1

Intro to Environmental Stewardship, Regulations and Whole Farm Nutrient Balance

WHY WE ARE HERE.
An Introduction To The Environmental Stewardship, Regulations And Whole Farm Nutrient Balance

Dr. Mark Risse, Biological and Agricultural Engineering, mrisse@engr.uga.edu, 706-542-9067

Parts of this lesson were adapted from Lessons 1 and 2 of the National Livestock and Poultry Environmental Curriculum written by Dr. Rick Koelsch, The University of Nebraska

Intended Outcomes

The participants will

- Understand environmental issues associated with animal manure.
- Recognize the importance of balancing nutrient inputs and managed outputs for a livestock operation.
- Identify potential indicators of a "whole farm" nutrient imbalance within the producer's own operation.
- Be aware of fundamental strategies for addressing a whole farm nutrient imbalance.
- Understand the state of regulations and CNMP's in Georgia

Introduction to Environmental Issues with Manure

For most of the U.S. livestock industry, nutrients in manure represent the single largest threat to water quality. Thus, choices made relative to the management of nutrients within a livestock operation are absolutely critical to protecting water quality.

If managed correctly, manure is an excellent plant nutrient source and soil "builder" resulting in many important environmental benefits. Soils regularly receiving manure require less commercial fertilizer (conserving energy and limited phosphorus reserves), are higher in organic matter contributing to greater soil productivity, and may experience less runoff and erosion and better conservation of moisture. However, an increased risk to water quality will result from excess application of nutrients to a cropping system. The management level of the producer will often determine if the manure that is generated on his farm is a waste or a resource.

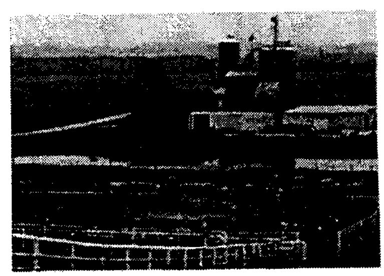
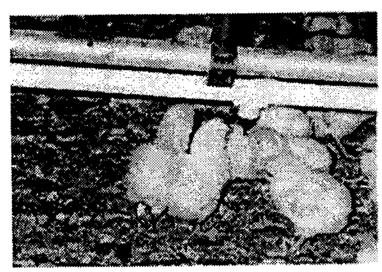
Farm operators should be well aware of the impacts that manure can have on water quality. Nitrogen, phosphorus, pathogens, and organic matter are the four primary contaminants that impact water quality. Nutrients, such as nitrogen and phosphorus, are essential for plant growth and make manure a good fertilizer. When nutrients reach rivers and lakes, they present environmental risks and can cause algal blooms, fish kills, and eutrophication. Nitrogen moves with water more easily than phosphorus and excess nitrates from nitrogen can cause health problems in animals and people. Pathogens are disease causing organisms. Manure can contain many pathogens including E. coli, C. parvum, and giardia. These organisms can present serious human health hazards but they usually can not survive long periods of time in lagoons or on land surfaces. Animal housing and manure storage should therefore be located away from surface water and wells to prevent transfer. Organic matter provides benefits in the soil but in water, the decomposition of organic matter creates Biological Oxygen Demand or BOD. This removes oxygen from the water and can often result in fish kills or other aquatic problems. Organic matter will usually on present problems when large amounts enter a water body and therefore is more of a direct discharge or point source problem.

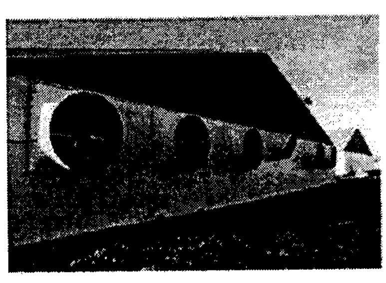
The following pages contain Lesson 1 of the National Livestock and Poultry Environmental Stewardship Curriculum. While it is not essential that you know all of the material in this lesson, you should look through it paying particular attention to the main points. After the course, I would suggest reading it in more detail. If you are interested in any of the other lessons in this National Curriculum, consult the website listed in the publication or contact the Midwest Plan Service.

Lesson 1

Principles of Environmental Stewardship

By Rick Koelsch, University of Nebraska




Financial Support

Funding for the development of this lesson was provided by USDA-CSREES and U.S. EPA Ag Center under a grant awarded to the University of Nebraska Cooperative Extension, University of Nebraska-Lincoln. The following organizations were also affiliated with this project: Farm*A*Syst, MidWest Plan Service, USDA-ARS, and USDA-NRCS.

Disclaimer

This lesson reflects the best professional judgment of the contributing authors and is based on information available as of the publication date. References to particular products should not be regarded as an endorsement.

Lesson 1
Principles of Environmental Stewardship

By Rick Koelsch, University of Nebraska

Intended Outcomes

The participants will

- Recognize key principles of environmental stewardship.
- Understand key environmental issues facing the livestock and poultry industry.
- Review those environmental and regulatory issues that are of local interest.

Contents

Activities

The participants will complete

- An assessment of the environmental stewardship principles that they have implemented with their own livestock/poultry operation.
- A prioritization of individual environmental issues within the local community.
- A review of applicable regulations.

PROJECT STATEMENT

This educational program, Livestock and Poultry Environmental Stewardship, consists of lessons arranged into the following six modules:

- Introduction
- Animal Dietary Strategies
- Manure Storage and Treatment
- Land Application and Nutrient Management
- Outdoor Air Quality
- Related Issues

Introduction

Is manure an environmental risk or benefit?

Management of manure and other byproducts of livestock and poultry production is a complex environmental issue. Given the same facts, rational individuals can often arrive at distinctly different conclusions. Is manure . . .

A source of pathogens, oxygen-depleting compounds, and nutrients that degrades the quality of our water for drinking and recreational use?

OR

A source of organic matter that improves the quality and productivity of our soil resources?

One of our nation's largest remaining sources of water pollution?

OR

A source of plant nutrients required for growth that can replace commercial nutrients both finite in supply and energy intensive in their production?

A source of gaseous emissions that reduces the quality of life in rural communities and contributes to possible neighbor health concerns?

OR

A means of recycling and sequestering carbon in the soils, contributing to a reduction in atmospheric carbon and global warming?

Both sets of conclusions about manure can be true. Manure can produce both substantial benefits and severe environmental degradation. The actual environmental results often depend upon choices that the producer makes.

The livestock and poultry industry is facing a growing scrutiny of its environmental stewardship.

Why are we here?

The livestock and poultry industry is facing a growing scrutiny of its environmental stewardship. Emotion and lack of understanding by the general public contributes to this scrutiny. Problems also result from a few producers who have contributed to highly visible impacts on the environment due to ignorance or outright disregard for the environment. These situations create a negative and often biased public view of livestock and poultry's impact on the environment.

However, real environmental concerns also result from livestock and poultry operations owned or managed by well-intentioned producers. Animal production has the potential to negatively affect surface water quality (from pathogens, phosphorus, ammonia, and organic matter); groundwater quality (from nitrate); soil quality (from soluble salts, copper, arsenic, and zinc); and air quality (from odors, dust, pests, and aerial pathogens). Manure and other byproducts of animal production, if not carefully managed, will have a significant negative impact on the environment.

Manure and other byproducts of animal production... can have a significant negative impact on the environment.

On May 5, 1998, Secretary of Agriculture Dan Glickman stated that animal waste is "the biggest conservation issue in agriculture today, bar

none" at the National Summit on Animal Waste and the Environment. Agricultural production has been identified by the U.S. Environmental Protection Agency (EPA) as the largest single contributor to water quality impairment for rivers and lakes (Table 1-1).

The purpose of this curriculum is to encourage a proactive stewardship response based on good science among those producers who recognize the seriousness of this environmental issue and expand the awareness of producers not familiar with current environmental concerns.

This educational program will assist you in

- Self-assessing your operation's current environmental strengths and weaknesses.
- Identifying choices that minimize manure's risk as a pollutant and enhance manure's value as a resource.
- Reviewing your operation's compliance with environmental standards established by regulatory processes.

Table 1-1. Five leading sources of water quality impairment.

Rank	Rivers	Lakes	Estuaries
1	Agriculture	Agriculture	Municipal point source
2	Municipal point sources	Urban runoff and storm sewers	Urban runoff and storm sewers
3	Urban runoff and storm sewers	Hydrologic/habitat modification	Agriculture
4	Resource extraction	Municipal point sources	Industrial point sources
5	Industrial point sources	Onsite wastewater disposal	Resource extraction

Source: EPA 1998.

Principles of Environmental Stewardship

Stewardship of air and water resources will be fundamental to the future survival of animal production systems.

Most producers are familiar with the benefits of stewardship of our soil resources. Practices such as reduced tillage, contour farming, terracing, and others have produced a dramatic improvement in agriculture's stewardship of those soil resources.

What stewardship principles apply to the management of manure? Stewardship of air and water resources will be fundamental to the future survival of animal production systems. Several fundamental principles of good stewardship must be considered in the future production of livestock and poultry. With the assistance of Table 1-2, you can complete a review of your operation's implementation of these principles.

Awareness of environmental risks

The potential impact of an individual operation on the environment varies with animal concentration, weather, terrain, soils, and a host of other conditions. What are the highest risk situations or practices for your livestock/poultry operations? Are you developing plans and investing resources to address the highest risk situations? Identification of critical environmental risks specific to your operation is the starting point of any good stewardship program. This curriculum provides one set of tools for assessing risks, commonly found in Appendixes A and B of individual lessons. Many land-grant university cooperative extension programs and livestock and poultry

commodity groups provide additional excellent resources for assessing environmental risk.

No point source discharge

Livestock and poultry production systems should be managed to allow no discharges to surface water from point sources such as animal housing and storage facilities. The "No Discharge" management standard for animal manure is distinctly different from our management of human waste, which commonly is discharged into surface waters following treatment. To attain this high environmental standard, livestock/poultry operations should be designed and managed to prevent discharges to waters of the state and United States except under the most unusual weather conditions (see Module C, Manure Storage and Treatment).

Minimizing discharges from nonpoint sources (e.g., land application) is also central to good environmental stewardship. Decisions related to timing and site selection of land application should be made to minimize the risk of discharges.

Balance in the use of nutrients

Nitrogen (N) and phosphorus (P) represent a double-edged sword. These are essential nutrients for all life forms but can become water quality contaminants when mismanaged. Livestock and poultry systems must

Livestock and poultry systems must maintain a balance between the nutrients arriving on-farm... and the nutrients leaving as managed products... .

Table 1-2. Environmental stewardship assessment. Check response most appropriate to your livestock or poultry operation to identify areas that may need improvement on your farm.

Stewardship principle	Low risk	Medium risk	High risk	Don't know
"My livestock operation..."	My operation fully attains this stewardship principle.	My operation is progressing toward this stewardship principle.	My operation requires significant changes to achieve this stewardship principle.	
"...has completed an environmental assessment and identified high-priority environmental risks."				
"... does not discharge from buildings or manure storage."				
"...maintains balance in nutrients entering and leaving (as managed products)."				
"...implements a nutrient plan for land application."				
"...is a good neighbor.				
"...complies with all environmental regulations."				
"...considers environmental issues before expansion."				

Good stewardship requires knowledge of and compliance with current regulatory requirements... .

maintain a balance between the nutrients arriving on-farm as purchased feed and fertilizer and the nutrients leaving as managed products (crops, animals, or animal products). An excess of nutrients arriving on farms results in a concentration of those nutrients (see Lesson 2, Whole Farm Nutrient Planning) and an increased risk of environmental losses (e.g., nitrates leaching to groundwater, ammonia volatilizing in the atmosphere, and P in runoff to surface waters).

Nutrient plan for land application

Land application will continue to be the ultimate destination of most manure. A good stewardship program includes a plan for managing manure nutrients in crop production systems. The plan must maintain a balance between nutrient application and crop use as well as minimize the risk of runoff and leaching of nutrients. "Manure...Take Credit" should be the slogan of every producer and advisor managing manure in a cropping program (see Module D, Land Application Nutrient Management).

Be a good neighbor

The byproducts of animal production create several potential nuisances (including odors, flies, noise, and others) in rural communities. A producer must be fully aware of these potential problems and the degree of concern they cause neighbors. Where reasonable technologies and management strategies are available to reduce or eliminate these nuisances, such strategies should be implemented (see Module E, Outdoor Air Quality). Where such options do not exist, producers may need to consider alternatives for offsetting these nuisances.

Know the rules

Good stewardship requires knowledge of and compliance with current regulatory requirements as established by federal, state, and local governments (Appendix B in most lessons). Most regulatory standards establish a **minimum** standard for environmental management. Knowledge of those rules and careful planning of manure management systems to attain those standards is essential. However, good stewardship often will require higher standards.

Expansion without environmental compromise

Concentration of livestock has allowed many producers to remain economically competitive. However, animal concentration also increases the concentration of nutrients, pathogens, odors, and other potential environmental concerns. Livestock expansion should occur only in areas where

- a beneficial end use of manure nutrients is available,
- separation distances and/or environmental strategies exist for maintaining quality of life for neighbors, and
- no high-risk, site-specific situations exist.

As you review these principles of good stewardship, it is important to recognize two fundamental differences between managing the byproducts of animal production and human waste. These differences impact why manure and human waste are managed in fundamentally different ways.

(1) Animal manure and other byproducts have substantially greater "pollution strength" (concentration of organic compounds and nutrients)

than human waste. Human waste has similar characteristics to animal manure, but it is diluted with very large quantities of clean water. For this reason, many of the conventional treatment processes used in municipal waste treatment cannot successfully treat animal manure to acceptable levels for discharge or would be cost prohibitive. As a result, the stewardship principles of no discharge, nutrient planning for land application, and knowing the rules are critical to the livestock industry's management of its byproducts.

(2) Biological, chemical, and physical processes occurring in the soil provide the primary treatment of livestock manure (Figure 1-1). Soil provides the opportunity for recycling nutrients, using carbon to improve soil quality, and filtering or treating pathogens. Typically, almost no recycling of nutrients and carbon occurs with human waste. If nutrients and carbon are successfully recycled, the benefits to soil quality, conservation of energy (N fertilizers are energy intensive), and reduction in use of resources with limited supplies (P fertilizers) can be substantial. However, livestock producers must recognize and operate within the recycling limitation of soil and cropping systems.

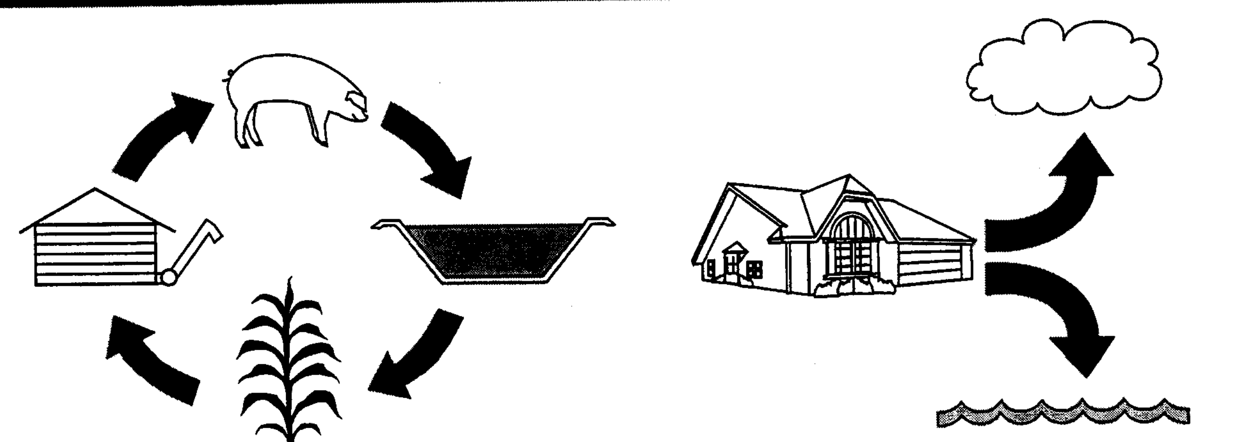
...the stewardship principles of no discharge, nutrient planning for land application, and knowing the rules are critical to the livestock industry's management of its byproducts.

Understanding Manure's Environmental Benefits

For centuries, animal manure has been recognized as an excellent source of plant nutrients and as a soil "builder" because of its contributions to improving soil quality. When compared to more conventional fertilizer, manure properly applied to land has the potential to provide environmental benefits, including

- Reduced nitrate leaching
- Reduced soil erosion and runoff

Recycling vs. Waste Disposal



Proper manure management focuses on recycling manure nutrients and carbon through land application and crop production.

Proper management of human waste focuses on dilution and treatment, allowing its relatively safe disposal into air and water.

Figure 1-1. Manure management systems focus on recycling of carbon and nutrients while human waste systems focus on disposal.

- Increased soil carbon and reduced atmospheric carbon levels (potentially benefiting global warming)
- Reduced energy demands for natural gas intensive N fertilizers
- Reduced demand for commercial P fertilizer, which is a limited resource
- Improved productivity of cropping systems

...it is manure's unique combination of these nutrients with organic carbon that provides its value to crop production and the environment.

Manure contains most elements required for plant growth including N, P, potassium, and micronutrients. However, it is manure's unique combination of these nutrients with organic carbon that provides its value to crop production and the environment. First, manure N is more stable than N applied as commercial fertilizer. A significant fraction of manure N is stored in an organic form that is slowly released as soils warm. Commercial fertilizer N is applied in either a nitrate or an ammonium (easily converted to nitrate) form. Nitrate-N is very soluble and mobile, and early in the growing season, it contributes to leaching during excess precipitation or irrigation. Manure N's slow transformation to crop-available forms is better timed to crop N needs, resulting in less leaching potential. In addition, some manure N is released very slowly, often not becoming available until the second or third year after application, thus providing long-term benefits.

Soil organic matter is considered nature's signature of a productive soil. Most nutrients that enter the plant root zone are involved in a range of microbial processes during their conversion to plant-available forms. Manure's organic carbon provides the energy source for the active, healthy soil microbial environment that both stabilize nutrient sources and make those nutrients available to crops.

Tilling the soil and harvesting grain and other crops has reduced the organic carbon content of soils. It is estimated that soil organic content has declined by 50% to 70% in the Midwest during the past 150 years. Several long-term manure application studies have illustrated manure's ability to reverse the trend or return soil organic levels back to their original level prior to cultivation.

In addition to the value of soil organic carbon from a nutrient perspective, manure contributes to improved soil structure, which contributes to improved water infiltration and greater water-holding capacity, benefiting crop water stress, soil erosion, and nutrient retention. An extensive review of the literature and historical soil conservation experiment station data (Risse and Gilley 2000) at selected locations around the United States suggested that manure produced substantial reductions in soil erosion (13%-77%) and runoff (1%-68%). Increased manure application rates produced greater reductions in soil erosion and runoff. During years when manure was not applied, a residual benefit of past manure application was noted.

Manure and Water Quality Concerns

Management of animal manure and other byproducts to minimize water quality impact represents a substantial challenge facing the livestock and poultry industry. The following discussion briefly summarizes the components of manure that are of greatest concern, their specific impact on water quality, and their common pathways to surface and/or groundwater.

Water quality contaminants

Manure contains the following four primary contaminants that impact water quality: (1) N, (2) P, (3) pathogens, and (4) organic matter. Those contaminants, their environmental risk, and common pathway to water are summarized in Table 1-3.

Nitrogen (N). For growth and survival, all living things require N, the fundamental building block of protein. Livestock and poultry use only part of the protein in their rations for the production of meat or other animal products. The remaining protein is excreted as N in manure in the form of urea (in urine) and organic-N (in feces). Urea is quickly transformed into ammonium-N. Nitrate-N can originate from manure N.

Most N in manure exists in an ammonium or organic N form (Figure 1-2). In these forms, it is likely to be transported with surface water runoff and erosion. These forms of N are unlikely to leach through soils with the exception of macropore flow to shallow water tables or tile lines. In general, the filtering ability of soil restricts movement of organic compounds, and the negatively charged clay soil particles restrict the movement of positively charged ammonium-N (NH_4^+).

Ammonium-N in surface water also represents an environmental risk. In most natural surface waters, total ammonium-N concentrations greater than about 2 ppm exceed the chronic criteria for fish. The toxicity of ammonium-N varies with acidity and water temperature. In alkaline water at high temperatures, toxic conditions can exist down to 0.1 ppm.

The role of N in water is receiving growing scrutiny due to its contribution to harmful alga blooms in coastal waters and to nitrates in drinking water. Algae or phytoplankton are microscopic, single-celled plants. Most species of algae are not harmful and serve as the energy producers at the base of the food web, without which higher life on this planet would not exist. Occasionally, conditions allow algae to grow very fast or "bloom." These conditions have resulted in hypoxic (low oxygen level) regions in the Gulf of Mexico, Chesapeake Bay, and other locations. The low oxygen levels inhibit aquatic life and reduce fishery production. In addition, some alga blooms produce toxins that result in fish lesions and fish kills. Pfiesteria and other related species have been identified in the estuaries of the Mid- and South Atlantic states as well as red tides and brown tides along the Florida and Texas coasts. Growing evidence exists that nutrient loading is a contributor to hypoxic conditions in coastal waters. While it has not been clearly established that nutrients from agriculture and other sources are responsible for outbreaks of Pfiesteria and other harmful alga blooms, there is some scientific consensus about this linkage.

Table 1-3. Summary of potential manure contaminants of water quality, the associated environmental risk, and most common pathway to water.

Potential pollutant	Environmental risk	Most common pathway to water
Nitrate-N	Blue baby syndrome	Leaching to groundwater
Ammonia-N	Fish kills	Surface water runoff
P	Eutrophication	Erosion and surface water runoff
Pathogens	Human health risk	Surface water runoff
Organic solids	Reduced oxygen level in water body–fish kills	Surface water runoff

Manure contains the following four primary contaminants that impact water quality:
(1) N
(2) P
(3) Pathogens
(4) Organic matter

The role of N in water is receiving growing scrutiny due to its contribution to harmful alga blooms...and to nitrates in drinking water.

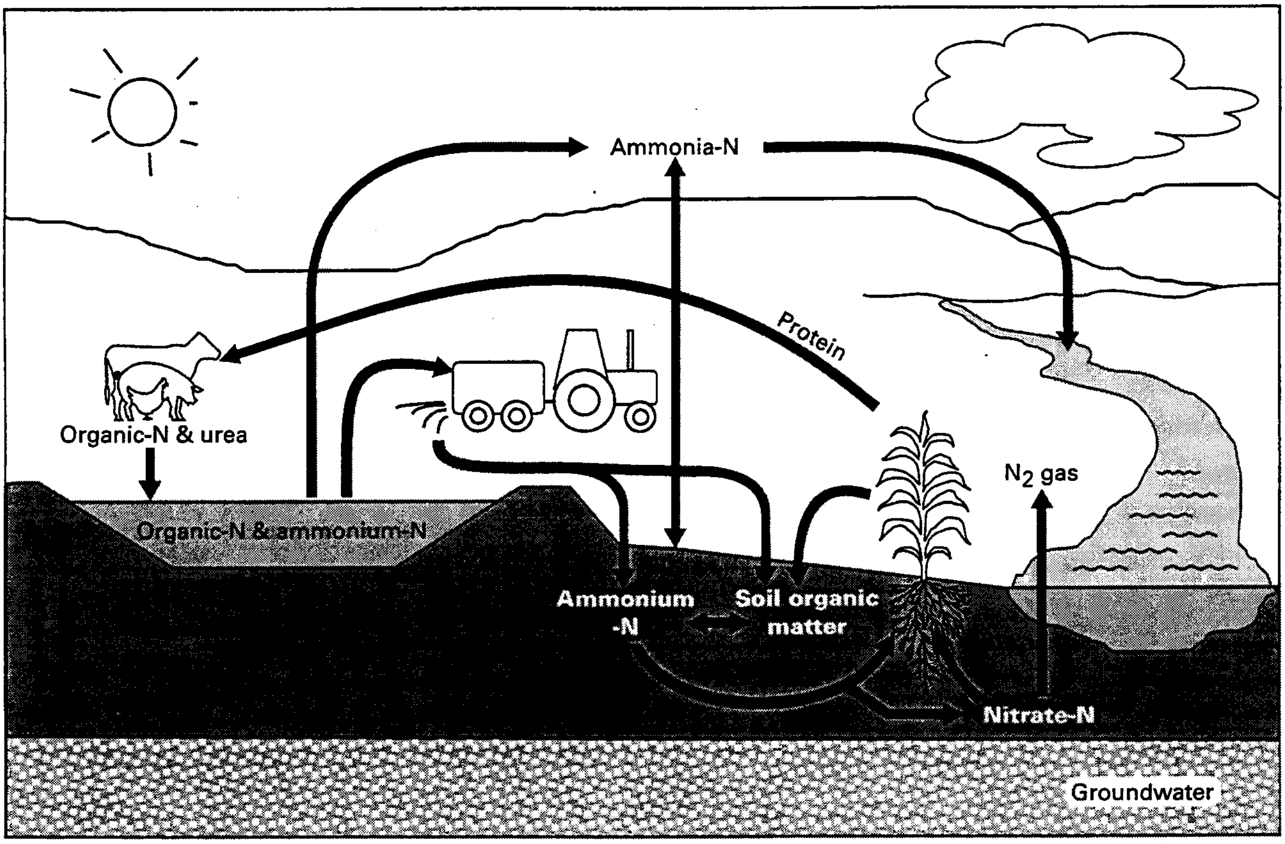


Figure 1-2. Common nitrogen pathways on a livestock and crop production system.

Phosphorus transported from agricultural lands to surface waters can promote eutrophication, ...one of the leading water quality issues facing the nation's lakes and reservoir... .

If sufficient oxygen is available, ammonium-N can be transformed into nitrate-N (nitrification), which is soluble in water, and can leach through soils to groundwater. Nitrate-N from manure is likely to exist only in soil following land application of manure and in mechanically aerated lagoons.

Nitrate contamination of drinking water supply restricts the oxygen in the bloodstream in infants under the age of 6 months, causing methemoglobinemia (blue baby syndrome). Infants and pregnant women are at greatest risk. In addition, there are other less well-documented health impacts. The U.S. EPA has set a maximum contaminant level of 10 parts per million (ppm) for nitrate-N in public water supplies.

Phosphorus (P). Because it is essential to plant growth and development, P is essential for modern crop production. It plays many critical functions; the primary one being the storage and transfer of energy through the plant. In confined livestock production, supplemental P is often essential to bone development and optimum animal performance. Commercially mined P has limited reserves remaining in the United States. Thus, better use of manure P provides an increasingly important alternative to commercial fertilizers.

Phosphorus transported from agricultural lands to surface waters can promote eutrophication. Eutrophication, one of the leading water quality issues facing the nation's lakes and reservoirs, refers to an abnormally high growth of algae and aquatic weeds in surface waters. As this organic material

dies, natural oxygen levels decline, which can cause changes in fish population or fish kills. Other common problems associated with eutrophied water bodies include less desirable or restricted recreational use, unpalatable drinking water, and increased difficulty and cost of drinking water treatment. Eutrophic surface waters may also experience massive blooms of cyanobacteria, which can kill livestock and pose health hazards to humans.

Eutrophication is caused by an overabundance of nutrients in runoff water feeding a lake or reservoir. Excess P is the limiting nutrient for most freshwater lakes and reservoirs. In brackish and saline estuaries, N can be the limiting nutrient triggering alga blooms. The U.S. EPA is discussing national criteria for P compounds in water. Their current recommendations suggest that total P should not exceed

- 0.05 mg/L in a stream at a point where it enters a lake or reservoir.
- 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs.

Phosphorus typically moves with runoff and erosion. It is stored in soils primarily fixed to soil minerals (iron, aluminum, and calcium) or in organic matter (living soil bacteria, crop residue, and partially decayed organic matter). Thus, soil erosion is a primary transport mechanism of P to surface water.

...soil erosion is a primary transport mechanism of P... .

Soil water also contains a small amount of dissolved P, essential for plant uptake. Because the balance among the various P pools is heavily in favor of the organic and soil mineral forms, P leaching is rarely an issue. However, as soil, mineral, and organic pools of P increase, dissolved P in runoff water is becoming a greater concern. Dissolved P is readily available to algae and the key contributor to eutrophication of surface waters.

Agriculture and, in particular, livestock production will receive significant scrutiny relative to solving N- and P-related water quality concerns. A Government Accounting Office (GAO) report (USGAO 1995) to the U.S. Senate suggested that livestock and poultry manure is a major contributor of total N and P inputs into U.S. watersheds (Figure 1-3). Manure nutrients inputs were substantially greater than those associated with more traditional sources of pollution (e.g., municipalities, industry). The comparison in Figure 1-3 is not a good comparison of "apples" with "apples." The point source category (municipalities and industry) represents a direct discharge to rivers and lakes. Animal manures and fertilizers are land applied with only a fraction reaching surface water. The livestock industry's management of manure in land application will determine the magnitude of risk associated with manure.

Pathogens. A pathogen is typically considered any virus, bacterium, or protozoa capable of causing infection or disease in other animals or humans. For the purpose of this discussion, the focus will be on pathogens in livestock and poultry manure representing a risk to human health.

Cryptosporidium parvum...and giardia are the two pathogens shed in animal manure of greatest concern for transmission to humans via water.

Cryptosporidium parvum (*C. parvum*) and giardia are the two pathogens shed in animal manure of greatest concern for transmission to humans via water. The concern about these organisms is a result of three factors:

(1) A healthy adult human can become infected with relatively few oocytes.
(2) These protozoa originate from a variety of domestic animals, wildlife, and humans.
(3) Commonly used water disinfectants such as chlorine are not effective in controlling these protozoa.

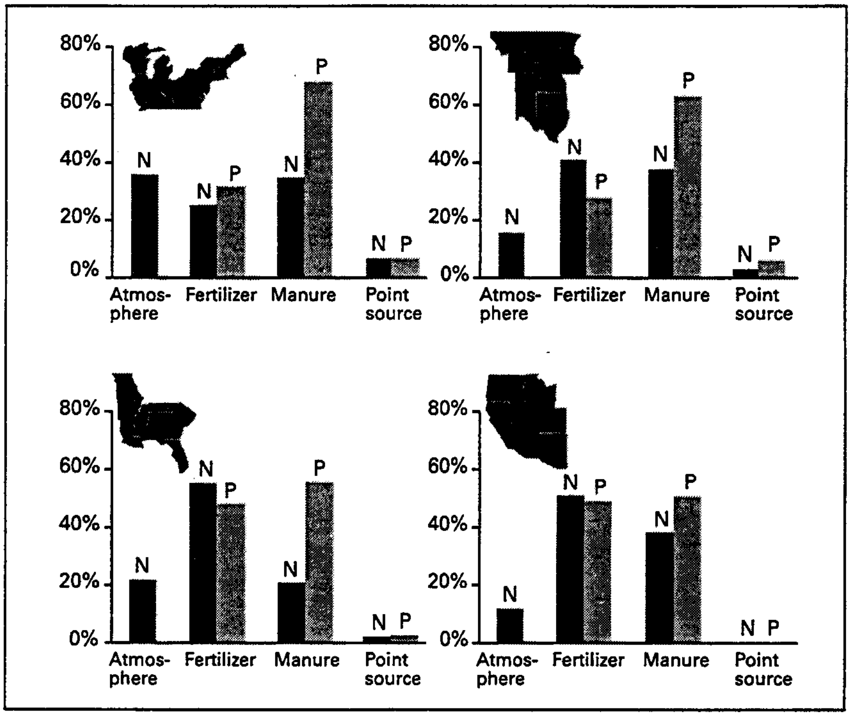


Figure 1-3. Sources of N and P inputs to watersheds in the four regions of the United States.
Source: USGAO 1995.

Three potential reservoirs for *C. parvum*...exist: wildlife, domestic animals, and humans.

C. parvum and giardia are parasites that cause severe diarrhea, nausea, fever, vomiting, and fatigue in humans. In healthy humans, the infections from either organism are usually self-limiting and do not pose serious health risks. However, the risk can be much greater for the very young, elderly, and those with immune depressed systems (e.g., those receiving chemotherapy, those with AIDS, or those who have received organ transplants).

Livestock and poultry shed a number of viruses in feces, but as a general rule, these viruses are not transmitted to humans. However, influenza viruses from swine may be an exception although the route of transmission does not typically involve swine excrement. Several potential bacterial pathogens shed by livestock are also capable of infecting humans. However, unless bacteria in feces has direct access to a drinking water supply, it is relatively unlikely that bacteria originating from livestock will infect humans. In addition, bacteria can be controlled with common water disinfectants such as chlorine. Location of drinking water wells (no chlorine treatment) in close proximity to animal housing or manure storage has caused human illnesses and deaths due to bacteria such as *E. coli* from livestock feces.

Because of the human health risks associated with *C. parvum* and giardia and the challenges of removing these pathogens from public water supplies, much of the remaining discussion will focus on these two organisms.

Three potential reservoirs for *C. parvum* and giardia exist: wildlife, domestic animals, and humans. A recent national study of *C. parvum* in beef and dairy cattle found that 59% of dairy farms and 22.4% of heifers tested positive. *C. parvum* was greatest for calves between 1 and 3 weeks of age and

was rare for animals older than 3 months. Generally, cattle testing positive for giardia were less than 6 months but older than those with *C. parvum*. Another study has suggested that *C. parvum* is common to cow calf herds supplying young stock for beef production but at lower rates than observed in dairies.

Additional studies have found unweaned foals and suckling lambs have the greatest risk of infection within these species. Among pigs, infection is not limited to young animals and is strongly affected by management practices such as sanitation. Dogs, cats, and rodents can all be affected and are partially responsible for pathogen transmission on many farms. Poultry is not a carrier of *Cryptosporidium* organisms that infect humans.

Most pathogens, including *C. parvum* and giardia, do not multiply outside a host organism and have a limited lifetime outside a host. The viability of these organisms can range from a few days to many months, depending upon a number of environmental factors. Those environmental factors include

- Temperature: Environmental temperatures above 100°F and especially those commonly achieved by composting will dramatically reduce pathogen survival.
- pH: High and low pH are effective for reducing pathogen survival. A pH of 9.0 or greater will limit most pathogen survival. For pathogen control, municipalities often treat human sludge to achieve a pH above 12.
- Freezing or freeze/thaw: Freezing temperatures and freeze/thaw cycles can reduce the survival of bacteria and viruses. Moderate temperatures can extend the life span of pathogens.
- Anaerobic/aerobic decomposition: Normal microbial decomposition of manure under anaerobic and aerobic conditions produces antibacterial and antiviral compounds.

Most pathogens ...do not multiply outside a host organism and have a limited lifetime outside a host.

Pathogens are most likely to be transported to water with surface runoff and erosion or by direct animal access to surface water. Streams and lakes used for drinking water supply and recreational purposes provide the greatest opportunity for transporting these pathogens to humans. Livestock operations located upstream of surface water used for drinking water supply or recreation should recognize the potential risks associated with pathogens.

Pathogens are unlikely to move through soils to groundwater. Soils provide a filtering mechanism, especially for larger organisms such as protozoa and bacteria. Filtering of smaller organisms such as viruses may be more dependent on organic matter and the soil's clay content. Macropore flow can lead to pathogens bypassing the soil's filter and reaching tile drainage or shallow water tables. Researchers have commonly observed contaminated drainage from tile shortly after the land application of manure.

A wide range of livestock, domestic animals, wildlife, and humans carries pathogens. It is important to recognize that any of these animals can play important roles in transporting pathogens between livestock and to local surface waters. Control measures must consider the potential for transport by domestic animals, wildlife, and humans.

Organic matter. Organic matter in manure, like nutrients, can be a valuable environmental resource if managed properly or an environmental pollutant if managed poorly.

Organic matter in manure, like nutrients, can be a valuable environmental resource if managed properly or an environmental pollutant if managed poorly.

If manure is allowed to discharge to a water body or run off from a land application site, the organic matter can become a harmful pollutant. Organic matter in the form of manure, silage leachate, and milking center wastewater

degrades rapidly and consumes considerable oxygen (often measured as biological oxygen demand, BOD, or chemical oxygen demand, COD). If this occurs in an aquatic environment, oxygen can be quickly depleted. Fish kills are often caused in part by this depletion of oxygen. Manure, silage leachate, and waste milk are extremely high in degradable organic matter. These products can be 50 to 250 times more concentrated than raw municipal sewage (primarily because livestock production does not add the large volume of fresh water that is used in dilution and transport of municipal waste).

Fish kills are often caused in part by ...depletion of oxygen.

Organic matter, like pathogens, P, and ammonia, is transported to water primarily by surface water runoff. Rarely does it leach through soils. Organic matter is unlikely to be transported in sufficient quantities to nearby surface waters unless one of the following situations occurs:

(1) A direct discharge from a livestock housing, manure storage, open lot, or other facilities is allowed to enter surface water drainage.
(2) A catastrophic failure such as an earthen storage break or continuous application by an irrigation system on the same location.
(3) Significant rainfall occurs immediately after the surface application of manure.
(4) Significant application is made on frozen, snow-covered, or saturated soils in close proximity to surface water.

Contaminant pathways

The potential pollutants discussed previously typically follow one or more of five possible pathways for reaching water, including runoff, leaching, macropore flow, wells, and ammonia volatilization and deposition (see Figure 1-4).

Runoff. Runoff from open lots, land application sites, and manure and feed storage units is a common pathway for contaminant transport. All contaminants in manure will travel with surface water runoff and soil erosion. Pollution associated with P, pathogens, ammonia, and organic matter are most commonly associated with runoff or erosion.

Nitrates are the primary contaminant that leaches to groundwater.

Leaching. Nitrates are the primary contaminant that leaches to groundwater. Dissolved contaminants such as nitrate -N will leach beyond a crop's root zone when the soil moisture exceeds its water-holding capacity and eventually contaminate groundwater. Most contaminants in manure and other byproducts (e.g., organic matter, pathogens, and typically P) are filtered by soil and will NOT leach to groundwater. Soil structure, chemical bonding with soil minerals, and negatively charged soil particles typically restrict the movement of most contaminants. However, it is possible to exceed the soil's ability to restrict contaminant movement. For example, soils with low cation exchange capacity (sandy soils) can allow ammonia movement of up to a few feet per year below manure storages.

Macropore flow. Most contaminants in manure can travel through soil to shallow groundwater tables or tile drains by macropore flow. Macropore flow (root holes, wormholes, and cracks due to soil drying) can provide pathways for contaminants to bypass the soil's filtering capability. Sinkholes and karst topography also provide opportunities for contaminants to directly reach groundwater.

Wells. Wells can provide a direct pathway for contaminants to reach groundwater. Abandoned wells, wells with poor well-casing designs, or wells located in close proximity to open lots or manure storage can provide a pathway for all manure contaminants to move to groundwater.

Ammonia volatilization and deposition. Ammonia-N volatilizes from manure storage, lagoons, and open lots. Once volatilized, most ammonia is redeposited with rainfall or through dry deposition. It can be transported over long distances. Many areas of the world profit from this nutrient deposition. However, some areas of the world are experiencing high enough deposition that it threatens vitality and growth in local ecosystems. In the United States, coastal areas are often adversely affected by ammonia deposition. Nitrogen availability rather than P typically limits eutrophication in coastal waters.

Manure and Air Quality Concerns

Air quality issues associated with livestock systems are the focus of Lessons 40 through 44. Primary sources of odorous gases and other contaminants, measurement of odor, and technology- and management-based control measures will be discussed in detail in those lessons. A brief introduction to air quality concerns follows.

Common compounds

Manure handling and storage associated with confinement livestock and poultry systems result in a wide range of air emissions. More than 160 volatile compounds have been identified as contributing to the odor from confinement facilities.

More than 160 volatile compounds have been identified as contributing to the odor from confinement facilities.

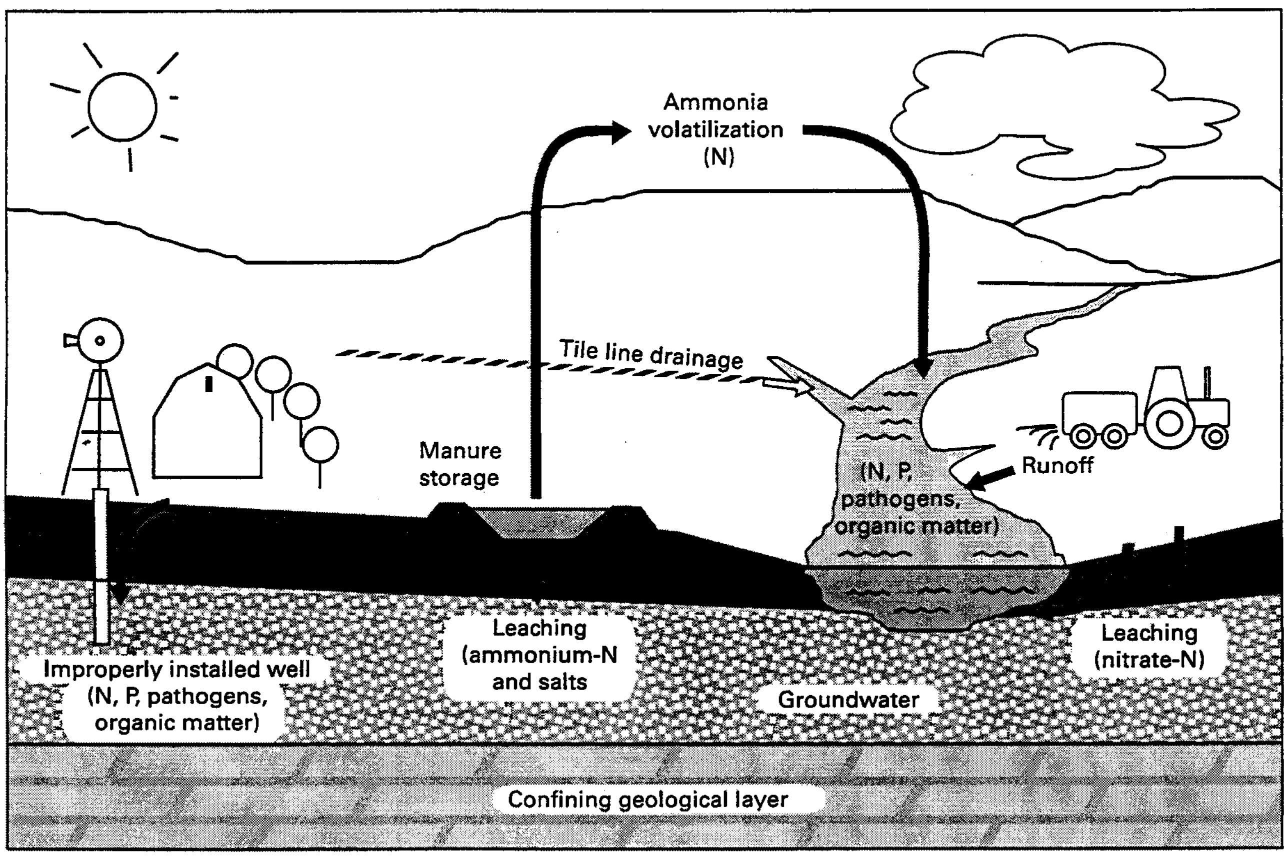


Figure 1-4. Common pathways for manure contaminants to reach surface and groundwater.

Table 1-4. Common odorous compounds associated with livestock manure.

Volatile fatty acids	Ammonia and amines	Phenolics/N heterocyles	Sulfur compounds
Acetic	Ammonia	Phenol	Hydrogen sulfide
Proprionic	Methylamine	P-cresol	Dimethyl sulfide
Butyric	Ethylamine	Indole	Methyl mercaptan
Isobutyric		Skatole	Ethyl mercaptan
Isovaleric			Diethyl sulfide

Many of these volatile compounds contribute to observed odors. The primary groupings of odorous compounds are listed in Table 1-4. Because of the vast number of compounds contributing to an odor observation and the variation in the relative importance of individual gases for individual situations, attempts to identify a single indicator gas have not generally proven successful. In addition, other emissions are associated with livestock production. Dust emission from animal housing is gaining greater attention due to its possible health impact upon neighbors and its ability to serve as a carrier of odor compounds. Finally, the production of non-odorous gases including methane and carbon dioxide is gaining some attention as a potential contributor to global warming.

Anaerobic degradation of manure is an additional significant contributor of most compounds.

These compounds originate from a variety of sources. Metabolic processes within the gastrointestinal tract of livestock contribute some of these compounds. Anaerobic degradation of manure is an additional significant contributor of most compounds.

Anaerobic degradation involves the reduction of complex organic compounds to a variety of odorous volatile fatty acids (VFAs) by acid-forming bacteria. Methane-forming bacteria convert VFAs to odorless methane and carbon dioxide. If these anaerobic processes are in balance, most odorous compounds are eliminated. However, under certain conditions in manure storage or overloaded anaerobic treatment lagoons, acid-forming and methane-forming processes are not in balance, resulting in an accumulation of VFAs. In addition, sulfate-reducing bacteria found in anaerobic environments convert sulfate to hydrogen sulfide and other sulfur-containing compounds. Anaerobic degradation by sulfate-reducing bacteria and an imbalance of acid- and methane-forming bacteria are significant sources of odorous compounds.

Environmental Impacts

Odorous volatile compounds are commonly considered to be an unpleasant or nuisance experience by many neighbors. Neighbors' determination of odor nuisance is often related to a number of physical factors (frequency, duration, and intensity of odor experience) and social factors (neighbor's past experience with agriculture, neighbor's relationship with producer, and appearance of livestock or poultry operation). Neighbors' odor nuisance issues must be taken seriously. These experiences are commonly a critical driving force to discontent within a community, opposition to new or expanding facilities, and additional scrutiny of potential other environmental issues.

Recent research suggests that neighbors have strong emotional reactions and possible health-related responses to livestock-related odors. These concerns are summarized in Lesson 40, Emissions from Animal Production

Systems. These reactions can impact psychological health and possibly physiological health.

Some community concerns and regulatory efforts have focused on individual gases as opposed to the general issue of odor. Hydrogen sulfide is one such gas. In general, the relationship between livestock odors and hydrogen sulfide is very weak. Hydrogen sulfide alone is not considered to be an acceptable indicator of odor. However, health-related concerns are a more common justification of standards or regulations for hydrogen sulfide. Exposure to concentrations of 2,000 ppm for a few minutes can be fatal. Long exposures at 300 ppm have also caused deaths. To avoid these concerns, worker health organizations have established average workplace concentration limits of 10 ppm. Some states have established levels as low as 0.03 ppm to 0.1 ppm for community exposure limits, assuming that a greater range of susceptibility to hydrogen sulfide exposure would be found within the general population than within a healthy workplace population.

Hydrogen sulfide alone is not considered to be an acceptable indicator of odor.

Livestock production is a source of greenhouse gases (methane and carbon dioxide). These gases are primary end products of anaerobic and aerobic (carbon dioxide only) decomposition of manure and other byproducts. It has been estimated that carbon dioxide and methane account for, respectively, 66% and 18% of the greenhouse gas effect. However, the carbon released from manure originated from plants that removed carbon dioxide as part of the photosynthetic process. Agriculture recycles greenhouse gases as opposed to contributing additional greenhouse gases, which occurs with the combustion of fossil fuels. In addition, regular land application of manure to cropland increases the organic matter (carbon content) of those soils, which may be an important sink for reducing greenhouse gases.

Ammonia is released in large quantities by livestock production. Anaerobic lagoons may lose more than two-thirds of the N in manure as ammonia. Open lots for livestock production will volatilize roughly half of the N, primarily as ammonia. As described previously in the water quality section, the primary problems associated with ammonia relate to its deposition on land or water.

Issues of Local Concern

The previous discussion introduced several potentially negative impacts of manure on the environment. Within your local community, it is likely that only a few of these potential issues are of critical concern. These high-priority issues may result from unique local conditions, a history of environmental concerns, and/or public policy and regulatory actions.

It is important that the producer's future investments of time and resources focus primarily on high-priority local environmental issues. Use the following assessment tools to identify those high-priority issues based upon local community concerns (see Appendix A) and regulations (see Appendix B). These priorities should be considered in your livestock operation's future environmental stewardship efforts.

It is important that the producer's future investments of time and resources focus primarily on high-priority local environmental issues.

APPENDIX A
Environmental Stewardship Assessment: Primary environmental issues of local concern

Environmental issue	Check importance of environmental issue locally.			Is this issue regulated?
	High	Medium	Low	
		Water Quality		
Nitrate contamination of groundwater				___Yes ___ No ___Don't know
Eutrophication from nutrient movement to surface water				___Yes ___ No ___Don't know
Fish kills from discharges or spills to surface water				___Yes ___ No ___Don't know
Protection of community drinking water supplies				___Yes ___ No ___Don't know
Pathogen contamination of water				___Yes ___ No ___Don't know
Other:___________________				___Yes ___ No ___Don't know
		Air Quality		
Odors				___Yes ___ No ___Don't know
Dust				___Yes ___ No ___Don't know
Ammonia volatilization and deposition				___Yes ___ No ___Don't know
Hydrogen sulfide				___Yes ___ No ___Don't know
Other:___________________				___Yes ___ No ___Don't know

APPENDIX B

Regulatory Compliance Assessment: Issues that may define your farm's priorities

Regulatory Issue	Is this issue addressed by regulations? If "Yes," summarize those regulations.			Is my livestock/poultry operation in compliance?
Which agencies are involved in administrating regulations related to livestock/poultry manure?	___ U.S. EPA ___ State ___ Local List Name, Address, Phone No.			
Do livestock-related regulations address:	Federal:	State:	Local:	
• Groundwater quality?	___ Yes _x_ No	___ Yes ___ No	___ Yes ___ No	
• Surface water quality?	_x_ Yes ___ No	___ Yes ___ No	___ Yes ___ No	
• Air quality?	___ Yes _x_ No	___ Yes ___ No	___ Yes ___ No	
Do regulations vary based upon size of livestock/poultry operation?	___ Yes ___ No			___ Yes ___ No ___ Not applicable ___ Don't Know
Do regulations vary based on livestock/poultry species?	___ Yes ___ No			___ Yes ___ No ___ Not applicable ___ Don't Know
Do regulations vary based on confinement or pasture-based systems?	___ Yes ___ No			___ Yes ___ No ___ Not applicable ___ Don't Know
Is a permit required for construction of a manure management facility?	___ Yes ___ No			___ Yes ___ No ___ Not applicable ___ Don't Know
Is a permit required for operation of a manure management facility?	___ Yes ___ No			___ Yes ___ No ___ Not applicable ___ Don't Know
Other:	___ Yes ___ No			___ Yes ___ No ___ Not applicable ___ Don't Know

About the Author

This lesson was written by Rick Koelsch, Livestock Environmental Engineer, University of Nebraska-Lincoln, who can be reached at this e-mail address: rkoelsch1@unl.edu

References

Risse, L.M., and J.E. Gilley. 2000. Manure impacts on runoff and soil loss. Proceedings of the Eighth International Symposium on Animal, Agricultural, and Food Processing Wastes. ASAE. St. Joseph, Michigan, 578–587.

Council for Agricultural Science and Technology (CAST). 1996. *Integrated Animal Waste Management.* Task Force Report No. 128. Ames, Iowa.

United States Environmental Protection Agency (EPA) 1998. *Clean Water Action Plan: Restoring and Protecting America's Waters.* Document ISBN-0-16-049536-9. Washington, D.C.:GPO.

United States General Accounting Office (GAO). 1995. *Animal Agriculture: Information on Waste Management and Water Quality Issues.* Briefing Report to the Committee on Agriculture, Nutrition, and Forestry, U.S. Senate. Gaithersburg, Maryland.

Glossary

Aerobic. Microbial processes that occur in the presence of free oxygen.

Anaerobic. Microbial processes that occur in the absence of free oxygen.

Biological oxygen demand (BOD). Laboratory measurement of the oxygen consumed by microbial use of organic compounds as a food source. It is a common measure of a contaminant's strength or concentration.

Chemical oxygen demand (COD). A standard test for approximating the amount of oxygen required to oxidize a substance to carbon dioxide and water.

Cryptosporidium parvum (C. parvum). A protozoa commonly found in the excrement of mammals that can cause disease in humans.

Environmental Protection Agency (EPA). Federal agency charged with implementation of U.S. environmental policy including federal regulations that relate to livestock and poultry production.

Eutrophication. Designates a water body that has experienced an increase in the available nutrients, an environment that favors plant over animal life, and a reduced dissolved oxygen level.

Giardia. A protozoa commonly found in mammal excrement that can cause disease in humans.

Hypoxic. Refers to a water body that is deficient in dissolved oxygen.

Blue baby syndrome (Methemoglobinemia). When drinking water contains elevated levels of nitrates, it often causes human infants to develop a potentially fatal condition that gives a blue cast to their skin.

N. Nitrogen.

P. Phosphorus.

Parts per million (ppm). A commonly used measure of concentration of a chemical.

Pathogen. An agent such as a bacteria that can cause disease.

Volatile fatty acids (VFAs). Organic acids resulting from the decomposition of manure that can be released into the atmosphere. These compounds are a major contributor to the odors associated with manure.

Volatilization. Process by which compounds that evaporate readily at normal temperatures and pressures, such as ammonium, release into the atmosphere as ammonia gas.

Index

FUNDING
This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture; the U.S. Environmental Protection Agency, National Agriculture Assistance Center; and the University of Nebraska Cooperative Extension, University of Nebraska-Lincoln, under Cooperative Agreement Number 97-EXCA-3-0642.

Reviewers

Many colleagues reviewed drafts of the Livestock and Poultry Environmental Stewardship curriculum and offered input over a two-year period. Thus, it is impossible to list all reviewers; however, certain reviewers provided in-depth reviews, which greatly improved the curriculum's overall quality, and pilot tested the curriculum within their state. These reviewers, also members of the Review and Pilot Team, are listed below.

Ted Funk
Extension Specialist
Agricultural Engineering
University of Illinois

Carol Galloway
USEPA Ag Center
Kansas City, KS

Mohammed Ibrahim
Extension Specialist
North Carolina A&T State University

Gary Jackson
Professor, Soil Science, and Director,
National Farm*A*Syst Program
University of Wisconsin, Madison

Barry Kintzer
National Environmental Engineer
USDA-NRCS
Washington, D.C.

Rick Koelsch
Livestock Environmental Engineer
University of Nebraska

Deanne Meyer
Livestock Waste Management Specialist
University of California-Davis

Mark Risse
Extension Engineer, Agricultural Pollution Prevention
University of Georgia

Peter Wright
Senior Extension Associate, PRO-DAIRY
Cornell University

Finally, recognition must also be given to three individuals, members of the Access Team, who helped determine the final appearance of the curriculum lessons: Don Jones, Purdue University; Jack Moore, MidWest Plan Service; and Ginah Mortensen, EPA Ag Center.

Livestock and Poultry Environmental Stewardship Curriculum: Lesson Organization

This curriculum consists of 27 lessons arranged into six modules. Please note that the current lesson is highlighted.

Module A. Introduction

1. **Principles of Environmental Stewardship**
2. Whole Farm Nutrient Planning

Module B. Animal Dietary Strategies

10. Reducing the Nutrient Excretion and Odor of Pigs Through Nutritional Means
11. Using Dietary and Management Strategies to Reduce the Nutrient Excretion of Poultry
12. Feeding Dairy Cows to Reduce Nutrient Excretion
13. Using Dietary Strategies to Reduce the Nutrient Excretion of Feedlot Cattle

Module C. Manure Storage and Treatment

20. Planning and Evaluation of Manure Storage
21. Sizing Manure Storage, Typical Nutrient Characteristics
22. Open Lot Runoff Management Options
23. Manure Storage Construction and Safety, New Facility Considerations
24. Operation and Maintenance of Manure Storage Facilities
25. Manure Treatment Options

Module D. Land Application and Nutrient Management

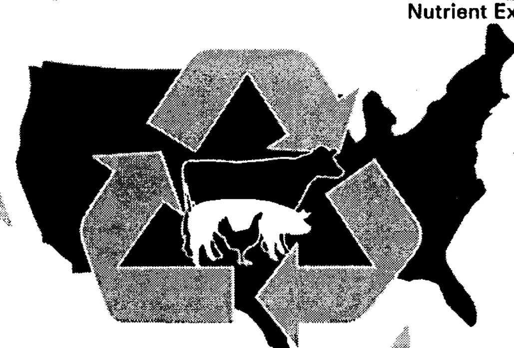
30. Soil Utilization of Manure
31. Manure Utilization Plans
32. Land Application Best Management Practices
33. Selecting Land Application Sites
34. Phosphorus Management for Agriculture and the Environment
35. Land Application Records and Sampling
36. Land Application Equipment

Module E. Outdoor Air Quality

40. Emission from Animal Production Systems
41. Emission Control Strategies for Building Sources
42. Controlling Dust and Odor from Open Lot Livestock Facilities
43. Emission Control Strategies for Manure Storage Facilities
44. Emission Control Strategies for Land Application

Module F. Related Issues

50. Emergency Action Plans
51. Mortality Management
52. Environmental Risk and Regulatory Assessment Workbook



Introduction to Nutrient Issues

For most of the U.S. livestock industry, nutrients in manure represent the single largest threat to water quality. Thus, choices made relative to the management of nutrients within a livestock operation are absolutely critical to protecting water quality.

If managed correctly, manure is an excellent plant nutrient source and soil "builder" resulting in many important environmental benefits. Soils regularly receiving manure require less commercial fertilizer (conserving energy and limited phosphorus reserves), are higher in organic matter contributing to greater soil productivity, and may experience less runoff and erosion and better conservation of moisture. However, an increased risk to water quality will result from excess application of nutrients to a cropping system.

Nutrient Concentration and Distribution

If one reviews all the environmental issues associated with Animal Feeding Operations, nutrients and more specifically the concentration of nutrients on livestock or poultry operations leads to many of the problems. Most nutrient-related issues associated with livestock production are a result of poor nutrient "distribution." This distribution issue can be a local or a regional issue.

