8.3 Nutrient Management Planning

Nutrient management is a planning tool farmers use to control the amount, source, placement, form, and timing of the application of nutrients and soil amendments (USDA NRCS, 1999). Planning is conducted at the farm level because nutrient requirements vary with such factors as the type of crop being planted, soil type, climate, and planting season. The primary objective of a nutrient management plan (NMP) is to balance crop nutrient requirements with nutrient availability over the course of the growing season. By accurately determining crop nutrient requirements, farmers are able to increase crop growth rates and yields while reducing nutrient losses to the environment.

Proper land application of manure is dependent on soil chemistry, timing of application, and recommended guidelines for applying at agronomic rates (the amount of manure or commercial fertilizers needed to provide only the amount of a particular nutrient that will be used by a specific crop or crop rotation). Manure is an excellent organic fertilizer source and is a soil amendment that benefits a soil's chemical, physical, and biological properties. The predominant chemical benefit of manure to the soil is the supply of the major plant nutrients— nitrogen (N), phosphorus (P), and potassium (K). In addition, livestock manure supplies micronutrients and non-nutrient benefits such as organic matter, which are advantageous to plant growth. The organic matter increases the nutrient- and water-holding capacity of the soil and improves the physical structure. Finally, manure is a source of food and energy for soil microorganisms, which can directly and indirectly benefit the physical, chemical, and biological properties of the soil. The combination of these non-nutrient benefits to soil health has been found to boost corn yields by 7 percent, soybean yields by 8 percent, and alfalfa yields by 9 percent (Vetsch, 1999).

In spite of the benefits listed above, repeated applications of manure can elevate levels of N, P, K, and other micronutrients, as well as acidify soils and increase salinity. Excessive application of these nutrients can lead to surface runoff or leaching. Therefore, land application of manure, if improperly managed, can contribute to the degradation of surface water and ground water (Liskey et al., 1992). Excessive amounts of some nutrients in soils can also reduce crop yields (Brown, 1995).

More efficient use of fertilizer, animal manure, and process wastewater can result in higher yields, reduced input requirements, greater profits, and improved environmental protection. It is possible to further reduce fertilizer expenses and diminish water pollution by employing specific farming practices that help to reduce nutrient losses from manured fields. The best ways to conserve manure P and K are to apply only the amount of manure needed to meet the crop's nutrient needs, and to minimize transport of these nutrients from the field by using conservation practices that reduce erosion and runoff. These approaches also aid in preventing N losses, but N management must also include proper handling, storage, treatment, and timing of manure application and incorporation into the soil.

Sources of nutrients applied for crop production include commercial fertilizer, animal manure, and process wastewater. Nutrient application, manure management planning, erosion control, and other management practices are incorporated within what is referred to by USDA (and described in Section 8.3.1) as a "comprehensive nutrient management plan" or CNMP (USEPA, 1999b). EPA is not requiring all CAFO operators to develop and implement a CNMP. However, EPA recommends the use of USDA NRCS's *Comprehensive Nutrient Management Planning Technical Guidance* (National Planning Procedures Handbook Subpart E, Parts 600.50-600.54 and Subpart F, Part 600.75).

In 1999, the USDA NRCS published a National Conservation Practice Standard on Nutrient Management (Code 590) that provides guidance on managing the amount, source, placement, form and timing of the application of nutrients and soils amendments (e.g., manure). Several methods are presented for determining that proper nutrient application rates are used. Section 8.3.2.4 discusses some of these methods including: the P threshold, the P index, and soil testing. During the period 2001-2002, all states developed nutrient management standards that are in compliance with USDA's 590 standard. Most states developed a state-specific variation of the P index but the soil test method was used by one state to comply with the 590 standard (Landers personal communication, 2002).

8.3.1 Comprehensive Nutrient Management Plans (CNMPs)

As discussed in the USDA-EPA Unified National Strategy for Animal Feeding Operations (USEPA, 1999b), site-specific CNMPs may include some or all of the six components described below, based on the operational needs of the facility. Many of the CNMP components described in the strategy have been addressed in other parts of this document and are cross-referenced below. This section focuses on parts of component 2 (Land Application of Manure and Wastewater) and component 4 (Recordkeeping), however, all six of the CNMP components are presented here to illustrate what a CNMP may contain.

Component 1: Manure and Wastewater Handling and Storage: This portion of a CNMP, addressed more fully in Section 8.2, identifies practices for handling and storing manure to prevent water pollution. Manure and wastewater handling and storage practices should also consider odor and other environmental and public health concerns. Handling and storage considerations include the following:

- Clean water diversion. Siting and management practices should divert clean water from contact with feedlots and holding pens, animal manure, or manure storage systems. Clean water can include rain falling on the roofs of facilities, runoff from adjacent land, and other sources.
- Leakage prevention. Construction and maintenance of buildings, collection systems, conveyance systems, and permanent and temporary storage facilities should prevent leakage of organic matter, nutrients, and pathogens to ground or surface water.

- Adequate storage. Liquid manure storage systems should safely store the quantity and contents of animal manure and wastewater produced, contaminated runoff from the facility, and rainfall. Dry manure, such as that produced in broiler and turkey operations, should be stored in production buildings or storage facilities or otherwise stored in such a way as to prevent polluted runoff. The location of manure storage systems should consider proximity to water bodies, floodplains, and other environmentally sensitive areas.
- Manure treatments. Manure should be handled and treated to reduce the loss of nutrients to the atmosphere during storage; make the material a more stable fertilizer when applied to the land; or reduce pathogens, vector attraction, and odors, as appropriate.
- Management of dead animals. Dead animals should be disposed of in a way that does not adversely affect ground or surface water or create public health concerns. Composting and rendering are common methods used to dispose of dead animals.

Component 2: Land Application of Manure and Wastewater: Land application is the most common, and usually the most desirable, method of using manure and wastewater because of the value of the nutrients and organic matter they contain. Land application should be planned to ensure that the proper amount of nutrients are applied in a manner that does not adversely affect the environment or endanger public health. Land application in accordance with a CNMP should minimize the risk of adverse impacts on water quality and public health. Considerations for appropriate land application should include the following:

- Nutrient balance. The primary purpose of nutrient management is to achieve the level of nutrients (e.g., N and P) required to grow the planned crop by balancing the nutrients already in the soil and provided by other sources, with those which will be applied in manure, biosolids, and commercial fertilizer. At a minimum, nutrient management should prevent the application of nutrients at rates that will exceed the capacity of the soil and the planned crops to assimilate nutrients and prevent pollution. Soils, manure, and wastewater should be tested to determine nutrient content.
- Timing and methods of application. Care must be taken when applying manure and wastewater to the land to prevent them from entering streams, other water bodies, or environmentally sensitive areas. The timing and methods of application should minimize the loss of nutrients to ground or surface water and the loss of N to the atmosphere. Manure and wastewater application equipment should be calibrated to ensure that the quantity of material being applied is what was planned. These topics are discussed in Section 8.4.

Component 3: Site Management: Tillage, crop residue management, grazing management, and other conservation practices should be used to minimize movement to ground and surface water of soil, organic material, nutrients, and pathogens from lands to which manure and wastewater are applied. Forest riparian buffers, filter strips, field borders, contour buffer strips, and other conservation practices should be installed to intercept, store, and use nutrients or other pollutants that might migrate from fields to which manure and wastewater are applied. Site management is addressed in Section 8.4.

Component 4: Recordkeeping: CAFO operators should keep records that indicate the quantity of manure produced and how the manure was used including where, when, and the amount of nutrients applied. Soil and manure testing should be incorporated into the recordkeeping system. The records should be kept after manure leaves the operation.

Component 5: Other Utilization Options: Where the potential for environmentally sound land application is limited, alternative uses of manure, such as sale of manure to other farmers, centralized treatment, composting, sale of compost to other users, and using manure for power generation may also be appropriate. Several of these options are described in Section 8.2. All manure use options should be designed and implemented in such a way as to reduce risks to human health and the environment, and they must comply with all relevant regulations.

Component 6: Feed Management: Animal diets and feed may be modified to reduce the amounts of nutrients in manure. Use of feed management activities, such as phase feeding, amino acid-supplemented low-protein diets, use of low-phytate-phosphorus grain, and enzymes such as phytase or other additives, can reduce the nutrient content of manure, as described in Section 8.1. Reduced inputs and greater assimilation of P by the animal reduce the amount of P excreted and produce a manure that has a N to P ratio closer to that required by crop and forage plants.

Other information that should be part of an NMP is provided in the USDA-NRCS Nutrient Management Conservation Practice Standard Code 590 (USDA NRCS, 1999). It includes aerial photographs or site maps; crop rotation information; realistic crop yield goals; sampling results for soil, manure, and so forth; quantification of all nutrient sources; and the complete nutrient budget for the crop rotation.

Practice: Developing a Comprehensive Nutrient Management Plan

Description: Effective nutrient management requires a thorough analysis of all the major factors affecting field nutrient levels. In general, a CNMP addresses, as necessary and appropriate, manure and wastewater handling and storage, land application of manure and other nutrient sources, site management, recordkeeping, and feed management. CNMPs also address other options for manure use when the potential for environmentally sound land application of manure is limited at the point where the manure is generated.

NMPs typically involves the use of farm and field maps showing acreage, crops and crop rotations, soils, water bodies, and other field limitations (e.g., sinkholes, shallow soils over fractured bedrock, shallow aquifers). Realistic yield expectations for the crops to be grown, soil and manure testing results, nutrient analysis of irrigation water and atmospheric deposition, crop nutrient requirements, timing and application methods for nutrients, and provisions for the proper calibration and operation of nutrient application equipment are all key elements of an NMP.

Application and Performance: CNMPs apply to all farms and all land to which nutrients are applied. Plans are developed by the grower with assistance, as needed, from qualified company staff, government agency specialists, and private consultants. To be effective, NMPs must be site-specific and tailored to the soils, landscapes, and management of the particular farm (Oldham, 1999).

A wide range of studies has found that implementation of nutrient management results in improved nutrient use efficiency, that is, providing for profitable crop production while minimizing nutrient losses and water quality impacts.

Numerous studies have reported significant decreases in N and P applications to cropland due to nutrient management, particularly in areas of concentrated livestock production. Significant reductions in nutrient losses in runoff or leaching often accompany reductions in inputs. However, nutrient management may yield other environmental benefits as well.

Nutrient management may affect N and P availability in soils even more than N and P losses. In a study of nutrient management on Virginia farms, average annual mineral N availability was reduced by 53 kg/ha, while N losses were reduced by 21 kg/ha; average annual phosphate availability was reduced by 29 kg/ha, while average P losses were reduced by only 4 kg/ha (VanDyke et al. 1999). By reducing available nutrients not used by the crop, nutrient management can also reduce immobilized N and P that are subject to loss with eroded sediment in subsequent years.

In rare cases, nutrient management may result in no net decrease (or even an increase) in some nutrient applications on a farm due to redistribution of manure or fertilizer among fields or to optimization of nutrient applications for crop production. In livestock operations, for example, fields nearest the waste storage facility may have received excessive amounts of manure while remote fields received little or none. In such cases, nutrient management will promote more uniform manure application, which will reduce potential water quality impacts by decreasing excessive nutrient levels on some fields and insuring an adequate nutrient supply for crop production on others.

Furthermore, in the process of nutrient management, the producer may discover that he/she had been under fertilizing and additional nutrients are required to produce a good crop. Existence of a healthy crop contributes to good erosion control and nutrient uptake, while poor crop cover would expose soil to erosion and perhaps leave unused nutrients in the soil for leaching or runoff.

Nutrient management can improve the overall efficiency in the use of resources for crop production. Use of animal waste effectively recycles nutrients that might otherwise become water pollutants. Effective use of manure nutrients can lead to reduced demands for commercial N and P fertilizers including reduced energy demands for natural gas intensive N fertilizers (Risse, et al. 2001). More efficient animal waste and fertilizer management may improve the efficiency of equipment and machinery use on the farm.

Numerous studies have shown that nutrient management can yield increased farm income as over-application of purchased nutrients is avoided and better use is made of animal waste for crop production.

Improved use of animal waste has significant benefits to the maintenance of soil quality. With a good NMP, adequate soil fertility and soil organic matter content are maintained on all farm fields. There are ample data to show that the use of animal waste to improve and maintain soil quality has produced substantial reductions in soil erosion (13 to77 percent) and runoff (1 to 68 percent) across the country (Risse and Gilley 2000)

Finally, efficient use of animal waste in an NMP may contribute to reductions in greenhouse gas emissions. Nitrous oxide and methane from manure and fertilizer account for about 5 percent of total U.S. emissions of greenhouse gasses, notably where nutrients are applied to cropland in excess of recommended amounts (USEPA, 1998). Improving management and use of animal waste could therefore reduce emissions of nitrous oxides and methane and increase organic carbon storage in soil (Ogg 1999).

Advantages and Limitations: A good NMP should help growers minimize adverse environmental impacts and maximize the benefits of using litter and manure. In a national survey of growers of corn, soybeans, wheat, and cotton, more than 80 percent of those who had used manure in the Northeast, southern plains, Southeast, and Corn Belt reported that they had reduced the amount of fertilizer applied to land receiving manure (Marketing Directions, 1998). Approximately 30 percent of the respondents reported that they had saved money through crop nutrient management, while more than 20 percent reported increased yields, about 18 percent claimed reduced fertilizer costs, and approximately 10 percent reported that profits had increased and the soil quality had improved. Despite the potential savings, some farmers are reluctant to develop NMPs because of the cost. Only 4 to 22 percent of respondents indicated that they have an NMP.

Proper crediting and application of hog manure has been reported to save $40 to $50 per acre in fertilizer expenses in Iowa (CTIC, 1998a). Similarly, injecting hog manure has resulted in savings of $60 to $80 per acre in Minnesota. Although savings vary from farm to farm, proper crediting and application of manure under a good NMP can result in considerable cost savings for producers.

When animal manure and litter are used as nutrient sources, those activities which affect the availability and characteristics of such sources need to be factored into the NMP. For example, an NMP in which poultry litter is used as a nutrient source should take into account the amount of litter to be removed and the time of removal so that sufficient land is available for proper land application. Alternatively, the plan would need to consider whether storage facilities are available for the quantity of material that must be handled prior to land application. Whenever possible, litter removal should be planned so that fresh litter, containing the maximum amount of nutrients, can be applied immediately to meet crop or forage plant needs.

The CNMP will need to be revisited and possibly revised if the livestock facility increases in size, or if there are changes in animal types, animal waste management, processes, crops, or other significant areas.

Nutrient management services are available in the major farming regions, and both low and high-tech options, such as precision agriculture, are available to producers. A CNMP is only as good as the information provided; the extent to which assumptions regarding yield, weather, and similar factors prove true; and the extent to which the plan is followed precisely.

Operational Factors: Climate, temperature, and rainfall are all critical factors to be considered in the development of an NMP. Since CNMPs are site-specific, the requirements of each CNMP will vary depending on the conditions at each facility.

Demonstration Status: A report on state programs related to AFOs indicates that 27 states already require the development and use of waste management plans (USEPA, 1999a). The complexity and details of these plans vary among states, but they typically address waste generated, application rate, timing, location, nutrient testing, and reporting provisions. Further, industry data and site visits conducted by EPA indicate that practically all CAFOs have some form of management plan in place.

8.3.2 Nutrient Budget Analysis

For animal operations at which land application is the primary method of final disposal, a well-designed NMP determines the land area required to accept manure at a set rate that provides adequate nutrients for plants and avoids overloading soils and endangering the environment. The four major steps of this process are as follows:

- Determine crop yield goals based on site-specific conditions (e.g., soil characteristics).
- Determine crop nutrient needs based on individual yield goals.
- Determine nutrients available in manure and from other potential sources (e.g., irrigation water).
- Determine nutrients already available in the soil.

These four steps constitute a nutrient budget analysis, which provides the operator with an estimate of how much animal waste can be efficiently applied to agricultural crops so that nutrient losses are minimized. Various organizations, including Iowa State University (ISU, 1995), USDA NRCS (1998b), and USEPA (1999b), have developed guidance on performing nutrient budget analysis. The Iowa State University guidance includes detailed worksheets for estimating nutrient needs versus supply from animal manure and other sources.

8.3.2.1 Crop Yield Goals

Practice: Establishing Crop Yield Goals

Description: Establishing realistic yield goals should be the first step of an NMP. The yield goal is the realistic estimate of crop that will be harvested based on the soil and climate in the area (USDA NRCS, 1995). Realistic yield goals can be determined through the following:

- Historical yield information (Consolidated Farm Service Agency-USDA).
- Soil-based estimates of yield potential (county soil survey books and current soil nutrient content reports).
- Farmer's or owner's records of past yields.
- Yield records from a previous owner.

Yield potential is based on soil characteristics and productivity. The soil's yield potential can be obtained from Soil Survey Reports, county extension agencies, or NRCS offices. As the equation below shows, individual yield goals are calculated by multiplying the total acreage of a certain soil type by the yield potential of that soil, then dividing that sum by the total acres in the field:

$$\frac{\text{Total Acreage} \times \text{Yield Potential}}{\text{Total Acres in the Field}} = \frac{(\qquad)}{(\qquad)} = \underline{\qquad\qquad} \text{ bu/acre (Individual Yield Goal)}$$

Application and Performance: Realistic yield goals apply to all farms and all land to which nutrients are applied. Yield goals can be developed by the grower with assistance, as needed, from qualified company staff, government agency specialists, and private consultants. To be effective, yield goals must be site-specific, tailored to the soils on each field.

How well this practice performs depends on both good science and good fortune. Farmers are typically encouraged to set yield goals 5 to 10 percent above the average yield for the past 5 years or so (Hirschi et al., 1997). The intent is allow the farmer to benefit from a good year, while still reducing waste in the event that an off year occurs. Hirschi reports, however, that a survey of farmers in Nebraska showed that only one in ten reached their yield goals, with a full 40 percent of the farmers falling more than 20 percent below their yield goals.

Estimation of realistic yield goals does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Reliance on a realistic yield goal is, by its very nature, an advantage for farmers. The challenge is to establish a yield goal that is truly realistic. Farmers who rely on their own yield records should use an average from the past 5 to 7 years, recognizing that it is impossible to foretell growing seasons accurately (Oldham, 1999).

If yield goals are set too high, there is the risk that nutrients will be applied in excess of crop needs. This translates into increased expense, increased levels of nutrients in the soil, and increased risk to surface water and ground water (Hirschi et al., 1997). If yield goals are set too low, the crop yield may be diminished because of a lack of nutrients. Further, if the crop yield is low during a bumper crop year, the producer risks a substantial loss of profits.

Universities publish yield goal information for use by farmers in all states, providing a ready source of information in the absence of better, site-specific records. In addition, seed suppliers have yield information that can be shared with farmers including the results from local field trials.

Operational Factors: A key challenge in estimating crop yield is determining which historic yield data, industry data, and university recommendations are most appropriate for a given farm. Farmers need to recognize that exceptionally good years are rare (Hirschi et al, 1997). Assumptions regarding the year's weather are also key, and, because farming is a business, crop prices affect farmers' estimates of realistic yield as well.

If planting dates are affected by spring weather, yields may suffer, creating the potential for over application of nutrients. Similarly, extended droughts or wet periods may affect yields. Hail and other similar weather events can also harm crops, resulting in actual yields that fall short of even reasonable yield goals.

Demonstration Status: Estimation of crop yield is a basic feature of farming, although the methods used and accuracy of the estimates vary.

8.3.2.2 Crop Nutrient Needs

Practice: Estimating Crop Nutrient Needs

Description: Crop nutrient needs are the nutrients required by the crop and soil to produce the yield goal. Crop nutrient needs can be calculated for detailed manure nutrient planning. For AFOs, N and P are the primary nutrients of concern, and significant research has been conducted on specific crop requirements for these nutrients. In some cases, nutrient planning analyses also evaluate K requirements.

Crop nutrient needs can be estimated by multiplying the realistic yield goal by a local factor for each nutrient-crop combination. For example, N factors for corn are provided for three regions in Iowa (USDA NRCS, 1995). If the yield goal is 125 bushels per acre and the N factor is 0.90, the N need for corn is 112.5 pounds per acre (125 x 0.90).

Application and Performance: Estimation of crop nutrient needs is a practice that applies to all farms and all land to which nutrients are applied. These estimates can be developed by the grower with assistance, as needed, from qualified company staff, government agency specialists, and private consultants. Nutrient uptake and removal data for common crops are available from the NRCS, the local extension office, and other sources (Oldham, 1999).

The accuracy of this calculation depends on the accuracy of the yield goal and nutrient factors for the crop. In the case of Iowa corn, for example, N factors vary from 0.90 to 1.22. A farmer preparing for a good year might add a 10 percent cushion to the yield goal of 125 bushels per acre used above, resulting in a revised yield goal of 137.5 bushels per acre. The N need increases to 123.75 pounds per acre, an increase of 10 percent as well. If the year turns sour and the yield is 112.5 bushels per acre (10 percent less), the excess N applied becomes 22.5 pounds per acre (123.75-101.25) instead of 11.25 pounds per acre (112.5-101.25), or 100 percent greater.

Estimation of crop nutrient needs does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: The determination of N needs should account for any N in the organic fraction of manure that is not available the first year, any N carryover from previous legume crops, N carryover from previous manure applications, and any commercial N that will be applied. The major factors determining the amount and availability of carryover N are the total amount of N applied, N uptake in the initial crop, losses to air and water, N concentration, C:N ratio, soil temperature, and soil moisture (Wilkinson, 1992).

In their analysis of nutrient availability from livestock, Lander et al. (USDA NRCS, 1998a) assumed that 70 percent of N applied in manure would be available to the crop. NH_3 volatilization, nitrate leaching, and runoff losses reduce the amount of available nutrient, and the percentage available also varies depending on soil temperature, soil moisture, organism availability, and the presence of other nutrients and essentials. When dry or liquid manure is incorporated immediately following application in the north-central region of the United States, about 50 percent of the N is available to the crop (Hirschi et al., 1997).

In North Carolina, it is estimated that half of the total N in irrigated lagoon liquid and 70 percent of the total N in manure slurries that are incorporated into the soil is available to plants (Barker and Zublena, 1996). Plant availability coefficients for N range from 25 percent (dry litter or semisolid manure broadcast without cultivation, and liquid manure slurry irrigated without cultivation) to 95 percent (injected liquid manure slurry and lagoon liquid), depending on form of the manure and method of application (Barker, 1996). For both P and K, the range is 60 to 80 percent, with the higher values for injection of liquid manure slurries and lagoon liquids, and application of lagoon liquids through broadcasting or irrigation with cultivation. The lower values in the range apply to broadcasting dry litter and semisolid manure with no cultivation. The results from plot studies conducted on Cecil sandy loam in Georgia indicate that carryover N from broiler litter should be factored into NMPs for periods longer than 3 years (Wilkinson, 1992).

In Ohio, only about one-third of the Org-N in animal manure is available to crops during the year it is applied (Veenhuizen et al., 1999). The P and K in the manure are available during the year they are applied, as are the equivalent amounts of fertilizer-grade P and K. Ohio State University Extension has published tables that show the estimated percentage of residual organic N that will be available in the 10 years after initial application.

In addition to Org-N in manure, other sources of N can be significant and are included in the calculation of N needs:

- Mineralization of soil organic matter
- Atmospheric deposition
- Residue mineralization
- Irrigation water

If appropriate, contributions from these sources should be subtracted from the total amount of N needed. A general value for calculating the N mineralized per acre from soil organic matter (SOM) is 40 pounds per year for each 1 percent of SOM. The amount of N from atmospheric deposition can be as much as 26 pounds per acre per year, but local data should be used for this estimate. Irrigation additions can be estimated by multiplying the N concentration (in parts per million) by the quantity of water applied (in acre-inches) by 0.227 (USDA NRCS, 1996a).

As discussed earlier, nutrient planning based on N levels alone could lead to excessive soil P levels, thereby increasing the potential for P to be transported in runoff and erosion. Soil P levels should be determined and compared with crop needs before manure or fertilizer containing P is applied. This can be accomplished by comparing annual P removal rates based on the type of crop planted with the amount of P applied the previous year. As with N, data are available for plant removal rates by specific crop.

Operational Factors: As noted above, the major factors determining the amount and availability of carryover N include losses to air and water, soil temperature, and soil moisture (Wilkinson, 1992). In addition, mineralization of soil organic matter, atmospheric deposition, residue mineralization, and irrigation water applications are all related to climate, temperature, and rainfall.

Demonstration Status: Estimation of crop nutrient needs is a basic feature of farming. The methods used vary, however, as does the accuracy of the estimates.

8.3.2.3 Nutrients Available in Manure

Manure is an excellent fertilizer because it contains at least low concentrations of every element necessary for plant growth. The most important macronutrients in manure are N, P, and K, all of which come from urine and feces. The chemical composition of manure when it is excreted from the animal is determined largely by the following variables:

- Species of animal
- Breed
- Age
- Gender
- Genetics
- Feed ration composition

The composition of manure at the time it is applied usually varies greatly from when it was excreted from the animal. The nutrients in manure undergo decomposition at varying rates influenced by the following factors:

- Climate (heat, humidity, wind, and other factors).
- Length of time the manure is stored.
- Amount of feed, bedding, and water added to manure before removal from the animal housing facility.
- Type of production facility.
- Method of manure handling and storage.
- Method and timing of land application.
- Use of manure/pit additives.
- Soil characteristics at time of application.
- Type of crop to which manure is applied.
- Net precipitation/evaporation in storage structure.
- Uncontrollable anomalies (e.g., broken water line).
- Ratio of nutrients that have been transformed or lost to the atmosphere or soil profile.

Given these many factors, it is nearly impossible to predict the nutrient content of manure in every animal production setting. Several state extension and university publications have attempted to predict nutrient contents for different species of animals at specific production phases. These book values are an educated guess at best and vary widely from state to state. It is imperative that livestock producers monitor the nutrient content of their manure on a consistent basis. Knowing the content of macronutrients in manure is an important step to proper land application.

Nitrogen

The total amount of N in manure is excreted in two forms. Urea, which rapidly hydrolyzes to NH_3, is the major N component of urine. Org-N, excreted in feces, is a result of unutilized feed, microbial growth, and metabolism in the animal.

$$\text{Total N} = NH_3 \text{ (ammonia)} + \text{Org-N}$$

The ratio of NH_3 to Org-N in the manure at the time of excretion is largely dependent on species, feed intake, and the other factors discussed above.

Before land application, inorganic N forms can be lost either to the atmosphere or into the soil profile, decreasing the nutrient value of the manure. Depending on the type of manure-handling and storage system and other factors described above, variable amounts of Org-N can be mineralized to inorganic forms, which then can be lost to the atmosphere or into the soil profile. N can be lost from manure in the following three ways:

1. NH_3 is volatilized into the atmosphere.
2. NO_3 (nitrate, a product of mineralization and nitrification) undergoes denitrification and is released into the atmosphere as N_2 (inert N gas).
3. NO_3 (nitrate, a water soluble form of N) is leached and carried down through the soil profile, where it is unavailable to plants.

Agitation of liquid manure prior to land application is extremely important. Solids will separate from still manure. The liquid will largely consist of the mineralized, inorganic forms of N, whereas the solid portions will contain the organic forms of N that are unavailable to plants. Proper agitation suspends the solids and helps ensure that the manure will be a more uniform and predictable fertilizer.

When manure is applied to land, the N content exists in two major forms, the ratio of which can be determined only by manure analysis. The amount of N that will be available to fertilize the plant will depend on the method and timing of application. The balance of the N available to the plant will be lost in one of the three ways described above or will remain immobilized in the organic form. It is generally agreed that 25 to 50 percent of N applied in the organic form will undergo mineralization and become available to plants in the first year. The remaining Org-N will mineralize and become available in subsequent years.

When manure is applied to the surface of land without incorporation into the soil, much of the inorganic N remains on the surface, is lost, and will never be available to the plant. Volatilization of NH_3 is the most significant loss factor and is greatest when drying conditions (dry, warm, sunny days) dominate. Field estimates of volatilization loss from surface-applied manure range from about 10 to 70 percent of NH_3-N applied (CAST, 1996).

When manure is incorporated into the soil, inorganic forms of N available to the plant are placed directly into the root zone and volatilization is minimized. The inorganic ammonia/ammonium is either taken up by the plant or converted to nitrate. The nitrate can then be taken up by the plant, denitrified, and released into the atmosphere as N gas, or carried by water through the root zone. In addition, the organic N fraction has more contact with soil microbes when incorporated, resulting in a greater rate of mineralization.

Phosphorus

The vast majority of P contained in manure is derived from the feces. Only small amounts of P are present in livestock urine. As with N, the amount of P excreted by an animal depends on several factors already discussed.

The introduction of water, bedding, and feed into the manure can affect both the nutrient concentration and the content of the manure product. Manure handling and storage have little influence on the P concentration. Any loss of P is a result of runoff from feedlots or solids settling in holding basins, storage tanks, or lagoons. This will not be a loss if it is collected and used later.

Most of the P is present in solid manure. As stated for N, proper agitation resuspends the solids and makes the manure a more uniform and predictable fertilizer.

Although method and timing of land application have little direct effect on the transformation of P to plant-available forms, they greatly influence the potential loss of P through runoff. Estimates of P vary widely (CAST, 1996); however, by current estimates, somewhere near 70 percent is available for plant uptake in the first year following manure application (Koelsch, 1997).

Potassium

In most species, K is equally present in both urine and feces. Similarly, the amount of K in manure is fairly constant between liquids and solids and is not influenced by agitation. As with the other macronutrients, the amount of K excreted by an animal depends on a multitude of factors already discussed.

As with P, the introduction of water, bedding, and feed to the manure can affect both the K concentration and the content of the manure product. Manure handling and storage have little influence on the K concentration. Any loss of K is a result of runoff from feedlots or solids settling in holding basins, storage tanks, or lagoons. This will not be a loss if it is collected and used later.

As for P, the method and timing of land application have little direct effect on the transformation of K to plant-available forms, but they greatly influence the potential loss of K through runoff.

Most of the K in manure is in the soluble form and is therefore readily available for plant uptake. Availability is estimated to be about 90 percent (Koelsch, 1997).

Swine-Specific Information

Swine excrete approximately 80 percent of the N and P and approximately 90 percent of the K in the feed ration (Sutton et al., 1996). Swine manure can be handled as a slurry, liquid (with the addition of wastewater), or solid (with the addition of large amounts of bedding).

Estimates of the nutrient content of swine manure classified by manure handling type and production phase are given in Table 8-19. The values were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Table 8-19. Swine Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998	pounds/ton	12.4	6.9	4.3	4.4
USDA NRCS, 1996a (farrow, storage tank under slats)	pounds/1,000 gal	29.2	23.3	15.0	23.3
USDA NRCS, 1996a (nursery, storage tank under slats)	pounds/1,000 gal	40.0	33.3	13.3	13.3
USDA NRCS, 1996a (grow/finish, storage tank under slats)	pounds/1,000 gal	52.5	—	22.5	18.3
USDA NRCS, 199a6 (breeding/gestation, storage tank under slats)	pounds/1,000 gal	25.0	—	10.0	17.5
USDA NRCS, 1996a (anaerobic lagoon liquid)	pounds/1,000 gal	2.9	1.8	0.6	3.2
USDA NRCS, 1996a (anaerobic lagoon sludge)	pounds/1,000 gal	25.0	6.3	22.5	63.3
USDA NRCS, 1998a (Breeding hogs, after losses)	pounds/ton	3.3	—	3.6	7.0
USDA NRCS, 1998a (Other types of hogs, after losses) [a]	pounds/ton	2.8	—	2.8	7.2
Jones and Sutton, 1994 (farrow, pit storage)	pounds/1,000 gal	15.0	7.5	5.2	9.1
Jones and Sutton, 1994 (nursery, pit storage)	pounds/1,000 gal	24.0	14.0	8.7	18.3
Jones and Sutton, 1994 (grow/finish, pit storage)	pounds/1,000 gal	32.8	19.0	11.5	22.4
Jones and Sutton, 1994 (breeding/gestation, pit storage)	pounds/1,000 gal	25.0	12.0	13.5	22.4
Jones and Sutton, 1994 (farrow, anaerobic lagoon)	pounds/1,000 gal	4.1	3.0	0.9	1.7
Jones and Sutton, 1994 (nursery, anaerobic lagoon)	pounds/1,000 gal	5.0	3.8	1.4	2.7
Jones and Sutton, 1994 (grow/finish, anaerobic lagoon)	pounds/1,000 gal	5.6	4.5	1.7	3.5
Jones and Sutton, 1994 (breeding/gestation, anaerobic lagoon)	pounds/1,000 gal	4.4	3.3	1.9	3.3
Reichow, 1995 (no bedding)	pounds/ton	10.0	6.0	3.9	6.6
Reichow, 1995 (bedding)	pounds/ton	8.0	5.0	3.1	5.8
NCSU, 1994 (paved surface scraped)	pounds/ton	13.0	5.6	5.8	7.6
NCSU, 1994 (liquid manure slurry)	pounds/1,000 gal	26.5	16.8	8.3	12.6
NCSU, 1994 (anaerobic lagoon liquid)	pounds/1,000 gal	4.7	3.8	0.8	4.0
NCSU, 1994 (anaerobic lagoon sludge)	pounds/1,000 gal	24.4	5.9	23.0	5.4

—Data not available.
[a] Selected for nutrient production calculations throughout this document.

Poultry-Specific Information

Excreted poultry manure has a moisture content of around 80 percent. It can be handled as a slurry or liquid, or in a dry form with added bedding (referred to as litter). Estimates of the nutrient content of chicken and turkey manure are given in Table 8-20. The values were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Table 8-20. Poultry Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998 (layer)	pounds/ton	26.3	6.6	9.4	9.4
USDA NRCS, 1996a (layer, anaerobic lagoon supernatant)	pounds/1,000 gal	6.3	4.6	0.8	8.3
USDA NRCS, 1996a (layer, anaerobic lagoon sludge)	pounds/1,000 gal	32.5	7.7	45.8	6.0
USDA NRCS, 1996a (layer with no bedding or litter)	pounds/ton	35.4		22.9	25.0
Jones and Sutton, 1994 (layer, pit storage)	pounds/1,000 gal	60.0	13.0	19.7	23.2
Jones and Sutton, 1994 (layer, anaerobic lagoon)	pounds/1,000 gal	7.0	5.5	1.7	2.9
NCSU, 1994 (layer paved surface scraped)	pounds/ton	28.2	14.0	13.8	16.2
NCSU, 1994 (layer unpaved deep pit storage)	pounds/ton	33.6	11.8	22.3	21.9
NCSU, 1994 (layer liquid manure slurry)	pounds/1,000 gal	57.3	36.8	22.7	27.5
NCSU, 1994 (layer anaerobic lagoon liquid)	pounds/1,000 gal	6.6	5.6	0.7	8.5
NCSU, 1994 (layer anaerobic lagoon sludge)	pounds/1,000 gal	20.8	6.5	33.7	8.1
ASAE, 1998 (broiler)	pounds/ton	25.9	—	7.1	9.4
USDA NRCS, 1996a (broiler litter)	pounds/1,000 gal	38.9	—	19.4	22.9
USDA NRCS, 1998a (broiler, as excreted)	pounds/ton	26.8	—	7.8	10.5
USDA NRCS, 1998a (broiler, after losses) [a]	pounds/ton	16.1	—	6.6	9.5
Jones and Sutton, 1994 (broiler, pit storage)	pounds/1,000 gal	63.0	13.0	17.5	24.1
Jones and Sutton, 1994 (broiler, anaerobic lagoon)	pounds/1,000 gal	8.5	5.0	1.9	2.9
NCSU, 1994 (broiler litter)	pounds/ton	71.4	12.0	30.3	38.7
NCSU, 1994 (stockpiled broiler litter)	pounds/ton	32.6	6.9	33.5	26.6
NCSU, 1994 (broiler house manure cake)	pounds/ton	45.5	11.8	23.0	29.9
ASAE, 1998 (turkey)	pounds/ton	26.4	3.4	9.8	10.2
USDA NRCS, 1996a (turkey litter)	pounds/1,000 gal	72.4	0.8	32.9	37.0
USDA NRCS, 1998a (turkeys for slaughter, as excreted)	pounds/ton	30.4	—	11.8	11.6
USDA NRCS, 1998a (turkeys for slaughter, after losses) [a]	pounds/ton	16.2	—	10.1	10.4
USDA NRCS, 1998a (turkey hens, as excreted)	pounds/ton	22.4	—	13.2	7.6
USDA NRCS, 1998a (turkey hens, after losses) [a]	pounds/ton	11.2	—	11.2	6.8
Jones and Sutton, 1994 (turkey tom, pit storage)	pounds/1,000 gal	53.0	16.0	17.5	24.4
Jones and Sutton, 1994 (turkey hen, pit storage)	pounds/1,000 gal	60.0	20.0	16.6	26.6
Jones and Sutton, 1994 (turkey tom, anaerobic lagoon)	pounds/1,000 gal	8.0	6.0	1.7	3.7
Jones and Sutton, 1994 (turkey hen, anaerobic lagoon)	pounds/1,000 gal	8.0	6.0	1.7	3.3
NCSU, 1994 (turkey house manure cake)	pounds/ton	44.8	20.1	20.3	24.8
NCSU, 1994 (stockpiled turkey litter)	pounds/ton	31.6	5.5	30.4	25.0

—Data not available.
[a] Selected for nutrient production calculations throughout this document

Dairy Specific Information

Because of the variety of housing and production options associated with dairies, many dairies have a combination of solid-, liquid-, or semisolid-based handling systems. Milking parlors commonly generate a large amount of wastewater from frequent flushing and cleaning of facilities and cows. Dry cows are often housed outdoors in open lots, while cows being milked may be kept in covered or completely enclosed freestall barns or holding pens.

