starter only) |

3900-FM-WM0459 10/2001

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATERSHED MANAGEMENT

# FARM NUTRIENT MANAGEMENT PLAN

| CROP GROUP (ROTATION SEQUENCE) | ACRES | (Shaded areas are planned Manure Application times) | | | | | | | | | | | | DATE ______<br>CROP YEAR ______<br>NOTES:<br>- Do not spread manure on frozen soils in fields ______<br>- High leaching soils are identified in fields ______<br>- Sensitive areas are identified in fields ______ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | |
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EXCESS MANURE PRODUCTION: ______ (Tons or Gallons) of ______ Manure (type) are available during ______ (time of year). This manure cannot be spread in an environmentally safe manner on your owned/rented land, based on your Farm Nutrient Management Plan. It must be exported to other land.

| CROP GROUP | SPREAD PERIOD | FIELD DESCRIP. | ACRES | MANURE GROUP* | APPLICATION RATE PER ACRE | LOAD SIZE Tons or Gallons | LOADS/ ACRE | TOTAL APPLIED | INCORP. TIME | FERTILIZER (LB/AC) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | STARTER | OTHER |
| | | | | | | | | | | | |
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*MANURE GROUP/DESCRIPTION
1) ______
2) ______

MANURE GROUP/DESCRIPTION
3) ______
4) ______

MANURE GROUP/DESCRIPTION
5) ______
6) ______

The following management practices are essential in implementing this plan: Field Practice

# MANURE APPLICATION GUIDELINES

**General Recommendations**

- Manure should not be spread on:

    1) frozen soils subject to flooding
    2) sloping soils adjacent to streams, rivers or lakes; or
    3) on other slopes unless land is treated to meet soil loss tolerance (T).

- Specific management guidelines on soils with high leaching potential are incorporated into the application rates in this plan or as part of the recommended management practices.

- Manure should not be spread within 100 feet of springs, wells, open sinkholes with drainage toward them or other sensitive areas.

- Spread manure uniformly and at rates recommended on you “Nutrient Application Schedule”.

- You will need to calibrate manure spreader(s) so you know rate of application.

**Special Considerations for your Nutrient Management Plan**

- Plant corn silage ground with a cover crop, i.e., rye, where possible.

- Cover crops must be planted early enough to obtain 4 to 6 inches of growth and 50% ground cover. This will help to hold nutrients and reduce pollution by runoff.

- Nutrients in the crop residue will remain for subsequent crop utilization.

- Immediately before side dressing for corn (in June or when the corn is approximately one foot tall), a soil nitrogen test is recommended to determine nitrogen needs. These tests are available as an addition to the standard laboratory soil test or as a field Quick-test performed by your County Extension Agent, County Conservation District technician or other qualified personnel.

- Future application rates are to be based on results of the manure and soil tests. For the first few years, manure testing should be done annually. Soil testing should be done once every three years or when there is a crop change. Manure testing after the first few years can be reduced to once every two or three years unless there is a considerable change in the farm operation from year to year. Considerable changes include: more milkhouse waste produced or other change in the volume of liquid added, a change in feed rations, change in animal numbers, etc.

- The use of manure and soil tests may reduce excess applications of nutrients.

- The soil nitrogen test is recommended on fields where the amount of available nitrogen needed for optimum yields is questionable.

## MANURE MANAGEMENT MANUAL

Below is a table of contents for *Manure Management for Environmental Protection* and its supplements. The complete collection is referred to as the Manure Management Manual. Followed by the abbreviation used in pagination.



Copies of *Manure Management for Environmental Protection* and its supplements are available from the water quality manager in the Department of Environmental Protection regional offices listed below:

**Southeast Regional Office**
555 North Lane, Suite 1
Conshohocken, PA 19428-2233
Telephone: 24 hours (610) 832-6000

| | |
|---|---|
| Berks | Lehigh |
| Bucks | Montgomery |
| Chester | Northampton |
| Delaware | Philadelphia |

**Northeast Regional Office**
Two Public Square
Wilkes-Barre, PA 18711-0790
Telephone: 24 hours (570) 826-2511

| | | |
|---|---|---|
| Carbon | Monroe | Susquehanna |
| Lackawanna | Northampton | Wayne |
| Lehigh | Pike | Wyoming |
| Luzerne | Schuylkill | |

**Southcentral Regional Office**
909 Elmerton Avenue
Harrisburg, PA 17110
Telephone: 24 hours (717) 705-4700

| | | |
|---|---|---|
| Adams | Franklin | Lebanon |
| Bedford | Fulton | Mifflin |
| Berks | Huntingdon | Perry |
| Blair | Juniata | York |
| Cumberland | Lancaster | |
| Dauphin | | |

**Northcentral Regional Office**
208 West Third Street
Williamsport, PA 17701
Telephone: 24 hours (570)327-3636

| | | |
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| Bradford | Columbia | Snyder |
| Cameron | Lycoming | Sullivan |
| Centre | Montour | Tioga |
| Clearfield | Northumberland | Union |
| Clinton | Potter | |

**Southwest Regional Office**
400 Waterfront Drive
Pittsburgh, PA 15222-4745
Telephone: 24 hours (412) 442-4000

| | | |
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| Allegheny | Fayette | Washington |
| Armstrong | Green | Westmoreland |
| Beaver | Indiana | |
| Cambria | Somerset | |

**Northwest Regional Office**
230 Chestnut Street
Meadville, PA 16335-3481
Telephone: 24 hours (800) 373-3398

| | | |
|---|---|---|
| Butler | Erie | Mercer |
| Clarion | Forest | Venango |
| Crawford | Lawrence | Venango |
| Elk | McKean | |

For more information, please visit the PA PowerPort at www.state.pa.us,
PA Keyword: “Nutrient Management”).