- *Single-field nutrient distribution issues.* An integrated crop and livestock farm commonly experiences this distribution problem within its own boundaries. Some fields, often those closest to the livestock facility, receive excessive manure applications while commercial fertilizer is purchased to meet the needs of fields more distant from the livestock. Spreading manure based upon convenience and not the crop's nutrient requirements causes water quality problems.

- *Individual farm nutrient distribution issues.* Farms focused primarily on livestock production import significant quantities of nutrients as animal feeds. Livestock utilize only 10% to 30% of these nutrients, excreting the remaining as manure. This results in a concentration of nutrients on the livestock farm and a shortage of nutrients (typically replaced by purchased commercial fertilizers) on neighboring crop farms. The separation of ownership of crop and livestock production can result in a concentration of nutrients on the livestock farm while neighboring crop farms import substantial commercial fertilizer nutrients. In Georgia, this is evident in that North Georgia has excess nutrients while South Georgia has a substantial need for imported fertilizers. (See Figure 1)

- *Regional nutrient distribution issues* have developed in the last 30 years as livestock/poultry production has concentrated in specific, but separate, regions of the country. Examples of these regional nutrient distribution problems include the concentration of pork production in the Carolinas, poultry concentration in southern and mid-Atlantic states, beef cattle production in the High Plains, and dairy in western, north central, and northeastern states. Many of these regions import significant quantities of nutrients primarily as feed grains from the Corn Belt. The nutrients excreted by these animals can overwhelm the ability of locally grown crops to recycle these nutrients.

Whole Farm Nutrient Management

Nutrients are transported along multiple pathways and in a variety of forms on a livestock operation. Our tendency is to focus on a small part of the total picture, such as the nutrients in manure and their losses into the environment. However, an understanding of the big picture is necessary in identifying the underlying cause of nutrient-related water quality problems as well as the solutions.

A picture of the flow of nutrients on a farm is presented in Figure 2. Nutrients arrive on a livestock operation as purchased products (fertilizer, animal feed, and purchased animals), nitrogen fixed by legume crops, and nitrates in rain and irrigation water. These "Inputs" are the origin of all nutrients

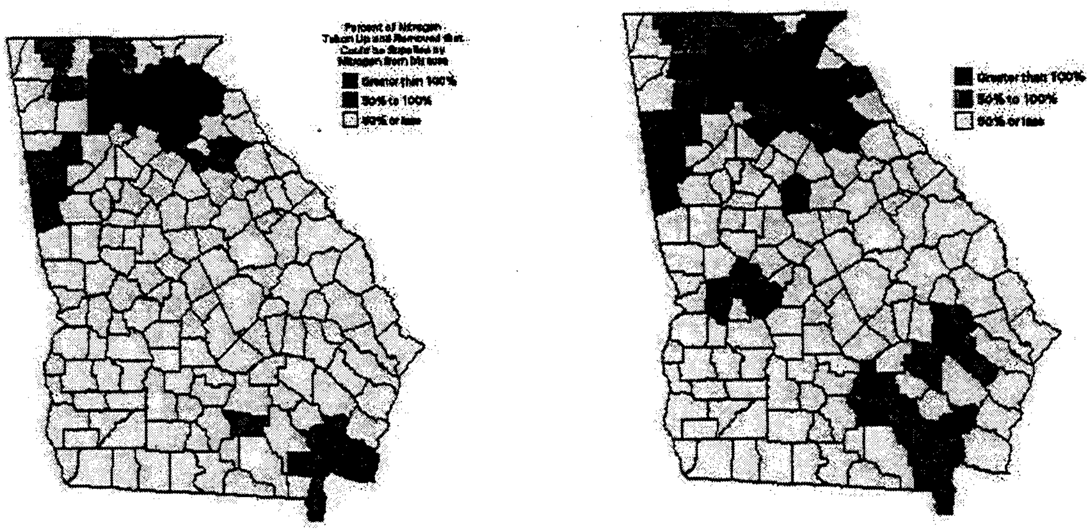


Figure 1. Nutrient Imbalances in Georgia. The figure on the left shows nitrogen while the one on the right depicts phosphorus. In each figure, the nutrient needs for the total amount of cropland, pastures, and hayfields in a county were calculated. The nutrients generated in the form of animal waste were also calculated for each county. The lighter counties can supply less than 50% of the nutrient needs with animal waste, the gray shades supply between 50% and 100%, and the dark counties produce more nutrients than they can use in their county.

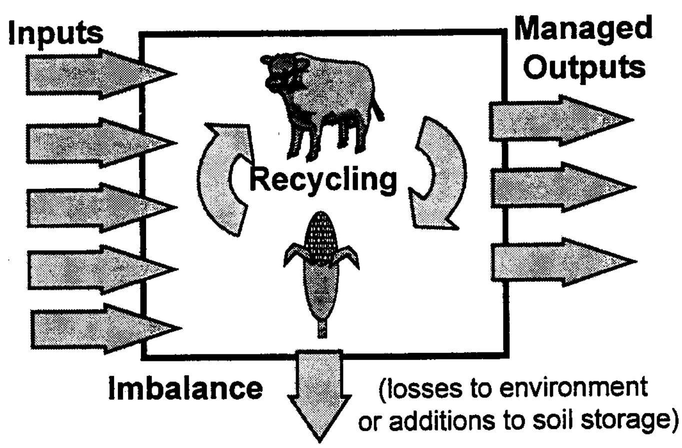


Figure 2. A whole farm nutrient balance considers all nutrient inputs, managed outputs, and losses for a livestock or poultry farm.

required for crop and livestock production as well as those nutrients that escape into the environment. Within the boundaries of the farm, there is a "Recycling" of nutrients between the livestock and crop components. Manure nutrients are recycled, at least in part, for crop production. Feed crop nutrients are in turn recycled as animal feed for livestock or poultry production.

Nutrients exit a livestock operation preferably as "Managed Outputs" including animals and crops sold and possibly other products moved off farm (e.g., manure sold or given to a neighboring crop producer). Some nutrients exit the farm as losses to the environment (nitrates in groundwater, ammonia volatilized into the atmosphere, and nitrogen and phosphorus into surface water). Nutrients (especially

phosphorus) also accumulate in large quantities in the soil. Although not a direct loss to the environment, a growing accumulation of nutrients in the soil adds to the risk of future environmental losses.

The "Imbalance" is the difference between the "Inputs" and the "Managed Outputs." This "Imbalance" accounts for both the direct environmental loss and the accumulation of nutrients in the soil. Livestock operations with an imbalance produce an increasing risk to water quality. In contrast, livestock operations that have achieved a balance represent a potentially sustainable production system.

Typical Nutrient Balances

The nutrient balance is illustrated for a feedlot, dairy, and swine operation in Figure 3. For this feedlot, the input to output ratio was 2.5:1 for nitrogen (imbalance of 650 tons/year) and 2:1 for phosphorus (imbalance of 120 tons/year). The magnitude of the imbalance is smaller for the dairy and swine operation. However, the ratio of inputs to outputs ranges from 2.5:1 to more than 4:1. Inputs to outputs ratios of 2:1 up to 4:1 are common for many livestock operations.

A phosphorus balance provides a preferred indicator of the risk to water quality. An imbalance in nitrogen does not distinguish between the relatively benign losses (e.g., denitrification of nitrate to N^2 gas) and the relatively harmful environmental losses (e.g., nitrate loss to water). In contrast, phosphorus losses impact only water quality through increased soil phosphorus levels and greater concentration of phosphorus moving with surface runoff water.

Farms with a phosphorus input to output ratio near 1:1 have the potential to be environmentally

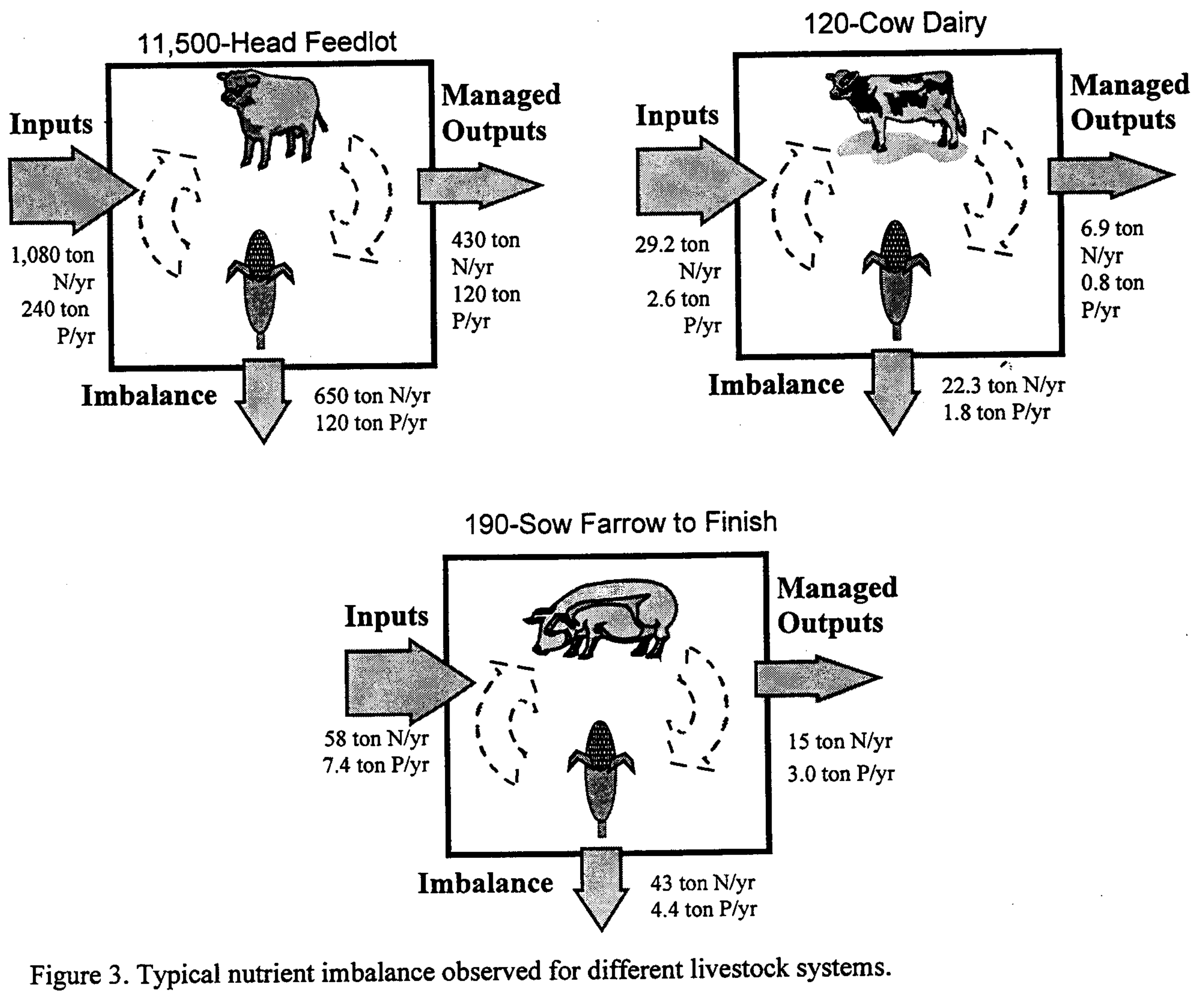


Figure 3. Typical nutrient imbalance observed for different livestock systems.

sustainable. Since soil storage is the primary reservoir for phosphorus, average soil phosphorus level should not be increasing. Livestock and poultry operations with a large imbalance (1.5:1 and greater) would expect steadily increasing soil phosphorus levels. Runoff and erosion from land application sites will carry an increasing phosphorus load as soil phosphorus levels increase. Measures to reduce runoff and erosion will partially reduce this risk and provide temporary solutions. The phosphorus imbalance must be corrected before this growing pollution potential will stabilize. These "High Risk" operations are not environmentally sustainable.

Sources of Nutrient Inputs

The source of nutrient inputs to livestock operations is important to understanding preferred management practices for reducing water quality risk. Commercial fertilizer can be a common source of nutrient inputs for many livestock operations, especially those with large cropping programs. Purchased animal feeds are often the most significant source of the nitrogen and phosphorus inputs even in regions that grow most animal feeds locally. Efforts to correct nutrient imbalances must focus on options for utilizing feed nutrients more efficiently and reducing purchased feed inputs. Other potential sources of nutrient inputs include purchased animals, legume-fixed nitrogen, and nitrates in irrigation water. These sources are typically insignificant or offer few options for input reduction. The one exception may be legume-fixed nitrogen grown on dairy operations.

Is My Livestock/Poultry Operation in Balance?

An understanding of nutrient balance and primary source of purchased nutrients is key to operating a livestock operation in an environmentally sustainable manner. Three methods for estimating whether a nutrient imbalance may be an issue on your farm are provided. Those methods include

(1) A checklist of potential indicators of nutrient imbalance (Table 1).

(2) Manure nutrient production vs. crop nutrient utilization. This method checks the ability of your land base to utilize the nutrients in manure. An excess of manure nutrients for crop production suggests a likely whole farm nutrient imbalance. This will be part of your CNMP.

(3) Whole Farm Nutrient Balance provides the "bottom line" answer to this issue. It also provides a measurement of progress made toward environmental sustainability following the implementation of changes. The producer must be willing to assemble information for animal purchases and sales, feed and grain purchases and sales, fertilizer purchases, manure sales, and possibly other contributors for a one-year period. A spreadsheet to aid the producer in conducting a whole farm nutrient balance is located at http://manure.unl.edu/Koelsch-nbalance.html.

Table 1. Environmental Stewardship Inspection. Indicators of a possible imbalance that may exist on my farm (check those that apply). "Yes" response indicates that potential for nutrient imbalance is high.

Yes	No	Don't Know	
____	____	____	Soil phosphorus levels for the majority of fields are increasing with time.
____	____	____	Soil phosphorus levels for the majority of fields are identified as "High" or "Very High" on the soil test.
____	____	____	The majority (more than 50%) of the protein and phosphorus in the ration originates from off-farm sources.
____	____	____	Livestock feed programs routinely contain higher levels of protein and/or phosphorus than National Research Council or land-grant university recommendations.
____	____	____	A manure nutrient management plan is not currently in use for determining appropriate manure application rates to crops.
____	____	____	Less than 1 acre of crop land is available per animal (1,000 lbs. of live weight), and no manure is transported to off-farm users.

The indicators found in Table 1 may help producers identify if an accumulation of nutrients is an issue on his farm. Increasing soil phosphorus levels is probably the best indicator of a potential imbalance. Most of the accumulation of phosphorus within a livestock and crop farm is likely to be stored in the soil. In addition, a livestock operation's reliance on purchased feed for the majority of feed nutrients is also an excellent indicator of a nutrient imbalance.

Strategies to Improve Nutrient Balance

Evaluating a livestock system's nutrient balance from a whole farm perspective provides a more complete picture of the driving forces behind nutrient-related environmental issues. The original sources of these nutrient inputs are clearly identified, which in turn suggest management strategies for reducing excess nutrient accumulations. The following four management strategies are likely to reduce nutrient imbalances:

(1) Efficient use of manure nutrients in crop production
(2) Alternative livestock feeding programs
(3) Marketing of manure nutrients
(4) Manure treatment

Efficient use of manure nutrients in crop production. By accurately crediting manure nutrients in a cropping program, the purchases of commercial fertilizer can be reduced or eliminated and the risk to the environment reduced. This practice is especially important to livestock operations with significant crop production and substantial nutrient inputs as commercial fertilizers. It may offer greater benefit for nitrogen-related issues due to common use of commercial nitrogen fertilizers as insurance on manure applied fields.

Alternative livestock feeding programs. Opportunities are available for reducing both nitrogen and phosphorus inputs by alternative livestock feeding programs. Specific management practices for reducing nutrient inputs as feeds will be discussed in a later section.

In addition to changes in feed rations, some additional options that may reduce purchased feed nutrient inputs include (1) alternative crops or crop rotations that allow a greater on-farm production of livestock protein and phosphorus requirements and (2) harvesting and storage practices that improve the quality of animal feed and reduce losses.

Marketing of manure nutrients. Marketing of manure creates an additional managed output, similar to the sale of crops or livestock products. Manure may be marketed in raw forms, however, often processes such as composting can create value added products for sale.

Manure treatment. In some situations, it may be necessary for animal production systems to consider manure treatment technologies similar to municipal and industrial waste treatment systems. Many manure treatment systems focus on disposal of nutrients with modest environmental impact. For example, treatment systems commonly dispose of wastewater nitrogen as nitrogen gas (no environmental impact) or ammonia (some environmental impact). This is a preferable alternative to nitrogen losses to surface or ground water. Other treatment systems enhance the value of manure (e.g., solids separation or odor stabilization) to allow alternative uses of the nutrients. Complementary manure treatment and manure marketing strategies can contribute to improved nutrient balance. For example, some producers are successfully combining composting (for odor control and volume reduction) with marketing of manure to crop farms and urban clients.

A single strategy will likely not fit all situations. For systems with sufficient land base for utilization of manure nutrients, a strategy that utilizes manure nutrients effectively may be most appropriate. This strategy should focus on preventing manure nutrient losses and reducing commercial fertilizer inputs as a means of achieving a nutrient balance and gaining the greatest benefit from manure. Little incentive exists for animal production facilities with sufficient land to reduce nutrient excretion by changing diets or marketing manure to off-farm customers. Alternative feeding programs to reduce phosphorus in manure may better match the ratio of manure nitrogen to phosphorus with crop needs.

When the land base becomes insufficient for utilizing the nutrients in manure, livestock dietary options for reducing manure nutrients may be an important strategy for attaining a nutrient balance. If neighboring crop farms or other nutrient users are in the vicinity of concentrated livestock operations, manure treatment and marketing of manure nutrients to off-farm customers may also be an important alternative. If nutrient uses do not exist, manure treatment options that benignly dispose of nutrients may be an important option. These alternatives will be discussed in greater detail in later lessons.

Comprehensive Nutrient Management Planning

Recently, the concept of Comprehensive Nutrient Management Planning (CNMP) was introduced by the U.S. Environmental Protection Agency (EPA) and U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). Nutrient management was chosen as the essential regulatory element. This is partially due to the fact the nutrients create most of the water quality problems but also because the methods for controlling nutrient losses will also reduce the loss of other contaminants such as pathogens and organic matter. It is anticipated that the CNMP will serve as the cornerstone of environmental plans assembled by animal feeding operations to address federal and state regulations.

A CNMP performs several basic functions. Figure 4 illustrates one state's CNMP framework designed to perform these key functions. Some critical functions of a CNMP follow.

- A CNMP should serve as the environmental "operating plan" for a livestock or poultry operation. It should detail the management practices for minimizing the impact of nutrients and manure on soil, water, and air resources. The producer should be intimately familiar with this "operating plan" and use it to guide management decisions and convey desired outcomes to all participants in an animal operation (owner, manager, employees, and advisors). This same plan should also convey to appropriate regulatory agencies the management strategies employed.
- A CNMP should carefully analyze nutrient issues from a (1) "whole farm" perspective, assessing concentration of nutrients within the farm (comparison of sources and quantities arriving on-farm and exported from the farm), as well as (2) the "individual component" perspective such as a crop nutrient balance or animal feeding program analysis. Historically, only the crop nutrient management component was considered in most environmental plans.
- A CNMP should integrate nutrient management planning with other environmental considerations such as soil conservation and odor management. Many proposed BMPs can positively affect some resources (e.g., manure incorporation can reduce odor concerns) while damaging other resources (e.g., manure incorporation can increase soil erosion). Balancing the protection of water, soil, and air resources should be the objective of a successful CNMP.
- A CNMP should establish a record-keeping system that will document the degree implementation and success of the proposed management practices and identify future changes to improve the plan.

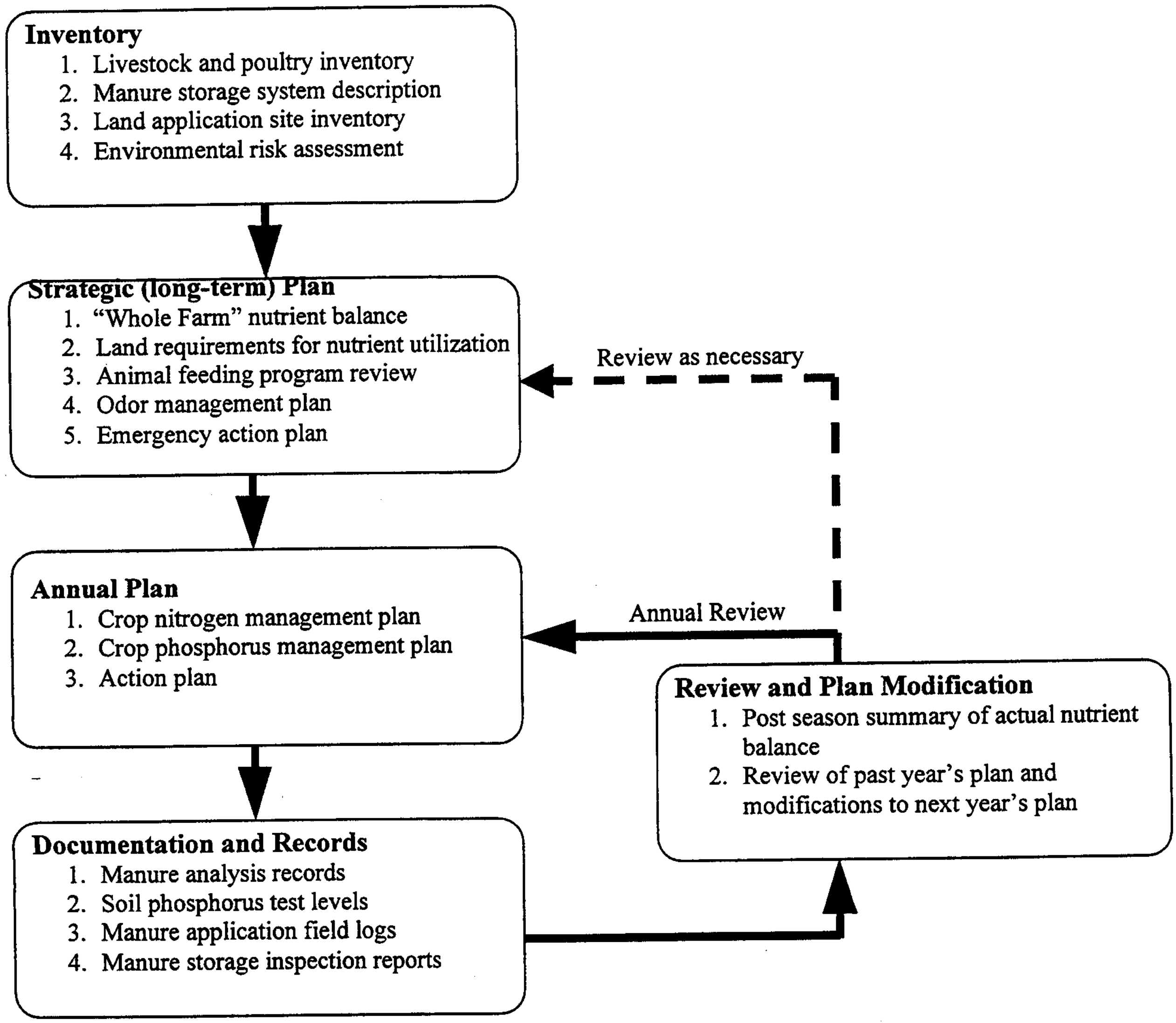


Figure 4. A conceptual framework for a CNMP. This CNMP organizes components according to a chronological order that a producer would follow in the CNMP's development and implementation.

Currently EPA draft guidelines for CNMP provide some early indications of the key issues to be addressed (Table 2). In addition, the NRCS has a Field Office Technical Guide and Standards that state that the objective of a CNMP is to combine management activities and conservation practices into a system that, when implemented, will minimize the adverse impacts of animal feeding operations on water quality. In Georgia, CNMP's are required on animal feeding operations with more than 300 animal units. A task force requested by the Environmental Protection Division and working with the NRCS in Georgia has recently completed a document outlining the components necessary in Georgia (Attached to the end of this chapter). In Georgia, a CNMP must contain the following information:

- Maps containing information such as property lines, land use, field boundaries, surface water, well locations, and buffers

- manure nutrients produced from either site specific data or book values
- nitrogen available for land application on an annual basis
- details about the land application system such as the system type, frequency of irrigation, crops, and Best Management Practices used
- nutrient balance (the amount of nutrients generated on the farm versus the amount of nutrients that can be used by crops on the farm)
- a mortality management plan for typical annual mortalities and catastrophic mortalities.
- a list of the records kept on the farm
- an emergency response plan
- a closure plan

Table 2. Summary of issues addressed by a CNMP as initially defined by EPA's Guidance Manual and Example NPDES Permit for Concentrated Animal Feeding Operations (CAFOs)[1].

Planning components of CNMP	Issues addressed
A manure handling and storage plan	(1) Diversion of clean water, (2) prevention of leakage, (3) adequate storage, (4) manure treatment, and (5) management of mortality
Land application plan	(1) Proper nutrient application rates to achieve a crop nutrient balance and (2) Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater.
Recordkeeping	Manure production, utilization, and export to off-farm users.
Other utilization options plan	Alternative safe manure utilization strategies such as sale of manure, treatment technologies, or energy generation.
Feed management plan	Alternative feed programs to minimize the nutrients in manure.

[1]Reference is available from http://www.epa.gov/owm/afoguide.htm.

CNMPs must be developed by Certified Planners. The Georgia Department of Agriculture will certify planners and maintain a list of certified individuals. The certified planners will include NRCS personnel, county agents, certified crop advisors, and other professionals who have attended the CNMP training and demonstrated they can develop an acceptable CNMP. Depending on the size of your operation, these plans can be complex. While the plans must be reviewed by a certified specialist, often you can save time or money by developing as much of it as possible on your own. There are resources to help you develop your plan. You can obtain assistance from your county extension agent, NRCS personnel, and from various consultants. There are also various extension publications that can help. Many of these publications and other tools are available on the University of Georgia AWARE website.

It is important to note that a CNMP is different from a simple nutrient budget for a field. It looks at the entire farm and serves as both a planning and documentation tool. While plans that do not include all components are still excellent tools, we must recognize that regulatory agencies will be expecting more comprehensive plans as outlined in this document.

Georgia Regulations

The past several years have brought many changes in the way animal feeding operations are regulated in Georgia. These changes are largely driven by an increasing focus on agriculture as a source of non-point source pollution. Since the U.S. Clean Water Act was passed in 1970, we have put a tremendous amount of resources into cleaning up point source pollution from municipalities and industries through the National Pollution Discharge Elimination Permit (NPDES) system. Large confined animal feeding operations (CAFOs) are regulated under the NPDES system. Because the program has been successful in reducing much of the nation's point source pollution, attention has now turned to reducing pollution from non-point sources such as urban stormwater runoff and agricultural runoff.

As part of the focus on agricultural sources of pollution, the United States Environmental Protection Agency (USEPA) and the United States Department of Agriculture (USDA) have developed a Unified National Strategy for Animal Feeding Operations. An Animal Feeding Operation (AFO) is defined as an operation that confines animals for feeding for 45 days or more during a year in an area that does not support vegetation. At this time pastures are not considered part of an AFO. The unified strategy focuses on using Comprehensive Nutrient Management Plans to reduce the risk of excess nitrogen and phosphorus entering our surface and ground waters. The strategy also includes a plan to revise the regulations for CAFOs under the NPDES system. Draft proposals of these revisions as well as comments from many groups around the country are available on the AWARE webpage.

The national focus on animal feeding operations (AFOs) increased pressure for Georgia to develop regulations for these operations. In Georgia, the NPDES program is administered by the Georgia Department of Natural Resources, Environmental Protection Division (EPD) and the state regulations must be at least as stringent as the federal regulations. In 1999, the Georgia Department of Natural Resources proposed new regulations for the swine industry. These rules were finalized in April of 2000. Then in December of 2000, new rules and regulations were proposed for non-swine animal feeding operations. These regulations were approved in January of 2001, and only apply to operations with liquid manure handling systems. Currently, the Department of Natural Resources in considering changes to the swine regulations to bring them more in line with the non-swine regulations. Both the swine and non-swine regulations are amendments to Georgia's Rules for Water Quality Control, Chapter 391-3-6. The complete non-swine regulations as well as the proposed swine regulations are available in the appendix.

The federal and Georgia approach to regulating AFOs are designed to target the largest operations on the assumption that larger operations pose a greater pollution "risk". Consequently, operations are regulated according to the number of "animal units". An animal unit (A.U.) is the method that USEPA uses to standardize the regulations across animal species. Different regulations apply for AFOs with 300 A.U. or less, 301-1,000 A.U., 1,001-3,000 A.U. and more than 3,000 A.U. Table 1 gives the number of animals of different species in these categories. An important thing to remember is fact two or more operations under common ownership are counted as a single farm if they adjoin each other (are contiguous) or if they use a common area system for manure treatment or utilization.

Table 1. Animal unit equivalents for different species.

Animal Type	300 A.U.	1,000 A.U.	3,000 A.U.
Beef cattle	300	1,000	3,000
Dairy cattle (milked or dry)	200	700	2,100
Horses	150	500	1,500
Swine (greater than 55 lbs)	750	2,500	7,500
Laying Hens or Broilers*	9,000	30,000	90,000

* Only if liquid manure handling system is used

Although small operations (<300 A.U.) are not subject to these state regulations, they are subject to the Clean Water Act and the Georgia Water Quality and Control Act. They are not allowed to have discharge to surface waters and should use nutrient management planning. Remember, if there is evidence of pollution, even a small operation can be designated a CAFO by EPD, and would be subject to the Georgia animal waste regulations.

There are several things common to the swine and non-swine regulations. Both regulations focus on the operations developing and following a comprehensive nutrient management plan (CNMP) and having a Certified Operator. Smaller operations (301 to 1,000 A.U.) have to apply for a Land Application

System Permit (LAS) and larger operations have to obtain the more detailed NPDES permit. Both these permits must be obtained from EPD. A brief summary of the regulations follows.

Swine Feeding Operation Permit Requirements

Some of the important regulations and dates that an existing swine producer needs to be aware of are:

Operations with 750 to 2,500 head that are more than 55 lbs:
- ✓ submit registration form by October 31, 2000
- ✓ submit CNMP by October 31, 2001
- ✓ train and certify an operator by October 31, 2001
- ✓ implement CNMP by October 31, 2002.

Registration forms and NPDES permit forms are located in the appendix or available from EPD. The NPDES forms (Form 1 and Form 2B) are also available from the USEPA website - http://www.epa.gov/owm/npdes.htm#forms.

Requirements for existing swine operations with more than 2,500 head that are 55 lbs or more include all of the requirements above and an individual NPDES permit. This permit was required by October 31, 2000. If you are in this category and did not apply for the individual NPDES permit, you should do so immediately. As mentioned before, the individual NPDES permits are more complicated to prepare. One major difference is that these operations will have to develop a groundwater monitoring plan for lagoons and sprayfields (although the sprayfield requirement is removed in the new proposed rule). These operations may need to obtain a consultant to prepare the individual NPDES. Requirements for new operations are more stringent than existing operations and the requirements for operations above 7,500 head are much more complex. The swine regulations are summarized in Tables 4a and 4b.

Non-Swine Feeding Operations

The non-swine regulations are similar to the swine regulations. Important requirements for existing operations are:

Operations with 301 - 1,000 A.U.
- ✓ apply for LAS permit by October 31, 2001
- ✓ submit CNMP by October 31, 2002
- ✓ implement CNMP by October 31, 2003
- ✓ train and certify an operator by October 31, 2002

Operations greater than 1,000 A.U.
- ✓ meet the requirements for smaller operations
- ✓ apply for NPDES permit that includes a public notification
- ✓ install at least one downgradient well for each lagoon
- ✓ monitor effluent and wells semi-annually
- ✓ submit documentation of lagoon closure when it occurs

Again, requirements for new operations are more stringent. In addition to the above requirements new operations must have waste handling and storage facilities that meet Natural Resources Conservation Service (NRCS) design criteria, cannot locate in the 100-year flood plain, must maintain two feet of freeboard in the lagoon, must maintain buffers in the land application area and must meet all requirements and be approved before expansion or start up. The non-swine regulations are summarized in Table 5.

Certified Operators

In addition to the CNMPs, all operations greater than 300 A.U. must have Certified Operators. A Certified Operator must attend training and pass an exam. They must also obtain 4 hrs. of continuing education every two years. The Georgia Department of Agriculture oversees the training, certification and continuing education requirements. If you attend regular educational activities, consult the organizers about contacting the Department of Agriculture to obtain continuing education for these activities.

The new regulations require changes in the way AFOs do business. The focus on management of nutrients can improve profitability by better use of nutrients produced on the farms and reduced need for fertilizer purchase. There may also be opportunities for composting and selling manures for off-farm uses. Although the new regulations require more recordkeeping, the records may help improve farm management and productivity. While these regulations may appear complex, they are designed to protect both the farmer and the environment. Compliance with these regulations will provide the farmer documentation that they are making a reasonable effort to operate their farm in a safe and environmentally sound manner.

SUMMARY OF ESSENTIAL INFORMATION

Environmental Stewardship and Regulations

Manure can be a benefit or a liability. It can fertilize and build soils or pollute waters and adversely impact health. The choices and management decisions that a producer makes determine which it is.

According to the Environmental Protection Agency, agriculture is the leading source of water quality impairments in rivers and streams.

Point source discharges of water or waste are those that come from a known source such as a ditch or pipe. Non-point source discharges are driven by rainfall and usually come from runoff over the land surface. Most agricultural operations and all swine housing and manure storage facilities in Georgia are subject to the "No Discharge" standard. This means that there can not be any direct point source discharges to waters of the state or nation and that non-point source discharges from the land application areas need to be minimized. It is nearly impossible to prevent all non-point source pollution as runoff and soil erosion are natural processes that occur on all landscapes.

Some stewardship principles include no discharge of pollutants, nutrient planning for land application, compliance with all regulations, consideration for environmental issues before expansion, and being a good neighbor.

Nitrogen, phosphorus, pathogens, and organic matter are the four primary contaminants that impact water quality.

Nutrients, such as nitrogen and phosphorus, are essential for plant growth and make manure a good fertilizer. When nutrients reach rivers and lakes, they present environmental risks and can cause algal blooms, fish kills, and eutrophication. Nitrogen moves with water more easily than phosphorus and excess nitrates from nitrogen can cause health problems in animals and people.

Pathogens are disease causing organisms. Manure can contain many pathogens. These organisms can present serious human health hazards but they usually can not survive long periods of time in lagoons or on land surfaces. Animal housing and manure storage should therefore be located away from surface water and wells to prevent transfer.

A Comprehensive Nutrient Management Plan (CNMP) is a strategy for making wise use of nutrients to enhance farm profits and protect water quality. It is an excellent management tool for insuring that nutrients from a livestock operation do not impair water quality.

CNMP's include several components such as maps of your operation, soil and manure analysis, calculations of the nutrients needed on each field and the nutrients available in manure resources, a balance for the farm with suggestions for off-farm uses if excess nutrients are available, manure storage and handling strategies, BMP's and plans for land application, an emergency response plan, a mortality management plan, and some sort of record keeping system.

CNMP's are living documents. They must be updated regularly and the owner/operator needs to understand all components of the plan.

A CNMP is NOT a fertilizer recommendation for a single field. It must be COMPREHENSIVE and look at how much manure is generated on the farm and where it will be used. Examples of nutrient inputs to a farm include feed, animals, fertilizer, legumes, and irrigation. Outputs can include animals, crops, and manure. Ideally, these should be equal but often the inputs far exceed the outputs. This imbalance causes problems such a losses to the environment and elevated soil nutrient levels.

Strategies for improving the nutrient balance include 1) more efficient use of manure nutrients in crop production, 2) changing the livestock feeding program, 3) marketing the manure off the farm, and 4) changing the manure treatment method.

CNMP's must be approved by certified planners. The University of Georgia Cooperative Extension Service, the USDA Natural Resources Conservation Service, Certified Crop Advisors, professional engineers, and other private consultants should be able to assist producers in developing CNMP's.

It is important to review and know the summary of Georgia regulations. Pay particular attention to size classifications, agencies involved, and major requirements. Remember, all agricultural operations, regardless of size, are subject to the Clean Water Act and can not contaminate waters of the State or Nation.

Nutrient Management for Georgia Agriculture

Developing a Comprehensive Nutrient Management Plan

Prepared by the Nutrient Management Task Force • Cooperative Extension Service • The University of Georgia College of Agricultural and Environmental Sciences

What is a Comprehensive Nutrient Management Plan?

A Comprehensive Nutrient Management Plan (CNMP) is a strategy for making wise use of plant nutrients to enhance farm profits while protecting water resources. It is a plan that looks at every part of your farming operation and helps you find better ways to use manures, fertilizers and other nutrient sources. Successful nutrient management requires thorough planning and recognizes that every farm is different. The type of farming you do and the lay of your land will affect your CNMP. For example, CNMPs on farms that do not have animals will not require as much detail as those that do. The best CNMP is one that is matched to the farming operation and the needs of the person implementing the plan—the Georgia farmer!

Who is Required to Have CNMPs?

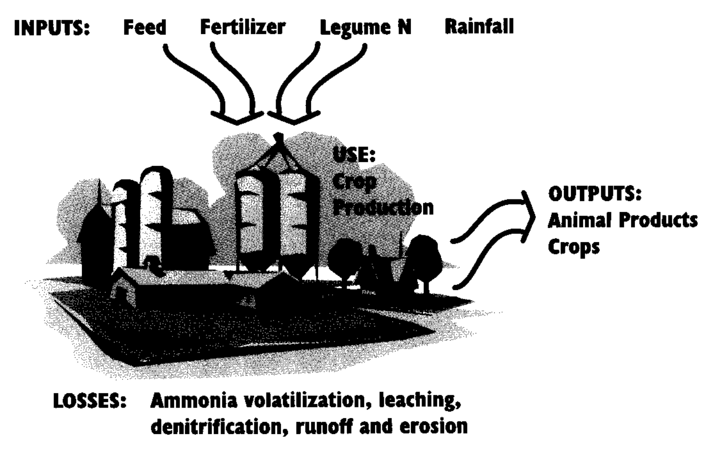
The United States Environmental Protection Agency and the United States Department of Agriculture have recently released a Unified National Strategy for managing animal feeding operations. This strategy sets a national goal for all animal feeding operations to have CNMPs. In Georgia, any animal feeding operation that receives a permit through the Georgia Environmental Protection Division is required to have a CNMP.

Other producers who are not required to have a permit are being encouraged to voluntarily adopt CNMPs. Many organizations such as the Georgia Poultry Federation and the Georgia Pork Producers have established initiatives to assist producers to better manage nutrients on the farm.

What Are the Parts of a Successful CNMP?

A Comprehensive Nutrient Management Plan looks at how nutrients are used and managed throughout the farm. It is more than a nutrient management plan that only looks at nutrient supply and needs for a particular field. Nutrients are brought to the farm through feeds, fertilizers, animal manures and other off-farm inputs. These inputs are used, and some are recycled by plants and animals on the farm. Nutrients leave the farm in harvested crops and animal products. These are nutrient outputs. Ideally, nutrient inputs and outputs should be roughly the same. When nutrient inputs to the farm greatly exceed nutrient outputs from the farm, the risk of nutrient losses to groundwater and surface water is greater. When you check nutrient inputs against nutrient outputs, you are creating a mass balance. This nutrient mass balance is an important part of a CNMP and important to understand for your farming operation.

Another important part of a successful CNMP is best management practices (BMPs). BMPs, such as soil testing and manure analysis, help you select the right nutrient rate and application strategy so that crops use nutrients efficiently. This not only reduces nutrient losses and protects the environment but also increases farm profitability. BMPs may also include managing the farm to reduce soil erosion and improve soil tilth through conservation tillage, planting cover crops to catch excess nutrients, or using filter strips and buffers to protect water quality. Preventative maintenance, record keeping, mortality management and emergency response plans must also be included in a CNMP for livestock and poultry operations.



THE BASIC STEPS

CNMPs consist of six major parts: evaluation of nutrient needs, inventory of nutrient supply, determination of nutrient balance, mortality management, preventative maintenance and inspection, and an emergency response plan. Not all farms will require all six parts. For example, farms without livestock or poultry may not need sections on mortality management or emergency response plans.

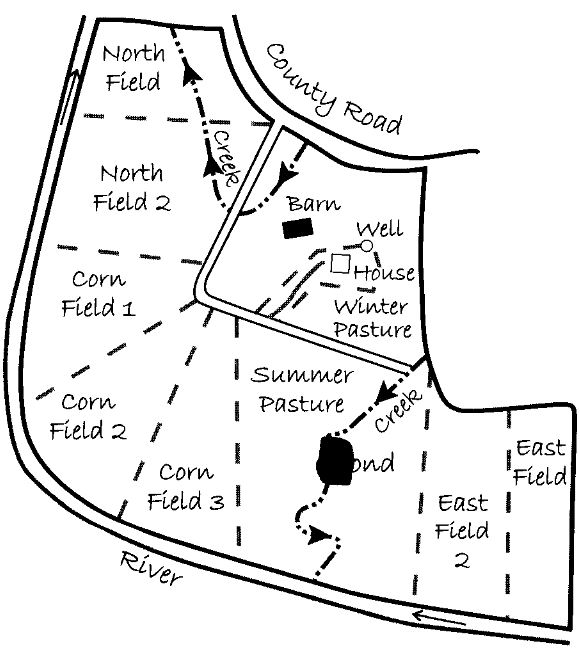
Evaluation of Nutrient Needs

Maps and Field Information

You will need a detailed map of your farm. The map should include the following:

- farm property lines,
- your fields with the field identification,
- the location of all surface waters such as streams, rivers, ponds or lakes,
- arrows showing the direction that streams or rivers flow, and
- a soils map, if available.

This map will serve as the basis for the entire plan, so each field should have a unique identification. In addition to the map, prepare a list of the crops to be grown in each field with a realistic yield goal for each crop. Most of this information is available at your local USDA Farm Service Center.

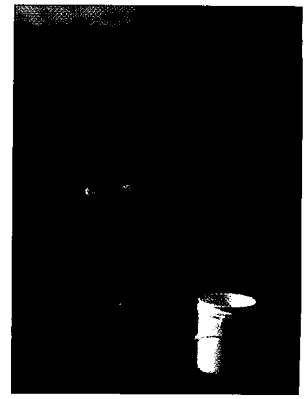


Locate Critical Areas

Certain areas on your farm such as streams and rivers, wellheads, and lakes or ponds are sensitive to nutrient overload. You should create zones around these areas on your map where nutrient use will be reduced or eliminated. By buffering these areas, water quality problems may be decreased. Areas such as roads, off-site dwellings and areas of public gatherings should also be noted on your map. Your plan may want to limit the use of manures near these types of areas to reduce odor complaints.

Soil Testing

Complete and accurate soil tests are important for a successful nutrient management plan. You will need annual soil tests to determine how much nutrient addition is needed. The needed nutrients can be supplied from commercial fertilizer and/or organic sources. Be sure to take representative soil samples and have them tested by a reputable laboratory familiar with Georgia soils and crop production. Your county Extension agent can help you submit samples to the University of Georgia Extension Soil, Plant and Water Laboratory.



Determine Nutrients Needed for Each Field

Once you have set realistic yield goals and you have your soil test results, you can determine the nutrients that your crops will need. The amount of nutrients needed should be based on your local growing conditions. At a minimum, the amounts of nitrogen, phosphorus and potassium should be listed in the plan for each field. Most soil and plant analysis labs will give you recommended application rates based on the soil test results. Your county Extension agent can also help you with this.

Inventory of Nutrient Supply

Many of the nutrients needed to grow your crops are already present on your farm in the soil, in animal manures, or in crop residues. Knowing the amounts of nutrients already present in these sources is important so that you do not buy more nutrients than needed.

Determine the Quantity of Nutrients Available on Your Farm

Supply planning starts with an inventory of the nutrients produced on the farm. Animal manure is an important source of nutrients. The quantity of manure collected and stored, either dry or liquid should be determined. An inventory should also be performed of any other by-products available, such as: mortality compost, lagoon sludge (if lagoon cleaning is planned), crop residue nutrients or nitrogen from legumes. This information will allow you to balance your nutrient purchases with what is available on your farm for the realistic production level of the crops grown.

Nutrient Analysis

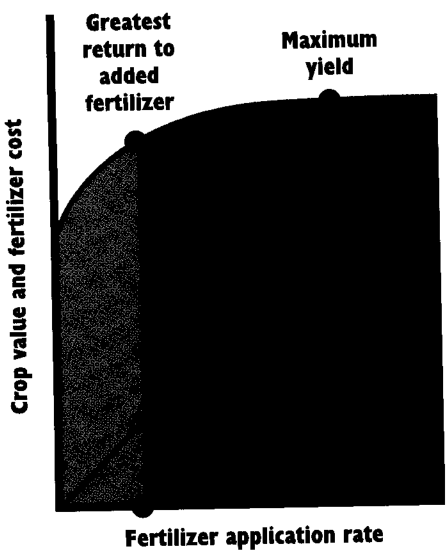
Animal manure and other organic products are not all the same as far as nutrient content is concerned. An analy-

sis of these products tells you the nutrient content so that you can match this with soil test recommendations and determine application rates. The lab results will help you determine how much of the nutrients in the manure will be available to your crops. The amount credited to the nutrient budget should be based on plant available nutrient levels, which may be substantially different from the total nutrient content. The county Extension office has information on manure and litter testing.

Determining Nutrient Balance

Balance Between Supply and Need

Once you have determined both the supply and need of nutrients for each of your fields, a critical aspect of CNMPs is balancing the two. This can be done in several ways. Currently, most CNMPs are developed based on nitrogen; however, other factors such as phosphorus or metals could control how much poultry litter or manure you can put out under certain conditions. A phosphorus index is currently being developed to help producers determine when nutrient management based on phosphorus would be advisable. If your crop acreage is small relative to the number of animals, the nutrient balance will also allow you to evaluate how much manure or litter you may need to move off your farm to avoid over-application of nutrients.

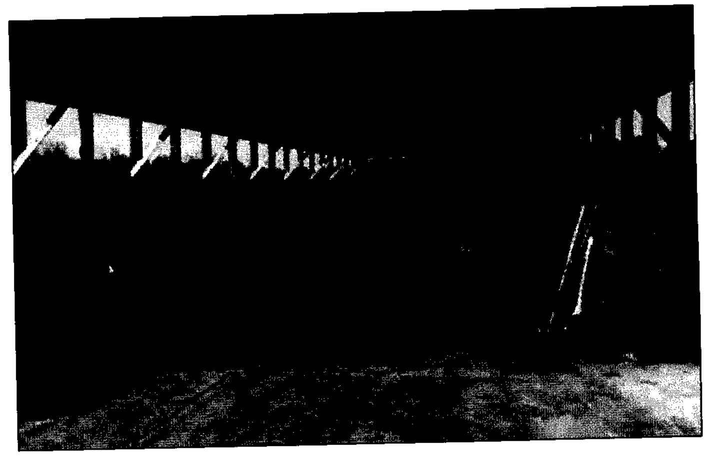


Can the Nutrient Supply on Your Farm Be Managed or Changed?

After evaluation of the nutrient supply on your farm and the nutrient needs of your crops, you may find that the balance of nutrients is not ideal. You may have more of one or more nutrients (usually phosphorus) than you need. Many management practices can change the nutrient balance. These include:

- changes in storage practices,
- adjustments of animal feeds,
- modification of treatment methods, and
- chemical amendments.

For example, you may be able to reduce nutrient losses in your manure treatment and/or storage system. Sometimes reducing nitrogen losses can make manures a better-balanced fertilizer for your crops. In addition, animal diets can sometimes be changed to reduce nutrient excretion in their manure. Enzymes can be added to the diet to reduce nutrients in the manure. Phytase is a supplemental enzyme that allows better use of the phosphorus already present in grains, so less phosphorus has to be added to the animal's diet.

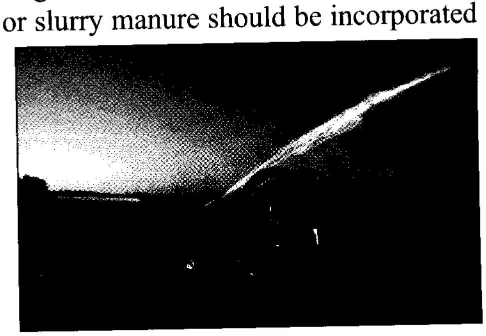


Manure Storage

Manure storage is critical. It effects both the quantity and quality of nutrients that will need to be land applied or exported from the farm. The storage structures and design capacities need to be identified as part of a CNMP. These structures also need to be managed to prevent nutrient losses and protect water quality. For example, clean water should always be diverted from barnyard and manure storage areas to reduce the potential for nutrients reaching ground or surface waters.

Manure Application to Fields

Manures should be applied near the time that crops need nutrients using calibrated spreaders or irrigation equipment. Solid or slurry manure should be incorporated into the soil when appropriate. Incorporation or mixing into the soil greatly reduces losses of nitrogen to the air and keeps more in the soil where it is needed. This reduces potential odor emissions. Slurry manure can also be injected into the soil so that incorporation is not required. Accurate records of application rates and times are also essential.



Identify Alternative Uses for Excess Manures

If your manure production exceeds nutrient needs on-farm, you should identify alternatives to land application of your manure. Potential options include selling manures to other farmers, composting manures for use by homeowners or possibly selling it to other off-farm users.

Mortality Management

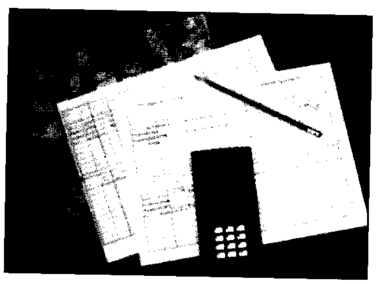
A complete CNMP should identify how livestock or poultry mortalities will be managed. This should include:

- estimated amounts of normal mortality,
- methods of disposal or utilization, and
- plans for dealing with catastrophic mortality events.

The Georgia Department of Agriculture regulates mortality disposal and all plans should meet its requirements. Approved methods of disposal include burial, composting, incineration and rendering.

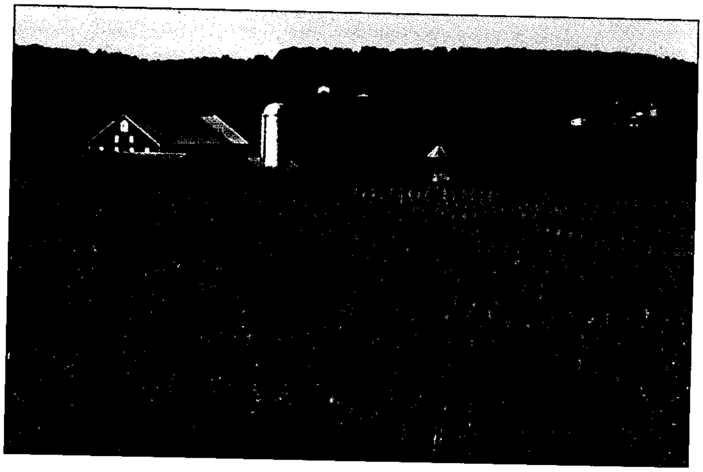
Preventative Maintenance and Inspections

Keeping good, detailed records that help you monitor your progress is essential to know if your CNMP is accomplishing the goals you have set. You should keep all results from soil, plant and manure tests, and examine how they change with time due to your management practices. Records should also be kept on crop yields, manure production, manure exports, nutrient application rates, timing and application methods. Keep detailed schedules and records on calibration of spraying and spreading equipment, maintenance of pumps and other machinery, and inspections and current capacities on manure storage facilities. When you have a major change in production, your plan should be updated to reflect these changes.



Emergency Response Plans

The final aspect of your plan should include the procedures to be followed in an emergency. This may include actions taken to contain or manage any unauthorized discharge of manure or wastewater, listing of the proper authorities to notify when certain events occur and any authorizations necessary to obtain essential equipment or access to neighboring properties during these events. It should also outline a plan for training new employees in these procedures.



Where Can You Obtain Information Needed for Your CNMP?

The University of Georgia Cooperative Extension Service, the USDA Natural Resources Conservation Service, the Georgia Department of Agriculture and Certified Crop Advisors, or other private consultants, should all be able to assist you in developing parts of a comprehensive nutrient management plan. In addition, computer software and publications will be available through your county Extension agent to aid you in the process.

A CNMP is a good tool to help you use your on and off farm resources more efficiently and prevent future problems. A successful CNMP will help you obtain the maximum profit while protecting the environment.

The University of Georgia and Ft. Valley State University, the U.S. Department of Agriculture and counties of the state cooperating. The Cooperative Extension Service, the University of Georgia College of Agricultural and Environmental Sciences offers educational programs, assistance and materials to all people without regard to race, color, national origin, age, sex or disability.

An Equal Opportunity Employer/Affirmative Action Organization Committed to a Diverse Work Force

Bulletin 1185

December 1999

Issued in furtherance of Cooperative Extension work, Acts of May 18 and June 30, 1914, The University of Georgia College of Agricultural and Environmental Sciences and the U.S. Department of Agriculture cooperating.

Gale A. Buchanan, Dean and Director

2

Maps and Critical Areas for CNMP's

Maps for Comprehensive Nutrient Management Plans

Julia W. Gaskin, Biological & Agricultural Engineering Dept., University of Georgia
Vernon Jones, USDA Natural Resources Conservation Service

Introduction

A comprehensive nutrient management plan (CNMP) is a planning tool for making wise use of plant nutrients while protecting water resources. The basis of a CNMP is an accurate map of your farm. The map or maps will help you identify areas suitable for land application of manures and areas that need protection or that may need special management due to environmental sensitivity. The maps will also help you evaluate your crop rotation and calculate acreage you have available for using animal manures. Although a CNMP evaluates the use of all sources of nutrients, this document will focus on preparing maps for the management of nutrients from organic sources such as manures.

Maps for CNMP should be on a known scale and include:

- farm property lines
- land use - cropland, pasture, forest, etc
- farm field boundaries with field identification
- surface water locations, including streams, rivers, ponds, ditches, and wetlands
- arrows showing the direction of stream or river water flow
- well locations
- buffers around sensitive areas
- any residences or public gathering areas
- North arrow
- date prepared
- "Prepared with assistance from (NAME)"
- road names or numbers
- name of county
- legend with map symbols
- BAR SCALE on the map

Making a Base Map

How do you go about getting this information? First is the "old-fashioned way".

You will need:

- several copies of the Farm Service Agency (FSA) maps of your farm
- a copy of the county soil survey map of your farm from Natural Resources Conservation Service (NRCS), formerly Soil Conservation Service (SCS)
- colored pencils
- a ruler
- a transparent dot grid or other method to determine acreage

Use the FSA map as your base map. Remember when maps are photocopied, the scale can change. You should use a bar scale to make sure your scale is accurate. Draw a 1-inch line

on a piece of paper and place it on the map before it is copied. Then measure the 1-inch line on the map copy to make sure it still measures one inch. If it does not, you will have to set up a ratio to determine the true scale of the map. An example of how to set up a ratio for a map follows. The original scale is 1 inch = 660 feet, and on the copy the 1-inch line measures 1.2 inches. The ratio looks like this: 1 in/1.2 in = 660 ft/ x ft.

You solve the ratio like this:

$$1x = 1.2(660)$$
$$x = 792 \text{ feet}$$

The new scale is 1 inch = 792 feet.

Because the FSA maps are aerial photographs, they will show land use and many surface water features, as well as roads with road names or numbers. It should show your property lines and field boundary lines. Your fields should be identified with a unique name or number and the acreage of each field shown. A sample map is shown in Figure 1. Review the map to make sure nothing has changed. If property lines or field lines have changed, make changes on the FSA map in black pencil.