Estimates of the nutrient content of dairy manure classified by manure handling type are given in Table 8-21. The values were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Table 8-21. Dairy Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998	pounds/ton	10.5	1.8	2.2	6.7
USDA NRCS, 1996a (as excreted, lactating cow)	pounds/ton	11.3	—	1.8	6.5
USDA NRCS, 1996a (as excreted, dry cow)	pounds/ton	8.8	—	1.2	5.6
USDA NRCS, 1996a (heifer)	pounds/ton	7.3	—	0.9	5.6
USDA NRCS, 1996a (anaerobic lagoon supernatant)	pounds/1,000 gal	1.7	1.0	0.5	4.2
USDA NRCS, 1996a (anaerobic lagoon sludge)	pounds/1,000 gal	20.8	4.2	9.2	12.5
USDA NRCS, 1996a (aerobic lagoon supernatant)	pounds/1,000 gal	0.2	0.1	0.1	—
USDA NRCS, 1998a (milk cows, as excreted)	pounds/ton	10.7	—	1.9	6.7
USDA NRCS, 1998a (milk cows, after losses) [a]	pounds/ton	4.3	—	1.7	6.0
USDA NRCS, 1998a (heifer & heifer calves, as excreted)	pounds/ton	6.1	—	1.3	5.0
USDA NRCS, 1998a (heifer & heifer calves, after losses) [a]	pounds/ton	1.8	—	1.1	4.5
Reichow, 1995 (dry without bedding)	pounds/ton	9.0	4.0	1.7	8.3
Reichow, 1995 (dry with bedding)	pounds/ton	9.0	5.0	—	—
Jones and Sutton, 1994 (mature cow, pit storage)	pounds/1,000 gal	31.0	6.5	6.6	15.8
Jones and Sutton, 1994 (heifer, pit storage)	pounds/1,000 gal	32.0	6.0	6.1	23.2
Jones and Sutton, 1994 (dairy calf, pit storage)	pounds/1,000 gal	27.0	5.0	6.1	19.9
Jones and Sutton, 1994 (mature cow, anaerobic lagoon)	pounds/1,000 gal	4.2	2.3	0.8	2.5
Jones and Sutton, 1994 (heifer, anaerobic lagoon)	pounds/1,000 gal	4.3	2.1	0.9	2.5
Jones and Sutton, 1994 (dairy calf, anaerobic lagoon)	pounds/1,000 gal	3.0	2.0	0.4	2.1
NCSU, 1994 (paved surface scraped)	pounds/ton	10.3	2.5	3.1	7.1
NCSU, 1994 (liquid manure slurry)	pounds/1,000 gal	22.0	9.2	6.0	16.6
NCSU, 1994 (anaerobic lagoon liquid)	pounds/1,000 gal	4.9	3.2	1.2	5.4
NCSU, 1994 (anaerobic lagoon sludge)	pounds/1,000 gal	19.2	6.2	18.3	7.7

—Data not available.
[a] Selected for nutrient production calculations throughout this document

Beef Cattle-Specific Information

Most beef cattle are produced in an open-lot setting, but some moderate-size operations produce beef in confinement. The nutrient content of feedlot manure is extremely difficult to quantify because of inconsistency in collection methods and content. Varying amounts of dirt, bedding, and precipitation are mixed with the bedding at different times of the year.

Estimates of the nutrient content of beef manure are given in Table 8-22. The ranges were compiled from university, extension service, and government agency publications from around the United States. The wide range of values is due to the many factors discussed earlier in this section.

Table 8-22. Beef Manure Nutrient Content Ranges

Source	Units	Total N	NH_4	P	K
ASAE, 1998	pounds/ton	11.7	3.0	3.2	7.2
USDA NRCS, 1996a (as excreted, high forage diet)	pounds/ton	10.5	—	3.7	8.1
USDA NRCS, 1996a (as excreted, high energy diet)	pounds/ton	10.2	—	3.2	7.1
USDA NRCS, 1996a (feedlot manure)	pounds/ton	24.0	—	16.0	3.4
USDA NRCS, 1998a (beef cows, as excreted)	pounds/ton	11.0	—	3.8	8.3
USDA NRCS, 1998a (beef cows, after losses) [a]	pounds/ton	3.3	—	3.2	7.4
USDA NRCS, 1998a (steers, calves, bulls, and bull calves, as excreted)	pounds/ton	11.0	—	3.4	7.9
USDA NRCS, 1998a (steers, calves, bulls, and bull calves, after losses) [a]	pounds/ton	3.3	—	2.9	7.1
USDA NRCS, 1998a (fattened cattle, as excreted)	pounds/ton	11.0	—	3.4	7.9
USDA NRCS, 1998a (fattened cattle, after losses) [a]	pounds/ton	4.4		2.9	7.1
Reichow, 1995 (dry without bedding)	pounds/ton	21.0	7.0	6.1	19.1
Reichow, 1995 (dry with bedding)	pounds/ton	21.0	8.0	7.9	21.6
Jones and Sutton, 1994 (pit storage)	pounds/1,000 gal	20.0	—	3.1	16.5
Jones and Sutton, 1994 (anaerobic lagoon)	pounds/1,000 gal	4.0	—	0.6	2.7
NCSU, 1994 (paved surface scraped)	pounds/ton	13.8	1.9	4.2	10.7
NCSU, 1994 (unpaved surface scraped)	pounds/ton	25.0	4.7	7.8	17.9
NCSU, 1994 (liquid manure slurry)	pounds/1,000 gal	35.0	14.6	9.9	61.6
NCSU, 1994 (anaerobic lagoon, liquid)	pounds/1,000 gal	3.4	2.3	0.8	4.1
NCSU, 1994 (anaerobic lagoon, sludge)	pounds/1,000 gal	38.2		25.7	12.1

—Data not available.
[a] Selected for nutrient production calculations throughout this document.

Practice: Manure Testing

Description: The nutrient composition of manure varies widely among farms because of differences in animal species and management, and manure storage and handling (Busch et al., 2000). The only method available for determining the actual nutrient content of manure for a particular operation is laboratory analysis. Typical laboratory reports show the moisture content and percentage of N, P, K, Ca, Mg, and Na, as well as the concentration (parts per million) of Zn, Fe, Cu, Mn (McFarland et al., 1998; USDA NRCS, 1996a). Other information, such as the pH and conductivity for liquid samples, is also provided.

Sampling should be performed as close as possible to the time of land application to limit error resulting from losses occurring during handling, storage, and application (Schmitt, 1999; Busch et al., 2000; Bonner et al., 1998; Sharpley et al., 1994). The best time to collect a representative manure sample is during the loading or application process (Schmitt, 1999), but the test results from such sampling cannot be used to plan the current manure applications. Sampling during hauling is considered more accurate and safer than sampling at storage structures (Busch et al., 2000). Subsamples should be collected from several loads and then composited into a single sample. This applies to liquid, solid, or semisolid systems. Because the nutrients in manure are not distributed evenly between the urine and feces portions, mixing is critical to obtaining a representative sample.

Barker and Zublena (1996) recommend that land-applied manure be sampled and analyzed twice annually for nutrient and mineral content. New sampling should be conducted whenever animal management practices change. For example, if there is a significant change in animal rations or operation management (e.g., a change in the size or type of animals raised), new sampling should be conducted. If manure is applied several times a year, samples should be taken during the period of maximum manure application. For example, if the manure that has accumulated all winter will be used as a nutrient source, sampling should be done before application in the spring.

For systems that are emptied or cleaned out once a year, it is recommended that sampling be conducted each time the manure is applied (Busch et al., 2000). This applies to uncovered lagoons, pits, basins, and stacking slabs. Manure from under-barn concrete pits or covered aboveground tanks will not vary as much between applications, unless the type of animal or another significant factor changes. Systems emptied twice a year or more might differ between application times, so a fall analysis might not be accurate for planning spring applications.

Application and Performance: Manure sampling is a practice that applies to all farms and all land on which manure is applied. The farmer or trained consultants can conduct the sampling.

Manure sampling does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Manure analysis is the only way in which the actual nutrient content can be determined. Standardized tables of manure nutrient content do not reflect how variable the true nutrient content can be, but they can be useful in planning facilities and land application areas (Hirschi et al., 1997).

Convenient laboratory reports allow farmers to easily determine the pounds per ton of nutrients in solid manure, or pounds per acre-inch in liquid manure (McFarland et al., 1998). Laboratories are available at universities in most states, and lists of service providers can be obtained from county offices and the Internet.

Without manure analysis, farmers might buy more commercial fertilizer than is needed or spread too much manure on their fields (USDA NRCS, 1996a). Either practice can result in overfertilization, which, in turn, can depress crop yields and cut profits. Improper spreading of manure can also pollute surface and ground water.

Sampling from manure application equipment is quick, but the test results cannot be used to plan the current year's manure applications. Sampling before hauling allows use of the test results for the current year, but retrieving an accurate sample is difficult because the manure is not mixed. Further, there is the danger of falling into manure storage structures.

Operational Factors: Sample collection procedures vary considerably depending on manure form and storage, but all are intended to provide representative samples in a safe and convenient manner. Homogeneity is the key to simple sampling procedures, but the nutrient content of manure usually varies considerably within storage structures and stockpiles. For this reason, agitation of liquid manure and mixing of solid manure are generally recommended prior to sampling. Alternatively, several samples can be taken from different locations and depths within a lagoon, pit, or manure stack. Sampling each of several loads of hauled manure is another option to address spatial variability of manure nutrient content. The process of agitating and loading manure is believed to provide mixing that ensures representative sampling (Busch et al., 2000).

The number of samples to be taken for suitable results depends on the variability of the manure sampled (Busch et al., 2000). One sample may be adequate for agitated liquid slurries and lagoon liquids, whereas three or more samples may be needed for stacked solids. It is recommended that one sample be taken per poultry house.

Hirschi et al. (1997) recommend taking solid manure samples from several locations in a manure stack or on a feedlot, mixing them together in a tied, 1-gallon plastic bag, placing that bag inside another bag, and then freezing the sample before shipping to a laboratory for analysis. Busch et al. (2000) say that 10 to 20 subsamples should be taken from different depths and locations using a pitchfork or shovel. In Texas, five to seven random subsamples are recommended (McFarland et al., 1998). The subsamples are placed in a pile and mixed before a composite sample is taken.

Busch et al. (2000) recommend that samples be taken from the manure in the tank or spreader box on its way to the field for application. For solid manure, samples should be collected from application equipment using a pitchfork, shovel, or plastic glove, avoiding large pieces or chunks of bedding. The sample taken to the lab should be a mixture of manure taken from several (5 to 10) loads representing the beginning, middle, and end of the application process. Subsamples should be mixed thoroughly, prior to filling a sample jar three-fourths full, allowing room for gas expansion. Jars should be cleaned and sealed in a plastic bag, and samples should be frozen before being mailed.

Bonner et al. (1998) suggest that samples can be collected by using catch pans in the field as the material is applied to the land. Samples from multiple pans are mixed to form the overall sample, and a 1-liter plastic bottle is filled halfway to allow for gas expansion. Samples should be frozen or kept cold until delivered to a laboratory.

Rather than sampling from the lagoon or pit, samples can be retrieved with a plastic pail or a coffee can on a pole from the top of the spreader or from the bottom unloading port (Busch et al., 2000). Sampling should be done immediately after filling.

Hirschi et al. (1997) recommend agitating or mixing liquid manures prior to sampling unless it is more practical to take samples from several areas within a lagoon or pit and then mix them. To sample from lagoons and storage facilities, a plastic container attached to a pole or rod is recommended (Bonner et al., 1998; McFarland et al., 1998; Busch et al., 2000). Alternatively, a ½- or ¾-inch PVC pipe can be pushed into the manure to a depth no closer than 1 foot from the bottom (Busch et al., 2000). The sample can be secured by placing a hand over the top of the pipe and pulling the pipe up. Samples should be taken from 5 to 10 locations around the lagoon, covering several depths to include solids. After mixing the samples in a bucket, a representative sample is then taken to a laboratory for analysis.

Demonstration Status: Manure sampling is practiced widely across the United States, but many farmers still do not test manure or employ an N credit from manure when determining commercial fertilizer needs (Stevenson, 1995). A 1995 survey of 1,477 swine producers showed that 92 percent of operations had not had their manure tested for nutrients within the past 12 months (USDA APHIS, 1995). Approximately 6 percent had tested their manure for nutrients once during the past 12 months, while another 1.5 percent had tested it twice. These findings are supported by a crop nutrient management survey in which only 2 to 17 percent of respondents in various regions stated that they factored manure nutrient values into their NMPs (Marketing Directions, 1998).

8.3.2.4 Nutrients Available in Soil

A major problem in using organic nutrient sources such as animal waste is that their nutrient content is rarely balanced with the specific soil and crop needs. For example, the N:P ratio in applied manure is usually around 3 or less, whereas the ratio at which crops use nutrients typically ranges from 5 to 7. Therefore, when manure is applied at rates based solely on N analysis and crop need for N, P is applied in excess of crop needs. Because the amounts of P added in manure exceed the amounts removed by crops, continuous use of manure can result in accumulations of excess P in the soil, increasing the potential for P to be transported in runoff and erosion (Sharpley et al., 1999).

A recent change of emphasis in NMPs has been to base manure application rates on both P and N needs. Different soil types can accommodate different P concentrations before experiencing significant P export in runoff. The amount of P that a soil can hold depends on the availability of binding sites. For example, a clayey soil will tend to be able to retain more P than a sandy soil because clays have a greater surface area and typically contain a greater proportion of iron, which has a strong affinity for P. Table 8-23 demonstrates the variability of the P-binding capacity of several soils. P bound to soils is primarily in a particulate form; however, as a soil becomes saturated with P, the finite number of binding sites will be overwhelmed and P can be released into runoff or ground water in a soluble form.

Table 8-23. Maximum P-Fixation Capacity of Several Soils of Varied Clay Contents.

Soil Great Group (and series)	Location	Percent clay	Maximum P fixation (mg P/ kg soil)
Evesboro (Quartzipsamment)	Maryland	6	125
Kitsap (Xerochrept)	Washington	12	453
Matapeake (Hapludult)	Maryland	15	465
Newberg (Haploxeroll)	Washington	38	905

Source: Brady and Weil, 1996.

P Threshold - The concept of a P threshold (TH) has been developed to identify soil P levels at which soluble losses of P in runoff become significant. The recently revised USDA NRCS nutrient management policy (Part 402) addressing organic soil amendments, such as manures, proposes that for soils with a known P TH the following P manure application rates apply:

- If soil P levels are below 75 percent of the P TH, N-based manure application is allowed.
- If soil P levels are between 75 percent and 150 percent of the P TH, manure application rates should be based on the amount of P estimated to be removed by the crop.
- If soil P levels are between 150 percent and 200 percent of the P TH, manure application rates should be based on one-half the amount of the P estimated to be removed by the crop.
- If soil P levels are greater than twice (200 percent) the P TH, no manure should be added to the soil.
- When no soil-specific TH data are available, P application should be based on soil P test levels.

- If the soil P test level is low or medium, the application rate of organic soil amendments (e.g., manure) can be based on the soil's N content.
- If the soil P level is high, the manure application rate should be based on 1.5 times the P estimated to be removed by the crop.
- If the soil P level is very high, the manure application rate should be based on the P estimated to be removed by the crop.
- If the soil P level is excessive, no manure should be applied.

Phosphorus Index The concept of a P index is still evolving, but it is a tool that assesses the potential risk of P movement to water bodies. Both natural (e.g., rainfall, soil type, slope) and human (e.g., farming practices) factors influence the transformation and ultimate fate of P in the agricultural landscape. The P index looks at site-specific characteristics to identify where corrective soil and water conservation practices can be used to reduce the movement of P into surface water and thus reduce the threat of eutrophication. These characteristics are assigned a value based upon the site vulnerability and are weighted according to their assumed relative effect on potential P loss. Table 8-24 presents a list of nine site characteristics that may be used

Table 8-24. The P index.

Site characteristic (Weighting factor)	Loss rating (value)				
	None	Low (1)	Medium (2)	High (4)	Very high (8)
Soil erosion (1.5)	N/A	<5 tons/acre	5 to 10 tons/acre	10 to 15 tons/acre	>15 tons/acre
Irrigation erosion (1.5)	N/A	Infrequent irrigation on well-drained soils	Moderate irrigation on soils with slopes <5%	Frequent irrigation on soils with slopes of 2 to 5%	Frequent irrigation on soils with slopes of >5%
Soil runoff class (0.5)	N/A	Very low or low	Medium	Optimum	Excessive
Distance from watercourse (1.0)	> 1,000 ft	1,000 to 500 ft	500 to 200 ft	200 to 30 ft	<30 ft
Soil test P (1.0)	N/A	Low	Medium	Optimum	Excessive
P fertilizer application rate, lb P/acre (0.75)	None applied	<15	16 to 40	41 to 65	>65
P fertilizer application method (0.5)	None applied	Placed with planter deeper than 2 inches	Incorporated immediately before crop	Incorporated >3 months before crop or surface applied <3 months before crop	Surface applied to pasture or applied >3 months before crop
Organic P source application rate, lb P/acre (1.0)	None applied	<15	16 to 40	41 to 65	>65
Organic P source application method (0.5)	None applied	Injected deeper than 2 inches	Incorporated immediately before planting	Incorporated >3 months before crop or surface applied <3 months before crop	Surface applied to pasture or applied >3 months before crop

Source: USDA ARS, 1999.

to develop a P index (USDA ARS, 1999). Also presented are suggested weighting factors and loss ratings. The USDA continues to perform extensive research on factors that may be used in the development of a P index. Most states have developed customized P indexes to account for site-specific conditions that influence both soluble P losses and particulate P losses resulting from erosion.

The vulnerability of the site to P loss is estimated by multiplying the ratings value for each characteristic by the weighting factor and then summing all the weighted values to produce the P index for the site. Table 8-25 presents generalized interpretation of the P index. Site-specific factors will have a large impact on P loss. USDA recommends that efforts by farmers, extension agronomists, and soil conservation specialists be coordinated to identify management options that can reduce P loss to surface waters. Management options recommended by USDA include soil testing, soil conservation, and nutrient management. Actions become progressively proactive as the P index of a site increases.

For instance, an area prone to P transport, such as a field rich in P located on erodible soils adjacent to a reservoir, would receive a high score identifying the importance of implementing a management program. Such a site would need a comprehensive long-term P management plan including no application of fertilizer or manure for 3 or more years. Fields with a lower P index would require less severe management options and manure and fertilizer application programs could be developed accordingly.

Table 8-25. Generalized Interpretation of the P index.

P index	General vulnerability to P loss
< 8	**Low** potential for P loss. If current farming practices are maintained, there is a low probability of adverse impacts on surface waters.
8 to 14	**Medium** potential for P loss. The chance for adverse impacts on surface waters exists, and some remediation should be taken to minimize the probability of P loss.
15 to 32	**High** potential for P loss and adverse impacts on surface waters. Soil and water conservation measures and P management plans are needed to minimize the probability of P loss.
> 32	**Very high** potential for P loss and adverse impacts on surface waters. All necessary soil and water conservation measures and a P management plan must be implemented to minimize the P loss.

Source: USDA ARS, 1999.

Practice: Soil Testing

Description: Soil testing, an important tool for determining crop nutrient needs, evaluates the fertility of the soil to determine the basic amounts of fertilizer and lime to apply (USDA NRCS, 1996a). Soil tests should be conducted to determine the optimum nutrient application of N and P, pH, and organic matter. Typical laboratory reports show soil pH, P, K, Ca, Mg, Zn, and Mn levels, plus fertilizer and lime recommendations (USDA NRCS, 1996a). Special analyses for organic matter, nitrate-N, and soluble salts can be requested.

The best time to sample soil is after harvest or before fall or spring fertilization. Late summer and fall are best because K test results are most reliable at these times (Hirschi et al., 1997). The worst time to sample is shortly after the application of lime, commercial fertilizer, or manure, or when the soil is extremely wet. Samples are usually composited to determine a general application rate for a specific field or field section. The goal is to obtain a representative view of the field conditions. This can be achieved by sampling in areas that have similar soil types, crop rotation, tillage type, and past fertility programs. In addition, soil samples should be taken at random in a zigzag pattern, making sure to avoid irregularities in the land (e.g., fence lines, very wet areas) to get samples that accurately portray the landscape. Two weaknesses of random sampling in a zigzag pattern are the assumptions that the composite sample is representative of the entire field and that the result of the sampling produces an average value for the field (Pocknee and Boydell, 1995). Samples can be gathered and composited over smaller areas to determine distinct treatment options. To evaluate the variability of the land, the grid method of dividing the field into 5-acre plots can also be used. Treatment decisions can be made by balancing labor requirements, environmental concerns, and economics.

Grid-cell sampling and grid-point sampling are two sampling methods used on farms where precision farming is practiced. In grid-cell sampling, an imaginary grid is laid over the sampling area and soil cores are taken randomly within each cell, bulked, and mixed. A subsample is then taken from the composite sample for analysis. This approach is considered similar to the random sampling method, with the exception that the sampled area is divided up into many smaller "fields." In grid-point sampling, a similar imaginary grid is used, but the soil cores are taken from within a small radius of each grid intersection, bulked, mixed, and subsampled for analysis. Each of these methods has its limitations. Grid-cell sampling is very time-intensive because most of the field needs to be covered in the sampling process, whereas grid-point sampling will not work well unless grid sizes are very small. Thus, both methods tend to be expensive because of the labor involved. A newer method, directed sampling, is based on spatial patterns defined by some prior knowledge about a field. Sampled areas are divided into homogeneous soil units of varying size. Factors such as field management history, soil maps, soil color, yield maps, topography, and past soil tests are combined and analyzed using a geographic information system (GIS) to determine optimal sampling patterns.

Sampling equipment for grid sampling includes four-wheelers and trucks equipped with global positioning system (GPS) capabilities and mechanized sampling arms (Pocknee and Boydell, 1995). Costs for custom service range from $7 to $15 per acre, including soil sampling, analysis of standard elements, and mapping.

Recommendations regarding sampling frequency range from once a year to once every 4 years. In Arizona, soil sampling for residual nitrate content analysis is recommended prior to planting annual crops (Doerge et al., 1991). For sandy soils in North Carolina, sampling is recommended once every 2 to 3 years; testing once every 4 years is suitable for silt and clay loam soils (Baird et al., 1997). A minimum frequency of once every 4 years is generally recommended in the central United States (Hirschi et al., 1997). In Mississippi, soil samples should be taken once every 3 years or once per crop rotation (Crouse and McCarty, 1998).

Application and Performance: Soil sampling is a practice that applies to all farms and all land to which nutrients are applied. The farmer or trained consultants can conduct the sampling.

Soil sampling does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Soil analysis is the only way in which the actual nutrient content can be determined. N testing has not been consistently reliable because N is highly mobile in soil, but drier parts of the Corn Belt have had some success with both the early spring nitrate-N test and the pre-sidedress N test (Hirschi et al., 1997). There is also some evidence that the pre-sidedress test is most helpful on soils to which manure has been applied.

A late spring N test ensures that the proper amount of N was applied to the crops. Because this test is used to make site-specific adjustments of application rates, following the recommendations provided by this test can help achieve expected crop yields. For example, where N is too high, the late spring N test will indicate that additional N application is not needed by the crop and may contaminate water supplies. Records should be kept and adjustments made to N applications on future crops.

Without soil analysis, farmers might buy more commercial fertilizer than is needed or spread too much manure on their fields (USDA NRCS, 1996a). Either practice can result in overfertilization, which, in turn, can depress crop yields and cut profits. Improper spreading of manure also can pollute surface and ground water.

Convenient laboratory reports allow farmers to easily determine the pounds of nutrients per acre of soil (McFarland et al., 1998). Recommendations based on soil testing results are developed using crop response data from within a state or region with similar soils, cropping systems, and climate (Sims et al., 1998). For this reason, it is important to send samples to a laboratory that is familiar with the crops, soils, and management practices that will be used on the particular farm. The better the information provided to laboratories for each soil sample—such as previous fertilizer use, management plans, and soil series—the greater the potential for receiving a better recommendation. Laboratories are available at universities in most states, and lists of service providers can be obtained from county offices and the Internet.

Operational Factors: Soil samples can be taken with a probe, auger, or spade and collected in a clean bucket. Probes and augers are preferred because they provide an equal amount of soil from each depth (Crouse and McCarty, 1998). For uniform fields, one sample is satisfactory, but most fields are not uniform in treatment, slope, soil type, or drainage, and so should be divided into small areas of 5 to 10 acres each for sampling (USDA NRCS, 1996a). It is recommended that a soil map be used to guide sampling, and a separate, composite soil sample should be taken for each distinct kind of land, soil texture, soil organic matter, fertility level, and management unit (Crouse and McCarty, 1998). The samples should be taken from 20 or more places in the field, using a zig-zag pattern (USDA NRCS, 1996a). Samples should not be taken from unusual areas such as turn rows, old fence rows, old roadbeds, eroded spots, areas where lime or manure have been piled, or in the fertilizer band of row crops. A soil auger, soil tube, or spade can be used for sampling at the plow depth for cropland (6 to 8 inches or more) and at 2 to 4 inches for pasture. Samples should be placed in a clean plastic pail, mixed thoroughly with all clods broken up, and then sent to a laboratory in a 1/2-pint box for analysis.

Recommendations regarding the appropriate field size to be sampled vary somewhat, as shown in Table 8-24.

Table 8-24. Recommended Field Size for Soil Sampling.

Location	Field Size	Comments	Source
Arizona	40 acres or less	15–20 subsamples	Doerge et al., 1991
Hawaii	2–5 acres	5–10 subsamples	Hue et al., 1997
Minnesota	5–20 acres	15–20 subsamples	Rosen 1994
North Carolina	20 acres or less	15–20 subsamples	Baird et al., 1997
Texas	10–40 acres	10–15 subsamples	McFarland et al., 1998
U.S.	20–30 acres	20–25 subsamples	Sims et al., 1998
U.S.	5–10 acres	20 or more subsamples	USDA NRCS, 1996a

Sampling for the early spring nitrate-N test involves taking soil samples in 1-foot increments down to a depth of 2 to 3 feet in early spring, while the pre-sidedress N test calls for sampling from the top 1 foot of soil when corn is 6 to 12 inches tall (Hirschi et al., 1997). Guidelines on interpretation of early spring nitrate tests vary across states.

P soil tests are based on the chemical reactions that control P availability in soils (Sims et al., 1998). These reactions vary among soils, so a range of soil tests is available in the United States, including the Bray P1 (used in the North Central and Midwest Regions), Mehlich 3 (in widespread use in the United States), Mehlich 1 (Southeast and Mid-Atlantic), Morgan and Modified Morgan (Northeast), and Olsen and AB-DTPA (West and Northwest).

Demonstration Status: Soil testing is widely practiced in the United States. In a national survey of corn, soybeans, wheat, and cotton growers, 32 to 60 percent of respondents said that they perform soil testing (Marketing Directions, 1998).

8.3.2.5 Manure Application Rates and Land Requirements

Practice: Determining Manure Application Rates and Land Requirements

Description: The final step of a nutrient management analysis is to determine the amount of manure that can be applied to field crops to meet crop needs while simultaneously preventing excessive nutrient losses. This step involves using the information developed in the nutrient budget analysis to compare crop nutrient requirements with the supply of nutrients provided per unit volume of animal waste. Soil testing helps in determining the rates at which manure should be applied by establishing which nutrients are already present in the soil and available to the crop. Testing manure identifies the amount and types of nutrients it contains and helps to ensure that nutrients are not overapplied to the land. Depending on the cropping system, different amounts of nutrients will be required for optimum production. This final analysis allows the operator to determine how much land acreage is required to apply the animal manure generated or, conversely, how much manure can be applied to the available acreage. These final calculations are illustrated in Figures 8-13 and 8-14.

Determine land area needed for manure application.

Total pounds of usable nutrients available and pounds of nutrients available to plants in each gallon have been calculated. This information should be used to calculate the number of acres you need for manure application.

From nitrogen planning:
Net usable nitrogen available ____________ lb
Net nitrogen amount ÷ ____________ lb N/acre
Land area needed for spreading nitrogen: = ____________ acres

From phosphorus planning:
Net usable P_2O_5 available: ____________ lb
Total P_2O_5 needs: ÷ ____________ lb P_2O_5/acre
Land area needed for spreading P_2O_5: = ____________ acres

Acres required:
Greater of the two above values (a or b): ____________

Adapted from Iowa State University, 1995.

Figure 8-13. Example procedure for determining land needed for manure application.

Determine manure volume to apply.

Total annual volume of manure:		____________	gal or T
Land area required for spreading:	÷	____________	acres
Manure volume used on field:	=	____________	gal or T/acre

If the field is smaller than the acres calculated above, calculate the manure to apply to this field:

Land area in field:		____________	acres
Manure volume to apply :	x	____________	gal or T/acre
Manure volume used on field:	=	____________	gal or T

Determine the number of gallons or tons of manure remaining to be spread:

Total annual volume of manure:		____________	gal or T
Manure volume used on field:	–	____________	gal or T
Manure volume remaining:	=	____________	gal or T

Manure volume remaining:		____________	gal or T
Manure volume to apply :	÷	____________	gal or T/acre
Additional land area for spreading:	=	____________	acres

Adapted from Iowa State University, 1995.

Figure 8-14. Example calculations for determining manure application rate.

Figure 8-13 illustrates that two possible strategies for determining the correct agronomic application rate of manure are (1) applying enough manure to ensure the proper amount of N is available to the crop, and (2) applying manure based on desired amounts of P, then adding commercial N and K to make up the differences in crop needs. Depending on the frequency of application, the first method might increase the risk of oversupplying P and K, thereby potentially adversely affecting soil and water quality (Dick et al., 1999). For this reason, the strategy requiring the greater land area for spreading is selected in the analysis illustrated by Figure 8-13.

Application and Performance: Determining manure application rates and land requirements applies to all farms and all land to which manure is applied. This analysis does not address direct treatment or reduction of any pollutants, but is essential to determining the proper manure and commercial fertilizer application rates.

Advantages and Limitations: Without this analysis, farmers may buy more commercial fertilizer than is needed or spread too much manure on their fields (USDA NRCS, 1996a). Either practice can result in overfertilization, which, in turn, can depress crop yields and cut profits. Improper spreading of manure also can pollute surface and ground water.

In cases where there is inadequate land to receive manure generated on the farm, alternative approaches to handling the manure, described elsewhere in this document, need to be considered.

Operational Factors: Although the correct manure application rate is determined by soil and manure nutrient composition, as well as the nutrient requirements for the crop system, further consideration should be given to soil type and timing of application. Attention to these factors aids in determining which fields are most appropriate for manure application. Before applying manure, operators should consider the soil properties for each field. Coarse-textured soils (high sand content) accept higher liquid application rates without runoff because of their increased permeability; however, manure should be applied frequently and at low rates throughout the growing season because such soils have a low ability to hold nutrients, which creates a potential for nitrate leaching (NCSU, 1998). Fall applications of animal manure on coarse-textured soils are generally not recommended. Fine-textured soils (high clay content) have slow water infiltration rates, and therefore application rates of manure should be limited to avoid runoff. Application on soils with high water tables should be limited to avoid nitrate leaching into ground water (Purdue University, 1994).

Demonstration Status: A 1995 survey of 1,477 swine producers showed that 92 percent of operations had not had their manure tested for nutrients within the past 12 months (USDA APHIS, 1995). Approximately 6 percent had tested their manure for nutrients once during the past 12 months, while another 1.5 percent had tested it twice. These findings are supported by a crop nutrient management survey in which only 2 to 17 percent of respondents in various regions stated that they factored manure nutrient value into their NMPs (Marketing Directions, 1998). Like manure testing, analysis of land requirements and application rates is practiced widely across the United States, but many farmers still do not test manure or employ an N credit from manure when determining commercial fertilizer needs (Stevenson, 1995).

8.3.3 Recordkeeping

The key to a successful nutrient management system is sound recordkeeping. Such a recordkeeping regime should include the following:

Practice: Recordkeeping

Description: Recordkeeping for a CNMP includes recording manure generation; field application (amount, rate, method, incorporation); the results and interpretation of manure, soil, and litter analysis; visual inspections of equipment and fields; manure spreader calibration worksheets; manure application worksheets (nutrient budget analyses); and related information on a monthly or more frequent basis.

Application and Performance: Recordkeeping applies to all farms and all land to which nutrients are applied. Recordkeeping does not address direct treatment or reduction of any pollutants, but is essential to tracking the results of activities associated with nutrient management.

Advantages and Limitations: Without recordkeeping, farmers will have little ability to determine what works and does not work with regard to on-farm nutrient management. Failure to learn from past successes and mistakes may cause farmers to continue in an endless loop of buying more commercial fertilizer than is needed, spreading too much manure on their fields, and realizing smaller profits than would otherwise be obtainable. For example, tracking manure sampling locations, dates, and methods will help establish a firm basis for adjusting sampling frequencies to provide an accurate assessment of manure nutrient content (Busch et al., 2000).

Recordkeeping can seem to be nothing but a burden unless tools are provided with which farmers can analyze the information for their own benefit. Fortunately, a great number of tools are currently available from universities and industry to help farmers use their records to make better business decisions. For example, MAX (Farming for Maximum Efficiency Program) is a program designed to help farmers look at their profit margins, rather than just their yields (CTIC, 1998b). MAX software is provided to cooperators to help them document their savings.

Operational Factors: Recordkeeping can be performed using pencil and paper, personal computers, portable computers, or GIS-based systems.

Demonstration Status: Recordkeeping of some form is conducted on all farms as a matter of business.

8.3.4 Certification of Nutrient Management Planners

Practice: Training and Certification for Nutrient Management Planners

Description: CNMPs should be developed or modified by a certified specialist. Certified specialists are persons who have a demonstrated ability to develop CNMPs in accordance with applicable USDA and state standards and are certified by USDA or a USDA-sanctioned organization. Certified specialists would include individuals who have received certifications through a state or local agency, third-party organization approved by NRCS, or NRCS personnel. In addition, USDA develops agreements with third-party vendors similar to the 1998 agreement with the Certified Crop Advisors (CCAs) and consistent with NRCS standards and specifications (or state standards if more restrictive)[1]. CCAs provide technical assistance to producers in nutrient management, pest management, and residue management. The purpose of using a certified specialist is to ensure that CNMPs are developed, reviewed, and approved by persons who have the appropriate knowledge and expertise to ensure that plans fully and effectively address the core components of CNMPs, as appropriate and necessary, and that plans are appropriately tailored to the site-specific needs and conditions of the farm. Because of the multidisciplinary nature of CNMPs, it is likely that a range of expertise will be needed to develop an effective CNMP (e.g., professional engineer, crop specialist, soil specialist).

Application and Performance: Certification of nutrient management planners applies to all farms and all land to which nutrients are applied. Farmers may seek certification themselves or choose to seek assistance from certified professionals when developing their NMPs.

Certification provides no direct treatment or reduction of any pollutants, but is essential to ensuring that CNMPs developed and implemented are effective in preventing pollution.

Advantages and Limitations: Without certification, those who develop CNMPs might not have the skills or knowledge necessary to develop cost-effective plans. This could result in both water pollution and less-than-optimal farm profits.

If a producer chooses to attain certification, a time commitment is required, and training and travel expenses may be incurred. Course fees of $25 and 1 day of time lost are considered reasonable estimates of costs based on a review of both state training programs for nutrient management and pesticide certification costs provided by various state extension services. The major advantage of becoming certified is that the farmer will be able to develop his or her own CNMPs without the need for outside technical assistance. Certification would ultimately provide benefits with regard to time commitments, convenience, and expense.

Farmers who choose not to obtain certification will need to purchase services from those who are certified.

Operational Factors: Producers might need to travel within their state to attain certification.

Demonstration Status: Some states already have certification programs in place for nutrient management planning, which can provide an excellent foundation for CNMP certification programs. In addition, USDA develops agreements with third-party vendors similar to the 1998 agreement with the CCAs.

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[1] Third-party vendor certification programs may include, but are not limited to, (1) the American Society of Agronomy’s certification programs including Certified Crop Advisors (CCA) and Certified Professional Agronomists (CPAg), Crop Scientists (CPCSc), and Soil Scientists (CPSSc), (2) land grant university certification programs, (3) National Alliance of Independent Crop Consultants (NAICC), and (4) state certification programs.

8.4 Land Application and Field Management

Two important factors that affect nutrient loss are field application timing and application method.

8.4.1 Application Timing

The longer manure remains in the soil before crops take up its nutrients, the more likely those nutrients will be lost through volatilization, denitrification, leaching, erosion and surface runoff. Timing of application is extremely important. To minimize N losses, a good BMP is to apply manure as near as possible to planting time or to the crop growth stage during which N is most needed. Because of regional variations in climate, crops grown, soils, and other factors, timing considerations vary across regions.

Spring is the best time for land application to conserve the greatest amount of nutrients. Available nutrients are used during the cropping season. Nutrient losses are still possible, however, because the likelihood of wet field conditions may result in export by surface runoff or leaching. Spring applications result in less time for organic decomposition of manure (an issue for manure with a low percentage of moisture) and the release of some nutrients. Four main considerations often prevent manure application in the spring. First, a livestock producer might not have sufficient storage capacity for an entire year of manure and might be forced to apply at multiple times during the year. Second, time constraints and labor availability for farmers and applicators during the spring season make it difficult to complete manure application. Third, time constraints are complicated further if there are wet field conditions. Finally, applying manure in the spring creates a potential for greater soil compaction which can cause yield loss. Field equipment, such as heavy manure tanks, compacts the soil and can alter soil structure and reduce water movement. Tillage to break up this compaction is not a viable option in reduced-till cropping systems. Freezing and thawing cycles in winter months lessen the effect of compaction caused during fall application.

Conversely, fall application usually results in greater nutrient losses (25 to 50 percent total N loss, depending on soil type, climate, and crop) than spring application, especially when the manure is not incorporated into the soil (MWPS, 1993). These N losses are a result of NH_3 volatilization and conversion to nitrate, which may be lost by denitrification and leaching. However, fall applications allow soil microorganisms time to more fully decompose manure and release previously unavailable nutrients for the following cropping season. This is especially advantageous for solid manure, which contains high levels of organic matter. When temperatures are below 50 °F, microbial action of the soil slows and prevents nitrification, thereby immobilizing some of the nutrients. In the fall, manure is best applied to fields to be planted in winter grains or cover crops. If winter crops are not scheduled to be planted, manure should be applied to fields that require nutrients in the subsequent crop year or have the most existing vegetation or crop residues, or to sod fields to be plowed the next spring.

Summer application is suitable for small-grain stubble, noncrop fields, or little-used pastures. Manure can also be applied effectively to pure grass stands or to old legume-grass mixtures, but not on young stands of legume forage. Summer application allows a farmer or applicator to spread out the workload of a busy spring and fall.

Winter is the least desirable application time, for both nutrient utilization and pollution prevention. Late fall or winter applications might be desirable because of greater labor availability and better soil trafficability. Although there may be significant losses of available N, the Org-N fraction will still contribute to the plant-available N pool. The potential for nutrient runoff is an environmental concern for applications that cannot be incorporated, especially during winter. Winter applications of manure should include working the manure into the soil either by tillage or by subsurface injection, thereby reducing runoff potential. In northern areas where frozen soil and snow cover are common conditions, winter manure application should be avoided. Winter manure application is prohibited in a number of northern states and in most Canadian provinces. There may be some limited local justification for winter manure application, such as reduced NH_3 volatilization and odor problems (Steenhuis et al., 1979), reduced runoff due to a mulching effect of solid manure (Young and Holt, 1977; Clausen, 1990), enhanced die-off of some microorganisms in freeze-thaw cycles (Kibbey et al., 1978; Stoddard et al., 1998), avoidance of soil compaction, and simplified farm management schedules. However, considerable research has demonstrated that runoff from manure application on frozen or snow-covered ground has a high risk of water quality impact.