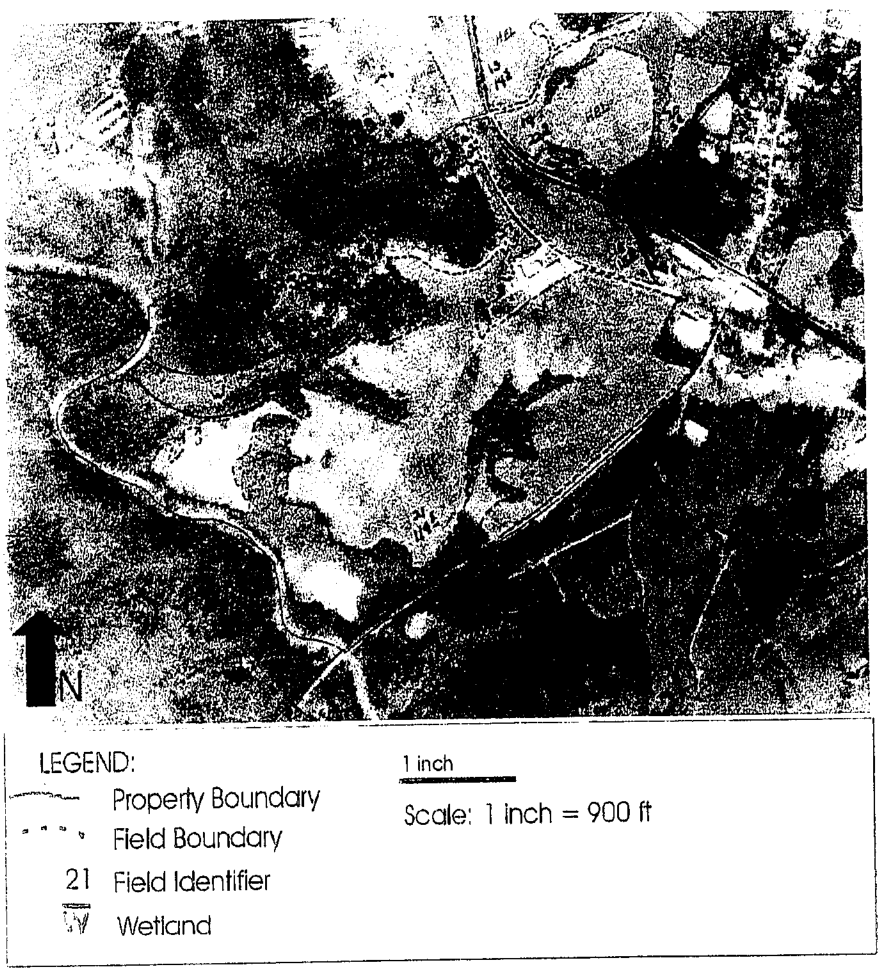
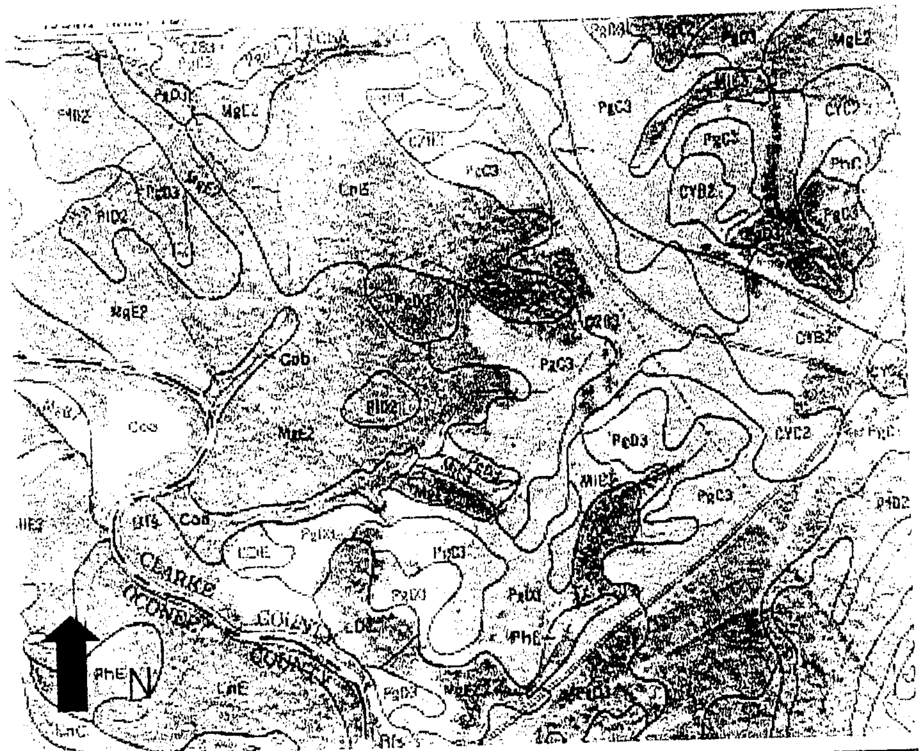


Figure 1. Sample of a base map from the Farm Service Agency

Take out the copy of the county soil survey map with your farm on it. Figure 2 shows the corresponding soils map for Figure 1. Locate your farm on the map. The soil survey map is NOT the same scale as the FSA map, but you should be able to use features such as roads, rivers, fields, etc to locate your property boundaries. The soils map will have streams marked on it in this symbol ~~~~ or this symbol ~~ ··· ~~. Use these markings, with your knowledge of your farm, to determine where streams are on the FSA map.



1 INCH

Scale: 1 INCH = 733 FT.

LEGEND:

·-·-·-·—	Stream
MG E2	Soil Map Unit

Figure 2. Corresponding soils map for Figure 1.

Using the symbols above or a solid blue line, mark the streams on the FSA map in blue pencil. Add arrows to the stream symbol to show the direction of stream flow. Outline other surface waterbodies such as ponds, rivers, and wetlands in blue. Your FSA map may already have wetlands marked on it. If it doesn't and you are unsure about whether an area on your farm is a wetland, contact the NRCS for a wetland determination. Finally, mark any wellhead locations in blue. Figure 3 shows the base FSA map with the water symbols added.

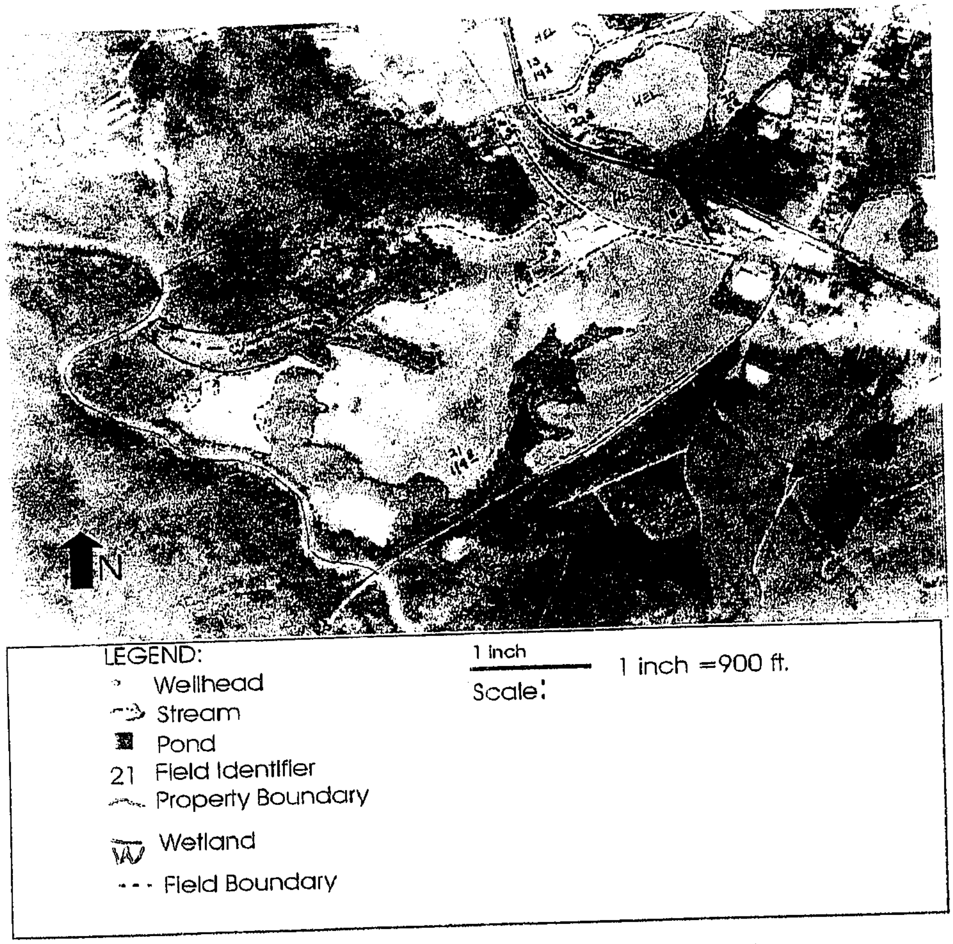


Figure 3. The FSA base map with water symbols added.

Suitable Areas - Site suitability for manure application is largely determined by the soils and topography, although you may want to consider how close a field is to public roads, public gathering areas or residences. The best sites for manure application are on level to gently sloping, deep, well-drained soils with some clay content. You should avoid:

Soils less than 24 inches to bedrock
Soils with water tables less than 36 inches below the soil surface
Slopes greater than 12 to 15%.

You should also be careful about irrigation with manure wastewater on deep sandy soils. Water moves very rapidly through these soils and they have a limited ability to hold nutrients.

You probably have a good idea where these types of soils occur on your farm, but you can obtain this soils information from the county soil survey. Your soils map will have symbols on it that indicates the type of soils you have. Look up the symbol in the Soil Legend to get the name of the soil and the range of slopes associated with that map unit. Then go to the Soil and Water Feature Table, where you can look up the water table depth and depth to bedrock for that map unit. Remember the county soil survey is on a large scale and maps the dominant soils on the site. This means that soils other than the one mapped can and most likely will exist in a given field. If you have questions about whether the soils on your farm have the above characteristics, contact the NRCS.

If you have fields or parts of fields that have the characteristics listed above, you may need to exclude them from manure or wastewater application. Mark these areas on your base map.

You should discuss these areas with NRCS or county extension personnel to determine if the need to be permanently excluded from your land application program or if they can be used seasonally or with special management.

You should keep the soils information you have developed with your CNMP. The information may prove useful if the CNMP needs to modified.

Buffering Sensitive Areas - Sensitive areas are things such as wellheads, streams, or wetlands that are sensitive to nutrient inputs. Buffers around wellheads will reduce the potential for groundwater contamination due to nutrients from manures, fertilizers or pesticides. Table 1 gives the distances required by law that you need to have separating wellheads from various potential contaminants. Table 2 gives recommendations for separation distances from potential contaminants.

Table 1. Minimum distances between wells and potential contaminants based on the Georgia Well Standards Act of 1985.

Distance from Well (feet)	Potential Contamination Source
10	Sewer line
50	Septic tank
100	Septic tank absorption field
150	Cesspool or Seepage pit
100	Animal or fowl enclosure

Table 2. Recommended separation distances from various potential contaminants.*

Distance from Well (feet)	Potential Contamination Source
150	Waste lagoon
50	Dead animal burial pits
100	Pesticide storage, mixing & loading facilties
100	Fertilizer storage
500	Petroleum tanks
250	Manure or chemical application

*Tyson, A. 1996.Improving Drinking Water Well Condition. Georgia Farm*A*Syst, Cooperative Extension Service Bulletin 1152-3.

Buffers around streams, rivers, ponds and wetlands reduce the chance these surface waters will become overloaded with nutrients. Most fresh waterbodies in Georgia are particularly sensitive to phosphorus. Phosphorus in runoff or in water moving through the soil into the surface water can cause excessive algae growth that creates problems for recreation and other uses. Table 3 gives some general guidelines for buffer widths. Effective buffers are highly site specific and depend on land use, slope, and vegetation. You should review any

proposed buffers with NRCS or county extension personnel. Governmental rules and regulations may require specific buffer widths and these take precedence over any recommended buffer widths.

Table 2. Guidelines for surface water buffers. Animal manures should not be applied within these buffers. Fertilizers should be used carefully.

Distance from Surface Waterbody *	*Feature*
At least 50 feet	Ponds, sinkholes, wetlands
At least 90 feet if buffer slope is less than15%	Streams, rivers
At least 120 feet if buffer slope is greater than 15%	Streams, rivers
At least 35 feet	Ditches

* Gaskin, J. and G. Harris, 1999. Nutrient Management Farm*A*Syst University of Georgia,Cooperative Extension Service Bulletin 1152-16

Calculating Acreage - Now that you have determined the buffers needed around these sensitive areas, you need to mark them on your FSA map, determine the acreage and subtract the acreage from the total acreage of the field. Make sure you know the correct scale for your FSA map. First measure the correct buffer distance with your ruler and outline the buffer area in green pencil (Figure 4). You may want to shade or otherwise mark the buffer area.

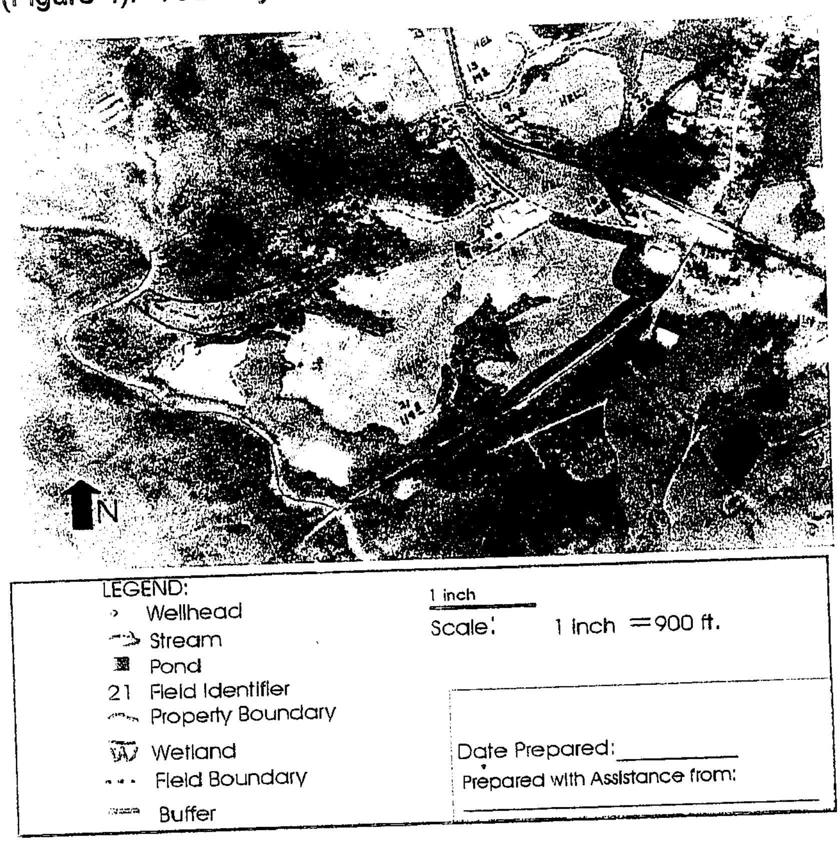


Figure 4. The FSA base map with buffers added. This map has all the information needed for a CNMP.

Now calculate the acreage in each field that is not useable for manure application due to the buffers, sensitive areas or unsuitable areas. Buffer areas can be calculated using a planimeter, measuring the area with a ruler, or a dot grid. A dot grid is a transparent piece of paper with a known number of dots per square inch. Place the dot grid over the buffer area and count the number of dots within the buffer. If a dots fall on the buffer line, include every other dots in your count for the buffer area. Divide the total number of dots by the number of dots per square inch to get the square inches of land in the buffer. Now find the scale of your map. Multiply the number of feet per inch by itself to get square feet per square inch. Then multiply the number of square inches from your dot grid by the square feet for your base map, convert to acres, and you're done. The example below may help you remember this procedure.

Find Field 21 on Figure 4. This field has buffers drawn around public roads, the property boundary and along a wetland area. The buffer along the public road is 150 feet, and those around streams, wetlands and the pond are 100 feet. Using a dot grid with 40 dots per square inch, we counted 19 dots within the buffer area. We divided the 19 dots by 40 dots per square inch to get 0.48 square inches. Our map in Figure 4 has a scale of 1 inch = 900 feet, which is equivalent to 810,000 square feet per square inch. Dividing 810,000 by 43,560 square feet, we get 19 acres per square inch. If we multiply 0.48 square inches by 19 acres per square inch, we find we have 9.1 acres in buffers. We have to subtract this 9.1 acres from the total field acreage of 119.8 acres to get the number of "spreadable" acres. Remember to subtract all the buffer areas or other areas unsuitable for manure application from the field acreage, so you have an good idea about how much land is available for use.

You may also want to limit your use of manures in areas close to houses or public gathering places, if there is a potential for odor complaints. These areas should also be marked on your map, and subtracted from your useable land acres. Note Fields 16 and 17 in Figure 4. These fields border a busy public road. If a 150 -foot buffers is used to reduce possibility of complaints, the useable area in the fields is too small to use. So these fields will not be included in the land to be used for manure application.

Computer Generated Maps

NRCS Toolkit - A second way to acquire the map information needed for a CNMP is to use the NRCS Toolkit. USDA Service Center Offices are equipped with computers and technology that can generate a similar map for you. A conservationist can come to your farm, and use an electronic aerial photo of the farm with the FSA property lines and field lines. You can work with the conservationist to add streams, as well as other water bodies, and locate buffers. This technology is in place in several district offices and should be available throughout the state in the near future. To read more about the NRCS Toolkit go to *http://www.ga.nrcs.usda.gov/ga/gapas/index.html*.

Figures 5, 6, and 7are examples of computer generated maps. Figure 5 is an electronic aerial photo with the farm boundaries (black line), field boundaries (red line), 150 foot setback around the property line (green line), 100-foot buffer around surface water and wetlands (light violet) well (small circle), streams and pond (blue) overlain on the photo. Figure 6 is the electronic version of a USGS topographic map with the same information as Figure 5 on it. Figure 7 is the base map (Figure 5) with electronic topographic information overlain. The computer will calculate the area of the fields, buffers and any other area that is desired. As more soil surveys are digitized, the soil map will be available for overlaying on the base aerial photo.

The maps labeled "Jon Doe" (Figure 8) and "Nutrient Mgt. Plan Map" (Figure 9)are examples of actual maps from nutrient management plans prepared using the NRCS Toolkit. Having the electronic maps permits revision or update with minimal time and effort. These maps show the basics for nutrient management plans. They include the property boundaries, field numbers, size and boundaries, the lagoon or holding pond, sensitive areas and buffering, setbacks required by the EPD rules, and SCALE. Please note that on the Jon Doe map (Figure 8) the 150-foot setback from the property line is continuous around the farm. This 150-foot setback could be placed only on fields that are going to be used for manure application similar to Figure 4 and Figure 5.

Online Maps - The Georgia Spatial Data Infrastructure web site has electronic maps of the state of Georgia. The internet (URL) address is: http://gis.state.ga.us/. These can also be used to make the base map for your CNMP. To locate the maps, click on the button labeled 'Clearinghouse'. Now click on the button labeled 'Online maps'. There are many choices of maps available on this page. The button labeled 'orthophotography viewer' contains the 1993 aerial photographs. Click on the Georgia map as close as possible to where your farm is located. You will be able to move around on the aerial photographs and locate your farm. You can then print out the aerial photograph or save it electronically. After you have obtained the aerial photograph of your farm, you can hand draw the property boundaries, streams , fields, etc. or use computer software to add the needed features.

Summary

You have now developed the basis for your CNMP. These maps are critical for conservation, planning land application of manures, and crop rotations. You should keep them as accurate as possible.

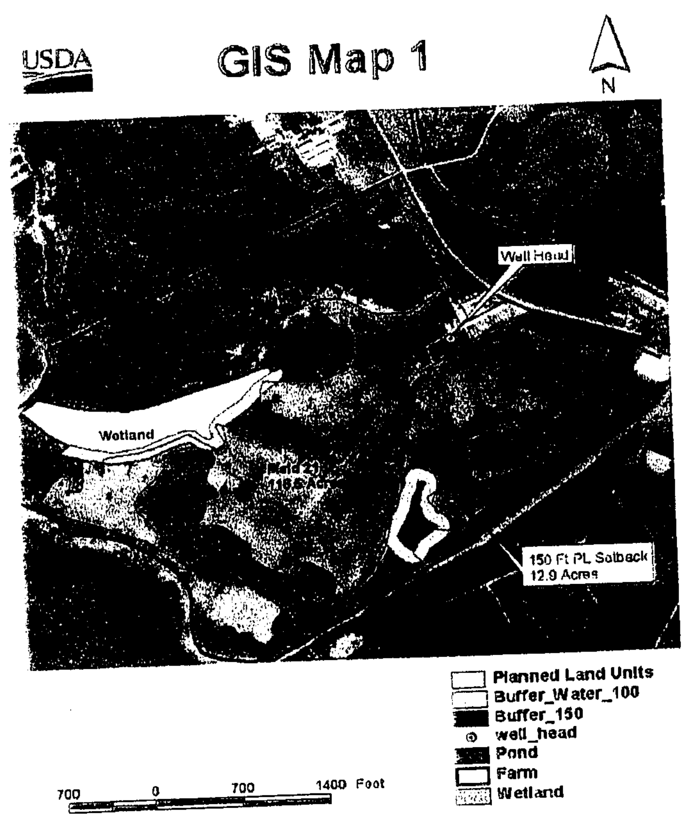


Figure 5. Electronic aerial photo used as a base map for a CNMP.

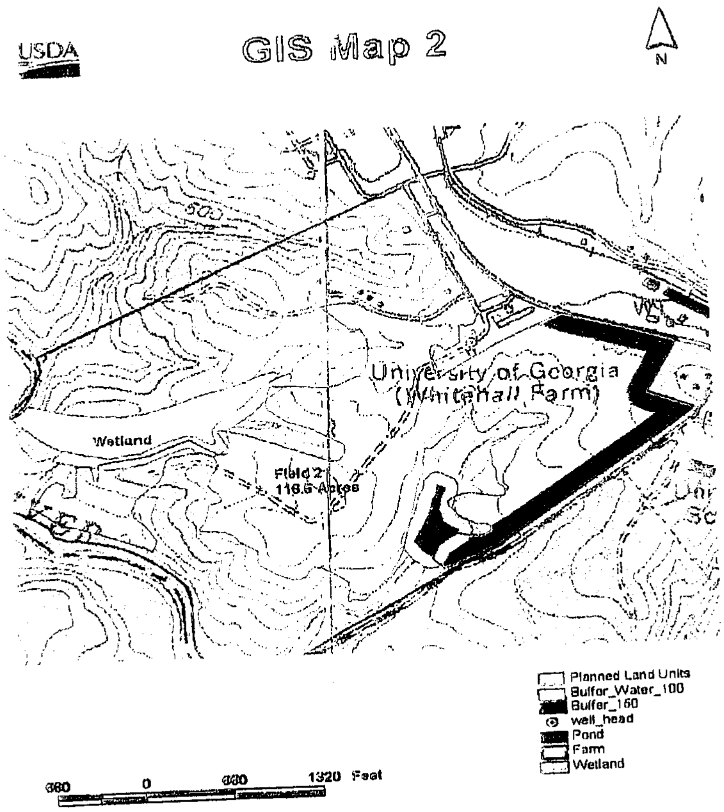


Figure 6. Electronic topographic map.

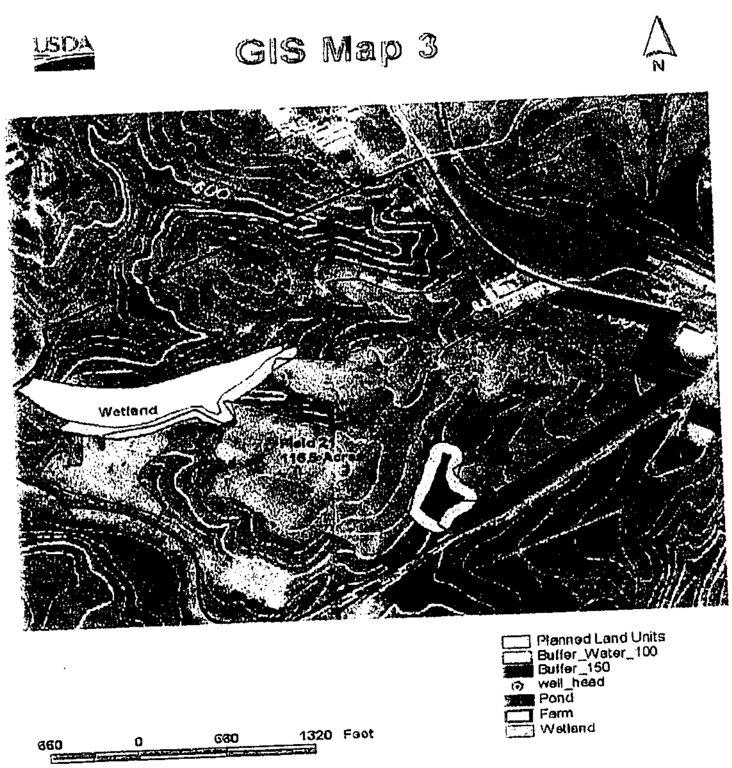


Figure 7. Electronic base map with topographic features overlain.

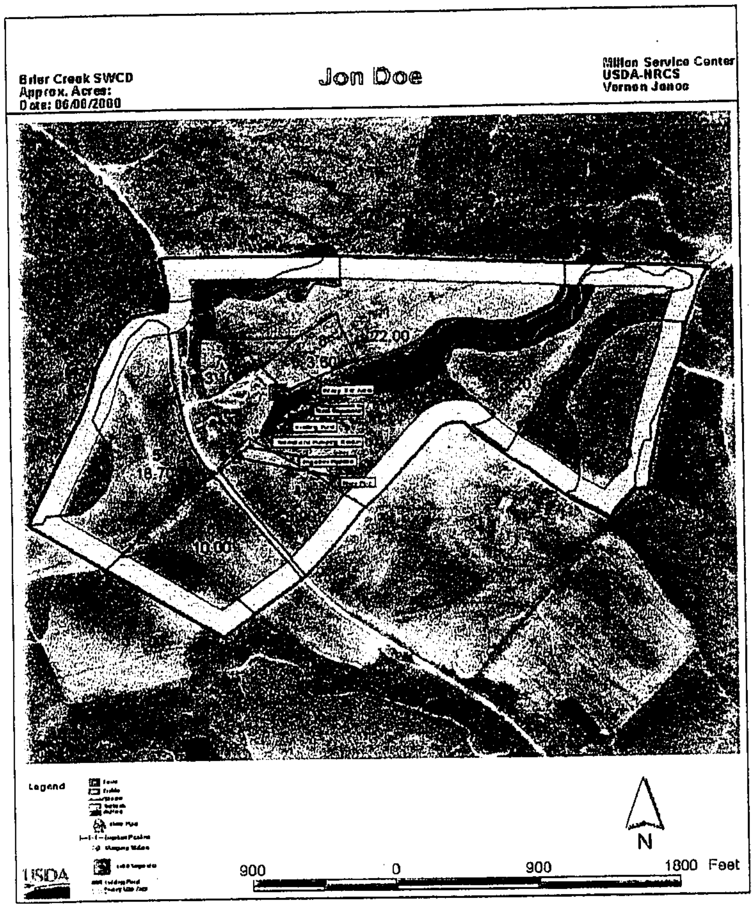


Figure 8. Example of CNMP map.

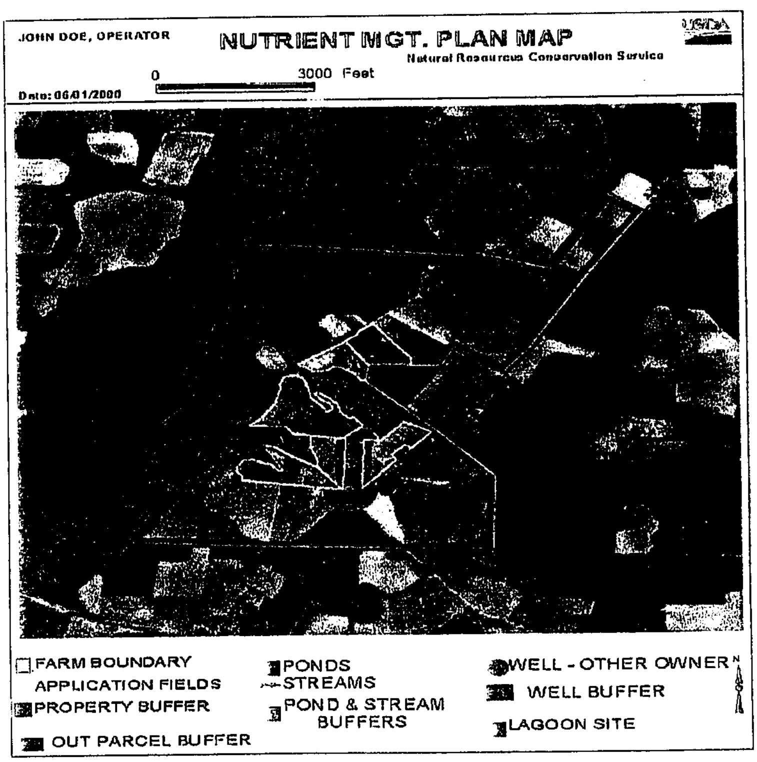
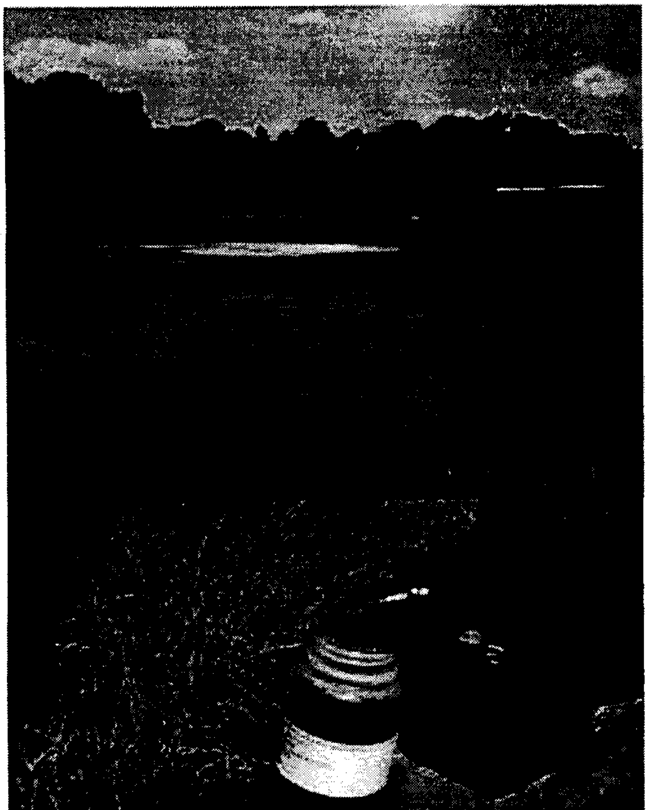
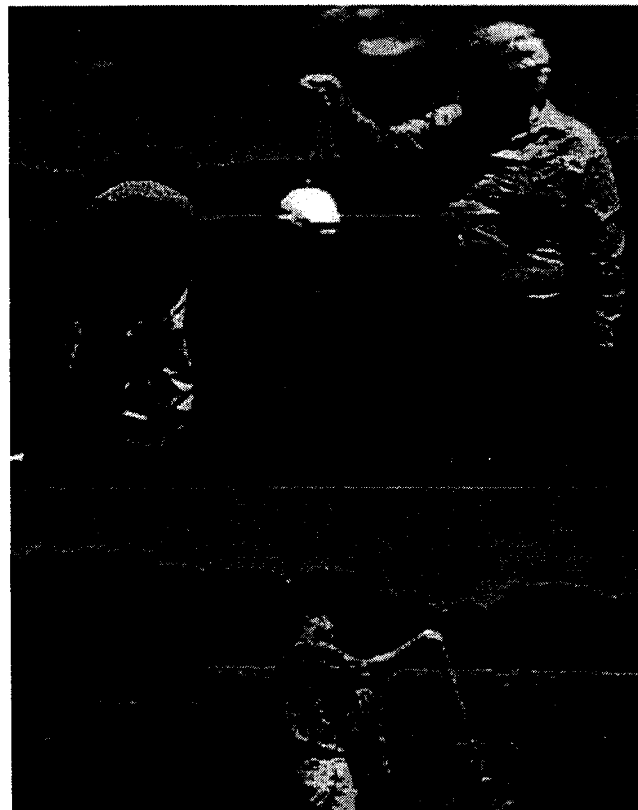


Figure 9. Example of CNMP map.

3

Soil, Manure and Monitoring Well Testing in Georgia

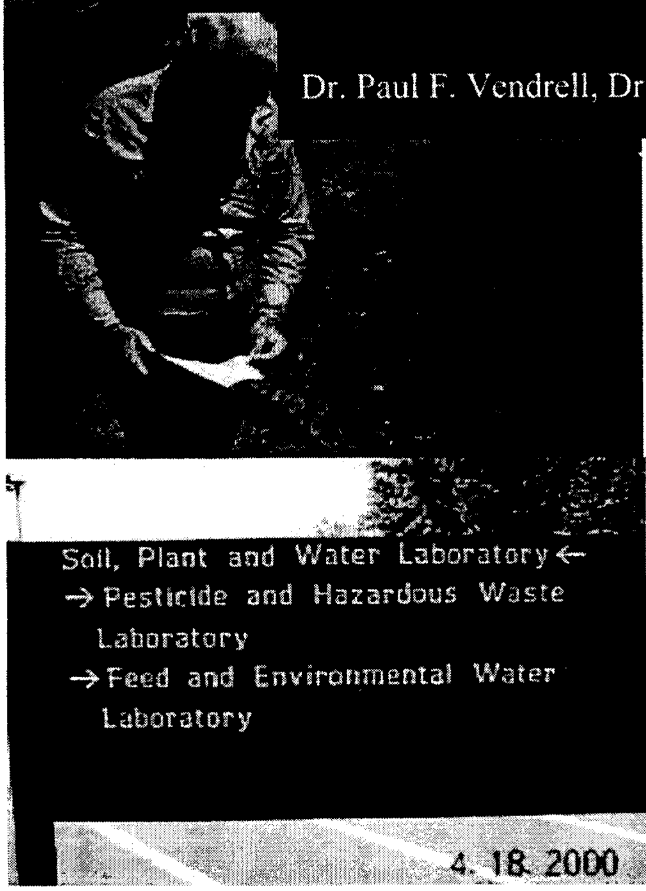




Soil, Manure, and Monitoring Well Testing in Georgia

by:

Dr. Paul F. Vendrell, Dr. Parshall B. Bush, and Dr. David E. Kissel



SOIL, MANURE, AND MONITORING WELL TESTING

Acknowledgements: This training lesson was modified and adapted in part from the materials prepared for Lesson 34 from the Livestock and Poultry Environmental Stewardship Curriculum Project by Karl Shaffer[1] and Ron Sheffield[1] and other material prepared by Owen Plank[2] and Wayne Jordan[3].

Outline

I. Introduction

II. Manure Testing
- A. Manure Sample Collection
  1. Liquid manure
     a. Lagoon effluent
     b. Liquid slurry
     c. Lagoon sludge
  2. Solid manure
     a. Stockpiled manure or litter
     b. Surface-scraped manure
     c. Composted manure
- B. Test to Request
  1. Basic UGA manure test package
  2. Additional test on liquid manure for CNMP
  3. Georgia regulations for testing lagoon effluent
- C. Manure Report

III. Soil Testing
- A. Soil Sample Collection
  1. When
  2. Where
  3. How
- B. Soil Test Parameters
- C. Soil Test Report

IV. Monitoring Well Testing
- A. Monitoring Well Location
- B. Monitoring Well Construction
- C. Groundwater Monitoring Requirement
- D. Sampling and Analysis
- E. Guidance Documents

V. Review Questions

[1] Shafer, K. and R. Sheffield, 2000, Lesson 34, Land application records and sampling, USDA/EPA National Curriculum Project, http://www.mwpshq.org/curriculum_project/currproj.htm .

[2] Plank, C. O., 2000, Soil testing, Leaflet 99,Cooperative Extension Service Publication, University of Georgia, College of Agriculture and Environmental Sciences, http://www.ces.uga.edu/pubcd/L99.htm .

[3] Jordan, C. W., 2000, Soil and manure sampling and analysis, Unpublished information, Agricultural and Environmental Services Laboratories, University of Georgia, Cooperative Extension Service, College of Agriculture and Environmental Sciences.

INTRODUCTION

The collection and analysis of soil, manure, and monitoring well water are addressed in this training. Soil and manure testing are needed to perform comprehensive nutrient management planning (CNMP). Utilization of manure or lagoon effluent within a CNMP requires soil and manure testing for measurement of plant available nutrients. Soil test reports give the level of available plant nutrients and provide recommendations for any additional lime and fertilizer nutrients needed to achieve optimum crop yields. Animal manure is a valuable resource and can be used to provide the additional soil nutrients prescribed in the soil test recommendations. Growers should not base application rates on laboratory test results from previous years because nutrient concentrations can change significantly, particularly when the manure has been exposed to the environment. For example, nutrient levels in a lagoon or storage pond can be greatly influenced by rainfall.

For regulatory purposes the lagoon effluent and water from the monitoring wells need to be sampled semiannually and tested. Total Kjeldahl nitrogen (TKN) and nitrate-nitrogen (NO_3-N) are required for the lagoon effluent. However, in order to use the lagoon effluent as a fertilizer source in nutrient management, additional testing for phosphorus, potassium, and micronutrients will be necessary. Monitoring wells require TKN and NO_3-N and possibly other primary drinking water parameters may be advisable.

Utilization of swine manure or lagoon effluent within a CNMP requires soil and manure testing. Soil test reports give the level of available plant nutrients and provide recommendations for any additional lime and fertilizer nutrients needed to achieve optimum crops yield. Animal manure is a valuable resource and can be used to provide the additional soil nutrients prescribed in the soil test recommendations. Growers should not base application rates on laboratory test results from previous years because nutrient concentrations can change significantly, particularly when the manure has been exposed to the environment. For example, nutrient levels in a lagoon or storage pond can be greatly influenced by rainfall.

Producers who fail to test each manure source before or just after land application are faced with a number of questions they simply may not be able to answer: Are they supplying plants with adequate nutrients? Are they building up excess nutrients that may ultimately move into surface water or groundwater? Are they applying heavy metals at levels that may be toxic to plants and permanently alter soil productivity?

MANURE TESTING

Manures can be quite variable in nutrient content. This variability may be due to different animal species, feed composition, bedding material, storage and handling as well as other factors. Testing at or near the time of application tells you the fertilizer value to make decisions about rates to apply. Some livestock producers are faced with nutrient management regulations that require manure testing. Also, if buying or selling litter/manure for fertilizer use, testing will help both buyer and seller establish the fertilizer value.

Manure Sample Collection

According to the Georgia Environmental Protection Division (EPD) "Animal Non-Swine Feeding Operation Permit Requirements", lagoon effluent is to be sampled semiannually. Preferably, the sample should be taken as near the application time as possible prior to the manure application. However, if it is urgent to pump down a full lagoon or storage pond, you should not wait until you can sample and obtain the results. You should sample the day of irrigation. The results can later be used to determine the nutrients applied to the fields and identify the need for additional nutrients to complete crop production.

Manures should be sampled and tested near the time of application because the nutrient content can change considerably over time, particularly if stockpiled and unprotected from the weather. Nitrogen (N) is the nutrient that is the most likely to be affected. The frequency for testing your manure will depend upon several factors, but, as noted above, lagoon effluent needs to be tested at least semiannually. The type of manure and overall management system will also be factors. Animal producers using lagoon manure storage systems should sample every time that the liquid or slurry will be pumped and applied to the land. Proper sampling is the key to reliable manure analysis. Although laboratory procedures are accurate, they have little value if the sample fails to represent the manure product. Manure samples submitted to a laboratory should represent the average composition of the material that will be applied to the field. Reliable samples typically consist of material collected from a number of locations. Precise sampling methods vary according to the type of manure. The laboratory,

County Extension Agent, or crop consultant should have specific instructions on sampling.

Liquid Manure

Liquid manure samples submitted for analysis should meet the following requirements:

- Place sample in a sealed, clean plastic container with about a 1-pint volume. Glass is not suitable because it is breakable and may contain contaminants.
- Leave at least 1 inch of air space in the plastic container to allow for expansion caused by the release of gas from the manure material.
- Refrigerate or freeze samples that cannot be shipped on the day they are collected. This will minimize chemical reactions and pressure buildup from gases.

Ideally, liquid manure should be sampled after it is thoroughly mixed. Because this is sometimes impractical, samples can also be taken in accordance with the suggestions that follow.

Lagoon effluent: Premixing the surface liquid in the lagoon is not needed, provided it is the only component that is being pumped. Growers with multistage systems should draw samples from the lagoon they intend to pump for crop irrigation.

Samples should be collected using a clean, plastic container similar to the one shown in Figure 1. One pint of material should be taken from at least eight sites around the lagoon and then mixed in the larger clean, plastic container. Effluent should be collected at least 6 feet from the edge of the lagoon at a depth of about a foot. Shallower samples from anaerobic lagoons may be less representative than deep samples because oxygen transfer near the surface sometimes alters the chemistry of the solution. Floating debris and scum should be avoided. One pint of the mixed material should be sent to the laboratory. Galvanized containers should never be used for collection, mixing, or storage due to the risk of contamination from metals like zinc in the container.

Liquid slurry: Manure slurries that are applied from a pit or storage pond should be mixed prior to sampling. If you agitate your pit or basin prior to sampling, a sampling device pictured in Figure 1 can be used. If you wish to sample a storage structure without

agitation, you must use a composite sampling device as shown in Figure 2. Manure should be collected from approximately eight areas around the pit or pond and mixed thoroughly in a clean, plastic container. An 8- to 10-foot section of 0.5- to 0.75-inch plastic pipe can also be used: extend the pipe into the pit with ball plug open, pull up the ball plug (or press your thumb over the end to form an air lock), and remove the pipe from the manure, releasing the air lock to deposit the manure into the plastic container.

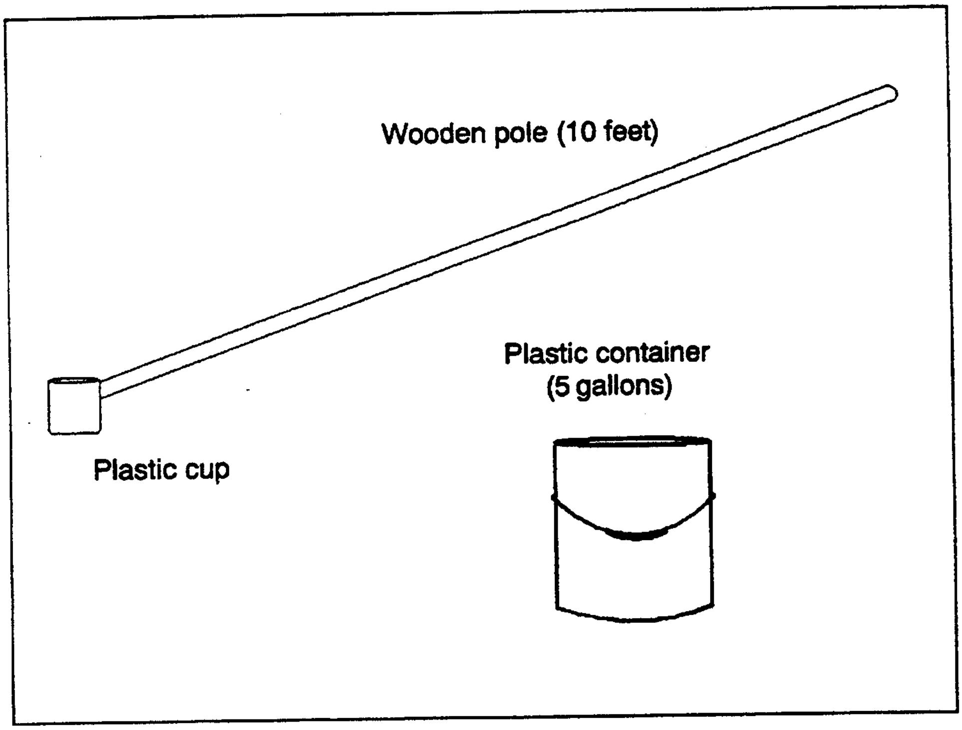


Figure 1. Liquid manure sampling device

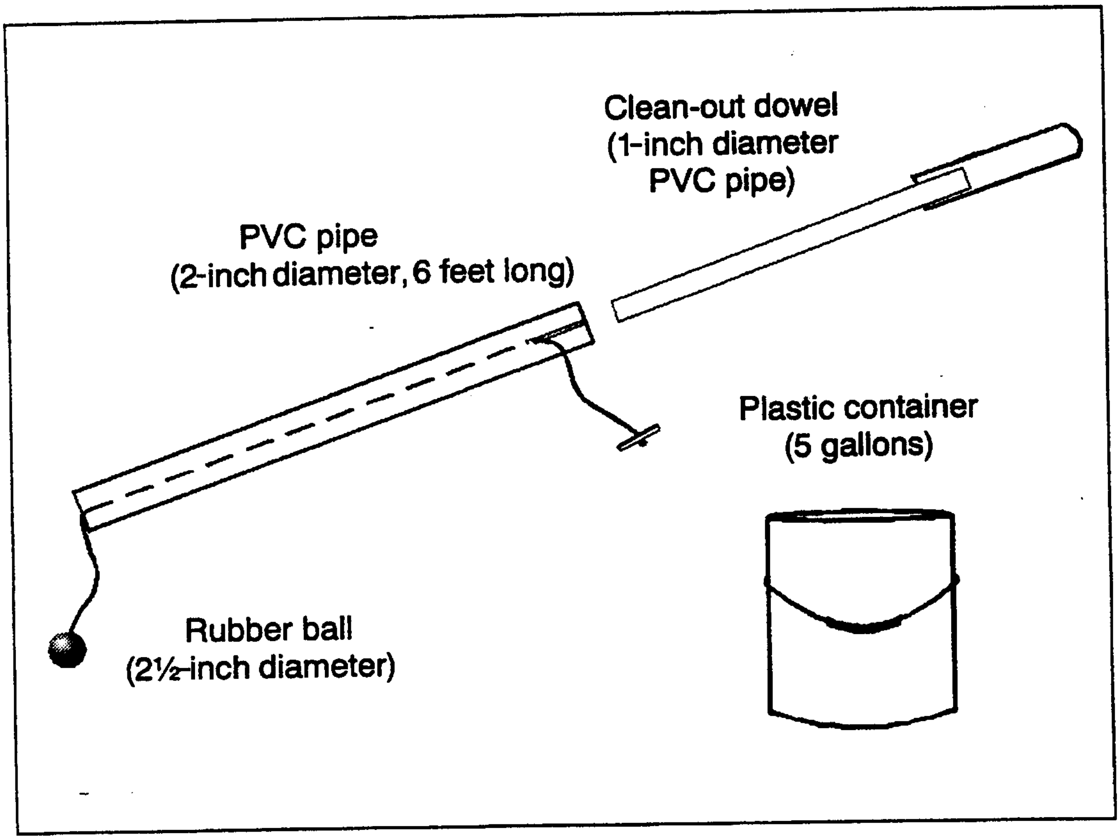


Figure 2. Composite sampling device

Lagoon sludge: Representative samples of lagoon sludge are more difficult to obtain than samples with lower solid contents. Two common methods are used. One method requires lagoon pump-down to the sludge layers. Then, during sludge agitation, a liquid or slurry type of sample described above may be collected. The other method requires insertion of a probe into the lagoon to the bottom to obtain a column of material. A "sludge-judge" is a device commonly used for this type of sampling. The sludge component of this column is then released into a clean plastic bucket, and several (12-20) other sampling points around the lagoon are likewise collected to obtain a composite, representative sample. This procedure must be performed with a boat or mobile floating dock.

For analysis, most laboratories require at least 1 pint of material in a plastic container. The sample should not be rinsed into the container because doing so dilutes the mixture and distorts nutrient evaluations. However, if water is typically added to the

manure prior to land application, a proportionate quantity of water should be added to the sample.

Solid Manure

Solid manure samples should represent the average moisture content of the manure. A one-quart sample is adequate for analysis. Samples should be taken from approximately eight different areas in the manure pile, placed in a clean, plastic container, and thoroughly mixed. Approximately one quart of the mixed sample should be placed in a plastic bag, sealed, and shipped directly to the laboratory. Samples stored for more than two days should be refrigerated. Figure 3 shows a device for sampling solid manure.

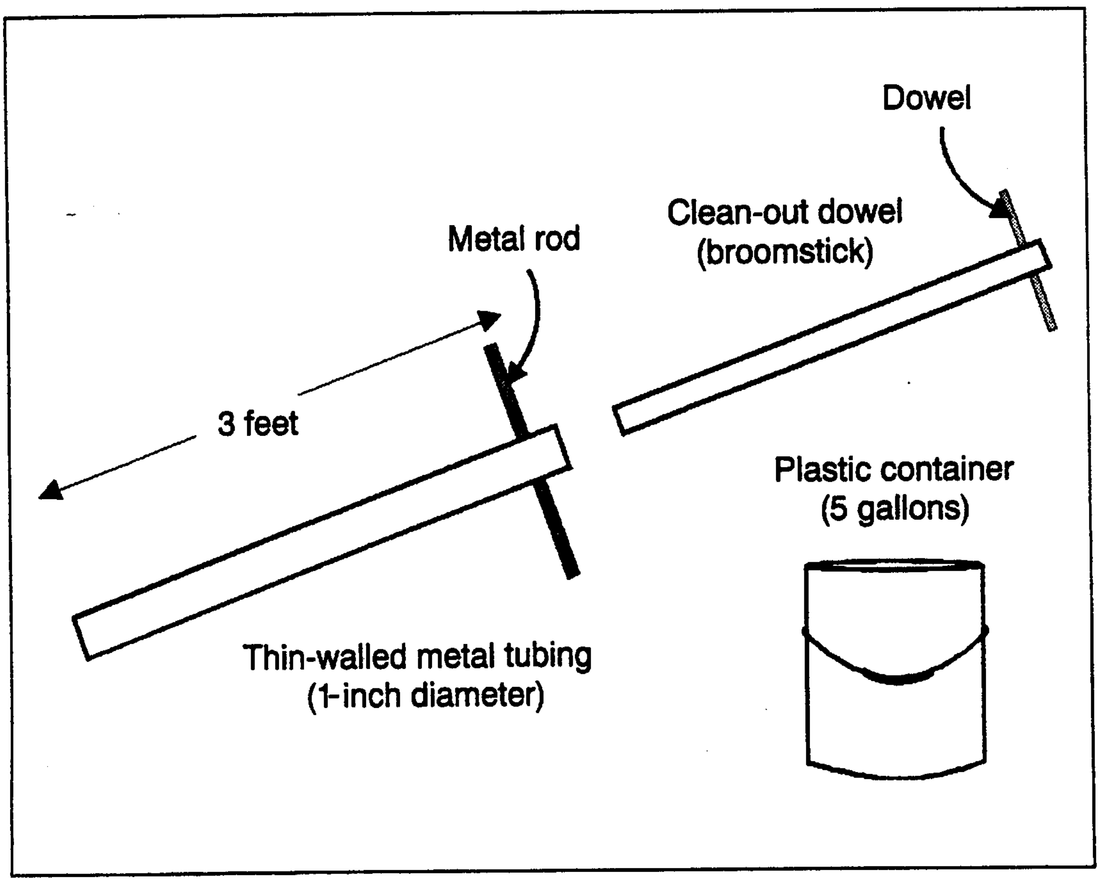


Figure 3. Solid manure sampling device

Stockpiled manure or litter: Ideally, stockpiled manure and litter should be stored under cover on an impervious surface. The weathered exterior of uncovered waste may not accurately represent the majority of the material. Rainfall generally moves water-soluble nutrients down into the pile. If an unprotected stockpile is used over an extended period, it should be sampled before each application.

Stockpiled manure should be sampled at a depth of at least 18 inches at six or more locations. The collected material should be combined in a plastic container and mixed thoroughly. The one-quart laboratory sample should be taken from this mixture, placed in a plastic bag, sealed, and shipped to the laboratory for analysis. If the sample cannot be shipped within one day of sampling, it should be refrigerated.

Surface-scraped manure: Surface-scraped and piled materials should be treated like stockpiled manure. Follow the same procedures for taking samples. Ideally, surface-scraped materials should be protected from the weather unless they are used immediately.

Composted manure: Ideally, composted manure should be stored under cover on an impervious surface. Although nutrients are somewhat stabilized in these materials, some nutrients can leach out during rains. When compost is left unprotected, samples should be submitted to the laboratory each time the material is applied. Sampling procedures are the same as those described for stockpiled waste.

In-house Litter: Litter in the poultry house can vary considerably depending on location within the house. Litter around watering systems, feeders, and brooders should be sampled proportionate to the entire house floor. Special attention should be given to sampling in-house litter by making every effort to representatively sample the entire volume of litter that will be cleaned out and land applied. Collect at least 10 to 12 one-pint samples throughout the house and combine these samples into a plastic bucket. Take care to sample the entire depth of litter without including soil from the house floor. After thoroughly mixing the individual samples in the bucket, place approximately one quart of this mixture into a plastic bag or plastic wide-mouth jar.

Manure Tests to Request

The County Extension Office has sample submission forms and information on tests that are most often needed and can assist with shipping samples to the University of

Georgia (UGA) Ag and Environmental Services Laboratories. The UGA manure sample submission forms are displayed in Figures 4 and 5. Poultry producers should use the form illustrated in Figure 5, Poultry Litter/Manure Submission Form for Nutrient Management Plans. All others should use the form illustrated in Figure 4, Animal Waste Submission Form for Land Application. If using an independent or company laboratory, contact them directly about services and prices.

Basic UGA manure test package: Your individual permits will dictate the frequency and kinds of testing. The basic manure test package at the UGA Ag and Environmental Services Laboratories includes: (all are as total elemental nutrient)

- nitrogen (N),
- phosphorus (P),
- potassium (K),
- calcium (Ca),
- magnesium (Mg),
- sodium (Na),
- sulfur (S),
- aluminum (Al),
- iron (Fe),
- boron (B),
- copper (Cu),
- manganese (Mn), and
- zinc (Zn).

Additional test on liquid manure for CNMP: Lagoon effluent samples submitted for basic manure testing at the UGA Ag Services Labs will have additional analyses that include:

- total Kjeldahl nitrogen (TKN), (for permit)
- nitrate nitrogen, (for permit).
- Ammonium nitrogen (not required for permit but used for nutrient management)

The University of Georgia
College of Agricultural and Environmental Sciences
Cooperative Extension Service

1785

SOIL, PLANT, AND WATER LABORATORY
2400 College Station Road

****
| LAB# ______________ |
*********[Lab Use Only]*********

ANIMAL WASTE
SUBMISSION FORM FOR LAND APPLICATION

Please Note - Retain a copy of this form for your files. Submit one copy per sample.

Name: ______________________ **Sample #:** ______________
Mailing address: ______________________ **County:** ______________
City,State,Zip: ______________________
Phone #: ______________________ **Date Received:** ______________

Check kind and Condition

	Kind	Condition
LITTER	**A** Broiler ______	**E** Fresh/Stackhouse ______
	B Layer ______	**F** Deep Stacked ______
	C Breeder ______	**G** Composted ______
	D Pullet ______	**D** Other ______
MANURE	**I** Dairy ______	
	J Swine ______	**N** Slurry ______
	K Beef ______	**O** Solid ______
	L Horse ______	**P** Composted ______
	M Other ______	
LAGOON	**Q** Swine ______	**S** Layer ______
	R Dairy ______	**T** Other ______

Application Method:
(Check One)

Broadcast Surface ______

Broadcast Incorporated ______

Soil Injected ______

Irrigation applied ______

Other ______

TEST REQUESTED (Check all that apply and consult schedule for fees):

Total Minerals: ______ (Includes: total Kjeldahl nitrogen (excluding nitrate nitrogen),phosphorus,potassium, calcium,magnesium,sulfur,manganese,iron,aluminum,boron,copper,zinc,sodium)

Total Kjeldahl Nitrogen only ______
(excluding nitrate nitrogen)

Nitrate Nitrogen ______
(important for lagoons)

Ammonium Nitrogen ______ Moisture or Solids ______ ___ Other ______

****

FOR LAB USE ONLY

Date Received: ______________ **Date Returned:** ______________
Payment Received: ______________ **Invoice #:** ______________

NH_4-N _____ **Moisture** _____ **NO_3-N** _____ **Total Nitrogen:** _____ **Other** _____

Figure 4. Example of the UGA "Animal Waste Submission Form for Land Application"

The University of Georgia
College of Agricultural and Environmental Sciences
Cooperative Extension Service

SOIL, PLANT, AND WATER LABORATORY
2400 College Station Road

****
| LAB# ______________________ |
*********[Lab Use Only]*********

POULTRY LITTER/MANURE SUBMISSION FORM

FOR NUTRIENT MANAGEMENT PLANS

Please Note - Retain a copy of this form for your files. Submit one copy per sample.

Name: ______________________________

Mailing address: ______________________

City,State,Zip: ________________________

Phone #: ____________________________

Sample #: __________ **(One form per sample)**

County: ____________________

Date: ____________________

For Free Basic Test please answer the following:

1. Have you attended Nutrient Management Training?: Yes ___ No ___
   *If you have not received training check with your County Extension Agent.
2. Will these results be used for Nutrient Management Planning?: Yes ___ No ___
3. How many flocks were produced on this litter?: ____
4. Was the litter caked ___ or full clean-out ___ ? *(Check One)*

Please check all that apply:

Kind	Condition
Broiler ______	Fresh ______
Layer ______	Stockpiled ______
Breeder ______	Composted ______
Pullet ______	Lagoon ______

Application Method:
(Check One)
Surface ______
Incorporated ______
(within 2 days)
Soil Injected ______
Irrigation applied ______

TESTS REQUESTED:

______ Total Minerals (free basic test)
(Includes: total nitrogen,phosphorus,potassium,calcium,magnesium,sulfur,manganese, iron,aluminum,boron,copper,zinc,sodium)

______ Extra Tests (price per fee schedule)
Nitrate Nitrogen ______ Ammonium Nitrogen ______
Moisture ______ Solids ______ ___ Other ______

****

FOR LAB USE ONLY

Date Received: ____________ **Date Returned:** ____________
Payment Received: ____________ **Invoice #:** ____________

NH_4-N _____ **Moisture/Solids** _____ **NO_3-N** _____ **Total Nitrogen:** _____ **Other** _____

Figure 5. Example of the UGA Poultry Litter / Manure Submission Form for Nutrient Management Plans"

Manure Report

The UGA Ag and Environmental Services Laboratories reports results for solid manures in both percentages and pounds of nutrients per ton on an "as received" basis since this is how you will be applying the material. In the Animal Waste Report (Figure 6), liquid sample results are reported as parts per million (ppm) and converted into both pounds per 1,000 gallons and pounds per acre inch of application for your convenience in determining rates per acre. The phosphorus and potassium are reported in the fertilizer basis as P_2O_5 and K_2O respectively. Other laboratories may report their results differently. If a lab reports phosphorus and potassium as elemental P or K, you must convert them into the fertilizer basis of P_2O_5 or K_2O. This can be done with the following conversions:

P multiplied by 2.29 = P_2O_5

K multiplied by1.20 = K_2O

The amount of the total nutrients in manure that will be available to plants varies depending on the type of manure and whether it will be applied to the surface of the soil, incorporated or injected. County Extension Agents and other qualified professionals can assist with the calculation of manure nutrient availability based on when and how you will make application. This information, combined with the soil test report and other information, is necessary to develop a CNMP.