Extremely high runoff N and P concentrations have been reported from plot studies of winter-applied manure: 23.5 – 1086.0 mg TKN/L and 1.6 – 15.4 mg total P/L (Thompson et al., 1979; Melvin and Lorimor, 1996). In two Vermont field studies, Clausen (1990, 1991) reported 165 to 224 percent, increases in total P concentrations, 246 to 1480 percent, increases in soluble P concentrations, 114 percent increases in TKN concentrations, and up to 576 percent increases in NH_3-N following winter application of dairy manure. Mass losses of up to 22 percent of applied N and up to 27 percent of applied P from winter-applied manure have been reported (Midgeley and Dunklee, 1945; Hensler et al., 1970; Phillips et al., 1975; Converse et al., 1976; Klausner et al., 1976; Young and Mutchler, 1976; Clausen, 1990 and 1991; Melvin and Lorimer, 1996). Much of this loss can occur in a single storm event (Klausner et al., 1976). Such losses may represent a significant portion of annual crop nutrient needs.

On a watershed basis, runoff from winter-applied manure can be an important source of annual nutrient loading to water bodies. In a Wisconsin lake, 25 percent of annual P load from animal waste sources was estimated to arise from winter spreading (Moore and Madison, 1985). In New York, snowmelt runoff from winter-manured cropland contributed more P to Cannonsville Reservoir than did runoff from poorly managed barnyards (Brown et al., 1989). Clausen and Meals (1989) estimated that 40 percent of Vermont streams and lakes would experience significant water quality impairments from the addition of just two winter-spread fields in their watersheds.

Winter application of manure can increase microorganism losses in runoff from agricultural land compared to applications in other seasons (Reddy et al., 1981). Cool temperatures enhance survival of fecal bacteria (Reddy et al., 1981; Kibby et al., 1978). Although some researchers have reported that freezing conditions are lethal to fecal bacteria (Kibby et al., 1978; Stoddard et al., 1998), research results are conflicting. Kudva et al. (1998) found that *E. coli* can survive >100 days in manure frozen at –20 ºC. Vansteelant (2000) observed that freeze/thaw of soil/slurry mix only reduced *E. coli* levels by about 90 percent. Studies have found that winter-spreading of manure does not guarantee die-off of *Cryptosporidium* oocysts (Carrington and Ransome, 1994; Fayer and Nerad, 1996). Finally, because incorporation or injection of manure is impossible in winter applications, filtration and adsorption through soil contact, important mechanisms for attenuating microorganism losses (Gerba et al., 1975; Patni et al., 1985), is prevented.

There are several additional disadvantages to winter manure application. Runoff from winter-spread fields, whether during winter thaws or in spring snowmelt, would occur before the growing season when riparian buffers or vegetated filter strips are relatively inactive and ineffective in removing pollutants from runoff before delivery to surface waters. In cases where winter spreading is carried out because of lack of adequate manure storage, the loss of management flexibility makes good nutrient management difficult.

Although several studies have reported little water quality impact from winter-spread manure (Klausner, 1976; Young and Mutchler, 1976; Young and Holt, 1977), such findings typically result from fortuitous circumstances of weather, soil properties, and timing/position of manure in the snowpack. The spatial and temporal variability and unpredictability of such factors makes the possibility of ideal conditions both unlikely and impossible to predict.

8.4.2 Application Methods

Manure can be handled as a liquid (less than 4 percent solids), semisolid or slurry (4 to 20 percent solids), or solid (greater than 20 percent solids). The amount of bedding and water dilution influence the form, as do the species and production phase of the animals. Consequently, the manure form dictates the way manure will be collected, stored, and finally applied to land (MWPS, 1993).

Liquid manure and slurry manure are applied using similar methods, but equipment needs for the two manure forms may vary depending on percentage of solids content. Chopper pumps may be necessary to reduce the particle size of bedding or feed. Agitation of liquid manure is extremely important prior to land application. Inadequate agitation results in inconsistent nutrient content and makes the manure difficult to credit as a valuable fertilizer source. A lack of uniform application can also lead to nutrient excesses and deficiencies, yield loss, and increased incidence of ground and surface water contamination. Furthermore, insufficient agitation can cause a buildup of solids in the storage tank and lead to decreased capacity. A disadvantage to liquid manure-handling systems is that they may require the addition of water for collection of the manure, increasing the amount of material that must be handled and applied.

The liquid-based manure is applied to fields by means of tank wagons, drag-hose systems, or irrigation systems. Tank wagons can either broadcast manure (surface apply) or inject it into the soil. The method of injection, and the corresponding level of disturbance to the soil surface, is extremely variable. With the proper implement type, disruption to the soil surface and residue cover can be minimal and appropriate for reduced-tillage operations. Depending on the specific implement chosen, injection is the preferred method in reduced-till or no-till cropping systems. Soil incorporation occurs immediately and crop residues are left on the surface to act as a mulch. The amount of exposed soil surface is minimized, resulting in reduced erosion. Injection systems can reduce odor by 20 to 90 percent (Hanna, 1998). There is less nutrient loss to air and diminished runoff as well. For injection, a liquid manure spreader or "umbilical" system, and equipment to deposit manure below the soil surface are necessary. Injection requires more horsepower, fuel, and time than broadcasting. Liquid-based manure can also be pumped from a tanker or storage facility located adjacent to the field through a long flexible hose. This umbilical or drag-hose system is feasible for both broadcasting and injecting manure. Irrigation equipment applies liquid manure pumped directly from storage (usually lagoons). Wastewater and manure can be applied by means of sprinkler or surface (flood) irrigation.

Solid manure is broadcast using box-type or open-tank spreaders. Spreader mechanisms include paddles, flails, and augers. Rate calibration of box spreaders is often difficult, resulting in less uniform application, difficulty crediting fertilizer values, nutrient excesses and deficiencies resulting in yield loss, and increased potential for ground and surface water contamination.

Surface application, or broadcasting, is defined as the application of manure to land without incorporation. Simply applying manure to the soil surface can lead to losses of most of the available N, depending on soil temperature and moisture. N is lost through volatilization of NH_3 gas, denitrification of nitrates, and leaching. Volatilization losses are greatest with lower humidity and with increases in time, temperature, and wind speed. High- moisture conditions can carry water-soluble nitrates through the soil profile and out of the plant root zone, potentially causing ground water contamination. University extension services generally recommend a certain correction factor (Table 8-25). Environmental conditions such as temperature, wind, and humidity influence this factor. Generally, P and K losses are negligible, regardless of application method. However, some P and K is lost through soil erosion and runoff.

Table 8-25. Correction Factors to Account for Nitrogen Volatilization Losses During Land Application of Animal Manure.

Application Method	Correction Factor
Direct injection	0.98
Broadcast and incorporation within 24 hours	0.95
Broadcast and incorporation after 24 hours	0.80
Broadcast liquid, no incorporation	0.75
Broadcast dry, no incorporation	0.70
Irrigation, no incorporation	0.60

Source: Adapted from Iowa State University Extension PM-1811, November 1999.

Solid and liquid manures can be incorporated into the soil by tillage in a row-crop system. Incorporation increases the amount of N available for crops by limiting volatilization, denitrification, and surface runoff. Incorporation also reduces odor and encourages mineralization of Org-N by microbial action in the soil, thereby increasing the amount of N readily available to the plants. Although incorporation by tillage makes the nutrients less susceptible to runoff, the resulting reduction in crop residue can increase sediment runoff. If manure nutrients are to be fully used, incorporation should be performed within 12 to 24 hours of land application.

8.4.3 Manure Application Equipment

Livestock producers and custom manure applicators consider six predominant criteria when choosing an application system: (1) the amount of land to be covered/fertilized, (2) the amount of manure to be spread, (3) water content and consistency of the manure, (4) the frequency of application and importance of timeliness, (5) soil trafficability, and (6) distance between storage and the field to be treated. The fundamental classes of application equipment are solid waste spreaders, liquid waste tankers, umbilical systems, and liquid waste irrigation systems. Table 8-26 presents the advantages and disadvantages of the different application systems.

Table 8-26. Advantages and Disadvantages of Manure Application Equipment.

Application Method	Description	Advantages	Disadvantages
Solid			
Box spreader	Common box spreader with aprons, paddles, or hydraulic push system. Depending on size, can be pulled by as small as a 15-hp tractor.	Equipment readily available. Mobile. Equipment relatively inexpensive. High solids content allows less total volume to be handled.	Limited capacity. High labor and time requirement. Fairly difficult to achieve uniform application. Significant nutrient loss and odor if not incorporated immediately. Moderate risk of soil compaction. Uneven applications when conditions are windy.
Flail spreader	V-bottom spreader with chains attached to a rotating shaft to sling the manure out of the top or side of the tank. Can be pulled by 30- to 90-hp tractor.	Wide, even application. Spreads solid, frozen, chunky, slurry, semisolid, or bedded manure. Low maintenance because of few moving parts.	Moderate risk of soil compaction. Higher cost and power requirements than box spreader. Significant nutrient loss and odor if not incorporated immediately. Uneven applications when conditions are windy.
Hopper spreader	V-bottom spreader with large auger across bottom of spreader. Manure spread by impeller on side.	Wide, even application.	Moderate risk of soil compaction. Higher cost and power requirements than box spreader. Significant nutrient loss and odor if not incorporated immediately. Uneven applications when conditions are windy.

Application Method	Description	Advantages	Disadvantages
Liquid (Broadcast)			
Tank spreader	Mounted tank shoots manure in widespread pattern. Can be on one side, both sides, or directly behind spreader. Also can have drop hoses. Spreading width of 15 to 25 feet. Capacity of 1,000 to 5,000 gallons.	Simple to manage. Less costly than injectors. Requires less hp than injectors.	Great nutrient loss and odor possibilities. Uneven applications when conditions are windy. Air contact results in some nutrient loss. High risk of soil compaction.
Tractor-pulled flexible hose (drag-hose)	Manure is pumped from the storage facility or tanker at the edge of the field through hose pulled by tractor. Tractor-mounted unit consists of pipe, nozzle, and deflector plate. Spread pattern similar to that of broadcast tank spreader.	Simple design. Relatively inexpensive. Low power required to pull hose. Low risk of soil compaction.	Great nutrient loss and odor possibilities. Uneven applications when conditions are windy. Air contact results in some nutrient loss. May be limited by distance from storage to fields and by terrain.
Liquid (Injection)			
Tank spreader	Front- or rear-mounted tank. Soil is opened and manure deposited below surface by variable methods. Capacity of 1,000 to 5,000 gallons.	Odor is minimized. Nutrients not lost to atmosphere. Nutrients can be placed near plant's root zone in a standing crop. Depending on implement type, soil surface and residue disturbed minimally.	Pulling injectors require more horsepower. Operation difficult in stony soil. More expensive than broadcasting. High risk of soil compaction. Increased application time as compared with broadcasting.
Tractor-pulled flexible hose (drag-hose)	Manure is pumped from storage facility or tanker at the edge of the field through hose pulled by tractor and fed into injectors. Injectors must be lifted from ground to turn. Rigid, swinging pipe on equipment prevents hose damage by tractor. 150- to 200-hp tractor needed.	Odor controlled during spreading. N retained. Requires less power than tanker injection systems. Low soil compaction risk.	Some manure may be spilled at end of runs. May be limited by distance from the storage to fields and by terrain. Increased application time as compared with broadcasting by drag-hose.
Irrigation			
Surface irrigation	Manure transported to application site through rigid irrigation pipes. Manure spread on field via gated pipes or open ditches.	Low initial investment. Low energy requirements. Little equipment needed. Little soil compaction. Few mechanical parts. Timely manure application.	Moderate labor requirement. High degree of management skill needed. Limited to slopes of less than 2 percent. May be limited by distance to field. High odor levels possible. Difficult to control runoff and achieve uniform application. Significant nutrient loss if not incorporated immediately.

Application Method	Description	Advantages	Disadvantages
Hand-moved sprinklers	Manure transported through rigid irrigation pipe, including a mainline and one or more aluminum pipe laterals. One parcel irrigated at a time. Pipe is disassembled and moved by hand to next parcel.	Low initial investment. Few mechanical parts. Low power requirement. Adapts to field shape. Little soil compaction. Timely manure application.	High labor requirement. Sprinklers can clog. Significant nutrient loss if not incorporated immediately. High odor levels possible. Uneven distribution in windy conditions.
Towline sprinklers	Manure transported through rigid irrigation pipe, including a mainline and one or more aluminum pipe laterals. One parcel irrigated at a time. Laterals are stronger and are moved using a tractor.	Low initial investment. Requires less labor than hand-move sprinklers. Few mechanical parts. Low power requirement. Little soil compaction. Timely manure application.	Not adaptable to irregular field shapes because of fixed laterals. Sprinklers can clog. Require tractor lanes for towing in tall crops. Significant nutrient loss if not incorporated immediately. High odor possible. Uneven distribution in windy conditions.
Stationary big gun	Manure transported through rigid irrigation pipes. Single large gun sprays manure in a circle. Must be moved by hand.	Moderate labor requirement. Few mechanical parts. Adaptable to irregular land area. Requires less pipe than small sprinklers. Big nozzle allows spreading of manures with more solids. Little soil compaction. Timely manure application.	Moderate to high initial investment. High power requirement. Uneven distribution in windy conditions. Significant nutrient loss if not incorporated immediately. High odor possible.
Towed big gun	Manure transported through rigid irrigation pipes. Functions like a towline system with the laterals replaced by a big gun.	Few mechanical parts. Requires less labor than hand-move or stationary gun systems. Requires less pipe than small sprinklers. Big nozzle allows spreading of manures with more solids. Little soil compaction. Timely manure application.	Moderate to high initial investment. High power requirement. Uneven distribution in windy conditions. Less adaptable to land area. Requires tractor driving lanes. Significant nutrient loss if not incorporated immediately. High odor possible.
Traveling gun	Manure transported through rigid irrigation pipes. Irrigation gun travels across field, spreading manure in semicircular pattern. Hard or soft hose types available. Soft hose system is less expensive.	Lowest labor requirement of all sprinkler systems. Big nozzle allows spreading of manures with more solids. Little soil compaction. Less energy required than tank spreader. Timely manure application.	High initial costs. May be limited by distance to field. Uniform application difficult in very windy conditions. Possibility of high odor levels. Significant nutrient loss if not incorporated immediately. Environmental damage likely if not supervised. High odor possible.

Sources: MWPS, 1993; and Bartok, 1994.
hp = horsepower

Practice: Solid Manure Application with Spreaders

Description: Solid and semisolid manure can be applied to land using box, V-bottom, or flail spreaders. Spreaders are either tractor-pulled or mounted on trucks, depending on the load capacity. The manure is discharged from the rear, side, or bottom of the spreader with the aid of paddles, flails, chains, or augers (MWPS, 1993).

Application and Performance: Solid waste application methods are appropriate for manure containing 20 percent or more solids (MWPS, 1993). Spreaders are most appropriate for smaller operations with frequent manure removal from small areas (USDA NRCS, 1996a).

Advantages and Limitations: Spreaders are relatively inexpensive but have a limited load capacity. They require power to operate and, because of the open-air application method, often present odor problems during and after application. In addition, calibration can be difficult and create a problem with uniform application and nutrient crediting. Most spreaders must be filled using a tractor front-end loader. Smaller spreaders require a greater time investment because of the number of return trips to the manure source for refilling. Increasing spreader capacity reduces the time investment but increases the risk of soil compaction. V-box bottom spreaders can achieve a more uniform application than box spreaders but require more power and investment.

Operational Factors: Spreaders are constructed of treated wood or steel and include a plastic or fiberglass interior lining to assist with loading and unloading. The spreaders can rot or rust, depending on the construction material, and tractor front-end loaders can damage the spreader and lining during loading. To prevent deterioration and damage, operators should load the spreader carefully, clean and lubricate it regularly, and protect it from the weather.

Demonstration Status: Of grow-finish swine operations that dispose of waste on owned or rented land, 57.8 percent use broadcast/solid spreader methods. Only 13.7 percent of large grow-finish operations (marketing more than 10,000 head) use broadcast/solid spreader methods (USDA APHIS, 1996a).

On dairy farms with fewer than 100 milk cows, 90.6 percent broadcast manure with a solid spreader. As herd size increases, solid handling is less common. Solid handling is most common in the northeastern and midwestern areas of the United States (USDA APHIS, 1997).

Fewer than 1 in 7 producers with fewer than 100 milk cows incorporate manure into soil within 24 hours of application. This ratio increases with herd size to more than one-third of producers with more than 500 cows incorporating manure into the soil in less than 24 hours (USDA APHIS, 1997).

Practice: Liquid Manure Application With Tankers

Description: Manure is applied to the soil surface or injected into the soil using spreader pump tankers or vacuum tankers. The spreader pump tanker is composed of a tank and pump mounted on a truck or wagon and requires a separate pump to load the manure. The vacuum tanker is mounted in a similar fashion but includes a pump that both loads and unloads the manure. Tankers usually include an agitating device (either auger or pump type) to keep solids suspended. Chopper pumps may be needed to prevent malfunctions caused by clogging with manure solids or fibrous material. A gated opening at the rear bottom of the tank either discharges the manure into a spinner for broadcasting or directs it through hoses to an injection device.

Application and Performance: Tankers are used for spreading slurry and liquid manure with less than 10 percent solids. Tankers are appropriate for moderate- to large-size operations. Thorough agitation prior to and during tanker loading is necessary to limit inconsistency of manure.

Tankers using injection systems can decrease runoff by causing minimal soil surface disturbance and maintaining a residue cover.

Advantages and Limitations: Broadcast tankers use less power and are less expensive than injector tankers but result in greater nutrient loss and odor problems. Tankers with injector systems decrease the loss of N and odorous gases to the atmosphere, and place nutrients near the plant's root zone where they are needed. Depending on the specific injector system, there is a significant decrease in disturbance to the soil surface and residue, limiting the potential for erosion. The weight of both types of tanker spreaders can cause soil compaction.

Operational Factors: Tankers must be cleaned and repaired regularly and should be protected from the weather. Vacuum pumps, moisture traps, pipe couplers, tires, and power shafts must be maintained regularly. Sand, often used in dairy freestall barns, can cause damage to the pumps. A vacuum tanker used for swine manure typically lasts 10 years (USDA NRCS, 1996a).

Demonstration Status: Slurry surface application is practiced at 46.0 percent of all grow-finish operations that apply wastes to land, while subsurface injection of slurry is practiced at 21.9 percent of these operations (USDA APHIS, 1996a).

Slurry surface application is practiced at 44.6 percent of dairy farms having more than 200 milk cows. Subsurface slurry application is practiced at only 8.6 percent of dairy operations of the same size (USDA APHIS, 1997).

Practice: Liquid Manure Application With a Drag-Hose System

Description: The drag-hose system pumps manure from the manure storage tank, or from a portable tank adjacent to the field, through a supply line that can be up to 3 miles long. The supply line attaches to a flexible hose that is pulled across the field by a tractor. Manure is fed through the hose to applicator implements similar to the types found on tankers. The manure can be broadcast or injected.

Application and Performance: Drag-hose systems are used for spreading slurry and liquid manure with less than 10 percent solids. They are appropriate for moderate- to large-size operations. Up to 40 acres of a field can be covered before the hoses must be repositioned. Thorough agitation prior to and during pumping is necessary to limit inconsistency of manure.

Use of certain injection systems can decrease runoff and erosion by causing minimal soil surface disturbance and maintaining residue cover.

Advantages and Limitations: The drag-hose system eliminates the need for repeated trips with a wagon or tanker to the manure storage site. It takes more initial setup time, but overall it has a smaller fuel and labor requirement than other spreader systems. Another benefit is decreased soil compaction and decreased road traffic. The weight of the liquid-based manure is dispersed over a much greater surface area and there is less equipment weight.

The person using a drag-hose system must be careful not to cut the line or break the umbilical cord during manure application.

For application rates under or around 2,000 gallons per acre, a drag-hose may not be practical because a certain amount of pressure is needed to keep the hose from collapsing.

Operational Factors: The application of drag-hose systems is limited by the distance the supply lines can travel, as well as by terrain.

Demonstration Status: Drag-hose systems are becoming increasingly popular as consolidation takes place in livestock production. It should be noted that the demonstration figures given in the tanker section also pertain to and include swine and dairy operations using the drag-hose system for slurry application.

Practice: Liquid Waste Application by Irrigation

Description: Irrigation systems use pipes to transfer liquid manure and wastewater from the containment facility (usually a lagoon) to the field. Wastewater can be transferred to the field through portable or stationary pipes or through an open ditch with siphon tubes or gated pipe. Manure is applied to the land using either a sprinkler or surface irrigation system.

Sprinkler systems most often used for manure disposal include handmove sprinklers, towlines, and big guns (MWPS, 1993). Surface irrigation systems include border, furrow, corrugation, flood, and gated pipe irrigation (MWPS, 1993). Descriptions of individual irrigation systems are included in Table 8-26.

Application and Performance: Irrigation systems are increasingly used by hog operations that spread over a million gallons of wastewater per year (USDA NRCS, 1996a). Most irrigation systems can handle manure that contains up to 4 percent solids (MWPS, 1993). Solid separation practices may be necessary to achieve this level.

Irrigation system selection varies according to the percentage of solids present in the manure, the size of the operation, the labor and initial investment available, field topography, and crop height.

Advantages and Limitations: Irrigation systems minimize soil compaction, labor costs, and equipment needed for large operations, and espread the manure more quickly than tank spreaders. Also, irrigation makes it possible to move large quantities of manure in a short time period. Finally, irrigation systems can be used to transport water during dry periods, and they are especially effective if crop irrigation systems are already in place.

However, N is easily lost to volatilization and denitrification if not incorporated into the soil. Odor from the wastewater can create a nuisance. Other problems that might alter the viability of the irrigation system include windy conditions that reduce the uniformity of spreading and increase odor problems off-site, the fact that soils might not be permeable enough to absorb the rapidly applied liquid, and a crop height that prevents application (MWPS, 1993; USDA NRCS, 1996a).

Although irrigation systems can reduce the overall labor cost of large spreading operations, labor communication and coordination are needed for initiating, maintaining, and ceasing an irrigation cycle. System operators must agitate manure before and during pumping to keep solids in suspension. Surface irrigation application must be closely monitored to control runoff and application uniformity. Pipes must be flushed with clean water after manure is applied to prevent clogs. Irrigation pipes are susceptible to breakage and should be regularly inspected.

Operational Factors: Single-nozzle sprinklers perform better where wind is a problem. Also, one large nozzle is less likely to plug than two smaller nozzles with the same flow capacity.

Demonstration Status: Irrigation of swine wastewater is practiced at 12.8 percent of grow-finish operations which dispose of their waste on owned or rented land. Nearly 80 percent of grow-finish operations with more than 10,000 head use irrigation for land application of manure.

Land application of wastewater by irrigation is also common at large dairy operations; 40.5 percent of producers with more than 200 cows used irrigation for manure application.

Practice: Center Pivot Irrigation

Description: Center pivots are a method of precisely irrigating virtually any type of crop (with the exception of trees) over large areas of land. In a center pivot, an electrically driven lateral assembly extends from a center point where the water is delivered, and the lateral circles around this point, spraying water. A center pivot generally uses 100 to more than 150 pounds of pressure per square inch (psi) to operate and therefore requires a 30- to 75-horsepower motor.

The center pivot system is constructed mainly of aluminum or galvanized steel and consists of the following main components:

- Pivot: The central point of the system around which the lateral assembly rotates. The pivot is positioned on a concrete anchor and contains various controls for operating the system including timing and flow rate. Wastewater from a lagoon, pond, or other storage structure is pumped to the pivot as the initial step in applying the waste to the land.
- Lateral: A pipe and sprinklers that distribute the wastewater across the site as it moves around the pivot, typically 6 to 10 feet above the ground surface. The lateral extends out from the pivot and may consist of one or more spans depending on the site characteristics. A typical span may be from 80 to 250 feet long, whereas the entire lateral may be as long as 2,600 feet.
- Tower: A structure located at the end point of each span that provides support for the pipe. Each tower is on wheels and is propelled by either an electrically driven motor, a hydraulic drive wheel, or liquid pressure, which makes it possible for the entire lateral to move slowly around the pivot.

The center pivot is designed specifically for each facility, based on wastewater volume and characteristics, as well as site characteristics such as soil type, parcel geometry, and slope. The soil type (i.e., its permeability and infiltration rate) affects the selection of the water spraying pattern. The soil composition (e.g., porous, tightly packed) affects tire size selection as to whether it allows good traction and flotation. Overall site geometry dictates the location and layout of the pivots, the length of the laterals, and the length and number of spans and towers. Center pivots can be designed for sites with slopes of up to approximately 15 percent, although this depends on the type of crop cover and methods used to alleviate runoff. Figure 8-15 presents a schematic of a central pivot irrigation system.

Application and Performance: Using a center pivot, nutrients in the wastewater, such as N and P, can be efficiently applied to the cropland to meet crop needs. With a known nutrient concentration in the wastewater, the animal waste can be agronomically applied to cropland very precisely by appropriately metering the flow based on crop uptake values. Agronomic application helps reduce runoff of pollutants from cropland and overapplication of nutrients to the soil.

Center pivot irrigation does not provide wastewater treatment. Nutrients, pathogens, and other pollutants simply pass through and are distributed by the center pivot.

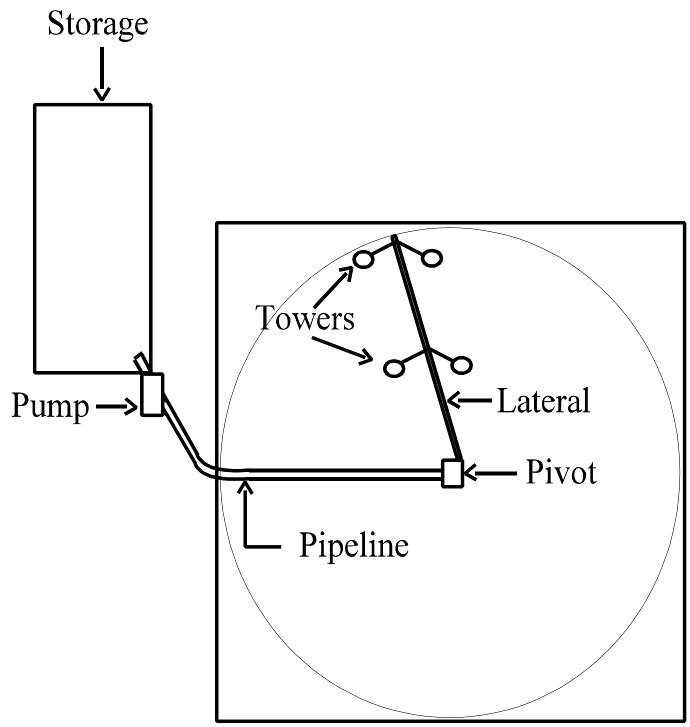

Figure 8-15. Schematic of a center pivot irrigation system.

Operational Factors: According to one manufacturer (Valley Industries), center pivot systems can be designed to handle wastes containing up to 5 percent solids. Thus, it may be necessary to have a solids removal step (e.g., settling basin or mechanical separator) prior to wastewater storage and subsequent land application. It is also a good practice to flush the pipes with clean water following waste application to prevent clogging of pipes and sprinkler nozzles.

Salt accumulation in the soil may be an issue, especially in drier climates. Salt concentrations in the wastewater and soil should be monitored to determine if salinity is a problem at a particular site.

Odor may also be a problem when using a center pivot to apply liquid animal wastewater to the land. However, techniques can be implemented to reduce the dispersion of the waste stream into the wind, such as positioning the sprinklers closer to the ground, using low-trajectory sprinklers, and using low-pressure sprinklers. Proper timing of application based on environmental conditions (i.e, monitoring wind velocity and direction) can also help reduce odor problems.

Application efficiency (i.e., the percentage of the total water pumped that reaches the ground or plant surface) depends primarily on climatic factors such as ambient temperature, relative humidity, and wind velocity and direction. A typical application efficiency is about 90 percent, provided that at least 1 inch of water is applied.

Advantages and Limitations: As noted above, a center pivot is an effective means of distributing liquid animal waste and supplying nutrients to cropland at agronomic rates. The center pivot design is fairly flexible and can be adapted to a wide range of site and wastewater characteristics. Center pivots are also advantageous because they can distribute the wastewater quickly, uniformly, and with minimal soil compaction. Center pivots have low operating labor costs compared with manual application methods.

One limitation of a center pivot system is the relatively high capital investment it entails. Other limitations may result from sloped lands, high solids content of waste, and potential odor problems. Center pivots are also vulnerable to high winds and lightning. Additionally, swine waste is fairly corrosive so the waste either needs to be treated to reduce its corrosivity or system components such as piping need to be corrosion-resistant (e.g., galvanized or lined pipe). Another concern with center pivot spraying is N loss through volatilization, which is estimated to be as high as 25 percent (USDA NRCS, 1996a).

Demonstration Status: Center pivots have been in operation in the United States since the 1950s. In the 1970s, center pivots started to become popular as a means of land-applying wastewater from municipal, industrial, and agricultural sources. Today, center pivots are widely used in agriculture including land application of wastewater from swine, beef, and dairy facilities.

Practice: Calibration of Application Equipment

Description: Three conditions must be addressed to ensure that application rates are accurate (Schmitt and Rehm, 1998). First, analysis of a properly collected manure sample is needed to quantify nutrient content. Second, the rate of manure being applied to the field must be known and kept constant; calibration must be conducted for all manure applications. Third, the application or spread pattern of the manure must be uniform throughout the field.

Manure spreaders can discharge manure at varying rates, depending on forward travel speed, power take-off speed, gear box settings, discharge opening, width of spread, overlap patterns, and other parameters (USDA NRCS, 1996a). Calibration defines the combination of settings and travel speed needed to apply manure at a desired rate.

The actual rate at which a spreader applies manure will differ from the manufacturer's estimates, so calibration is necessary to ensure accurate manure application (Hirschi et al., 1997). Two basic methods, the load-area method and weight-area method, can be used for calibration (USDA NRCS, 1996a). In the load-area method, the amount of manure in a loaded spreader is measured and the rate is determined based on the number of loads needed to cover a known area of land. In the weight-area method, manure spread over a small surface is weighed, and the weight per unit area is calculated. Although there are only two basic calibration methods, a variety of specific calibration procedures are available, many of which require knowledge of the tank's or spreader's load size (Hirschi et al., 1997).

For solid systems, the spreader can be weighed before and after going to the field to determine the weight of manure spread (Schmitt and Rehm, 1998). Using the width of the spread manure and the distance traveled per load, the weight of manure applied per acre can be calculated. Alternatively, the rate per acre can be estimated using the weight of a full load as determined with a scale, the number of loads per field, and the field acreage. A third method is to lay a tarp or sheet of strong plastic in a field and make a pass over it with the spreader. The manure deposited on the tarp or sheet of plastic is then collected and weighed. Using the area of the tarp or plastic sheet, the weight of manure applied per unit area can be determined. Because of the small area involved in this method, there is high variability, so multiple samples should be collected. Knowledge of the variability in application rate, however, is useful information when one considers that uniform application is desired.

For liquid systems, calibration requires that the manure be measured in gallons per acre. The best way to determine the volume applied is to weigh the tank before and after spreading the manure and then to divide by the density of liquid manure (8.3 lb/gallon) (Schmitt and Rehm, 1998). Combining this information with the width of the spread pattern and the distance the tank travels before emptying the tank will provide the data necessary to determine the application rate. A second option for liquid systems that does not involve a scale is to fill the tank, count the number of loads applied uniformly per unit area of field, and then calculate the volume per acre using the known volume of a filled tank.

Manure application rates must often be adjusted to match the recommended rate (Schmitt and Rehm, 1998). The most common method of changing the application rate is to change the speed at which the spreader is driven across the field. Solid manure equipment may also have an adjustment that changes the chain speed in the box, thereby changing the application rate. Liquid manure application equipment may have valve opening adjustments to alter the rate. Because the flow rate may change from the beginning to the end of a tank of liquid manure, some equipment uses pressurized tanks, flow pumps, and newer distributor designs to address the problem of variable flow. Once equipment is adjusted or driving rates are changed to achieve new application rates, recalibration is necessary to maintain the accuracy in calculating application rates.

A wide range of water measurement devices is available including some that primarily measure rate or volume of flow, and some that primarily measure rate of flow (USDA NRCS, 1997). A suitable measuring device, calibrated in the laboratory or field, can be used to determine total application volume, which, combined with the measured nutrient concentration in the applied liquid, can be used to determine the quantity of nutrients applied to the receiving land. Dividing the quantity of nutrients by the land acreage provides the nutrient application rate. Rain gauges can be used in the field to check the uniformity of application of sprinkler systems.

Application and Performance: Calibration is a practice that applies to all farms and all land on which manure is applied, and it can be performed by the producer with little training.

Calibration of manure application equipment provides no direct treatment or reduction of any pollutants, but it is essential to accurate application of manure.

Planning manure application based on plant P requirements may result in application rates below the capability of some manure-spreading equipment. However, a general consensus among selected extension service specialists and equipment manufacturers indicates that box spreaders and liquid spreaders can be reliably calibrated to application rates as low as 2 to 3 tons/acre and 1,500 to 2,000 gallons/acre, respectively (Tetra Tech, 2001). This will allow for P-based application of manure under most conditions.

Advantages and Limitations: Calibrating manure applicators helps to ensure that applications are adequate for crop needs, but not excessive and a source of water quality problems (USDA NRCS, 1995).

Calibration of spreaders should take less than 1 hour (Hirschi et al., 1997).

Operational Factors: Agitation of liquid manure is extremely important prior to land application. Inadequate agitation results in inconsistent nutrient content and makes the manure difficult to credit accurately as a valuable fertilizer source. A lack of uniform application can also lead to nutrient excesses and deficiencies, yield loss, and increased incidence of ground and surface water contamination.

Solid manure is broadcast using box-type or open-tank spreaders. Spreader mechanisms include paddles, flails, and augers. Rate calibration of box spreaders is often difficult, resulting in less uniform application, difficulty crediting fertilizer values, nutrient excesses and deficiencies resulting in yield loss, and increased potential for ground and surface water contamination.

Windy conditions can affect the uniformity of applications with sprinklers. System operators must agitate manure before and during pumping to keep solids in suspension. Surface irrigation application must be closely monitored to control runoff and application uniformity.

Demonstration Status: Calibration of manure spreaders is a topic that has been addressed in technical guidance and extension service publications across the United States. Information regarding the extent to which farmers calibrate manure applicators was not found, but information regarding the extent to which manure is sampled is probably indicative of the maximum extent to which calibration is practiced.

Manure sampling is practiced widely across the United States, but many farmers still do not test manure or employ an N credit from manure when determining commercial fertilizer needs (Stevenson, 1995). A 1995 survey of 1,477 swine producers showed that 92 percent of operations had not had their manure tested for nutrients within the past 12 months (USDA NAHMS, 1999). Approximately 6 percent had tested their manure for nutrients once during the past 12 months, while another 1.5 percent had tested it twice. These findings are supported by a crop nutrient management survey in which only 2 to 17 percent of respondents in various regions stated that they factored manure nutrient value into their NMPs (Marketing Directions, 1998).

Practice: Transportation of Waste Off Site

Description: Animals at an AFO generate a large amount of liquid and semi-solid waste every day. This waste is rich in nutrients and can be applied to cropland as fertilizer. Often, there are more nutrients present in the waste than can be used by the crops on site. In this case, or in the case where the operation has no cropland, the waste must be transported off site to a facility that can manage the waste properly.

Application and Performance: At an agronomic application rate, some facilities will be able to apply all produced animal waste to on-site cropland. However, some AFOs do not have sufficient land to accommodate all of the waste on site. These facilities must transport the waste off site using farm equipment or by hiring a contractor to haul the waste away. Hiring a contractor is a viable option for operations that do not have the capital to purchase their own trucks to haul excess waste.

Transportation does not "treat" the waste; however, it does move the waste off the farm. By transporting the waste off site, the operation prevents potential pollution by limiting the time that waste remains on the feedlot, and thereby reduces the likelihood of nutrients, pathogens, and other pollutants being carried from the stockpile by rainfall, runoff, seepage, or volatilization.

The cost of transporting waste off site is determined by the quantity and consistency of the waste as well as the distance the waste must be transported to be managed properly. Semisolid or liquid manure can be more expensive to haul because it requires a tanker truck for transport and is heavier due to a higher moisture content. Solid waste is easier to handle and is therefore less expensive to transport. Because the amount of manure transported off site is dictated by the amount that is applied to on-site cropland, it is expected that facilities will apply semisolid or liquid waste to fields before they apply solid waste. The distance manure must be hauled to be properly managed depends on the proximity of operations that need additional nutrients.

Advantages and Limitations: One advantage of transportation as a waste management practice is not having to treat and dispose of the waste on site. Excess waste at one operation can be transported to and used as fertilizer at another operation, distributing the nutrient load among cropland at multiple facilities. In addition, in some cases the operation owner is able to sell the waste to a compost or fertilizer facility or another farm operation. This income can potentially offset the cost of the transportation.

It is important to consider the potential nonwater-quality impacts that result from increased diesel truck traffic. EPA assumes that some facilities do not currently apply at agronomic rates, and therefore, there will be an increase in excess waste once operations begin applying agronomically. This increase in excess waste requires an increase in truck traffic, causing an increase in exhaust emissions from the trucks transporting the waste.

Operational Factors: There are three operational factors considered in determining transportation practices: the amount of waste to be transported, type of waste to be transported (semisolid or liquid), and the distance from the operation to the off-site destination. The amount of waste to be transported per year determines the size of the trucks that are required and the time that is spent hauling the waste. The consistency of the waste determines the type of truck that is used and the cost of handling that waste. The distance of the off-site facility from the operation determines how far the waste must be hauled and the cost of transporting the waste. The regional location of the operation also plays a role in determining how frequently the waste needs to be transported (e.g., if there are seasons in which the waste is not applied, due to climate or crop cycles).

Demonstration Status: It is not known what portion of AFOs have their waste hauled by contractors and what portion opt to own and operate their own vehicles. It is assumed that each operation chooses the most economically beneficial option, which in most cases is to contract-haul the waste off site.

Beef: Eleven percent of beef feedlots across the country currently sell excess manure waste, and 27 percent give away their manure waste. Approximately 3 percent of beef operations currently pay to have manure waste hauled off site (USDA APHIS, 2000).

Dairy: In 1997, 23 percent of dairies with more than 200 head give away some portion of their manure waste, and 18 percent sold or received compensation for their manure waste (USDA APHIS, 1997).

Poultry: Most poultry operations are currently transporting their waste off site. Nationwide, broiler operations transport about 95 percent of their waste. The percentage of layer operations transporting waste varies by region: 40 percent in the Central Region, 100 percent in the Midwest Region, 75 percent in the Mid-Atlantic Region, 95 percent in the Pacific Region, and 50 percent in the South Region (USDA NAHMS, 2000).