The University of Georgia
College of Agricultural and Environmental Sciences
Cooperative Extension Service

1785

Animal Waste Report

Soil, Plant and Water Laboratory

____
(CEC/CEA Signature)

Sample ID

Grower Information	*Lab Information*	*County Information*
Client: **John Doe** 123 McIntosh Street Athens, GA 30605 Sample: Type: **Lagoon-Swine-Irrigation Applied**	Lab #JD Completed: 07/31/2001 Printed: 08/08/2001	**Clarke County** 2152 W. Broad Street Athens, GA 30606 706-613-3640

Results

(Reported on an as-received wet basis.)

Lab Results	ppm	lbs/ 1000 gal	lbs/ acre inch
Total Kjeldahl Nitrogen	**310**	**2.57**	**70.2**
Ammonium-Nitrogen	**209**	**1.73**	**47.4**
Nitrate-Nitrogen	**4.00**	**0.03**	**0.91**
Phosphorus (P_2O_5)	**133**	**1.10**	**30.0**
Potassium (K_2O)	**543**	**4.50**	**123**
Calcium	**35.0**	**0.29**	**7.94**
Magnesium	**18.1**	**0.15**	**4.11**
Sulfur	**19.6**	**0.16**	**4.45**

Lab Results	ppm	lbs/ 1000 gal	lbs/ acre inch
Manganese	**0.36**	**negligible**	**negligible**
Iron	**5.50**	**0.05**	**1.25**
Aluminum	**4.50**	**0.04**	**1.02**
Boron	**0.79**	**0.01**	**0.18**
Copper	**0.20**	**negligible**	**negligible**
Zinc	**0.25**	**negligible**	**negligible**
Sodium	**108**	**0.90**	**24.5**

% Solids ________

Total Kjeldahl Nitrogen includes ammonium and organic nitrogen combined, and does not include nitrate.

Application Information: The amount of reported nitrogen expected to be available for crop production will vary depending on several factors. Your County Agent can assist in calculating the amount of nitrogen that will be available under your specific set of conditions.

Rates of the animal waste product to apply for crop production should be based on soil test recommendations and take into consideration the nutrient content of the product as well as the method of application, the amount of nutrients applied from commercial fertilizer, and previous crop residue. Where large amounts of animal waste are used annually it is important that regular soil testing be used to monitor the impact on soil fertility levels.

Figure 6. Example of a liquid manure report form the UGA Ag and Environmental Services Laboratories

SOIL TESTING

Presently, manure application rates are based on the nitrogen requirement of a crop or forage and according to a CNMP, sufficient animal waste can be applied to satisfy that need. In the southern United States, soil test nitrogen does not accurately predict the response of crops and forages to residual soil nitrogen; consequently, soil nitrogen is not measured. In Georgia, nitrogen fertilizer recommendations are based on long-term experiments conducted to determine the rates of N fertilizers needed for specific crops. In a CNMP, the rate of animal waste applied is based on nitrogen requirements. Therefore, why do soil testing if nitrogen is the regulating nutrient? Crop yield and nitrogen uptake will increase when other nutrient deficiencies are corrected, such as low pH, other macronutrients, or micronutrients. Nitrogen fertilizer recommendations are made on the assumption that all other nutrients are at optimum levels and soil testing is the way to detect nutrient deficiencies other that nitrogen. Another reason for soil testing is that repeated manure applications can lead to over applications of nutrients, especially phosphorus (P). Soil testing can track the build-up of P and assist with management decisions to utilize this high phosphorus animal waste on soils with lower soil test P. Soil testing can also monitor any build-up of zinc, which could possibly increase to toxic levels (for sensitive crops like peanuts) from long-term and heavy applications of poultry litter.

Soil Sample Collection

When: Soils should be tested annually. Fall is a good time to take samples, but samples can be taken at any time of the year. To make good comparisons from year to year it is important to sample at approximately the same time each year.

Where: There can be considerable variation in nutrient and pH levels within a field. For most accurate results the sample must be representative of the field or area from which it is collected. Areas within a field that have obviously different soil type, drainage, crop growth, or slope characteristics should be sampled separately. Figure 7 illustrates the recommended zigzag pattern for soil core collection and the logic behind collecting separate samples due to changing field conditions. Figure 8 illustrates an example of taking separate soil samples based on topography and differing management

practices. Avoid areas where fertilizer or lime has been spilled or stockpiled as well as areas around old house or barn locations.

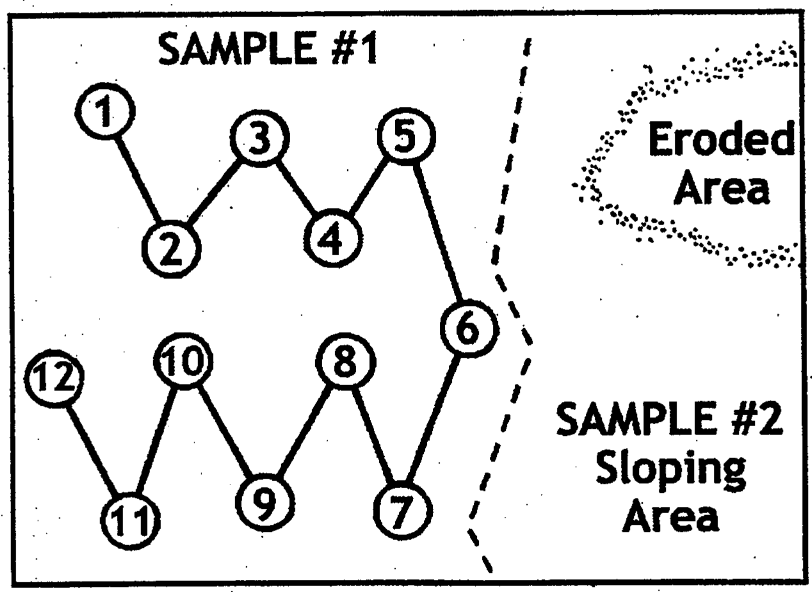


Figure 7. Zigzag pattern for collecting soil samples

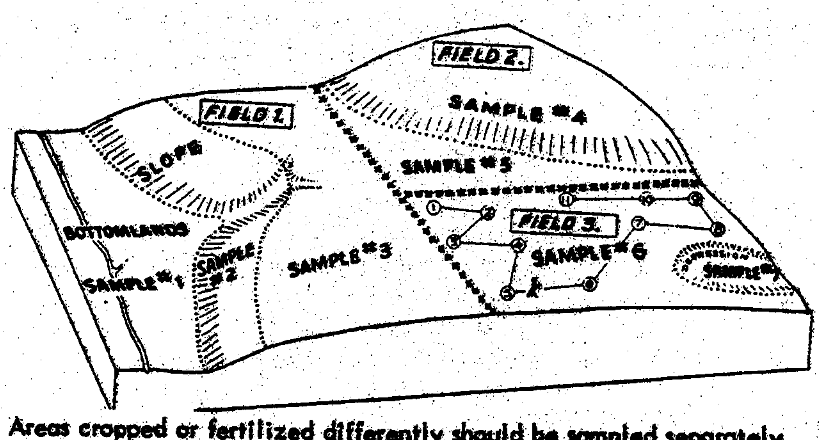


Figure 8. Collection of separate samples based on topography and differing management practices

How: The depth of sampling depends on management practices. From plowed fields take the sample to 6 inches or to plow depth. No-till fields or pastures should be sampled to 4-inches depth (Figure 9). From each area to be sampled take 10 to 20 cores at random, place in clean, plastic container and thoroughly mix. Remove about a pint of the composite soil for submission to the laboratory. Be sure to clearly mark each sample so that you know which field and area of field it represents.

For submission to the UGA Agricultural and Environmental Services Laboratories, contact the local County Extension Agent for more information on soil sampling, submission forms, and sample bags. Private laboratories can also provide information on these topics and the services offered.

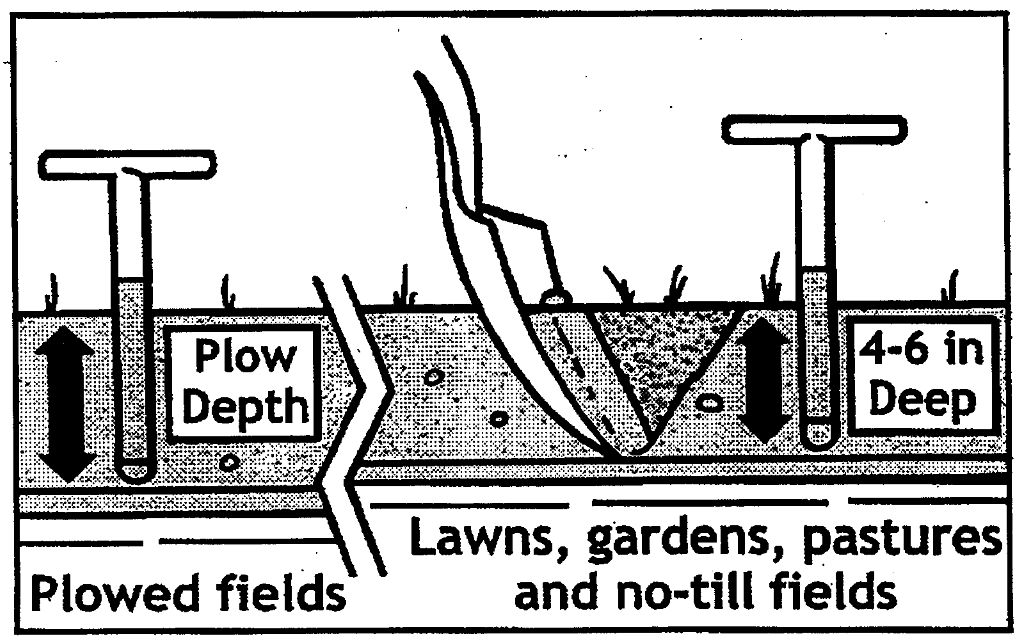


Figure 9. Soil sampling depths for plowed fields (6 inches or plow depth) and no-till or pastures (4 inches)

Soil Test Parameters

The routine soil test conducted by the UGA Ag and Environmental Services Laboratories include:

- phosphorus (P),
- potassium (K),
- calcium (Ca),
- magnesium (Mg),
- manganese (Mn),
- zinc (Zn),
- pH and,
- lime requirement.

Soil tests for nitrogen (N) are generally not reliable for predicting crop response due primarily to the high rainfall of the southeastern U.S.; therefore, recommendations given in soil test reports are based on long-term experiments conducted to determine the rates of N fertilizers needed for specific crops. Other tests like cation exchange capacity (CEC), organic matter, copper (Cu), and boron (B) are available on request. The UGA Ag and Environmental Services Laboratories methods are well correlated with Georgia soils. Various independent laboratories also provide soil-testing services. It is important that the laboratory of your choice uses methods and makes recommendations based on Georgia conditions.

Soil Test Report

The laboratory report will show the test results and give a recommendation for fertilizer nutrients and lime if needed. The recommended rates of nutrients may be supplied from commercial fertilizers, animal manures, lagoon effluents or a combination of sources.

Soil test results are usually reported in pounds of nutrients per acre but some laboratories may give the results as parts per million (ppm). These numbers are merely an index of the nutrients in the soil and are not the actual amounts available for plant uptake. To simplify the interpretation, soil test results are classified into low, medium, high and very high categories. These categories refer to the relative nutrient-supplying

power of the soil. Little or no fertilizer nutrients are recommended when soil test levels are rated as high and very high. Examples of UGA soil test reports and recommendations are given in Figures 10 and 11. Nutrient application to soils with very high soil tests could lead to a nutrient imbalance as well as contribute to surface water quality problems.

In summary, a soil test report tells you the fertility status of the soil and how much, if any, additional nutrients are needed for the particular crop. When animal manure will be used as the fertilizer source it is essential to also know the nutrient content of the manure so appropriate rates can be applied.

The University of Georgia
College of Agricultural and Environmental Sciences
Cooperative Extension Service
1785

Soil Test Report

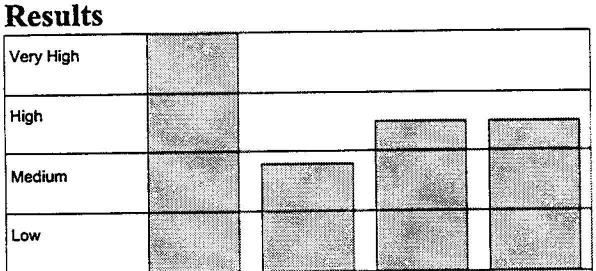
Soil, Plant and Water Laboratory

(CEC/CEA Signature)

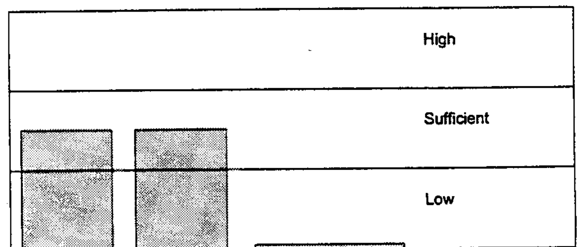
Sample ID

Grower Information	Lab Information	County Information
Client: **John Doe** 123 McIntosh Street Athens, GA 30605 Sample: 1 Crop: Common Bermuda Pasture	Lab #JD Completed: 07/02/2001 Printed: 08/08/2001	**Clarke County** 2152 W. Broad Street Athens, GA 30606 706-613-3640

Results



	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Soil Test Index	261 lbs/Acre	179 lbs/Acre	1496 lbs/Acre	151 lbs/Acre



Zinc (Zn)	Manganese (Mn)	Soil pH	
133 lbs/Acre	36 lbs/Acre	5.2 (7.40 Lime Index)	Soil Test Index

Recommendations

Limestone	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulfur (S)	Boron (B)	Manganese (Mn)	Zinc (Zn)
2.0 tons/Acre	*	0 lbs/Acre	30 lbs/Acre	--	--	--	--

*For pastures not intensively grazed apply 75 to 125 pounds nitrogen per acre. For intensively grazed pastures apply 125 to 175 pounds nitrogen per acre.

If excess forage is common under grazing conditions, split the pasture in half and apply nitrogen to only one section in March, and to the remaining apply nitrogen in July or August, dependent upon the amount of forage that will be utilized.

If no phosphate (P_2O_5) or potash (K_2O) is recommended and none is applied, sample soil again next year.

NOTE: The amount of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) actually applied may deviate 10 pounds per acre from that recommended without appreciably affecting yields.

Figure 10. Example of a UGA soil test report and fertilizer recommendations for common Bermuda pasture

The University of Georgia
College of Agricultural and Environmental Sciences
Cooperative Extension Service

1785

Soil Test Report

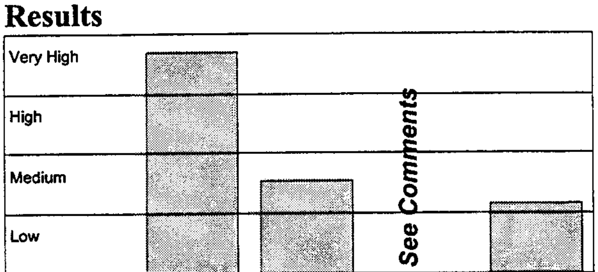
Soil, Plant and Water Laboratory

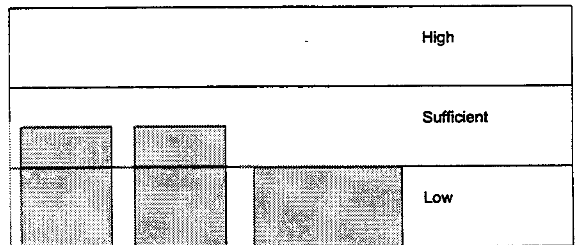
(CEC/CEA Signature)

Sample ID

Grower Information	Lab Information	County Information
Client: **John Doe** 123 McIntosh Street Athens, GA 30605 Sample: 1 Crop: Peanuts	Lab #JD Completed: 07/02/2001 Printed: 08/08/2001	**Clarke County** 2152 W. Broad Street Athens, GA 30606 706-613-3640

Results





	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Soil Test Index	54 lbs/Acre	78 lbs/Acre	609 lbs/Acre	71 lbs/Acre

Zinc (Zn)	Manganese (Mn)	Soil pH	
2 lbs/Acre	12 lbs/Acre	6.0	Soil Test Index

Recommendations

Limestone	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)	Sulfur (S)	Boron (B)	Manganese (Mn)	Zinc (Zn)
0.0 tons/Acre	0 lbs/Acre	0 lbs/Acre	50 lbs/Acre	0 lbs/Acre	0.5 lbs/Acre	0 lbs/Acre	0 lbs/Acre

Apply inoculum when field has not been planted in peanuts for more than 5 years.

Calcium should be applied to all peanuts saved for seed purposes and to all large-seeded Virginia type varieties regardless of soil test levels. The broadcast rates for Runner or Spanish type saved for seed are 160 to 200 pounds calcium per acre as gypsum and for large-seeded Virginia type 320 to 400 pounds calcium per acre as gypsum. When banding over the row reduce the broadcast rates proportionately.

For Runner and Spanish types for market production, lime that is recommended and applied after deep turning and incorporated no more than 3-inches prior to planting should supply adequate calcium. When lime is not applied or when large amounts of rainfall occur between application of lime and planting, a soil sample should be taken 10 - 14 days after planting to determine calcium level in the pegging zone. Take pegging zone samples 3-inches deep and request the special calcium test to determine if gypsum should be applied.

When applying boron it may be applied with the fertilizer, preplant incorporated herbicides, or split in two early fungicide applications (prior to early bloom).

If plant residues are removed from the field, soil test prior to planting the next crop.

NOTE: The amount of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) actually applied may deviate 10 pounds per acre from that recommended without appreciably affecting yields.

Figure 11. Example of a UGA soil test report and fertilizer recommendations for peanuts

Monitoring Well Testing

Water quality monitoring is required by the Georgia Environmental Protection Division (EPD) to detect and quantify contamination, as well as to measure the effectiveness of waste holding systems for animal feeding operations over 1000 animal units. Monitoring should be thought of as a tool used to measure the efficiency of site design and location factors affecting ground water quality. It is beyond the scope of this training to give detailed instructions on well installation and monitoring and we recommend that you contract a professional that has the skills and experience with this type of monitoring.

Monitoring Well Location

Monitoring points should be located so that they detect contamination as early as possible, while observing standards of good practice and common sense. The monitoring wells should be as close as possible to the outer down-gradient edge of the lagoon. In most cases, the focus of monitoring will be the shallowest saturated zone, which is likely to be the first area impacted. Monitoring wells should be no deeper than is absolutely necessary to monitor the first year-round water-bearing unit encountered. Existing wells can be used if approved by GA-EPD. However, pre-existing wells are usually not located down-gradient of lagoons.

Monitoring Well Construction

The actual placement and construction details of the monitoring wells are based on the hydrogeology of the site. Down-gradient wells must be located, and screened to insure that releases from the waste management unit will be detected. Down-gradient wells must be located at the edge of the waste management unit. Minimums of three wells are needed to calculate a hydrologic gradient and designate a down-gradient well. Determining the down-gradient location without additional wells to measure water elevations will be the "best-guess" of the well driller, geologist, or professional engineer based on surface topography. It is advisable to install two other temporary wells to monitor water elevations and confirm that the permanent well is actually down-gradient during the semiannual monitoring.

Details for well construction are given in EPD's "Manual for Groundwater Monitoring". A licensed well driller under the supervision of a licensed geologist or professional engineer should install monitoring wells. At the completion of the fieldwork and well installation, a land surface contour map and potentiometer surface maps should be prepared.

Groundwater Monitoring Requirements

Table 1. Groundwater monitoring parameters under non-swine and proposed swine feeding operation permit requirements.

Parameter	Measurement Frequency	Tolerances	Sample Holding Time
Nitrate-Nitrogen (mg/l as N)	Semiannually	10 ppm nitrate-N	14 days
Total Kjeldahl-N (mg/l TKN)	Semiannually	-	28 Days
Depth to Groundwater	Semiannually	-	On-site

Note 1:	Sampling container: plastic or glass.
Note 2:	Semiannual monitoring results are generally submitted with the June and December reports to the EPD.
Note 3:	Most permits will contain the statement, "Groundwater leaving the land application system boundaries must not exceed primary maximum contaminate levels for drinking water" (Table 2). At the initiation of well water monitoring program, it is a good idea to have samples analyzed run for primary drinking water parameters plus chloride and sulfates. These parameters need not be run again unless a problem develops.

Table 2. **Primary drinking water standards**

Contaminant	Maximum Contaminant Level
Primary	**(ppm)**
Arsenic	0.05*
Barium	2.0
Cadmium	0.005
Chromium	0.10
Fluoride	4.0
Lead	0.015
Mercury	0.002
Nitrate	10.0
Nitrite	1.0
Total Nitrate and Nitrite	10.0
Selenium	0.05

*Note: EPA is currently proposing to lower value to 0.005 ppm.

Contaminant	Maximum Contaminant Level
Secondary	**(ppm)**
(Swine operation contaminants of interest in monitoring wells)	
Chloride	250
Copper	1.0
Sulfate	250
Zinc	5.0

Sampling and Analysis

An effective groundwater sampling and analysis program requires a written plan to include: procedures for sample collection, sample preparation and collection, analytical procedures and chain-of-custody control.

To meet the current parameter requirements (Table 1), the depth to groundwater must be determined semiannually (Figure 12). Following determination of the depth to water table, the well should be purged. For shallow low yielding wells, the well is usually purged (bailed dry) with a dedicated bailer. Disposable Teflon bailers are recommended (Figure 13). If the well cannot be bailed dry, then 3 well volumes should be removed prior to sampling. The well is allowed to recharge and the well is sampled for TKN and nitrate-N. Table 3 contains a list of equipment available from several sources and estimated prices.

Figure 12. Measuring the depth to groundwater

Figure 13. Teflon well bailer

Sampling personnel should wear clean plastic gloves and an effort should be made to minimize contact of the bailing equipment with the ground. Cleanliness and attention to detail minimize cross contamination. A distilled water blank should be carried to the field and put through the entire sampling procedure.

Samples for nitrate-N and TKN determination should be stabilized and collected in a glass or plastic container, stabilized to pH <2 with sulfuric acid and shipped to the laboratory as soon as possible. Samples can be held on ice (4 C) until stabilization. A chain-of-custody form that documents the sample handling from sampling to analysis should be maintained (Figure 14).

Table 3. Equipment and supplies available from Ben Meadows, Forestry Suppliers, Fisher Scientific, VWR Scientific and other scientific supply houses

Parameter	Instrument	Estimated Price
Well purging	Bailer (disposable, Teflon)	$250/case of 12
Depth to water table	Conductivity tape	$250
Nitrate	Laboratory analysis	$8-20/sample

SAMPLE SUBMISSION FORM
(Chain of Custody Record)

Agricultural Services Laboratory
2300 College Station Road Athens, Georgia 30602
(706) 542-9023

PROJ. NO.	PROJECT NAME	Name of Facility/Site
SAMPLERS: (signature)		
Split Samples Offered ( ) Acc. ( ) Dec.		Facility/Site Location

Sta No	Date	Time	Comp	Grab	Pesticide Requested	Sample Number	Sample Type	Sample Description	Remarks	PS Number

Sent by: (signature)	Preservation Method	Received by: (signature) Telephone
Date Sent:	Time Sent:	Title Date Time

Figure 14. Chain-of-custody form

Guidance Documents

1. Georgia DNR. 1991. Manual for Groundwater Monitoring. Environmental Protection Division. Atlanta Georgia.

2. McLemore, W. H. 1981. Monitoring Well Construction for Hazardous-Waste Sites in Georgia. (Georgia Geologic Survey Circular No. 5) Georgia Department of Natural Resources, Environmental Protection Division. Atlanta Georgia.

3. Georgia DNR. 2000. Rules and Regulations for Water Quality Control Chapter 391-3-6. Revised April 2000. Environmental Protection Division. Atlanta Georgia.

4. Georgia DNR. 1991. The Water Well Standards Act of 1991 Official Code of Georgia 12-5-120 through 12-5-138. Environmental Protection Division. Atlanta Georgia.

These documents can be found at the Georgia Department of Natural Resources.
Contact: Thomas E. Hopkins, 4220 International Parkway, Atlanta, GA 30354.
Phone: (404) 362-4916 or (404) 362-2680
Email: Tom_Hopkins@dnr.mail.state.ga.us

REVIEW QUESTIONS*

1. Why is manure tested for developing a CNMP?
2. When should manures be sampled for laboratory analysis?
3. How should manure be sampled?
4. How do you calculate the rate of manure to apply?
5. Why should soil be tested when developing a CNMP?
6. How should soil samples be taken in the field? Sampling zones, sampling depths, number of samples, walking patterns.
7. Which nutrients are measured in the routine soil test?
8. Which nutrients are of primary environmental concern and why?
9. What monitoring parameters are required by the Animal (Non-Swine) Feeding Operations Permit on lagoon effluent and groundwater? How frequently must wells be sampled?
10. What well monitoring parameter is determined on-site?
11. Where is the proper location for the monitoring well?
12. Who should be responsible for constructing the monitoring wells?

*** For Planners only (Review questions 1-12).**
For Operators (Review questions 1-8 only).

4

Assessment of the Nutrient Supply on Livestock and Poultry Farms

Assessment of the Nutrient Supply on Livestock and Poultry Farms

G. Larry Newton, Animal & Dairy Science Department

Introduction

A manure utilization plan is a plan that addresses manure production and how manure nutrients are utilized on the farm . Typically, the manure is used as a nutrient and organic matter source in a cropping system. However, there are other possible end uses of manure. The plan must describe all manure nutrients and the ultimate end use of all manure (crops, local landowners, composted and bagged, re-feeding blends, incineration, etc.). Manure nutrients must be tracked because livestock and poultry use only a small portion of the nutrients fed to them to produce meat, milk, and eggs. The remaining nutrients are excreted in the urine and feces. Depending on the species of livestock, about 70% to 80% of the nitrogen (N), 60% to 85% of the phosphorus (P), and 80% to 90% of the potassium (K) is returned in the manure.

Manure utilization planning is a two-part process. The first component can be termed *strategic planning*, because it focuses on average manure generation volumes, manure storage times, and average manure nutrient contents to develop a general cropping plan and to estimate the number of acres needed to properly land apply the manure. The second component can be referred to as the *annual plan*. The annual plan refers to the actual implementation of the strategic plan. It covers such things as how many acres of which crops will be grown during the year, the planned times for manure applications, results from periodic soil tests and manure analyses, and records of manure applications and crop yields. Once manure begins to be produced on the farm, the manure utilization plan must be implemented. A manure utilization plan requires careful attention to make it work properly. The farm owner or manager will need to understand how to use the information in the plan, along with monitoring information and equipment calibration to make the plan work. Accurate crediting of manure nutrients within a total crop nutrient program is fundamental to utilizing manure as a resource.

Components of a Manure Utilization Plan

Manure utilization plans can vary a great deal in the components and the way in which they are organized. However written, all plans should address the following basic components:

1) Manure generation and other sources of nutrients (can be referred to as Sources)
2) Manure nutrient availability (can also include Placement and Timing)
3) Crop selection and crop nutrient requirements (can be referred to as Amounts or Needs)
4) Best management practices (BMPs)
5) Summary of laws, rules, and regulations that must be followed.

While the first three components must be considered together to ensure that the manure nutrients generated on the farm are applied in harmony with crop needs and soil characteristics, this lesson will concentrate on the first component, nutrient sources and quantities.

Manure utilization plans may be written for one primary nutrient (often nitrogen) or several plant nutrients. Generally, two major plant nutrients (nitrogen and phosphorus) are the ones targeted in manure utilization plans because they are required in relatively large quantities for plant growth, and if mismanaged are likely to have the most adverse affect on the environment. Other nutrients, including potassium and micronutrients, may also have some effect on a manure utilization plan.

Nutrient Sources

Animal manures contain significant levels of plant nutrients and crop residues and/or legumes can provide nutrients for the subsequent crop. Accounting for and utilizing these nutrients can improve both the environmental and economic response of the fields. Planning starts with an inventory of the nutrients produced in the manure of animals grown on the farm, the quantities of manure collected and stored, either dry or as liquid, and analyses of the nutrient content of the stored manure. An inventory of any other by-products available, such as mortality compost or lagoon sludge (if lagoon cleaning is planned), and of any crop residue nutrients or legume nitrogen expected in each field should also be performed. This information will allow manure nutrients to be balanced with purchased fertilizer nutrients to support the expected yields of the crops grown. If the crop acreage is small relative to the number of animals, it will also allow evaluation of the extent that it may be necessary to move nutrients off the farm, and thus avoid over application of manure with the increased potential for movement of nutrients to ground and surface water.

Animal manure

The first part of developing a manure utilization plan is assessing the amounts of manure nutrients that are being generated, or for new operations, the amounts that are expected to be generated. There are four basic methods for estimating the quantities of manure nutrients produced and available for use as fertilizer. The first method involves multiplying the weight of the animals by average excretion estimates for each species and class of animal. After this value is adjusted for the amount of time that the animals are present on the farm, expected losses due to handling, treatment, and storage are calculated to estimate the amounts of nutrients that will be available for utilization. A second method, which will give a more accurate estimate of nutrient excretion in most cases, involves the development of a nutrient balance for the animals. The nutrient content of the feeds used on the farm during the year is calculated, thus the total pounds of nitrogen (N, calculated from protein content), phosphorus (P), and potassium (K) that were fed are known. Next the total amount of animals or animal product sold or moved off the farm during the year is calculated. This is multiplied by the N, P, and K content of the animals or animal products (usually based on average compositions, but may be adjusted for lean percentage, milk protein content, etc.) to get the amounts of nutrients moved off the farm. The difference between the feed nutrients and the animal nutrients is an accurate estimate of the quantities of manure nutrients. This estimate is then corrected for the expected handling, treatment, and storage losses to estimate the amount of nutrients available for use as fertilizer. The third method for estimating manure nutrients involves the use of standard concentration values multiplied by the quantity of manure in storage. While this method has some application for litter based situations, the variation in nutrient content (especially N) of manures held as liquids or slurries generally precludes its use in those situations. The fourth method involves measuring the amounts of manure removed from treatment or storage, sampling the manure for analysis of nutrient content, and calculating the total nutrients available for use as fertilizer. This method is most accurate from the standpoint of developing a cropping plan (because it also accounts for treatment and storage losses), and should be a goal of the nutrient management plan. However, one of the methods of estimating the quantity of nutrients excreted should also be used, especially if there is a need to reduce the amounts of nutrients produced on the farm, there is a need for additional N fertilizer on the farm and loss estimates are helpful, or a lagoon treatment and storage system is used. When lagoons are used, much of the P may accumulate in sludge on the bottom, where it is usually not available for the annual cropping plan. In those cases, the difference between the estimated P excretion and the amount of P calculated from manure volumes and concentrations pumped from a lagoon is likely to be present in the sludge, and it will have to be managed when the lagoon is emptied.

Other nutrient sources
When developing manure utilization plans, all sources of nutrients on the farm need to be considered. Sources of nutrients include nutrients already in the soil, commercial fertilizers, crop residues, and other manure or by-product applications. To account for these nutrients, manure and soil analysis should be used. Examples of other sources would include legumes and crop residues which can leave plant-available nitrogen (PAN, discussed in another lesson) for the following crop. Manure and soil sampling and analysis will be covered in other lessons. When planning manure applications, the producer should account for all nutrient sources when determining manure application rates to fields.

What Are the Amounts of Manure Nutrients Produced on a Farm.

The nutrient value of manure can vary from farm to farm and from time to time on the same farm. Factors that affect the nutrient levels include:

The lean growth potential or other production characteristics of the animals.
The animal diets fed (ration composition).
The amounts of feed wastage.
Time of year (season, temperatures).
The handling and treatment of the manure between animal excretion and land application.
Length of time manure is in a storage structure and/or the level of sludge buildup.
The timing of land application and the method used.

On a per unit of body weight basis, animals with greater lean gain, or other product production potential will require greater protein intakes and will excrete larger amounts of N than less productive animals. However, on a per pound of lean growth (or unit of other product), their excretion of N may be no more, and usually less, than that of animals with lower potential. Manure nutrient excretion can be minimized by feeding animals according to their needs at any given time. In addition to balancing diets with needs, the availability or digestibility of the feed nutrients will affect excretion. These concepts will be covered in more detail in another lesson.

Feed wastage can be a significant contribution to waste nutrients in some cases. For example, if properly adjusted, most modern swine feeders are capable of limiting feed wastage to 5% or less (and others, especially some wet/dry feeders, to 1%), while some older feeders allowed feed wastage as high as 20%, which can be especially important in slotted floor housing. A 20% feed wastage can result in an increase of 30% or more in the manure N and P. Pelleting or crumbling feed also generally reduces feed wastage and reduces separation of nutrients during handling, contributing to improved animal feed efficiency. Season differences in manure nutrient excretion are related to the increased feed intake, decreased water intake associated with cold conditions and the decreased feed intake, increased water intake associated with hot environments. These fluctuations can be minimized by formulating diets to counteract part of these effects. Manure nutrient losses related to handling and treatment will be discussed in another lesson but will also be covered to some extent later in this lesson. Nitrogen is the nutrient that is most influenced by handling and treatment since it occurs in several forms, some of which are gases that can and will be lost to the atmosphere. Storage losses can also affect the supply of manure nutrients available for use as fertilizer. In addition to N, P management is often influenced by storage, especially for lagoons where much of it may end up in the sludge, rather than being available for the yearly soil fertility program. Manure application methods and timing will be covered and discussed in another lesson. All these possible variations are reasons to have manure analyzed frequently.

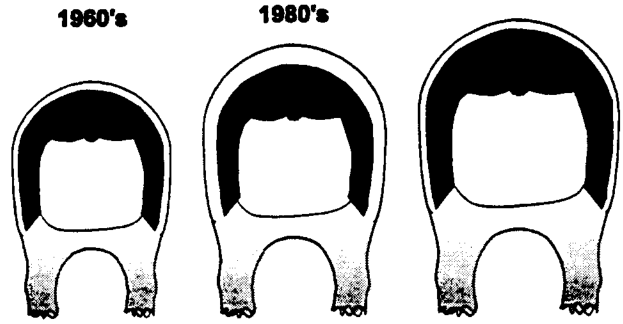
Calculating Manure Nutrient Excretion using Standard Excretion Estimates.

Table 1 (all Tables are attached at the end of the lesson) illustrates the use of standard excretion estimates to calculate the yearly nutrient excretion of the animals. In all the tables, nitrogen is calculate as N, phosphorus is calculated as phosphate (P_2O_5), and potassium is calculated as potash (K_2O). In order to use Table 1, locate the proper animal class in column 1, fill in the yearly average number of animals of that class in column 2, fill in the average weight of the animals in column 3 (mean of starting and ending weight, ending weight - starting weight / 2, for growing animals), and do the indicated multiplications for the remaining columns. (Multiply animal numbers by animal weight to get total weight of animals, then multiply that total by the excretion factors given for N, P_2O_5, and K_2O - an example line for finishing swine is given in the table.) When that is done, add up the N, P_2O_5, and K_2O (across the bottom of the table) for all the animal classes to get the total excretions for the farm. The average capacity should be the yearly average. For example, if the farm has a 3,000 head capacity swine feeding floor that is open 4 weeks per year, the yearly average number of animals might be 2,770 (3,000 pigs X 337days/365days, or 3,000 X 0.923 = 2,770).

The excretion factors given in Table 1 were developed from data collected during the mid to late 1980's. As a consequence, the resulting excretion estimates will likely be somewhat inaccurate, especially for pigs. The differences in finished pigs over time is illustrated in Figure 1, below, which also lists the previous excretion factors (for N and P_2O_5), which were developed from mid to late 1960's data. Similar changes may have occurred for other animal species, so excretion factors for most classes of animals are currently being re-evaluated, and revised factors may be available in the near future.

For the swine example, there were significant numbers of very lean, “stress susceptible”, “double muscled” pigs during the late 1960's. Because of production problems associated with these pigs, they were selected against, and, on average, pigs reaching slaughter houses became slightly fatter. During the 1990's, with productivity back in the swine herd, increased leanness was achieved and slaughter weights were further increased. In addition, a 1995 survey of states producing 75% of the US slaughter hogs estimated that 67% of pigs were fed more than two grower/finisher diets (29% were fed two diets), and that 25% of the hogs marketed in the Southeast were split-sex fed (38% in the Midwest). The management and feeding of nursery pigs has also changed, with more early weaning and phase nursery diets, including increased use of animal products and amino acids. As an indirect result, many nursery diets contain a higher proportion of highly available P sources than in the past (lower levels of phytate P, covered in another lesson), which should result in lower P excretion. Using nutrient balance estimates for current practices and pigs, it appears that on a body weight basis, N excretion has returned to 1960's levels, or greater, and that P excretion has returned

Figure 1. Some Changes in Pigs Over the Past 30 Years



	Mid to Late 1960's	Mid to Late 1980's	Late 1990's
Market Wt (lb)	210	225	255
lb/lb body wt/yr			
N Excretion	0.164	0.153	?
P Excretion	0.125	0.134	?

to 1960's levels, or lower. Since it is difficult and cumbersome to have tables which list estimated excretion factors for a large number of animal and feeding alternatives and provide space for calculations, a computer aided excretion estimator has been developed which should provide improved nutrient excretion estimates compared to those derived from Table 1. This program will be available at training sessions, and after testing and further review, at County Extension Offices and on the Web. In addition, a number of other manure nutrient calculating programs and models are available. A good place to start looking for other manure software is the UGA AWARE web page (www.bae.uga/outreach/aware/). Other animal and farm management models are also available which calculate estimated nutrient excretion, and some ration balancing programs are also useful when using the nutrient balance method of estimating nutrient excretion.

Calculating Manure Nutrient Excretion using Nutrient Balance Estimates.

Tables 2a, b, and c illustrate the procedures for calculating manure nutrient excretion estimates using nutrient balance procedures. It has been shown that calculating manure nutrients by subtracting the nutrient content of the animals or animal products moved off the farm from the feed nutrients fed to the animals generally provides a more accurate estimate of nutrient excretion than does the use of standard excretion estimates. Table 2a list the factors which are used to convert feed protein, phosphorus, and potassium to amounts of N, P_2O_5, and K_2O and the average composition values of whole animals and products necessary to convert animal live weights and products to amounts of N, P_2O_5, and K_2O.

Table 2b contains an example calculation for a swine finishing farm marketing 6,000 pigs per year. In that example it was assumed that the feeds were purchased and that only two diets were fed, in order to make the example shorter and simpler. Any number of diets could be included, or if diets are mixed on-farm, it is usually simpler to calculate from ingredients. In that case, the total quantity of corn, soybean meal, other protein supplements (milk by-products in nursery diets, amino acids, etc.), and phosphorus supplements would be entered on a separate line for each. Purchased animals moving onto the farm would complete the nutrient inputs. Nutrient outputs from the swine operation would include all animals sold or otherwise moved off the farm. The difference in nutrient inputs and nutrient outputs will be a close estimate of manure nutrients produced on that farm. Table 2c is a blank table for use in calculating manure nutrients for a farm, should this method be selected.

Calculating manure nutrient output using the estimated balance method will usually result in larger values than would be obtained by using the standard excretion method. Part of this difference is due to the fact that normal feed "shrinkage" is included as input, and especially since any spilled and wasted feed is included in the manure nutrient estimate. Even more accurate estimates can be obtained by adjusting the animal and product composition factors to account for differences in lean percentage and product nutrient content between different herds or flocks, some software allows this to be done.

Calculating Manure Nutrients Using Standard Concentration Values.

As noted above, when manure is in a relatively dry state and nutrient concentrations are not affected by widely varying amounts of dilution water, such as with poultry litter, manure nutrients can be calculated by estimating manure production of the animals and multiplying this amount by standard nutrient concentration values for the particular type of manure and storage system. This procedure thus also estimates the storage losses which occur prior to removal of the manure for land application. The procedures for calculating manure nutrients using this method are illustrated in Tables 3a, b, and c. Table 3a lists manure production and nutrient concentration values for some classes of poultry. The per bird manure production estimates are used in Table 3b to estimate the total quantity of manure produced on the farm during the year, example calculations are shown for broilers and layers, with additional lines for other calculations. The quantity of manure calculated in Table 3b is then entered into Table 3c, along with the appropriate concentration (pounds/ton) values for nitrogen, phosphate, and potash from Table 3a. The calculations in Table 3c are then completed to estimate the total quantities of nutrients produced on the farm during the year. Example calculations are again provided, along with additional blank lines for other calculations.

Treatment and storage losses.

Before discussing the fourth method of estimating manure nutrient production on farms, it is necessary to briefly discuss nutrient losses during handling, treatment, and storage. Table 4 lists some manure treatment and storage options along with factors used to estimate the quantities of nutrients remaining after treatment and/or storage. The example given in the table is for a top loaded manure storage tank or structure. To use the table to estimate the nutrients remaining after storage, find the appropriate system in column 1, place the N excretion estimate (from either Table1 or 2, or a software derived estimate) in column 2, the P_2O_5 excretion estimate in column 5, the K_2O excretion estimate in column 8, and perform the indicated multiplications. Notice that for lagoons, much of the P_2O_5 is calculated as lost during storage. This is not really the case, as most of this P actually remains in the lagoon sludge and will have to be managed at some point when sludge is removed from the lagoon.

The amount of P_2O_5 in the lagoon sludge can be estimated by filling in Table 5. If the lagoon is emptied essentially completely at some point during the year, P reductions will be minimal. If all lagoons are agitated during pumping such that some sludge is re-suspended, P reductions will be much less than 65%, but will depend upon the degree of agitation. The computer aided nutrient calculator mentioned above includes calculations for nutrient losses during treatment and storage, but does not include separating lagoon P between sludge and effluent, since it will likely vary from farm to farm, depending upon effluent removal practices. If lagoons are not agitated and only effluent is removed, P_2O_5 calculations from the computer calculation should be factored as in Table 5. In addition, the computer estimate will provide a ranges for N losses. If the treatment and storage time are relatively short (90 days or less) the N values will likely be near the larger amount, whereas if manure is applied only once per year, the N value will likely be nearer the lower value.

Calculating Manure Nutrients from Measured Quantities and Sample Analyses.

If amounts of manure handled on the farm each year are known, plus there are manure nutrient analyses, calculation of manure nutrients available for use as fertilizer can be calculated in a straight forward manner. For farms that handle slurry and dry manures, the manure quantity may be estimated from the number of loads handled during a typical clean-out operation along with the number of clean-outs per year. For operations that use a liquid manure management option such as flush floors and lagoons, the volume of manure generated is more difficult to determine. Liquid system manure generation can be estimated if good records on irrigation applications (from a meter, pump capacity X run times, or rain gauges in the field) are maintained. These quantities will need to be multiplied by concentration values obtained from samples submitted to a laboratory, in order to obtain total yearly nutrient estimates. Manure sampling procedures are covered in another lesson. In some cases there may be a need or desire to estimate micronutrient (such as copper or zinc) production and land application. Manure sampling and analysis is a logical way of obtaining those values. Table 6a and b are provided for making manure nutrient calculations from measured quantities and nutrient concentrations. If the concentration of nutrients in manure from the animals varies with the time of year, an average composition should be used or calculate an amount for each clean out by season of the year and add them for a yearly total, or develop seasonal land application plans. Table 6a contains an example to illustrate how the calculations are made and Table 6b is a blank table for additional calculations.

If there is a good handle on manure generation and manure composition, this is likely the most accurate estimate of manure nutrients available for use as crop fertilizer. This estimate will include animal effects, diet effects, feed wastage effects, and, most importantly, treatment and storage losses. It should be a goal of the plan to arrive at this point, in order to more accurately manage nutrients on the farm. However, if the farm uses lagoons, one of the first two methods should also be used in order to estimate the quantity of P_2O_5 accumulating in lagoon sludge, that will have to be managed at some point in time.

Results from either method of manure nutrient estimation may be used for planning purposes (strategic plan). As records of manure quantities are developed and manure samples are submitted to a laboratory to determine the actual nutrient content, the plan will be updated and modified to reflect these more accurate estimates. *Where manure analyses and quantities are available, they should be used to develop the initial manure utilization plans and application rates.*

Other Nutrient Sources

Note that Table 6 includes a line (6) used to enter other on-farm nutrient sources. This could be mortality compost (an amount and nutrient analysis will be needed) or possibly nitrogen fixed by

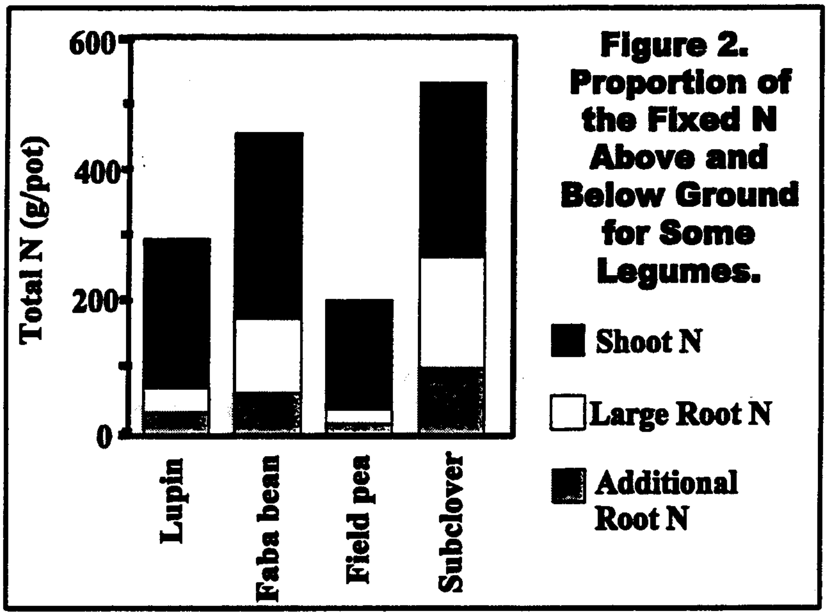


Figure 2. Proportion of the Fixed N Above and Below Ground for Some Legumes.

(From: http://www.agric.wa.gov.au/cropupdates/1998/pulses/nitro.html-ssi)

legumes. Table 7 lists estimates for available N amounts following some legumes. The actual amount of N will vary with management of the legume, especially if none of the plant was harvested (as with a winter legume which was not grazed cut for hay), part of the plant was harvested (as with soybeans), or most of the plant was harvested (as with peanuts plus peanut hay). Soybeans, peanuts, and lupin for example, may accumulate more than 250 lbs of N per acre, but much of this N is removed with seed harvest. Figure 2 shows above and below ground N accumulations for some legumes as an illustration of how harvest can affect N remaining after a legume crop. (It should be noted that subclover seed develop below the soil surface.)

Parts of this lesson were taken from National Curriculum Lesson 31: Manure Utilization Plans, written by Karl Shaffer, 6/1/2000 draft.

Table 1. Total manure nutrients produced by livestock. Nitrogen, P_2O_5, and K_2O production can be calculated by entering a livestock operation's information into Columns 2 and 3 for the appropriate animal species and class and multiplying by the relevant factors.

1. Livestock or Poultry Species	2. Number of animals (average capacity)	3. Average Weight, lbs.	4. Total Animal Weight (Col 2 X Col 3)	5. Lbs. of N/ lb. of animal weight per year	6. Lbs. N/ yr. (Col 4XCol 5)	7. Lbs. of P_2O_5 /lbs. of animal weight per year	8. Lbs. P_2O_5 /yr. (Col 4X Col7)	9. Lbs. of K_2O/lbs. of animal weight per year	10. Lbs. K_2O/ yr. (Col 4XCol 9)
Example: Swine... Finish	*2,000*	*150*	*300, 000*	*0.15*	*45,000*	*0.13*	*39,000*	*0.10*	*30,000*
Swine: Nursery				0.22		0.21		0.15	
Grow				0.15		0.13		0.10	
Finish				0.15		0.13		0.10	
Sows & Litter				0.17		0.12		0.13	
Sows (Gestation)				0.07		0.05		0.05	
Gilts				0.088		0. 066		0.058	
Boars				0.055		0. 042		0.044	
Beef (450- 750 lbs)				0.11		0.083		0. 088	
Beef feeder (high- energy diet)				0.11		0.078		0. 092	
Beef feeder (high- forage diet)				0.11		0.091		0. 11	
Beef Cow				0.12		0.10		0.11	
Dairy Cow... 50 lbs/ d milk				0.18		0.087		0. 100	
Dairy Cow... 70 lbs/ d milk				0.22		0.096		0. 110	
Dairy Cow... 100 lbs/ d milk				0.27		0.110		0. 130	
Dairy Dry Cow				0.11		0.074		0. 079	
Dairy Heifers/ Calves				0.11		0.033		0. 11	
Layer				0.30		0.26		0.15	
Pullet				0.23		0.20		0.11	
Broiler				0.40		0.28		0.20	
Turkey				0.27		0.23		0.12	
Total: If more than one manure storage or treatment system is used for different groups of animals, it is best to separate the groupings of animals and their nutrient excretion totals for each manure system.			System 1:						
			System 2:						

Source: NRCS Agricultural Waste Management Handbook, 4/ 92 with exception of lactating and dry dairy cows. Dairy estimates are from H. H. Van Horn 1991, Achieving environmental balance of nutrient flow through animal production systems. *The Professional Animal Scientist* . 7(3): 22- 33.

Table 2a. Calculating Nutrient Excretion Using Input-Output Balance: Nutrient factors.

Feed and Animal Factors for determining N, P_2O_5, K_2O Content of Inputs and Outputs of an Animal Enterprise.

Material	Multiplication Factor for:		
	N	P_2O_5	K_2O
Feeds, Grains, Protein Supplements, Minerals	Multiply % Protein by 0.0016	Multiply % Phosphorus by 0.0229	Multiply % Potassium by 0.012
Pigs less than 100 lbs.	Use 0.025	Use 0.0128	Use 0.003
Swine from 100 to 300 lbs.	Use 0.024	Use 0.0108	Use 0.0029
Swine over 300 lbs.	Use 0.023	Use 0.0108	Use 0.0028
Dairy Cattle	Use 0.012	Use 0.016	Use 0.0024
Milk	Multiply % Protein by 0.0015	Use 0.0023	Use 0.0018
Beef Cattle, 400 lbs.	Use 0.029	Use 0.0071	Use 0.0023
Beef Cattle, 600 lbs.	Use 0.024	Use 0.0058	Use 0.0023
Beef Cattle, 800 lbs.	Use 0.02	Use 0.0051	Use 0.0023
Beef Cattle, 1000 lbs.	Use 0.015	Use 0.0038	Use 0.0023
Broiler Chickens	Use 0.029	Use 0.0046	?
Layer Hens	Use 0.026	Use 0 .0141	?
Chicken Eggs	Use 0.019	Use 0.0048	Use 0.0021
Turkey	Use 0.028	?	?

Table 2b. Calculating Nutrient Excretion Using Input-Output. Example Calculations for a 2000 Head Swine Finisher Farm Using Purchased Feed.

Inputs - Outputs	1. Quantity	2. Percent Protein	3. X 0.0016 (Feed N factor)	4. N Quantity (Col 1 X Col 3)	5. Percent Phosphorus	6. X 0.0229 (Feed P_2O_5 factor)	7. P_2O_5 Quantity (Col 1 X Col 6)	8. Percent Potassium	9. X 0.012 (Feed K_2O factor)	10. K_2O Quantity (Col 1 X Col 9)
Inputs										
Example: Grower Feed	*537 tons*	*16.78*	*0.02685*	*14.417 tons*	*0.66*	*0.01511*	*8.116 tons*	*0.72*	*0.00864*	*4.639 tons*
Example: Finisher Feed	*1,035 tons*	*14.20*	*0.02272*	*23.515 tons*	*0.55*	*0.0126*	*13.036 tons*	*0.60*	*0.0072*	*7.452 tons*
Example: Total Feed Inputs	*1,572 tons*			*37.932 tons*			*21.152 tons*			*12.091 tons*
Example: 6,060 pigs @ 50 lbs	*151.5 tons*		0.025	*3.787 tons*		.0128	*1.939 tons*		0.003	*0.455 tons*
Example: Total Inputs				*41.719 tons*			*23.091 tons*			*12.546 tons*
Outputs										
Example: 6.000 pigs @ 255 lb	*765 tons*		0.024	*18.360 tons*		0.0108	*8.262 tons*		0.0029	*2.219 tons*
Balance										
Example: Nutrient Excretion				*23.359 tons*			*14.829 tons*			*10.327 tons*

Table 2c. Calculating Nutrient Excretion Using Input-Output. Table for doing Your Calculations, Following Example Above.

Inputs - Outputs	1. Quantity	2. Percent Protein	3. X 0.0016 (Feed N factor)	4. N Quantity (Col 1 X Col 3)	5. Percent Phosphorus	6. X 0.0229 (Feed P_2O_5 factor)	7. P_2O_5 Quantity (Col 1 X Col 6)	8. Percent Potassium	9. X 0.012 (Feed K_2O factor)	10. K_2O Quantity (Col 1 X Col 9)
Inputs										
Outputs										
Balance										

Table 3a. Typical Amount And Nutrient Composition For Poultry Manures Handled As Solids[a].

Manure Type	Pounds of Manure per Bird Produced or Maintained per Year	Nutrient		
		Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)
		Pounds / Ton of Litter or Manure		
Broilers (litter)	2.5	66	50	40
Breeders (litter)	44.0	31	40	35
Pullets (litter)	8.0	(68)	(53)	(41)
Layers (highrise)	40.0	38	56	30
Stockpiled Litter		36	55	35

[a]Adapted from L. Vest, B. Merka, and W.L. Segars, 1998.

Table 3b. Calculating Manure Quantities For Poultry Farms Using Dry Manure Handling.

Type of Bird	1. Number of birds housed	2. Turns per year	3.[a] Total birds per year	4. Manure per bird, lbs	5. Total manure per year, lbs.	6. Tons of manure / year
Examples			*(Col 1 X Col 2)*	*(from Table 3a)*	*(Col 3 X Col 4)*	*(Col 5 / 2,000)*
Broilers	*40,000*	*6*	*240,000*	*2.5*	*600,000*	*300*
Layers	*70,000*	*1*	*70,000*	*40*	*2,800,000*	*1,400*
Additional Lines For Your Use:						

[a]You may also start in this column.

Table 3c. Calculating Nutrient Quantities For Dry Poultry Manure Systems.

Bird or Manure Type	1. Tons of manure / year	2. Pounds N / ton	3. Total pounds N	4. Pounds P_2O_5 / ton	5. Total pounds P_2O_5	6. Pounds K_2O / ton	7. Total pounds K_2O
Example:	*(Table 3b)*	*(Table 3a)*	*(Col 1 X Col 2)*	*(Table 3a)*	*(Col 1 X Col 4)*	*(Table 3a)*	*(Col 1 X Col 6)*
Broilers	*300*	*66*	*19,800*	*50*	*15,000*	*40*	*12,000*
Layers	*1,400*	*38*	*53,200*	*56*	*78,400*	*30*	*42,000*
Additional Lines For Your Use:							

Table 4. Nutrients available (annually) after losses from open lot, storage, or lagoon [1]. Locate your storage/treatment system in column 1, then enter the total manure nutrients produced (from Table 1 or 2) in Columns 2, 5, and 8 and multiply by the relevant factors listed for your manure management system..

1. Manure Storage/ Treatment System	Nitrogen			P_2O_5			K_2O		
	2. N Produced, Table 1 or 2	3. Multiplication Factor	4. Available N After Losses	5. P_2O_5 Produced, Table 1 or 2	6. Multiplication Factor	7. Available P_2O_5 After Losses	8. K_2O Produced, Table 1 or 2	9. Multiplication Factor	10. Available K_2O After Losses
Example: Storage (liquid swine manure, top loaded storage)	*45,000*	*X 0.70 =*	*31,500*	*39,000*	*X 1.0 =*	*= 39,000*	*30,000*	*X 1.0 =*	*= 30,000*
Open lot or feedlot		X 0.6 =			X 0.95 =			X 0.7 =	
Manure pack under roof		X 0.70 =			X 1.0 =			X 1.0 =	
Bedded pack for swine (e. g., hoop building)		X 0.50 =			X 1.0 =			X 1.0 =	
Bedded pack & compost for swine (e. g., hoop building)		X 0.35 =			X 1.0 =			X 1.0 =	
Solid/ semi- solid manure & bedding held in roofed storage		X 0.75 =			X 1.0 =			X 1.0 =	
Solid/ semi- solid manure & bedding held in unroofed storage		X 0.65 =			X 0.95 =			X 0.9 =	
Liquid/ slurry storage in covered storage		X 0.90 =			X 1.0 =			X 1.0 =	
Liquid/ slurry storage in uncovered storage		X 0.75 =			X 1.0 =			X 1.0 =	
Storage (pit beneath slatted floor)		X 0.85 =			X 1.0 =			X 1.0 =	
Poultry manure stored in pit beneath slatted floor		X 0.85 =			X 1.0 =			X 1.0 =	
Poultry manure on shavings or sawdust held in housing		X 0.70 =			X 1.0 =			X 1.0 =	
Compost		X 0.70 =			X 0.95 =			X 0.9 =	
One - cell anaerobic treatment lagoon		X 0.20 =			X 0.35 =			X 0.65 =	
Multi- cell anaerobic treatment lagoon		X 0.10 =			X 0.35 =			X 0.65 =	

1 Multiplication factor is portion of nutrients retained in the manure. Remaining N volatilizes into air as ammonia and remaining phosphate settles to lagoon bottom as solids or is lost as runoff in open lot. Actual losses for individual situations may vary substantially from listed values .

Table 5. Phosphorus retained as settled solids by an anaerobic treatment lagoon [1].

Enter quantity of total manure phosphorus estimated from Tables 1 or 2, interval (years) between when settled solids are removed, and complete the calculation.