Swine: Four to 6 percent of swine operations currently transfer some manure off site (USDA APHIS 1995), while 23 percent of small swine operations and 54 percent of large swine operations do not have enough land to apply agronomically under an N-based application scenario (Kellogg et al., 2000).

8.4.4 Runoff Control

Fields to which manure is to be applied should have an appropriate conservation management system in place to prevent nutrients from leaving the landscape. In the event of mismanaged manure application, such as applying manure prior to an unexpected rainfall, conservation practices that reduce soil erosion and water runoff, including grassed waterways, sediment basins, and buffers, can help to minimize the transport of nutrients off-site.

Susceptibility to erosion and the rate at which it occurs depend on land use, geology, geomorphology, climate, soil texture, soil structure, and the nature and density of vegetation in the area. Soil erosion can be caused by wind or water and involves the detachment of soil particles, their transport, and their eventual deposition away from their original position. Movement of soil by water occurs in three stages: (1) soil particles, or aggregates, are detached from the soil surface when raindrops splash onto the soil surface or are broken loose by fast-moving water; (2) the detached particles are removed or transported by moving water; and (3) the soil particles fall out of suspension when the water velocity slows, and are deposited as sediment at a new site.

Soil erosion caused by water is generally recognized in four different forms: sheet erosion, rill erosion, ephemeral erosion, and gully erosion. Erosion occurs during or immediately after rainstorms or snowmelt. Sheet erosion is the loss of a uniform, thin layer of soil by raindrop splash or water runoff. The thin layer of topsoil, about the thickness of a dime, disappears gradually, making soil loss visibly imperceptible until numerous layers are lost.

Rill erosion often occurs in conjunction with sheet erosion and is a process in which numerous channels, a few inches deep, are formed by fast-flowing surface water. The detachment of soil particles results from the shear stress that water exerts on the soil. The shear stress is related to the velocity of water flow. Therefore, when water gains velocity on steeper and longer slopes, rill erosion increases. Sheet and rill erosion carry mostly fine-textured small particles and aggregates. Fine-textured particles contain the bulk of plant-available nutrients, pesticides, and other absorbed pollutants because there is more surface area per given volume of soil.

Ephemeral erosion occurs when concentrated water flows through depressions or drainage areas. The water forms shallow channels that can be erased by tillage practices. Ephemeral erosion is a precursor to gully erosion if left untreated.

Once rills become large enough to restrict vehicular access, they are referred to as gullies. Gully erosion results from the removal of vast amounts of topsoil and subsoil by fast-flowing surface water through depressions or drainage areas. Gully erosion detaches and transports soil particles that are the size of fine to medium sand. These larger soil particles often contain a much lower proportion of absorbed nutrients, organic material, and pollutants than the fine-textured soil particles from sheet and rill erosion.

It is not practical to prevent all erosion, but the preferred strategy is to reduce erosion losses to tolerable rates. In general terms, tolerable soil loss, sometimes referred to as T, is the maximum rate of soil erosion that can occur while still maintaining long-term soil productivity. These tolerable soil loss levels determined by USDA NRCS are based on soil depth and texture, parent material, productivity, and previous erosion rates. The levels range from 1 to 5 tons/acre/year (2 to 11 metric tons/hectare/year). The strategies for controlling erosion involve reducing soil detachment and reducing sediment transport.

Surface water runoff contains pollutants including nutrients (e.g., N and P) and some pathogens. Excessive manure application can cause increased nitrate concentration in water. If the rate of manure application exceeds plant or crop N needs, nitrates may leach through the soil and into ground water. Nitrates in drinking water are the cause of methemoglobinemia ("blue baby syndrome").

Agricultural nonpoint source pollutants, such as those contained in manure, can migrate off the field and into surface water through soil erosion. Excessive nutrients attached to the sediment and carried into surface water bodies can cause algae blooms, fish kills, and odors. Combinations of BMPs can be used to protect surface water by reducing the amount of nutrient-rich sediment that is detached and transported away from a field.

A BMP is a practical, affordable strategy for conserving soil and water resources without sacrificing profitability. BMPs that reduce soil erosion are part of a broader integrated soil management system that improves overall soil health and water quality. In addition, BMPs benefit crop production in a variety of ways such as improved drainage, improved moisture-holding capacity, pest management, and ultimately, long-term profitability.

Runoff Control Practices

Livestock manure can be a resource if managed correctly. A large proportion of livestock manure is returned to the land as organic fertilizer. Unfortunately, if manure is handled incorrectly, it can become a source of pollution that ends up in streams or lakes. The nutrients in animal manure, especially P and N, can cause eutrophication of water.

Eutrophication is a natural process that takes place in all surface water bodies. The natural process is accelerated by increased sediment and nutrient loading in the water. It is characterized by an aquatic environment rich in nutrients and prolific plant production (algae). As a result of nutrient enrichment, the biomass of the water body increases and eventually produces a noxious environment that accelerates algae growth, leading to a reduction in water quality.

The transport of manure nutrients to streams and lakes is very similar to the transport of nutrients from commercial fertilizers. N is water-soluble and moves largely with the flow of water. Injecting or incorporating manure into the land however, significantly reduces the amount of N transported with runoff. Yet N can still move with ground water or subsurface water flow.

Reducing P levels in surface water is the best way to limit algae growth. Most of the P transported by surface water is attached to sediment particles. Therefore, reducing soil erosion is essential to protecting water quality.

Manure from properly managed grazing animals has little detrimental effect on water quality. In a grazing system, 100 percent of the manure generated by the grazing animal is applied to the land daily. In addition, the runoff from a well-managed grazing system carries very little sediment or nutrients; however, manure from feedlots or overgrazed pastures is more susceptible to runoff and sediment delivery (Hatfield, 1998).

Practices to Reduce Soil Detachment

The most effective strategy for keeping soil on the field is to reduce soil detachment. Crop canopy and crop residue on the soil surface protect against soil detachment by intercepting falling raindrops and dissipating their energy. In addition, a layer of plant material on the ground creates a thick layer of still air next to the soil to buffer against wind erosion. Keeping sufficient cover on the soil is therefore a key factor to controlling both wind and soil erosion.

Conservation practices, such as no-tillage, preserve or increase organic matter and soil structure. No-tillage reduces soil detachment and transport and results in improved water infiltration and surface stability. No-tillage also increases the size of soil aggregates, thereby reducing the potential of wind to detach soil particles.

Combinations of the following practices can be used to effectively reduce soil detachment by wind or water erosion:

- Conservation tillage (including mulch-tillage, no-tillage, strip-tillage, and ridge-tillage)
- Cover crops
- Contour stripcropping/contour buffer strips
- Crosswind trap strips
- Crosswind ridges
- Crosswind stripcropping
- Crop rotation (including small grains, grasses, and forage legumes)
- Chemical fallow or no fallow
- Grassed waterways
- Pasture management
- Shelterbelts/field windbreaks

Practices to Reduce Transport Within the Field

Sediment transport can be reduced in several ways including the use of vegetative cover, crop residue, and barriers. Vegetation slows runoff, increases infiltration, reduces wind velocity, and traps sediment. Strips of permanent vegetation (e.g., contour strip cropping and contour grass strips) slow runoff and trap sediment. Contour farming creates rough surfaces that slow surface water velocity and reduce transport of sediment.

Reductions in slope length and steepness reduce sediment-carrying capacity by slowing velocity. Terraces and diversions are common barrier techniques that reduce slope length and slow, or stop, surface runoff.

By decreasing the distance across a field that is unsheltered from wind, or by creating soil ridges and other barriers, sediment transport by wind can be reduced.

Combinations of the following practices can be used to effectively reduce soil transport by wind or water erosion:

- Buffers
  - Shelterbelts/field windbreaks
  - Contour strip cropping/contour buffer strips
  - Riparian buffers
  - Filter strips
  - Grassed waterways
  - Field borders
  - Crosswind trap strips
  - Contour or cross slope farming
- Conservation tillage, (including mulch-tillage, no-tillage, strip-tillage, and ridge-tillage)
- Crop rotation (including grains, grasses and forage legumes)
- Chemical fallow or no fallow
- Cover crops
- Crosswind ridges
- Crosswind stripcropping
- Diversions
- Ponds
- Sediment basins
- Terraces

Practices to Trap Sediment Below the Field or Critical Area

Practices are also typically needed to trap sediment leaving the field before it reaches a wetland or riparian area. Deposition of sediment is achieved by practices that slow water velocity and increase infiltration. Combinations of the following practices can be used to effectively trap sediment below the field or critical area:

- Contour strip cropping/contour buffer strips
- Crosswind traps strips
- Crosswind stripcropping
- Diversions
- Filter strips
- Grassed waterways
- Ponds
- Riparian buffers
- Sediment basins
- Shelterbelts/field windbreaks
- Terraces
- Wetlands

Practices That Have Multiple Functions to Reduce Detachment, Transport, and Sediment Delivery

Many conservation practices have multiple functions. Table 8-27 identifies the primary functions of each practice.

Considerations in BMP Selection

The selection of the most effective BMPs to protect water quality depends on the objectives of the farmer and the specific site conditions of individual fields. The best combination of BMPs for any specific field depends on factors such as the following:

- Rainfall—more rainfall means more erosion potential.
- Soil type—some soils erode more easily than others.
- Length of slope—a longer slope has increased potential for erosion due to increased runoff energy.
- Steepness of slope—steep slopes erode more easily than gradual slopes.
- Ground cover—the more the soil is covered with protective grasses, legumes, or crop residues, the better the erosion control.

Table 8-27. Primary Functions of Soil Conservation Practices.

Conservation Practice	Detachment	Transport	Sedimentation
Chemical fallow or no fallow	O	O	
Conservation Tillage (mulch-till, ridge-till, strip-till, and no-till)	X / O	X / O	
Contour or Cross Slope		X	
Contour Stripcropping/Contour Buffer Strips	X	X	X
Cover Crops	X	X	
Crop Rotation (including small grains, grasses, and forage legumes)	X	X	
Crosswind Trap Strips	O	O	O
Crosswind Ridges	O	O	
Crosswind Stripcropping	O	O	O
Diversions		X	X
Field Borders		X	
Filter Strips		X	X
Grassed Waterways	X	X	X
Ponds		X	X
Riparian Buffers		X	X
Sediment Basins		X	X
Shelterbelts/Field Windbreaks	O	O	O
Terraces		X	X
Wetlands			X

Note: X = water erosion; O = wind erosion

Other factors to consider include:

- Type of farm operation.
- Size of the field or farm.
- Nutrient levels of manure.
- Nutrient requirements of crops.
- Proximity to a waterway (stream, lake), water source (drinking water well), or water of the state.
- Relationship of one erosion control practice to other supporting conservation practices.
- Conservation plan if required by USDA NRCS.
- Economic feasibility.

Agricultural nonpoint source runoff management practices that protect natural resources generally have two principal goals: (1) to reduce runoff volume, and (2) to contain and treat agricultural runoff. An effective runoff control system meets both of these goals by integrating several practices in a way that meets the needs of the particular management system. Strategies for controlling erosion involve reducing soil detachment, reducing sediment transport, and trapping sediment before it reaches a water body.

Soil erosion can be reduced by using a single conservation practice or a combination of practices. The following section explains conservation practices that can be used separately or in combination to reduce manure runoff and improve water quality.

Practice: Crop Residue Management

Description: Tillage operations influence the amount and distribution of plant residues on or near the soil surface. In the past, the preferred system, conventional tillage, was designed to bury as much residue and leave the soil surface as smooth as possible, which unfortunately led to significant soil erosion. In contrast, residue management systems are designed to leave residue on top of the soil surface to increase infiltration and reduce erosion. In general, the more residue left on the soil surface, the more protection from erosion the soil has. The amount of crop residue left after planting depends on the original amount of residue available, the tillage implements used, the number of tillage passes, and the depth and speed at which tillage was performed.

Crop residue management has been designated by many terms since its inception. The NRCS and the Conservation Technology Information Center (CTIC) have adopted the following terms and definitions.

- Conventional-till: Tillage types that leave less than 15 percent residue cover after planting. Generally this involves plowing or intensive (numerous) tillage trips.
- Reduced-till: Tillage types that leave 15 to 30 percent residue cover after planting.
- Conservation tillage: Any tillage and planting system that leaves 30 percent, or more, of the ground covered after planting with the previous year's crop residues. Conservation tillage systems include mulch-till, no-till, strip-till, and ridge-till.
- Mulch-till: Full-width tillage that disturbs the entire soil surface is performed prior to and during planting. Tillage tools such as chisels, field cultivators, discs, sweeps, or bands are used. Weed control is accomplished with herbicides and/or cultivation.
- No-till and strip-till: The soil is left undisturbed from harvest to planting except strips up to one-third of the row width (strips may involve only residue disturbance or may include soil disturbance). Planting or drilling is accomplished using disc openers, coulter(s), row cleaners, in-row chisels, or roto-tillers. Weeds are controlled primarily with herbicides. Cultivation may be used for emergency weed control. Other common terms used to describe no-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

- Ridge-till: The soil is left undisturbed from harvest to planting except for strips up to one-third of the row width. Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is completed with sweeps, disc openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weeds are controlled with herbicides (frequently banded) and/or cultivation. Ridges are rebuilt during cultivation (CTIC, 1998a).

No-till, strip-till, and ridge-till provide the most soil conservation protection.

Application and Performance: Plant residues can aid in soil erosion control. Residues can protect the soil from the time of rowcrop harvest through the time the succeeding crop has developed sufficiently to provide adequate canopy protection. Conservation tillage reduces soil erosion by reducing detachment. It also reduces transport by minimizing soil crusting and increasing infiltration, which reduces runoff. The residue acts as small dams, slowing the movement of water across the field and reducing its ability to carry soil particles.

Conservation tillage increases the size of soil aggregates, which reduces the potential of wind to detach soil particles and thereby reduces wind erosion. The residue also slows the wind speed at ground level, reducing its ability to carry soil particles.

Advantages and Limitations: Benefits other than soil conservation that can be gained include the following:

- Reduced tillage costs
- Reduced labor
- Reduced runoff
- Reduced fuel use
- Reduced machinery wear
- Reduced PM in air from wind erosion
- Increased soil moisture
- Improved surface water quality
- Increased water infiltration
- Decreased soil compaction
- Improved soil tilth
- Increased populations and diversity of wildlife
- Increased sequestration of greenhouse gases (carbon dioxide)

Normally, the cost of changing from a conventional tillage system to a conservation tillage system is minimal if current equipment can be adapted. The cost of changing is associated with the purchase of additional attachments for equipment and depends on the type of conservation tillage to be done (no-till, ridge-till, mulch-till, and so forth). The incremental cost of these attachments may range from $1.00 to $3.00/acre/year. However, if equipment is impossible to adapt or needs extreme adaptations, the investment in changing to a conservation tillage system can become significant.

Intensive overall management is critical to the success of a no-tillage or ridge-tillage system. Constraints and challenges within the system should be considered before choosing a no-tillage or ridge-tillage method. The most successful system needs a strong commitment from a knowledgeable manager. Management considerations and system constraints include the following:

- Manure application and the need to incorporate.
- Alternative methods or equipment modifications for nutrient placement.
- The need to apply or incorporate lime.
- Planter and harvesting attachments need to be correctly installed and maintained.
- Critical timing of field operations.
- Greater reliance on herbicides for weed control.
- Shifts in weed populations and weed varieties.
- Increased N requirements due to an increase in residue that has a high C:N ratio.
- Delays in spring field operations due to cold, wet soils.
- Delayed seed germination due to cold, wet soils.

Conservation tillage can be used on cropland fields where excess sheet and rill erosion and wind erosion are a concern. Conservation tillage is most effective when used with other supporting conservation practices such as grassed waterways, contouring, and field borders.

Operational Factors: In the northern areas of the United States where soil temperatures stay colder for longer periods of time, no-till may not be as well adapted as some of the other conservation tillage systems. In these areas strip-till or ridge-till may be better options.

Demonstration Status: Conservation tillage is used across the United States and in conjunction with all the major crops.

Practice: Crop Rotation

Description: Crop rotation is the practice of alternating high-residue crops with low-residue crops on the same piece of land, from year to year. Although crop rotations can vary significantly, a typical rotation giving significant erosion protection could include high-residue-producing crops like small grains and hay, and low-residue-producing row crops like corn and soybeans. A typical rotation using these crops would be corn-soybeans-corn-small grain-hay-hay.

Application and Performance: The soil conservation purpose of a crop rotation is to alternate crops that have high erosion potential with crops that have low erosion potential because it is the average soil loss over time that is critical. It is expected that in those years when low-residue crops are planted, significant erosion may occur. However, in years when high-residue crops are planted, very little erosion will occur. Therefore, the average rate of soil erosion throughout the rotation sequence will be significantly lower than it would be if only low-residue crops had been planted. A rotation of corn-soybeans-corn-small grain-hay-hay could be expected to reduce soil erosion by 50 percent as compared with just corn and soybeans, depending on the tillage system (Renard et al, 1997).

Advantages and Limitations: Weather conditions, unexpected herbicide carryover, and marketing considerations may result in a desire to change a scheduled crop rotation. Since most farmers want to balance production acres of different crops, they need to have the flexibility of changing the rotations in one field because of an unexpected condition in another field.

Operational Factors: Crop rotation can be used where sheet and rill erosion is a problem on cropland. Crop rotation works best with other supporting conservation practices such as conservation tillage, contouring, and grassed waterways. A market or use for the small grains or hay is needed before farmers will adopt the use of crop rotation.

Demonstration Status: The use of crop rotations is generally adopted in those regions that have dairy herds because of the need for hay.

Practice: Contouring and Cross-Slope Farming

Description: Contour farming is the practice of tilling, planting, and cultivating crops around a slope on a nearly level line that slowly grades water to a nonerosive area that can handle concentrated flow. In gentle rains, the contoured rows are able to slowly grade the water to a nonerosive area such as a grassed waterway or field border. In heavier rains, when the water runs over the tops of the rows, the rows serve as mini dams to slow the water. Slowing the water allows for more infiltration of water into the soil profile and reduces sediment transport in the field.

On some slopes, strict contour farming that results in sharp turns and endless point rows is impractical. Farm machinery may be too large to accommodate the tight turns and numerous point rows and increases the amount of time required to complete field operations. In this case, an alternative to contouring is cross-slope farming, which allows greater deviation from the contour line. Although cross-slope makes farming easier, it is generally only half as effective as contouring in reducing soil erosion.

In some areas of the country, using a rollover plow on the contour is beneficial to turn the soil uphill while performing conventional tillage. By using a rollover plow on the contour, soil is mechanically moved up-slope.

To allow for the removal of water in a concentrated flow, waterways need to be seeded, or shaped and seeded.

Application and Performance: Contouring can reduce soil erosion by 25 to 50 percent and cross-slope farming can reduce soil erosion by 10 to 25 percent depending on slope length, slope steepness, field roughness, and row grade (Renard et al, 1997).

Advantages and Limitations: Because contouring and cross-slope farming slow the runoff of water, water infiltration is increased and soil erosion is reduced. The increased water infiltration may also mean more available subsoil moisture during the growing season. Horsepower requirements may also be lower when farming on the contour or cross-slope.

On longer slopes, both contouring and cross-slope farming become less effective and should then be used in combination with a supporting conservation practice such as terraces or contour strip cropping.

The major disadvantage of contouring, and to a lesser extent cross-slope farming, is the increased time needed to perform the tilling, planting, spraying, cultivating, and harvesting operations. Contouring may require 25 to 50 percent more time as compared with farming straight rows. Cross-slope farming may require 10 to 25 percent more time as compared to farming straight rows. This increased time leads to higher labor, fuel, and equipment costs on a per acre basis.

Operational Factors: Contouring or cross-slope farming can be used on most slopes on which row crops are planted.

Demonstration Status: Contouring or cross-slope farming is widely adopted across the United States.

Practice: Contour Stripcropping/Contour Buffer Strips

Description: Contour stripcropping is a system of growing crops in approximately even-width strips or bands on the contour. The crops are arranged so that a strip of meadow or close- growing crop is alternated with a strip of row crop. Contour stripcropping combines the soil protection of both contouring and crop rotation. The widths of rowcrop strips should equal the widths of the hay or small grain strips. The strips of hay or small grain slow water flow and trap sediment from the row crop strips above them.

Contour buffer strips can be used when a higher percentage of row crop acres are needed. A contour buffer strip system allows for the hay or small grain strips to be narrower than the strips of row crop. Because a contour buffer strip system results in more row crop acres, it is less effective than contour strip cropping in reducing soil erosion.

The strip width depends on the steepness of the slope and the management practices being used. It is also designed to accommodate the width of equipment (planters, sprayers, and harvesters). An even number of equipment passes along each strip which improves field operation efficiency by starting and finishing a pass at the same end of the field. Grassed field borders and grassed waterways are an integral part of any stripcropping system. They provide access lanes and safe areas for concentrated water runoff.

Application and Performance: Contour stripcropping is very effective in reducing sheet and rill erosion. It can reduce soil loss by as much as 75 percent, depending on the type of crop rotation and the steepness of the slope. Depending on the width of the grass strip and the row crop strip, and the steepness of the slope, contour buffer strips can reduce sheet and rill erosion by as much as 75 percent or as little as 20 percent (Renard et al., 1997).

Advantages and Limitations: Choosing to use contour stripcropping or contour buffer strips is an excellent conservation practice for a farmer who can use small grains or hay. Instead of planting one entire field to small grains or hay and another entire field to row crops, strips of hay or grain can be alternated, thereby reducing soil erosion.

Effective stripcropping systems require strips that are wide enough to be farmed efficiently. If possible, consolidation of fields may be necessary. The major disadvantage of using contour stripcropping or contour buffer strips as an erosion control practice is the same as that of contouring: increased time to perform the field operations (e.g., tillage, planting, spraying, and harvesting). These practices may require 25 to 50 percent more time than farming straight rows. Increased time used in field operations leads to higher labor, fuel, and equipment costs on a per acre basis.

Operational Factors: Contour stripcropping and contour buffer strips can be used where sheet and rill erosion are a problem in cropland, and they work best with other supporting conservation practices such as conservation tillage and grassed waterways. The use of contour stripcropping and contour buffer strips is practical only if there is a market or use for the small grains or hay.

Demonstration Status: The use of crop rotations is generally adopted in those regions that have dairy herds, beef cattle, or sheep because of the need for hay.

Practice: Grassed Waterways

Description: Grassed waterways are areas planted to grass or other permanent vegetative cover where water usually concentrates as it runs off a field. They can be either natural or man-made channels. Grass in the waterway slows the water as it leaves the field. Grassed waterways can serve as safe outlets for graded terraces, diversions, and contour rows. They can also serve as passageways for water that enters a farm from other land located higher in the drainage basin. Grassed waterways significantly reduce gully erosion and aid in trapping sediment.

Application and Performance: Grassed waterways protect the soil from erosion at points of concentrated water flow. They are designed to safely carry runoff water from the area that drains into them to a stable outlet. Small waterways are designed in a parabolic shape and are built wide enough and deep enough to carry the peak runoff from a 24-hour storm that would be expected to occur once every 10 years.

The decision to mow or not to mow grassed waterways depends on supporting conservation practices and other management concerns. To increase the lifespan of the waterway, it is best to mow or clip the grass in the waterway. If grasses are allowed to grow, the flow rate of the waterway is slowed, increasing the rate of sedimentation in the waterway, which in turn increases the cost of maintaining the waterway. If waterways are clipped, however, water flows faster and the sediment is carried farther down slope before being dropped out. If manure is applied in the waterway drainage area, grassed waterways should not be mowed. To prevent excessive sedimentation in the unmowed waterways, other supporting conservation practices, such as contouring, conservation tillage, or barrier systems, should be in place.

Advantages and Limitations: The goal of a waterway design is to protect against soil loss while minimizing siltation and gullying in the waterway. Gullies can form along the side of a waterway if the water does not enter the waterway or if the runoff spills out of the waterway and runs parallel to it. This can be caused by inadequate design (too shallow or too narrow) or inadequate maintenance, and in some cases by flooding. Even under the best conditions, grassed waterways tend to either silt in or develop channels or gullies. Timely maintenance and repairs can prevent major reconstruction. Silt can be cleaned out and small gullies can be filled in. However, if the waterway is damaged too badly, it will need to be completely reshaped and reseeded. Often heavy equipment such as a bulldozer or a scraper is required.

Grassed waterways permanently take land out of cereal and row crop production, but they can be harvested for forage production if the farmer has a use or market for the forage and the equipment to harvest the forage.

The cost of waterway construction depends on the depth and width of the waterway. It ranges from $1.50 to $3.50 per linear foot, with mulch and seed. In addition to the construction cost, there is a maintenance cost. The cost to maintain a waterway is highly variable depending on drainage area size, soil type, grade of the waterway, and level of control of soil erosion above the waterway. Some waterways can function for 10 years without maintenance, whereas others need maintenance on a yearly basis.

Operational Factors: Grassed waterways can be used where ephemeral erosion and gully erosion are a problem.

Demonstration Status: Grassed waterways are used across the United States and in conjunction with all the major crops.

Practice: Terraces

Description: Terraces are earthen structures that run perpendicular to the slope and intercept runoff on moderate to steep slopes. They transform long slopes into a series of shorter slopes. On shorter slopes, water velocity is slower and therefore has less power to detach soil particles. Terraces slow water, catch water at intervals down slope, and temporarily store it in the terrace channel.

Depending on the soil type, the water can either infiltrate into the ground or be delivered into a grassed waterway or an underground tile. Terraces are spaced to control rill erosion and to stop ephemeral gullying. Terrace spacing is determined by several factors including soil type, slope, and the use of other supporting conservation practices such as conservation tillage and crop rotation. When more than one terrace is placed on a hillside, it is best to construct the terraces parallel to each other and at spacings that are multiple widths of field equipment. This approach helps eliminate short rows and improves the efficiency of field operations.

Application and Performance: Terraces reduce the rate of runoff and allow soil particles to settle out.

Advantages and Limitations: One of the biggest advantages of terraces is that they are permanent conservation practices. A farmer usually does not adopt terracing one year and decide the next year not to use it, unlike such management practices as conservation tillage or contouring. In almost all cases, terraces will not be removed until they have exceeded their life expectancy of 20 years.

A disadvantage of terraces is that they are built with heavy construction equipment and the soil structure around the terrace can be permanently altered. Terraces are built by pushing soil up, which usually requires a bulldozer. Compaction on the lower side of the terrace is always a concern and can last for years after the terrace is constructed.

Terraces can permanently remove land from production. The amount of land removed from production depends on the terrace system installed, but it normally ranges from 0 to 5 percent of the overall land base. The cost to install terraces ranges between $0.75 and $3.00 per linear foot, including seeding. In many cases terraces also require either a tile line or a waterway as an outlet for the water. The cost of installing tile can range from $.75 to $1.50 per linear foot. Waterway costs are covered in the section on grassed waterways. It can cost in the range of $100 to $165 to protect 1 acre of land with terraces and suitable outlets. In addition to construction costs, there are always maintenance costs. If excessive rains occur, terraces will overtop and require maintenance. The sediment collected in terrace channels should be cleaned out periodically, at least every 10 years, or sooner, depending on the sedimentation rate. Maintenance also includes removing trees and shrubs from the terrace and repairing rodent damage.

In addition to the loss of cropland and cost of construction and maintenance, terraces are laid out on the contour, which can increase the time, fuel, and equipment costs associated with field operations. See the section on contouring and cross-slope farming for costs associated with contouring.

Operational Factors: Terraces can be used when sheet, rill, or ephemeral erosion are a concern.

Demonstration Status: Terraces are widely adopted across the United States.

Practice: Field Borders

Description: A field border is a band or strip of perennial vegetation, usually grass or legume, established at the edge of a field. From a soil conservation standpoint, field borders are used to replace end rows that run up and down a hill. Sometimes field borders replace end rows all the way around the field, and other times they are used where slope length and steepness present a concern for soil erosion. Field borders can be used in fields that are contoured, cross-sloped, contour stripcropped, contour buffer stripped, or terraced.

Application and Performance: Field borders reduce detachment, slow transport, and help reduce sediment load in water.

Advantages and Limitations: Field borders reduce acres of cereal crops or row crops in production. However, if the field border is planted to forage, it can be harvested, as long as the farmer has the proper equipment and a use or market for the crop. The cost of seeding an acre of field borders is approximately $50 to $70 per acre.

Operational Factors: Field borders can be used with all crops and in all regions of the United States.

Demonstration Status: Field borders are commonly used as a conservation practices in combination with other practices.

Practice: Sediment Basin

Description: A sediment basin is a barrier structure constructed to collect and store manure, sediment, or other debris.

Application and Performance: Sediment basins are constructed to accumulate and temporarily store water runoff. For controlling manure runoff, sediment basins may be used in two types of settings, to capture feedlot or field runoff. As runoff accumulates and water is slowly discharged through an outlet, soil particles settle out and are trapped in the basin. Frequently, a filter strip is positioned as a secondary treatment practice below the sediment basin to catch the additional sediment flowing through the outlet. Sediment basins reduce the transport of soil and manure by flowing water.

Advantages and Limitations: The construction cost of sediment basins is quite variable, depending on the steepness of the land and the size of the drainage area flowing into the basin. However, basins are normally a cost-effective practice to capture sediment.

On-site erosion control cannot be achieved with sediment basins, because they do little to stop detachment and transport of soil.

Operational Factors: Sediment basins can be used with all crops and in all regions of the United States.

Demonstration Status: Sediment basins are commonly used as conservation practices in all cropland systems.

Practice: Cover Crops

Description: A cover crop is a crop of close-growing grass, legumes, or small grain grown primarily for seasonal protection and soil improvement. These crops are also known as green manure crops. Cover crops are usually grown for 1 year or less, except where there is permanent cover (e.g., orchards). They increase vegetative and residue cover during periods when erosion energy is high, and especially when primary crops do not furnish adequate cover. Cover crops may be established by conventional or conservation tillage (no-till or mulch-till) methods or by aerial seeding.

Cover crops should be planted immediately after harvest of a primary crop to maximize the erosion control benefits. Recommended seeding dates vary from year to year and depend on soil type, local climatic conditions, field exposure, and the species of cover crop being grown.

Application and Performance: Cover crops control erosion during periods when the major crops do not furnish adequate cover. Since cover crops provide a quick canopy, they reduce the impact of raindrops on the soil surface, thereby reducing soil particle detachment. Cover crops also slow the surface flow of water, reducing transport of sediment and increasing water infiltration. Cover crops can add organic material to the soil; they improve water infiltration, soil aeration, and soil quality. In addition, cover crops can control plant nutrients and soil moisture in the root zone. If a legume crop is used as a cover crop, it will provide N for the next year’s crop.

Actively growing cover crops use available nutrients in the soil, especially N, thus preventing or decreasing leaching or other loss. These nutrients may then become available to the following crop during the decaying process of the green manure.

Advantages and Limitations: Cover crops increase transpiration. In areas of the United States where moisture is limited, cover crops may use up too much of the available soil moisture. Loss of available soil moisture may reduce the yield of the primary crop planted after the cover crop, reducing profits.

Preparing a seedbed and drilling in a winter cereal crop costs $40 to $45 per acre. Broadcast seeding after harvest, followed by a tillage pass that levels the soil surface, costs $35 per acre. Broadcast seeding prior to harvest costs $15 per acre.

Operational Factors: Cover crops can be used when major crops do not furnish adequate cover and sheet and rill erosion is a problem.

Demonstration Status: Cover crops are used throughout the United States.

Practice: Filter Strip/Riparian Buffer

Description: Filter strips are strips of grass used to intercept or trap field sediment, organics, pesticides, and other potential pollutants before they reach a body of water.

Riparian buffers are streamside plantings of trees, shrubs, and grasses that can intercept contaminants from both surface water and ground water before they reach a stream.

Application and Performance: Filter strips and riparian buffers are designed to intercept undesirable contaminants such as sediment, manure, fertilizers, pesticides, bacteria, pathogens, and heavy metals from surface and subsurface flows of water to a water body. They provide a buffer between a contaminant source and water bodies. Buffers and filter strips slow the velocity of water, allowing soil particles to settle out.

Advantages and Limitations: Buffer strips and riparian buffers reduce the acreage in cereal crops or row crops, but they can be harvested for forage production if the farmer has a use or market for the forage and the equipment to harvest the forage. Depending on whether the filter strip or riparian buffer strip is seeded to grass or planted to trees, the cost of seeding can range from $50 to $500 per acre.

Operational Factors: Buffer strips and riparian buffers can be used with all crops and in all regions of the United States.

Demonstration Status: Filter strips and riparian buffers have been widely promoted and adopted throughout the United States with programs like the Conservation Reserve Program (CRP).

Practice: Crosswind Trap Strips, Crosswind Ridges, Crosswind Stripcropping, and Shelterbelts/Field Windbreaks

Description: Crosswind trap strips are rows of perennial vegetation planted in varying widths and situated perpendicular to the prevailing wind direction. They can effectively prevent wind erosion in cropping areas with high, average annual wind speeds.

Crosswind ridges are formed by tillage or planting and are aligned across the prevailing wind erosion direction. The ridges reduce wind velocity near the ground, and the soil particles that do start to move are trapped in the furrows between the ridge crests.

Crosswind stripcropping is growing crops in strips established across the prevailing wind direction and arranged so that the strips susceptible to wind erosion are alternated with strips having a protective cover that is resistant to wind erosion.

A shelterbelt or field windbreak is a row (or rows) of trees, shrubs, or other plants used to reduce wind erosion, protect young crops, and control blowing snow. Shelterbelts also provide excellent protection from the elements for wildlife, livestock, houses, and farm buildings. Field windbreaks are similar to shelterbelts but are located along crop field borders or within the field itself. In some areas of the country, they may also be called hedgerow plantings.

Application and Performance: These practices are designed to reduce soil erosion by increasing the soil roughness and reducing the wind speed at the soil surface.

Advantages and Limitations: The same practices that reduce wind erosion also reduce moisture loss. Snow is more likely to stay on the field than to blow off, thereby increasing soil moisture. A drawback to crosswind trap strips, shelterbelts, and field windbreaks is that they take cropland out of production. Also, they are a physical barrier to operations such as manure application with an umbilical cord system.

Operational Factors: These practices can be used anywhere that wind erosion is a concern in row crops.

Demonstration Status: These practices are used where row crops are planted in the Plains states.

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CHAPTER 9

ESTIMATION OF REGULATED OPERATIONS AND UNFUNDED MANDATES

9.0 INTRODUCTION TO NPDES PROGRAM

Under the National Pollutant Discharge Elimination System (NPDES) permit program, all point sources that discharge pollutants to waters of the United States must apply for an NPDES permit and may discharge pollutants only under the terms of that permit. Such permits include nationally established technology-based effluent discharge limitations. In the absence of national effluent limitations, NPDES permit writers must establish technology-based limitations and standards on a case-by-case basis, based on the permit writer's best professional judgment.

In addition to the technology-based effluent limits, permits may also include water quality-based effluent limits where technology-based limits are not sufficient to ensure compliance with the water quality standards or to implement a Total Maximum Daily Load (TMDL). Permits may include specific BMPs to achieve effluent limitations, typically included as special conditions. In addition, NPDES permits normally include monitoring and reporting requirements, as well as standard conditions that apply to all permits (such as duty to properly operate and maintain equipment).

EPA's analysis of the final rule includes estimates of the incremental costs and benefits of changes in the NPDES permit regulations in 40 CFR 122. To obtain incremental values, EPA developed estimates of the number of regulated operations for a baseline compliance scenario and a compliance scenario based on the final rule. Section 9.1 describes how EPA derived baseline estimates. Section 9.2 provides the estimates of the number of operations affected under the final rule. Section 9.3 provides estimates of the new expenditures states are expected to incur when they implement the final rule.

9.1 Industry Baseline Compliance with 1976 Regulations

EPA promulgated the original NPDES regulations for CAFOs in 1976. For the purposes of this analysis, EPA assumes that all operations covered by the 1976 regulations are currently in compliance with the existing regulatory program. This assumption generates the baseline number of regulated operations estimated for the final rule.

More specifically, EPA assumes that all operations are fully complying with the existing regulations because they fall into one of two categories. The first category consists of those operations that are defined or designated as CAFOs and that have in fact obtained a permit. EPA assumes, for purposes of costing the new regulations, that these CAFOs are in full compliance with their existing permits. The second category consists of all of the other unpermitted AFOs. EPA assumes that these operations do not need a permit because they do not meet the definition of a CAFO. For example, they might not meet the criteria for being defined as a Medium CAFO, or for Large CAFOs they might meet the criteria, but are excluded from the definition because they do not discharge except in the event of a 25-year, 24-hour storm. In reality, however, there are probably a number of unpermitted operations that are subject to the regulations and should have a permit (for example, they incorrectly claim they are a "no discharge" facility, as discussed in the preamble).

The following sections present EPA's approach and assumptions for estimating the population of AFOs that are subject to permitting under the 1976 NPDES CAFO permitting regulations. The universe of AFOs and CAFOs is discussed by livestock category, size of operation, and production region. EPA's assumptions about what is needed to comply with the current CAFO regulations are consistent with EPA's views as stated in its 1995 CAFO guidance manual, *Guidance Manual on NPDES Regulations for Concentrated Animal Feeding Operations* (USEPA, 1995; USEPA, 1999).

9.1.1 Total Medium and Large Animal Feeding Operations

EPA's estimates of Large and Medium AFOs by livestock category are provided in Table 9-1. The breakdowns by size are based the following animal thresholds, which are from the 1976 NPDES CAFO regulation. The discussion in this section pertains to which operations in these categories are considered effectively regulated by the 1976 rule.

Large operations that stable or confine more than:

- 1,000 beef cattle
- 700 mature dairy
- 2,500 swine over 55 pounds
- 55,000 turkeys
- 500 horses
- 5,000 ducks
- 30,000 laying hens or broilers using liquid manure systems

Medium operations that stable or confine:

- 300 to 1,000 beef cattle
- 200 to 700 mature dairy

- 750 to 2,500 swine over 55 pounds
- 16,500 to 55,000 turkeys
- 150 to 500 horses
- 1,500 to 5,000 ducks
- 9,000 to 30,000 laying hens or broilers using liquid manure systems

AFO estimates for additional animal categories that will be regulated under the final rule have also been included in Table 9-1 to provide a summary of all Medium and Large AFOs potentially regulated as CAFOs. In addition to breakdowns by livestock or poultry category and facility size, Table 9-1 shows that the primary livestock or poultry sectors have been divided into five production regions consistent with development of the Cost Models. The designation and use of production regions allows for the aggregation of critical data on the number of facilities, production quantities, and financial conditions, which might otherwise not be possible because of concerns about disclosure[1]. The facilities listed below as medium AFOs include all AFOs in that size range and are not limited to those facilities that may be defined or designated under current conditions or the final rule.

Table 9-1. Total 1997 Facilities with Confined Animal Inventories by Livestock or Poultry Sector, Operation Size, and Region.