Total Pounds P_2O_5 Produced Annually, from Tables 1 or 2	Single or Multiple Cell Treatment Lagoon		
	Years Between Solids Removal	Portion Retained in Lagoon	Total P_2O_5 in Settled Solids
Example: 39,000 lbs	*X 5*	*X 0.65 =*	*126,750 lbs.*
	X	X 0.65 =	
	X	X 0.65 =	

[1] This applies to an anaerobic treatment lagoon with a permanent liquid pool and no agitation at the time of effluent removal.

Table 6a. Example of Calculating Manure Nutrient Generation Using Measured Quantities and Analyses.

Example: You operate a swine-finishing operation with a 4,000-head capacity. Your manure-handling system is a slurry system, and the manure analysis shows 25.2 pounds of N, 23.7 pounds of P_2O_5, and 16.8 pounds of K_2O per 1,000 gallons of manure. Your application system is a honeywagon with incorporation. Manure generation is (4,000 head X 751 gal/animal =) 3,004,000 gal/year.

Use this worksheet when you know the volume of manure that is handled based on cleanout or pumping records.				
1	Manure generation, tons or thousands of gallons/year	*3,004 thousand gal.*		
		N	P_2O_5	K_2O
2	Manure analysis, lb/ton or lb/1,000 gallons	*25.2*	*23.7*	*16.8*
3	Manure nutrient availability coefficients*	*0.7*	*0.8*	*0.8*
4	Corrected manure analysis* (multiply above two rows, 2 X 3, for each column)	*17.64*	*18.96*	*13.44*
5	Total manure nutrients to handle (manure generation X corrected manure analysis)	*52,990 lbs.*	*56,956 lbs.*	*40,374 lbs.*
6	Total other nutrients on the farm (includes starter fertilizer, residual N credits, other waste sources, N from recent soil test. Note: These are on a field-by-field basis.)	*625 lbs.* [a]	*0*	*0*
7	Total nutrients to handle in cropping system	*53,615*	*56,956*	*40,374*

*These are needed if lab results are not in plant-available nutrients (discussed in another lesson). If lab results are plant-available nutrients, skip this part.

[a] Based on 25 acres of soybeans at 25 pounds of residual N per acre.

Table 6b. Calculating Manure Nutrient Generation Using Measured Quantities and Analyses.
Table for Your Use.

Use this worksheet when you know the volume of manure that is handled based on cleanout or pumping records.				
1	Manure generation, tons or thousands of gallons/year			
		N	P_2O_5	K_2O
2	Manure analysis, lb/ton or lb/1,000 gallons			
3	Manure nutrient availability coefficients*			
4	Corrected manure analysis* (multiply above two rows, 2 X 3, for each column)			
5	Total manure nutrients to handle (manure generation X corrected manure analysis)			
6	Total other nutrients on the farm (includes starter fertilizer, residual N credits, other waste sources, N from recent soil test. Note: These are on a field-by-field basis.)			
7	Total nutrients to handle in cropping system			

*These are needed if lab results are not in plant-available nutrients (discussed in another lesson). If lab results are plant-available nutrients, skip this part.

Table 7. Nitrogen residual following some legume crops.

Legume Crop Type	N Available for Next Crop, Pounds Per Acre
Peanuts	20 - 40
Soybeans	30 - 45
Clovers[1]	40 - 100
Alfalfa[1]	50 - 125
Lupin[1]	50 - 150
Hairy vetch	80 - 110

[1] For forage crops, N remaining for next crop depends upon amount of top growth harvested and the stage of growth at termination; for lupin it is assumed that termination is before significant seed development.

Summary

The manure nutrient supply on an animal farm originally came from the feed which was fed to the animals. Therefore the quantity of manure nutrients is affected by the productivity of the animals (the proportion of the feed nutrients converted into growth or other products). This conversion efficiency is affected by the nutritional balance of the diets fed relative to the nutritional needs of the animals at their current productivity stage. In addition, feed wastage often contributes nutrients directly to manure management systems, without the reduction in amounts associated with animal digestion. Two of the easiest and least costly (often profitable) methods of reducing manure nutrient production are to more closely balance the diets to the needs of the animals and to take steps to minimize feed wastage (such as frequent feeder adjustment, use of pelleted feeds, or installing feeders of newer design).

There are four basic methods for estimating the production of manure nutrients on farms. The first involves multiplying animal weight by excretion factors for nitrogen (N), phosphorus (P), and potassium (K). For pigs, and likely other animals, as their feeding and management have changed, the published standard excretion factors currently in use most likely underestimate N excretion and overestimate P excretion, as leaner pigs tend to excrete more N and less P than fatter pigs. The second method involves subtracting the estimated nutrient content of animals and animal products leaving the farm from the nutrient content of the feeds used on the farm. Manure N is derived from the protein and amino acids in the feed and manure P and K are derived from minerals in the feedstuffs and mineral supplements. Since all of the nutrients in the feed must go somewhere, if the amounts fed are known, this procedure will generally produce a more accurate estimate than the use of standard excretion estimates.

For both of these nutrient excretion estimation methods, nutrient losses which occur during treatment and storage of manure must be taken into account in order to estimate the quantities of nutrients available for use as fertilizer. Nitrogen voided in the urine (about half of the N excretion in most animals) is quickly converted to ammonia. Loss of this ammonia to the air can occur quickly under some conditions. During treatment and storage of manure, additional N is often converted to ammonia (and in some cases to nitrate, which is subject to denitrification and loss to the atmosphere as well). Nitrogen losses will often have larger effects on the amount of manure N available for use as plant fertilizer than the amount actually excreted.

The third method for estimating manure nutrient quantities is to calculate the expected manure production and multiply it by standard nutrient concentration values. These concentration values are usually for manures as they are removed from storage, thus this method does account for an average nutrient loss. The fourth method is to measure the quantity of manure removed from storage each year, sample and analyze it to determine the nutrient concentration of the manure, and multiply the concentrations by the quantity to estimate the total manure nutrients. This method automatically accounts for everything from wasted feed to treatment and storage losses, but it does not account for some nutrient separations, such as P in lagoon sludge, which will eventually have to be managed. It should be a goal of the nutrient management plan to develop a measurement and sampling procedure for calculating nutrient quantities, since it will be less likely that manure nutrients will be under or over applied to fields, since either could be uneconomic and over application could also be environmentally unsound. With either calculation method, other on-farm nutrient sources may also need to be accounted, such as mortality compost, or, on a field by field basis, legume N fixation.

5

Manure Storage and Treatment Systems

Manure Storage and Treatment Systems

John W. Worley

Table of Contents

Goals/Objectives of Manure Storage and Treatment Systems

Animal waste storage and treatment systems have historically been selected and designed to efficiently utilize valuable fertilizer nutrients for crop production while protecting soil, air, and water quality. The primary reason to store manure is to allow the producer to land spread the manure at a time that is compatible with the climatic and cropping characteristics of the land receiving the manure. Manure nutrients can be best utilized when spread near or during the growing season of the crop. Therefore, the type of crop and method of manure application are important considerations in planning manure storage and treatment facilities. The selection of the system also depends on the owner/operator's goals for utilization of waste. If the nutrients in the waste are needed for crop production, a system is designed to conserve and utilize in a timely manner as much of each nutrient as possible. If the nutrients are not needed for crop production, the manure tends to be seen as something that must be disposed of as economically as possible. The goal then is to reduce the waste stream as much as possible. In either case, the waste storage/treatment system is designed to provide storage and/or treatment without allowing surface or ground water to become contaminated with excess nutrients, pathogens, or organic matter which can cause oxygen levels in water to drop below the level needed to sustain aquatic life.

Alternative Storage and Treatment Systems

Most swine and dairy operations and some poultry operations use liquid or slurry manure storage and handling systems. In fact, in Georgia, most of the systems are liquid. The discussion here will therefore focus on liquid systems. However, slurry systems will also be discussed in order to enhance understanding of the difference between the goals and management strategies of the two systems. "Dry" systems (systems where manure is handled as a solid) will also be discussed. Some systems use solids separation devices to remove some of the solids from the liquid stream. These systems are really a combination of liquid and dry systems and must be handled as such.

Liquid Storage Systems (Lagoons)

Lagoons are probably the most common form of liquid manure handling system. A lagoon is a waste treatment system as well as a storage facility for manure, and it represents the most economical means currently available of reducing the waste stream in liquid systems. A properly operating lagoon will reduce odors and convert much of the organic matter into gases which are given off into the air. Odor reduction comes as a result of purple sulfur bacteria which grow near the surface of the lagoon and convert odorous compounds (primarily hydrogen sulfide) into less offensive gases.

Nutrient reduction is primarily in the form of nitrogen which is converted to nitrogen gas and ammonia. Some of the phosphorus and potassium tend to settle to the bottom of the lagoon and are stored in the sludge. Thus the land needed to apply nutrients from a lagoon is reduced since the nutrients in the lagoon are reduced. It must be noted, however that phosphorus and potassium are still in the lagoon and must be accounted for in nutrient management budgets

when the sludge is removed. If properly designed, constructed, and managed, a lagoon will minimize seepage of nutrients into the ground below, and will present a minimum risk of overflow into surface waters.

Advantages of lagoon storage of manure may include cost per animal unit, ability to store large amounts of manure and/or runoff, treatment of manure to reduce odors, and potential to handle manure with conventional pumping and irrigating equipment. Disadvantages of lagoons may include lack of appropriate soil materials for construction, the need for solids separation or sludge removal equipment if bedding or other non-biodegradable materials are present, aesthetic appearance and/or public perception. In addition, the effluent from a lagoon is less well balanced with crop needs, since nitrogen is released, and phosphorus and potassium remain in the lagoon.

Manure Slurry Storage Systems

Manure slurry storage systems tend to be used when the need for nutrients for crop growth in the area is high since these systems tend to maintain higher levels of nutrients (particularly nitrogen) than do lagoons. Many types of facilities are used to store manure in the slurry form. One type is the under-floor pit in which manure is deposited directly into the pit (usually 6 ft deep or more) through slatted floors. Other slurry manure storage facilities include fabricated or earthen structures. Fabricated manure storage tanks are usually either concrete or coated metal (glass-lined steel). Such tanks may be above ground, or partially or fully below ground. Manure is usually scraped or flushed from the production buildings and may flow into these tanks by gravity or be pumped into the tank from a collection sump or reception pit. Adequate agitation is necessary to suspend solids and facilitate complete removal of the contents of these manure tanks. If needed for odor control, fabricated tanks are usually the least costly to cover.

Slurry manure may also be stored in earthen structures or basins. Because storage volume can usually be obtained at less cost in an earthen basin than in a fabricated facility, these facilities are often used when manure and wastewater volumes are relatively large due to wash-water use or lot runoff. Earthen structures require a relatively high degree of planning and preliminary investigation to ensure that proper soil materials are available to create a seal and that the seal is constructed properly. These facilities are basically similar to lagoons, but smaller since less water is added to the manure. Space requirements are greater with earthen structures than fabricated manure storage tanks due to the required berms and front/back slopes that have structural integrity and can be properly maintained. Maintenance requirements may be greater with earthen structures due to the need for maintaining and mowing a vegetative cover on the berm area and keeping it free of weeds, trees, and shrubs. Agitation is equally important in earthen structures, and access points for agitation and pumping should be part of the design plan. Some earthen storage units are partially or completely lined with concrete and built with an access ramp so that loading and hauling equipment can enter the basin. Earthen storage structures are more difficult to cover than tanks if odor control is needed. Odor is generally a greater problem in slurry storage structures than in a properly operating lagoon, but if coverage is necessary, it is less costly in a slurry storage facility because of the smaller size.

Advantages of storing manure in the slurry form may include less volume (higher solids content compared to a lagoon), adaptability to tank storage either under floor or above ground,

possibility of covering the manure storage facility to reduce odors, higher nutrient retention, and the potential to collect and transport hydraulically. Disadvantages may include higher odor potential (unless storage unit is covered), increased danger of toxic or combustible gas buildup in enclosed areas, number of loads or trips that must be made when the storage is emptied, and odor and runoff potential if the slurry is spread without injection or incorporation.

Dry Systems and Solids Separators

Dry manure storage can be as simple as using the confinement building itself as storage, as is often done in poultry houses where three or more flocks of chickens are raised before cleaning out the building. In cases where crop needs do not coincide with the need to clean out a broiler house, a dry swine house, or a dairy lot; manure is often stacked either in a building or outside until it can be utilized by a crop. These stacks should always be covered to protect them against runoff in case of rain **or** the runoff should be contained and treated as a liquid waste.

When swine are raised on litter, they tend to dung in limited areas of the building, so that the litter is very nonhomogeneous when removed from the building. Some loads contain almost no nutrients, and some are very concentrated. To achieve a homogeneous product, it is necessary to compost, or at least stack and mix the material from these houses. Some producers have experimented with only removing the wet areas which contain most of the nutrients and reusing the dry litter, but it is not clear if this system is sustainable because of concerns about worms and parasites transferring from one batch of pigs to the next.

Another type of "dry" storage is a settling basin used to separate solids from a liquid stream. Typically, these basins are designed to store 3 to 4 weeks of manure, with two or more basins being utilized in order to allow one basin to drain while the other one is being filled. This design allows more flexibility in timing the application of solids onto crops and pastures. These basins are lined with concrete and the runoff from them flows into a lagoon to prevent contamination of surface waters.

Mechanical solid separators are also used. These devices usually produce a dryer product than a settling basin which is better for composting or hauling to remote sites or off the farm. Their main disadvantage is that, being mechanical systems, they do break down and require periodic maintenance. They also have a cost of operation involved since they require energy to operate. The solids fractions from these systems are typically stored on a concrete pad with the runoff going into a lagoon or protected by vegetated buffers.

Basic Design Principles

Lagoons

A lagoon must be sized to provide adequate storage for manure, dilution water so that proper microbial digestion will occur, storage of sludge (indigestible materials that settle to the bottom), storage of rain water and wash water, and a safety margin in case of severe storms. (See Figure 1.) If all of these capacities are not accounted for, the lagoon will not function properly, will begin to act like a manure storage facility, and will have to be pumped out much more frequently. Adequate sizing of a lagoon depends upon location, the number and size of animals using the lagoon, whether or not solids separation will be used, and how long sludge will be

allowed to build up before removing. In addition, good management practices, such as loading the lagoon on a uniform basis, maintaining proper vegetation on berms, regular inspections and maintaining safe levels in the lagoon are necessary to provide safe, efficient operation.

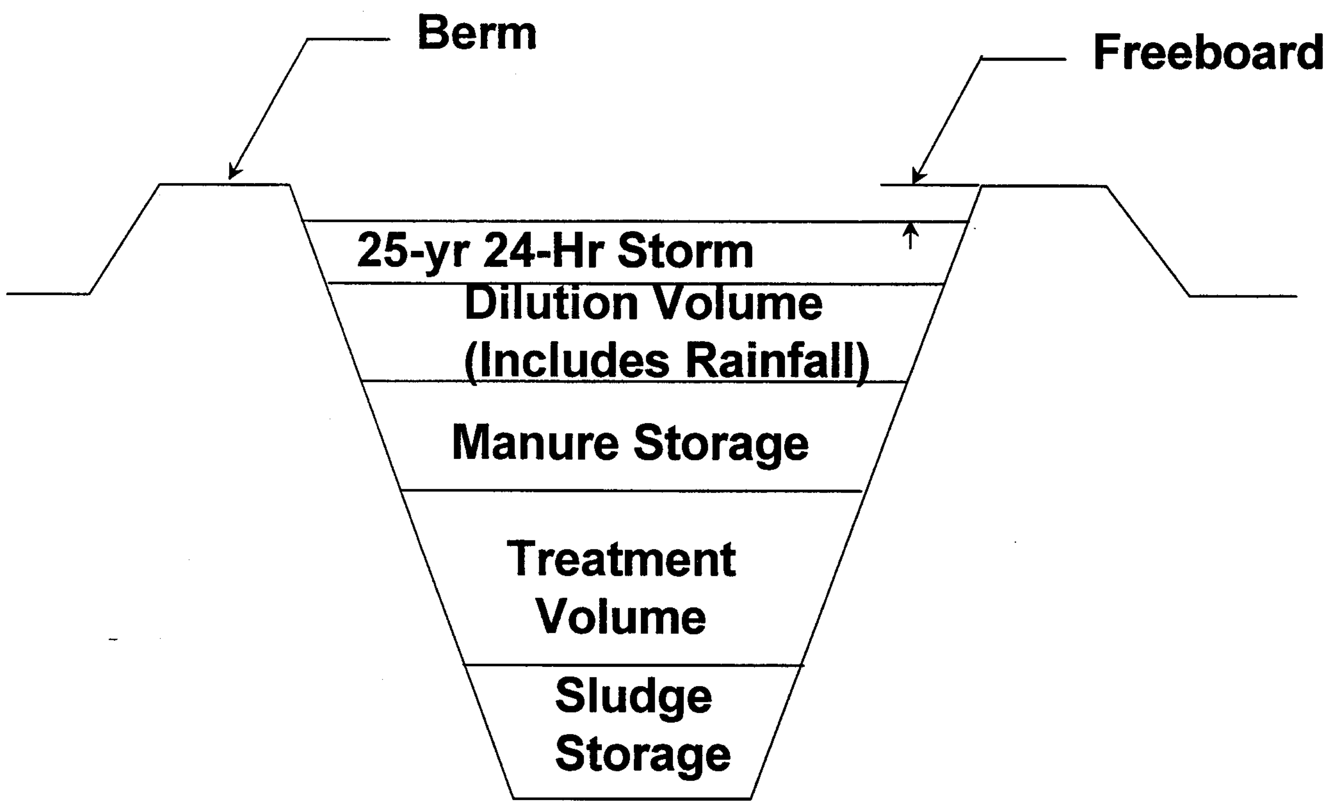


Figure 1. Capacities that must be included in a proper lagoon design.

Lagoons must be designed by a properly trained engineer (NRCS or consulting engineer). The berms (walls) must be designed to be stable under load and the lagoon must be properly lined with either a compacted clay or synthetic liner to prevent leakage into ground water. The owner/operator should understand the limitations of the system, and how the expansion of animal numbers will prevent the lagoon from operating properly. He/she should know the capacity of the lagoon, how many animals it is supposed to handle, how often it should be pumped down, and to what level it should be pumped down. Any major expansion or change in the operation of a facility would require a reassessment by the design engineer.

Manure Slurry Storage

The actual size of a manure slurry storage structure needed depends upon the same factors used in sizing a lagoon with the notable exception that no treatment volume of water must be added since microbial breakdown of manure is not desired. Manure is left in a more solid state, which hinders bacterial growth. Also, sludge accumulation is not accounted for since this facility should be completely emptied one or more times per year. The design storage period plays a significant role in sizing these structures. Storage period needed depends primarily upon cropping system, climatic conditions, and labor/equipment availability. Most operations utilizing a single, full-season annual row crop or small grain crop will need at least six months manure storage to schedule land spreading around cropping operations. Experience has shown that even a full year's storage is beneficial when wet conditions may make fall application difficult and manure needs to be stored until spring.

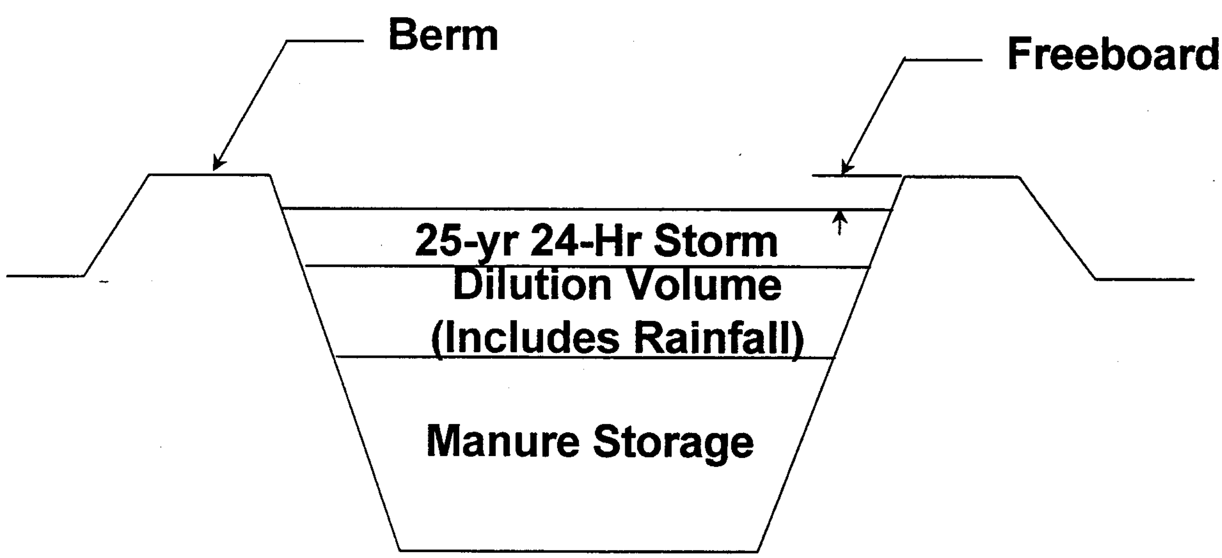


Figure 2. A manure storage facility is smaller than a lagoon, but must still be sized to handle volumes according to the planned management.

A manure storage facility for a given number of animals is much smaller than a lagoon for the same farm (See Figure 2), since no storage space is needed for dilution water. However, adequate size must still be supplied for manure storage, rainwater, and a safety factor for severe storms.

As in the case of lagoons, a manure slurry storage system should be designed by an NRCS or properly trained consulting engineer, whether it is an earthen basin (Figure 2) or a concrete or steel structure. The engineer should also be consulted before any expansion or major change in the operation takes place.

Dry Systems and Solid Separators

If manure is to be stored in a building (commonly called "dry-stack houses" in the poultry industry, the building should be designed to safely handle the loads it will experience, and should be designed to withstand the corrosive atmosphere in which it will exist while manure is stored in it. Assistance on building design is available from the NRCS or the Cooperative Extension Service Plan Service. Concrete floors are recommended, but clay floors are acceptable if mortality composting is not to be done in the facility.

Storage of manure in stacks outside a building should be avoided. Stacks can be covered with plastic which will protect them from leaching while in place, but when the stack is removed and spread on a field, it is almost impossible to remove all of the material, and the remaining manure can leach into the soil. Experience has shown that the most highly contaminated areas on a poultry farm is around old stacks and at the entrance to the houses where spillage occurs when houses are cleaned out.

Settling basins for separating solids should be designed to be structurally sound and to be large enough to provide flexibility in the timing of manure application from the basin. Again, assistance can be gained from the NRCS or Cooperative Extension Service Plan Service.

Effects on Nutrient Management

The amount of nutrients available for use on crops is affected by the method used to store manure, as well as the application method. In estimating the total amount of nutrients available for use annually, the total nutrients excreted must be adjusted for storage and application losses. When applying material from an aerobic lagoon for instance, up to 90% of the excreted nitrogen can be lost during the anaerobic treatment of the waste. This nitrogen is lost to the atmosphere primarily in the forms of nitrogen gas and ammonia. There are also losses of phosphorus and potassium, but unlike nitrogen, these nutrients accumulate in the sludge layer of the lagoon, which must eventually be removed and applied to the land unless some arrangements can be made to remove the sludge from the farm. For this reason, 90 to 95% of excreted phosphorus and potassium should be accounted for in the overall farm nutrient management plan. Five to 10% may be lost in moving the waste material (spillage when loading, leaching when stored outside, etc.) Table 1 shows estimated available nitrogen after storage losses as a percentage of total nitrogen produced for various species and storage methods.

Table 2 illustrates how manure values can vary with system and time and thus result in different recommended or allowable loading rates. The only way to know the exact composition of manure is to have it tested. While the numbers below may represent average values, the variation from one system to another is great, and manure testing is an absolute essential for determining proper application rates.

Table 1. Estimated available nitrogen after storage losses (% of total nitrogen produced) for different systems.

Management System	Dairy	Poultry	Swine
Anaerobic Lagoon	20-35	20-30	20-30
Manure Slurry Storage	65-80		70-75
Manure Stored in Pit Beneath Slats	70-85	80-90	70-85
Manure and Bedding in Covered Storage	65-80	55-70	
Manure stored in open lot	70-85		55-70

Table 2. Average manure accumulation and nutrient values for different swine manure systems .(These values may be used as planning guidelines.)

Nutrient Composition of Swine Manure					
Manure Type	Manure Accumulation	Total Nitrogen	Ammonium NH_4-N	Phosphorus P_2O_5	Potassium K_2O
Fresh	82 lb/1,000 lb of animal/day	12 lb/ton	7 lb/ton	9 lb/ton	9 lb/ton
Scraped[1]	58 lb/1,000 lb of animal/day	13 lb/ton	7 lb/ton	12 lb/ton	9 lb/ton
Liquid Slurry[2]	16.7 gal/1,000 lb of animal/day	31 lb/1,000 gal	7 lb/1,000 gal	12 lb/1,000 gal	17 lb/1,000 gal
Anaerobic Lagoon Sludge	0.74 gal/1,000 lb of animal/day	22 lb/1,000 gal	6 lb/1,000 gal	49 lb/1,000 gal	7 lb/1,000 gal
Anaerobic Lagoon Liquid	20.3 gal/1,000 lb of animal/day	136 lb/acre-inch (5 lb/1,000 gal)	111 lb/acre-inch (4 lb/1,000 gal)	53 lb/acre-inch (2 lb/1,000 gal)	133 lb/acre-inch (5 lb/1,000 gal)

[1]Collected within 1 week.
[2]Six to 12 months accumulation of manure, urine, and excess water usage, which does not include fresh water for flushing or lot runoff.
Source: North Carolina Agricultural Chemicals Manual.

Operation and Monitoring of Lagoons and Slurry Storages

Lagoons combine storage and treatment functions and thus are more sensitive to management inputs than are solid or slurry facilities. The establishment and maintenance of desirable microbiological populations in lagoons requires more specific procedures in the way lagoons are loaded and monitored.

Startup and loading procedures

Lagoon startup is a very important factor in developing a mature lagoon that has an acceptable odor level and will perform in the expected manner over the long term. Lagoons are designed with a "treatment volume" that provides an environment for development and maintenance of a bacterial population that degrades and stabilizes manure. The size of the treatment volume is based on a volatile solids (VS) loading rate, which depends primarily upon temperature. Volatile solids are the "non-mineral" or organic solids in manure that are subject to bacterial degradation. At warmer temperatures, bacteria are more active and VS loading rates are higher. The converse is true for cooler temperatures. For the bacteria to develop and function properly, the actual VS loading rate should be as designed. The proper VS loading rate is achieved only if the lagoon contains a volume of water equal to the treatment volume at startup. A lagoon with only one-tenth of the treatment volume filled at startup will experience an "overload" by a factor of 10 (VS loading rate is ten times greater than designed). Therefore, it is very important to plan a procedure to have sufficient water in a lagoon at startup. The treatment volume should be used as a target. Achieving this goal may require identifying a water source (pond, lake) and implementing the needed pumping procedures to transfer the desired volume of water to the lagoon. Since bacteria are more active at warmer temperatures, consideration should be given to starting a lagoon in the spring or early summer. In this way, bacteria will have a warm season to establish themselves before activity slows during the winter. Spring startup of lagoons often requires special planning of construction schedules and animal procurement.

<u>Problems associated with insufficient volume at startup include excessive odor and high rates of sludge buildup. A lagoon that is started with insufficient volume may take years to recover and may never attain an operating state equal to a lagoon that is started properly.</u>

In addition to startup, long-term loading procedures are critical to lagoon performance. A somewhat common and unfortunate practice in the livestock industry is to expand animal numbers without expanding lagoon size. This results in a proportionate increase in VS loading, and the associated problems can be expected to develop. Volatile solids loading should not be increased beyond the design loading. Alternatives to reduce VS loading (or expand animal numbers) include solids separation, construction of additional lagoon volume, or pretreatment of manure. Lagoons should also receive manure in a consistent manner (no "slug" loading). This is usually accomplished in modern production systems utilizing hydraulic transport of the manure to the lagoon.

Salt and Nutrient Levels, Testing

Bacterial activity is somewhat sensitive to salt levels in the lagoon. Salts are a natural byproduct of the biological degradation of manure. The removal of some salts as the lagoon is

pumped and the addition of fresh water via rainfall, runoff, and wash water combine to generally keep salt levels within an acceptable range. However, some conditions can occur that may lead to elevated salt levels. These include extended periods of dry weather, high rates of evaporation, little or no dilution with lot runoff and wash water, and perhaps overloading of the lagoon. Elevated salt levels inhibit bacterial activity, and lagoon performance is characterized by increased odors or "sour" smells and increased sludge buildup rates. A simple field test called "electrical conductivity" (EC) is effective in monitoring salt levels. A University of Missouri study found that EC values in the range of 8,000 to 12,000 μmho/cm (or S/cm) were associated with greatest bacterial activity. If salt levels rise too high in a lagoon, the most effective remediation is to pump the lagoon and add water from a freshwater source (pond or lake). The availability of such a freshwater source is an enhancement to long-term lagoon operation, and consideration should be given to such a source when planning a lagoon.

While overall salt levels are the primary concern in lagoon health, occasionally other more specific compounds may affect lagoon performance. These might include copper, arsenic, (dietary inputs), certain medications, and perhaps excessive use of harsh cleaning agents. If reduced lagoon performance is suspected due to factors such as these, specific testing may be required to isolate the source.

Overall Monitoring Activities

Certain activities are advisable and necessary in maintaining a manure storage structure and ensuring that it is performing as expected. Some of these activities may be required by regulation, but all are evidence of good management and stewardship regardless of regulatory requirements.

Monitoring During Pumping Activities

Experience has shown that unplanned discharges and spills sometimes occur with pumping activities. Sources of such unplanned discharges include burst or ruptured piping, leaking joints, operation of loading pumps past the full point of hauling equipment, and other factors. Hence, pumping activities should be closely monitored, especially in the "start-up" phase, to ensure that no spills or discharges occur. Continuous pumping systems such as drag-hose or irrigation systems can be equipped with automatic shut-off devices (which usually sense pressure) to minimize risk of discharge in the event of pipe failure.

Liners

Liners in earthen manure storage impoundments are designed and constructed to provide an adequate barrier between the potential contaminants in the impoundment and groundwater. Hence, liner integrity is extremely important in maintaining an environmentally sound manure storage facility. To the extent possible, liners should be regularly inspected for signs of damage, erosion, or other compromising factors. Wave action can cause liner erosion at the level of the liquid in the impoundment. If this condition is severe, consideration might be given to the use of riprap or similar mitigation methods to preserve liner integrity. The area around the pipes that discharge into the impoundment is also subject to erosion, especially if the pipes discharge

directly onto the liner surface. A better configuration is to install inlet pipes such that they discharge into at least 4 feet of liquid, which may require a supporting structure for the end of the pipe. Concrete or rock chutes should be used with inlet pipes that discharge onto the liner surface. Agitation is also an activity that can damage liners. Care should be taken to operate agitators a sufficient distance above the liner so that liquid velocities are reduced enough to ensure that erosion does not occur. Heavy or unusual rainfall events can also erode liners, and special attention should be given to liner inspection after such storm events.

Logbooks and record keeping

Certain data and record keeping involving manure storage structures can aid in overall maintenance and management, and is also evidence of responsible operation and good record keeping. In addition to the periodic inspections, manure levels in a storage structure should be monitored and recorded. This data can illustrate the effects of excessive rainfall and lot runoff, and help in planning pump-down or other land application activities. Manure levels should be observed and recorded frequently enough to provide a "feel' for the rate of accumulation, and pumping activities should be scheduled accordingly.

When a lagoon is pumped or other manure storage structure is emptied, the date of the activity should be recorded along with the volume or amount of manure removed, locations where the manure is spread, and the nutrient content (lab analysis) of the manure. Calibration of pumping equipment is necessary to accurately estimate amounts pumped. This information may be required by the regulatory agency for interim or year-end reports, or may be useful in the event of litigation.

Pump-down or Manure-Level Markers

Pump-down or manure-level markers, or indicators, are a simple but important component of a manure storage facility. Such a marker enables the operator to ascertain quickly and easily the degree of fill of the manure storage facility, the point at which pumping or emptying should begin, and the point at which it should end. The presence of a durable, easily read marker gives inspection or regulatory personnel confidence that a manure storage facility is being managed properly.

Experience has shown that pump-down markers must be made of durable materials and properly installed to afford the long life needed. The operator or inspector should be able to ascertain the following information when observing a pump-down marker:

- When pumping operations should begin and end
- Level at which overflow will occur
- Fraction of total storage that is currently filled

A common practice is to install steel fence posts at the upper and lower pump-down levels for earthen impoundments. While this approach provides basic information on beginning and ending pump-down, experience has shown that more knowledge is needed. Also, fence posts installed in this manner are subject to damage and displacement. A good pump-down marker will indicate the level, or elevation, of manure throughout the possible range (from lower pump-down level to overflow, or spillway) in the storage facility. Experience has shown that a

6" x 6" treated wood pole properly imbedded makes a good pump-down marker. Notches or other indicators can be carved into the pole to show pertinent elevations. Painted numbers or colors on the pole are not durable enough to maintain readability over a number of years. Figure 3 shows a type of pump-down marker that provides the information needed.

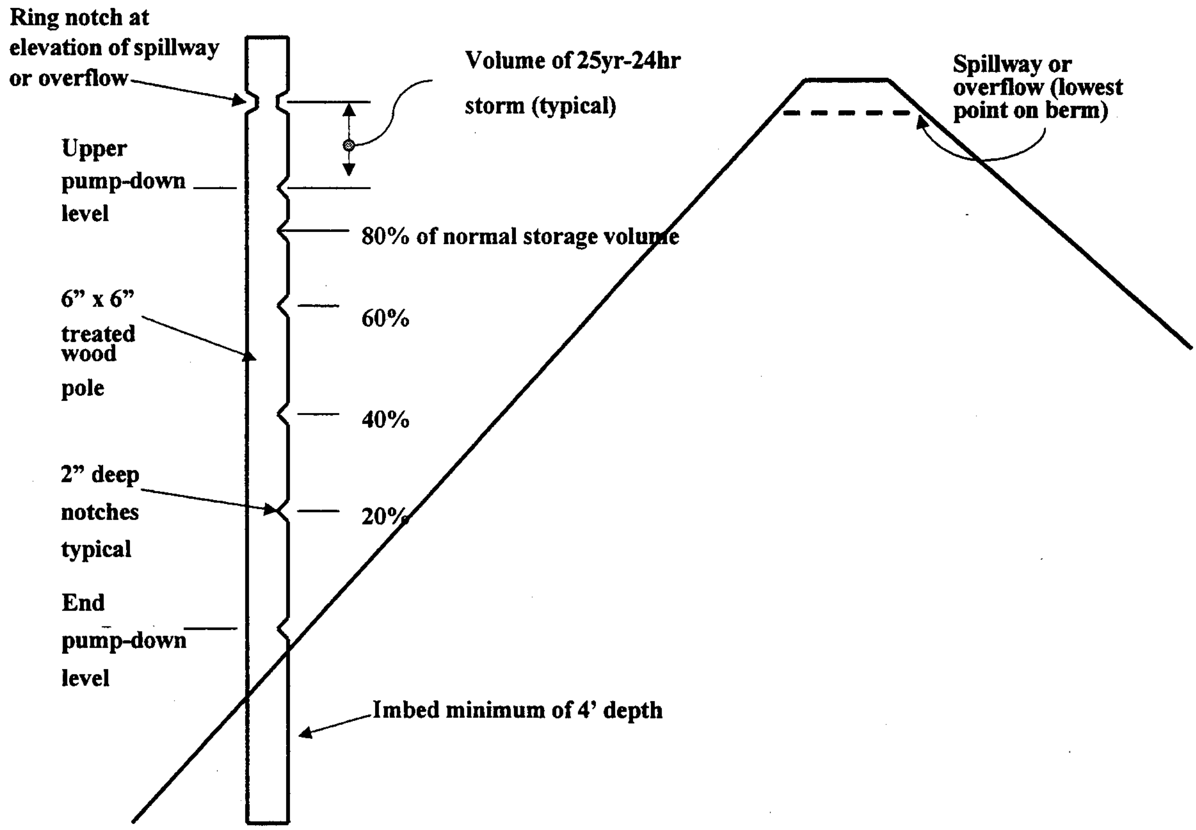


Figure 3. Pump-down marker in earthen impoundment

Weather stations

A simple weather station that indicates or records rainfall can be a useful tool in maintaining and managing a manure storage structure. Rainfall has a significant impact on open storage structures and structures serving open lots, so knowledge of rainfall amounts can be very useful. Some permits are written that provide for a "legal" discharge under certain climatic events. A weather station can aid in the documentation of such events without resorting to "off-site" data from stations that may not be descriptive of conditions at the storage facility. Recorded rainfall data is also evidence of good stewardship.

Aesthetics and appearance

Aesthetics and appearance may not be critical factors in protecting the environment or complying with environmental regulations. However, these characteristics are major factors in the perceptions formed by the general public, tour groups, regulatory or inspection personnel, and others who may not be intimately associated or familiar with the livestock industry. Therefore, aesthetics and appearance should be given major priority for the overall benefit and viability of animal agriculture.

The general cleanliness and sanitation characteristics of a livestock enterprise are often perceived as a measure of the concern of that enterprise for environmental stewardship and environmental compliance. A clean, well-landscaped production area will project a positive image for the operation, while the presence of debris, litter, and poorly maintained buildings will project a negative image. Typical items of concern for livestock production enterprises include leftover construction debris or refuse; old, unused vehicles; worn-out equipment; rusted equipment from the buildings (farrowing crates, pen dividers, feeders); torn and worn-out ventilation curtains; and loose roofing panels, etc. All livestock production operations experience animal death loss. A specific plan managing animal mortalities should be developed and implemented. The visual and olfactory perceptions generated by the presence of dead animals in or around the production facility are highly offensive and likely will be attributed to the industry as a whole by the general public. Additionally, poorly managed mortalities represent a very real health and disease risk to the enterprise.

Few activities undertaken by the producer are as effective as frequent mowing in conveying a positive image of livestock production. Producers who maintain "front yard quality" around the production and manure storage facilities provide a powerful first impression of pride and responsibility. Conversely, the presence of tall grass, weeds, shrubs, and trees in undesirable locations creates an impression of laxity and disrespect for environmental responsibility. Regulatory personnel inspect most livestock production and manure storage facilities at some interval. If tall grass, weeds, brush, and trees hamper the inspector, a positive report is an unlikely outcome. Routine inspections for seepage, rodent burrowing, erosion, or other damage are much more effective if the areas have been mowed at regular intervals.

Control of Surface Water

As confined production units become larger, control of surface water in the production area is a primary concern. Wider, longer buildings, placed relatively close together, create high rates of discharge from roof and paved areas. Special considerations and landscaping are needed to manage this water in a manner that does not create erosion and unwanted ditches and washed-out culverts or waterways. A surface water management plan should be developed based on a design storm event, expected runoff rates, soil types and erosive velocities, and properly designed and vegetated channels for carrying surface water away from the production area. Some states may require that surface water from production areas be contained and/or checked for contaminant levels before discharge to a watercourse.

Closure of Waste Impoundments

Anaerobic lagoons have been used for a number of years to treat and store animal waste from swine, poultry, and dairy cattle. Bacteria in the lagoons treat the waste by digesting organic matter and converting much of the mass to gases (ammonia, nitrogen, methane, and many others). A typical active lagoon consists of a large, dilute layer of fresh manure, water, and partially digested manure; and a layer of thick sludge at the bottom, which is primarily material that cannot be broken down by the anaerobic bacteria. The thickness of the sludge layer depends on the age of the lagoon, and on the loading rate and species of animals whose waste is being processed and stored.

Concerns have arisen over the past few years about what happens to lagoons when they no longer serve their intended purpose. As a result, provisions have been written into new rules that would require lagoons on Confined Animal Feeding Operations (CAFO's) greater than 1,000 animal units to be properly closed when no longer in service.

The rule citation is as follows:

Rule 391-3-6-.21 (5) (j)
When the owner or operator ceases operation of the AFO, he must notify the Division (EPD) of that fact within three months, and he must properly close all waste storage lagoons within eighteen months. In the case of voluntary closure, a period of twenty-four months from notification is allowed. Proper closure of a lagoon entails removing all waste from the lagoon and land applying it at agronomic rates, and in a manner so as not to discharge to any surface water stream.

The regulations also reference the Natural Resources Conservation Service (NRCS) Practice Standards as the guiding document for interpretation of the requirements. The NRCS Code that covers this subject is Code 360, Closure of Waste Impoundments. This document can be found on the web at: http://www.ga.nrcs.usda.gov/ga/gapas/FOTG/fotg_toc_frame.html under "Practice Standards and Specifications."

There are three options for managing the earthen lagoon after closure:

1. ***Complete closure and fill.***
2. ***Breaching the lagoon berm.***
3. ***Conversion to a farm pond or irrigation storage structure.***

In either case, the first steps are the same:

1. Remove all pipes or other structures that convey waste into the structure. Pipes should be dug up and ditches refilled
2. Remove as much of the stored waste and sludge as possible. This can be done by agitating the lagoon and pumping as much material out as possible, refilling with water

and repeating until almost all material has been removed. Alternatively, the effluent (relatively dilute liquid on top) can be pumped out, and the sludge can be removed using a slurry pump or excavation equipment.

3. All material must be land applied at agronomic rates (such that crops can utilize the nutrients).

If the lagoon is to be completely closed, it should then be filled in and the land returned to its approximate original contours. Soil should be mounded slightly in the lagoon area (4% slope) in order to allow for settling and to encourage surface water to run away from the site. Vegetation should be established on the site to prevent erosion.

If the lagoon berm is to be breached, all surface water runoff should first be diverted away from the lagoon. The breach should have sufficient side slope to prevent erosion. The NRCS can help with this design. It should be low enough to allow all water to flow from the structure and prevent ponding. Vegetation should be established on the entire site including the sides of the breach to prevent erosion.

If the lagoon is to be used as a farm pond, a watering source for livestock, or an irrigation storage pond, the structure should meet the requirements for these types of structures. A properly designed lagoon will probably meet those requirements without major alterations, but the NRCS should be able to provide technical assistance to assure this requirement is met. Water quality samples should be taken and submitted to assure safety before allowing livestock to drink from a converted lagoon. Dissolved oxygen (DO) levels should be higher than 3 milligrams per liter and nitrate nitrogen should be below 30 milligrams per liter.

Summary

Lagoons, manure slurry storage structures, and dry systems each have advantages and disadvantages. Lagoons reduce the nitrogen and organic matter in the waste stream by volatilizing them (converting them to gases and moving them into the air.) They also reduce the odor released compared to a slurry storage, but they are more expensive because of their larger size and must be carefully managed to maintain a healthy bacterial population. Slurry storage structures are smaller (do not include treatment volume or sludge storage), conserve more nutrients in the waste, and are easier to cover if necessary, but they tend to produce more odor if not covered. Dry systems keep manure in a concentrated form making it more transportable and less likely to flow into surface waters, but it must be handled as a solid which usually requires more labor than liquid systems which can use automated pumps. Solids separation devices remove much of the solids going into a liquid system and thus reduce the required volume for treating the waste, but they do require a large financial investment and require two types of manure handling equipment (liquid and dry). Whichever type of system is used, it is important to understand that it cannot perform as designed unless it is managed properly. For a lagoon, that includes starting it about 1/3 full of water before waste is added, preferably in the Spring, loading

it evenly, and maintaining the level between the minimum and maximum levels. For a slurry storage, it includes cleaning it out on a regular schedule, according to crop needs, and minimizing the amount of water entering the storage. Solids separating systems must have the solid fraction removed regularly (within the flexibility provided in the design) in order to keep them operating properly, and mechanical systems must be regularly maintained to avoid break downs.

Regular inspections and records of these inspections are vital to maintaining any manure storage and handling facility and to being able to prove that you are doing a good job managing your facility. Inspections should include investigations of existing or potential leaks, aesthetic appearance of facilities, and variations in odor levels. Regular monitoring and recording of lagoon levels is aided by the use of an easily read marker that shows **at a minimum** the overflow level, maximum storage level, and minimum pump-down level for the lagoon. Lagoon levels and weather forecasts should be studied so that pumping can be scheduled before it has to be done on an emergency basis. Berms should be checked for leaks, rodent burrows, erosion, and tree growth. Aesthetics include regular mowing and establishing vegetative screens where needed to present a pleasing picture to neighbors and those passing the farm.

If a lagoon is no longer used to store animal waste, it should be properly closed, including removal of all waste material. The structure can be filled in and reclaimed, the berm may be breached, or the structure can be converted for use as a farm pond. In any case all conveyances should be removed and exposed ground should be planted in a cover crop to prevent erosion. Until these steps occur, the lagoon should be managed just as it was before closure.

Appendix A
Monthly Manure Storage Facility Checklist

Farm:______________________________ Facility ID:______________________________

Inspected by:____ Date:__________________

Manure Level

Manure level today: (Distance below maximum fill level)__________ft.

Last observation:______________ft. Date:________

Earthen Storage Facilities

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Are embankments well-sodded with no bare areas?	Yes	No	
Are embankments free of trees or woody shrubs?	Yes	No	
Does the berm or embankment have a consistent elevation (i.e., no low or settled areas other than the planned spillway)?	Yes	No	
Is the spillway free of erosion?	Yes	No	
Are all berms and embankments free of erosion?	Yes	No	
Is the base of the embankment free of soggy, damp areas and other evidence of seepage or leaks?	Yes	No	
Are the embankments free of burrowing or other rodent damage?	Yes	No	
Is the liner free of damage due to rainfall, wind, or wave action?	Yes	No	
Is the liner free of erosion damage around inlet/outlet pipes and agitation points?	Yes	No	
Does the lagoon contain at least the minimum volume for treatment?	Yes	No	

Concrete/Steel Tanks

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Are tanks free of visible cracks or structural damage in walls or foundation?	Yes	No	
Is the area around the tank free of seepage or other evidence of leakage?	Yes	No	
Is the manure loadout area free of spills or accumulations of manure?	Yes	No	
Does surface water properly drain away from the manure tank?	Yes	No	

Diversions

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Is roof water and field runoff diverted?	Yes	No	
Are diversion ditches adequately sized to handle runoff without overtopping?	Yes	No	
Are diversion channels vegetated and free of erosion?	Yes	No	
Is storage available in secondary containment structures if required?	Yes	No	
Is there adequate drainage of surface water around production buildings and manure storage facilities?	Yes	No	

Components

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Are level markers properly installed and easy to read?	Yes	No	
Are manure inlet pipes submerged and properly supported?	Yes	No	
Are drains, sewer lines, and cleanouts in good condition and operating properly?	Yes	No	
Are perimeter drains or tiles open and functioning?	Yes	No	
Are recycle pumps, valves, controls, and pressure lines operating properly?	Yes	No	

Appearance

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Is the manure storage site neat and recently mowed?	Yes	No	
Is the manure storage site free of refuse, debris, unused materials, and junk?	Yes	No	
Is the manure storage site screened by visual barriers, and are these barriers maintained?	Yes	No	
Is the manure storage site free of carcasses, afterbirth, or medical wastes?	Yes	No	
Is the manure storage site properly fenced and marked?	Yes	No	
Is the lagoon purple and actively bubbling?	Yes	No	
Is the manure storage surface free of excessive floating materials or vegetation growth?	Yes	No	

6

Phosphorus Issues

Phosphorus Issues

Dr. David Radcliffe and Miguel Cabrera
Crop and Soil Sciences Department, University of Georgia

Intended Outcomes

The participants will

- Understand how P affects water quality
- Understand why manures present a special problem with P
- Understand how to assess risk of P loss from a field

Regulatory Background

The new Georgia swine, dairy, and layer regulations require that Comprehensive Nutrient Management Plans (CNMPs) be developed that meet NRCS standards. Starting in the fall of 2001, the NRCS standards require that CMNPs consider the risk of P losses from a field reaching a sensitive stream, river, or lake (NRCS, 1999).

How P Affects Water Quality

According to a recent survey by the U.S. EPA, accelerated *eutrophication* is the main cause of water quality "impairment" in the U.S. (U.S. EPA, 1996). Eutrophication is the natural aging of lakes or streams brought on by nutrient enrichment. This process is accelerated by human activities which increase nutrient loading rates to water. While both P and N contribute to eutrophication, P is the primary agent in freshwater eutrophication. In salt water estuaries, N is the primary nutrient controlling eutrophication.

Eutrophication restricts water use for fisheries, recreation, industry, and drinking, due to the increased growth of undesirable algae and aquatic weeds and oxygen shortages caused by their death and decomposition. Also, an increasing number of water resources are experiencing periodic algal blooms. These blooms contribute to a wide range of water-related problems including summer fish kills, unpalatability of drinking water, and formation of carcinogens during drinking water chlorination. This has increased the public awareness of eutrophication and the need for solutions.

Lakes are more sensitive to P than streams and rivers. A trophic index is used to measure the level of eutrophication in lakes and is based on P concentrations, chlorophyll-a content), and depth of visibility. Lakes with a trophic index above 60 are considered eutrophic. According to a survey by the Georgia Department of Natural Resources (DNR), several of the large lakes in Georgia show signs of eutrophication (Table 1). Due to accelerated eutrophication, the DNR has set limitations for three lakes in Georgia on the amount of P that can enter from tributaries. These lakes are Jackson, West Point, and Walter F. George. Phosphorus limitations for Lake Allatoona and Lake Lanier have been proposed.

The sources of P entering streams, rivers, and lakes in Georgia include sewage treatment plants and factories that discharge into streams, runoff from lawns with failing septic systems or fertilizer, runoff from agricultural land with manure or fertilizer, and natural background sources such as rock minerals and wildlife.

Ground water is not affected by P because of the absence of algae. Only when ground water returns quickly to a stream, river, or lake, do we need to worry about P leaching to ground water.

Table 1. Large lakes in Georgia with the ten highest levels of trophic index (DNR, 1995).

Lake	Trophic Index	Lake	Trophic Index
High Falls	65	Sinclair	59
Walter F. George	65	Seminole	59
Blackshear	64	Jackson	59
Oconee	63	Goatrock	58
Tobesofkee	60	Worth	57

What Happens When P is Added to Soils

Phosphorus is added to agricultural land as fertilizer or manure because it supplies an important element needed for plant growth. Phosphorus in soils exists in a number of mineral and organic forms, but most of it is adsorbed to iron and *aluminum* oxides in Georgia soils. These oxides have a large, but not unlimited, number of adsorption sites for P and when the adsorption sites start to fill up, there is more and more P dissolved in the soil water. It is mainly this *dissolved* P that is available to plants, and susceptible to runoff.

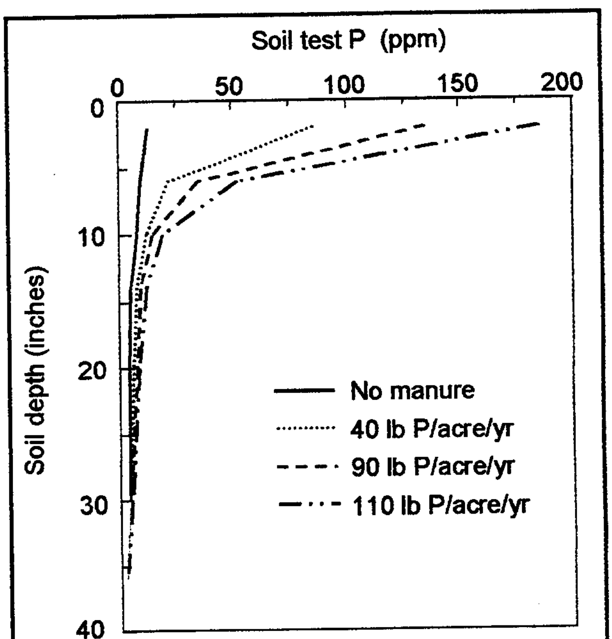


Figure 1. Soil test P as a function of depth for different rates of manure application.

P in soils can be expressed as P or P_2O_5. To convert P to P_2O_5, multiply by 2.29. When *discussing* plant available forms of soil P as determined by soil testing laboratories, we refer to them as *soil test P* (usually in parts per million or ppm) and identify in each case the specific method of analysis used (Mehlich-1, Mehlich-3, Bray-1, etc). Soil test P can also be expressed in lbs/acre. Based on a six inch soil depth containing 2 million pounds of soil, to convert

ppm to lbs/acre, multiply by 2.0.

In most soils, the P content of the topsoil is much greater than the subsoil (Fig. 1). As manure and fertilizers are added to soil, the levels at the surface increase sharply, but there is little effect in the subsoil in most cases. This is because most of the P is tightly adsorbed and doesn't move very far. In addition, P is cycled from roots to aboveground parts of the plant and redeposited in crop residues on the soil surface. In very sandy soils which are low in iron and aluminum oxides, P can move into the subsoil.

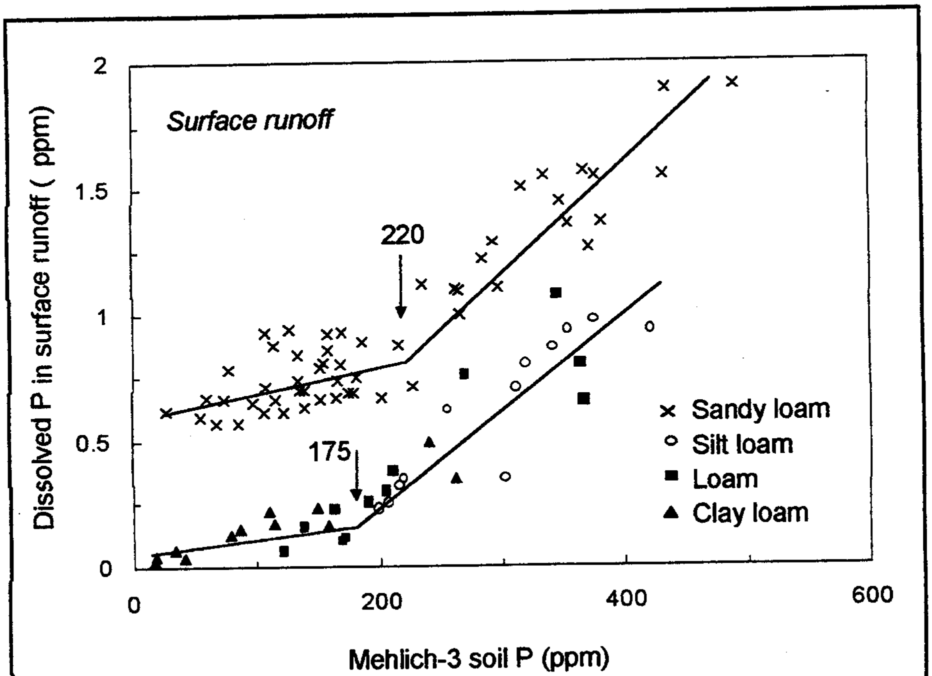


Figure 2. Dissolved P as a function of soil test P in four soils.

In recent years, we have learned that the concentration of P in runoff from agricultural fields increases as the soil test P level goes up. Part of the reason for this can be soil erosion where soil particles with high concentrations of adsorbed P are being washed off the field. But even in grass fields, where there is almost no erosion, research has shown that dissolved P concentrations in runoff increase with soil test P (Fig. 2). The reason why P concentrations in runoff increase with soil test P levels is that when rain occurs there is a thin layer of water near the surface that mixes with the soil water and can run off. If the concentration of P in the soil water is high (because most of the adsorption sites near the surface are filled with P), then the concentration in the runoff water will also be high. In Fig. 2, all soils show that P concentrations in runoff increase more sharply beyond a certain level of soil test P. This probably represents the level where most of the adsorption sites near the soil surface are filled.

There is no clear answer to what is an unacceptable concentration for P in runoff. The concentration of total P (adsorbed and dissolved) that is thought to trigger eutrophication in lakes is only 0.05 ppm.

In Fig. 2, even the lowest levels of soil test P produce concentrations in this range. Most researchers agree that a realistic target is to try and keep agricultural runoff P concentrations below 1.0 ppm. The level of soil test P above which runoff concentrations exceed 1.0 ppm is sometimes referred to as the *environmental threshold* soil test P. In Fig. 2, the environmental threshold level would be approximately 300 ppm soil test P for the sandy loam and 400 ppm soil test P for the silt loam. By comparison, the *agronomic threshold* level (soil P level above which there is no increase in yield) for most crops using a Mehlich-3 extractant is around 50 ppm. In general, the environmental threshold is 2-4 times higher than the agronomic threshold.

Why Manures Present a Special Problem for Phosphorus

For the most part, soil test P levels at the surface in excess of the environmental threshold are unlikely to occur unless manures are being used. Even though farmers have been encouraged to "build soil test P" levels in the past, the cost of fertilizers discourages over-application of P in most cases. Manures present a special problem because the N-to-P ratio in manure is not the same as what most crops need. Most crops use about 8 lbs of N for every lb of P, or a ratio of 8-to-1. But manures usually have a much lower ratio. For example, a typical sample of broiler litter would have 71 lbs of total N and 30 lbs of total P per ton of litter, a ratio of 2.4-to-1 (Table 2). Since only about half of the manure N is usually available to plants (due to losses and limited organic N decomposition), the effective ratio is 1.2-to-1. This means for every 8 lbs of broiler litter N applied, one applies 6.7 lbs of P (8 divided by 1.2), or 6.7 times as much as the crop needs. As a result, excess P builds up at the soil surface in fields that receive repeated manure applications. Average N-to-P ratios vary for different manures and storage methods (Table 3). Values for a given operation need to be determined from periodic manure sample analysis.

Table 2. N-to-P ratios for different manures, ratios adjusted for available N, and the resulting over-application of P.

Type of Manure	N Content[1]	P Content[1]	N-to-P Ratio	Adjusted N-to-P Ratio[2]	Over-application of P
Anerobic swine lagoon	128 lbs/acre-in	22 lbs/acre-in	5.8	2.9	2.8 times crop needs
Anerobic dairy lagoon	132 lbs/acre-in	33 lbs/acre-in	4.0	2.0	4.0 times crop needs
Anerobic layer lagoon	179 lbs/acre-in	20 lbs/acre-in	9.0	4.5	1.7 times crop needs
Broiler litter	71 lbs/ton	30 lbs/ton	2.4	1.2	6.7 times crop needs

[1] from Barker et al. (1994).
[2] adjusted for available N (assumed to be half of the total N).

As a result of the low N-to-P ratio in manure, excess P builds up at the soil surface in fields that receive repeated applications. This appears to have happened in many grass fields in the Piedmont region of Georgia where broiler litter applications are common. In 1995, 42% of the bermuda grass and 33% of the summer grass soil samples submitted to the University of Georgia Soil Analysis Laboratory tested High or Very High in soil test P.

Dry manures present a special additional problem when they are applied to grass fields and not incorporated. Under these circumstances, there is very little contact between the manure P and the oxides in soils. Rain water mixes directly with the manure causing a high concentration of dissolved P in the runoff. Some of adsorbed organic P also enters runoff as the manure is eroded from the site. Research has shown that runoff P concentrations are unrelated to soil test P in these situations. Runoff P concentrations can be quite high (> 25 ppm) when runoff occurs within a few weeks of manure application.

Best Management Practices to Reduce P Runoff Losses

There are a number of best management practices (BMPs) that can be adopted to reduce the risk of P contamination of surface waters. Some of these reduce the source of P and others inhibit transport.

The most obvious BMP for reducing the P source is to base nutrient management plans (NMP) on the crop's need for P rather than N (a P-based vs. a N-based NMP). This means that additional land must be found for manure application or livestock numbers must be reduced. Another way to reduce the P source is to make P in the feed more digestible so that lower levels can fed. This can be done by adding phytase enzyme to feed or through the use of new hybrids of corn that have a highly digestible form of P (Ertl et al., 1998). The P source can also be reduced by adding a compound called *alum* to the manure. The aluminum in alum combines with P in the manure and forms an insoluble compound. As a result, the dissolved P levels in runoff are lower when alum-treated manure is applied to fields (Moore and Miller, 1994). A simple way to reduce the source is not to apply manure during periods when runoff-producing rains are expected, for example in the winter months. If it's possible to incorporate dry manure or inject lagoon slurries, this will also reduce the source.

One of the most important BMPs that affect transport is the use of grass filter strips and stream-side buffers. Grass filter strips are very effective in filtering out P adsorbed to sediment because they slow down the flow of water and cause the sediment to settle out. They have less of an effect on the P dissolved in runoff. Artificially drained fields (tile drains or ditches) present a special danger in that transport from the field to the stream is enhanced. High concentration P water may move to the drains in sandy soils where there is little adsorption. Avoiding manure application to artificially drained fields is the best practice. Transport of P can also be reduced by any BMP that reduces runoff and erosion. Examples would be conservation tillage, terracing, contour plowing, and impoundments.

Determining the Risk for P Loss in a Field

If the risk for P loss to a sensitive water body is sufficiently high, then a P-based plan should be adopted. But how do we determine the risk and what is *sufficiently high*? The NRCS has directed their state offices that they may use one of three different approaches to assess the risk for P loss (NRCS, 1999). They can use the agronomic threshold level of soil test P as the dividing line between N-based and P- based plans. In other words, in Georgia if your soil test P was above 40 lbs/acre in the Piedmont or 60 lbs/acre in the Coastal Plain you would be on a P-based plan. The second option is to determine what the environmental threshold soil test P level is for benchmark soils and use this as the dividing line. Since environmental thresholds are usually 2-4 times the agronomic thresholds, soil test P would have to be above 80-160 lbs/acre in the Piedmont or 120-240 lbs/acre in the Coastal Plain to trigger a P-based plan.

These two approaches are fairly simple (especially the first since we already know the agronomic threshold for our soils and crops), but they have the disadvantage that they ignore any assessment of the likelihood that P will actually be transported to a sensitive water body. The third option is to use a *P index* that attempts to assess the risk for the P source and P transport factors. This might be compared to the heat index which gives us a temperature that has been adjusted to take into account both temperature and humidity and more accurately represents how hot it will seem to us. The disadvantage of the P-index is that it is more complex.

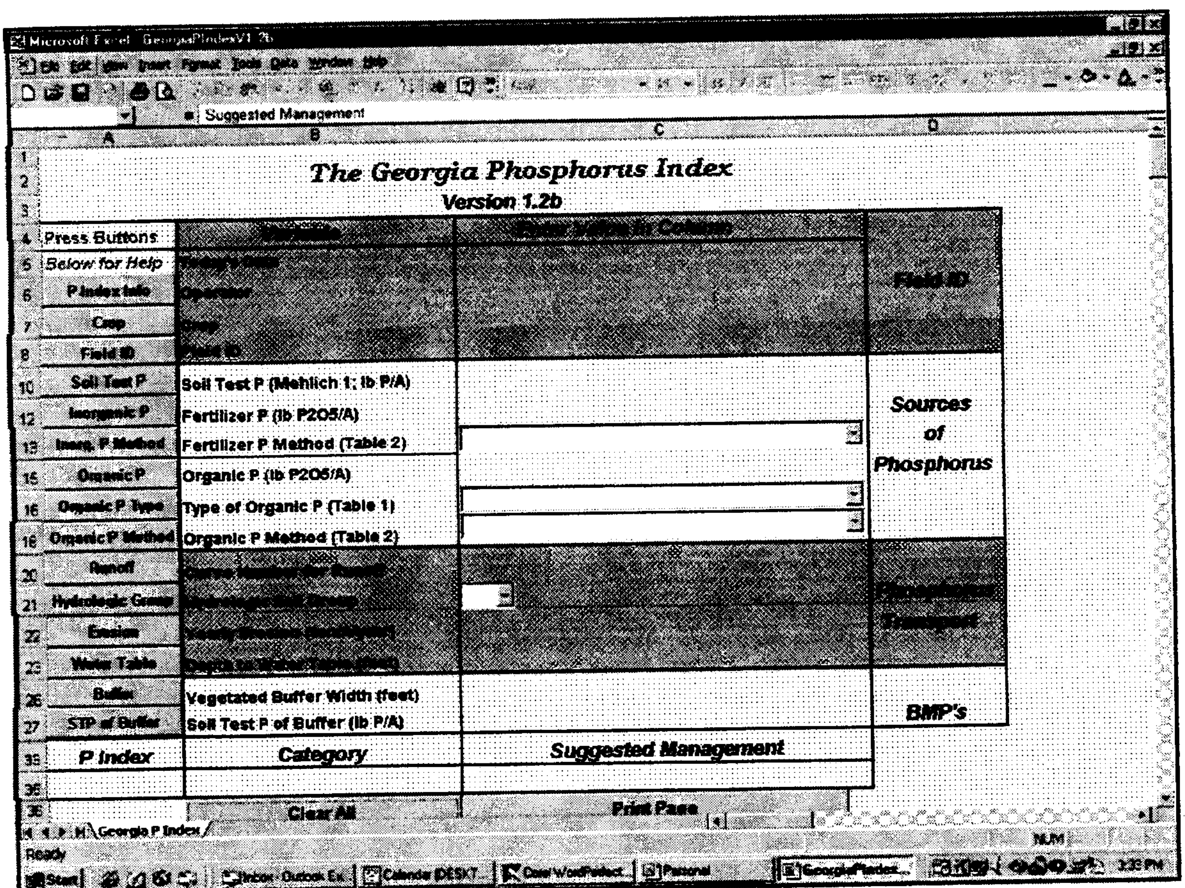


Figure 3. Georgia P index source, transport, and BMP factors.

In Georgia, the NRCS state office appointed a task force in the summer of 2000 to consider which method should be used to assess P loss risk. This group decided that the P index provides the greatest flexibility and has developed an index suitable adapted to Georgia.

Georgia P Index

The index is calculated using a spreadsheet and considers source, transport, and BMP factors (Fig. 3). The sources of P include soil test P, fertilizer P, and organic P (manures). The methods of applying fertilizers and manures are also considered. The transport mechanisms include runoff, erosion, and drainage (a function of the soil hydrologic group and the depth to the water table). The only BMP considered (aside from methods of applying fertilizers and manures) is vegetated buffers. To be effective in filtering P, the soil test P in the buffer must not be too high so that too is a factor.

Table 3. Interpretation of the Georgia P index.

P Index Range	Category	Generalized Interpretation
0 to < 40	Low	Low potential for P movement from this site. Nitrogen-based nutrient management planning is usually satisfactory.
40 to ≤ 75	Medium	Medium potential for P movement from this site. Use conservation practices and P applications that maintain a P Index < 75.
75 to < 100	High	High potential for P movement from this site. Add conservation practices or reduce P applications to achieve a P Index < 75 in the short term. If this cannot be achieved with realistic conservation practices and reduced P rates in the short term, then a management plan needs to be developed with the goal of achieving a P Index < 75 within 5 years.
≥ to 100	Very High	Very high potential for P movement from this site. Add conservation practices or reduce P applications to achieve a P Index < 100 in the short term. Develop a management plan with the goal of achieving a P Index < 75 within 5 years.

The source, transport, and BMP factors are combined to get an overall P index:

P Index = *Risk of Soluble P in Runoff + Risk of Particulate P in Runoff + Risk of Soluble P in Leachate*

Depending on the value of the P index, the site is considered to have a Low, Medium, High, or Very High potential for P loss (Table 3). If the P index is low, then N-based NMPs can be used. If the P index is too high, then a management plan to reduce the P index needs to be implemented and could include a P-based NMP.

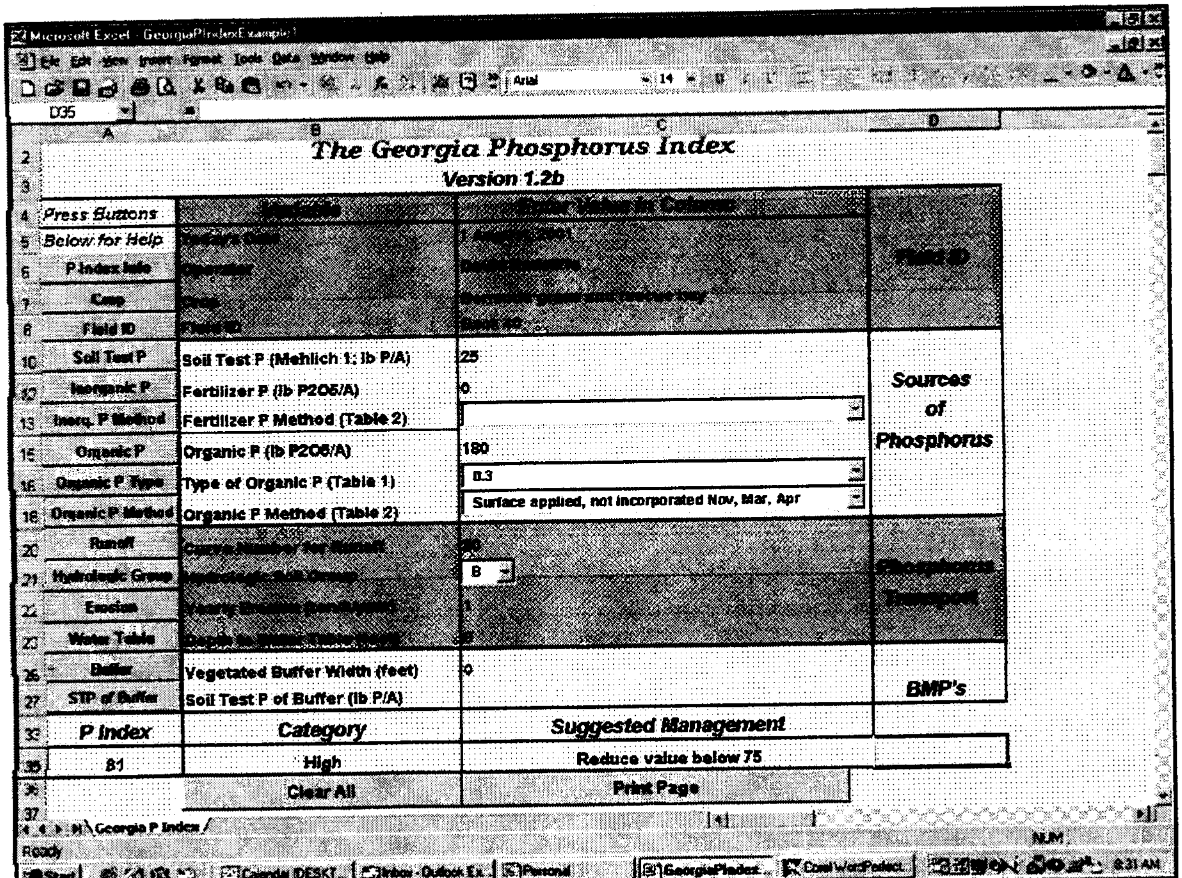


Figure 4. Georgia P index example calculation with manure application in March.

Suppose we have a hay field with the following source characteristics: the soil test P level is 25 lb/acre; poultry litter without any alum added is surface applied annually in March at a rate of 3 tons/acre (equivalent to 180 lbs P_2O_5 /acre); no fertilizer is applied. The site has the following transport characteristics: the runoff curve number is 80 (calculated using TR-55 or obtained from NRCS); the soil hydrologic group is B (obtained from Soil Survey database); the estimated annual erosion is one ton/acre (calculated using USLE or obtained from NRCS farm plan); the depth to the water table is 8 feet or more; there are no buffers around the field.

The calculated P index is 81, which is in the High category and we are advised to change our management plant in order to reduce the P index below 75 (Fig. 4). By simply changing the time of application of the manure from March to sometime in the period May to October we can reduce the risk of runoff and lower the P index to 62, which is in the Medium category and we can stay on a N-

based plan (Fig. 5). Alternatively, a 10-ft wide buffer could be used (assuming the soil test P in the buffer area was the same as the field) to reduce the P index to within the Medium category.

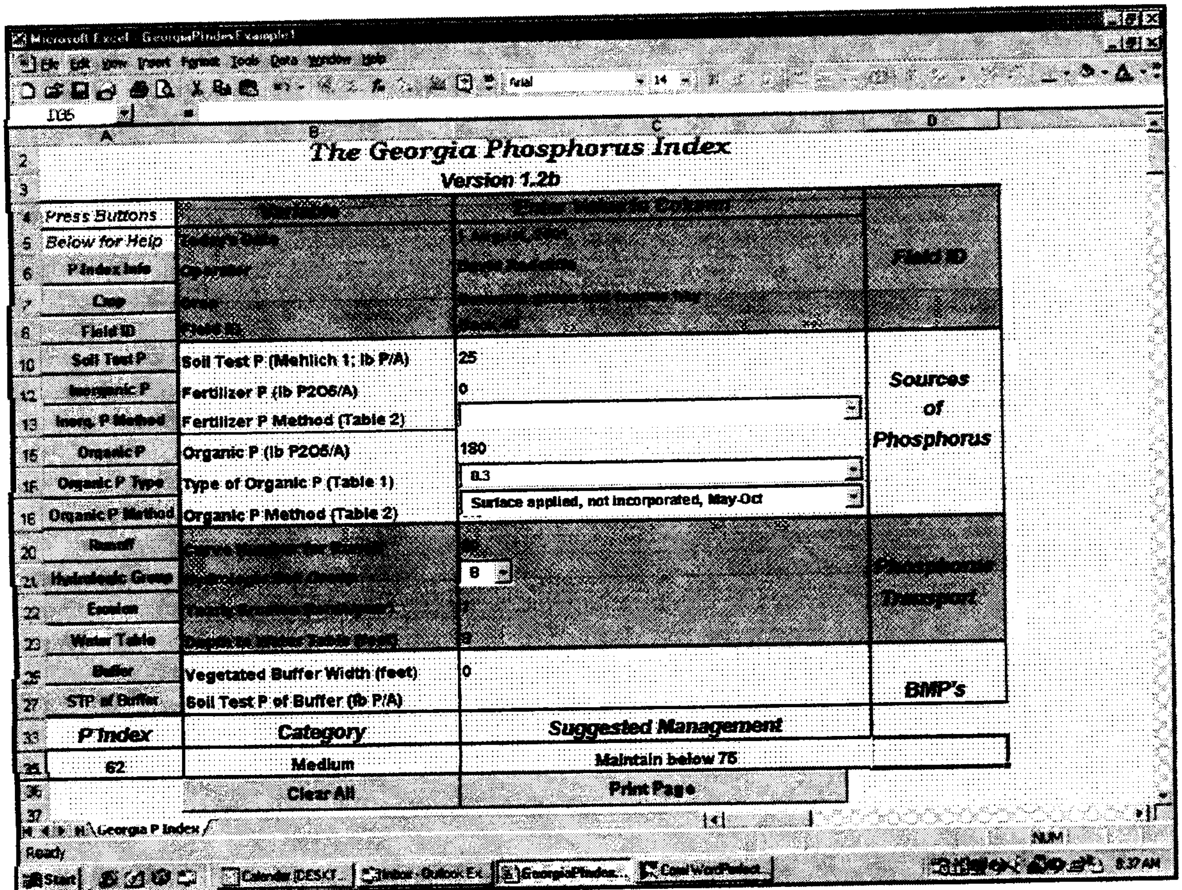


Figure 5. Georgia P index example calculation with manure application May-Oct.

Summary of Essential Information

The most essential points in this lesson are listed below.

- The primary water quality concern with P is that it can cause eutrophication of lakes.
- Several large lakes in Georgia already show signs of eutrophication.
- Most of the P in soils is tightly adsorbed in the topsoil; but soil can be eroded with runoff, and a small amount of P is dissolved and also available to runoff.
- As the soil test P level at the soil surface goes up, so does the concentration of P in runoff.
- Manures present a special problem because the N-to-P ratio in manure is not the same as what most crops need – as a result P is over-applied when a N-based NMP is used.
- P-based plans will require substantially lower manure application rates.
- For P contamination to occur, there must be a source of high concentration P and a mechanism for transporting the P to a sensitive water body.

- There are a number of best management practices that limit the source or transport of P.
- The P index will be used to determine which fields in Georgia should have a P-based NMP.

References

Barker, J.C., J.P. Zublena, and C.R. Campbell. 1994. Agri-waste management: Livestock manure production and characterization in North Carolina. North Carolina Cooperative Extension Service. Raleigh, NC.

DNR. 1995. 1993 major lake monitoring project. Georgia Department of Natural Resources. Atlanta, GA. 30334.

Ertl, D.S., K.A. Young, and V. Raboy. 1998. Plant genetic approaches to phosphorous management in agricultural production. J. Environ. Qual. 27:299-304.

Gburek, W.J., A.N. Sharpley, L. Heathwaite, and G.J. Folmar. 2000. Phosphorus management at the watershed scale: A modification of the phosphorus index. J. Environ. Qual. 29:130-144.

Moore, P.A., Jr. and D.M. Miller. 1994. Decreasing phosphorus solubility in poultry litter with aluminum, calcium, and iron amendments. J. Environ. Qual. 23:325-330.

NRCS. 1999. Nutrient management conservation practice standard. Code 590. http://www.ga.nrcs.usda.gov/ga/gapas/cps_ga.htm.

Peterjohn, W.T. and D.L. Correl. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology 65:1466-1475.

U.S. EPA. 1996. Environmental indicators of water quality in the United States. EPA 841-R-94-002. USEPA. Office of Water (4503F). U.S. Govt. Printing Office. Washington, D.C.

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description: Cover type	Hydrologic condition	A	B	C	D
		Curve numbers for hydrologic soil group			
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Runoff

When CN and the amount of rainfall have been determined for the watershed, determine runoff by using figure 2-1, table 2-1, or equations 2-3 and 2-4. The runoff is usually rounded to the nearest hundredth of an inch.

Limitations

- Curve numbers describe average conditions that are useful for design purposes. If the rainfall event used is a historical storm, the modeling accuracy decreases.

- Use the runoff curve number equation with caution when re-creating specific features of an actual storm. The equation does not contain an expression for time and, therefore, does not account for rainfall duration or intensity.

- The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a, which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors, was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place. The opposite effect, a greater initial loss, can occur if the impervious areas have surface depressions that store some runoff. To use a relationship other than $I_a = 0.2S$, one must redevelop equation 2-3, figure 2-1, table 2-1, and table 2-2 by using the original rainfall-runoff data to establish new S or CN relationships for each cover and hydrologic soil group.

- Runoff from snowmelt or rain on frozen ground cannot be estimated using these procedures.

- The CN procedure is less accurate when runoff is less than 0.5 inch. As a check, use another procedure to determine runoff.

- The SCS runoff procedures apply only to direct surface runoff: do not overlook large sources of subsurface flow or high ground water levels that contribute to runoff. These conditions are often related to HSG A soils and forest areas that have been assigned relatively low CN's in table 2-2. Good judgment and experience based on stream gage records are needed to adjust CN's as conditions warrant.

- When the weighted CN is less than 40, use another procedure to determine runoff.

Examples

Four examples illustrate the procedure for computing runoff curve number (CN) and runoff (Q) in inches. Worksheet 2 in appendix D is provided to assist TR-55 users. Figures 2-5 to 2-8 represent the use of worksheet 2 for each example. All four examples are based on the same watershed and the same storm event.

The watershed covers 250 acres in Dyer County, northwestern Tennessee. Seventy percent (175 acres) is a Loring soil, which is in hydrologic soil group C. Thirty percent (75 acres) is a Memphis soil, which is in group B. The event is a 25-year frequency, 24-hour storm with total rainfall of 6 inches.

Cover type and conditions in the watershed are different for each example. The examples, therefore, illustrate how to compute CN and Q for various situations of proposed, planned, or present development.

Example 2-1

The present cover type is pasture in good hydrologic condition. (See figure 2-5 for worksheet 2 information.)

Example 2-2

Seventy percent (175 acres) of the watershed, consisting of all the Memphis soil and 100 acres of the Loring soil, is 1/2-acre residential lots with lawns in good hydrologic condition. The rest of the watershed is scattered open space in good hydrologic condition. (See figure 2-6.)

Figure 2-5 Worksheet 2 for example 2-1

Worksheet 2: Runoff curve number and runoff

Project: Heavenly Acres	By: WJR	Date: 10/1/85	
Location: Dyer County, Tennessee	Checked: NM	Date: 10/3/85	

Check one: [X] Present [ ] Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Figure 2-3	CN 1/ Figure 2-4	Area [ ] acres [ ] mi² [X] %	Product of CN x area
Memphis, B	Pasture, good condition	61			30	1830
Loring, C	Pasture, good condition	74			70	5180
					Totals ➡ 100	7010

1/ Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7010}{100} = 70.1$; Use CN ➡ 70

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour)	in	6.0		
Runoff, Q (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	in	2.81		

Worksheet 2: Runoff curve number and runoff

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN [1/] Figure 2-3	CN [1/] Figure 2-4	Area ☐ acres ☐ mi^2 ☐ %	Product of CN x area
				Totals ➡		

[1/] Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ____________ = ________ ; **Use CN ➡** ☐

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	in			

7

Nutrient Budgeting of Manure

Nutrient Budgeting of Manure

Glen Harris

Introduction

Animal manures have been used as a fertilizer and soil amendment for crop land since man first domesticated animals. Used properly and at appropriate rates, animal manures can recycle and supply valuable plant nutrients and improve soil quality. Used improperly and at rates that exceed crop nutrient needs, animal waste can be an environmental and true waste disposal problem.

Animal waste come in a variety of forms and are applied in a variety of methods. Solid manure, liquid manure, litters, composts, and lagoon effluents represent the most common types of manure that are now applied to soils through a variety of spreading, tillage, and irrigation practices. Compared to inorganic commercial fertilizers, animal manures are generally bulky, highly variable in composition and low in nutrient content. The amount of a manure required to supply nutrients to a crop can easily be 10- to 100-fold the amount of commercial fertilizer needed by the same crop. Although low in nutrient content, the large volume of manure normally generated on a farm can represent a significant amount of fertilizer value. For these reasons, land application is the most common usage of animal manures. The economics of hauling animal manures great distances or using manures for alternative purposes such as feed or fuel are not currently feasible. Until the economic feasibility and practicality of transporting manures long distances or alternative usage improves, land application will continue to be the primary way animal manures are handled. Also, the potential to over apply animal manures on land close to concentrated animal feeding operations will remain.

Animal manures usually contain significant amounts of the primary nutrients (N, P and K) and lesser amounts of secondary (Ca, Mg, S) and micronutrients (Zn, Mn, etc) essential for plant growth. Balancing the nutrients contained in animal manures with crop needs and determining an appropriate application rate for agronomic purposes used to be referred to as a "nutrient management plan". Now it is more common to view this exercise as a key component of a larger "comprehensive nutrient management plan". Traditionally, manure application rates are calculated to provide nitrogen (N) to crops. This is due to the fact that most crops demand more N than any other fertilizer element. Nitrogen is also usually the most expensive fertilizer nutrient to purchase. Balancing manure rates with a crop's need for N is also known as using N as a "priority nutrient" or using an "N-based plan". For many years, the environmental concern associated with excessive nitrogen applications from manure was nitrate leaching into groundwater. N-based nutrient management plans are a way to deal with this concern. Recently, environmental concerns have focused more on excessive phosphorous applications from manures and the adverse effect on surface water quality. Although using P as the priority nutrient, or "P-based" plans, are not currently required, they may be in the future and they need to be considered.

Nutrient budgets or balances can be either calculated by hand or by using a computer program. A "Nutrient Budget Worksheet" is provided at the end of this chapter for hand calculations (Appendix A). This worksheet was originally developed for dairy manure nutrient management in Georgia. Space for calculations based on only one priority nutrient (N or P, not both) is provided however. The preferred method of calculating nutrient balances of manure is to use the "Georgia Field Level Nutrient Budget Worksheet" (Appendix B). This spreadsheet can be downloaded as either an Excel or Quattro Pro

program by going to the AWARE homepage at http://www.engr.uga.edu/service/extension/aware . Simply click where instructed under "Nutrient Management Planning in Georgia" in the upper right hand corner of the page.

Nutrient budgeting, either by hand or using the computer, can serve a number of different purposes. The most common purpose will be to determine the proper application rate for a given field in a real situation using real numbers for crop needs and nutrients in manure. Nutrient budgeting can also be used as a planning tool at the farm level to determine if adequate land base is present for the cropping system planned. Finally, nutrient budgeting can be used as an educational tool to calculate application rates based on various "simulated" scenarios, for example, how much manure can I apply if I have this particular soil test phosphorous level?

Regardless if done by hand or by computer, nutrient budgeting or balances contain three basic steps:

1) Determine Crop Nutrient Needs,
2) Determine Nutrients Supplied by Manure
3) Balance Crop Nutrient Needs with Nutrients Supplied by Manure

Determine Crop Nutrient Needs

The first step of any nutrient budgeting plan is to determine the nutrient requirements of the crop to be grown. Crops are an integral part of the system. Without a crop to actively utilize nutrients and prevent erosion, nutrients applied in manure could be washed directly into surface streams or leached into the groundwater. The vegetative cover also reduces the potential for runoff and erosion from an area.

When selecting a crop, there are numerous considerations other than nutrient requirement. Two important considerations are the suitability and adaptation of the crop to the local environment and the economic value of the crop. The crop must also be able to absorb nutrients when manure applications are made as well as produce adequate yields.

Insufficient nutrient supply from manure applications can result in deficiencies, which can reduce crop yield and quality, and decrease utilization of manure nutrients. Excessive applications can negatively affect both the plant and the environment. The effect of too much fertilization on plant growth depends on the crop and nutrients involved. In most cases, too much phosphorus (P) and potassium (K) have little effect on plant growth and yield unless so much is applied that salt injury results. However, too much P in the soil may have negative environmental consequences if significant amounts of P exit the site.

Too much nitrogen (N) can reduce yields by making plants more susceptible to diseases and insects, increasing lodging, and stimulating vegetative growth at the expense of fruit or grain production. Excess metals, such as copper and zinc, can be also be toxic to plants. In extreme cases, soil concentrations of these metals can be high enough to limit or prevent the growth of certain crops.

Crops vary in their ability to use nutrients. Some examples of the nutrient uptake by common crops are shown in Table A.

Table A. Plant nutrient uptake by specified crop and removed with the harvested part of the crop. Table A represents U.S. Averages.

Crop	N	P_2O_5	K_2O	Units
Grain Crops				
Barley (Grain)	0.87	0.37	0.25	lbs./bu.
(Straw)	15.00	5.04	30.12	lbs./ton
Buckwheat (Grain)	0.79	0.34	0.26	lbs./bu.
(Straw)	15.60	2.29	54.46	lbs./ton
Corn Grain (Grain)	0.90	0.36	0.27	lbs./bu.
(Stover)	22.20	9.16	32.29	lbs./ton
Oats (Grain)	1.27	0.51	0.38	lbs./bu.
(Straw)	12.60	7.33	40.00	lbs./ton
Rice (Grain)	0.63	0.25	0.12	lbs./bu.
(Straw)	12.00	4.12	27.95	lbs./ton
Rye (Grain)	1.16	0.33	0.33	lbs./bu.
(Straw)	10.00	5.50	16.63	lbs./ton
Sorghum (Grain)	0.94	0.46	0.28	lbs./bu.
(Stover)	21.60	6.87	31.57	lbs./ton
Wheat (Grain)	1.25	0.85	0.38	lbs./bu.
(Straw)	13.40	3.21	23.37	lbs./ton
Oil Crops				
Flax (Grain)	2.29	0.71	0.57	
(Straw)	24.80	5.04	42.17	lbs./ton
Peanuts (Grain)	36.00	3.89	6.02	lbs./1000 lbs.
(Vines)	46.60	10.99	42.17	lbs./ton
Rapeseed (Grain)	1.80	0.90	0.46	lbs./bu.
(Straw)	89.60	19.69	81.20	lbs./ton
Soybeans (Grain)	3.75	0.88	1.37	lbs./bu.
(Stover)	45.00	10.08	25.06	lbs./ton
Sunflower (Grain)	35.70	39.16	13.37	lbs./1000 lbs.
(Stover)	30.00	8.24	70.36	lbs./ton
Fiber Crops				
Cotton	26.70	13.28	10.00	lbs./1000 lbs.
(Seed Stalk)	17.50	5.04	17.47	lbs./1000 lbs.
Pulpwood	0.12	0.05	0.07	%
(Bark & branches)	0.12	0.05	0.07	%
Forage Crops				
Alfalfa	45.00	10.08	45.06	lbs./ton
Bahiagrass	25.40	5.95	41.69	lbs./ton
Big bluestem	19.80	38.93	42.17	lbs./ton
Birdsfoot trefoil	49.80	10.08	43.86	lbs./ton
Bluegrass-pastd.	58.20	19.69	46.99	lbs./ton
Bromegrass	37.40	9.62	61.45	lbs./ton
Clover-grass	30.40	12.37	40.72	lbs./ton
Dallisgrass	38.40	9.16	41.45	lbs./ton
Guineagrass	25.00	20.15	45.54	lbs./ton

Crop	N	P_2O_5	K_2O	Units
Forage Crops (continued)				
Bermudagrass	37.60	8.70	33.73	lbs./ton
Indiangrass	20.00	38.93	28.92	lbs./ton
Lespedeza	46.60	9.62	25.54	lbs./ton
Little bluestem	22.00	38.93	34.94	lbs./ton
Orchardgrass	29.40	9.16	52.05	lbs./ton
Panagolagrass	26.00	21.53	45.06	lbs./ton
Paragrass	16.40	17.86	38.31	lbs./ton
Red clover	40.00	10.08	40.00	lbs./ton
Reed canarygrass	27.00	8.24	-	lbs./ton
Ryegrass	33.40	12.37	34.22	lbs./ton
Switchgrass	23.00	4.58	45.78	lbs./ton
Tall fescue	39.40	9.16	48.19	lbs./ton
Timothy	24.00	10.08	38.07	lbs./ton
Wheatgrass	28.40	12.37	64.58	lbs./ton
Silage Crops				
Alfalfa haylage	27.90	7.56	27.95	lbs./ton
Corn silage	7.70	4.01	9.19	lbs./ton
Forage sorghum	8.64	2.61	7.37	lbs./ton
Oat haylage	12.80	5.13	9.06	lbs./ton
Sorghum-sudan	13.60	3.66	17.47	lbs./ton
Sugar Crops				
Sugarcane	3.20	1.83	8.92	lbs./ton
Sugar beets	4.00	1.37	3.37	lbs./ton
Sugar beet tops	8.60	1.83	24.82	lbs./ton
Tobacco				
All types	37.50	7.56	60.00	Lbs./1000 lbs.
Vegetable Crops				
Bell peppers	8.00	5.50	11.81	lbs./ton
Beans, dry	62.60	20.61	20.72	lbs./ton
Cabbage	6.60	1.83	6.51	lbs./ton
Carrots	3.80	1.83	6.02	lbs./ton
Cassava	8.00	5.95	15.18	lbs./ton
Celery	3.40	4.12	10.84	lbs./ton
Cucumbers	4.00	3.21	7.95	lbs./ton
Lettuce (heads)	4.60	3.66	11.08	lbs./ton
Onions	6.00	2.75	5.30	lbs./ton
Peas	73.60	18.32	21.69	lbs./ton
Potatoes	6.60	2.75	12.53	lbs./ton
Snap beans	17.60	11.91	23.13	lbs./ton
Sweet corn	17.80	10.99	13.98	lbs./ton
Sweet potatoes	6.00	1.83	10.12	lbs./ton
Table beets	5.20	1.83	6.75	lbs./ton

Source: NRCS Agricultural Waste Management Field Handbook 1992.

Please note that Table A is generalized for the U.S., and specific data for your region should be obtained from local experts. These values can be used to determine crop nutrient needs. However, the best way and preferred method of determining crop nutrient needs is through soil testing. Public or private services can be used as long as the laboratories are considered reputable and use methods adapted for your local region. Most soil testing laboratories give results and recommendations for the major plant nutrients (N, P, K), secondary plant nutrients (Ca, Mg, S), micronutrients (Mn, Zn) and pH. Even though most manure budgets will be based on either N or P, it is important always soil test and keep good records of all of these essential plant nutrients in order to provide an overall proper balance of soil fertility to the crop.

Another important reason for soil sampling on a routine basis is to track soil pH and follow appropriate lime recommendations. Some animal manures such as poultry litter have a slight liming capacity. Therefore, where poultry manures are used, liming may not be recommended as frequently compared to where they are not used. In addition, nutrient availability in soils is very dependent on proper soil pH. If soil pH is not closely monitored (recommend annually for fields receiving manure applications), nutrient availability and uptake may be very different from expected results. Not only is liming important for proper availability of essential plant nutrients, but liming can also render certain nutrients that are toxic to most plants, like aluminum for example, unavailable.

Even though soils are not tested for N content, N recommendations for crop growth are included on soil test reports. The reason soil N is not analyzed is that this element is highly mobile in the soil and is constantly going through transformations such as mineralization, leaching, volatilization, and immobilization. Some areas in the U.S. are able to utilize soil nitrate testing for pre-plant or pre-sidedress N recommendations. However, on highly weathered, low organic matter, sandy soils of the Southeast, these testing procedures have not been deemed successful. Therefore, N recommendations as found on the soil test reports in the Southeastern U.S. are based on field studies where varying rates of N fertilizer were applied and crop yield response was measured.

Legume plants, such as peanuts, soybeans, clovers and vetches, are not good candidates for receiving manure applications since they fix their own N. When non-legume plants like corn or cotton follow these plants in rotation, the "residual" nitrogen must be accounted for in the nutrient budget. Alfalfa, vetch and clover give an N "credit" of 80 lb/a to the following crop, whereas soybeans and peanuts are worth 30 lb N/a. These values can also be easily referenced in a Table 2 in the UGA computer spreadsheet program.

Fertilizer credits, not only N but P and maybe K too, also need to be accounted for when using commercial fertilizer or any other nutrient source in conjunction with animal manure. A good example of this would be the use of starter fertilizer such as 10-34-0 on corn or cotton. Both the hand and computer versions of the nutrient budget sheets have space just under the input line for "crop needs" to factor in both other fertilizer and residual N credits from legumes. In the computer version, once you enter the values for "Commercial Fertilizer Applications" and "Residual N from Legumes" the final crop nutrient needs of the plant are automatically calculated and appear in the "Net Manure Nutrient Needs of Crop" columns for N, P_2O_5 and K_2O.

Final crop yields are not determined by soil fertility alone. Other factors such as soil management,

climate, plant population, timing, pest control, and variety selection are also important. Because the amount of nutrients required by a crop usually varies directly with the yield, expected yields must be considered. Fortunately, soil test reports from reputable laboratories in your area should already account for yield goals. In some cases, for example cotton fertilizer recommendations in Georgia, most labs request input on yield goal and adjust accordingly. In other cases, for example corn recommendations from the University of Georgia, different yield goals are used for dryland vs. irrigated. Guidelines are also given to adjust for higher yields. Where yield records are available, you can average the three highest yields in five consecutive crop years to calculate a realistic yield goal for a given field. Using an unrealistic yield goal that is too high, can result in overapplication of nutrients in manure. On the otherhand, underestimating yield goal or potential can result in under application of nutrient and possibly crop nutrient deficiencies.

Determine Nutrients Supplied by Manure

The second basic step in developing a nutrient budgeting plan is very similar to the first. In this case instead of having soil analyzed to determine crop nutrient needs, the animal manure is analyzed to determine the nutrient supplying power of the manure. Like with soil sampling, taking a representative sample is important to get an accurate estimate of the nutrient content. Also as with a soil sample, the manure sample should be analyzed by a reputable laboratory. Using "book values" to estimate nutrient content of manure should be avoided whenever possible.

Most laboratories will analyze manure samples for primary nutrients (N, P and K), secondary nutrients (Ca, Mg and S) and micronutrients. Primary and secondary nutrients are often reported as % and micronutrients as parts per million (ppm). Most laboratories also report results on an "as is" or "wet basis" so the moisture does not have to be factored back in. Laboratories such as the UGA lab also report P as P_2O_5 and K as K_2O so they are already on a "fertilizer" basis. The UGA lab also converts and reports each nutrient from % or ppm to lb/ton for "dry" manures to lbs/1000 gal for liquid manures.

In case these conversions are not already made by the laboratory that analyzed the manure, the following conversion factors prove to be useful:

lbs of P x 2.29 = lbs of P_2O_5
lbs of K x 1.2 = lbs of K_2O
parts per million (ppm) and milligrams per liter (mg/l) are assumed to be equal since (1 ppm = 1 mg/l)
ppm or mg/l x 0.002 = lbs/ton
ppm or mg/l x 0.226 = lbs/acre-inch
ppm or mg/l x 0.008 = lbs/thousand gallons
one acre-inch = 27,000 gallons

The nutrients contained in manures and reported as "total" N, P_2O_5 or K_2O are <u>not</u> usually considered to be 100 % available for crop uptake like inorganic commercial fertilizers. This is due to some of the nutrients being in "organic" forms and is especially important for N. Inorganic nutrients are readily available to growing plants; in other words, they are already in a form for plant uptake. Organic nutrients, on the other hand, must go through a mineralization process to become plant available.

Mineralization is the conversion from an organic form to an inorganic form so that nutrients become plant available. Mineralization is performed by soil microbes and takes place over time.

Some labs report manure nutrient results on a "plant-available" basis and some don't. The UGA lab for example, reports total N, P_2O_5 and K_2O. In this case, availability coefficients must be used to calculate the true nutrient supplying capacity of the manure. The availability coefficients that should be used can be found in Table B. This table is also identical to Table 1 provided with the UGA computer spreadsheet for manure nutrient budgeting.

Table B. Livestock manure nutrient first-year availability coefficients

TYPE OF MANURE	APPLICATION METHOD								
	Soil incorporation			Broadcast			Irrigation		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Scraped manure									
Dairy	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Beef	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Swine	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Sheep/Goat	0.6	0.8	1.0	0.5	0.7	0.9	*	*	*
Horse, stable	0.5	0.8	1.0	0.5	0.7	0.9	*	*	*
Poultry House Litter									
All poultry litters	0.7	0.8	1.0	0.5	0.7	0.9	*	*	*
Liquid manure slurry									
Dairy	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Beef	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Swine	0.7	0.8	1.0	0.4	0.7	1.0	0.3	0.7	1.0
Layer	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Lagoon liquid									
Dairy	0.8	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Beef	0.8	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Swine	0.9	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Layer	0.9	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0

* Not applicable

You need to know two pieces of information in order to choose the correct availability coefficient 1) type of manure and 2) application method. For example, if you are dealing with poultry (broiler) litter that will be broadcast and then soil incorporated within two days, the availability coefficients for N, P_2O_5 and K_2O will be 0.7, 0.8 and 1.0 respectively. If calculating a nutrient budget by hand, you would multiply the values given for total N, P_2O_5 and K_2O by these coefficients to come up with "available" nutrients supplied by the manure. In the case of the computer program, you simply enter the coefficients on the appropriate line and "Manure Nutrients Available to crop" are automatically calculated.

The method of manure application affect nutrient availability in a number of ways. Manure placement affects the ability of crops to utilize most of the applied nutrients and the likelihood of manure runoff from the site. Application to the soil surface typically results in greater potential for

N loss through volatilization (escape as a gas) and runoff than where manures are incorporated (mixed with the topsoil) or injected. Uniformity of nutrient applications and distance from the root system can also influence crop response to nutrient applications. The method of application can also affect odor. Careful placement also means irrigating at rates that prevent runoff.

The application method for manures often depends on the type of application equipment that is available or is the method that is most cost or time effective. Many growers choose broadcast nutrient application because of fewer time constraints and lower cost.. Again, incorporating manures into soils where possible increases the availability coefficient. Where nutrient utilization is a prime consideration, the handling system may dictate the method of application. For example, solid or semisolid materials cannot be effectively injected into the soil or applied through an irrigation system, while lagoon liquids are most economically applied through an irrigation system. The application rate of the irrigation equipment will also determine if the manure moves into the soil or runs off.

Some labs will convert manure nutrient analyses to a "plant-available"basis, so that no calculations at all are necessary prior to manure application. However, in order for the lab to do this, you must supply them with information concerning type of manure and application method. If you provide this information and a lab does report the nutrients in manure on a "plant available" basis, still check their plant available factors to be sure it fits your situation and corresponds to the values listed in Table 2.

Another-term that is reported by some labs and may lead to some confusion is plant available nitrogen or "PAN". This term is usually calculated by multiplying the organic N fraction of manure by a mineralization factor and adding that value to analyzed values for the inorganic forms of nitrogen in manure (ammonium-N and nitrate-N). In fact, the UGA lab analyzes manures for ammonium and nitrate N. However, PAN is basically used to describe the portion of the total N that is available for crop uptake just like the N availability factors in Table B. **For simplicity, the N supplying capacity of manures should be calculated by multiplying total N by the appropriate availability coefficient, and <u>not</u> by using a "PAN" value.**

Balance Crop Nutrient Needs with Nutrients Supplied by Manure

The third and final step in calculating a nutrient budget for animal manures is to simply match the nutrient needs by the crop to be grown in step 1 (based on a soil test) with the nutrient supplying capacity of the manure calculated in step 2 (total N-P_2O_5-K_2O from a manure analysis times appropriate availability coefficients.

The best way to demonstrate how this would be done is with the following examples.

Example #1 - Using broiler litter for cotton production on a medium P testing soil in South Georgia

Given: 100 acres of cotton
Crop Needs based on soil test of 90-60-35 (lbs N-P_2O_5-K_2O per acre)
Manure analysis shows 60-60-40 (total N-P_2O_5-K_2O per ton "as is")
Application method = Soil Incorporated (availability coefficients for N-P_2O_5-K_2O = 0.7-0.8-1.0)

Calculate: 1) Appropriate application rate in ton/a for an N-based plan
2) Appropriate application rate in ton/a for an P-based plan

Answers: 1) 2.14 ton/a (90 lb N/a divided by 60 x 0.7 lb N/ton)
2) 1.25 ton/a (60 lb P_2O_5/a divided by 60 x 0.8)

Notice that a higher application rate of manure is recommended when N-based compared to P-based. This is very common and is due to the fact that most crops require less P than N, plus most manures contain about as much P as N. Based on these rates and since there is 100 acres available, the cotton farmer will be able to utilize 214 tons of litter if N-based (2.14 tons/a x 100 acres), but only 125 tons if P-based (1.25 x 100).

The example above is based on a soil testing in the "medium" range for P using the UGA lab. If the soil test P rating changes, either up or down, the application rate if using an N-based budget will not change. However, if a P-based budget is used and the soil test P is lower, then an application rate higher than 1.25 ton/a will be recommended. On the other hand, if the soil test rating for P increases into the high range, less manure than 1.25 ton/a will be recommended. Once the soil test rating for P increases into the "very high" range, a manure application rate of 0 ton/a will be recommended for the P-based budget. At this point, this recommendation is for agronomic purposes only, not environmental purposes.

Example # 2 - Using broiler litter for tall fescue pasture on a medium P testing soil in North Georgia

Given: 100 acres of tall fescue pasture
Crop Needs based on soil test of 50-30-25 (lbs N-P_2O_5-K_2O per acre)
Manure analysis shows 60-60-40 (total N-P_2O_5 K_2O per ton "as is")
Application method = Broadcast (availability coefficients for N-P_2O_5-K_2O = 0.5-0.7-0.9)

Calculate: 1) Appropriate application rate in ton/a for an N-based plan
2) Appropriate application rate in ton/a for an P-based plan

Answers: 1) 1.67 ton/a (50 lb N/a divided by 60 x 0.5 lb N/ton)
2) 0.7 ton/a (30 lb P_2O_5/a divided by 60 x 0.7)

Notice that the both the N-based and P-based application rates are lower than in the South Georgia cotton example above. This is basically due to the lower nutrient demand by tall fescue pasture and despite the fact that less nutrients from manure are available (lower availability coefficients) due to broadcasting rather than incorporating the litter. Based on these recommended application rate, this livestock producer would only be able to utilize 167 tons (1.67 tons/a x 100 acres) of litter if N-based and 70 (0.7 x 100)tons if P-based.

How To Use The UGA Computer Program

Both the "hand" (Appendix A) and computer (Appendix B) spreadsheets use the basic calculations and procedures as used in the two examples above. In addition, they both require some additional and useful record keeping information (for example farmer name, soil type, yield goal) that is not directly used in calculating the nutrient budget.

The main disadvantages of the "hand" spreadsheet is that all figures have to be recorded by hand, all calculations have to bee done using a calculator, and the nutrient budget can only be calculated using either N or P (but not both) as the priority nutrient.

The UGA computer spreadsheet is the preferred method of calculating nutrient budgets for manure because it makes a number of calculations automatically and includes a fertilizer value of manure used in $/ton or 1000 gallons.

Once you've downloaded the spreadsheet, you can enter information for a given field or situation into the spaces provided in the blue shaded area. All information recorded in the top half of the blue section, from the producer's name to the manure application method is important for record keeping but is not used in any of the calculations.

The key information is entered on the "Crop Nutrient Needs", "Manure Nutrient Concentrations" and "Availability Coefficients" lines. The "Commercial Fertilizer Applications" and Residual N from Legumes" (use the "Legume" tab to go to Table 2) are used to calculate "Net Manure Nutrient Needs of Crop". Default values of 34 cents/lb N, 25 cents/lb P_2O_5 and 16 cents/lb K_2O are automatically entered on the "Equivalent Fertilizer Price" line. These values can be changed to reflect local prices of the fertilizer to be used by your farmer. They are then used to calculate the "Fertilizer Value" of the manure.

Anytime a value in the blue box that is used in a calculation is changed, the affected values below should change. For example, if the "Crop Nutrient Needs" for N is changed, then the recommended manure application rate found in the yellow box below should change.
Use both the "Legume" and more importantly the "Availability" tabs for easy reference for input onto the "Residual N from Legumes" and "Availability Coefficients" lines in the blue box.
There is also a series of tabs with helpful information for most of the inputs. These can be found in Appendix B as "Additional Instructions on NBW Data Entry". Notice also that there is a "units/a" button for the "Manure Nutrient Concentration" input line that guides the user to lb/ton for dry manure and either lb/ac-in or lb/thousand gallons for liquid manures.

Once you have completed a "worksheet" it can be printed either using the "print" button or by highlighting the desired cells on the spreadsheet and using the print command on the main "File" pulldown menu. The individual record can also be saved, using the "save as" command under the "File" menu. Each time you can save the new record with a different and unique filename.

To show what a completed Nutrient Budget Worksheet using the UGA computer program would look like, Examples # 1 and #2 discussed earlier can be found on the last two pages of this chapter.

Appendix A

NUTRIENT BUDGET WORKSHEET

1. Producer____________ . County____________ 3. Date____________
4. Farm #___1___ 5. Tract #____________ 6. Field # ____________ 7. Acres____________
8. Soil Series____________ 9. Leaching Potential ____________
10. Tillage Practices____________
11. Planned Crop____________ 12. Yield Expectations____________
13. Soil Test Rating: (a) P____________ (b) K____________ (c) pH____________
14. Nutrients recommended (lbs/ac): (a) N________; (b) P_2O_5________; (c) K_2O________
15. Lbs/ac starter fertilizer used: (a) N________; (b) P_2O_5________; (c) K_2O________
16. Residual nitrogen credit from legumes (see back) ____________ lbs/ac
17. Net N needs of crop (14a minus 15a and 16)____________ lbs/ac
18. Net P_2O_5 needs of crop (14b minus 15b)____________ lbs/ac
19. Net K_2O needs of crop (14c minus 15c)____________ lbs/ac
20. Type of manure____________
21. Manure nutrient content: (a) N ____________ (lbs/ton) (lbs/ac-in)
    (b) P_2O_5 ____________ (lbs/ton) (lbs/ac-in)
    (c) K_2O ____________ (lbs/ton) (lbs/ac-in)
22. Manure application method (see back)____________
23. Nutrients in manure available to crop: (21a, b & c multiplied times the availability coefficient)(see back)
    (a) Available N ____________ (lbs/ton) (lbs/ac-in)
    (b) Available P_2O_5 ____________ (lbs/ton) (lbs/ac-in)
    (c) AvailableK_2O ____________ (lbs/ton) (lbs/ac-in)
24. Manure application rate to supply the priority nutrient:
    (a) Priority nutrient ____________ ________
    (b) Amount of priority nutrient needed (17, 18 or 19) ____________ lbs/ac
    (c) Rate of manure needed (24b divided by 23a, 23b, or 23c) ____________ (tons/ac) (in/ac)
25. Pounds per acre of available nutrients supplied at the manure application rate needed to supply the priority nutrient:
    (a) N ____________ lb/ac
    (23a) (24c) (tons/ac or in/ac)
    (b) P_2O_5 ____________ lb/ac
    (23b) (24c) (tons/ac or in/ac)
    (c) K_2O ____________ b/ac
    (23c) (24c) (tons/ac or in/ac)
26. Nutrient balance: (Net nutrient need (-) or excess (–) after the application of manure at the calculated rate)
    (a) N balance ______ - ______ = ______ lb/ac
    (25a) (17)
    (b) P_2O_5 balance______ - ______ = ______ lb/ac
    (25b) (18)
    (c) K_2O balance______ - ______ = ______ lb/ac

a

27. Completed by____________ Title____________
    Agency____ The University of Georgia Cooperative Extension Service ____

Appendix B

Georgia Field Level Nutrient Budget Worksheet

A Worksheet for Managing the Nutrients in Manures from Georgia's Farms

Producer:		**County:**		**Date:**	01/01/00
Farm #:	**Tract #:** 0	**Field #:**	0	**Acres:**	0.0
Soil Series:		**Surface Soil Texture:**			
Planned Crop:		**Realistic Yield Expectation:**		0.0	Tons/A
Soil Test Index:	P = 0 (Lb/A)	K =	0 (Lb/A)	pH =	0.0
Manure Type:		**Application Method:**			

	N	P2O5	K2O	
Crop Nutrients Needs:	0	0	0	Lb/A
Commercial Fertilizer Applications:	0	0	0	Lb/A
Residual N from Legumes:	0	NA	NA	Lb/A
Manure Nutrient Concentration:	0.0	0.0	0.0	Lb/Ton
Availability Coefficients:	0.0	0.0	0.0	NA
Equivalent Fertilizer Price:	0.34	0.25	0.16	$/Lb
Net Manure Nutrient Needs of Crop:	0.0	0.0	0.0	Lb/A
Manure Nutrients Available to Crop:	0.0	0.0	0.0	Lb/Ton
Fertilizer Value:	0.00	0.00	0.00	Total = 0.00 $/Ton

Manure application rate for supplying crop :	N needs =	ERR	Ton/A
	P2O5 needs =	ERR	

	N based Application		P2O5 based Application		
	Nutrients Applied	Balance	Nutrients Applied	Balance	
N	ERR	ERR	ERR	ERR	Lb/A
P2O5	ERR	ERR	ERR	ERR	Lb/A
K2O	ERR	ERR	ERR	ERR	Lb/A

Total manure applied to field based on:	N needs =	ERR	Ton
	P2O5 needs =	ERR	

* If peanuts or tobacco are included in your crop rotation be sure to test soil following each manure application for recommendations on avoiding nutrient toxicity from high soil concentrations of Zn, or other micronutrients.

* See Farm*A*Syst Publications for information on applying animal waste, especially around streams, wells and on other environmentally sensitive areas.

* When making liquid manure applications, proper irrigation techniques must be used to prevent manure liquids from nutrient runninng off into surface water or leaching into groundwater.

Sincerely,

Name
Title
County, District, etc.

Manure Type and Application Method are both used to determine the availability of nutrients in manure. You should enter your manure type and application method based on the selections given below. Table 1 then gives details on Manure Availability Coefficients based on the selected manure type and application method.

Table 1. Livestock Manure Nutrient First-Year Availability Coefficients

MANURE TYPE	APPLICATION METHOD								
	Soil Incorporated[1]			Broadcast[2]			Irrigation[3]		
	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
Scraped manure									
Dairy	0.6	0.8	1.0	0.5	0.7	0.9	NA	NA	NA
Beef	0.6	0.8	1.0	0.5	0.7	0.9	NA	NA	NA
Swine	0.6	0.8	1.0	0.5	0.7	0.9	NA	NA	NA
Sheep/Goat	0.6	0.8	1.0	0.5	0.7	0.9	NA	NA	NA
Horse, Stable	0.5	0.8	1.0	0.5	0.7	0.9	NA	NA	NA
Poultry house litter									
All Poultry Litters	0.7	0.8	1.0	0.5	0.7	0.9	NA	NA	NA
Liquid manure slurry									
Dairy	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Beef	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Swine	0.7	0.8	1.0	0.4	0.7	1.0	0.3	0.7	1.0
Layer	0.7	0.8	1.0	0.5	0.7	1.0	0.4	0.7	1.0
Anaerobic lagoon liquid									
Dairy	0.8	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Beef	0.8	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Swine	0.9	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Layer	0.9	0.9	1.0	0.5	0.8	1.0	0.5	0.8	1.0
Anaerobic lagoon sludge									
All	* See Lagoon Clean-out and Closure publication								

[1] Surface spread manure plowed or disked into soil within 2 days
[2] Surface spread manure uncovered for one month or longer
[3] Sprinkler irrigated liquid uncovered for one month or longer

Estimates for Residual Nitrogen provided by legumes grown in rotation can be found in Table 2. Legume crops have the ability to fix N, or convert atmospheric N into a plant available form. Some of this fixed N is available to crops planted behind legumes. As a result, N fixed by legumes must be accounted for in a NBW to accurately manage this nutrient.

Table 2. Estimated Residual Nitrogen Provided by a Good Stand of Legumes Grown in Rotation

Legume	Residual Nitrogen Available
Alfalfa, Vetch, or Clover[1]	80 Lb/A
Soybeans, or Peanuts[2]	30 Lb/A

[1] Killed before planting current spring crop.
[2] Legume is planted in previous year/season. More nitrogen will be available if the fall planted crop immediately follows the legume. On sandy soils and in years with normally high precipitation, less nitrogen will be available to spring-planted crops.

Additional Instructions on NBW Data Entry

Producer is either the name of the farm or the name of the producer who owns and/or opperates the farm

Farm #, Tract #, Field#, and Acreage are all available from local Farm Service Agency Office. These are records and do not affect the manure application rates.

Soil Series and Surface Soil Texture are both available from local NRCS Office. These records can be h determining runoff and leaching potential. If unknown, they may be left blank.

Planned Crop is the crop that will be growing when manure applications are being made.
Realistic Yield Expectations are based on the production history of each field - be sure to indicate units.

Soil Test Index values are listed on the Soil Test Report for each field tested. For more information on soi testing, consult with your local UGA County Extension Agent.

Crop Nutrient Needs are listed in the Recommendations section of a Soil Test Report.

Fertilizer Applications are those which have already been made, or any planned for fields receiving man application(s). In other words, fertilizer application is the sum total of each nutrient (N, P2O5 and K2O) ap as starter fertilizer, mid-season side dress, etc.

Manure Nutrient Concentration values can be found on Animal Waste Analysis Reports.
Use the Unit/A button to choose the appropriate manure nutrient concentration uni 

Equivalent Fertilizer Price is the price per pound of Elemental Nitrogen, Phosphate (P2O5), or Potash (K These values are available through local fertilizer dealers.

Print Worksheet Data Entry Instructions Sheet.