Sector	Region	Medium Operations	Large Operations
Beef	Central	326	557
	Mid-Atlantic	100	11
	Midwest	2,198	1,124
	Pacific	44	74
	South	14	0
	Total	2,682	1,766
Dairy	Central	1,034	401
	Mid-Atlantic	1,407	103
	Midwest	1,503	96
	Pacific	1,406	759
	South	430	91
	Total	5,780	1,450
Swine	Central	153	82
	Mid-Atlantic	905	1,220
	Midwest	8,484	2,431
	Pacific	31	15

[1] For example, USDA Census of Agriculture data are not typically released unless there is a sufficient number of observations to ensure confidentially. Consequently, if data were aggregated on a state basis (instead of a regional basis), many key data points needed to describe the industry segments would be unavailable.

	South	328	176
	Total	9,901	3,924
Layer	Central	301	143
	Mid-Atlantic	394	211
	Midwest	346	312
	Pacific	110	125
	South	819	321
	Total	1,970	1,112
Broiler	Central	694	164
	Mid-Atlantic	2,892	413
	Midwest	411	56
	Pacific	184	15
	South	6,221	984
	Total	10,402	1,632
Turkey	Central	67	36
	Mid-Atlantic	692	88
	Midwest	574	149
	Pacific	110	45
	South	172	70
	Total	1,615	388
Heifers[1]	Central	195	145
	Mid-Atlantic	0	0
	Midwest	395	0
	Pacific	134	97
	South	0	0
	Total	724	242
Veal[1]	Central	3	0
	Mid-Atlantic	1	0
	Midwest	53	12
	Pacific	0	0
	South	0	0
	Total	57	12
Horses	Total	1,123	195
Ducks	Total	71	21
	Grand Total	34,325	10,742

[1]New livestock category in the final rule.

9.1.2 Baseline Compliance Estimates

The following subsections describe the livestock or poultry categories that EPA assumes are in full compliance with current NPDES regulations for CAFOs. In general, the large operations shown in Table 9-1 are currently defined as CAFOs, unless they are exempt because they have no discharges except in the event of a 25-year, 24-hour storm. Therefore, subsequent estimates of large operations currently in compliance include the large AFOs shown in Table 9-1. The exception for large layer and broiler operations is discussed below. The medium operations in Table 9-1 may be defined as CAFOs if either of the following conditions apply:

- Pollutants are discharged into navigable waters through a man-made ditch, flushing system, or other similar man-made device (the "MMD discharge" condition).
- Pollutants are discharged directly into waters of the United States, which originate outside of and pass over, across, or through the facility, or otherwise come into direct contact with the animals confined in the operation (the "direct contact" condition).

The number of medium operations meeting either condition is not known with any great degree of certainty. EPA derived estimates of the medium livestock operations that might meet either condition based on the best available information from USDA Extension personnel, state water quality staff, industry representatives, and other stakeholders, and BPJ judgement. The estimates are generally based on best estimates of the share of operations that might meet at least one condition. EPA multiplied these percentages by the estimate of total medium operations to derive the number of CAFOs for the medium category. In some instances, information supported different percentages across regions. The following sections provide EPA's estimates of the number of medium CAFOs under current regulations.

9.1.2.1 Beef

The beef industry is concentrated in the Midwest Region. The second largest production area is the Central Region.

EPA's estimates of the number of medium-size beef AFOs with a direct discharge or stream running through part of the production area were developed through various contacts with state agricultural and environmental personnel and USDA contacts. There are very limited data addressing these criteria, and opinions vary even within production regions. Information obtained from key states in each region indicates that the share of AFOs potentially meeting either criterion ranges from approximately 3 percent (Funk, 2002) to less than 6 percent in the Midwest (Lawrence, 2002). The share is less than 10 percent in the Central and Pacific Regions (Johnson, 2002), and close to 0 percent in the Mid-Atlantic and South Regions (Kniffen, 2002; Sadler, 2002). Using conservative values to account for some uncertainty regarding conditions in other states, EPA assumed that 6 percent of Medium AFOs in the Midwest Region would meet the CAFO definition and that 10 percent would meet it in the Central and Pacific Regions. The assumption for the Mid-Atlantic and South should be close to zero, but EPA assumed a nonzero value to allow for the possibility of some Medium CAFOs in the states not contacted. There are 114 Medium AFOs in these regions and EPA assumed that 4 percent of regional AFOs would meet the CAFO definition, which generates approximately 5 CAFOs throughout both regions. Table 9-2 reports the number of Medium CAFOs that EPA estimates may be defined as CAFOs under the 1976 NPDES CAFO regulations, by region, based on these assumptions.

Table 9-2. Regulated Beef Feeding Operations by Size Category Assuming Full Compliance.

Region	Total	Medium Facilities	Large Facilities
Central	590	33	557
Mid-Atlantic	15	4	11
Midwest	1,255	131	1,124
Pacific	79	5	74
South	1	1	0
Total	1,940	174	1,766

9.1.2.2 Dairy

Compared to other livestock categories, dairies are relatively evenly distributed across all regions except the South. The large dairies tend to be concentrated in the Central and Pacific Regions, while the Midwest and Mid-Atlantic have the most medium dairies. Many of these dairies were designed and built on or near waters of the United States and, therefore, have direct contact. Others have some type of MMD discharge. Estimates for the percentage of dairies in the Midwest Region with direct contact or MMD discharge have a large range. Bickert (1999) estimated less than 10 for each criteria and Groves (1999) estimated a range of 25 percent to 75 percent for the direct contact criterion and almost zero percent for the MMD discharge. Holmes (1999) estimated that 15 percent of operations would have direct contact and 40 to 50 percent would have an MMD discharge. EPA assumed that, on average, 45 percent for the medium-size dairies throughout the Midwest would meet either criterion. This estimate places greater weight on the estimates of Holmes (<20 percent across criteria) and Bickert (55 to 65 percent across criteria). EPA assumed a slightly higher percentage of 55 percent for the Mid-Atlantic to reflect a higher propensity for direct contact in that region. According to Johnson (1999), less than 10 percent of medium-size operations in California will have either direct contact or an MMD discharge. EPA assumed that 10 percent of operations throughout the Pacific Region would be defined CAFOs. EPA assumed that the CAFO share in the Central Region is 20 percent, and 35 percent in the South. These are BPJ estimates based on the belief that operations in these regions are less likely than Midwest operations to meet either criterion, but more likely than Pacific Region operations.

Table 9-3 reports EPA’s estimates of medium dairy CAFOs. Nationwide, approximately one-third of all medium operations are defined as CAFOs. Table 9-3 also shows that all large operations should be effectively regulated by the existing requirements either because they have a discharge permit or because they have no discharge except in the event of the 25-year, 24-hour storm event.

Table 9-3. Regulated Dairy Feeding Operations by Size Category Assuming Full Compliance.

Region	Total	Medium Facilities	Large Facilities
Central	608	207	401
Mid-Atlantic	877	774	103
Midwest	773	677	96
Pacific	900	141	759
South	241	150	91
Total	3,399	1,949	1,450

9.1.2.3 Swine

The swine industry is heavily concentrated in the Midwest. This is particularly true for medium-size operations. The Mid-Atlantic is the second largest production region, followed by the South Region.

Table 9-4 shows that all large swine AFOs are assumed to be effectively regulated under the 1976 NPDES CAFO regulations because they are either permitted or exempt because they have no discharges except in the event of a 25-year, 24-hour storm. Based on contacts with USDA Extension personnel, EPA assumes that approximately 15 percent of facilities in this size category (across all regions) have direct contact or use an MMD (Greenless, et al., 1999; Steinhart, 1999).

Table 9-4. Regulated Swine Operations by Size Category Assuming Full Compliance.

Region	Total	Medium Operations	Large Operations
Central	105	23	82
Mid-Atlantic	1,355	135	1,220
Midwest	3,704	1,273	2,431
Pacific	20	5	15
South	225	49	176
Total	5,409	1,485	3,924

9.1.2.4 Layers

Under the 1976 NPDES CAFO regulations, a layer operation is defined as a large CAFO if it confines more than 30,000 birds and uses a wet manure management system, or if it maintains more than 100,000 birds using continuous overflow watering and has the potential to discharge pollutants to waters of the U.S. EPA recognizes that continuous overflow watering is an outdated technology that has fallen out of favor in the layer industry. Therefore, EPA's estimates of the effectively regulated baseline large CAFO operations is based on those that use a wet manure management system.

The estimates of large layer CAFOs include operations with actual wet manure-handling systems and operations that create a crude wet manure-handling system. Currently, as many as 60 percent of the operations in the South and Central Regions use a wet manure-handling system, whereas only 0 to 5 percent of the operations use a wet system in the other regions.

As noted in EPA's 1995 permitting guidance, dry poultry operations are subject to the NPDES regulations if they establish a "crude liquid manure system" by stacking manure or litter in an outside area unprotected from rainfall and runoff. Including these operations as defined large CAFOs brings the total for the South and Central Regions to approximately 70 percent of large operations and approximately 7 percent of operations in other regions. These additions based on storage practices are based on conversations with industry personnel, who indicate that layer operations generally have long-term (> 6 months) storage, after which the manure is either sold or land applied (Funk, 1999; Jacobson, 1999; Patterson, 1999; Thomas, 1999; Tyson, 1999; York, 2000). The large CAFO estimates in Table 9-5 reflect the number of operations having either type of wet manure system.

For medium-size operations, either the MMD discharge or the direct contact condition must apply for operations that either have a wet manure-handling system or create a crude one. The regulated medium-size layer operations in Table 9-5 reflect combined estimates for both types of operations.

For operations with wet manure-handling systems, EPA obtained estimates from experts in the five states that have the largest regional shares of operations. These estimates indicate that the CAFO conditions are rarely met, bordering on 0 percent of operations in any region (Carey, 2002; Ramsey, 2002; Parsons, 2002; Hopkins, 2002; Johnson, 2002, Earnst, 2002, and Solainian, 2002). EPA derived a share estimate by assuming a worst-case average of two CAFOs per state, the total of 10 CAFOs equals approximately 3 percent of the 349 Medium AFOs in these states. Applying this percentage to all medium-sized wet layer AFOs generates a total CAFO estimate of 24.

Similarly, experts for key states in the Central, Mid-Atlantic, Midwest, and South Regions indicated that very few, if any, medium-sized dry operations stored manure outside of the production houses in a manner that might meet either of the CAFO conditions (Carey, 2002; Ramsey, 2002; Parsons, 2002; Hopkins, 2002; Jones, 2002; and Solainian, 2002). Rather than assume there are no Medium CAFOs in these regions, EPA derived a share estimate by assuming that an average of two operations per state stored manure outside (i.e., eight total in the four states) and in all cases the practice led to either a direct contact condition or an MMD condition.

The resulting number of CAFOs accounts for 2 percent of medium-sized AFOs in these states. EPA applied this percentage to all AFOs in these regions. EPA used a slightly higher estimate of 5 percent for the Pacific Region based on information provided by Johnson (2002) and Earnst (2002). These assumptions generate a total of 26 Medium CAFO operations.

Table 9-5. Regulated Layer Operations by Size Category Assuming Full Compliance.

Region	Total	Medium Operations	Large Operations
Central	107	8	99
Mid-Atlantic	26	8	18
Midwest	28	7	21
Pacific	13	5	8
South	259	22	237
Total	433	50	383

9.1.2.5 Broilers

Under the 1976 NPDES CAFO regulations, broiler operations with more than 30,000 birds are defined as CAFOs only if they use a liquid manure-handling system; operations with 9,000 to 30,000 birds and a liquid manure-handling system would also need to meet either the MMD discharge or the direct contact condition to be defined a CAFO. Because few, if any, broiler operations use a liquid manure-handling system, the only way by which a broiler operation is defined as a CAFO currently is if, through its manure-handling practices, it creates a form of liquid manure-handling system (Carey, 1999). As noted, dry poultry operations may establish a "crude liquid manure system" by stacking litter in an outside area unprotected from rainfall or runoff. This analysis assumes that at most 10 percent of the large broiler operations and 5 percent of the medium operations stack litter temporarily, in a manner consistent with EPA's interpretation of a liquid manure handling system and, therefore, would be defined as CAFOs (York, 2000). Furthermore, EPA assumed that no broiler operations would otherwise have direct contact with waters of the U.S. (WOUS) or an MMD based on information provided by regional experts (Carey, 1999; Gale, 1999; Lory, 1999; Patterson, 1999; Thomas, 1999; Tyson, 1999). Table 9-6 presents regulated broiler operation numbers.

Table 9-6. Regulated Broiler Operations by Size Category Assuming Full Compliance.

Region	Total	Medium Operations	Large Operations
Central	51	35	16
Mid-Atlantic	186	145	41
Midwest	26	20	6
Pacific	11	9	2
South	409	311	98
Total	683	520	163

9.1.2.6 Turkeys

EPA assumes turkey operations with more than 55,000 birds (1,000 AUs) are in compliance, being either permitted or exempt because they have no discharges except in the event of a 25-year, 24-hour storm. The only other turkey AFOs subject to the NPDES program are those having between 16,500 and 50,000 birds and an MMD discharge; no operations meet the direct contact conditions. Because virtually all turkey operations use dry litter systems (Battaglia, 1999; Carey, 1999; Jones, 1999), the only that have the potential to discharge are those operations that have established a crude liquid manure system through the use of waste management practices that allow contact between manure and rainwater. EPA assumed that 5 percent of the medium operations in the South Region and 2 percent in the other regions have established crude liquid systems. Table 9-7 presents the number of turkey feeding operations in full compliance by region and size.

Table 9-7. Regulated Turkey Operations by Size Category Assuming Full Compliance.

Region	Total	Medium CAFOs	Large CAFOs
Central	38	2	36
Mid-Atlantic	102	14	88
Midwest	160	11	149
Pacific	47	2	45
South	78	8	70
Total	425	37	388

9.1.2.7 Designated Operations

A medium facility that is not defined a CAFO may be designated a CAFO under the 1976 NPDES CAFO regulations if a permit authority determines that it is a significant contributor of pollutants to waters of the United States. A small facility can be designated a CAFO only if pollutants are discharged into navigable waters through a man-made ditch, flushing system or other similar man-made device, or pollutants are discharged directly into WOUS that originate outside of and pass over, across, or through the facility, or otherwise come into direct contact with the animals confined in the operation.

EPA has historically made very limited use of the designation provisions of the NPDES CAFO regulation that was promulgated in 1976. It is understood that only a few operations have been designated CAFOs over a 25-year span of existing NPDES CAFO regulations. Because the final rule does not alter the conditions for designation, EPA assumes that designation will continue to occur in a limited number of cases where an AFO does not meet the regulatory definition of a CAFO, but is determined to be a significant contributor of pollutants to WOUS based on site-specific conditions.

EPA does not possess any location-specific information regarding which AFOs may meet the conditions for designation. Furthermore, EPA expects that many of these operations that have conditions that might make them candidates for designation would be able to seek out technical assistance through voluntary programs to alter those conditions and avoid designation. These two factors make estimating future designations difficult, but the ability to prevent being designated a CAFO should minimize the number of designations.

Based on the limited use of this provision under the current regulation and the ability of operators to address conditions that might lead to designation, EPA assumed no more than 0.5 percent of all medium AFOs would be designated CAFOs. Table 9-8 shows the estimates of designated Medium CAFOs under the current rule by sector.

Designation would in almost all cases be the tool of last resort to address small operations that are found to be significant contributors of pollutants. Most, if not all, of these operations would be able to avoid designation through technical assistance offered by USDA and other voluntary programs. Although a lack of empirical data regarding discharge conditions at small operations makes it difficult to derive designation estimates, EPA believes designation of Small CAFOs will occur in only a very limited number of cases, if at all. Given this, EPA assumed a very small number of designations be assigned to each sector for the purposes of estimating cost and burdens for the final rule.

Table 9-8 Estimated Small and Medium Designated CAFOs over a 5-Year Period by Sector.

Sector	Medium Designated CAFOs	Small Designated CAFOs
Beef	13	2
Dairy	28	2
Swine	50	2
Layer	8	2
Broiler	50	2
Turkey	8	2
Heifers	3	0
Total	160	12

9.1.2.8 Summary of Baseline Compliance Estimates by Size and Type

The estimated number of regulated AFOs based on an assumption of full compliance with the existing regulations is presented in Table 9-9. The estimates include the large and medium beef, dairy, swine, broiler, layer, and turkey operations that are CAFOs by definition or that meet the 25-year, 24-hour storm exemption and the medium-size operations that potentially meet either the MMD discharge or the direct contact condition. The estimates also include the 195 horse operations that have 500 or more horses and, therefore, meet the definition of a large CAFO, and 157 large duck operations that meet current CAFO definitions. The horse CAFOs comprise 50 farms, 45 racetracks, and 100 fairgrounds (Tetra Tech, 2002). EPA does not have information to indicate that any of the 1,123 medium horse AFOs will meet either condition to be CAFOs by definition, and EPA does not expect any medium or small horse AFOs to be designated CAFOs. For ducks, EPA assumed that all facilities greater that 5,000 head were either permitted or claimed the storage exemption. EPA assumed no duck operations in the medium category met the current definition of a CAFO. Finally, the estimates in Table 9-9 include the medium and small designated CAFOs.

Table 9-9. Summary of Effectively Regulated Operations by Size and Livestock Sector

Livestock Category	Total	Defined CAFOs		Designated CAFOs	
		Medium CAFOs	Large CAFOs[1]	Medium	Small
Beef	1,955	174	1,766	13	2
Dairy	3,429	1,949	1,450	28	2
Swine	5,461	1,485	3,924	50	2
Layer	443	50	383	8	2
Broiler	735	520	163	50	2
Turkey	435	37	388	8	2
Horse	195	0	195	0	0
Duck	157	0	157	0	0
Heifers	3	0	0	3	0
Total	12,813	4,215	8,426	160	12

[1]Includes permitted CAFOs and Large AFOs that are in current compliance because they do not discharge except in the instance of the 25-year, 24-hour storm event.

This summary of animal operations that should currently have NPDES permits does not correspond with the number of NPDES permits issued to date. Most sources place the estimate of the number of operations covered by NPDES permits at approximately 4,100 (SAIC, 1999).

There are two main reasons for the large disparity between these numbers. First, many of the large operations opt out of the NPDES program because they claim they do not discharge except in the event of a 25-year, 24-hour storm. Second, many authorized states have declined to issue NPDES permits for CAFOs, relying instead on regulatory mechanisms other than the NPDES program to regulate CAFOs.

9.2 Affected Entities under the Final Rule

The final rule will increase the number of regulated operations as well as the number of operations needing to obtain an NPDES permit, which will include newly covered operations and large operations currently claiming the storm exemption. It will also affect the permit requirements of facilities already operating under permit coverage.

9.2.1 Final Rule Provisions that Affect the Number of Regulated Operations

EPA estimates that the final rule increases the potential number of regulated entities by about 2,500 facilities. These facilities are predominantly large, dry poultry operations. Operations that confine immature animals are the second largest component of change. EPA assumes that the number designated under the 1976 rule, assuming full compliance, will be same as the number designated under the final rule. The new sectors and size threshold changes in the final rule that affect the number of regulated operations are:

Large operations that stable or confine:

- 1,000 heifers
- 1,000 veal
- 10,000 small swine under 55 pounds
- 82,000 layers using other than a liquid manure-handling system
- 125,000 broilers using other than a liquid manure handling system
- 30,000 ducks (dry operations)

Medium operations that stable or confine:

- 300 to 1,000 heifers
- 300 to 1,000 veal
- 3,000 to 10,000 small swine under 55 pounds
- 25,000 to 82,000 layers using other than a liquid manure-handling system
- 37,500 to 125,000 broilers using other than a liquid manure-handling system
- 10,000 to 30,000 ducks (dry operations)

In addition, the following revisions to 40 CFR 122 in the final rule may affect currently and newly regulated operations:

- Clarify the definition of an AFO
- Eliminate the 25-yr, 24-hr storm exemption
- Implement duty-to-apply requirement
- Eliminate the mixed animal multiplier
- Include facility closure requirements.

9.2.2 Number of Operations Required to Apply for Permit

The primary impact on the number of NDPES permits issued to CAFOs will come from the addition of dry poultry operations; stand-alone, immature animal operations; and operations previously exempt due to the 25-yr, 24-hr storm provision. As a result of removing the storm exemption, all of the large beef, dairy, swine, wet layer, turkey, and horse AFOs reported in Section 9.1 are considered CAFOs and will need to obtain a permit except in cases where the permitting authority makes a determination that there is no potential to discharge. Table 9-10 provides a summary of the total expected permitted facilities by sector based on the final rule. Many of the estimates are the same as those in Table 9-9. Additions are explained below.

Table 9-10. Summary of CAFOs by Livestock Sector and Region Required to Apply for Permit.

		Defined CAFOs		Designated CAFOs	
Livestock Category	**Total**	**Medium CAFOs**	**Large CAFOs**	**Medium**	**Small**
Beef	1,955	174	1,766	13	2
Dairy	3,429	1,949	1,450	28	2
Swine	5,461	1,485	3,924	50	2
Layer	1,172	50	1,112	8	2
Broiler	2,204	520	1,632	50	2
Turkey	435	37	388	8	2
Heifers	475	230	242	3	0
Veal	16	4	12	0	0
Horse	195	0	195	0	0
Duck	25	4	21	0	0
Total	15,367	4,453	10,742	160	12

The inclusion of all poultry operations, regardless of manure handling system, brings in all large broiler and dry layer feeding operations. The number of large broiler CAFOs increases from 163 to 1,632. The medium broiler CAFO estimate is unchanged from the baseline estimate because the dry operations that met the medium CAFO conditions before will continue to meet those conditions. Similarly, the number of large layer CAFOs increases from 383 to 1,112, but the Medium CAFO estimates are unchanged because the conditions that define CAFOs in this size category have not changed.

The thresholds for duck operations with dry manure-handling systems were changed from 5,000 to 30,000 ducks for large operations, and from 1,500 to 10,000 ducks for medium operations. These changes were based on data EPA received from Purdue University, The Indiana Poultry Association, and duck producers. The threshold for duck operations with wet manure-handling systems is has not changed and remains 5,000 ducks for large operations and 1,500 ducks for medium operations. Because almost all operations use dry manure-handling systems, the number of large duck CAFOs under the revised size thresholds of the final rule is 21. EPA assumed that the share of medium dry duck operations that meet either the MMD discharge or direct contact condition is the same as the broiler share. Thus, there are four Medium duck CAFOs.

Finally, final rule provisions for stand-alone, immature animal operations adds 488 newly regulated large and medium operations. The Large CAFOs comprise 242 heifer operations and 12 veal operations. EPA assumes that the incidence of medium-sized veal and heifer CAFOs would be the same as the regional percentages in the baseline descriptions for beef and dairy, respectively. These assumptions add 230 medium heifer CAFOs and four medium veal CAFOs to the estimate of regulated operations under the final rule.

9.3 Unfunded Mandates

This section provides EPA's estimates of the new expenditures States are expected to incur when they implement the final rule. These administrative expenditures are based primarily on estimates of the amount of labor time needed to incorporate new regulatory requirements into existing State NPDES programs and to administer CAFO permits on an annual basis. EPA obtained the labor burden estimates used in this analysis from various sources including communications with staff at EPA regional offices and a small sample of State agencies, previous NPDES-related cost and burden analyses, and comments on the proposed rule. Then EPA asked State agency and EPA regional staff to evaluate whether those estimates were appropriate for administering NPDES permits for CAFOs.

EPA's cost analysis presumes that States issue fewer than 100 percent of the permits because EPA has responsibility for issuing permits in States that do not have approved NPDES programs. For informational purposes, this section will also show cost estimates pertaining to EPA's portion of the NPDES permits for CAFOs.

EPA estimated administrative costs for States with approved NPDES programs (hereafter "approved States") for four categories of activities:

- NPDES rule modification
- NPDES program modification request
- implementation for general permits
- implementation for individual permits.

Rule modification is a one-time activity in which approved States modify their NPDES programs to incorporate the new requirements contained in the final rule. EPA received substantial comment in this area at proposal and believes that this analysis fully recognizes the types of activities that would be required and their associated burden. Specific actions will vary across States because CAFO permitting practices vary widely. Forty-three States have approved NPDES base programs through which CAFO permits can be issued.[2] EPA's State Compendium (2001) demonstrates that State permitting programs for CAFOs vary substantially. Some State programs utilize a combination of NPDES and non-NPDES permits while others issue only one or the other type of permit to CAFOs.

Rule modification may involve a variety of activities such as reviewing the final rule requirements, revising regulatory or statutory language, conducting public outreach to solicit inputs or make the public aware of program changes, conducting formal public notification hearings to solicit comments on draft changes, and finalizing and publishing regulatory statutory revisions. For some approved States, rule modification may be as simple as incorporating the final rule by reference. For others, regulatory changes may require a lengthy stakeholder process or changes to state statutes.

Information provided by State agencies suggests that the labor hours required to develop or modify regulations may range from 0.10 full time equivalents (FTEs) to 1.57 FTEs.[3] Hammerberg (2002) indicated that Maryland completes approximately two major rules and several minor rules per year with a staff of three, which suggests a range of 0.25 to 1.0 FTEs per rule depending on the level of complexity. Consistent with the lower end of this range, Allen (2002) agreed with a midpoint estimate of 750 hours or 0.36 FTEs and Coats (2002) provided an estimate of 500 hours or 0.20 FTEs for States in EPA Region 2. At the high end, Sylvester (2002) estimated that a final rule similar to the proposed rule would require 1.57 FTEs to implement in Wisconsin, with approximately one-third of the time devoted to initial drafting, one-third to hearings, and one-third to responding to comments and finalizing the rule. EPA believes that the final CAFO rule is less complex than the proposed rule and most States are not likely to require this level of effort to implement rule revisions. In particular, the final rule will not change the definition of a medium-size CAFO or the designation criteria for small CAFOs, and it will not require the ELG be applied to medium-size CAFOs. Also, it will not require CAFOs to have certified permit NMPs or that those plans be submitted to permitting authorities along with permit applications. Therefore, EPA placed greater weight on the Maryland and EPA Region 2 estimates than the Wisconsin estimate to derive a weighted average of 0.41 FTEs or approximately 850 hours (0.45×0.20 FTE + 0.45×0.36 FTE + 0.10×1.57 FTE).

Following rule development, the approved States will need to request EPA approval for the modifications made to their NPDES programs in response to the final rule. These applications consist of a narrative program description including enforcement and compliance plans; a legal

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[2] Six States—Alaska, Arizona, Idaho, Massachusetts, New Hampshire, and New Mexico—do not have approved NPDES programs. A seventh state, Oklahoma, has an approved base program, but is not authorized to administer the CAFO portion of the NPDES program; EPA Region 6 has responsibility for CAFO permits.

[3] One FTE is equivalent to 2,080 hours.

certification that the State has authority to implement the program (Attorney General's statement); a compilation of relevant statutes, regulations, guidance, and tribal agreements; and copies of permit application forms, permit forms and reporting forms. In general, the amount of labor time required to prepare the application will vary. EPA's labor hour estimate is based on program modification and approval burdens in an active NPDES ICR ("NPDES and Sewage Sludge Management State Program Requirements," OMB NO. 2040-0057, EPA ICR 0168.07), which estimates 250 hours per State to prepare and submit a request for NPDES Program Modification under 40 C.F.R. Part 123.62. Allen (2002) and Sylvester (2002) concurred with this estimate, but Coats (2002) noted that 80 hours might be sufficient.

Table 9-11 summarizes EPA's labor assumptions for these one-time costs and provides unit expenditure estimates based on an hourly loaded wage rate of $29.78 (in 2001 dollars).[4]

Table 9-11. State Administrative Costs for Rule Development and NPDES Program Modification Requests. (costs in 2001 dollars)

Administrative Activity	Unit Hours	Labor Cost	O&M Cost[1]
State Administrative Costs			
Rule Development	850 per State	$25,310	$2,120
NPDES Program Modification Requests	250 per State	$7,450	

1. States may incur public notification costs twice (i.e., for draft and final rules) while revising their regulations. The O&M cost estimate is based on the same assumption of $1,000 per public notice that was used for the proposed rule. That estimate assumed that public notices would be placed in four newspapers and each notice cost $250. The $1,000 was converted from 1999 dollars to 2001 dollars using the Consumer Price Index (1000 × 177.1/166.6 = 1060) (BLS, 2002a). This estimate is consistent with a cost estimate for public notification expenses provided by Tilley and Kirkpatrick (2002).

Approved States will incur annual costs to administer their permit programs. To administer State general permits, permitting authorities will need to:

- Update their general permits to incorporate final rule requirements.
- Review Notice of Intent (NOI) forms submitted by CAFO operators seeking coverage under a general permit.

[4] This estimate was based on the mean hourly wage rate of $20.53 for Conservation Scientists (SOC 19-1031) employed in the public sector (BLS, 2001) because employees in this occupation will most likely conduct permit review and facility inspections, which account for most of the burden hours. The rate was escalated from 2000 dollars to 2001 dollars using the Employment Cost Index, which indicates a 3.6 percent increase in wages and salaries for state and local government workers from December 2000 to December 2001 (BLS, 2002c). Then, the escalated wage rate ($21.27 = $20.53 × 1.036) was converted to a loaded wage rate using a total compensation-to-wage ratio of 1.4, which was the ratio in 2001 for all state and local workers (BLS, 2002b).

- Inspect CAFOs covered by the general permit.

- Review annual reports submitted by CAFOs covered by general permits.

To administer individual permits, State agencies will need to:

- Review application forms (i.e., Forms 1 and 2B)

- Request public comment prior to issuing a permit

- Conduct public hearings, as needed

- Inspect CAFOs covered by individual permits

- Review annual reports submitted by CAFOs covered by individual permits.

To update their general permits, the 43 approved States will need to revise the general permit conditions affected by the final rule (or develop a general permit for CAFOs in the 21 approved States that currently do not have such permits). For example, general permits will need to specify the method(s) that the permit authority is requiring the CAFO owner or operator to use to calculate the rate of appropriate manure application as a special condition, as well as incorporate the NMP requirements listed in 40 C.F.R. 122.42(e)(1). They may also need to reflect changes to animal thresholds between large, medium, and small CAFOs if current permits use the AU approach in the CAFO definition.

EPA estimated that States may need 300 hours to revise their general permits to reflect new provisions of the final rule. Information provided by State contacts indicated that initial general permit development was a contentious process that took two (Allen, 1999) to four years (KauzLoric, 1999) to complete. EPA does not believe that the changes necessitated by the final rule (e.g., adding the NMP requirements; adding new recordkeeping or reporting requirements; switching from size thresholds based on AU to animal counts; and altering the ELG, BPJ, or special conditions where necessary) will require the same magnitude of effort as initial permit development. Furthermore, EPA will develop a model permit that States can adopt in whole or part to minimize the costs of permit revisions. Sylvester (2002) estimated that revising Wisconsin's general permit may take 456 hours and Coats (2002) estimated that States in Region 2 would need 160 hours to revise their general permits. EPA's estimate of 300 hours or 0.14 FTE is the approximate midpoint between these estimates. Allen (2002) considered EPA's 300-hour estimate to be acceptable.

Revised general permits will be subject to public comment. EPA estimated costs for the proposed rule based on public notice, comment review, and response requiring 160 hours or 0.08 FTE. Comments from State employees in South Dakota (Pirner, 2001) and Illinois (Willhite, 2001) indicated that costs would be higher because the process for selecting the type of facilities that may be eligible under a general permit will be contentious. Subsequent information obtained by EPA indicates a wide range of time from as little as 100 hours (Coats, 2002) to as much as 968 hours (Sylvester, 2002); Allen (2002) considered EPA's revised estimate of 180 hours to be acceptable. EPA assumed that the 180-hour estimate reflects labor requirements for the 22 States that already provide general NPDES permit coverage for CAFOs (US EPA, 2001) because these States have already resolved the applicability issue, which should not be substantially affected by the final rule. For the 21 States with approved programs that do not currently provide coverage under a general permit, EPA used the high estimate of 968 hours provided by Sylvester (2002) to incorporate additional time for the decision making process regarding which CAFOs would qualify for general permit coverage. The weighted average across all 43 States is approximately 570 hours ($0.51 \times 180 + 0.49 \times 968$) or 0.27 FTE.

Finally, States may conduct hearings regarding general permit revisions (or development for the States that do not provide general permit coverage for CAFOs). For the proposed rule, EPA derived costs for 240 hours based on the assumption that a State holds four hearings, each requiring 60 hours of labor time. Allen (2002) and Coats (2002) considered that assumption acceptable. Sylvester (2002) recommended an alternative estimate of 616 hours based on 12 hearings requiring 48 staff hours each plus an additional 40 hours for material preparation. For the final rule, EPA assumed that its original 240-hour estimate is sufficient for the 22 States that only need to revise existing general permits, and that the 21 States that do not provide general permit coverage for CAFOs will conduct additional hearings. For those States, EPA used the 616-hour estimate. The weighted average across all States is approximately 420 hours ($0.51 \times 240 + 0.49 \times 616$).

Adding together the three labor estimates for general permit development, EPA obtained a total estimate of 1,290 hours per general permit. For the 22 States that already provide general permit coverage, aggregate hours would be 720 hours. For the 21 States that would need to provide general permit coverage and determine which CAFOs are eligible, aggregate hours would be approximately 1,880 hours. It is possible that some of the States not currently providing general permit coverage will continue to rely solely on individual permits for CAFOs. Thus, EPA's cost analysis assumption that all 43 States will incur general permit revision costs provides an upper bound cost estimate.

CAFOs seeking coverage under a State's (or EPA's) general permit will submit completed NOI forms that the permitting authority will need to review and make a determination of coverage. For the proposed rule, EPA estimated that NOI review would require 1 hour. Comments indicated that the labor requirement would be substantially higher. For example, a Wisconsin State employee (Bazzell, 2001) indicated an expected expenditure of approximately 100 hours to review the NOI and accompanying documents. Ohio employees (Jones, et al., 2001) indicated that the estimates provided in the proposed rule did not allow time to ensure that the facilities were meeting all permit conditions. Willhite (2001) also indicated that costs for review of the NOI would be substantially higher. EPA believes that much of the concern regarding its proposed rule estimate centered on review of the proposed permit nutrient plan. For example, 60 hours of the 96-hour Wisconsin estimate pertained to reviewing the content of the NMP (Sylvester, 2002); 32 hours were allocated for review and approval of manure storage and runoff management systems, and 4 hours for general review for completeness of information. The final rule does not require a CAFO to submit this plan with the permit application, so this concern does not pertain to the final rule.

Nevertheless, EPA has revised the information requirements for the NOI and subsequently increased its estimate of the amount of time required for review. The final rule requires the following information be provided on the revised NOI and Form 2B: name and address of operator; manure storage mode and capacity; physical location including latitude and longitude of the production area; number of animals by type; estimated amount of manure generated per year; acreage available for agricultural use of manure, or litter and wastewater (under the control of the owner or operator); estimated amount of manure, or litter and wastewater to be transferred off site; and date for development of NMP, and expected date for full implementation. Reviews of the revised NOI forms to ensure completeness and accuracy of this required information should not take longer than 4 hours. This estimate is consistent with the one provided by Sylvester (2002). Furthermore, Allen (2002), Coats (2002), and Domingo (2002) indicated four hours would be adequate for NOI review. The annual reports that CAFOs are now required to submit (regardless of permit type) will contain updates for some of the information provided on the NOI form. Consequently, EPA assumed that the State burden to review an annual report, enter data as needed, and maintain CAFO records is the same as the NOI review estimate—4 hours.

EPA assumed that compliance inspections for CAFOs covered by a general permit would require an average of 16 hours, which includes 6 hours for round-trip travel time, 2 hours to prepare for the inspection, 4 hours to conduct the on-site portion of the inspection, and 4 hours for reporting and record keeping. This estimate is slightly greater than the recommendation of 12 hours made by Sylvester (2002), which included 8 hours for the inspection and travel time and 4 hours for reporting and data entry. EPA's estimate also equals the average of two inspection burden estimates in an active NPDES ICR (“Pollutant Discharge Elimination System and Sewage Sludge Management State Programs,” OMB NO. 2040-0057, EPA ICR 0168.07). The reconnaissance inspection has a burden estimate of 8 hours and the compliance evaluation inspection has a burden estimate of 24 hours. On average, CAFO inspections will require less time than a typical compliance evaluation inspection, which includes inspection of effluent and receiving waters and discharge monitoring records. A reconnaissance inspection often does not include review of onsite records. Thus, a CAFO inspection that includes review of onsite records in addition to a visual inspection of the operation will most likely require more than eight hours.

State administration costs for individual permits include 100 hours per permit to review Forms 1 and 2B, issue public notices, and respond to comments. EPA increased this estimate from the 70 hours used in its analysis of the proposed rule in response to comments (Muldener, 2001). Sylvester (2002) and Allen (2002) concurred with this estimate; Harsh (2002) thought it might be low, but Coats (2002) considered it to be twice the time needed.

EPA estimated that the hearing time for an individual permit would require 200 hours based on estimates from Washington State (KauzLoric, 1999), which indicated that a hearing required approximately 100 to150 hours of State employee time. Using BPJ, EPA assumed an average of two hearings per permit and an average requirement of 100 hours per hearing. This is higher than the estimate per hearing provided by Sylvester (2002). Nevertheless, Sylvester agreed with the estimate, as did Coats (2002) and Allen (2002). Harsh (2002) provided an alternative estimate of 22 to 33 hours. EPA decided to retain an average estimate of 200 hours because some individual permits may attract numerous participants and require multiple hearings.

EPA assumed that the inspection time and annual report review and subsequent recordkeeping costs for operations with individual permits would be the same as operations with general permits. The average inspection time will most likely be the same because most of the 16-hour estimate is spent on activities that will not vary across permit types. Similarly, the annual report content requirements are the same for all CAFOs regardless of permit type. Thus, the labor requirement is 4 hours.

Table 9-12 summarizes EPA's assumptions for general permit administration and Table 9-13 provides the assumptions used to develop State costs for individual permits. The same State wage rate is used to estimate unit costs. These tables also provide unit cost estimates for EPA, which is the permitting authority in some States.[5]

States may also need to undertake enforcement actions, but EPA has adopted the standard analytical assumption of full compliance for the purposes of estimating State and private sector expenditures. Given CAFO costs that reflect full compliance assumptions, there should be no need for enforcement actions. Therefore, this analysis excludes enforcement costs.

Although, the overall unit costs for permitting are generally higher than those used in proposal, due to a decrease in the universe of potential permittees under the final rule, States will incur much smaller permitting costs compared to either of the regulatory alternatives considered for EPA's proposed rule. For the proposed rule, EPA coproposed the following:

- A three-tier alternative in which all Tier 2 facilities would be required to either apply for an NPDES permit or submit certification that they did not meet any conditions necessitating a permit.

- A two-tier alternative that lowered the threshold for AFOs that were automatically defined as CAFOs from 1000 AU to 500 AU.