Example #1

Georgia Field Level Nutrient Budget Worksheet

A Worksheet for Managing the Nutrients in Manures from Georgia's Farms

Producer:	Joe Farmer	**County:** Tift		**Date:** 10/20/00	
Farm #:	1 **Tract #:** 1	**Field #:** 1		**Acres:** 100.0	
Soil Series:	Tifton	**Surface Soil Texture:** Loamy Sand			
Planned Crop:	Cotton	**Realistic Yield Expectation:** 1250.0 lb/a			
Soil Test Index:	**P =** 60 (Lb/A)	**K =** 170 (Lb/A)		**pH =** 6.2	
Manure Type:		**Application Method:** Soil Incorporated			

	N	P2O5	K2O	
Crop Nutrients Needs:	90	60	35	Lb/A
Commercial Fertilizer Applications:	0	0	0	Lb/A
Residual N from Legumes:	0	NA	NA	Lb/A
Manure Nutrient Concentration:	60.0	60.0	40.0	Lb/Ton
Availability Coefficients:	0.7	0.8	1.0	NA
Equivalent Fertilizer Price:	0.34	0.25	0.16	$/Lb
Net Manure Nutrient Needs of Crop:	90.0	60.0	35.0	Lb/A
Manure Nutrients Available to Crop:	42.0	48.0	40.0	Lb/Ton
Fertilizer Value:	14.28	12.00	6.40	Total = 32.68 $/Ton

Manure application rate for supplying crop :	N needs =	2.1	Ton/A
	P2O5 needs =	1.2	

	N based Application		P2O5 based Application		
	Nutrients Applied	Balance	Nutrients Applied	Balance	
N	88	-2	50	-40	Lb/A
P2O5	101	41	58	-2	Lb/A
K2O	84	49	48	13	Lb/A

Total manure applied to field based on:	N needs =	210.0	Ton
	P2O5 needs =	120.0	

* If peanuts or tobacco are included in your crop rotation be sure to test soil following each manure application for recommendations on avoiding nutrient toxicity from high soil concentrations of Zn, or other micronutrients.

* See Farm*A*Syst Publications for information on applying animal waste, especially around streams, wells and on other environmentally sensitive areas.

* When making liquid manure applications, proper irrigation techniques must be used to prevent manure liquids from nutrient runninng off into surface water or leaching into groundwater.

Sincerely,

Name
Title
County, District, etc.

Example # 2

Georgia Field Level Nutrient Budget Worksheet

A Worksheet for Managing the Nutrients in Manures from Georgia's Farms

Producer:	Joe Farmer	**County:**	Clarke	**Date:**	10/20/00
Farm #:	1 **Tract #:** 1	**Field #:**	1	**Acres:**	100.0
Soil Series:	Cecil	**Surface Soil Texture:**	Sandy Loam		
Planned Crop:	Fescue Pasture	**Realistic Yield Expectation:**	2.0 acres/cow		
Soil Test Index:	P = 40 (Lb/A)	K = 200 (Lb/A)	pH = 6.2		
Manure Type:		**Application Method:**	Broadcast		

	N	P2O5	K2O	
Crop Nutrients Needs:	50	30	25	Lb/A
Commercial Fertilizer Applications:	0	0	0	Lb/A
Residual N from Legumes:	0	NA	NA	Lb/A
Manure Nutrient Concentration:	60.0	60.0	40.0	Lb/Ton
Availability Coefficients:	0.5	0.7	0.9	NA
Equivalent Fertilizer Price:	0.34	0.25	0.16	$/Lb
Net Manure Nutrient Needs of Crop:	50.0	30.0	25.0	Lb/A
Manure Nutrients Available to Crop:	30.0	42.0	36.0	Lb/Ton
Fertilizer Value:	10.20	10.50	5.76	Total = 26.46

Manure application rate for supplying crop :	N needs =	1.6	Ton/A
	P2O5 needs =	0.7	

	N based Application		P2O5 based Application		
	Nutrients Applied	Balance	Nutrients Applied	Balance	
N	48	-2	21	-29	Lb/A
P2O5	67	37	29	-1	Lb/A
K2O	58	33	25	0	Lb/A

Total manure applied to field based on:	N needs =	160.0	Ton
	P2O5 needs =	70.0	

* If peanuts or tobacco are included in your crop rotation be sure to test soil following each manure for recommendations on avoiding nutrient toxicity from high soil concentrations of Zn, or other micr

* See Farm*A*Syst Publications for information on applying animal waste, especially around stream and on other environmentally sensitive areas.

* When making liquid manure applications, proper irrigation techniques must be used to prevent manure liquids from nutrient runninng off into surface water or leaching into groundwater.

Sincerely,

Name
Title
County, District, etc.

8

Land Application of Animal Manure

Land Application of Animal Manure

Dr. Mark Risse

This lesson and the material in it are adapted from the National Animal and Poultry Waste Management Curriculum Lessons 30 through 36.

Intended Outcomes

The participant will:

- Understand key considerations in selecting and managing land application sites
- Identify activities related to timing of applications that may lead to higher environmental risk
- Become familiar with various land application systems and methods
- Understand the importance of equipment calibration
- Identify appropriate land application BMPs for their farm
- Develop procedures for proper record keeping for land application systems

Introduction

As agricultural producers strive to develop a more sustainable agriculture, the potential of animal manure to recycle nutrients, build soil quality, and maintain crop productivity becomes more important. At the same time, however, the nature of modern animal agriculture, with its highly concentrated production facilities and reliance upon feed supplements to maintain animal health and productivity, has raised serious questions about the effects of animal manure on the quality of our soil, water, atmosphere, and food supply. Because land application is the only practical alternative for much of animal-based agriculture, the cornerstone of most manure management programs will be a solid understanding of how animal manure and manure-amended soils affect agricultural production and the surrounding environment. The soil is a very effective manure treatment system if manure is applied at the proper rate, time, and location. While farm operators that need the nutrient resource in manure tend to use it better, even those that are using land application as a waste disposal practice can do it in an environmentally sound manner provided they know the impacts of their practices.

Manure utilization planning is a two-part process. In the last section we covered the first component which focused on developing a general cropping plan and estimate the number of acres needed to properly land apply the manure. The second component can be referred to as the *annual plan.* The annual plan refers to the actual implementation of the strategic plan. It covers such things as the planned times for manure applications, the manure application methods, best management practices, and records of manure applications and crop yields.

Selecting and Managing Land Application Sites

The importance of selecting the best site to apply manure cannot be over emphasized. Site selection is one of the major factors that directly affect the success of an operation. Spend the time up front selecting the best sites so that future, potentially expensive environmental problems and adverse public relations can be avoided. Even though the site may look good initially, its use may result in problems that could easily have been avoided by choosing another site.

Animal manure should not reach wetlands or surface waters of the state by runoff, drift, manmade conveyances (such as pipes or ditches), direct application, or direct discharge during operation or land application. Manure should not be applied to saturated soils, during rainfall events, or when the soil surface is frozen. Slopes steeper than 6% should also be unless there is

sufficient crop residue to prevent runoff, or unless manure is injected or incorporated into the soil. Check with local city and county officials for applicable regulations on zoning, health, building code, setback distances, etc.

The earlier section on maps presented some considerations and details but a few good rules to remember in selecting application sites are as follows:

1. Find a site that is as isolated as possible. Buffer or set-back restrictions can significantly reduce available land. Buffers are designed to minimize the potential for impacts to adjacent homeowners as well as impacts to the environment. It is also crucial to consider the direction of the prevailing wind in relation to the site and residential development in the area.
2. Find a site that is not too steep. The flatter the land, the lower the potential for runoff. In addition, flatter slopes generally have better soils and make the maintenance of a cover crop easier.
3. Find a site that is as far away from surface water as possible. This minimizes impacts should some of the wastewater be washed off the site. This extra buffer can be very important.
4. Find a site that has as deep a seasonal groundwater table as possible. This can reduce the risk of potential groundwater contamination.
5. Find a site that has good separation from bedrock. Areas where bedrock is close to the land surface make poor wastewater application sites.
6. Find a site where the soils are suitable for the intended crops to be grown.
7. Find a site where soils that are not too sandy. The clays and organic matter in soils help hold the nutrients and metals found in the wastewater, thereby preventing their movement to the groundwater and maximizing potential for plant uptake.

Obviously, the chances of finding the perfect site may not be easy and in some areas of the state may be difficult or impossible. But as stated earlier, every effort to find this perfect site, or one as close as possible, will definitely be worthwhile. Evaluating the environmental suitability of your application sites is one method you can use to identify those fields where manure application is most appropriate. Table 1 will allow you to measure the relative "risk" to the environment for land application sites. We recommend evaluations such as these be done on each field and included as part of your comprehensive nutrient management plan. Assessments such as Table 1 can also aid producers in determining which fields on their operation to use if several alternatives are available. Other general rules that can be used to select potential application sites include:

- Apply manure with the highest N content in the spring or fall; apply the lowest N manure in the summer.
- Haul the highest nutrient content manure to the furthest fields.
- Apply lowest nutrient content manure to closest fields. If possible, irrigate with collected runoff water and lagoon effluent.
- Apply the highest nutrient manure to crops with high nutrient demands.
- To avoid N leaching to groundwater, limit N applications on sandy soil and avoid soils with high water tables, tile drains or controlled drainage.
- To receive the most value from your manure, apply high-P manure to fields with the lowest soil P test levels.

Table 1 Field assessment for manure application.

CATEGORY		Field # ____ *Points*
1. Planned crop (check one)		
a. Continuous corn or corn not following legume	10	
b. Second-year corn following legume	8	
c. First-year corn following legume	1	
d. First-year corn following nonforage legume	8	
e. Nonforage legume	2	
f. Small grains (for grain)	6	
g. Small grain with seeding (removed as grain)	2	
h. Small grain with seeding (removed as hay or silage)	4	
i. Prior to direct seeding legume forage	8	
j. Topdress (good legume stand)	1	
k. Topdress (fair legume stand)	2	
l. Topdress (poor legume stand)	3	
m. Grass pasture or other nonlegumes	6	______
2. Soil test P (check one for each category)		
1. > 200 lbs/acre	1	
2. 100–200 lbs/acre	3	
3. 30–100 lbs/acre	5	
4. < 30 lbs/acre	10	
3. Site/soil limitations (check one for each category)		
a. Surface or groundwater proximity		
1. Applied and incorporated within 10-year floodplain or within 200 feet of surface water or groundwater access	1	
2. Application outside these restrictions	5	
b. Slope		
1. Slope > 12%	1	
2. Slope 6-12%; > 12% (incorporated, contoured, or terraced)	3	
3. Slope 2–6 %; 6-12% (incorporated, contoured, or terraced)	5	
4. Slope < 2%; <6% (incorporated, contoured, or terraced)	10	
c. Soil texture		
1. Sands, loamy sands	1	
2. Sandy loams, loams/sands, loamy sands; spring applied	3	
3. Other soils/sandy loams, loams, clays, spring applied	5	
d. Depth to bedrock		
1. 0–10 inches	0	
2. 10–20 inches	1	
3. > 20 inches	5	+ ______
4. Total Points (higher field score = higher priority for land application)		

If the producer does not own adequate land to properly use the manure, written agreements with third party landowners or applicators should be considered. You should be able to document where all manure generated on the farm will be used. Several example agreements are presented at the end of this chapter. Producers are encouraged to take samples of groundwater and surface water on farms where animal manure is routinely applied. Samples should be analyzed for nutrients and bacteria and these records should be kept with the other farm records.

Timing of Manure Applications

It has been said, with respect to nutrient management, that timing is everything. While there are certainly other factors that affect crop yields and nutrient management, timing is very important. If crops have access to nutrients when they are needed, quality and yields are higher. If, however, nutrients are supplied at times when crop need is low or nonexistent, then these nutrients pose a greater environmental risk, especially in regions with higher rainfall. Also, applications when the soil is saturated may lead to nutrient movement.

Some common crops grown to use nutrients in manure are shown in Table 2. A cropping system with a variety of crops offers the most flexibility for manure application over many parts of the year.

Table 2. Crops useful for manure utilization and their maximum uptake period in the southeastern United States. *

Crop	Uptake Period[1]
Corn (grain)	April–July
Corn (silage)	April–July
Sorghum (grain)	April–July
Small grains (grain)	Feb.–April
Small grains (hay, pasture)	Feb.–April
Soybean	July–Sept.
Cotton	June–August
Bermudagrass (hay, pasture)	April–Sept.
Tall fescue (hay, pasture)	Sept.–Nov. & Feb.–April
Alfalfa (hay)	May–August
Annual ryegrass (hay, silage, pasture)	Feb.–April & Sept.–Oct.
Millet (hay, silage)	May–August

[1] *Application should occur no more than 30 days before planting or green up of perennial forages.*

* Relevant crop growth periods for your local area should be substituted in this table.

Scheduling manure applications

Crop growth rates and application conditions are not uniform throughout the year. Likewise, crop nutrient requirement is not uniform. Realizing this fact, you need to understand when it is or is not appropriate to land apply manure. All nutrient sources should be applied at times that will maximize crop use and minimize loss. Ideally, manure nutrients should be applied to an actively growing crop or within 30 days of planting a crop. If crops for human

consumption are to be grown, manure should not be applied in the three weeks before harvest. Timing is most important for nutrients applied to soils with a high leaching potential. Applying nitrogen to a sandy soil when there is no crop to remove it will almost certainly result in loss of nitrogen to the shallow groundwater. Recommendations that are used for fertilizer nitrogen conservation (reduced leaching) should also be used for manure nitrogen. Manure that has primarily organic N can be successfully applied in the fall, prior to spring planting, if erosion and runoff control measures are in place but the losses will be greater.

In some cases, manure storage capacity dictates the frequency of manure applications. Low manure storage capacity will require frequent applications and year-round cropping systems, while larger storage volumes may allow less frequent applications to a single crop. Many storage structures are designed for 180-270 days of temporary storage. If the same fields are to be used, this means an actively growing crop must be present in both summer and winter. Double cropping or overseeding of perennial forages can be used to accomplish this, but a higher level of management is required to make this system work properly. For existing facilities, the temporary storage volume should be known, or can be calculated, and used to determine the number of days of temporary storage. Because manure production and storage capacity determine the maximum amount of time between manure applications, these factors strongly influence crop selection.

As seen in Figure 1, there are several months during the year when most crops are dormant. For example, bermudagrass is dormant in January and February, and growth is "slow" during March, November, and December. If the crop is not actively growing, there is little or no nutrient uptake. In this situation, any nitrogen applied to the bermudagrass field could leach through the soil and move down towards the water table. Consequently, land application is not generally recommended during dormant periods.

The risk of encountering an emergency situation can be significantly reduced by utilizing a cropping system that provides the flexibility of extending the application season throughout most of the year. For example, if bermudagrass is overseeded with rye in the winter, you have a cropping system in place that can accept some manure during every month in most years. There may still be one or two consecutive months when fields are too wet to apply manure. In a bermudagrass/rye cropping system, the peak storage duration in the lagoon is only for the wet weather period, rather than the five months or longer required if only bermudagrass is being grown.

Selecting the Appropriate Application Method

An environmentally friendly land application system for manure will require careful review of the equipment and management procedures previously used. Critical to this approach is the producer's willingness to treat manure or other livestock by-products as a nutrient resource and not as a waste. Manure application equipment must be selected and managed as fertilizer-spreading equipment as opposed to waste disposal equipment. Efficiency of manure nutrient use will need to be a producer's primary objective.

The proper location and selection of application sites and equipment are no assurance that problems will be eliminated. Manure spreading or spraying activities must be planned and managed to prevent adverse impact on the groundwater, surface water, nuisances, public health, and plants. Here are some considerations in selecting application equipment.

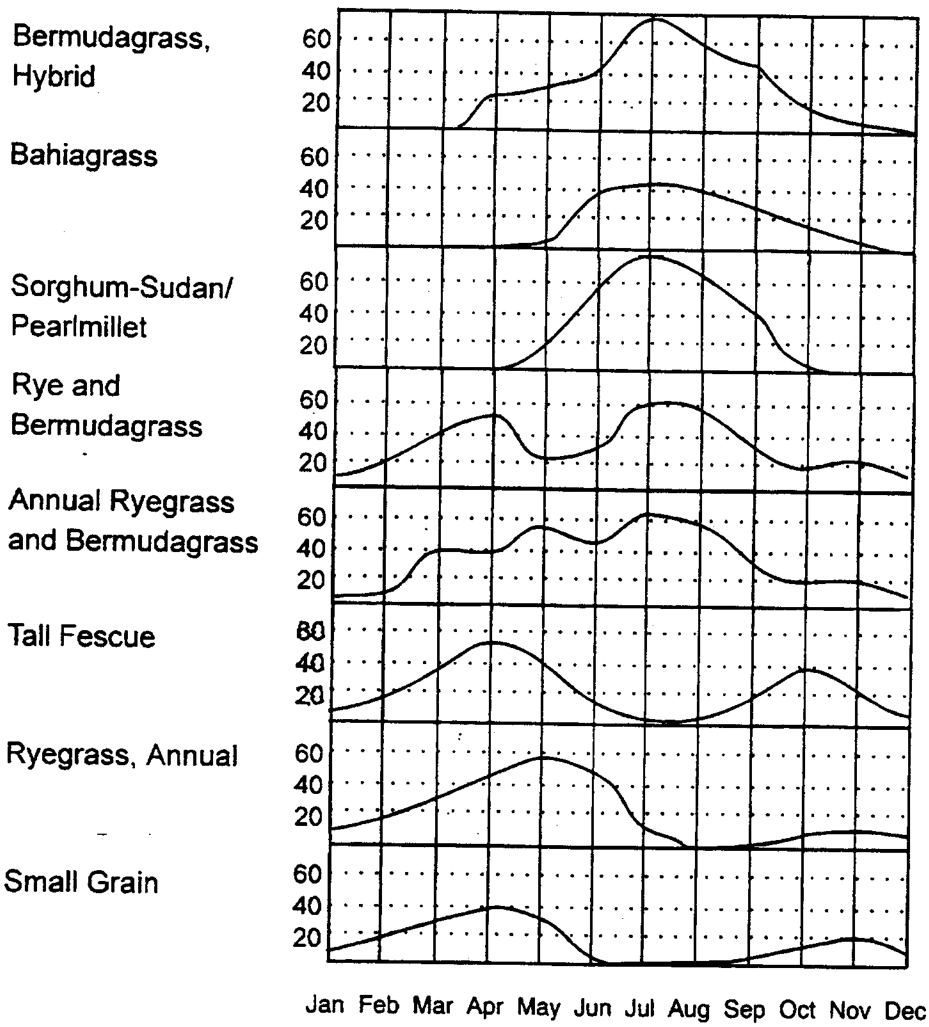


Figure 1. Growth rate of selected forage crops. Growth is expressed as pounds of forage produced per day per acre.

Manure spreader as a fertilizer applicator. The fundamental principle underlying both best management practices and future regulatory requirements for manure application will be efficient crop use of applied nutrients. Manure spreaders will need to be managed as any other fertilizer or chemical applicator. Spreaders and irrigation equipment will need to provide a uniform application of manure, a consistent application rate between loads, and a simple means of calibration. Appropriate equipment selection and careful operator management will contribute to efficient use of manure nutrients.

Timeliness of manure nutrient applications. The ability to move large quantities of manure during short periods of time is critical. Limited times of opportunity exist for application of manure to meet crop nutrient needs and minimize nutrient loss. Investments and planning decisions that enhance the farm's capacity to move manure or that store manure in closer proximity to application sites will enable improved timing of manure applications.

Conservation of nitrogen. The availability of nitrogen and phosphorus in manure does not meet crop needs. Typically, high soil phosphorus levels results from long-term applications of manure. The ammonium fraction, originally representing roughly half of the potentially

available nitrogen, is lost by long-term open lot storage of manure, anaerobic lagoons, and surface spreading of manure. Systems that conserve ammonium nitrogen and provide nutrients more in balance with crop needs increase the economic value of manure.

Odor Nuisances. Odor nuisances are the primary driving factor of more restrictive local zoning laws for agriculture. Application systems that allow you more flexibility in application timing and location can reduce odor nuisances. Manure application systems that minimize odor deserve consideration and preference where neighbors live close to application sites.

Soil Compaction. Manure spreaders are heavy. The manure alone in a 3,000-gallon liquid manure tank weighs more than 12 tons. In addition, manure is often applied at times of the year, late fall and early spring, when high soil moisture levels and the potential for compaction are common. Impact of manure application on potential soil compaction deserves consideration.

Table 3. Environmental rating of various manure application systems.

	Uniformity of Application	Conservation of Ammonium	Odor	Compaction	Timeliness of Manure Application
Solid Systems					
Box spreader: tractor pulled	Poor	very poor	fair	fair	poor
Box spreader: truck mounted	Poor	very poor	fair	fair	fair
Flail-type spreader	Fair	very poor	fair	fair	poor
Side-discharge spreader	Fair	very poor	fair	fair	poor
Spinner Spreader	Fair	very poor	fair	fair	fair
Dump truck	very poor	very poor	fair	poor	fair
Liquid Systems: Surface Spread					
Liquid tanker with splash plate	Poor	poor	poor	poor	fair
Liquid tanker with drop hoses	Fair	fair	good	poor	fair
Big gun irrigation system	Good	very poor	very poor	excellent	excellent
Center pivot irrigation system	Excellent	very poor	very poor	excellent	excellent
Liquid Systems: Incorporation					
Tanker with knife injectors	Good	excellent	excellent	poor	fair
Tanker with shallow incorporation	Good	excellent	excellent	poor	fair
Drag hose with shallow incorporation	Good	excellent	excellent	good	good

Equipment Calibration

You can avoid the potential adverse effect on ground and surface water caused by over fertilization by applying only the amount of manure, effluent, or wastewater necessary to maintain soil fertility for crop production. A nutrient management plan is of little use if the designed application rate can not be met. Calibration of manure-application equipment is important because it lets you know the amount of manure and wastewater you are applying to an

area. The calibration rate and nutrient concentration of manure nutrients lets you know the amount of plant-available nutrients you are applying. Then you can adjust your application rate to avoid over fertilization. Calibration will also:

- Verify actual application rates
- Troubleshoot equipment operation
- Determine appropriate overlaps
- Evaluate the uniformity of application
- Monitor changes in equipment operations (age and "wear and tear")
- Changes in manure "thickness"

The remainder of this chapter deals with different types of application equipment. Each section is followed by detailed descriptions of calibration techniques that can be used with that equipment.

Solid Manure Application Systems

Manure of 20% solids or more is typically handled by box, side discharge, or spinner-type spreaders. Box-type spreaders range in size from under three tons (100 cubic feet) to 20 tons (725 cubic feet). Box spreaders provide either a feed apron or a moving gate for delivering manure to the rear of the spreader. A spreader mechanism at the rear of the spreader (paddles, flails, or augers) distributes the manure. Both truck-mounted and tractor-towed spreaders are common. Flail-type spreaders provide an alternative for handling drier manure. They have a partially open top tank with chain flails for throwing manure out the side of the spreader. Flail units have the capability of handling a wider range of manure moisture levels ranging from dry to thick slurries. Side-discharge spreaders are open-top spreaders that use augers within the hopper to move wet manure toward a discharge gate. Manure is then discharged from the spreader by either a rotating paddle or set of spinning hammers. Side-discharge spreaders provide a uniform application of manure for many types of manure with the exception of dry poultry litter. Spinner-type spreaders are similar to hopper-style spreaders used to apply dry commercial fertilizer or lime and are traditionally used to apply dry poultry litter. Manure placed in the storage hopper is moved toward an adjustable gate via a chain drive. Manure then falls out of the spreader onto two spinning discs that propel the litter away from the spreader. Uniform application can easily be achieved with spinner spreaders by either varying the spinner speed or angle. Application rates can be adjusted by changing the travel speed and opening or closing the opening on the spreader gate.

With the growing concern about manure contamination of water and air resources, spreaders must be capable of performing as fertilizer spreaders. Typically, such equipment has been designed as disposal equipment with limited ability to calibrate application rates or maintain uniform and consistent application rates. Several considerations specific to solids application equipment follow:

- The operator must control application rate. Feed aprons or moving push gates, hydraulically driven or PTO powered, impact the application rate. Does the equipment allow the operator to adjust rate of application and return to the same setting with succeeding loads?
- Uniformity of manure application is critical for fertilizer applicators. Variations in application rate both perpendicular and parallel to the direction of travel are common.

- Transport speed and box or tank capacity impact timely delivery of manure. Often 50% or more of the time hauling manure is for transit between the feedlot or animal housing and field. Truck-mounted spreaders can provide substantial time savings over -pulled units for medium- and long-distance hauls. Trucks used for manure application must also be designed to travel in agriculture fields. Available four-wheel drive and duel or flotation-type tires should be considered for trucks that will apply manure. Increased box or tank capacities speed delivery. Spreaders must be selected to move and apply manure quickly.
- Ammonia losses are substantial for solid manure application that is not incorporated. Most of the ammonia nitrogen, representing between 20% and 65% of the total available nitrogen in manure, will be lost if not incorporated within a few days. Practices that allow for incorporating manure into the soil on the same day as applied will reduce ammonia losses and increase nitrogen available to crops.

Calibrating Manure Spreaders

Calibration of your spreader is a simple, effective way of improving utilization of nutrients in manure more effectively. Only by knowing the application rate of your spreader can you correctly apply manure to correspond to your crop needs and prevent water quality problems. Applicators can apply manure, bedding, and wastewater at varying rates and patterns, depending on forward travel and/or PTO speed, gear box settings, gate openings, operating pressures, spread widths, and overlaps. Calibration defines the combination of settings and travel speed needed to apply manure, bedding, or wastewater at a desired rate and to ensure uniform application. A brief calibration procedure is given below. An extension publication is also available at: http://www.ces.uga.edu/pubcd/C825-W.HTML

Solid and Semisolid Manure Spreaders

To calibrate a spreader for solid manure (20% or more solids), the following materials are needed:

1. Bucket
2. Plastic sheet, tarp, or old bed sheet. An even size, 8 feet by 8 feet, 10 feet by 10 feet, or 12 feet by 12 feet, will make calculations easier.
3. Scales

Solid and semisolid spreaders are rated by the manufacturer either in bushels or cubic feet (multiply bushels by 1.25 to get cubic feet). Most spreaders have two rating capacities: (1) struck or level full and (2) heaped. Calibration of solid manure spreaders based on its capacity (volume) is difficult to estimate accurately because the density of solid and semisolid manure is quite variable. Density is the weight of the manure per volume of manure (pounds per cubic foot). Manure density varies depending on the type and amount of bedding used as well as its storage method. Therefore, if you estimate spreader application rates as the volume of the manure the spreader holds, you are overlooking the fact that some manure weighs more than other manure. This can cause a significant error when calculating manure application rates.

Since manure and litters have different densities, an on-farm test should be done. To determine the load (tons) of a manure spreader,

1. Weigh an empty 5-gallon bucket.

2. Fill the bucket level full with the material to be spread. Do not pack the material in the bucket but ensure that it settles similar to a loaded spreader.
3. Weigh the bucket again. Subtract the empty bucket weight from this weight to calculate the weight of the contents.
4. Multiply weight of contents by 1.5 to calculate pounds per cubic feet, density.
5. Multiply the manure density by the cubic feet capacity of the spreader and divide by 2,000 to get the tons of material in a spreader load.

$$\text{Spreader load (tons)} = \frac{\text{weight of 5 gal manure} \times 1.5 \times \text{spreader capacity (ft}^3\text{)}}{2{,}000}$$

Calibration method

1. Locate a large, reasonably smooth flat area where manure can be applied.
2. Spread the plastic sheet, tarp, or bed sheet smoothly and evenly on the ground.
3. Fill the spreader with manure to the normal operating level. Drive the spreader at the normal application speed toward the sheet spread on the ground, allowing the manure to begin leaving the spreader at an even, normal rate.
4. Drive over the sheet at the normal application speed and settings while continuing to apply manure. If a rear discharge spreader is used, three passes should be made: First, drive directly over the center of the sheet; then make the other two passes on opposite sides of the center at the normal spreader spacing overlap.
5. Weigh the empty bucket and plastic sheet, tarp, or blanket.
6. Collect all manure spread on the sheet and place it in the bucket.
7. Weigh bucket and manure, and subtract the weight of the empty bucket and ground sheet. This will give you the pounds of manure applied to the sheet.
8. Repeat the procedure three times to get a reliable average.
9. Determine the average weight of the three manure applications.
10. Calculate the application rate using the following formula or Table 4:

$$\text{Application rate (tons/acre)} = \frac{\text{lb manure collected} \times 21.78}{\text{sheet length (ft)} \times \text{sheet width (ft)}}$$

11. Repeat the procedure at different speeds and/or spreader settings until the desired application rate is achieved.

Table 4. Calibration of solid manure spreaders.

Pounds of Manure Applied to Sheet	Tons of Manure Applied/Acre		
	Size of Ground Sheet		
	8' × 8'	10' × 10'	12' × 12'
1	0.34	0.22	0.15
2	0.68	0.44	0.30
3	1.02	0.65	0.45
4	1.36	0.87	0.61
5	1.70	1.09	0.76
6	2.04	1.31	0.91
7	2.38	1.52	1.06
8	2.72	1.74	1.21
9	3.06	1.96	1.36
10	3.40	2.18	1.51
15	5.10	3.27	2.27
20	6.81	4.36	3.03

Many times it may be necessary to adjust the rate in which waste is applied from the way it is normally spread. Changes in application rate can be accomplished by increasing or decreasing the speed at which the waste is being applied. To perform these calculations, the spreader load (tons), duration of application (minutes), and the average width (feet) of a normal application needs to be known. The application rate and travel speed can be found using the following equations:

$$\text{Application rate (tons/acre)} = \frac{\text{spreader load (tons)} \times 495}{\text{time (min)} \times \text{width (ft)} \times \text{travel speed (mph)}}$$

$$\text{Travel speed (mph)} = \frac{\text{spreader load (tons)} \times 495}{\text{time (min)} \times \text{width (ft)} \times \text{application rate (tons/acre)}}$$

Example #1:
What is the application rate (tons per acre) if you collect 8.5 pounds of manure on a 10-foot by 10-foot tarp during a calibration run?

$$\text{Application rate (tons/acre)} = \frac{8.5 \text{ lb manure} \times 21.78}{10 \text{ ft} \times 10 \text{ ft}} = 1.85 \text{ tons/acre}$$

Example #2:
What speed should you run if you wish to apply 4 tons of manure per acre with a 3-ton spreader? Your spreader application width is 20 feet, and your spreader empties in 6 minutes.

$$\text{Travel speed (mph)} = \frac{3\,\text{tons} \times 495}{6\,\text{min} \times 20\,\text{ft} \times 4\,\text{tons/acre}} = 3.1\,\text{mph}$$

When using this type of example, select the gear in the tractor or truck that most closely matches the required speed (do not adjust PTO speed). If the travel speed is too high or too low, then you will need to change the flow rate to alter the time it takes to empty the tank. This is accomplished by changing PTO rpm, by changing valve or gate settings, or by installing an orifice in the flow line. Any time you make adjustments, change the rpm, or use thicker manure you should re-calibrate the unit.

Spreader Pattern Uniformity and Determining Overlap

To determine the uniformity of spread and the amount of overlap needed, place a line of small pans or trays equally spaced (2 to 4 feet) across the spreader path. The pans should be a minimum of 12 inches by 12 inches (or 15 inches in diameter) but no more than 24 inches by 24 inches and 2 inches to 4 inches deep. Make one spreading pass directly over the center pan. Weigh the contents caught in each pan or pour the contents into equal-sized glass cylinders or clear plastic tubes and compare the amount in each.

The effective spread width can be found by locating the point on either side of the path center where manure contents caught in the containers are half of what it is in the center. The distance between these points is the effective spreader width. The outer fringes of the coverage area beyond these points should be overlapped on the next path to ensure a uniform rate over the entire field. "Flat-top," "pyramid," or "oval" patterns are most desirable and give the most uniform application. "M," "W," "steeple," or "offset" patterns (Figure 2) are not satisfactory, and one or more of the spreader adjustments should be made. Often, a manufacturer's representative should be contacted to assist in the correction of undesirable application patterns.

Slurry Manure Application Systems (Sludge)

Application of liquid or slurry manure has traditionally been performed by tank wagons. While this method has allowed disposal of manure at a relatively low financial cost, it includes some hidden cost including soil compaction, loss of ammonium nitrogen and odor. Many unique approaches to land application of liquid or slurry livestock manure have appeared recently. Alternative delivery systems that speed movement of manure, unique options for incorporating manure, and systems that minimize mixing of manure and air will enhance liquid application of manure.

Remote Manure Storages

Remote manure storage (or storages) is an integral part of many unique delivery systems. Location of the manure storage near the fields that receive manure as opposed to near the animal housing has several potential advantages. Manure is transported by pump or tanker to a remote storage throughout the year, minimizing the labor for moving manure during field application. Remote sites may provide location options where odor or visual nuisances are less of a concern or soil permeability is such that storage construction costs can be reduced.

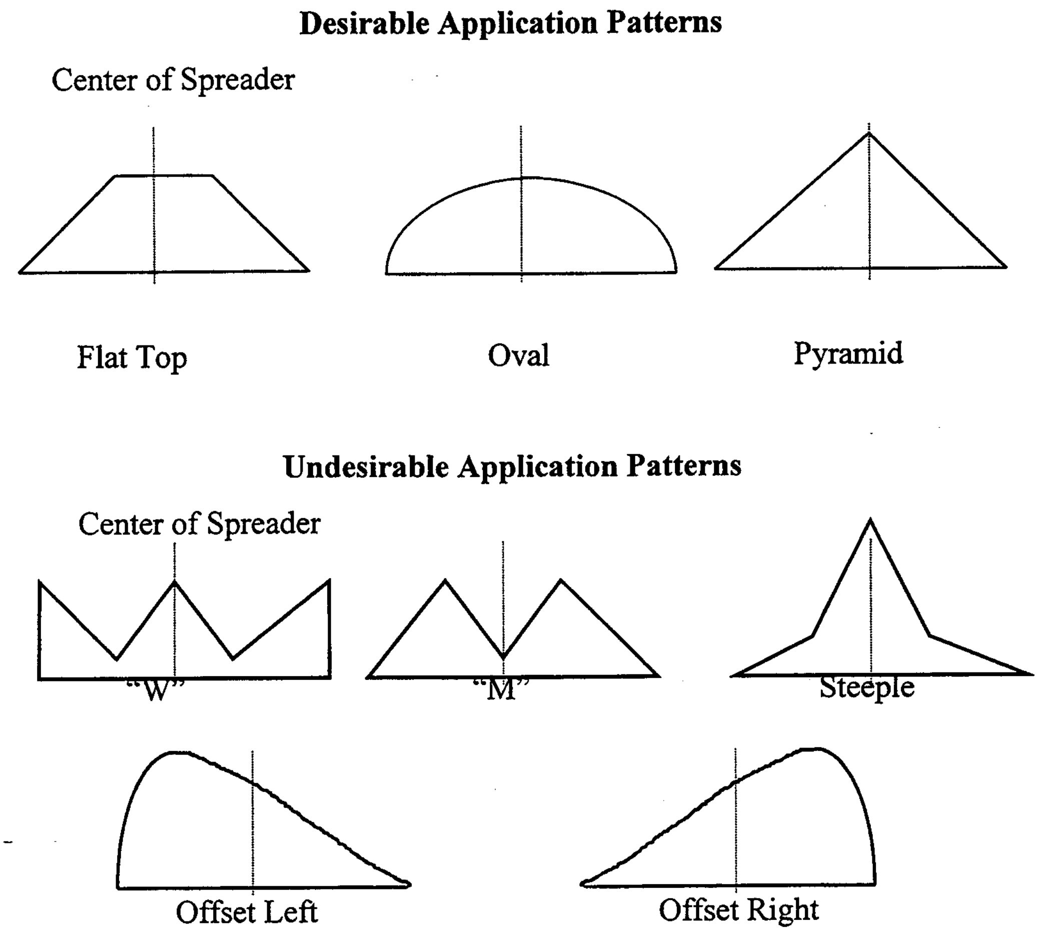


Figure 2. Desirable and undesirable application uniformity.

Hauling Liquid Manure

The standard 2,000- to 4,000-gallon tractor-pulled tanker cannot move manure fast enough for some livestock operations. In some regions, over-the-road tankers are being employed to shuttle manure from the manure storage to the edge of the field. Manure is then transferred to separate liquid application equipment or remote storage. Often, used semi-tractor milk or fuel tankers with capacities of 6,000 gallons or more are purchased for shuttle duty. Prior to implementing this approach, an individual should check licensing and inspection requirements and carrying capacity of local bridges.

Flexible Hose Systems

Pumping of liquid manure from the manure storage to the field is becoming increasingly common. Manure of up to 8% solids is being pumped several miles to a remote storage or field application equipment. Pipe friction is the primary limiting factor. Manure at solids content below 4% can be treated as water in estimating friction losses. An additional allowance for friction loss is required for pumping manure with a solids content above 4%. Manure handling systems that involve addition of significant dilution water or liquid-solids separation equipment provides a slurry that is most appropriate for this application.

To pump manure (> 4% solids) longer distances requires heavy-duty equipment. Aggressive chopper units are often installed just prior to the pump when solids separation equipment is not used. Industrial slurry pumps are selected to overcome the pipe friction losses and avoid potential wear problems. Buried PVC piping with higher pressure ratings (e.g., 160 psi) is generally selected. Because manure leaks are far more hazardous than water leaks, joints must be carefully assembled and tested. Special care must also be given to crossing streams and public roads. If public roads are to be crossed, appropriate local governments maintaining these roads should be approached early in the planning process.

Flexible hose delivery systems tied to a field implement or injector unit pulled by a tractor provides an alternative method for moving liquid manure quickly (Figure 3). These systems offer both odor/nutrient conservation and soil compaction benefits. A common approach begins with a high-volume, medium-pressure pump located at the liquid manure reservoir. Manure is delivered to the edge of the field (at the field's midpoint) by standard 6- or 8-inch irrigation line. At this point, a connection is made to a 660 foot long, 4 inch diameter soft irrigation hose. Often two lengths of hose are used. Manure is delivered to a tractor with toolbar-mounted injectors or splash plates immediately in front of a tillage implement. A flexible towed hose system distributes manure at rates of up to 1,000 gallons per minute so a one million gallon storage can be emptied in a matter of three to four days. Cost is often higher with these types of systems but they are applicable under certain conditions.

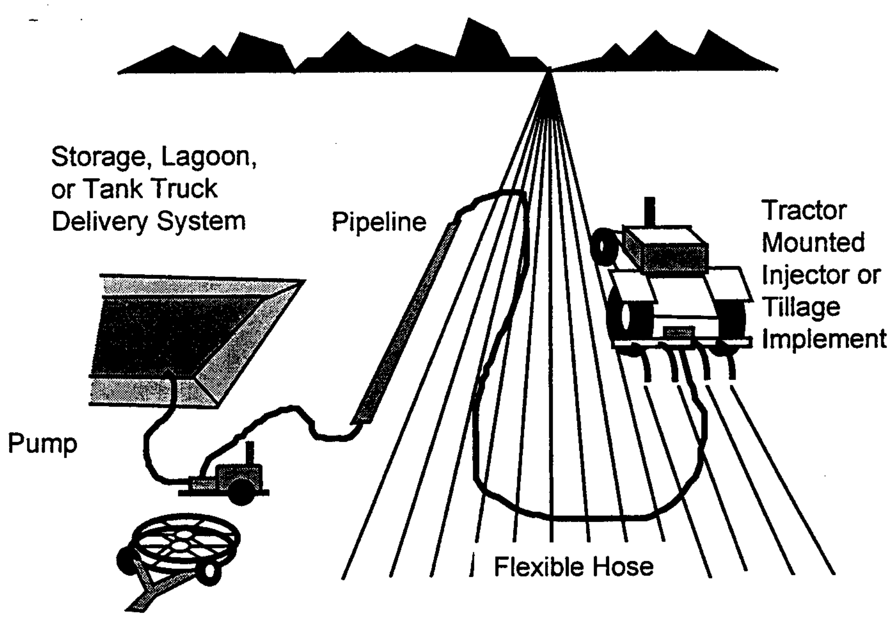


Figure 3. Towed hose systems move manure from storage to field via a pump, pipeline, and soft hose that are pulled behind the tractor and application equipment.

Surface Broadcast of Liquid Manure

Surface application of liquid slurries provides a low-cost means of handling the manure stream from many modern confinement systems. Tank wagons equipped with splash plates are commonly used to spread a lot of manure. However, surface application suffers from several disadvantages including

- Ammonia losses. Surface application of slurries results in losses of 10% to 25% of the available nitrogen, due to ammonia volatilization (Table 5).
- Odor. Aerosol sprays produced by mixing manure and air carry odors considerable distances.
- Uniformity. Splash plates and nozzles provide poor distribution of manure nutrients.

A few recent developments attempt to address these concerns. Boom-style application units for attachment to tank wagons or towed irrigation systems are appearing commercially for the first time. These systems use nozzles or drop hoses for distributing a slurry. They offer the opportunity to reduce odor concerns and improve uniformity of distribution.

Table 5. Nitrogen losses during land application. Percent of total nitrogen lost within 4 days of application.

Application Method	Type of Waste	Nitrogen Lost, %
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with	Solid	1-5
immediate incorporation	Liquid	1-5
Knifing	Liquid	0-1
Sprinkler irrigation	Liquid	0-1

Direct Incorporation of Liquid Manure

Options for direct incorporation of liquid manure are growing (Figure 4). Injector knives have been the traditional option. Knives, often placed on 20- to 25-inch centers, cut 12- to 14-inch deep grooves in the soil into which the manure is placed. Limited mixing of the soil and manure and high power requirements are commonly reported concerns.

Injector knives with sweeps that run four to six inches below the soil surface allow manure placement in a wider band at a shallower depth. Manure is placed immediately beneath a sweep (up to 18 inches wide), improving mixing of soil and manure. Location of the manure higher in the profile minimizes potential leaching and reduces power requirements. Sweeps can be used to apply a higher rate of manure than a conventional injector knife.

Other shallow incorporation tillage implements (s-tine cultivators and concave disks) are increasingly available options on many liquid manure tank wagons. These systems are most commonly used for pre-plant application of manure. Manure is applied near the tillage tool, which immediately mixes the manure into the soil. Speed of application, low power requirements, and uniform mixing of soil and manure have contributed to the growing popularity of this approach. In addition such systems are being used to side dress manure on row crops without foliage damage. Side dressing expands the season during which manure can be applied and improves the use of manure nutrients. All soil incorporation systems also offer the advantage of ammonia conservation and minimal odors.

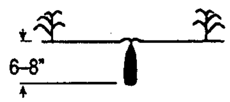
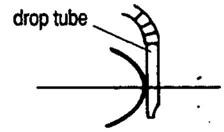
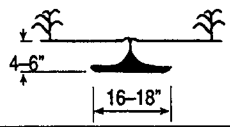
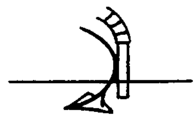
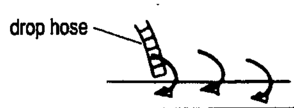
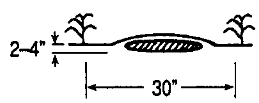
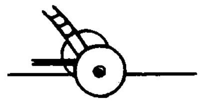
Row Crop Application Method	Placement of Manure (not to scale)	Application Implement (side views)
a) Injection: vertical knife/chisel		
b) Injection: horizontal sweep		
c) Shallow incorporation: s-tine cultivator (staggered)		
d) Shallow incorporation: concave disks		

Figure 4. Options for incorporation of manure in the soil.

Calibrating Liquid Manure Spreaders

Liquid tank spreaders must be accurately calibrated to apply wastes at proper rates. Calibration is the combination of settings and travel speed needed to apply wastes at a desired rate and to ensure uniform application. To calibrate, you must know the spreader capacity, which is normally rated by the manufacturer in gallons.

Calibration method

1. Spread at least one full load of waste, preferably in a square or rectangular field pattern for ease of measuring, with normal overlaps.
2. Measure the length and width of coverage, recognizing that the outer fringe areas of the coverage will receive much lighter applications than the overlapped areas.
3. Multiply the length by the width and divide by 43,560 to determine the coverage area in acres.

$$\text{Coverage area (area of rectangle in ft}^2\text{)} = \text{length (ft)} \times \text{width (ft)}$$

$$\text{Coverage area (acres)} = \frac{\text{length (ft)} \times \text{width (ft)}}{43{,}560 \text{ ft}^2 \text{ per acre}}$$

4. Divide the gallons of wastewater in the spreader by the acres covered to determine the application rate in gallons per acre.

$$\text{Application rate for spreader (gal or tons/acre)} = \frac{\text{spreader load volume (gal or tons)}}{\text{coverage area (acres)}}$$

Reminder: Liquid spreader capacities are normally rated by the manufacturer in gallons. Multiply by 0.0042 to get tons.

Example #3:
Your waste application method is a tractor-drawn tanker (honeywagon) with a 2,500-gallon capacity. You apply a load to a field and measure the application area as 22-feet wide by 280-feet long. What is the application rate in gallons per acre?

First, figure the coverage area:

$$\text{Coverage area (acres)} = \frac{280 \text{ ft} \times 22 \text{ ft}}{43{,}560 \text{ ft}^2} = 0.14 \text{ acre}$$

Then figure the application rate:

$$\text{Application rate for spreader (gal/acre)} = \frac{2{,}500 \text{ gal}}{0.14 \text{ acre}} = 17{,}857 \text{ gal/acre}$$

Drag-Hose Injectors

This method calculates the required speed to travel when pulling a drag hose application system (Figure 5) around the field. If you are not using a flow meter, you will have to operate the system for at least one hour before you can get an accurate reading of what you have removed from the storage tank or basin.

To calculate the required speed, you need to know

- The **volume** applied per hour (in gallons per hour) from a flow meter, the manufacturer's information or the amount removed from manure storage.
- The desired application **rate**, in gallons/acre
- The **width** of application, in feet

$$\text{Speed (miles/hr)} = \frac{8.25 \text{ x Volume/hr.}}{\text{Rate x Width}}$$

Select the appropriate gear in the field tractor to match the calculated speed. If the calculated speed is too fast, you could reduce the volume applied per hour by decreasing the power to the main pump. At the same time, you may also have to reduce the nozzle (or orifice) size to keep adequate pressure in the drag hose. Another way to compensate for an excessive calculated tractor speed is to increase the width of application. This could be accomplished by using a boom-style application.

Example #4:
A custom manure applicator measured pumped manure at a rate of 24,000 gallons per hour. His injector boom is 22 feet wide. He wants to apply 5,500 gallons per acre.

$$\textit{Speed} = \frac{8.25 \text{ x } 24{,}000 \text{ gal./hr.}}{5{,}500 \text{ gal/acre x } 22 \text{ ft.}}$$

$$\textit{Speed} = 1.6 \text{ miles/hr.}$$

He selected a gear giving a speed of 1.8 miles per hour.

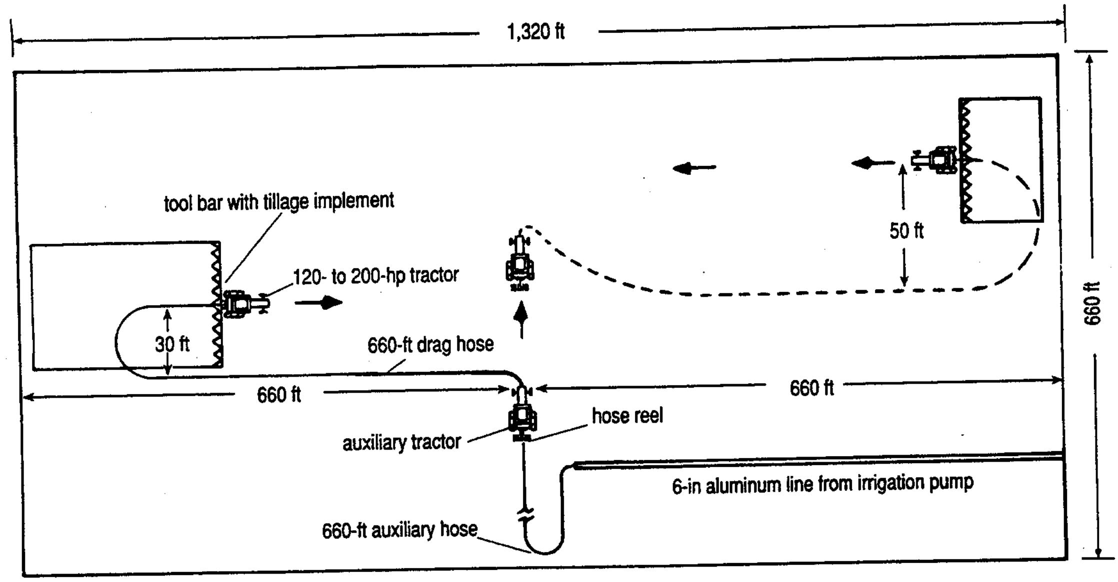


Figure 5. Hose-drag setup for 20-acre field.

Spot Check Applied Rate Across the Width of Application

All of the previous options give you the average application across the width. To check the variation across the width of application or along the length of application, you need to place a series of containers in the application path. Table 6 gives you the information to convert the depth of liquid in a straight-walled container to the application rate. Because such small depths are involved, the depth method only gives an approximation of application rate. A more accurate method is to weigh the contents of the container and convert this weight to an application rate.

Table 6. Chart to convert depths in straight wall container to application

Depth of Manure in Pail	Application Rate, Gallons/Acre
1/10 inch	2,250
1/8 inch	2,800
1/4 inch	5,650
3/8 inch	8,500
1/2 inch	11,300
5/8 inch	14,150
3/4 inch	17,000
1 inch	22,650

IRRIGATION

Direct irrigation of manure slurry through a large-diameter sprinkler nozzle is an alternative for farms that produce larger quantities of manure and have nearby pasture or cropland. Irrigation of liquid manure requires less labor, time, and operating expense than hauling and does not have the soil compaction problems.

Centrifugal pumps that can deliver at least 30 psi pressure at the sprinkler nozzle are needed for irrigation. In addition, due to the high solids content of the slurry, a lift pump or chopper-agitator pump is needed to help the centrifugal pump maintain its prime. Internal pump chopper mechanisms can help avoid clogging. Slurries with more than 4% solids cause higher friction losses in the pipes, requiring more pump pressure and horsepower. It is essential that the

irrigation lines be flushed with clean water after slurry pumping. With proper management, slurry manure up to 7% total solids can be irrigated.

Over application of nutrients is a concern with slurry irrigation systems. Moving sprinklers frequently helps to avoid this. Thus, traveling irrigators are usually recommended. A properly designed irrigation system provides uniform wastewater application at agronomic rates without direct runoff from the site. However, a "good design" does not guarantee proper land application. Management is also critical. You should be familiar with the system components, range of operating conditions, and maintenance procedures and schedules to keep your system in proper operating condition.

Types of Systems

As with water irrigation, there is no one system that is superior over another system. The following systems can be used for effluent irrigation:

- Stationary volume gun
- Solid set sprinkler
- Traveler
- Center pivot and linear move systems
- Hand-move sprinkler
- Side roll
- Furrow/Flood irrigation

Each of these systems are described in the next few pages. Although the equipment required for pumping and distributing lagoon effluent may be similar to conventional irrigation equipment, the smaller volume of water handled in most livestock lagoons and holding basins generally allows the use of smaller, less costly systems. It also is possible to use an application system for both effluent and fresh water irrigation. The type of irrigation system chosen depends on many farm specific parameters including the particle size of the solids in the effluent, the amount of available capital and how much time and labor is available for pumping, and the land available for application. Nevertheless, knowledge of the potential options available and their advantages and disadvantages could lead you to better decisions.

Stationary Volume Gun

This system can be used in many small effluent application systems. The system includes a pump and a main line similar to the hand-move systems, but with a single or multiple large-volume gun sprinklers. Advantages of the volume gun systems include larger flow rates and a larger wetted area so less labor is required in moving the sprinkler. Some volume guns are wheel mounted to facilitate moving the unit. Stationary volume guns typically have nozzle sizes that range from 0.5 to 2 inches, and operate best at pressures of 50 to 120 psi. Coverage areas of 1 to 4 acres can be obtained with proper selection of nozzle size and operating pressure. Gun sprinklers typically have higher application rates; therefore, adjacent guns should not be operated at the same time (referred to as "head to head"). Although stationary volume guns cost more than smaller hand-carry systems, the reduced labor cost and higher flow rates may offset the higher cost.

A typical volume gun that discharges 330 gpm at 90 psi pressure wets a 350-foot diameter circle (2.2 acres) with an application rate of 0.33 inches per hour. The power requirement is about 30 horsepower. This system requires labor for movement from one set or location to another to ensure that the soil does not become saturated resulting in runoff.

Table 7. Characteristics of Stationary Guns.

Advantages:	*Limitations:*
Few mechanical parts to malfunction Few plugging problems with large nozzle Flexible with respect to land area Pipe requirements are slightly less than with small sprinklers Moderate labor requirement	Moderate to high initial investment Water application pattern is easily distorted by wind Tendency to over-apply effluents with high nutrient concentrations

Stationary Sprinkler Systems

Stationary systems for land application of lagoon liquid are usually permanent installations (lateral lines are PVC pipes permanently installed below ground) (Figure 6). One of the main advantages of stationary sprinkler systems is that these systems are well suited to irregularly shaped fields. Thus, it is difficult to give a standard layout, but there are some common features between systems. To provide proper overlap, sprinkler spacings are normally 50% to 65% of the sprinkler-wetted diameter. Sprinkler spacing is based on nozzle flow rate and desired application rate. Sprinkler spacings are typically in the range of 80 feet by 80 feet, using single-nozzle sprinklers. Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed. In grazing conditions, all risers must be protected (stabilized) if left in the field with animals.

The minimum recommended nozzle size for wastewater is 1/4 inch. Typical operating pressure at the sprinkler is 50 to 60 PSI. Sprinklers can operate full or partial circle. The system should be zoned (any sprinklers operated at one time constitutes one zone) so that all sprinklers are operating on about the same amount of rotation to achieve uniform application.

Table 8. Characteristics of Stationary Sprinkler Systems.

Advantages:	*Limitations:*
Good for small or irregular-shaped fields Flexible with respect to land area Do not have to move equipment Low labor requirement	High initial investment Must protect from animals in fields Small-bore nozzles likely to get plugged or broken No flexibility to move to other (new) fields

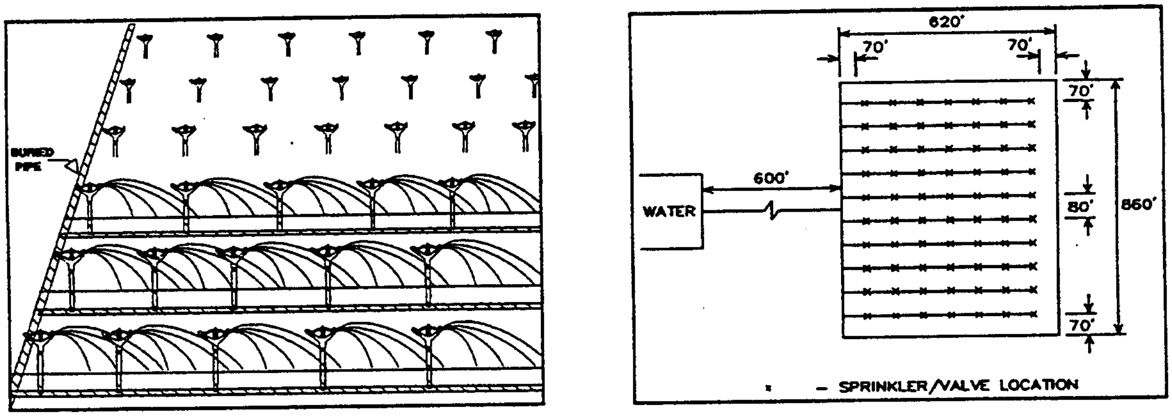


Figure 6. Stationary Sprinkler System

Traveling Sprinklers

Traveling sprinkler systems can be cable-tow traveler, hard-hose traveler, center pivot, or linear-move systems. The cable-tow traveler consists of a single-gun sprinkler mounted on a trailer with water being supplied through a flexible, synthetic fabric, rubber, or PVC-coated hose. Pressure rating on the hose is normally 160 PSI. A steel cable is used to guide the gun cart. The hose-drag traveler consists of a hose drum, a medium-density polyethylene (PE) hose, and a gun-type sprinkler. The hose drum is mounted on a multiwheel trailer or wagon. The gun sprinkler is mounted on a wheel or sled-type cart referred to as the gun cart. Normally, only one gun is mounted on the gun cart. The hose supplies wastewater to the gun sprinkler and also pulls the gun cart toward the drum. The distance between adjacent pulls is referred to as the lane spacing. To provide proper overlap, the lane spacing is normally 70% to 80% of the gun-wetted diameter.

The hose drum is rotated by a water turbine, water piston, water bellows, or an internal combustion engine commonly referred to as an auxillary drive unit. Regardless of the drive mechanism, the system should be equipped with speed compensation so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. If the solids content of the wastewater exceeds 1%, an engine drive should be used.

Nozzle sizes on gun-type travelers are 1/2 to 2 inches in diameter and require operating pressures of 75 to 100 PSI at the gun for uniform distribution. The gun sprinkler has either a taper bore nozzle or a ring nozzle. The ring nozzle provides better breakup of the wastewater stream, which results in smaller droplets with less impact energy (less soil compaction) and also provides better application uniformity throughout the wetted radius. But, for the same operating pressure and flow rate, the taper bore nozzle throws water about 5% further than the ring nozzle, i.e., the wetted diameter of a taper bore nozzle is 5% wider than the wetted diameter of a ring nozzle. This results in about a 10% larger wetted area such that the precipitation rate of a taper bore nozzle is approximately 10% less than that of a ring nozzle.