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[5] EPA used an hourly wage rate for a GS12, Step One Federal employee to estimate the cost of EPA staff. The U.S. Office of Personnel Management 2001 General Schedule reported a base annual salary of $51,927. EPA divided this by 2,080 hours to obtain an hourly rate of $24.96. Multiplying this rate by 1.6 to incorporate typical Federal benefits (OPM, 1999), EPA obtained a final hourly rate of $39.94 .

Table 9-12. State and Federal Administrative Costs Associated With General Permits.
(costs in 2001 dollars)

Administrative Activity	Unit Hours	Labor Cost	O&M Cost[1]
State Administrative Costs			
General Permit Development	1,290 per State	$38,420	$1,060
- Revise Permit	300 per State		
- Public Notice/Response to Comments	570 per State		
- Public Hearing(s)	420 per State		
Review and Approval of NOIs	4 per CAFO	$120	
Review Annual Reports	4 per CAFO	$120	
Facility Inspections	16 per CAFO	$480	
Federal Administrative Costs[2]			
Review and Approval of NOIs	4 per CAFO	$160	
Review Annual Reports	4 per CAFO	$160	
Facility Inspections	16 per CAFO	$640	

1. States may incur public notification costs for the general permit. The O&M cost estimate is based on the same assumption of $1,000 per public notice that was used for the proposed rule. That estimate assumed that public notices would be placed in four newspapers and each notice cost $250. The $1,000 was converted from 1999 dollars to 2001 dollars using the Consumer Price Index (1000 × 177.1/166.6 = 1060) (BLS, 2002a). This estimate is consistent with a cost estimate for public notification expenses provided by Tilley and Kirkpatrick (2002).

2. EPA employees will incur the same hourly burden for these activities as their State counterparts.

Table 9-13. State and Federal Administrative Costs Associated with Individual Permits.
(in 2001 dollars)

Administrative Activity	Unit Hours	Labor Cost	O&M Cost[1]
State Administrative Costs			
Application Review/Public Notification/Response to Comments	100 per CAFO	$2,980	$1,060
Public Hearing	200 per CAFO	$5,960	$1,060
Review Annual Reports	4 per CAFO	$120	
Facility Inspections	16 per CAFO	$480	
Federal Administrative Costs[2]			
Application Review/Public Notification/Response to Comments	100 per CAFO	$3,990	$1,060
Public Hearing	200 per CAFO	$7,990	$1,060
Review Annual Reports	4 per CAFO	$160	
Facility Inspections	16 per CAFO	$640	

1. States may incur public notification costs for each individual permit and hearing. The O&M cost estimate is based on the same assumption of $1,000 per public notice that was used for the proposed rule. That estimate assumed that public notices would be placed in four newspapers and each notice cost $250. The $1,000 was converted from 1999 dollars to 2001 dollars using the Consumer Price Index (1000 × 177.1/166.6 = 1060) (BLS, 2002a). This estimate is consistent with a cost estimate for public notification expenses provided by Tilley and Kirkpatrick (2002).

2. EPA employees will incur the same hourly burden for these activities as their State counterparts.

EPA estimated that 31,930 facilities would be affected under the proposed three-tier option. Under the proposed two-tier option, 25,540 facilities would have required NPDES permits. Based on the provisions of the final rule, EPA estimates that approximately 15,400 operations will require a permit. This estimate includes more than 10,700 large CAFOs, almost 4,500 medium operations defined as CAFOs, and almost 200 designated CAFOs. Because States incur most of their program costs through ongoing permit administration, EPA's final rule will be more cost effective and less burdensome than either of its proposed alternatives.

Of the 15,400 CAFOs requiring NPDES permits, EPA estimates that approximately 13,000 should have permits or meet the 25-year, 24-hour exemption under the 1976 regulations. EPA estimates, however, that only 4,100 permits have been issued, which implies that the permitting impact above the actual compliance baseline is approximately 11,300 permits.

EPA also recognizes that the final rule may affect permit conditions for those CAFOs that already have (or should have) permits. This could affect state costs for issuing permits and conducting inspections. Furthermore, revisions to the permit application forms may increase State review time as well as increase the time it takes producers to complete the forms. Thus, States may incur incremental costs for the baseline CAFOs that do (or should) have NPDES permits now. To simplify the analysis, EPA estimated an upper-bound impact that includes total permitting and inspection costs for all 15,400 CAFOs, although States are already incurring some portion of cost on 4,100 CAFOs. Actual new expenditures, therefore, will be lower than EPA's estimate suggests.

Operators or owners of a large CAFO may submit documentation that there is no potential to discharge in lieu of applying for a permit. The permitting authority would need to review the documentation and make a determination of whether there is a potential to discharge. Although there are no estimates of how many operations may pursue this option, given the stringent requirements, EPA believes that few, if any, operations will claim no potential to discharge. Therefore, EPA's cost analysis assumes that all CAFOs obtain NPDES permits. If any operation chooses to request a no-potential-to-discharge determination, then presumably doing so is as cost effective or more cost effective in the long run than obtaining a permit. Therefore, EPA concludes that its analysis may overstate costs should any CAFOs obtain an exemption based on no potential to discharge.

As noted above, only the approved States will incur costs. To derive State costs, EPA needed to estimate how often the States activities would occur. First, EPA estimated that 97 percent of the permitted CAFOs are located in these States based on its analysis of USDA livestock operation data. Second, EPA assumed that 70 percent of these CAFOs will request coverage under a State general permit (or EPA's general permit). The remaining 30 percent will obtain individual permits. EPA believes that the split between the two permit types is conservative (i.e., tending to overestimate costs) because the permit conditions for CAFOs are amenable to the use of a general permit. In particular, there are no facility-specific discharge limits that would require individual permitting. Third, EPA assumed that 12 percent of individual permits will require public hearings. The hearing percentage for individual permits is an average of estimates provided for Kansas (4 to 8 percent) and Indiana (15 to 20 percent). Finally, using best professional judgement, EPA assumed that each CAFO is inspected once within each 5-year permit period, which implies an annual inspection rate of 20 percent. The final rule contains no inspection frequency requirements and for NPDES purposes, this is a relatively high inspection rate because CAFOs fall into the category of nonmunicipal, minor dischargers, which have an annual inspection rate closer to 1 percent. States have indicated, however, that they inspect CAFOs more frequently to ensure compliance with multiple State requirements (US EPA, 2001). Although these frequent inspections may not be necessary to ensure NPDES compliance, inspectors can assess NPDES compliance status. Consequently, EPA increased its inspection rate estimate from 10 percent (used in the proposed rule) to 20 percent to reflect at least one NPDES-related inspection per CAFO every 5 years. This inspection rate includes the inspection required to designate a small or medium AFO, a CAFO.

Table 9-14 shows how the total estimate of 15,400 CAFOs and preceding assumptions generate the CAFO estimates for each of the permit-related costs shown in Tables 9-12 and 9-13. NPDES permits are valid for up to 5 years. Thus, States incur application review costs for each CAFO once every five years. To derive average annual costs, EPA assumed these costs would be incurred for 20 percent of total CAFOs each year. The annual CAFO column in Table 9-14 reflects this assumption.

Table 9-14. Derivation of CAFO Estimates Used to Calculate Annual Administrative Costs.[1]

Category	Total	Annual[1]
Total CAFOs	15,400	3,080
State-Issued Permits[2]	14,923	2,985
• General Permits	10,446	2,089
– Inspections	2,089	2,089
• Individual Permits	4,477	895
– Hearings	537	107
– Inspections	895	895
EPA-Issued Permits[2]	477	95
• General Permits	334	67
– Inspections	67	67
• Individual Permits	143	29
– Hearings	17	3
– Inspections	29	29

Detail may not add to totals because of independent rounding. The total CAFO estimate has been rounded to the nearest hundred for the purpose of this UMRA analysis.

1. Annual CAFO estimates for permit review costs equal total divided by 5 because permits are renewed every 5 years. Annual CAFO estimates for inspections equal 20 percent of total CAFOs.

2. EPA estimated the number of CAFOs in the 43 states with approved NPDES programs based on its analysis of USDA livestock operation data. EPA used this estimate to split total CAFOs between those receiving State-issued permits and EPA-issued permits.

To obtain the annual State costs reported in Table 9-15, EPA multiplied the one-time unit costs in Table 9-11 by the number of States expected to incur those costs. These one-time costs were then annualized over 5 years at a 7 percent discount rate.[6] Recurring annual permitting and inspection costs were derived by multiplying the unit costs in Tables 2 and 3 by their respective annual CAFO estimates in Table 9-14. Total annual State administrative costs are the sum of annualized one-time costs and annual permitting costs. The annual cost estimate for all States is $8.5 million. Federal costs for administering a portion of permits are shown in Table 9-16 for information purposes.

Table 9-15. Annual State Administrative Costs. (in 2001 dollars)

Administrative Activity	Unit Cost	Units	Total Cost ($millions)
Up-front State Costs			
Rule Development[1]	$27,430	43 States	$1.18
NPDES Program Modification Request	$7,450	43 States	$0.32
General Permit Development[1]	$39,480	43 States	$1.70
		Up-front Total	**$3.20**
		Annualized up-front Costs[2]	**$0.73**
Average Annual Implementation Costs for Permits and Inspections			
Review and Approve NOIs for General Permits	$120	2,089 CAFOs per year	$0.25
Review Applications/Public Notices/Respond to Comments for Individual Permits[1]	$4,040	895 CAFOs per year	$3.61
Public Hearings for Individual Permits[1]	$7,020	107 CAFOs per year	$0.75
Review Annual Reports (General and Individual Permits)	$120	14,923 CAFOs per year	$1.78
Facility Inspections (General and Individual Permits)	$480	2,984 CAFOs per year	$1.42
		Annual Permit Costs	**$7.81**
		Total Annual Costs	**$8.54**

Detail may not add to totals due to independent rounding.
1. Includes O&M costs.
2. Total up-front costs annualized over 5 years at a 7 percent discount rate.

[6] Assuming a 5-year annualization period generates a conservative annual estimate that tends to overstate costs because it treats these one-time activities as though they recur every five years, which is unlikely to be the case.

Table 9-16. Federal Administrative Costs. (in 2001 dollars)			
Administrative Activity	**Unit Cost**	**Units**	**Total Cost ($millions)[1]**
Average Annual Implementation Costs for Permits and Inspections			
Review and Approve NOIs for General Permits	$160	67 CAFOs per year	$0.01
Review Applications/Public Notices/Respond to Comments for Individual Permits[2]	$3,990	29 CAFOs per year	$0.15
Public Hearings for Individual Permits[2]	$7,990	3 CAFOs per year	$0.03
Review Annual Reports (General and Individual Permits)	$160	477 CAFOs per year	$0.08
Facility Inspection (General and Individual Permits)	$640	95 CAFOs per year	$0.06
		Annual Permit Costs	**$0.32**

Detail may not add to totals due to independent rounding.
1. EPA used an hourly wage rate for a GS12, Step One Federal employee to estimate the cost of the Agency staff. The U.S. Office of Personnel Management (OPM, 2001) General Schedule reported a base annual salary of $51,927 in 2001. EPA divided this by 2,080 hours to obtain an hourly rate of $24.96. Multiplying this rate by 1.6 to incorporate typical Federal benefits (OPM, 1999), EPA obtained a final hourly rate of $39.94.
2. Includes O&M costs.

New State expenditures as a result of the final rule are expected to differ across States. Although all approved States will incur up-front costs to revise their rules and implement programs, States with more CAFOs will incur more annual costs. EPA estimated that almost 50 percent of permitted CAFOs are located in seven States: approximately 9 percent in both Iowa and North Carolina; approximately 6 percent in both Georgia and California; and between 5 and 6 percent in each of Nebraska, Minnesota, and Texas. Thus, these States are likely to incur much higher annual costs than other States. State costs will also vary depending on the rate at which they utilize general versus individual permits.

States can use existing sources of financial assistance to revise and implement the final rule. Section 106 of the CWA authorizes EPA to provide federal assistance (from Congressional appropriations) to States, Tribes, and interstate agencies to establish and implement ongoing water pollution control programs. Section 106 grants offer broad support to States to administer programs to prevent and abate surface and ground water pollution from point and nonpoint sources. States may use the funding for a variety of activities including permitting, monitoring, and enforcement. Thus, State NPDES permit programs represent one type of State program that can be funded by Section 106 grants. The total appropriation for Section 106 grants for fiscal year 2002 was $192,476,900. On average, eligible States may receive between $60,000 to $9,000,000 of the total appropriation.

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CHAPTER 10

TECHNOLOGY OPTIONS CONSIDERED

This section describes the combinations of treatment technologies and best management practices (BMPs) that EPA configured as technology options for consideration as bases for the Concentrated Animal Feeding Operation (CAFO) effluent limitations guidelines and standards (ELGs). EPA developed technology options for the following:

- Best practicable control technology currently available (BPT);
- Best conventional pollutant control technology (BCT);
- Best available technology economically achievable (BAT); and
- New source performance standards (NSPS).

Technology bases for each option for each regulation were selected from the treatment technologies and BMPs described in Chapter 8. Sections 10.1 through 10.4 discuss the regulatory options that were considered for each of the regulations listed above.

10.0 INTRODUCTION

The regulations applicable to Large CAFOs are ELGs which are applied to individual operations through National Pollutant Discharge Elimination System (NPDES) permits issued by EPA or authorized states under Section 402 of the Clean Water Act (CWA). For Large CAFOs under Subparts C and D, the final ELG regulations prohibit the discharge of manure, litter, and other process wastewater, except for allowing discharge when rainfall causes an overflow from a facility designed, maintained, and operated to contain all process wastewaters, including storm water, plus runoff from the 25-year, 24-hour rainfall event.

All of these regulations are based upon the performance of specific technologies but not require the use of any specific technology.

10.1 Best Practicable Control Technology Currently Available (BPT)

The BPT effluent limitations control conventional, priority, and nonconventional pollutants when discharged from CAFOs to surface waters of the United States. Generally, EPA determines BPT effluent levels based upon the average of the best existing performances by plants of various sizes, ages, and unit processes within each industrial category or subcategory. In industrial categories where present practices are uniformly inadequate, however, EPA may determine that BPT requires higher levels of control than any currently in place if the technology to achieve those levels can be practicably applied.

In addition, CWA Section 304(b)(1)(B) requires a cost assessment for BPT limitations. In determining the BPT limits, EPA must consider the total cost of treatment technologies in relation to the effluent reduction benefits achieved. This inquiry does not limit EPA's broad discretion to adopt BPT limitations that are achievable with available technology unless the required additional reductions are "wholly out of proportion to the costs of achieving such marginal level of reduction." See Legislative History, op.cit. p. 170. Moreover, the inquiry does not require the Agency to quantify benefits in monetary terms. See e.g., American Iron and Steel Institute v. EPA, 526 F. 2d 1027 (3rd Cir., 1975).

In balancing costs against the benefits of effluent reduction, EPA considers the volume and nature of expected discharges after application of BPT, the general environmental effects of pollutants, and the cost and economic impacts of the required level of pollution control. In developing guidelines, the CWA does not require or permit consideration of water quality problems attributable to particular point sources, or water quality improvements in particular bodies of water. Therefore, EPA has not considered these factors in developing the final limitations. See Weyerhaeuser Company v. Costle, 590 F. 2d 1011 (D.C. Cir. 1978).

10.1.1 BPT Options for the Subpart C Subcategory

EPA incorporated the following BMPs into all BPT technology options:

Production Area BMPs

- Perform weekly inspections of all storm water diversion devices, runoff diversion structures, animal waste storage structures, and devices channeling contaminated storm water to the wastewater and manure storage and containment structure;
- Perform daily inspections of all water lines, including drinking water or cooling water lines;
- Install depth markers in all surface and liquid impoundments (e.g., lagoons, ponds, tanks) to indicate the design volume and to clearly indicate the minimum capacity necessary to contain the 25-year, 24-hour rainfall event, including additional freeboard requirements, or in the case of new sources subject to Subpart D, the runoff and direct precipitation from 100-year, 24-hour rainfall event;
- Correct any deficiencies found as a result of daily and weekly inspections as soon as possible;
- Do not dispose of mortalities in liquid manure or storm water storage or treatment systems, and mortalities must be handled in such a way as to prevent discharge of pollutants to surface water unless alternative technologies are approved; and
- Maintain on-site a complete copy of the records specified in 40 CFR 412.37(b). These records must be maintained for 5 years and if requested, be made available to the permitting authority.

Land Application BMPs

- Land-apply manure, litter, and other process wastewaters in accordance with a nutrient management plan that establishes application rates for each field based on the nitrogen requirements of the crop, or on the phosphorus requirements where necessary because of soil or other field conditions.
- Account for other sources of nutrients when establishing application rates, including previous applications of manure, litter, and other process wastewaters; residual nutrients in the soil; nitrogen credits from previous crops of legumes; and application of commercial fertilizers, biosolids, or irrigation water.
- Collect and analyze manure, litter, and other process wastewaters annually for nutrient content, including nitrogen and phosphorus.
- Calibrate manure application equipment annually.
- Applications of manure, litter, and other process wastewaters are prohibited within 100 feet of any down-gradient surface waters, open tile line intake structures, sinkholes, agricultural well heads, or other conduits to surface waters. As a compliance alternative to the 100-foot setback, the CAFO may elect to establish a 35-foot vegetated buffer where application of manure, litter, or other process wastewaters is prohibited. The CAFO may also demonstrate to the permitting authority that a setback or vegetated buffer is unnecessary because implementation of alternative conservation practices or site-specific conditions will provide pollutant reductions equivalent to or better than the reductions that would be achieved by the 100-foot setback.
- Maintain on-site the records specified in 40 CFR 412.37(c). These records must be maintained for 5 years and if requested, be made available to the permitting authority.

In addition, BPT options for Subpart C operations (dairy and beef cattle other than veal which includes heifer operations) include the following technology bases:

Option 1: Zero discharge from a facility designed, maintained, and operated to hold manure, litter, and other process wastewaters, including direct precipitation and runoff from a 25-year, 24-hour rainfall event. In addition, determine the maximum allowable nitrogen-based application rates based on the nitrogen requirement of the crop to be grown and realistic crop yields that reflect the yields obtained for the given (or similar) field in prior years. Manure, litter, and other process wastewater applications must not exceed the nitrogen-based application rate.

Option 1A: The same elements as Option 1, with the addition of storage capacity for the chronic storm event (10-year, 10-day storm) above any capacity necessary to hold manure, litter, and other process wastewaters, including direct precipitation and runoff from a 25-year, 24-hour rainfall event.

Option 2: The same elements as Option 1, except nitrogen-based agronomic application rates are replaced by phosphorus-based agronomic application rates when dictated by site-specific conditions. In addition, at least once every three years, collect and analyze representative soil samples for phosphorus content from all fields where manure, litter, and other process wastewaters are applied.

Options 3A/3B: The same elements as Option 2, plus ground-water monitoring, concrete pads, synthetically lined lagoons and/or synthetically lined storage ponds for operations located in environmentally sensitive areas such as karst terrain where ground water contamination is likely and an assessment of the ground water's hydrologic link to surface water for all other operations.

Options 3C/3D: The same elements as Option 2, plus permeability standards for lagoons and storage ponds for operations located in environmentally sensitive areas such as karst terrain. No additional requirements are placed on operations not located in environmentally sensitive areas.

Option 4: The same elements as Option 2, plus costs for additional surface water monitoring.

Option 5A: The same elements as Option 2, plus implementation of a drier manure management system (i.e., composting).

Option 6: For Large dairy operations only, the same elements as Option 2, plus implementation of anaerobic digestion with energy recovery.

Option 7: The same elements as Option 2, plus timing restrictions on land application of animal waste to frozen, snow-covered, or saturated ground.

In addition to the technology options described above, EPA conducted several sensitivity analyses of costs include the requirement that all operations use a phosphorus-based agronomic rate as opposed to only when dictated by site-specific conditions, and all recipients of manure from a CAFO prepare nutrient management plans.

10.1.2 BPT Options for the Subpart D Subcategory

BPT options for Subpart D operations (swine, poultry, and veal calves) are the same as those described in Section 10.2.1 for Subpart C operations for Options 1, 1A, 2, 3A/3B, 3C/3D, 4, and 7. Option 5A is replaced by Option 5 and Option 6 is modified to address the operations under Subpart D. Descriptions of Options 5 and 6 for Subpart D operations are described below.

Option 5: The same elements as Option 2, but based on zero discharge with no overflow under any circumstances (i.e., total confinement and covered storage).

Option 6: For Large swine operations, the same elements as Option 2, plus implementation of anaerobic digestion with energy recovery.

10.2 Best Conventional Pollutant Control Technology (BCT)

BCT limitations control the discharge of conventional pollutants from direct dischargers. Conventional pollutants include BOD, TSS, oil and grease, and pH. BCT is not an additional limitation, but rather replaces BAT for the control of conventional pollutants. To develop BCT limitations, EPA conducts a cost reasonableness evaluation, which consists of a two-part cost test: 1) the POTW test, and 2) the industry cost-effectiveness test.

In the POTW test, EPA calculates the cost per pound of conventional pollutants removed by industrial dischargers in upgrading from BPT to a BCT candidate technology and then compares this to the cost per pound of conventional pollutants removed in upgrading POTWs from secondary to tertiary treatment. The upgrade cost to industry, which is represented in dollars per pound of conventional pollutants removed, must be less than the POTW benchmark of $0.25 per pound (in 1976 dollars). In the industry cost-effectiveness test, the ratio of the incremental BPT to BCT cost, divided by the BPT cost for the industry, must be less than 1.29 (i.e., the cost increase must be less than 29 percent).

In developing BCT limits, EPA considered whether there are technologies that achieve greater removals of conventional pollutants than for BPT, and whether those technologies are cost-reasonable according to the BCT Cost Test. In each subcategory, EPA considered the same technologies and technology options when developing BCT options as were developed for BPT.

10.3 Best Available Technology Economically Achievable (BAT)

The factors considered in establishing a BAT level of control include: the age of process equipment and facilities, the processes employed, process changes, the engineering aspects of applying various types of control techniques to the costs of applying the control technology, non-water quality environmental impacts such as energy requirements, air pollution and solid waste generation, and such other factors as the Administrator deems appropriate (Section 304(b)(2)(B) of the Act). In general, the BAT technology level represents the best existing economically achievable performance among facilities with shared characteristics. BAT may include process changes or internal plant controls which are not common in the industry. BAT may also be transferred from a different subcategory or industrial category.

In each subcategory, EPA considered the same technologies and technology options when developing BAT options as were developed for BPT.

10.4 New Source Performance Standards (NSPS)

NSPS under Section 306 of the CWA represent the greatest degree of effluent reduction achievable through the application of the best available demonstrated control technology for all pollutants (i.e., conventional, nonconventional, and toxic pollutants). NSPS are applicable to new industrial direct discharging facilities. Congress envisioned that new treatment systems could meet tighter controls than existing sources because of the opportunity to incorporate the most efficient processes and treatment systems into plant design. Therefore, Congress directed EPA, in establishing NSPS, to consider the best demonstrated process changes, in-plant controls, operating methods, and end-of-pipe treatment technologies that reduce pollution to the maximum extent feasible.

In each subcategory, EPA considered the same technologies and technology options for all animal sectors when developing NSPS options as were developed for BPT. In addition, at proposal, EPA considered a zero discharge option with no exception for storm overflows, based on maintaining animals in total confinement.

CHAPTER 11

MODEL FARMS AND COSTS OF TECHNOLOGY BASES FOR REGULATION

This section describes the methodology used to estimate engineering compliance costs associated with implementing the regulatory options for the concentrated animal feeding operations (CAFOs) industry. The information contained in this section provides an overview of the methodology and assumptions built into the cost models. More detailed information on the cost methodology and specific technologies and practices is contained in the *Cost Methodology for the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations* (2002).

The following information is discussed in this section:

- Section 11.1: Overview of cost methodology;
- Section 11.2: Development of model farm operations;
- Section 11.3: Design and cost of waste and nutrient management technologies;
- Section 11.4: Development of frequency factors;
- Section 11.5: Summary of estimated industry costs by regulatory option; and
- Section 11.6: References.

11.1 Overview of Cost Methodology

To assess the economic impact of the effluent limitations guidelines and standards on the CAFOs industry, EPA estimated costs associated with regulatory compliance for each of the regulatory options described in Section 10. The economic burden is a function of the estimated costs of compliance to achieve the requirements, which may include initial fixed and capital costs, as well as annual operating and maintenance (O&M) costs. Estimation of these costs typically begins by identifying the practices and technologies that can be used to meet a particular requirement. The Agency then develops a cost model to estimate costs for their implementation.

EPA used the following approach to estimate compliance costs for the CAFOs industry:

- EPA collected data from published research, meetings with industry organizations, discussions with USDA cooperative extension agencies, review of USDA's Census of Agriculture data, and site visits to swine, poultry, beef, veal, and dairy CAFOs. These data were used to define model farms and to determine waste generation and nutrient concentration, current waste and nutrient practices, and the viability of waste management technologies for the model farms.

- EPA identified candidate waste and nutrient management practices and grouped appropriate technologies into regulatory options. These regulatory options serve as the bases of compliance cost and pollutant loading calculations.
- EPA developed technology frequency factors to estimate the percentage of the industry that already implements certain operations or practices required by the regulatory options (i.e., baseline conditions).
- EPA developed cost equations for estimating capital costs, initial fixed costs, and 3-year recurring costs, 5-year recurring costs, and annual O&M costs for the implementation and use of the different waste and nutrient practices targeted under the regulatory options. Cost equations were developed from information collected during the site visits, published information, vendor contacts, and engineering judgment.
- EPA developed and used computer cost models to estimate compliance costs and nutrient loads for each regulatory option.
- EPA used output from the cost model to estimate total annualized costs and the economic impact of each regulatory option on the CAFOs industry (presented in the *Economic Analysis*).

Table 11-1 presents the regulatory options and the waste and nutrient management components that make up each option.

Table 11-1. Summary of Regulatory Options for CAFOs

Technology or Practice	Options									
	1	1A	2	3A/ 3B	3C/ 3D	4	5	5A	6	7
Feedlot best management practices (BMPs), including storm water diversions, lagoon/pond depth markers, periodic inspections, and records	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mortality handling requirements (e.g., rendering, composting)[1]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nutrient management planning and recordkeeping (sample soils once every 3 years, sample manure twice per year)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Land application limited to nitrogen-based agronomic	✓	✓								
Land application limited to phosphorus-based agronomic application rates where dictated by site-specific conditions, and nitrogen-based application elsewhere			✓	✓	✓	✓	✓	✓	✓	✓
No manure application within 100 feet of any surface water, tile drain inlet, or sinkhole	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ground water requirements, including assessment of hydrologic link, monitoring wells (four per facility), impermeable pads under storage, impermeable lagoon/pond liners, and temporary/modified storage during upgrade				✓						
Ground water requirements including performance based standards for lagoons					✓					
Additional capacity for 10-year, 10-day chronic storm event		✓								
Surface water monitoring requirement, including four total grab samples upstream and downstream of both feedlot and land application areas, 12 times per year. One composite sample collected once per year at stockpile and surface impoundments. Samples are analyzed for nitrogen, phosphorus, and total suspended solids.						✓				
Drier manure technology basis[2,3]							✓	✓		
Anaerobic digestion									✓	
Timing requirements for land application (resulting in regional variation in storage periods)										✓

[1] There are no additional compliance costs expected for beef and dairy operations related to mortality handling requirements.
[2] Option 5 mandates "drier waste management." For beef feedlots and dairies, this technology basis is composting. For swine, poultry and veal operations, drier systems include covered lagoons.
[3] Option 5B mandates "no overflow" systems. For swine operations, the technology basis is high-rise housing for hogs, and for poultry operations the technology basis is dry systems.
(ERG, 2000a; Tetra Tech, Inc., 2000a)

11.2 Development of Model Farm Operations

For the purpose of estimating total costs and economic impacts, EPA calculated the costs of compliance for CAFOs to implement each of the regulatory options being considered. These costs reflect the range of capital costs, annual operating and maintenance costs, start-up or first year costs, as well as recurring costs that may be associated with complying with the regulations. EPA traditionally develops either facility-specific or model facility costs. Facility-specific compliance costs require detailed process information about many, if not all, facilities in the industry. These data typically include production, capacity, water use, wastewater generation, waste management operations (including design and cost data), monitoring data, geographic location, financial conditions, and any other industry-specific data that may be required for the analyses. EPA then uses each facility's information to determine how the potential regulatory options will impact that facility, and to estimate the cost of installing new pollution controls.

When facility-specific data are not available, EPA develops model facilities to provide a reasonable representation of the industry. Model facilities are developed to reflect the different characteristics found in the industry, such as the size or capacity of operations, types of operation, geographic locations, modes of operation, and types of waste management operations. These models are based on data gathered during site visits, information provided by industry members and their trade associations, and other available information. EPA estimates the number of facilities that are represented by each model. Cost and financial impacts are estimated for each model farm, then industry-level costs are calculated by multiplying model farm costs by the number of facilities represented by each particular model. Because of the amount and type of information that is available for the CAFOs industry, EPA has chosen a model-facility approach to estimate compliance costs.

EPA estimated compliance costs using a representative facility approach based on more than 1,700 farm-level models that were developed to depict conditions and to evaluate compliance costs for select representative CAFOs. The major factors used to differentiate individual model CAFOs include the commodity sector, the farm production region, the facility size (based on herd or flock size or the number of animals on site), and performance of the operation. EPA's model CAFOs primarily reflect the major animal sector groups, including beef cattle, dairy, hog, broiler, turkey, and egg laying operations. Practices at other subsector operations are also reflected by the cost models, such as replacement heifer operations, veal operations, flushed caged layers, and hog grow-finish and farrow-to-finish facilities. Model facilities with similar waste management and production practices were used to depict operations in regions that were not separately modeled.

Another key distinguishing factor incorporated into EPA's model CAFOs is the availability of cropland and pastureland to apply manure nutrients to land. For this analysis, nitrogen and phosphorus rates of land application are evaluated for three categories of cropland use: Category 1 CAFOs that have sufficient land for all on-farm nutrients generated, Category 2 CAFOs that have insufficient land, and Category 3 CAFOs that have no land. The number of CAFOs within a given category of land availability is drawn from 1997 USDA data and varies depending on which nutrient (nitrogen or phosphorus) is used as the basis to assess land application and nutrient management costs. For Category 2 and 3 CAFOs, EPA evaluated additional technologies that may be necessary to balance on-farm nutrients. These technologies may also be used to reduce off-site hauling costs associated with excess on-farm nutrients. Such technologies may include best management practices (BMPs) and various farm production technologies, such as feed management strategies, solid-liquid separation, composting, anaerobic digestion, and other retrofits to existing farm technologies.

EPA's model CAFOs also take into account such production factors as climate and farmland geography, as well as land application and waste management practices and other major production practices typically found in the key producing regions of the country. Required practices under existing state regulations are also taken into account. Model facilities reflect major production practices used by larger confined animal farms, generally those with more than 300 animal units. Therefore, the models do not reflect pasture and grazing type farms, nor do they reflect typical costs to small farms. EPA's cost models also reflect cost differences within sectors depending on manure composition, bedding use, and process water volumes.

11.2.1 Swine Operations

EPA developed the parameters describing the model swine farms using information from the National Agriculture Statistics Service (NASS), site visits to swine farms across the country, discussions with the National Pork Producers Council, and the USDA Natural Resources Conservation Service (NRCS). Dscriptions of the various components that make up the model farms are presented in the following discussion, and the sources of the information used to develop that piece of the model farm are noted.

11.2.1.1 Housing

Swine are typically housed in total confinement barns, and less commonly in other housing configurations such as open buildings with or without outside access and pastures (USDA, 1995). On many farms, small numbers of pigs (fewer than the number covered by this regulation) are raised outdoors; however, the trend in the industry is toward larger confinement farms at which pigs are raised indoors (North Carolina State University, 1998). For these reasons, the model swine farm is assumed to house its animals in total confinement barns.

11.2.1.2 Waste Management Systems

The characteristics of waste produced at an operation depends on the type of animals that are present. In farrow-to-finish operations, the pigs are born and raised at the same facility. Therefore, the manure at a farrow-to-finish farm has the characteristics of mixed excreta from varying ages. In grow-finish facilities, young pigs are first born and cared for at a nursery in another location, and then brought onto the finishing farm. Therefore, the manure at a grow/finish farm has characteristics of older pigs 7 weeks to slaughter weight. These are the two predominant types of swine operations in the United States from the size classes that would be covered under the final rule.

Swine houses with greater than 750 head typically store their wastes in pits under the house or flush the wastes to outside lagoons. Slatted floors or flush alleys are used to separate manure and wastes from the animal. It is common to allow manure to collect in a pit and wash the pit one to six times per day with water to move the waste to a lagoon. The waste is stored in the lagoon until it is applied to land or transported off site. Storing the waste in an anaerobic lagoon provides some treatment during storage, conditioning the wastewater for later land application, and reducing odors (NCSU, 1998). EPA developed model farms for farrow-to-finish and grow/finish operations in the Mid-Atlantic and Midwest regions that are assumed to use pits or flush alleys and anaerobic lagoon storage.

In the Midwest, a deep pit storage system is more common. Deep pit systems start with several inches of water in the pit, and the manure is collected and stored under the house until it is pumped out for field application, typically twice a year. This system uses less water, creating a manure slurry that has higher nutrient concentrations than the flush system described earlier. A survey of swine operations in 2000 shows that both lagoons and deep pits are commonly used for waste storage in the Midwest region (USDA APHIS, 2002). For purposes of developing the cost models, EPA estimated, from the USDA APHIS (2002) data, the percentage of farrow-to-finish and grow/finish operations in the Mid-Atlantic and Midwest regions that use pit storage. EPA developed model farms for farrow-to-finish and grow/finish operations in the Mid-Atlantic and Midwest regions that are assumed to use pit storage pumped twice per year.

Although not present in the statistics that were available to the EPA at the time of this analysis, EPA recognizes the increasing number of large swine operations in the Central region. Many of these larger operations in the Central region use evaporative lagoons instead of traditional anaerobic lagoons found in the Mid-Atlantic and Midwest. Thus, EPA developed model farms for large facilities in the Central region and assumed evaporative lagoons are used for waste storage.

EPA’s swine model farms under Option 5 assume that all lagoons are covered with a synthetic cover. Facilities that use deep pit storage are not assumed to need any additional practices to comply with Option 5.

Figure 11-1 presents these waste management systems used for the model swine farms in this cost model.

11.2.1.3 Size Group

The general trend in the U.S. swine industry is toward a smaller number of large operations that have a larger number of animals on site. The number of smaller facilities, which tend to house the animals outdoors, has significantly decreased over the past 10 years (North Carolina State University, 1998). The trend in the larger operations is toward extended use of confinement operations.

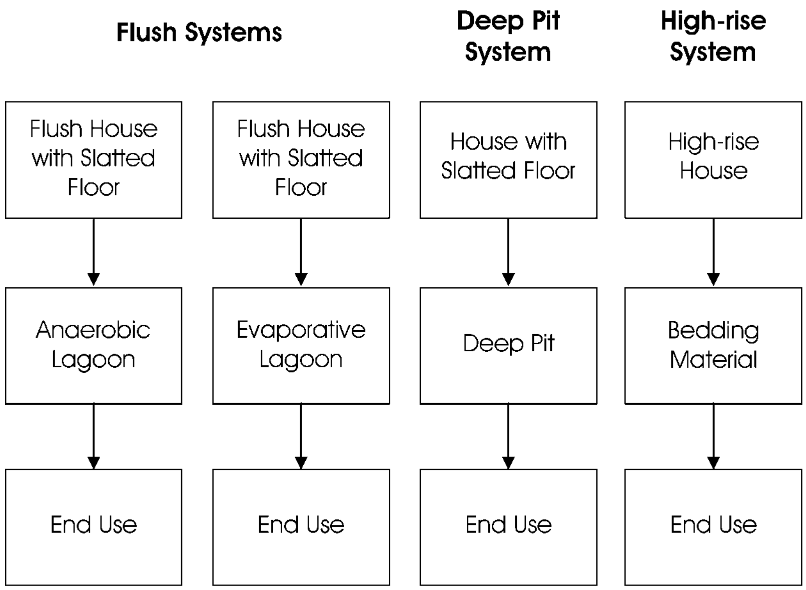


Figure 11-1. Swine Model Farm Waste Management System

For this regulation, five size groups were modeled for each type of model farm. The size groups are provided in Table 11-2.

Table 11-2. Number of Swine per Facility based on Modeled Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure

Region	Land Availability Category	Medium 1	Medium 2	Medium 3	Large 1	Large 2
Central	No excess	NA	NA	NA	2,500	6,037
Central	Excess, with acres	NA	NA	NA	3,304	9,890
Central	Excess, no acres	NA	NA	NA	4,999	34,944
Mid-Atlantic	No excess	883	1,346	1,888	2,500	6,390
Mid-Atlantic	Excess, with acres	964	1,496	2,077	4,134	12,375
Mid-Atlantic	Excess, no acres	976	1,477	2,051	4,424	14,929
Midwest	No excess	863	1,311	1,885	2,500	5,094
Midwest	Excess, with acres	926	1,415	1,965	2,878	9,172
Midwest	Excess, no acres	976	1,522	2,114	4,463	16,636

NA - Not applicable.

11.2.1.4 Region

Data from site visits and North Carolina State University's draft *Swine and Poultry Industry Characterization* indicate that the predominant type of waste management system at swine operations varies from region to region (NCSU, 1998). EPA decided to develop model farms for the Mid-Atlantic and Midwest regions because over 93 percent of the facilities with more than750 head were located in these two regions in 1997 (USDA NASS, 1999). EPA added additional model farms in the Central region based on comments received on the proposed rule that many large facilities had recently located in states in the Central region.

As previously mentioned, flush-to-lagoon waste storage systems are more common in the Mid-Atlantic region while deep-pit storage systems are common in the Midwest. Given the regional variances in waste management systems, other variations in farming practices (e.g., crop rotations), and differences in climate, swine operations with both type of waste storage systems were modeled in both regions. Large swine operations that use evaporative lagoons for waste storage were modeled in the Central region. Operations located in other regions were split among the modeled regions to fully account for operations in a given size class. Allocating operations from one region to another was necessary since the census data could not be obtained for all desired regions and size groups (USDA NASS, 1999).

11.2.2 Poultry Operations

EPA developed four model farms to represent poultry operations in the United States. The model farms are broiler, turkey, dry layer, and wet layer operations. EPA developed the parameters describing the model poultry farms using information from NASS, site visits to poultry farms across the country, and the USDA NRCS. A description of the various components of each model farm is presented in the following discussion, and the sources of the information used to develop each piece of the model farm are noted.

11.2.2.1 Housing

Broilers and turkeys are typically housed in long barns (approximately 40 feet wide and 400 to 500 feet long; NCSU, 1998) and are grown on the floor of the house. The floor of the barn is covered with a layer of bedding, such as wood shavings, and the broilers or turkeys deposit manure directly onto the bedding. Approximately 4 inches of bedding are initially added to the houses and top dressed with about 1 inch of new bedding between flocks.

Layers are typically confined in cages in high-rise housing or shallow pit flush housing. In a high-rise house, the layer cages are suspended over a bottom story, where the manure is deposited and stored. EPA used this configuration to model housing for dry layer model farms. In shallow pit flush housing, a single layer of cages is suspended over a shallow pit. Manure drops directly into the pit, where it is flushed out periodically using recycled lagoon water. EPA used this configuration to model housing for wet layer model farms.

These poultry housing systems are considered typical systems in the poultry industry (NCSU, 1998). Therefore, the cost model uses these farm housing systems in the model farms.

11.2.2.2 Waste Management Systems

Manure from broiler and turkey operations accumulate on the floor where it is mixed with bedding, forming litter. Litter close to drinking water forms a cake that is removed between flocks. The rest of the litter in a house is removed periodically (6 months to 2 years) from the barns, and then transported off site or applied to land. Typically, broiler and turkey operations are completely dry waste management systems (NCSU, 1998). Therefore, EPA used this waste management configuration in modeling both broiler and turkey model farms.

Layer operations may operate as a wet or a dry system. Approximately 12 percent of layer houses use a liquid flush system, in which waste is removed from the house and stored in a lagoon (USDA APHIS, 2000). Operations that use this type of waste management system are referred to as wet layers. The remaining layer operations typically operate as dry systems, with manure stored in the house for up to a year. A scraper is used to remove waste from the collection pit or cage area (NCSU, 1998). Operations that use this type of waste management system are referred to as dry layers. The lagoon wastewater and dry manure are stored until they are applied to land or transported off site. Figure 11-2 presents the waste management systems for poultry.

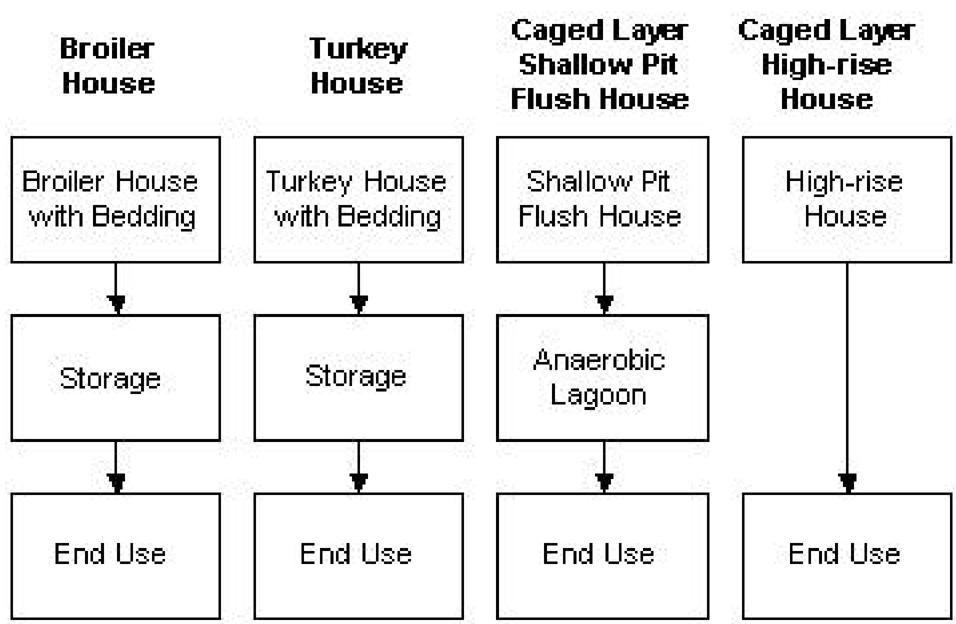


Figure 11-2. Poultry Model Farm Waste Management System

11.2.2.3 Size Group

For the final regulation, EPA modeled four size groups for broiler and dry layer operations, two size groups for wet layer operations, and four size groups for turkey operations. The size groups are presented in Tables 11-3, 11-4, and 11-5.

Table 11-3. Number of Broilers per Facility Based on Modeled Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure.

Region	Land Availability Category	Medium 1	Medium 2	Medium 3	Large 1	Large 2
Mid-Atlantic	No excess	39,642	55,618	85,355	125,000	219,247
Mid-Atlantic	Excess, with acres	39,851	58,110	89,171	132,696	326,246
Mid-Atlantic	Excess, no acres	39,609	56,176	86,342	149,292	385,154
South	No excess	38,845	53,886	82,820	125,000	219,247
South	Excess, with acres	39,427	57,644	88,596	135,091	312,224
South	Excess, no acres	39,419	57,557	88,516	132,017	325,838

Table 11-4. Average Head Count for Layer Operations.

Size Class	Size Class Interval (Number of Head)		Average Head Count per Operation
	Lower	Upper	
Dry Layer Operations			
Medium 1	25,000	49,999	36,068
Medium 2	50,000	74,999	61,734
Medium 3	75,000	81,999	78,546
Large 1	82,000	599,999	291,153
Large 2	≥600,000		856,368
Wet Layer Operations			
Medium 1	9,000	29,999	19,500
Large 1	≥30,000		146,426

Table 11-5. Turkey Facility Demographics from the 1997 Census of Agriculture Database.

Size Class	Size Class Interval (Number of Head)		Average Head Count per Operation
	Lower	Upper	
Medium 1	16,500	27,499	22,246
Medium 2	27,500	41,249	34,640
Medium 3	41,250	54,999	47,534
Large 1	≥55,000		127,396

Source: USDA NRCS, 2002.

11.2.2.4 Region

Data from site visits and North Carolina State University's draft *Swine and Poultry Industry Characterization* indicate that the predominant type of waste management system at poultry operations varies from region to region (NCSU, 1998). Most of the broiler operations in the United States are located in the South and Mid-Atlantic regions, while most of the egg-laying operations are located in the Midwest and South regions. Therefore, the model broiler farm reflects the South and Mid-Atlantic regions, and the model layer farm reflects the Midwest and South regions. State-level data from the 1997 Census of Agriculture indicate that states in the Midwest and Mid-Atlantic regions of the United States account for over 70 percent of all turkeys produced. For this reason, model turkey farms are located in the Mid-Atlantic and Midwest regions (USDA NASS, 1999).

11.2.4 Dairy Operations

EPA developed two model farms to represent medium- and large-sized dairies in the United States: a flush dairy and a hose/scrape dairy. EPA developed the parameters describing the dairy model farms from information from USDA, 1997 Agricultural Census data, data collected during site visits to dairy farms across the country, meetings with USDA extension agents, and meetings with the National Milk Producers Federation and Western United Dairymen. Description of the various components that make up the model farms are presented below, with the sources of the information used to develop each piece of the model farm.

11.2.4.1 Housing

To determine the type of housing used at the model farm, the type of animals on the farm were considered. In addition to the mature dairy herd (including lactating, dry, and close-up cows), there are often other animals on site at the dairy, including calves and heifers. The number of immature animals (i.e., calves and heifers) at the dairy is proportional to the number of mature cows in the herd, but further depends on the farm's management. For example, the dairy may house virtually no immature animals on site and obtain their replacement heifers from off-site operations, or the dairy could have close to a 1:1 ratio of immature animals to mature animals. Site visits suggest the trend that the largest dairy managers want to focus on milk production only, and prefer not to keep heifers on site.

Typically, according to Census of Agriculture data, for dairies greater than 200 milking cows, the number of calves and heifers on site equals approximately 60 percent of the mature dairy (milking) cows (USDA, 1997). EPA assumes that there are an equal number of calves and heifers on site (30 percent each) at the dairy model farms. Based on this information, the number of calves on site is estimated to be 30 percent of the number of mature cows on site, as are the number of heifers on site. The percentage of bulls is typically small (USDA, 1997), as most dairies do not keep them on site. For this reason, EPA assumed that their impact on the model farm waste management system is insignificant, and did not consider bulls in the dairy model farm.

The most common types of housing for mature cows include freestall barns, tie stalls/stanchions, pasture, drylots, and combinations of these (Stull, 1998). Based on site visits, most medium- to large-sized dairies (>200 mature dairy cattle) house their mature dairy cows in freestall barns; therefore, it is assumed that mature dairy cows are housed in freestall barns for the dairy model.

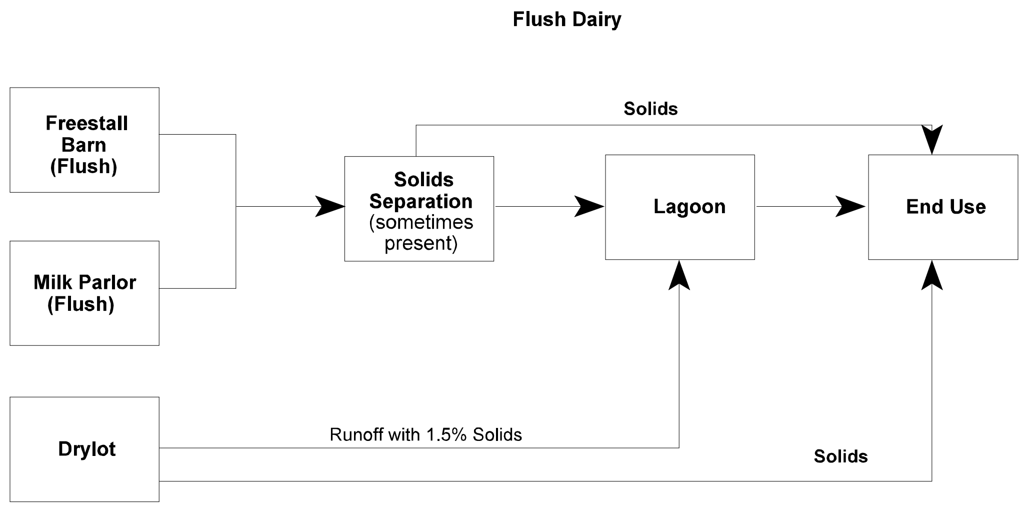
The most common types of calf and heifer housing are drylots, multiple animal pens, and pasture (USDA, 1996c). Based on site visits, most medium- to large-sized facilities use drylots to house their heifers and calves; therefore, it is assumed that calves are housed in hutches on drylots and heifers are housed in groups on drylots at dairies described in the model. EPA calculated the size of the drylot for the model farm using animal space requirements suggested by Midwest Plan Service (MWPS, 1995).

11.2.4.2 Waste Management Systems

Waste is generated in two main areas at dairies: the milking parlor and the housing areas. Waste from the milking parlor includes manure and wash water from cleaning the equipment and the parlor after each milking. Waste from the confinement barns includes bedding and manure for all barns, and wash water if the barns are flushed for cleaning. Waste generated from the drylots includes manure and runoff from any precipitation that falls on the drylot.

Based on site visits, most dairies transport their wastewater from the parlor and flush barns to a lagoon for storage and treatment. Some dairies use a solids separator (either gravity or mechanical) to remove larger solids prior to the wastewater entering the lagoon. Solids are removed from the separator frequently to prevent buildup in the separator, and they are stockpiled on site. Solid waste scraped from a barn is typically stacked on the feedlot for storage for later use or transport. Solid waste on the drylot is often mounded on the drylot for the cows and is later moved for transport or land application. Wastewater in the lagoon is held in storage for later use, typically as fertilizer on cropland either on or off site. Figure 11-4 presents the waste management systems used for model dairy farm.

The amount of waste generated at a dairy depends on how the operation cleans the barn and parlor on a daily basis. Some dairies clean the parlor and barns by flushing the waste (a flush dairy); others use less water, hosing down the parlor and scraping the manure from the barns (a hose/scrape dairy). EPA estimated the percentage of total dairies that operate as a flush dairy or a hose/scrape dairy using USDA data (USDA APHIS, 1996). Both flush and hose/scrape dairy systems are modeled separately as two model facilities.



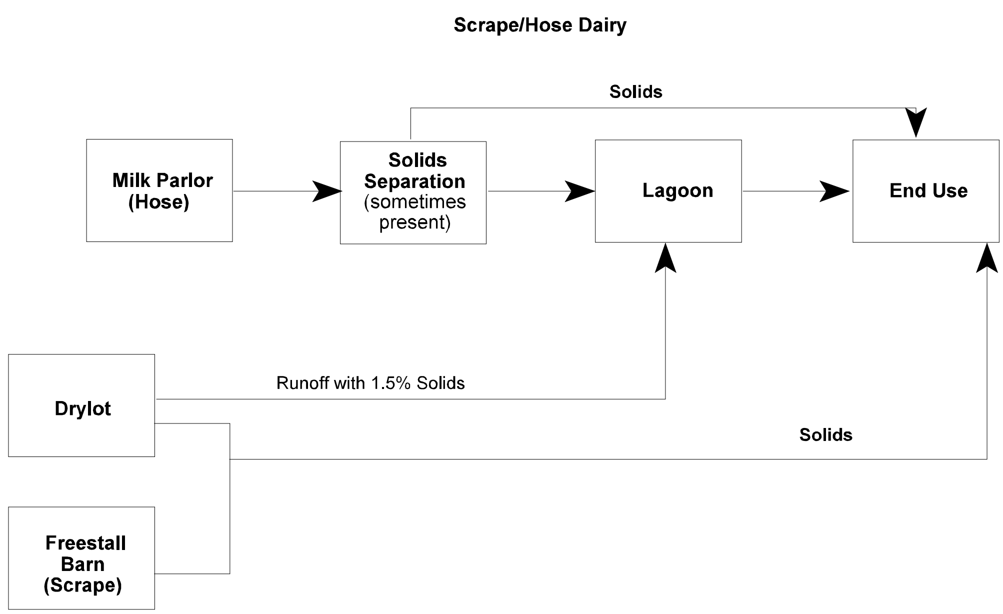


Figure 11-4 Dairy Model Farm Waste Management Systems

11.2.4.3 Size Group

Data collected during site visits indicate that dairies operate differently depending on their size. For example, larger dairies tend to already have lagoon storage, while moderate-sized dairies may have only a small amount of storage. Also, because feedlots with more than 700 animals are already regulated under the current rule, it was assumed for the cost model that these facilities are already in compliance with many of the components of the final rule. Therefore, four different size groups were used to model dairy operations with more than 200 animals. The size groups are presented in Table 11-6.

Table 11-6. Size Classes for Model Dairy Farms.

Size Class	Size Range	Average Head
Medium 1	200-349	250
Medium 2	350-524	425
Medium 3	525-699	600
Large 1	≥ 700	1,430

11.2.4.4 Region

Data from site visits indicate that dairies in varying regions of the country have different characteristics. These differences are primarily related to climate. For example, a dairy in the Pacific region receives a greater amount of rainfall annually than a dairy in the Central region; therefore, the Pacific dairy produces a higher amount of runoff to be contained and managed. Because operating characteristics may change between regions, dairies are modeled in five distinct regions of the United States: Central, Mid-Atlantic, Midwest, Pacific, and South.

11.2.5 Beef Feedlots and Heifer Operations

EPA developed one type of model farm to represent medium- and large-sized beef feedlots and heifer operations in the United States. The parameters describing the beef and heifer model farm were developed from information from USDA, data collected during site visits to beef feedlots across the country, meetings with USDA extension agents, the National Cattlemen's Beef Association, and the National Milk Producers Federation, and discussions with the Professional Heifer Growers Association. Descriptions of the various components that make up the model farm are presented below, with the sources of the information used to develop that piece of the model farm referenced.

11.2.5.1 Housing

The vast majority of beef feedlots and heifer operations in the United States house their cattle on drylots (USDA, 1995a). Some smaller operations use confinement barns at beef feedlots. However, since the majority of operations, including most new ones, use open lots, EPA used drylots as the housing for the beef and heifer model farm. Some operations raise their heifers on pasture, but because this regulation addresses only confined operations, the heifer model farm accounts only for animals housed on drylots. The size of the drylot is calculated using animal space requirements suggested by Midwest Plan Service (MWPS, 1995).

11.2.5.2 Waste Management System

Based on site visits, the drylot is the main area where waste is produced at beef feedlots and heifer operations. Waste from the drylot includes solid manure, which has dried on the drylot, and runoff, which is produced from precipitation that falls on the drylot and open feed areas.

Most beef operations in the United States divert runoff from the drylot to a storage pond (USDA, 1995a). Heifer operations typically operate like beef feedlots (Cady, 2000). As such, EPA assumed that runoff from the drylot is channeled to a storage pond at both beef and heifer operations. Some operations use a solids separator (typically an earthen basin) to remove solids from the waste stream prior to the runoff entering the pond. Solid waste from the drylot is often mounded on the drylot to provide topography for the cattle and is later moved from the drylot for transportation off site or land application on site (USDA, 1995a).

The beef and heifer model farm was developed following these typical characteristics of beef feedlots and heifer operations. Figure 11-5 presents the waste management system used as part of the beef and heifer model farm.

11.2.5.3 Size Group

Data collected during site visits indicate that beef feedlots and heifer operations operate differently depending on their size. For example, larger feedlots frequently have solid separators prior to a holding pond, while moderate sized facilities are less frequently equipped with solids separators. Moreover, feedlots with more than 1,000 beef cattle are already regulated under the current rule. EPA, therefore, assumes that these facilities are already in compliance with many components of the final rule. To account for these differences, five different size groups were used to model beef feedlots with more than 300 animal units and four different size groups were used to model heifer operations with more than 300 animals. The size groups are presented in Tables 11-7 and 11-8.

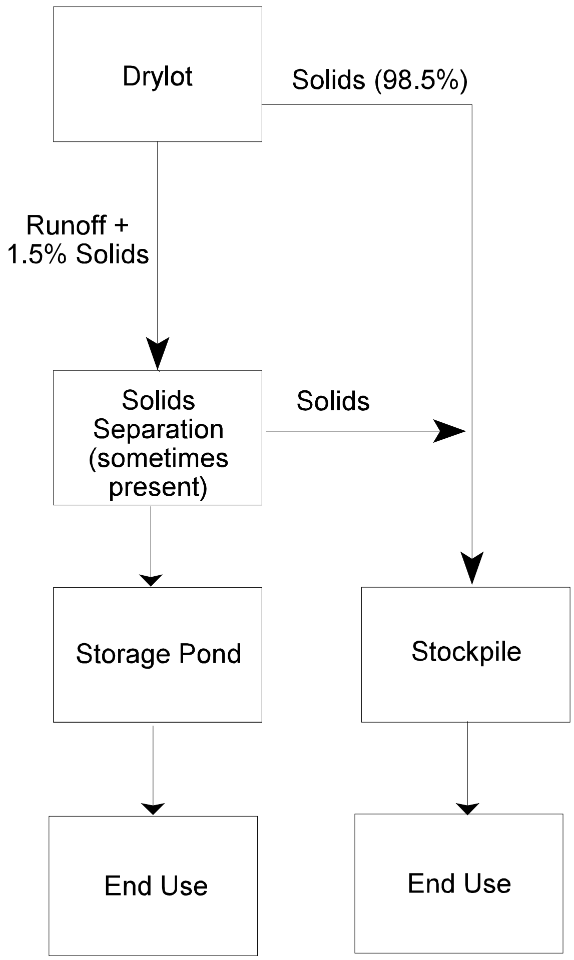


Figure 11-5. Beef and Heifer Model Farm Waste Management System

Table 11-7. Size Classes for Model Beef Farms

Size Class	Size Range	Average Head
Medium 1	300-499	370
Medium 2	500-749	552
Medium 3	750-999	766
Large 1	1,000-7,999	1,839
Large 2	≥ 8,000	25,897

Table 11-8. Size Classes for Model Heifer Farms

Size Class	Size Range	Average Head
Medium 1	300-499	400
Medium 2	500-749	625
Medium 3	750-999	875
Large 1	$\geq$ 1,000	1,500

11.2.5.4 Region

Data from site visits indicate that beef feedlots in varying regions of the country have different characteristics. These differences are primarily related to climate. For example, a beef feedlot in the Midwest region receives a greater amount of rainfall annually than a beef feedlot in the Central region; therefore, the Midwest feedlot produces a greater volume of runoff to be contained and managed. Because operating characteristics may change between regions to accommodate these climatological differences, beef feedlots are modeled in five diverse regions of the United States: Central, Mid-Atlantic, Midwest, Pacific, and South, as described in Section 1.1. Data from USDA indicate that heifer operations are located in similar areas as beef feedlots and would have similar characteristics as the beef feedlots.

11.2.6 Veal Operations

EPA developed one model farm to represent medium- and large-sized veal operations in the United States. The parameters describing the veal model farm are developed from information collected during site visits to veal operations in Indiana and discussions with the American Veal Association. Descriptions of the various components that make up the model farm are presented below, with the sources of the information used to develop that piece of the model farm referenced.

11.2.6.1 Housing

Veal calves are generally grouped by age in environmentally controlled buildings. The majority of veal operations in the United States utilize individual stalls or pens with slotted floors, which allow for efficient removal of waste (Wilson, 1995). Because this type of housing is the predominant type of housing used in the veal-producing industry, individual stalls in an environmentally controlled building is designated as the housing for the veal model farm.

11.2.6.2 Waste Management Systems

Based on site visits, the only significant source of waste at veal operations is from the veal confinement areas. Veal feces are very fluid; therefore, manure is typically handled in a liquid waste management system. Manure and waste that fall through the slotted floor are flushed regularly out of the barn. Flushing typically occurs twice daily. Most veal operations have a lagoon to receive and treat their wastewater from flushing, although some operations have a holding pit system in which the manure drops directly into the pit. The pit provides storage until the material can be land applied or transported off site. Wastewater in the lagoon is held in storage for later use as fertilizer off site.

EPA developed the veal model farm used in the cost model from these general characteristics. The animals are totally confined; therefore, the only source of wastewater is from flushing the manure and waste from the barns. Direct precipitation is also collected on the lagoon surface, if the lagoon is uncovered. Figure 11-6 presents a diagram of the veal model farm waste management system.

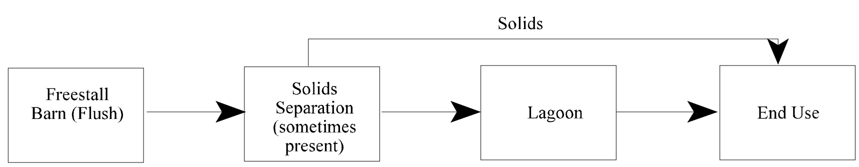


Figure 11-6. Veal Model Farm Waste Management System

11.2.6.3 Size Group

The veal industry standard operating procedures do not vary significantly based on the size of the operation, according to data collected during site visits and discussions with the American Veal Association (Crouch, 1999). The size groups are presented in Table 11-9.

Table 11-9. Size Classes for Model Veal Farm

Size Class	Size Range	Average Head
Medium 1	300-499	400
Medium 2	500-749	540
Medium 3	$\geq$750	1080

11.2.6.4 Region

The American Veal Association indicates that veal producers are located predominantly in the Midwest and Central regions (Crouch, 1999); therefore, only these two regions are modeled as part of the veal model farm.

11.3 Design and Cost of Waste and Nutrient Management Technologies

Two separate models were created to estimate compliance costs associated with regulatory options for CAFOs: one model to generate beef, dairy, heifer, and veal costs, and another model to generate swine, broiler, turkey, and layer costs. The cost models calculate model farm costs in three major steps:

1) Costs are calculated for each technology or practice that makes up each regulatory option for each model farm, based on model farm characteristics, including number of head, waste characteristics, and facility characteristics.

2) The costs for each technology or practice are then weighted for the entire model farm population, using frequency factors to indicate the portion of the model farm population that will incur that cost. These frequency factors define the performance of a model farm as having low, medium, or high requirements to comply with the regulatory option.

3) The weighted costs for each model farm population are summed, resulting in an average model farm cost for each model population in each performance category.

The resulting model farm cost represents the average cost that all of the operations within that model population are expected to incur within a performance category. The compliance costs that a single model farm incurs may be more or less than this average cost; however, the performance categories are expected to encompass the approximate range of compliance costs.

The cost estimates generated contain the following types of costs:

- **Capital costs** - Costs for facility upgrades (e.g., construction projects);

- **Fixed costs** - One-time costs for items that cannot be amortized (e.g., training);

- **Annual operating and maintenance (O&M) costs** - Annually recurring costs, which may be positive or negative. A positive O&M cost indicates an annual cost to operate, and a negative O&M cost indicates a benefit to operate, due to cost offsets;

- **Three-year recurring O&M costs** - O&M costs that occur only once every three years;

- **Five-year recurring O&M costs -** Application fees and reporting costs that occur only once every five years; and

- **Annual fertilizer costs -** Costs for additional commercial nitrogen fertilizer needed to supplement the nutrients available from manure application.

These costs provide the basis for evaluating the total annualized costs, cost effectiveness, and economic impact of each regulatory option.

The following sections discuss the six primary components of the costing methodology:

- Manure and nutrient production at each operation;
- Cropland acreage;
- Nutrient management planning;
- Facility upgrades;
- Land application; and
- Off-site transportation of manure.

Further detail on the cost methodology and data inputs to the cost model may be found in the *Cost Methodology for the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations (2002).*

11.3.1 Manure and Nutrient Production

The manure produced at each model farm provides the basis for the design of the technology components and model farm parameters, including determining farm acreage, nutrient management practices, equipment sizes, and the agronomic rate of applying waste to land. The quantity and characteristics of the waste for each model farm are calculated from values provided in the *Agricultural Waste Management Field Handbook* and the *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States* (USDA NRCS, 1996; USDA NRCS, 2000).

The quantity of manure generated from a feedlot operation depends on the animal type and the number of mature and immature animals that are present. Nutrient production at each model farm is calculated using waste characteristics data for excreted manure for each animal type. The mass production of each of these nutrients is calculated using the average weight of the animal while housed at the model farm, the waste concentration data, and the number of animals on site.

11.3.2 Available Acreage

Data on the amount of cropland and pastureland available to facilities for land application of manure are limited. Therefore, EPA classified the model farms into three categories that define how much land they have available and how the operation ultimately manages its waste:

- **Category 1:** Facilities with sufficient land to apply all of their generated manure at appropriate agronomic rates. No manure is transported off site.
- **Category 2:** Facilities without sufficient land to apply all of their generated manure at appropriate agronomic rates. The excess manure after agronomic application is transported off site.
- **Category 3:** Facilities without any available land for manure application. All of the manure is transported off site regardless of the regulatory options considered by EPA.

EPA defines Category 1 operations as having a sufficient amount of land, and at a minimum, the available land equals the amount of land required to agronomically apply all of the manure generated at the operation. Category 2 acreages are based on a 2000 USDA analysis that calculated the amount of nutrients present in manure that exceeded the amount that could be applied agronomically (Kellogg, 2000). EPA assumes Category 3 operations have no available land.

11.3.2.1 Agronomic Application Rates

Under all regulatory options considered, all operations are required to implement nitrogen-based agronomic application rates when applying animal waste or wastewater. Under Options 2 through 7, however, operations that are located in areas with certain site conditions (e.g., phosphorus-saturated soils) are required to follow more stringent phosphorus-based agronomic application rates. Costs for nitrogen-based application are different than costs for phosphorus-based application. These costs are weighted for a model farm using a "nutrient-based application factor" to account for these different costs, based on the percent of facilities in that region that would apply on a phosphorus-basis verses a nitrogen-basis. The nutrient-based application factors vary according to the type of facility (beef, dairy, swine, or poultry).

Agronomic application rates are calculated using crop yields, crop uptakes, and crop utilization factors. These crops vary by region and animal type. EPA selected representative crops for each model farm by contacting USDA state and county cooperative extension services and incorporating data from USDA's *Agricultural Waste Management Field Handbook* (USDA NRCS, 1996). EPA does not expect crops to vary significantly based on the size of the animal operation. Because veal operations are located predominantly in the Midwest, EPA developed only one set of crop assumptions for veal that reflect the Midwest region.

$$\text{Crop N Requirements (lb/acre)} = \text{Crop Yield (tons/acre)} \times \text{Crop Uptake (lb/ton)}_{\text{nitrogen}}$$

$$\text{Crop P Requirements (lb/acre)} = \text{Crop Yield (tons/acre)} \times \text{Crop Uptake (lb/ton)}_{\text{phosphorus}}$$

The average annual nitrogen and phosphorus crop removal and application rates were calculated by dividing the total crop requirements over the time to complete a full crop rotation. The cost model estimates that 70 percent of the nitrogen and 100 percent of the phosphorus in cattle manure that is applied to land is available for crop uptake and utilization over time (Lander, 1998); therefore, the agronomic application rate is calculated as the total crop nutrient requirements divided by the appropriate utilization factor.

$$\text{Manure Application Rate}_{\text{Nitrogen}}\ \text{(lb/acre)} = \text{Total Crop Nitrogen Requirements (lb/acre)} \div 70\%$$

$$\text{Manure Application Rate}_{\text{Phosphorus}}\ \text{(lb/acre)} = \text{Total Crop Phosphorus Requirements (lb/acre)} \div 100\%$$

When more than one crop is present, the agronomic rate is presented as the average of the individual agronomic rates for each crop. These agronomic rates for nitrogen- and phosphorus-based application scenarios are used as inputs to the cost model.

11.3.2.2 Category 1 Acreage

Category 1 acreages are calculated using the agronomic application rates, number of animals, manure generation estimates, nutrient content of the manure, and manure recoverability factors:

$$\text{Category 1 Acreage} = \frac{\text{\#Animals x Manure Generation (tons/head) x Nutrient Content (lbs/ton manure) x Recoverability Factor}}{\text{Agronomic application rate (lb/acre)}}$$

EPA defines recoverability factors as the percentage of manure, based on solids content, that it would be practical to recover. Recoverability factors are developed for each region, using USDA state-specific recoverability factors, and are based on the assumption that the decrease in nutrient value per ton of manure mirrors the reduction in solids content of the recoverable manure (Lander, 1998).

11.3.2.3 Category 2 Acreage

Category 2 acreages are calculated using Category 1 acreages, the estimate of excess manure from USDA's analysis, and acres required to apply excess manure to land (Kellogg, 2000):

Average Excess Nutrients (lbs/yr)	=	Excess Nutrients (lbs/yr)÷Number of Category 2 Facilities
Excess Acreage (acres)	=	Average Excess Nutrients (lbs/yr)÷Agronomic Application Rate (lb/acre)
Category 2 Acreage (acres)	=	Category 1 Acreage - Excess Acreage

11.3.3 Nutrient Management Planning

To minimize the release of nutrients to surface and ground waters, confined animal feeding operations must prevent excess application of manure nutrients on cropland through the process of nutrient management planning. Confined animal feeding operations apply manure nutrients to the land in the form of solid, liquid, or slurry. Manure is also stored prior to application in stockpiles, tanks, pits, storage ponds, or lagoons. Confined animal feeding operations prevent excess application by developing and abiding by appropriate manure application rates that are designed to add only the nutrients required by the planned crops at the expected yields. Nutrient management planning may also minimize releases of nutrients by specifying the timing andlocation of manure application.

Six nutrient management practices are evaluated as part of the costing methodology:

1. **Nutrient management plan -** a practice in which a documented plan is developed for each facility to ensure agronomic application of nutrients on cropland and management of waste on site. The plan includes costs for development of the plan, manure sampling and analysis (collecting samples from solid and liquid waste before each land application period), soil sampling and analysis (once every 3 years), hydrogeologic assessment for facilities located in ground water protection areas, periodic inspections of on-site facility upgrades, identification and protection of crop setback areas to protect waterfront areas, calibration of the manure spreader before each application period, and ongoing recordkeeping and recording. The plan is updated at least once every 5 years.

2. **Surface water monitoring** - a practice in which surface water samples are periodically collected and analyzed for indications of contaminated runoff into adjacent waters. Costs account for twelve sampling events per year, including four grab samples and one quality assurance sample per event, measuring for nitrate-nitrite, total Kjeldahl nitrogen, total phosphorus, and total suspended solids.

3. **Ground water assessment** - a practice for facilities to conduct a hydrogeologic assessment to determine if a direct hydrogeologic link exists between ground water and surface water.

4. **Ground water monitoring** - a practice for operations where ground water has a direct hydrogeologic link to surface water. Costs include installation of four 50-foot ground water wells and the collection of a sample from each well twice annually for indications of ground water contamination from the feedlot operation.

5. **Feeding strategies** - a practice in which the animal feed is monitored and adjusted to reduce the quantity of nutrients that are excreted from the animal. Costs include feeding strategies to reduce nitrogen and phosphorus in excrement from poultry and swine.

6. **Timing restrictions -** a practice in which manure is only land applied during times that the land and crops are most amenable to nutrient utilization. Costs for this practice are calculated for all animal sectors.

Further detail on the design of each practice may be found in the *Cost Methodology for the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations (2002).*

11.3.4 Facility Upgrades

Section 8.0 of this report describes treatment technologies and facility upgrades that are presented as part of this cost methodology. These facility upgrades include:

- Anaerobic digestion with energy recovery;
- Anaerobic lagoons;
- Field runoff controls;
- Lagoon covers;
- Lined manure storage;
- Liners for lagoons and ponds;
- Litter storage sheds;
- Manure composting equipment;
- Recycle flush water;
- Retrofit options;
- Screen solid-liquid separation;
- Sludge removal;
- Solids separation (settling basin);
- Storage ponds; and
- Storm water diversions (berms).

An overview of the costs and applicability of each of these upgrades to each of the animal sectors is presented below:

- **Anaerobic digestion with energy recovery**: Option 6 requires the use of anaerobic digestion for Large dairy and swine CAFOs, prior to discharge to a storage lagoon. The digester is designed to receive waste from all flushing, hose, and scrape operations, and combines this waste into a reactor to produce methane for energy use at the operation. Covered lagoon digesters are costed for large flush dairies and swine operations, and complete mix digesters are costed for large hose dairies. Runoff from the dairy feedlot is collected separately into a storage pond or lagoon.

- **Anaerobic lagoons:** Costs for anaerobic lagoons are included for facilities that collect mixtures of water and manure, such as dairies, veal operations, swine, and wet layer operations. Lagoons receive wastewater from flush barns, flush and hose milking parlors (for dairies), and runoff from drylots. They are designed to include process wastewater, plus the capacity for the 25-year, 24-hour storm event and average rainfall for the storage period.

- **Field runoff controls:** Under all options, costs are included to implement and maintain setbacks along waterbodies contained within land-applied cropland for all animal operations. The size and therefore the cost of the setback were calculated based on national estimates of land area and stream miles and the average size and cost of filter strips (USEPA, 2000; USEPA, 1993).

- **Lagoon covers:** Under Option 5, the regulation requires that facilities have zero potential for discharge from the feedlot. This requirement may be met by covering liquid storage basins and preventing direct precipitation from entering and adding to the storage volume. Swine, wet layers, and veal operations under Option 5 have costs for lagoon covers.

- **Lined manure storage:** The cost model includes costs for the installation and maintenance of concrete pads as part of the waste management system for beef, heifer, and dairy operations under Option 3. The pads are designed to store waste from drylots, separated solids, and scraped manure.

- **Liners for lagoons and ponds:** Under the ground water options, operations that store animal waste (e.g., runoff and/or process water) in a lagoon or pond are required to have a liner in place if they are located in an area where ground water has a hydrogeologic connection to surface water. The liner is composed of two parts: a synthetic portion and a clay portion. The liner is designed to cover the floor of the pond or lagoon, including sloped sidewalls. Costs are calculated for all animal sectors to install liners in their lagoons and ponds.

- **Litter storage sheds:** Litter storage is included in the costing for all dry poultry operations. Requirements for poultry litter storage structures are similar to those for mortality composting facilities in that they require a roof, foundation, and floor, and suitable building materials for side walls.

- **Manure composting equipment:** EPA designed windrow composting systems to treat and manage manure waste from drylots, separated solids, and scraped manure under Option 5A for beef, dairy, and heifer operations. Mortality composting systems are designed for swine and poultry operations to manage mortality waste under all options.

- **Recycle flush water:** In liquid-based systems, fresh water can be used for flushing or water from a secondary lagoon can be recycled as flush water. This technology is applied to Category 2, lagoon-based swine operations for all Options except Option 5.

- **Retrofit options:** In addition to the use of lagoon covers to comply with the requirements of Option 5, EPA investigated retrofitting swine and wet layer systems to replace lagoons as the waste management practice. Retrofitting to a "scraper system" was assessed for swine and wet layers facilities. In addition, retrofitting to a high-rise and hoop house for swine operations was assessed.
- **Screen solid-liquid separation:** The cost model includes costs for swine operations to install and operate screen separation. Screens are used to separate the solids from the liquids, allowing the solids to be handled more economically.
- **Sludge removal:** Sludge must be removed from lagoons periodically to keep storage capacity available. The cost model accounts for sludge cleanout annually for beef feedlots, dairies, and heifer operations and once every five years for liquid-based swine operations for all considered options.
- **Solids separation (settling basin):** The cost model includes solids separation as part of facility upgrades for beef and dairy operations, to facilitate the management of manure waste by separating the solid portion from the liquid portion. EPA costed earthen separators for beef feedlots, where runoff is the largest expected flow through the separator, and concrete-lined separators for dairy operations, where large amounts of flush water are expected through the separator. Concrete is used to prevent erosion of the side slopes of the separator.
- **Storage ponds:** The cost model includes costs for storage ponds for facilities that collect runoff from the feedlot, such as beef facilities in which the cattle are confined on dry lots, and as a holding pond for effluent from an anaerobic digester in Option 6. The storage pond receives waste from drylot runoff only and is designed to include capacity for the 25-year, 24-hour storm event and average rainfall for the storage period. Under Option 1A, the cost model also includes capacity for the 10-year, 10-day storm event.
- **Storm water diversions (berms):** Under all regulatory options, EPA requires that all animal operations contain any runoff collecting in potentially contaminated areas. EPA assumes that Large CAFOs already have stormwater diversions in place, because it is required by the current regulation.

EPA calculated costs for facility upgrades using design specifications in combination with cost estimates for each portion of the upgrade (e.g., excavation, compaction, gravel fill, etc.). Design specifications were obtained from various sources, including the Natural Resources Conservation Service (Conservation Practice Standards), the Midwest Plan Service, the *Agricultural Waste Management Field Handbook*, and other engineering design sources. EPA combined these design specifications with model-farm information, such as the animal type, manure generation, housing methods, and the type of farm, to calculate the required size of the component as well as the materials and labor required to construct and operate the upgrade. Then, cost-estimation guides, including *Means Building Construction Cost Data*, *Means Heavy Construction Cost Data*, *Richardson's*, EPA's *FarmWare* Model, and vendor-supplied cost data, were used to determine the costs for each of these items that comprise the upgrade.

11.3.5 Land Application

The cost model calculates costs for land application of manure and other waste for those operations that have land, but are not currently applying their waste. Based on site visits, EPA estimates that all beef, dairy, veal, and heifer operations that have land already have equipment to apply dry waste. However, some facilities are assumed to need liquid land application equipment as well. Land application costs are based on installation and operation of a center pivot irrigation system, or a traveling gun system, based on vendor supplied cost data (Zimmatic, Inc., 1999, Rifco, Inc., 2001). For swine and poultry operations, EPA estimated (based on site visits) that all facilities already land apply their waste, and no additional costs would be incurred under the regulatory options.

11.3.6 Off-Site Transport of Manure

Animal feeding operations use different methods of transportation to remove excess manure waste and wastewater from the feedlot operation. The costs associated with transporting excess waste off site were calculated using two methods: contract hauling waste or purchasing transportation equipment. For poultry and swine operations, EPA based transportation costs on operations contract hauling their waste. For beef and dairy operations, EPA based transportation costs on either contract hauling or purchasing equipment to self-haul waste (whichever was least expensive).

Contract Hauling

EPA evaluated contract hauling as a method for the transport of manure waste off site. In this method, the animal feeding operation hires an outside company to transport the excess waste. This method is advantageous to facilities that do not have the capacity to store excess waste on site, or the cropland acreage to agronomically apply the material. In addition, this method is useful for facilities that do not generate enough excess waste to warrant purchasing their own waste transportation trucks.

No capital costs are associated with contract hauling; only the operating cost to haul the waste. For beef and dairy operations, EPA calculated a set rate per mile for solid waste and for liquid waste, using vendor-supplied quotations and the average hauling distance for each region (ERG, 2000b; Tetra Tech, Inc., 2000b). For swine and poultry operations, EPA extracted costs for contract hauling solid waste and liquid waste from multiple published articles (Tetra Tech, Inc., 1999).

Purchase Equipment

Another method evaluated for the transport of manure waste off site was purchasing transportation equipment. In this method, the feedlot owner is responsible for purchasing the necessary trucks and hauling the waste to an off-site location. Depending on the type of waste to be transported, a solid waste truck, a liquid tanker truck, or both types of trucks would be required. In addition, the feedlot owner is responsible for determining a suitable location to transport the waste, as well as all costs associated with loading and unloading the trucks, driving the trucks to the off-site location, and maintaining the trucks. EPA did not base compliance costs for swine and poultry operations on purchasing transportation equipment, and therefore no costs are calculated for these facilities under this transportation option.

The capital and annual costs associated with the purchase and operation of a truck for waste transport depend on the type of waste (solid or liquid) and quantity of waste to be transported. The cost model includes an evaluation on the amount of solid and/or liquid waste the operation will ship off site, and a determination of the capital costs based on that information. Annual costs are also calculated using the quantity of liquid or solid waste, as well as the hauling distance, maintenance costs, labor, fuel rates, and other parameters (ERG, 2000b).

11.4 Development of Frequency Factors

EPA recognizes that most individual farms are currently implementing certain waste management techniques or practices that are called for in the regulatory options considered. Only costs that are the direct result of the regulation are included in the cost model. Therefore, costs already incurred by operations are not attributed to the regulation.

To reflect baseline industry conditions, EPA developed technology frequency factors to describe the percentage of the industry that already implements particular operations, techniques, or practices required by the final rule. In some cases, these frequency factors are based on an assumed performance category (i.e., high, medium, and low performance) as estimated by USDA. EPA also developed ground water control frequency factors based on the location of the facility and current state requirements for permeabilities of waste management storage units. In addition, EPA developed nutrient basis frequency factors describing the distribution of farms that would apply manure to soils on a nitrogen or phosphorus basis, land availability frequency factors describing the distribution of farms with and without sufficient cropland to land apply the manure and wastewater generated at the farm, and transportation frequency factors describing the distribution of farms transporting excess manure and wastewater off site.

Some technologies included in the cost model, including composting and anaerobic digestion, were assumed not to be present under baseline industry conditions. Therefore, EPA assumed all of the facilities incur the cost of implementing the technologies and did not develop frequency factors for these technologies.

EPA estimated frequency factors based on the sources below (each source was considered along with its limitations):

- **EPA site visit information -** This information was used to assess general practices of animal feeding operations and how they vary between regions and size classes.

- **Observations from industry experts** - Experts on animal feeding operations were contacted to provide insight into operations and practices, especially where data were limited or not publicly available.

- **USDA Agricultural Phosphorus and Eutrophication document (USDA, 1999)** - This source provides information on the phosphorus content in state soils using the soil test P. EPA used this information to determine the percentage of facilities in each state that would require nitrogen-based versus phosphorus-based application rates.

- **USDA, Animal Plant and Health Inspection Service (APHIS)/National Animal Health Monitoring System (NAHMS)** - This source provides information on animal housing practices, facility size, and waste system components sorted by size class and region. These data have limited use because of the small number of respondents in the size classes of interest.

- **State Compendium: Programs and Regulatory Activities Related to AFOs** - This summary of state regulatory programs was used to estimate frequency factors based on current waste-handling requirements that already apply to animal operations in various states and in specific size classes. Operations located in states whose requirements meet or exceed the option requirements would already be in compliance and would not incur any additional cost.

- **USDA, Estimation of Private and Public Costs Associated with Comprehensive Nutrient Management Plan Implementation: A Documentation** - This source provides frequency factors for three performance-based categories of facilities (low-performing; medium-performing, and high-performing) for a series of "representative" farms defined by USDA in eight USDA defined regions. USDA defined high performers to be 25 percent of the facilities, medium performers to be 50 percent of the facilities, and low performers to be 25 percent of the facilities.

11.5 Summary of Estimated Model Farm Costs by Regulatory Option

A summary of the estimated regulatory compliance costs is provided in the following tables. Capital, fixed, annual, three-year recurring costs, and five-year recurring costs are included for each animal sector for Options 1, 2, and 5. Costs are presented in 1997 dollars.

- Table 11-10: Summary of Industry Costs for Option 1
- Table 11-11: Summary of Industry Costs for Option 2
- Table 11-12: Summary of Industry Costs for Option 5

Table 11-10. Summary of Industry Costs for Option 1

Animal Type	Manure Type	Operation Type	Capital	Annual	Fixed	3-YearRec urring	5-YearRec urring
Beef	Solid/Liquid	Beef	$66,271,376	$8,689,062	$4,305,153	$592,050	$2,530,516
Dairy	Solid/Liquid	Flush	$262,639,714	$45,358,315	$2,626,098	$183,113	$894,258
Dairy	Solid/Liquid	Hose	$33,153,994	$4,072,126	$2,461,447	$2,798,726	$739,387
Heifers	Solid/Liquid	Heifers	$13,452,388	$1,319,976	$694,719	$204,401	$82,858
Veal	Liquid	Flush	$0	$30,553	$38,948	$2,422	$10,090
Chicken	Liquid	LW	$9,118,438	$1,296,980	$132,432	$19,525	$81,264
Chicken	Solid	BR	$93,407,347	$4,060,985	$2,184,684	$74,888	$1,009,264
Chicken	Solid	LA	$32,664,307	$1,746,196	$356,844	$51,695	$247,758
Swine	Evapor	FF	$108,469	$150,883	$84,495	$3,970	$35,289
Swine	Evapor	GF	$111,079	$154,573	$86,411	$4,054	$36,036
Swine	Liquid	FF	$5,308,843	$1,686,581	$844,688	$30,149	$241,083
Swine	Liquid	GF	$4,017,456	$1,135,603	$527,369	$22,505	$171,891
Swine	Pit	FF	$360,663	$1,497,912	$889,058	$30,374	$272,588
Swine	Pit	GF	$334,852	$1,720,540	$957,771	$38,814	$329,614
Turkey	Solid	SL	$31,170,087	$1,668,463	$701,880	$27,143	$450,698

Table 11-11. Summary of Industry Costs for Option 2.

Animal Type	Manure Type	Operation Type	Capital	Annual	Fixed	3-YearRecu rring	5-Year Recurring
Beef	Solid/Liquid	Beef	$96,942,128	$38,651,376	$7,672,585	$1,496,851	$9,179,452
Dairy	Solid/Liquid	Flush	$147,690,591	$115,353,998	$3,188,393	$334,556	$2,017,898
Dairy	Solid/Liquid	Hose	$35,758,320	$8,280,186	$3,066,584	$2,961,250	$1,916,937
Heifers	Solid/Liquid	Heifers	$16,559,995	$2,305,508	$842,928	$243,437	$312,186
Veal	Liquid	Flush	$0	$30,553	$38,948	$2,422	$10,090
Chicken	Liquid	LW	$14,047,475	$1,491,472	$144,601	$22,435	$93,337
Chicken	Solid	BR	$93,515,959	$4,120,237	$2,303,023	$83,562	$1,127,487
Chicken	Solid	LA	$32,642,246	$1,929,765	$333,911	$47,230	$224,575
Swine	Evapor	FF	$109,151	$151,249	$128,484	$8,945	$79,289
Swine	Evapor	GF	$112,054	$155,285	$131,852	$9,178	$81,337
Swine	Liquid	FF	$6,645,012	$1,803,879	$1,358,438	$86,947	$6,894,239
Swine	Liquid	GF	$4,934,234	$1,196,853	$855,210	$61,344	$5,231,336
Swine	Pit	FF	$505,620	$13,907,671	$1,398,631	$82,198	$781,926
Swine	Pit	GF	$454,228	$19,817,425	$1,538,482	$101,262	$910,429
Turkey	Solid	SL	$31,276,907	$2,864,728	$835,304	$35,254	$584,319

Table 11-12. Summary of Industry Costs for Option 5.

Animal Type	Manure Type	Operation Type	Capital	Annual	Fixed	3-Year Recurring	5-Year Recurring
Chicken	Liquid	LW	$22,224,957	$1,711,084	$200,193	$35,781	$148,929
Chicken	Solid	BR	$184,992,580	$4,120,237	$2,303,023	$83,562	$1,127,487
Chicken	Solid	LA	$32,642,246	$1,929,765	$333,911	$47,230	$224,575
Swine	Evapor	FF	$43,483,000	$1,830,320	$138,485	$10,060	$89,300
Swine	Evapor	GF	$44,603,942	$1,877,631	$142,109	$10,321	$91,605
Swine	Liquid	FF	$341,161,677	$10,805,902	$1,458,059	$98,623	$838,708
Swine	Liquid	GF	$250,152,138	$7,850,690	$920,791	$69,564	$552,835
Swine	Pit	FF	$37,452,731	$12,278,113	$1,398,631	$82,198	$781,926
Swine	Pit	GF	$46,434,556	$18,034,408	$1,538,482	$101,262	$910,429
Turkey	Solid	SL	$31,276,907	$2,864,728	$835,304	$35,254	$584,319
Veal	Liquid	Flush	$1,036,004	$82,351	$38,948	$2,422	$10,090

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CHAPTER 12

POLLUTANT LOADING REDUCTIONS FOR THE REVISED EFFLUENT LIMITATIONS GUIDELINES FOR CONCENTRATED ANIMAL FEEDING OPERATIONS

12.0 INTRODUCTION

Section 301(d) of the Clean Water Act (CWA) directs Environmental Protection Agency (EPA) to periodically review and revise, if necessary, Effluent Limitations Guidelines and Standards (ELGs) promulgated under CWA Sections 301, 304, and 306. Animal feeding operations (AFOs) have been identified as a major source of pollutants impairing surface water and ground water in the United States; therefore, EPA is revising the existing effluent guidelines for AFOs. The final regulation requires beef, dairy, veal, heifer, poultry, and swine AFOs to handle their manure in a more environmentally sound manner including upgrading facilities to reduce the runoff potential from feedlots, limiting land application of manure based on nitrogen (N) and phosphorus (P) agronomic rates, and encouraging other technologies (e.g., treatments that lower environmental impact or reduce the manure water content).

12.1 Computer Model Simulations

To support its rule revision, EPA performed computer model simulations of 13,500 different Sample Farms representing land application of manure by AFOs. Each Sample Farm represents various combinations of animal type, farm size, location, soil type, waste management and storage, incorporation technique, etc. For each Sample Farm, EPA estimated edge-of-field pollutant loadings (in pounds per year per acre of cropland) to serve as a basis for summing the national average annual pollutant reductions over a 25-year period of analysis. In sum, the interaction of these AFO facilities with the environment is based on approximately 228 million simulated days of Sample Farm performance. In addition to edge-of-field load reductions, EPA's assessment incorporated pollutant loadings from feedlots and manure storage structures, representing discharges from AFO production areas. These discharges generally include runoff from the feedlot or manure storage areas due to precipitation events, but also include, where actual discharge data was available, a limited number of discharges attributed to storage system failures and improper management.

The *Pollutant Loading Reductions for the Revised Effluent Limitations Guidelines for Concentrated Animal Feeding Operations*, or "Loads Report", describes the methods used by EPA to analyze these AFO and environment interactions, generate total pollutant loads, and then calculate potential pollutant load reductions associated with revisions to the existing CAFO

ELGs. These load reductions form the basis of potential benefits attributed to each technology option. Note, potential benefits associated with estimated national pollutant loads reductions are detailed in *Environmental and Economic Benefit Analysis of Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations* (or "Benefits Document"), and the economic impacts of rule revisions for each option is documented in *Economic Analysis of the Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations* ("Economic Analysis").

Finally, since this loads analysis reflects load reductions over a range of NPDES-permitting scenarios that could define CAFOs at different thresholds, all AFOs with more than 300 AUs were evaluated. Variations in farm size were also selected to correspond to different potential applicability thresholds for the revised ELG. These farm size variations allow load reductions to be calculated for the subset of AFOs defined as CAFOs, as well as the subset of CAFOs for which the ELG would apply. See the *Cost Report* for more information on the size thresholds evaluated.

12.2 Delineation of Potentially Affected Farm Cropland

EPA's loads assessment estimates the national sediment, nutrient, pathogen, and metals loadings to surface waters and ground water under the current effluent limitations guidelines (also called "pre-revised regulation" or "baseline") and after the implementation of various effluent limitations guidelines technology options (also referred to as "post-regulation" scenarios). EPA's national assessment starts with estimates of manure generation consistent with the methodology published by USDA in the 2002 "*Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients*." The next step estimates of fertilizer-based (both manure and synthetic) edge-of-field loads. See Section III.H of the Loads Report for more information.

Key to assessing the edge-of-field pollutant loads is a reasonable representation of land application of manure to croplands. Croplands are the primary destination for AFO generated manure (including treated or processed manure such as compost or pelletized litter). Analytical and mathematical models can be used to estimate pollutant loading from agricultural areas by simulating the physical, chemical, and biochemical processes that govern the transport of water and sediment. For example, field-scale models such as Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) (Knisel et al., 1993) and Erosion-Productivity Impact Calculator (EPIC) (Sharpley and Williams, 1990) provide estimates of pollutants in runoff and sediments that are leaving the field boundaries. Field-scale models permit a detailed assessment of pollutant load generation and the influence of various management technologies, but generally require detailing of variation in soil and crop type. In total, EPA used 13,500 different Sample Farms as inputs to GLEAMS to calculate the edge-of-field loads.

To provide a consistent basis for comparison, EPA evaluated pollutant loads at both AFO and non-AFO facilities for a cropland area totaling 21 million acres nationally. EPA used P-based fertilization, i.e., fertilization of cropland by applying manure at a P-based rate to calculate 21 million total acres for this analysis. In general, P-based fertilization at agronomic levels using manure requires about seven times the acreage needed than when applying manure N-based. Within the 21 million acres are multiple categories of AFO and non-AFO farms that reflect differences in fertilizer requirements and, therefore, application rates. Note, EPA's postrevision options do not affect the total generation of manure (i.e., production rates are constant), but rather the management of the AFO manure nutrients generated. Figure 12-1 indicates how, for baseline and three technology options (potential revised effluent guidelines technology options are described below), EPA maintained a constant total of 21 million acres in its assessment, to enable evaluation of AFO and non-AFO acres.

Additional information on the characterization of cropland acres potentially affected by EPA's rule revision is provided in Table 12-1. Category I AFO manure generation does not exceed the agronomic fertilizer requirements of their cropland acreage. Therefore, Category I farms are generally less affected by the various regulatory scenarios for land application. Category II AFOs have insufficent cropland to make full use of the manure they generate, so under baseline they either overapply manure to their croplands (a common occurrence according to site visits, compliance reports, literature, and state inspection reports in EPA's record). In most cases, this results in application rates 2 or 3 times the N application rate. For a limited number of sample

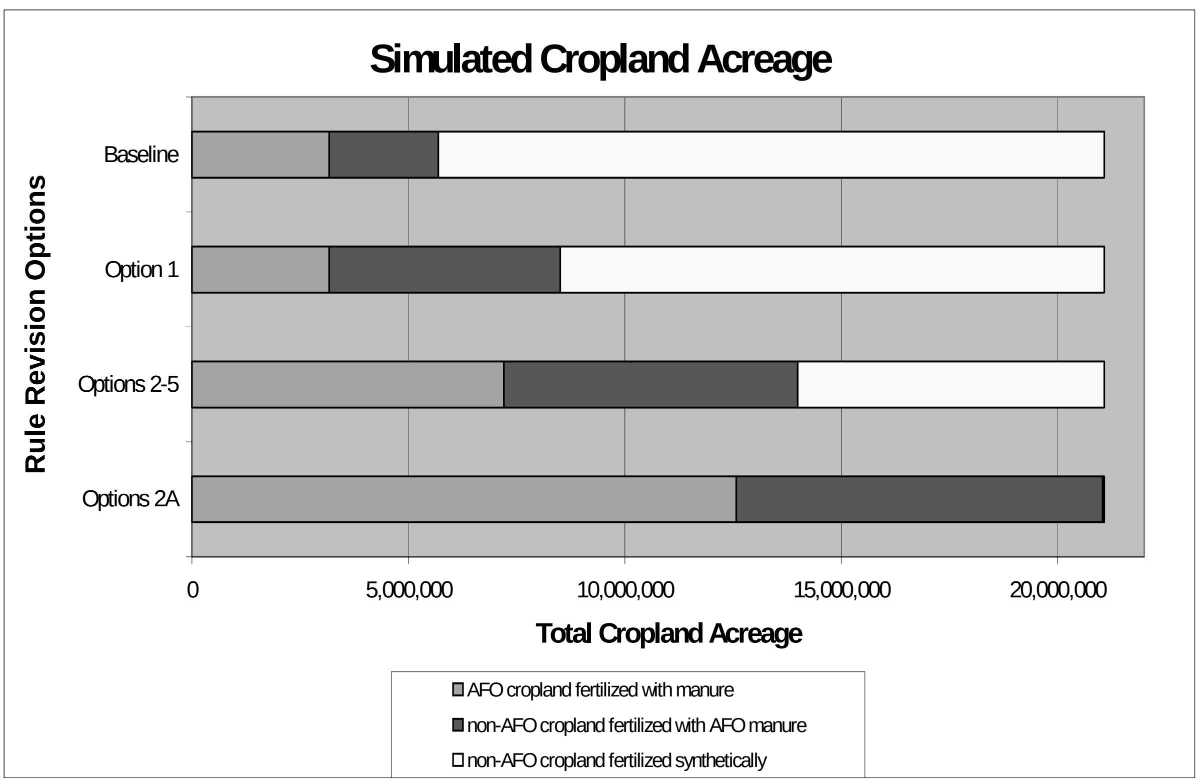

Figure 12-1. Delineation of cropland potentially affected by rule revisions

Table 12-1. Characterization of Farm Cropland Potentially Affected by Rule Revision, Based on Farm Conditions.

Farm Condition	Agronomic Limit based on Crop Selection	Baseline Acres (Prerevision)	Option 1 Acres	Option 2–5 Acres	Option 2A Acres
Category I - AFO cropland where manure is applied at agronomic rates.					
	N-based	1,415,812	1,415,812	784,137	0
	P-based	0	0	1,976,708	4,893,744
Category II - AFO cropland for facilities where manure application exceeds agronomic rates.					
	N-based within AFO facilities	1,755,734	1,755,734	910,503	0
	P-based within AFO facilities	0	0	3,571,789	7,840,241
	N-based for off-site non-AFO facilities	350,284	3,171,869	4,543,510	6,137,784
Category III - AFO farms with no land for manure application (Values are for non-AFO acreage receiving manure from AFOs).*					
	N-based	2,165,781	2,165,781	2,165,781	2,165,781
Total national acres in N-based condition (AFO manure fertilized)		5,687,611	8,509,196	8,403,931	8,303,565
Total national acres in P-based condition (AFO manure fertilized)		0	0	5,548,497	12,733,985
Non-AFO farms using commercial fertilizer (Used to ensure an consistent total acreage for cropland when comparing rule-revision options).					
	N-based and P-based	15,387,767	12,566,182	7,122,950	37,837
Total National Acreage Simulated		21,075,378	21,075,378	21,075,378	21,075,387

* Farms without available acreage to dispose of manure are assumed to disperse their manure to croplands of non-AFO farms at a rate less than five times N-based agronomic levels.

farms (34 out of 435 models), this would result in manure application at rates several times higher than the N rate. These higher manure application rates are likely to negatively affect crop responses. Based on land grant university application rates and the lower limit application attainable by certain land application designed for more concentrated animal manure (such as the limitations of poultry litter with broadcast spreaders), EPA set a limit of five (5) times the N rate for manure application rates at Category II operations. In the small number of cases where the Category II operations still had excess manure, the excess manure was transferred offsite to non-AFO cropland. Note that although 8 percent of the Sample Farms fall under this description, the number of CAFOs represented by these Sample Farms is small, such that these farms account for less than 4 percent of the total national loads. Finally, Category III AFO facilities have 10 or fewer acres of cropland, and all of the manure is transferred offsite to non-AFO croplands. The above described conditions for the three Categories of land availability comprise “baseline” conditions.

All manure transferred offsite is always assumed to be land-applied at an N-based rate. This assumption results in conservative (i.e. lower bound) estimates of load reductions, because load reductions are higher under P-based application rates, and some non-AFOs may be willing to accept manure and land apply manure at less than N-based rates. However, this assumption is deemed appropriate for this analysis as EPA expects very few non-AFO farms (such as row crop farmers) would accept manure as a fertilizer substitute if that farmer had to travel the same croplands more than once for fertilizer applications (i.e., once for manure applied at a P rate and once for supplemental N fertilizer to meet total crop requirements for N) . This analysis does not reflect alternative uses of manure because the processed, treated, or value-added manure is still ultimately land-applied (examples include compost, pelletized litter, digested manure, residual ash after incineration, etc.).

12.3 Modeled Changes from Baseline

For the post-regulation scenarios described below, departure from baseline conditions entails decreasing the over application of manure by linking application rates to crop requirements. As shown in Table 12-1, EPA's assessment differentiates between N-based and P-based fertilized cropland. Under the options considered, use of AFO manure at agronomic rates results in a decrease in synthetic (commercial) fertilizer needed to sustain crop yields on non-AFO cropland acres. This reduction in synthetic fertilizer affects the total estimated national pollutant loads, as detailed below. Note that application of manure on an agronomic N basis generally results in an overapplication of P, which over time can result in the buildup of soil P levels and increase P in the runoff. High levels of P in runoff is known to cause deleterious effects in surface waters. Additionally, application of manure at agronomic P rates results in a deficit of N. When assessing rule revisions, EPA assumed crops would receive the necessary commercial fertilizer to fulfill the total crops' N requirements. EPA also considered direct application to field surfaces versus incorporation of the manure. These two application methods have been shown to have quite different effects on sediment and nutrient transport, so this methodology considers the frequency of both application methods and the subsequent changes in loads.

Based on the farm categories defined in Table 12-1, Table 12-2 outlines what the rule-revision options entail in terms of nutrient application for AFO and non-AFO acres. Table 12-2 indicates how potential options establish requirements for agronomic fertilizing that is either N-based or P-based, and changes the categorization of cropland acres under management. In particular, the number of Category I farms (i.e. farms with sufficient cropland to assimilate all manure produced on the farm) under N-based application rates is lower than the number of Category I farms under P-based application rates. The total number of farms under all scenarios remains constant.

Technology Option 1 establishes manure application standards that prohibit application of manure in excess of the agronomic N rate. This scenario differs from baseline conditions in the decrease (about 3 million acres) in cropland receiving manure in excess of crop nitrogen requirements, and in the increased use of manure instead of synthetic fertilizer at non-AFO cropland. In other words, Category I farms continue to apply manure at a N based rates, Category III farms continue to transfer manure offsite, and Category II farms will spread manure over more acres. Options 2 through 5 establish manure application rates based on the limiting nutrient, either N or P. EPA used soil P test maps and USDA data to determine the percent of facilities in each state that would require N-based versus P-based application rates. This approach is based on a recent informal NRCS survey where 49 out of 50 states (all states except Idaho) reported an intention to use the Phosphorus Index (PI) to meet the NRCS Nutrient Management Standard 590.

Table 12-2. Overview of Regulatory Options.

Description of Assessed Regulatory Condition	**Description of Major Features**	
	AFO Acreage (On site)	**Non-AFO Acreage**
Baseline (prerevised regulatory baseline)	Category I, II, and III land receiving manure at N- to 5N-based rates or commercial fertilizer	Manure applied at agronomic N-based rate. Cropland not receiving manure has commercial fertilizer applied as needed to track a fixed total acreage.
Option 1	Category I, II, and III land receives manure at N-based rates or commercial fertilizer	
Options 2—5	Category I, II, and III land receives manure at N- or P-based rates depending on current soil P levels or commercial fertilizer	
Option 2a	Category I, II, and III land receives manure at P- based rates or commercial fertilizer	

Under Option 2 there are fewer Category I farms and correspondingly more Category II farms. The Category I farms apply commercial fertilizer N in addition to the manure to meet the total crop requirements for N. In addition, because P is used as the limiting nutrient for Options 2 through 5, an additional 6 million acres (8 million acres of cropland in total) are affected by a change in application rates at Category II facilities. Under Option 2A, all AFOs are assumed to apply manure to onsite cropland at the P-based rate with supplemental N added to bring the N applied to the crop removal rate. Option 2A was done as a sensitivity analysis to determine the upper bound load changes if all onsite manure was applied on a P-basis. Under Option 2, from 12 percent to 60 percent (on average roughly half) of all AFOs apply manure at a P-based rate, while the remaining AFOs continue to apply at a N-based rate identical to Option 1. See Chapter 1 of the *Loads Report* for a more detailed description of the model.

12.4   Methodology for Production Area Loads

EPA established a separate methodology for computing runoff and other discharges from the production area. EPA assumes CAFOs subject to the current ELG are in full compliance, therefore there are no runoff load reductions for these facilities. Medium size facilities (AFOs less than 1,000 AUs) may have runoff from the feedlot or manure storage areas. For purposes of this analysis, EPA assumes liquid waste storage facilities (ponds and lagoons) are designed in accordance with the NRCS Code 313 Waste Storage Facility or NRCS Code 359 Waste Treatment Lagoon. The storage capacity (days of storage) for each type of AFO is based on

USDA NAHMS data, site visits, and inspection/compliance reports. EPA then uses 25-year daily weather station precipitation and evaporation data from the county the Sample Farm is located in to represent the climate. Weather, manure generation, and process wastewater are tracked daily for 25 years to estimate the average annual overflow for each Sample Farm. Note that many Sample Farms, especially swine, poultry, and dairy operations, experienced no overflows using this methodology. The complete methodology and an example of the calculations for liquid storage overflows may be found in *Methodology for Estimating BAT Overflow from a Liquid Waste Storage Facility* in Appendices B and C of the *Loads Report*. In a similar manner, the runoff from stacked manure or uncovered litter stockpiles is calculated. See the *Loads Report* for more information.

Next, EPA reviewed available state inspection and discharge reports and university studies to determine the frequency of discharges occurring each year that are not attributable to precipitation at the time of the discharge. For example, one North Carolina study identified the probability of occurrence of permit violations on swine facilities in three North Carolina counties and identified the engineering and management factors that may relate to their occurrence. These discharges are generally infrequent, and when distributed across all Sample Farms, the load reductions attributable to these discharges are small. However, since many discharges are not thoroughly documented in state inspection/compliance reports, EPA believes the methodology is conservative and understates total discharges.

Finally, EPA evaluated the contribution of pollutants to surface waters through ground water with a direct hydrologic connection. Comprehensive studies conducted in North Carolina (Sheffield 2002) and Iowa (ISU 1999) conclude that all liquid impoundments leak, though the rate of leakage varies by soil type and liner construction (if any). Most studies of the lagoon leakage estimated ground water loads by simulating transport of pollutants through ground water aquifers. For its Sample Farm models, EPA assumed that 2,000 pounds per acre per year leaked from manure storage structures lined with silt loam soils. This reference value was used to develop direct and indirect manure storage structure leakage loadings for other soil types (i.e., soil permeability) based on work by Clapp and Hornberger (1978). However, these leakage values are for ammonium, which is not mobile in soils. For ammonium to mobilize, oxygen must be present to oxidize the ammonium to nitrate. Once nitrate is formed it can leach into ground water. Because soil under lagoons generally remains wet and anaerobic, only the outer fringe of the lagoon plume may oxidize and leach. Therefore, EPA assumed that 10 percent of the ammonia-nitrogen that reaches groundwater by leaching from the bottom of the manure storage structure reaches ground water in the form of nitrate-nitrogen. Sobecki and Clipper (1999) determined how many manure storage structures had direct seepage losses by evaluating the ground water pollution potential of AFO manure storage structures according to AFO region land characteristics. For these structures with a direct surface link, pollutant loads were assumed to directly connect with surface water and it was assumed that no ground water aquifer pollutant assimilation took place. See the *Loads Report* for more information.

12.5 Converting Site-specific Loads to National Loads

Each Sample Farm model represents a single combination of animal type, farm size, manure application technique, manure application rate, and farm location. Each Sample Farm model is also evaluated across the three categories of land availability and several soil types. EPA's estimate of the annual national total pollutant load was calculated by assigning the per farm pollutant loads from the suite of Sample Farm models to every AFO facility nationwide. Thus each Sample Farm model represents the behavior of a small fraction of the total AFO population. Sample Farm loads were subsequently extrapolated to the AFO region (See Chapter 4 for a description of EPA's regions) and eventually to national pollutant loads.

To orchestrate the feeding of sample model data into GLEAMS, EPA developed a processor (using the FORTRAN programming language), referred to as the Loadings Estimate Tool (LET). This program extracts data from several large databases, forms an input data file suitable for GLEAMS, feeds the data into GLEAMS, and then regulates GLEAMS output. LET also integrates pollutant loadings estimates from open-air feedlots, manure piles, runoff, and leaking lagoons, to estimate the average annual total pollutant loadings. These per facility production area pollutant loads or per acre land application loads were multiplied by the number of facilities specific to that particular state, farm size, animal type, and waste management system to obtain regional pollutant loads. These regional pollutant loads were then summed to obtain national pollutant loads. The following tables provide a summary of results for each pollutant parameter evaluated.

Tables 12-3 through 12-8 reflect the edge-of-field pollutant loads for Large CAFOs, and Tables 12-9 through 12-14 show the edge-of-field pollutant load reductions for Large CAFOs. Tables 12-15 through 12-20 reflect the edge-of-field loads from all Medium AFOs. Tables 12-21 through 12-26 show the edge-of-field load reductions from the permitted Medium AFOs *only*. No edge-of-field pollutant reductions occurred from the unpermitted Medium AFOs

Table 12-3. Edge-of-field nitrogen loads from Large CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	106	60	58	51	58
Dairy	45	31	30	27	30
Swine	89	87	85	75	110
Poultry	189	159	152	150	147
Total	428	338	325	304	345

Table 12-4. Edge-of-field phosphorous loads from Large CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	105	89	82	82	82
Dairy	19	16	14	14	14
Swine	26	26	22	22	18
Poultry	80	71	61	61	59
Total	230	202	178	178	173

Table 12-5. Edge-of-field sediment loads from Large CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	14,374	12,850	12,850	12,850	12,850
Dairy	2,351	2,225	2,225	2,225	2,225
Swine	3,726	3,726	3,583	3,583	4,311
Poultry	15,042	15,011	14,776	14,776	14,731
Total	35,493	33,813	33,434	33,434	34,118

Table 12-6. Edge-of-field *Fecal coliform* loads from Large CAFOs in 10^{19} colony forming units.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	437	424	423	423	423
Dairy	54	53	53	53	53
Swine	139	139	70	70	1
Poultry	64	57	29	29	0.7
Total	695	672	576	576	478

Table 12-7. Edge-of-field *Fecal streptococcus* loads from Large CAFOs in 10^{19} colony forming units.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	196	190	190	190	190
Dairy	214	206	207	207	207
Swine	4,103	4,087	2,068	2,068	39
Poultry	576	150	89	89	29
Total	5,089	4,633	2,554	2,554	465

Table 12-8. Edge-of-field metals loads from Large CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	2.8	2.7	2.6	2.6	2.6
Dairy	2.5	2.4	2.3	2.3	2.3
Swine	3.5	3.5	3.4	3.4	3.7
Poultry	11.2	10.9	10.7	10.7	10.6
Total	20.0	19.5	18.9	18.9	19.2

Table 12-9. Edge-of-field nitrogen load reductions from Large CAFOs in millions of pounds per year. Numbers in ( ) indicate negative values.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	45.2	47.9	54.3	47.9
Dairy	14.1	14.7	17.9	14.7
Swine	0.3	4.0	13.6	(21.3)
Poultry	29.9	36.4	38.1	41.6
Total	89.6	103.0	123.8	82.9

Table 12-10. Edge-of-field phosphorous load reductions from Large CAFOs in millions of pounds per year.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	15.6	23.1	23.1	23.1
Dairy	3.2	5.0	5.0	5.0
Swine	0.1	4.7	4.7	8.1
Poultry	8.5	19.2	19.2	20.4
Total	27.4	52.1	52.1	56.5

Table 12-11. Edge-of-field sediment load reductions from Large CAFOs in millions of pounds per year. Numbers in ( ) indicate negative values.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	1,524	1,524	1,524	1,524
Dairy	126	126	126	126
Swine	0	143	143	(585)
Poultry	31	266	266	311
Total	1,681	2,059	2,059	1,376

Table 12-12. Edge-of-field *Fecal coliform* load reductions from Large CAFOs in 10^{19} colony forming units.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	14.0	14.0	14.0	14.0
Dairy	1.3	1.3	1.3	1.3
Swine	0.5	69.1	69.1	138.0
Poultry	6.8	35.0	35.0	63.2
Total	22.7	119.5	119.5	216.6

Table 12-13. Edge-of-field *Fecal streptococcus* load reductions from Large CAFOs in 10^{19} colony forming units.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	6	6	6	6
Dairy	8	7	7	7
Swine	16	2,035	2,035	4,064
Poultry	426	487	487	547
Total	456	2,535	2,535	4,624

Table 12-14. Edge-of-field metals load reductions from Large CAFOs in millions of pounds per year. Numbers in ( ) indicate negative values.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	0.14	0.22	0.22	0.22
Dairy	0.03	0.14	0.14	0.14
Swine	0.01	0.13	0.13	(0.23)
Poultry	0.33	0.55	0.55	0.63
Total	0.51	1.04	1.04	0.76

Table 12-15. Edge-of-field nitrogen loads from Mediums CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	24	23	23	23	23
Dairy	60	56	55	53	55
Swine	101	101	100	98	102
Poultry	173	172	172	172	172
Total	358	353	351	347	353

Table 12-16. Edge-of-field phosphorous loads from Mediums CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	17	17	17	17	17
Dairy	24	23	22	22	22
Swine	22	22	21	21	20
Poultry	79	78	78	78	78
Total	141	140	137	137	136

Table 12-17. Edge-of-field sediment loads from Mediums CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	4,582	4,580	4,562	4,562	4,562
Dairy	2,885	2,882	2,827	2,827	2,827
Swine	3,910	3,910	3,890	3,890	3,898
Poultry	20,094	20,092	20,088	20,088	20,087
Total	31,470	31,464	31,367	31,367	31,374

Table 12-18. Edge-of-field *Fecal coliform* loads from Mediums CAFOs in 10^{19} colony forming units.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	22	10	10	10	10
Dairy	44	36	36	36	36
Swine	240	240	222	222	204
Poultry	40	40	40	40	39
Total	346	325	307	307	289

Table 12-19. Edge-of-field *Fecal streptococcus* loads from Mediums CAFOs in 10^{19} colony forming units.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	10	4	4	4	4
Dairy	254	201	201	201	201
Swine	7,057	7,055	6,530	6,530	6,003
Poultry	1,177	1,125	1,124	1,124	1,124
Total	8,498	8,385	7,859	7,859	7,332

Table 12-20. Edge-of-field metals loads from Mediums CAFOs in millions of pounds per year.

Sector	Baseline	Option 1	Option 2	Option 3	Option 5
Cattle	0.4	0.4	0.4	0.4	0.4
Dairy	3.4	3.4	3.3	3.3	3.3
Swine	2.9	2.9	2.9	2.9	2.8
Poultry	8.9	8.9	8.9	8.9	8.9
Total	15.7	15.7	15.6	15.6	15.6

Table 12-21. Edge-of-field nitrogen load reductions from Medium CAFOs in millions of pounds per year.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	0.17	0.22	0.22	0.22
Dairy	4.59	5.03	7.34	5.03
Swine	0.03	0.98	3.11	(0.59)
Poultry	0.81	0.88	0.90	0.95
Total	5.60	7.10	11.56	5.60

Table 12-22. Edge-of-field phosphorous load reductions from Medium CAFOs in millions of pounds per year.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	0.05	0.27	0.27	0.27
Dairy	1.33	2.55	2.55	2.55
Swine	0.01	0.70	0.70	1.50
Poultry	0.26	0.72	0.72	0.73
Total	1.66	4.24	4.24	5.05

Table 12-23. Edge-of-field sediment load reductions from Medium CAFOs in millions of pounds per year.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	1	20	20	20
Dairy	3	57	57	57
Swine	0	20	20	12
Poultry	2	6	6	7
Total	6	104	104	96

Table 12-24. Edge-of-field *Fecal coliform* load reductions from Medium CAFOs in 10^{19} colony forming units.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	12.1	12.1	12.1	12.1
Dairy	8.2	8.2	8.2	8.2
Swine	0.1	17.9	17.9	35.8
Poultry	0.1	0.5	0.5	0.8
Total	20.4	38.6	38.6	56.9

Table 12-25. Edge-of-field *Fecal streptococcus* load reductions from Medium CAFOs in 10^{19} colony forming units.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	5	5	5	5
Dairy	54	54	54	54
Swine	2	527	527	1,054
Poultry	52	53	53	54
Total	113	639	639	1,166

Table 12-26. Edge-of-field metals load reductions from Medium CAFOs in thousands of pounds per year.

Sector	Option 1	Option 2	Option 3	Option 5
Cattle	0.9	1.9	1.9	1.9
Dairy	23.2	80.3	80.3	80.3
Swine	0.1	18.5	18.5	42.4
Poultry	6.1	9.6	9.6	10.6
Total	30.2	110.2	110.2	135.1

12.6 References

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