A gun sprinkler with a taper bore nozzle is normally sold with only one size nozzle, while a ring nozzle is often provided with a set of rings ranging in size from 1/2 to 2 inches in diameter. This allows the operator flexibility to adjust flow rate and diameter of throw without sacrificing application uniformity. However, there is confusion that using a smaller ring with a lower flow rate will reduce the precipitation rate. This is not normally the case. Rather, the precipitation rate remains about the same because while a smaller nozzle results in a lower flow, it also results in a smaller wetted radius or diameter. The net effect is little or no change in the

precipitation rate. Furthermore, on water drive systems, the speed compensation mechanism is affected by flow rate. There is a minimum threshold flow required for proper operation of the speed compensation mechanism. If the flow drops below the threshold, the travel speed becomes disproportionately slower, resulting in excessive application even though a smaller nozzle is being used. System operators should be knowledgeable of the relationships between ring nozzle size, flow rate, wetted diameter, and travel speed before interchanging different nozzle sizes. As a general rule, operators should consult with a technical specialist before changing nozzle size to a size different than that specified in the certified waste management plan.

Table 9. Characteristics of Hard Hose Traveler Systems.

***Advantages*:**	***Limitations:***
Few or no plugging problems with the large nozzle Flexible with respect to land area Moderate labor requirement	High initial investment High power requirement More mechanical parts than the other systems, especially with an auxiliary engine High application rates

Center Pivots and Linear Move Systems

The use of center-pivot systems for wastewater irrigation is increasing. Center pivots are available in both fixed-pivot point and towable machines. They are available in size from single tower machines that cover around 2 acres to multi-tower machines that can cover several hundred ăcres. Center pivot manufactures can offer almost completely automated systems that use rotary sprinklers, small guns, or spray nozzles. There are several disadvantages including high cost, small sprinklers, and fixed land area covered. Drop-type spray nozzles offer the advantage of applying wastewater close to the ground at low pressure, which results in little wastewater drift due to wind. Linear-move systems are similar to center pivot systems, except that travel is in a straight line. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 PSI. Low-pressure systems reduce drift at the expense of higher application rates and greater potential for runoff. Low-pressure systems in the 20 psi range with nozzles less than ¼ inch diameter are not recommended for livestock effluent because they could be plugged by solids in the effluent.

Hand-move Sprinkler Systems

The least costly sprinkler system for effluent irrigation are the hand-move types that require labor to set up and move the system. Although considerable labor input is required, these systems may be desirable for small lagoons. Used hand-move systems may be available, but small nozzles in the sprinklers may not be suited for effluent irrigation. A screened inlet pipe will reduce problems with small nozzles. Nozzle sizes used for moderately to heavily loaded lagoons are generally in the 1/2- to l-inch range and typically cover 1/2 to 2 acres per sprinkler, depending on nozzle size and system operating pressure.

Side-Roll Systems

These systems roll sideways across a rectangular field but are limited to low-growing crops. Crop clearance is slightly less than one-half the diameter of the wheel. These systems use small sprinklers, require rectangular fields, and have several mechanical devices.

Furrow or Gated Pipe Irrigation

These systems consist of a pump or gravity flow arrangement from a lagoon storage basin to a distribution pipe that has holes at intervals along its length. Effluent is discharged through the holes at a rate compatible with the land slope and soil infiltration rate. The gated distribution pipe usually is laid as level as possible across the upper end of a sloped soil-plant filter or manure receiving area. Gate pipe systems are suitable for lands from 0.2% to 5.0% slope. Flatter slopes result in ponding or manure at the discharge point of the gated pipe, while steeper slopes cause effluent runoff with little opportunity for infiltration into the soil.

The advantages of gated pipe systems are relatively low cost, low operating pressures, and even distribution of effluent if the holes in the pipe are properly located and sized. The disadvantages of the gated pipe systems are high labor and management to ensure the proper operation of the systems. Gated pipe systems do not perform well on uneven or steeply sloped land. Traditionally, gated pipe has been used to irrigate row crops. However, properly designed and managed gated pipe systems have been successfully used to apply lagoon effluent to grassed areas.

Calibrating Irrigation Systems

Operating an irrigation system differently than assumed in the design will alter the application rate, uniformity of coverage, and subsequently the application uniformity. Operating with excessive pressure results in smaller droplets, greater potential for drift, and accelerates wear of the sprinkler nozzle. Pump wear tends to reduce operating pressure and flow. With continued use, nozzle wear results in an increase in the nozzle opening, which will increase the discharge rate while decreasing the wetted diameter. Clogging of nozzles or crystallization of main lines can result in increased pump pressure but reduced flow at the gun. Plugged intakes will reduce operating pressure. An operating pressure below design pressure greatly reduces the coverage diameter and application uniformity. Field calibration helps ensure that nutrients from liquid manure or lagoon effluent are applied uniformly and at proper rates.

The calibration of a hard hose or cable tow system involves setting out collection containers, operating the system, measuring the amount of wastewater collected in each container, and then computing the average application volume and application uniformity.

An in-line flow meter installed in the main irrigation line provides a good estimate of the total volume pumped from the lagoon during each irrigation cycle. The average application depth can be determined by dividing the pumped volume by the application area. The average application depth is computed from the following formula:

$$\text{Average application depth, inches} = \frac{\text{Volume pumped, gallons}}{27{,}154\ \text{(gal/ac-in)} \times \text{Application area, acres}}$$

The average application depth is the average amount applied throughout the field. Unfortunately, sprinklers do not apply the same depth of water throughout their wetted diameter. Under normal operating conditions, application depth decreases toward the outer perimeter of the wetted diameter. Big gun sprinkler systems typically have overlap based on a design sprinkler spacing of 70% to 80% of the wetted sprinkler diameter to compensate for the declining

application along the outer perimeter. When operated at the design pressure, this overlap results in acceptable application uniformity.

When operated improperly, well-designed systems will not provide acceptable application uniformity. For example, if the pressure is too low, the application depth will be several times higher near the center of sprinkler and water will not be thrown as far from the sprinkler as indicated in manufacturers' charts. Even though the average application depth may be acceptable, some areas receive excessively high application while others receive no application at all. When applying wastewater, it is important to determine the application uniformity so that you have some idea of nutrient application uniformity. Collection containers distributed throughout the application area must be used to evaluate application uniformity. In the following pages, we present the calibration methods for a traveling gun system and a center pivot. Procedures for calibrating other systems are available and can be obtained from your county agent, irrigation dealer, or from the authors.

Many types of containers can be used to collect flow and determine the application uniformity. Standard rain gauges work best and are recommended because they already have a graduated scale from which to read the application depth. Pans, plastic buckets, jars, or anything with a uniform opening and cross section can be used, if the container is deep enough (at least 4 inches deep) to prevent splash and excessive evaporation, and the liquid collected can be easily transferred to a scaled container for measuring. All containers should be the same size and shape to simplify application depth computations. All collection containers should be set up at the same height relative to the height of the sprinkler nozzle (discharge elevation). Normally, the top of each container should be no more than 36 inches above the ground. Collectors should be located so that there is no interference from the crop. The crop canopy should be trimmed to preclude interference or splash into the collection container.

Calibration should be performed during periods of low evaporation. Best times are before 10 a.m. or after 4 p.m. on cool days with light wind (less than 5 miles per hour. The volume (depth) collected during calibration should be read soon after the sprinkler gun cart has moved one wetted radius past the collection gauges, minimizing evaporation from the rain gauge. Where a procedure must be performed more than once, containers should be read and values recorded immediately after each setup.

Traveling Gun Systems

Hard hose and cable-tow traveling guns are calibrated by placing a row (transect) of collection containers or gauges perpendicular to the direction of travel (Figure 6). The outer gauge on each end of the row should extend past the furthest distance the gun will throw wastewater to ensure that the calibration is performed on the "full" wetted diameter of the gun sprinkler. Multiple rows increase the accuracy of the calibration.

Containers should be spaced no further apart than 1/16 of the wetted diameter of the gun sprinkler not to exceed 25 feet. At least 16 gauges should be used in the calibration. Sixteen gauges will be adequate except for large guns where the wetted diameter exceeds 400 feet. (Maximum recommended spacing between gauges, 25 feet X 16 = 400 feet.) As shown in Figure 7, gauges should be set at least one full wetted diameter of throw from either end of the travel lane. The system should be operated such that the minimum travel distance of the gun cart exceeds the wetted diameter of throw.

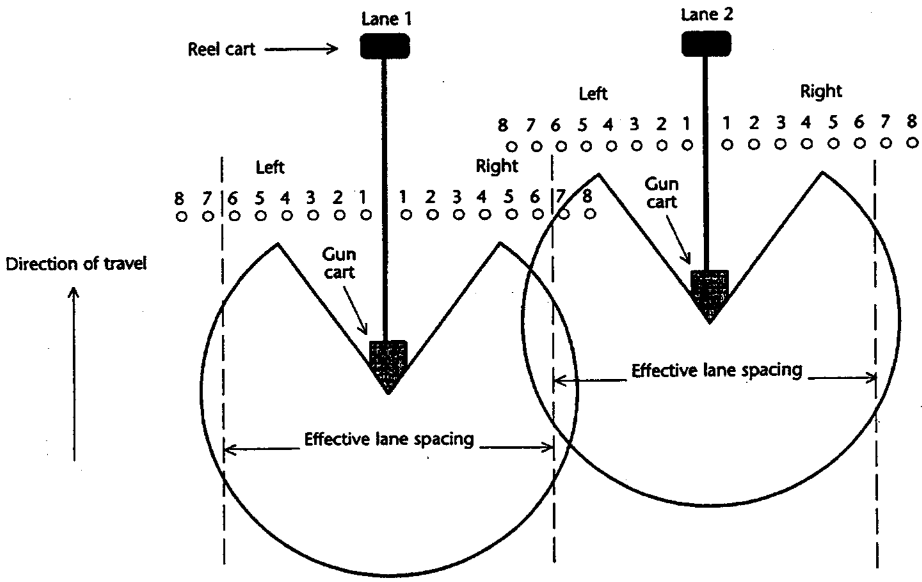


Figure 7. Calibration setup for hard hose travelers.

Calibration Method

1. Estimate the wetted diameter of the gun. Check the actual operating pressure at the sprinkler and verify the nozzle type and size. Determine wetted diameter from manufacturer's charts.
2. Determine the number of collection gauges and spacing between gauges. For a wetted diameter of 320 feet, the rain gauge spacing should not exceed 20 feet (320 ft/16 = 20 ft).
3. Label gauges outward from the gun cart as either left or right (L1, L2, L3, etc; R1, R2, R3, etc.)
4. Set out gauges along a row as labeled and shown in Figure 6, equally spaced at the distance determined in item 2 (20 feet). The row should be at least one wetted diameter from either end of the pull. The first gauge on each side of the travel lane should be ½ the gauge spacing from the center of the lane. For a gauge spacing of 20 feet, L1 and R1 should be 10 feet from the center of the lane.
5. Operate the system for the time required for the gun to completely pass all collection containers. Record the "starting" time when wastewater begins to be applied along the row of gauges, and the "ending" time when wastewater no longer is being applied anywhere along the row. Also record the distance traveled in feet for the time of operation.
6. Immediately record the amounts collected in each gauge.
7. Identify those gauges that fall outside the effective lane spacing. This volume is the overlap volume that would be collected when operating the system on the adjacent lane.

8. Superimpose (left to right and vice versa) the gauges just outside the effective width with the gauges just inside the effective width. Add the volumes together. For the layout shown in Figure 6, add the volume (depth) collected in gauge R8 (outside the effective lane spacing) to volume (depth) collected in gauge L5 (inside the effective lane spacing). Similarly, R7 is added to L6; L8 is added to R5; and L7 is added to R6. This is now the application volume (depth) within the effective lane spacing adjusted for overlap.
9. Add the amounts collected in all gauges and divide by the number of gauges within the effective area. This is the average application depth (inches) within the effective lane spacing.

$$\text{Average application depth} = \frac{\text{Sum of amounts collected in all gauges}}{\text{Number of gauges within effective width}}$$

10. Calculate the deviation depth for each gauge. The deviation depth is the difference between each individual gauge value and the average value of all gauges (#9). Record the absolute value of each deviation depth. Absolute value means the sign of the number (negative sign) is dropped, and all values are treated as positive. The symbol for absolute value is a straight thin line. For example, |2| means treat the number 2 as an absolute value. It does not mean the number 121. Because this symbol can lead to misunderstandings, it is not used with numbers in the worksheets. The symbol is used in formulas in the text.

$$\text{Deviation depth} = |\text{Depth collected in gauge I} - \text{average application depth}|$$

"I" refers to the gauge number

11. Add amounts in #10 to get "sum of the deviations" from the average depth and divide by the number of gauges to get the average deviation.

$$\text{Avg deviation depth, inches} = \frac{\text{Sum of deviations (add amounts computed in \#10)}}{\text{Number of gauges within effective lane spacing}}$$

12. The precipitation rate (inches/hour) is computed by dividing the average application depth (inch) (#9) by the application time (hours) (#5).

$$\text{Precipitation rate, inches/hour} = \frac{\text{Average application depth, inch}}{\text{Application time, hours}}$$

13. Compute the average travel speed.

$$\text{Average travel speed} = \frac{\text{Distance traveled, feet}}{\text{Time, minutes}}$$

14. Determine the application uniformity. The application uniformity is often computed using the mathematical formula referred to as the Christiansen Uniformity Coefficient (U_c). It is computed as follows:

$$U_c = \frac{\text{Average depth (\#9)} - \text{Average deviation (\#11)}}{\text{Average depth (\#9)}} \times 100$$

15. Interpret the calibration results. The higher the Uniformity Coefficient, the more uniform the application. A value of 100 would mean that the uniformity is perfect; the exact same amount was collected in every gauge.

For travelers with proper overlap and operated in light wind, an application uniformity greater than 85 is outstanding and very rare. Application uniformity between 70 to 85 is in the "good" range and is acceptable for wastewater application. Generally, an application uniformity below 70 is considered unacceptable for wastewater irrigation using travelers. If the computed U_c is less than 70, system adjustments are required. Contact your irrigation dealer or technical specialist for assistance.

Center Pivot

As Figures 8 and 9 show, center pivot and linear move irrigation systems are calibrated by placing one or more rows (transect) of collection containers parallel to the system. For center pivot systems with multiple towers, place the first collection container beside the first moving tower (140 to 180 feet from the pivot point). This will miss the area between the pivot point and first tower, but it is necessary to omit this system through this zone. The area missed will be less than 3 acres and will usually represent less than 10% of a typical sized system. If the system has only one moving tower, place the first container 100 feet from the pivot point tower. Place containers equally spaced to the end of the system. For lateral move systems, place containers throughout the entire length of the system.

Containers should be spaced no further apart than 1/2 the wetted diameter of rotary impact sprinklers, 1/4 the diameter of gun sprinklers, or 50 feet, whichever is less. On systems with spray nozzles, collection containers should be spaced no further than 30 feet. A 20- to 25-foot spacing is generally recommended for all types of sprinklers, which will result in six to eight collection containers between each tower. Collection containers should be placed such that they intercept discharge from a range of lateral distances from the sprinkler (midpoint, quarter point, directly under sprinkler, etc.). This can be accomplished by selecting a catch can spacing different from a multiple of the sprinkler spacing along the lateral. Where end guns are used, the transect of collection containers should extend beyond the throw of the gun.

The system should be operated so that the minimum travel distance exceeds the sprinkler wetted diameter for the containers closest to the pivot point tower. Application volumes should be read as soon as all gauges stop being wetted.

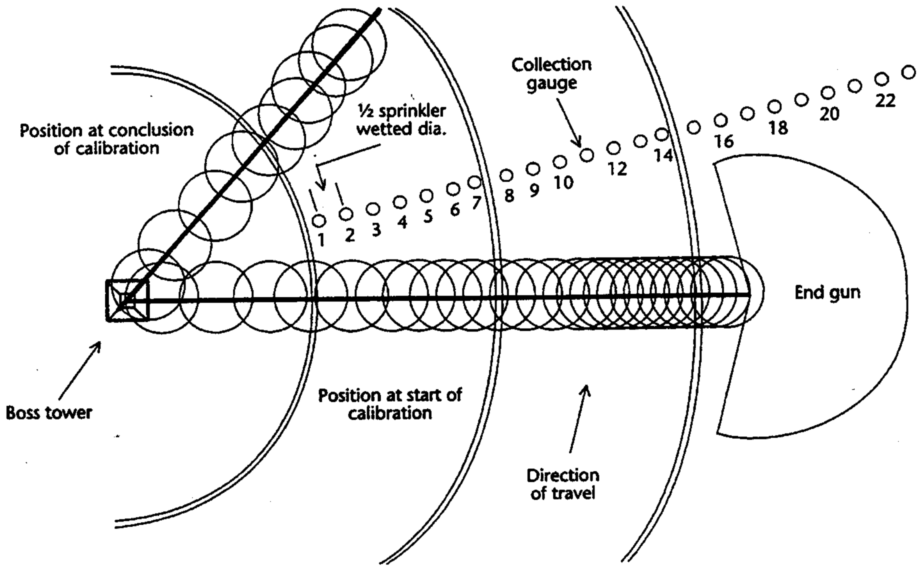


Figure 8. Collection container layout for calibration of a center pivot irrigation system.

Calibration Procedures

1. Determine the wetted diameter of the sprinkler, gun, or spray nozzle.
2. Determine the necessary spacing between collection gauges. The spacing should not exceed 50 feet. Twenty-five feet or less is generally recommended.
3. Determine the number of gauges required. Label gauges outward from the pivot point tower.
4. Place gauges along a row as labeled and shown in Figure 8, equally spaced at the distance determined in item 2. The row should be in the direction of system travel and at least one-half sprinkler wetted diameter from the sprinkler nearest the pivot point tower.

Note: The alignment of the row relative to the center pivot system does not matter as long as the system operates completely over each collection gauge. For most setups, the gauges closest to the pivot point tower will control how long the system must be operated to complete the calibration.

5. Operate the system for the time required for the sprinkler nearest the pivot point tower to completely pass the collection containers. Record the time of operation (in minutes) and distance traveled (in feet) at a reference point along the system.
6. Immediately record the amounts collected in each gauge.
7. Add the amounts in item 6 and divide by the number of gauges. This is the average application depth (inches).

$$\text{Average application depth} = \frac{\text{Sum of amounts collected in all gauges}}{\text{Number of gauges}}$$

8. Where an end gun is used, identify those gauges at the outward end where the depth caught is less than 1/2 the average application depth computed in item 7. The distance to the last usable gauge is the effective diameter of the system from which the effective acreage is computed.

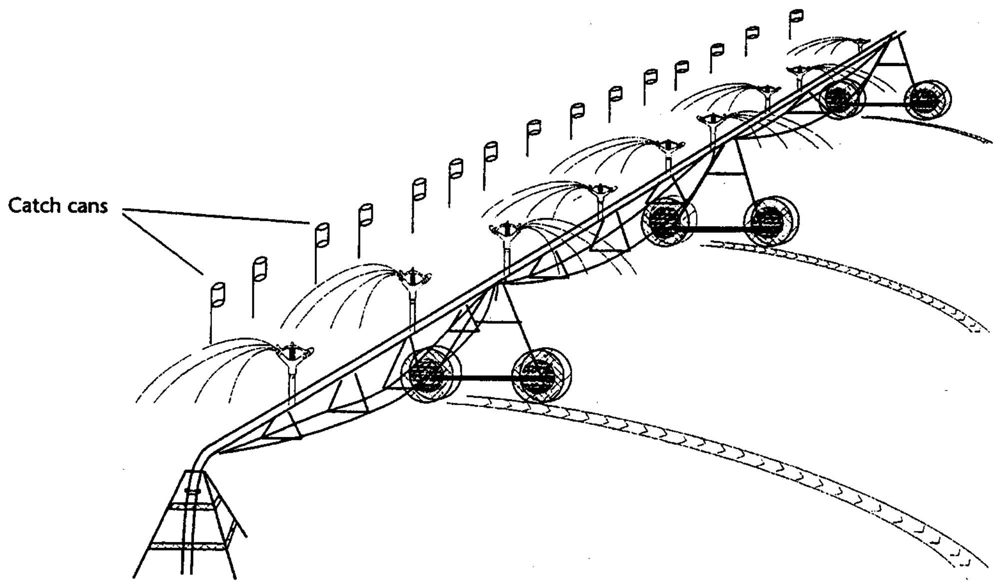


Figure 9. Calibration layout for center pivot irrigation systems.

9. Recompute the average application depth for the "usable" gauges identified in item 8 that fall within the effective width of the system. (Eliminate gauges on the outer end of the system where the depth caught is less than half the average application depth.)

Note: All gauges interior to the "effective width" of the system are included in the computations regardless of the amount caught in them.

10. Compute the reference travel speed and compare to the manufacturer's chart.

$$\text{Travel speed, ft/min} = \frac{\text{Distance traveled, ft}}{\text{Time, min}}$$

11. Calculate the deviation depth for each "usable" gauge. The deviation depth is the difference between each individual gauge value and the average value of all gauges (item 9). Record the absolute value of each deviation depth. (Absolute value means the sign of the number [negative sign] is dropped, and all values are treated as positive).

    Deviation depth = |Depth collected in gauge I – average application depth|

    "I" refers to the gauge number

12. Add amounts in item 11 to get the "sum of the deviations" from the average depth and divide by the number of gauges to get the average deviation.

$$\text{Average deviation depth} = \frac{\text{Sum of deviations (add amounts computed in item11)}}{\text{Number of usable gauges}}$$

13. Determine the application uniformity. The application uniformity is often computed using the mathematical formula referred to as the Christiansen Uniformity Coefficient. It is computed as follows:

$$U_c = \frac{\text{Average depth (item 7)} - \text{Average deviation (item12)}}{\text{Average depth (item 7)}} \times 100$$

14. Interpret the calibration results. The higher the Uniformity Coefficient, the more uniform the application. A value of 100 would mean that the uniformity is perfect, that the exact same amount was collected in every gauge.

For center pivot and linear move systems operated in light wind, an application uniformity greater than 85 is common. Application uniformity between 70 to 85 is in the "good" range and is acceptable for wastewater application. Generally, an application uniformity below 70 is considered unacceptable for wastewater irrigation using center pivots and linear move systems. If the computed U_c is less than 70, system adjustments are required. Common problems include clogged nozzles, sprinklers not rotating properly, inadequate system pressure, sprinklers installed in the wrong order, end gun not adjusted properly, wrong end gun nozzle, and/or worn nozzles. Contact your irrigation dealer or technical specialist for assistance.

Best Management Practices

Best Management Practices (BMPs) refers to a combination of practices determined to be effective economical approaches to preventing or reducing pollution generated by nonpoint sources. BMPs can be structural as in the construction of terraces, dams, pesticide mixing facilities, or fencing or they can be managerial like crop rotation, nutrient management, and conservation tillage. Both types of BMPs require good management to be effective in reducing the generation or delivery of pollutants from agricultural activities. Preventive practices such as these are the most practical approaches to reducing nonpoint source pollution. In a nutrient management plan, it is important that you indicate the BMPs that will be used on all land application areas.

Factors controlling BMP effectiveness

BMPs are used to reduce the effects of all forms of pollutants. They use a variety of mechanisms that result in varying degrees of effectiveness. When selecting BMPs, you should use a systematic approach to insure that the practice you select will solve your problem. The following questions can help you in the selection process.

What pollutants are contributing to the problem?
Sediment, Nutrients, Bacteria, etc.
Where are the pollutants being transported?
Surface or Ground Water
How are the pollutants being delivered?
Availability, transport paths, in the water or on sediment

You also need to remember that the most effective plan will probably consist of several different BMPs that target different mechanisms. Some BMPs may solve a surface water quality problem but create a ground water quality problem. This should be considered when the selection is being made rather than after a new problem arises. The BMPs for your operation should be designed (and the installation reviewed) by an expert trained in these systems. Finally, if a BMP is not economically feasible and well suited for the site, you probably shouldn't use it. Consider all costs including effects on yield, production and machinery costs, labor and maintenance, and field conditions when selecting BMPs. Often a very effective BMP will rapidly become a problem if all the costs are not considered before implementation.

All activities within a watershed affect NPS pollution but control of soil erosion is probably the best opportunity for preventing pollution since sediment is not only a pollutant itself, but also carries nutrients and pesticides with it. While soil erosion is a natural process, it is accelerated by any activity that disturbs the soil surface. The amount of soil erosion that occurs is related to five factors; the rainfall and runoff, the soil erodibility, the slope length and steepness, the cropping and management of the soil, and any support practices that are implemented to prevent erosion. Man can do very little to change the rainfall a location receives and has little effect on the natural properties of the soil that affect erosion. However, man can manage to reduce the impact of these factors. For example, increasing the amount of rainfall the goes into the soil (infiltration) is an indirect means of reducing erosion. Knowledge of rainfall patterns will also allow farmers to insure that the soil is protected during the periods of the year when they receive the largest amounts of rainfall. Traditionally, farmers have controlled soil erosion through modifications in slope steepness and slope length and in cropping and management. Since the dawn of agriculture, man has known that longer and steeper slopes produce more soil erosion and has used methods such as the construction of levies and terraces to reduce slope length and steepness. More recently, practices such as strip cropping and vegetated waterway construction have been used to reduce runoff velocities and slope length. Crop canopy and surface cover or residue acts as a buffer between the soil surface and the raindrops, absorbing much of the rainfall energy and ultimately reducing soil erosion. Therefore, crops that produce more vegetative cover, have longer growing seasons, or produce a persistent residue will have less soil erosion. Any cropping system with less tillage or greater amounts of vegetative production, such as perennial systems, will result is less sediment leaving the field.

While most BMPs reduce soil erosion and transport, some BMPs use other mechanisms to reduce the impact of a pollutant. There are three stages to the pollutant delivery process: availability, detachment, and transport. BMPs may be effective by addressing any of these three factors. Availability is a measure of how much of a substance in the environment can become a pollutant. For example, an effective BMP for reducing the amount of animal waste entering surface water may be to simply decrease the amount that you are land applying to an area so that less is available. Once a substance is available; however, it must be detached from the target site to become a pollutant. Pollutants may be detached as individual particles in the water or attached to soil particles. If a pollutant is soluble, then detachment occurs when it is dissolved in water. For example, dry manures applied to the surface are more easily detached than the same amount of liquid manure that has soaked into the soil. Transport is the final link in the pollutant delivery chain. To become a pollutant, the element must travel from the point where it was applied to the surface or ground water. Pollutants are often transported by surface runoff or infiltration, however, this transport can often be reduced through BMPs. For example, using a filter strip to collect sediment before entering a stream is an example of reducing the amount of pollutant transport.

BMPs, when properly carried out, improve water quality. Generally, an animal operation will have a combination of several BMPs. Best management practices relating to manure management are those practices that optimize nutrient uptake by plants and minimize nutrient impact on the environment. They will change over time as technology and understanding of the complex environment improve. Likewise, BMPs are very site specific, and a BMP in one place may not be useful for another location. Key BMPs for land application are listed in Table 10.

Table 10. Common BMPs for land application of manure

BMP	Mode of Action
Soil, Manure or Plant Analysis	Insures that proper crop nutrient requirements are met and manure is not over applied: Amount
Nutrient Management Plan	Insures that proper crop nutrient requirements are met and manure is not over applied: Amount
Calibration of Application Equipment	Insures that proper crop nutrient requirements are met and manure is not over applied: Amount
Manure treatments such as alum	Reduces availability of nutrients to runoff
Manure injection or incorporation	Places nutrients in the root zone and reduces availability to runoff: Availability
Critical area protection/ Vegetated waterways	Removes areas prone to runoff and erosion from production and manure application; Availability
Water diversions	Diverts water from running onto fields; Availability
Terraces or Contour planting	Reduces erosion and encourages infiltration; Transport
Riparian Buffers or Filter Strips	Acts as trap to remove pollutants before entering waterways; Transport
Cover crops, "scavenger crops, or crop rotation	Reduces erosion and encourages infiltration, improves soil quality and provides additional uptake; Transport and availability
Conservation or Reduced Tillage	Reduces erosion and encourages infiltration, improves soil quality and provides additional uptake; Transport and availability
Ponds or retention structures	Acts as trap to remove pollutants before entering waterways; Transport
Rotational Grazing/ Pasture Management	Reduces runoff and erosion, increases plant uptake; Transport and availability

BMPs to Reduce Nutrient Losses

Managing the amount, source, form, placement, and timing of nutrient applications are activities that will accomplish both crop production and water quality goals. This holds true for all nutrient sources including manure, organic wastes, chemical fertilizers, and crop residues. Nutrient management plans are essential to apply the right amount of nutrients, in the right place, and at the right time to maximize yield and environmental protection. Proper nutrient management encompasses more than simply applying the right amount of nutrients. It is also important to make sure these nutrients are applied at the right time and in the proper locations. Proper maintenance and calibration of the application equipment is critical since a precisely calculated application rate does little if your machinery is not functioning properly. Nutrients also need to be applied when the vegetation can use it, during the spring or before periods of rapid growth. Avoid applying any nutrients during periods when the soil is saturated or frozen. It does little good to spend a lot of time and money on nutrients that will be washed off the soil surface with the first large rainfall so avoid land application immediately preceding large rainfall events. If possible, incorporation is the best way to insure that the plant nutrients remain in the soil.

A summary of the major nutrient management practices to enhance surface water and groundwater quality includes

1. Application of nutrients at rates commensurate with crop uptake requirements is one of the single most important management practices used for reduction of off site transport of nutrients.
2. Maintaining good crop growing conditions will reduce both surface runoff losses and subsurface losses of plant nutrients. Preventing pest damage to the crop, adjusting soil pH for optimum growth, providing good soil tilth for root development, planting suitable crop varieties, and improving water management practices will increase crop efficiency in nutrient uptake.
3. Timing of nutrient application to coincide with plant growth requirements increases uptake efficiency and reduces exposure of applied nutrients to surface runoff and subsurface leaching. Optimum time of application depends on the type of crop, climate, soil conditions, and chemical formulation of fertilizer or manure. Consult a certified crop advisor or professional agronomist to discuss when manure/nutrients should be applied to maximize crop uptake.
4. Certain soil and water conservation practices will reduce sediment-associated nutrient losses. Contouring, terraces, sod-based rotations, conservation tillage, and no-tillage reduce edge-of-field losses of sediment-bound-nitrogen and sediment-bound-phosphorus by reducing sediment transport.
5. Proper selection and calibration of equipment will ensure proper placement and rate of nutrient delivery. Improper calibration and equipment maintenance will result in over or under application of nutrients or uneven nutrient distribution. Appropriate handling and loading procedures will prevent localized spills and concentration of manure nutrients.
6. Crop sequences, cover crops, and surface crop residues are useful tools for reducing runoff and leaching losses of soluble nutrients. Winter cover crops may theoretically capture residual nutrients after harvest of a summer crop. Nutrient credits for "green manures" and cover crops must be taken to determine the appropriate rate of additional manure application. A suitable cover crop should be planted to scavenge nutrients especially in sandy, leachable soils. On soils with a high potential for leaching, multiple applications at lower rates should be used.
7. Deep-rooted crops, including alfalfa and to a lesser extent, soybeans, will scavenge nitrate leached past the usual soil-rooting zone. Used in crop rotation following shallow-rooted or heavily fertilized row crops, deep-rooted crops will recover excess nitrate from the soil and reduce the amount available for leaching to groundwater.
8. Use commercial fertilizer only when manure does not meet crop requirements.
9. Manure should not be applied more than 30 days prior to planting of the crop or forages breaking dormancy. Incorporate manure to reduce N loss, odors, and nutrient runoff for crops where tillage is normally used.
10. Applications of animal manure should not be made to grassed waterways. If applications are made, they should be conducted at agronomic rates and during periods of low rainfall to minimize runoff from the site.
11. On manure application sites that are grazed, reduce nitrogen rate by 25% or more to account for nutrient cycling through the grazing animals.

Pasture Management

There are several keys to maintaining adequate and sustainable pastures. Plant selection is critical as the plant must be adapted to both the soil and climate to insure adequate cover throughout the year. Determining proper stocking rates that will not damage the vegetative cover and result in increased soil erosion is also essential. Controlling animal traffic can help to prevent bare spots that could lead to the formation of gullies. If application sites are grazed, producers are encouraged to develop a grazing plan. Plans should encourage controlled frequent rotational grazing, multiple drinking water sites, and strategic harvesting to optimize manure and urine distribution by grazing animals. These practices will minimize potential point sources from stock camps, shade trees, water tanks, and heavy use areas. It is also essential to reduce manure application rates as nutrient removal rates are much lower for grazed pastures than for hayfields.

Water Control Structures

No matter how well you manage a operation, there will be times when runoff occurs. Since all water flows downhill, the total amount of surface runoff going past a given point will increase as you move downhill. As the runoff concentrates in rills and gullies its erosive force and its ability to transport pollutants continues to increase. Often structural practices such as terraces, diversions, grassed waterways, sediment basins, subsurface drainage, or even farm ponds can be used control the flow of water and protect water quality. While these practices are often costly to install, they usually have production and aesthetic benefits in addition to their environmental benefits.

Steep slopes and irregularities on the land surface contribute to increased flow concentrations and the formation of rills and gullies. Terraces and diversions can be used on steep or long slopes. Both of these practices are effective because they slow the runoff down by encouraging flow across the hillside rather than down the steeper hill slope.A grassed waterway is a natural or constructed channel, usually broad and shallow, planted with perennial grasses to protect soils from erosion by concentrated flow. These waterways serve as conduits for transporting excess rainfall and diverted runoff from the fields or pastures without excessive soil erosion. The vegetation also acts as a filter to remove suspended sediment and some nutrients. Grassed waterways require careful maintenance and periodic reshaping, especially after large or intense storms.

The use of sediment basins or small farm ponds is one final method of preventing off-farm pollution. A sediment basin is a barrier or dam constructed across a waterway to reduce the velocity of the runoff water so that much of the sediment and associated nutrients settle to the basin bottom. Small sediment basins require regular sediment removal while larger basins can almost appear to be a pond and may support fish and wild life. A well-placed pond can collect all of the runoff from a farm and have a positive impact on water quality. It acts as a detention basin by removing sediment and nutrients from the flow and reducing the volumes of flow occurring at peak conditions. It can also filter many nutrients if aquatic vegetation or fish are used. Finally, the pond can act as a buffer between the farm and the external environment.

Summary of Essential Information
Site Selection is critical to preventing environmental problems with dedicated land application sites. Ideal sites should be isolated, on slopes less than 7% slope, away from streams, rivers and wells, have deep seasonal groundwater tables, with soils that are suitable for maintaining good vegetative growth.

When determining which manure to place on which fields, remember, manure with the highest nutrient content should go to fields that are further away and have the highest nutrient demand. High P manure should be placed on fields with the lowest soil test P.

Keys to limiting nutrient movement include placing the right amount of nutrient, in the right time, and at the right spot. This will minimize losses and maximize nutrient use. The right amount is determined through soil and manure analysis and nutrient management budgeting. The right time is when the plants can use the nutrients and when the risk of pollution is lowest (ie. Avoiding applications prior to large storms and periods of high rainfall). The right place is in a location where plant roots can reach the nutrients and buffering critical areas such as stream banks and wells. Timing of application should be dictated by plant need and not the capacity of the storage structure.

When choosing an application method, you should consider initial cost, labor and operating costs, uniformity and precision of application equipment, timeliness of use, conservation of nutrients, odor, and soil compaction. Reliability is also important. Which system handles equipment failures better?

Calibration of application equipment is essential. It will verify actual application rates, troubleshoot equipment problems, determine appropriate overlaps, evaluate application uniformity, and monitor changes in equipment operation and manure properties.
Solid treatment and application methods are generally preferred to liquid and slurry systems because there are usually great utilization options and lower transportation and handling costs.

To determine actual application rates, you need to know the amount applied and the area it was applied on. This can be accomplished at various scales from field scale to collection in a rain gage. Application uniformity requires measurement of the distribution and requires several measurements of application rates at specific points. Knowledge of uniformity is essential for determining proper overlap and also for evaluating application system capabilities.

Surface applications of manure result in much greater nitrogen losses. Manure broadcast as a solid generally loses 15 to 30% of its nitrogen while liquids lose 10 to 25%. Immediate incorporation can reduce this to 1 to 5%. Nitrogen losses and odor are much lower with injection or low pressure irrigation.

Best Management Practices are effective economical approaches for preventing or reducing pollution generated from non-point sources. To be effective, BMP's must be properly planned, designed, and implemented or installed. This requires knowledge of the sources of pollutants, their transport mechanisms, and the effects on water quality. These are the tools that the agricultural community has to protect water quality. While the tools can be effective, good

management and desire are the most important aspects of preventing agricultural nonpoint source pollution. These principles can not be mandated or implemented by anyone other than the landowner so it is ultimately their responsibility to become an environmental steward and protect our water for future generations.

Reducing soil erosion is critical because sediment is a pollutant and also because it often carries nutrients and other pollutants with it. The amount of runoff and soil erosion at a given point is dependent on the climate (rainfall), soil type, cover and management and the slope length and steepness. Anything you can do to increase vegetative or residue cover, increase infiltration into the soil, or slow down the runoff coming off a field will decrease pollutant transport off the field.

Some BMP's like filter strips and buffers are effective at trapping pollutants and limiting transport offsite. Farm ponds and sedimentation basins are also excellent traps

Test Questions, Land Application

1. Which of the sites would be *best* suited as a dedicated liquid manure application site supplied via irrigation?

a) A 25 acre pasture on sandy clay loam soil, 3% slopes, 2000 ft from nearest well or stream, quarter of a mile to nearest neighbor, 50 ft to groundwater table with quite a few rock outcrops.
b) A 20 acre hayfield on sandy clay loam soil, 2% slopes, 1000 ft from nearest well or stream, half a mile to nearest neighbor, 45 ft to groundwater table with no rock outcrops or other geologic features.
c) A 10 acre corn field on very sandy soils, 2.5% slopes, one irrigation well on north edge of field and a swampy area on the south side, with neighbors located 500 feet downwind.
d) A 150 acre cotton on clay soil, 8-15% slopes, surrounded by forest, one stream running across the center of the field and no other important features.
Ans: b

2. Reducing soil erosion in land application areas is critical because:

a) sediment is a pollutant
b) it often carries nutrients and other pollutants with it
c) loss of topsoil impacts crop productivity
d) all of the above
Ans:d

3. Which of the following is *not* a factor that would influence the amount of runoff and erosion that comes from and land application site?

a) the slope
b) the nutrient content of the manure applied
c) the crop being grown
d) the amount of rainfall the site gets
Ans: b

4. Which of the following practices would *not* reduce the amount of nonpoint source pollution reaching a stream down-gradient from a land application site?

a) Installing a 50 ft. grass filter on the edge of the field
b) Converting it from a pasture to a hayfield
c) Installing terraces to break the slope
d) Changing it from conservation tillage to conventional tillage
Ans: d

5. Which of the following would *not* reduce nutrient losses to runoff and erosion?

a) Applying manure based on plant needs and manure analysis
b) Applying manure when plants are actively growing
c) Applying manure in the fall for spring planted crops
d) Applying manure in several small applications rather than one annual application
Ans:c

6. In general, manure with the highest nutrient content should:

a) Go on fields furthest away to reduce transport costs
b) Go on fields furthest away since in smells the worst
c) Go on the closest fields since they will probably have the lowest soil nutrients
d) Go on the soils with the highest soil test P levels
ans:a

7. Which is the least important consideration in choosing an application method?
a) Nutrient losses during application
b) Horsepower of the equipment
c) Operating cost
d) Uniformity of application
ans: b

8. Calibration can *not* be used to determine:
a) nutrient content of manure
b) uniformity of manure application
c) actual application rates
d) overlap and lane spacings for spreaders

8. Which equation below could be used to determine the average application rate for a field?
a) Total amount in a load divided by the area that the load was applied on
b) Total area of the field divided by the density of the manure
c) Total amount in a load divided by the amount the spreader holds
d) Total area of the field multiplied by the time in takes to get to the field
ans:a

9. Which application method would result in the greatest amount of nitrogen loss?
a) Subsurface injection of slurry manure
b) Low pressure irrigation of liquid manure
c) Surface application of solid manure
d) Irrigation of liquid manure followed by immediate incorporation
ans: c

9

Record Keeping

Record Keeping
Dr. Mark Risse

Introduction

Regular monitoring and record keeping is essential on all animal feeding operations. It is your best insurance against accidental discharges and documents that you are doing things correctly in the event of a compliance inspection. In addition, some records may be required as part of your CNMP. Keeping accurate records, along with the implementation of proper BMPs on your farm, is the primary way you prove to state water quality agencies and to the general public that your manure management system is not causing an environmental impact. Assistance with record keeping can be obtained from Certified Crop Advisors and other technical specialists, the local Cooperative Extension Service, the Natural Resources Conservation Service, and the local Soil and Water Conservation District.

Record keeping is a major component of farm inspections that are conducted by state water quality agencies or local soil and water conservation districts. Often a complaint leading to an inspection can easily be dealt with if proper records are available. In Georgia, the recommended records that all producers should maintain include the following:

Application Records	Other Records
Yields	Weather data
Soil tests	Animal population
Manure Analysis	Nutrient Management Plan
Land application events	Monthly inspections
Equipment calibration	Equipment maintenance
Field nutrient budget sheets	Farm*A*Syst or environmental assessments
Off-farm nutrient utilization sheets	Water quality monitoring

Application records will be discussed in more detail below. The other records are discussed in other sections of this notebook but briefly mentioned here as well. Most of these records should be part of your comprehensive nutrient management plan and you should store them with your plan even though they will not be submitted as part of the plan. These records should be maintained for at least five years or as long as they are useful.

At a minimum, the weather records should include daily farm rainfall records. These can be obtained through simple rain gages or more complex weather stations. Rainfall data is very useful in both managing crops and irrigation scheduling and in monitoring your manure storage. Some producers have also found it useful to keep wind speed and direction data where odor is an issue.

For all lagoons or manure storages, you should record weekly lagoon level (freeboard) records as well as inspection records. The section of this notebook on manure storage and treatment presents a sample inspection worksheet. Often this is an overlooked task that needs to be regularly scheduled. These records not only prevent emergencies but can also aid in a better understanding of your storage structures.

Equipment maintenance records seem trivial, especially when maintenance is only performed when equipment breaks down, but we know that well maintained equipment is more reliable and efficient. Good maintenance programs can save you money in the long term. Many people regularly change the oil in their cars and get improved gas mileage and longer engine life as a result. Do we do the same thing with our irrigation pumps? What will happen when the lagoon is 2 inches into the freeboard and it finally decides to breakdown?

The last two records, water quality monitoring and environmental assessments are proactive measures producers should use. Environmental assessments will be discussed in more detail in a future section. If these are conducted, keep them around to show what you are doing right and progress toward improvement. If water quality monitoring is required as part of your permit, the permit will dictate the frequency and types of ground and surface water monitoring you should do. If not, these records are very useful in catching problems early as well as documenting that you are not the source of a problem. We

recommend testing of all wells at least bi-annually for drinking water contaminants. For surface water flowing through your operation, semi-annual upstream and downstream testing for nitrate would be the cheapest and most effective strategy.

Application Records

Growers who use manure, commercial fertilizer, or waste materials, such as municipal biosolids or industrial residuals, as fertilizer or a source of lime should maintain records of the analytical results, application rates, and soil tests for each application site. A certain amount of record keeping is needed to keep up with the management of the manure application system. The record keeping forms provided here will help you document site-specific data that is currently limited on many animal operations. These forms will allow you to easily track your applications and provide you with an easy resource to ensure that you do not exceed manure applications to any fields. When combined with such site-specific data as your waste analysis, plant analysis, soils analysis, crop yields, and other farm plan items, these forms will provide evidence that you are managing your manure application properly and not exceeding agronomic rates.

Forms included here are as follows:

1. **IRR-1**: Irrigation Field Record is used to record each irrigation event. The IRR–1 or 2 forms can be used with all types of irrigation systems including solid-set sprinklers, solid-set volume guns, hard hose travelers, center pivots, and liner move irrigation systems. The irrigation field record forms would also be used to record applications with a drag-hose injector.
2. **IRR-2:** Cumulative Irrigation Field Record is to record the total annual waste application to one field per crop cycle. It enables the operator to calculate the total nitrogen application to the field and compare it to the recommended nitrogen loading rate.
3. **SLUR-1:** Liquid Manure Slurry Field Record is used to record manure application from liquid tanks. These forms would be used to record the broadcast or injection of any liquid manure, effluent, and sludge.
4. **SLUR-2:** Cumulative Liquid Manure Slurry Field Record is to record the total annual waste application to one field per crop cycle with a slurry or pump and haul system. It provides for calculating the total nitrogen application to the field and comparing it to the recommended nitrogen loading rate.
5. **SLD-1:** "Solid" or Semisolid Manure Field Record is to be used to record each application event from a manure box, flail, or side-discharge spreader. These forms would be used to record the broadcast of any solid manure, separated manure solids, bedding, litter, or compost.
6. **SLD-2:** Cumulative Solid Field Record is to record the total annual waste application to one field per crop cycle. It provides for calculating the total nitrogen application to the field and comparing it to the recommended nitrogen loading rate.

The record forms IRR-2, SLUR-2, and SLD-2 require the operator to make calculations to determine the amount of N that has been applied to a given crop. The necessary formulas to complete the forms are provided in the first row of the form.

Note: For recording purposes, field size is that portion of the field that receives manure applications. This is often referred to as the "wetted" or "irrigated" area when using irrigation. Wetted area is equal to or less than field size due to irrigation system layout, area required for required or recommended buffers, and the shape of the field. Application areas within fields may also be reduced by their inaccessibility with spreader equipment because of slope, seasonal wetness, or even soil type.

Access Forms

It is important for operators have permission to land apply manure on land that is rented or being used for application that is owned by another person. While this may be considered overkill to some, it

could be your only protection in the event of a spill or environmental investigation. It also may be required as part of a comprehensive nutrient management plan on farms that are land limited. A couple of example agreements are included with this chapter to assist you in developing these forms. These are only examples and may not be legally binding.

When transporting manure off-site or selling manure, records should include the amount sold, the buyer, and the manure nutrient content. It is also advisable to give the buyer a copy of the manure analysis and information in appropriate utilization.

Review of Essential Information

Record keeping and monitoring can prevent emergencies and problems from occurring, document compliance and stewardship, and improve the efficiency of your operation.

Suggested records that should be kept on animal feeding operations include application records, weather data, animal population, manure storage inspections, equipment maintenance, water quality monitoring, and environmental assessments.

Application records for manure should include soil tests, manure analysis, crop yields, land application events, equipment calibration, field nutrient budget sheets, and off-farm nutrient utilization sheets

When transporting manure off-site or selling manure, records should include the amount sold, the buyer, and the manure nutrient content. You should also provide some information on proper utilization to the buyer.

Form IRR-1

Irrigation Field Record
For Recording Irrigation Events on Different Fields

Farm Owner ______________________

Irrigation Operator ______________________

Facility Number __________ - __________

Tract #	Field #	Date (mm/dd/yr)	Crop Type	Field Size, acres	Irrigation Time			Number of Sprinklers Operating
					Start Time	End Time	Total Minutes	

Form IRR-2

Irrigation Field Record
One Form for Each Field Per Crop Cycle

Tract # ______ Field # ______

Field Size (acres) = **(A)** ______

Farm Owner ______

Facility Number ______ - ______

Irrigation Operator ______

From Manure Utilization Plan

Crop Type ______

Recommended PAN Loading, lb/acre = **(B)** ______

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Irrigation									
Date (mm/dd/yr)	Start Time (hr:min)	End Time (hr:min)	Total Minutes (3) - (2)	# of Sprinklers Operating	Flow Rate, gal/min	Total Volume, gallons (4) × (5) × (6)	Volume Per Acre, gal/ac (7) ÷ (A)	Waste Analysis [1] PAN, lb/1,000 gal	PAN Applied, lb/ac [(8) × (9)] ÷ 1,000	Nitrogen Balance [2], lb/ac (B) - (10)
					Crop Cycle Totals					

Owner's Signature

Operator's Signature

[1] See your manure management plan for sampling frequency. A recent manure analysis is your best method of properly utilizing your manure nutrients.
[2] Enter the value received by subtracting column (10) from **(B)**. Continue subtracting column (10) from column (11) following each application event.

Form SLUR-1

Slurry and Sludge Application Field Record
For Recording Slurry Application Events on Different Fields

Farm Owner ____________________

Spreader Operator ____________________

Facility Number __________ - __________

Tract #	Field #	Date (mm/dd/yr)	Crop Type	Field Size, acres	Application Method [3]	# of Loads Per Field	Volume of Loads [4], gallons

[3] SI = soil incorporated (disked); BR = broadcast (surface applied)
[4] Can be found in operator's manual for the spreader. Contact a local dealer if you do not have your owner's manual.

Form SLUR-2

Slurry and Sludge Application Field Record
One Form for Each Field Per Crop Cycle

Tract # ________ Field # ________

Field Size (acres) = **(A)** ________

Farm Owner ________

Facility Number ________ - ________

Spreader Operator ________

From Manure Utilization Plan

Crop Type ________

Recommended PAN Loading (lb/acre) = **(B)** ________

(1) Date (mm/dd/yr)	(2) # of Loads Per Field	(3) Volume of Loads [5]	(4) Total Volume (gallons) (2) × (3)	(5) Volume Per Acre (gal/ac) (4) + (A)	(6) Waste Analysis [6] PAN (lb/1000 gal)	(7) PAN Applied (lb/ac) [(5) × (6)] + 1,000	(8) Nitrogen Balance [7] (lb/ac) **(B)** - (7)
			Crop Cycle Totals				

Owner's Signature

Operator's Signature

[5] Can be found in operator's manual for the spreader. Contact a local dealer if you do not have your owner's manual.

[6] See your manure management plan for sampling frequency. A recent manure analysis is your best method of properly utilizing your manure nutrients.

[7] Enter the value received by subtracting column (7) from **(B)**. Continue subtracting column (7) from column (8) following each application event.

Form SLD-1

Solid Manure Application Field Record
For Recording Solid Manure Application Events on Different Fields

Farm Owner ______________________

Spreader Operator ______________________

Facility Number ________ - ________

Tract #	Field #	Date (mm/dd/yr)	Crop Type	Field Size (acres)	Application Method [8]	# of Loads Per Field	Volume of Loads [9] (tons)

[8] SI = soil incorporated (disked); BR = broadcast (surface applied)

[9] Can be found in operator's manual for the spreader. Contact a local dealer if you do not have your owner's manual.

Form SLD-2

Solid Manure Application Field Record
One Form for Each Field Per Crop Cycle

Tract # ____ Field # ____

Field Size (acres) = **(A)** ____

Farm Owner ____

Facility Number ____ - ____

Spreader Operator ____

From Manure Utilization Plan

Crop Type ____

Recommended PAN Loading (lb/acre) = **(B)** ____

(1) Date (mm/dd/yr)	(2) # of Loads Per Field	(3) Weight of Loads[10] (tons)	(4) Total Weight (tons) (2) × (3)	(5) *Weight Per Acre (tons/ac)* (4) ÷ (A)	(6) Waste Analysis[11] PAN (lb/ton)	(7) PAN Applied (lb/ac) (6) × (5)	(8) Nitrogen Balance[12] (lb/ac) **(B)** - (7)
			Crop Cycle Totals				

Owner's Signature

Operator's Signature

---

[10] Can be found in operator's manual for the spreader. Contact a local dealer if you do not have your owner's manual.

[11] See your manure management plan for sampling frequency. A recent manure analysis is your best method of properly utilizing your manure nutrients.

[12] Enter the value received by subtracting column (7) from **(B)**. Continue subtracting column (7) from column (8) following each application event.

Example of Manure Agreement

MANURE UTILIZATION AGREEMENT FOR LEASED LAND

I, ____________________________, hereby give __________________ permission to apply waste from his poultry production facility on ________ acres of my land for the duration of the time shown below.

I understand that this manure contains nitrogen, phosphorus, potassium, and trace elements, and when properly applied should not harm my land or crops. I also understand that the use of animal manure will reduce my need for commercial fertilizer.

Adjacent Landowner: ________________________________ Date: _________

Manure Producer: ___________________________________ Date: _________

Technical Representatives: ___________________________ Date: _________

Term of Agreement: ____________________,2000___ to _________, ____.

Example of third party form

Manure Utilization - Third Party Applicator Agreement

I, ____________________________ hereby acknowledge that I have received a copy, have read, and understand the Nutrient Management Plan dated _______________ that was developed for/by ________________________________ for their facility located at ____ ____ in _________________ County.

I hereby agree to manage and land apply the manure that I received from this facility in a manner consistent with all Federal, State and local laws.

Third Party Receiver: _______________________________ Date: _________

Manure Producer: __________________________________ Date: _________

Technical Representatives:

Term of Agreement: ____________________,20___ to _________, _20___

Test Questions: Records

1. Which of the following does not need to be routinely recorded in your manure application records?

a) nutrient content of manure
b) temperature of manure
c) amount applied
d) time of application
ans:b

2. Record keeping and monitoring can:

a. prevent emergencies and problems from occurring
b. document compliance and stewardship
c. improve the efficiency of your operation
d. all of the above

ans:d

3. Which of the follow is NOT suggested with selling manure to someone off your farm?

a. recording the buyer's name and amount purchased
b. only transporting off site if you control delivery
c. supplying the buyer with the nutrient content of the manure
d. supplying the buyer with some information on proper utilization

ans:b

10

Emergency Action Plans

Emergency Action Plans

Dr. Mark Risse
Adapted from Lesson 50 of National Animal and Poultry Waste Management Curriculum

Manure spills and discharges largely just don't happen, they are caused. Behind most spills is a chain of events that leads up to an unsafe act, improper judgement, unsafe conditions, or a combination of factors. Manure spills and discharges are the most common cause of regulatory penalties in Georgia and the Nation. Preventing and properly responding to discharges on the farm is everyone's concern. Communication between the farm owner, supervisors, agencies with emergency response responsibilities and employees generates ideas and awareness that leads to accident prevention and quick response in the event a spill occurs. Education programs, response plans, and regular inspections of your manure management and application system are essential in providing the lines of communication that lead to a safe, accident-free operation.

Intended Outcomes

The producer will:

- Recognize the need for developing an Emergency Action Plan
- Identify the steps involved in reporting and responding to a manure spill
- Identify activities related to their manure management system that may lead to higher environmental or human health risk
- Be prepared to develop an Emergency Action Plan for their facility

What is an Emergency Action Plan?
A basic, yet thorough, common sense plan that will help you make the right decision during an emergency.

Why have an Emergency Action Plan?
Murphy's Law: accidents will happen.
If it is written down, you will use it.
Plan before potential emergencies.
To protect you and other against environmental damage.
It should be part of a Comprehensive Farm Plan.

Emergency action plans are needed to minimize the environmental impact in the event of manure spills, discharges or mishaps. In several states these plans are required on all livestock operations, especially those with liquid manure management systems. According to Georgia swine regulations, an emergency action plan is a required component of a CNMP. The plan should be available to all employees and they should be trained in its use. This plan will be implemented in the event that manure or other wastes from your operation are leaking, overflowing, or running off the site. You should NOT wait until manure or wastewater reaches a stream or leaves your property. You should make every effort to ensure that this does not happen.

Prevention
The most important part of the plan is preventing spills from occurring in the first place.

Many "emergencies" can be prevented using routine maintenance. Inspections are often a key to finding problems before they turn into emergencies. Inspections of all manure storage or lagoons should be conducted on a regular basis; at least monthly but preferably weekly. Embankment areas should be keep mowed and free of trees and shrubs to allow for visual inspection of the embankment for any sign of seepage or cracks. If you notice any seepage, consult NRCS or the engineer who designed the facility to discuss the extent of seepage or cracking and what measures can be taken to further investigate or repair the situation. Consult NRCS, professional engineers, or tank manufacturers before making any modifications or repairs to your storage structure or lagoon. In many instances, specific procedures must be taken to insure that the structural integrity of the unit or embankment is not compromised in the process of making any modification or repair. Major spills and lagoon breeches have been caused by failing to follow these procedures.

Several livestock producers across the country are using electronic monitoring devices to assist them in managing their lagoon or storage basin levels. These monitors (Figure 1) consist of a liquid level sensor, microcomputer, rain gauge and phone connection. Lagoon levels and rainfall values are recorded twice a day and transmitted to a service provider who prepares weekly records. The monitors can also warn producers by either phone or pager of potential environmental or operating hazards such as approaching or reaching maximum storage levels or regulatory freeboards. Breech alarms can also be set on the monitors to contact producers in the event of a tank rupture or lagoon spill. Some lagoon monitors can also be modified to monitor livestock buildings in case of power outages. Similar power and liquid level monitoring devices can be used on other areas of the manure handling system such as pumping/lift stations. Livestock facilities should also consider secondary containment around existing storage facilities, pumping/lift stations, recycle pumps or production houses. These structures should be designed to collect the spilled manure and excess rainfall that may collect in an area. The collected liquid can then be transported and applied to cropland at agronomic rates.

Figure 1 Remote lagoon monitoring

Another prevention practice is the installation of low-pressure, low-flow or other automatic shut-off switches on pumping equipment for liquid irrigation systems. If these devices are not used, you should keep radio or cellular communications with someone who will remain close to the pump. Check all irrigation lines prior to pumping and look for defects, insecure or worn connections. Place solid pipes over any watercourses, wetlands, ditches or containment areas so that they are always visible for inspection.

Types of Emergencies

Your response to emergency situations will be governed by site- and situation-specific circumstance, which your own plan should address. However, there are responses you should consider based on the type of emergency you are experiencing. These responses can be broken

down according to three stages of emergency defined as imminent pollution or emergency, pollution in progress, and pollution discovered after the fact. These instructions should be available to all employees at the facility, as accidents, leaks, and breaks can happen at any time.

Imminent Pollution
In this type of situation, there have not yet been any leaks or spills. However, ignoring the fact that an emergency exists will probably result in a spill or leak within a short time. The main sources of this type of emergency are when lagoons, holding ponds, or pits are nearing capacity, or when there is potential for wastes to run off an application field.

Storage capacity about to be exceeded. Long periods of excessive rain or malfunctioning livestock water systems may cause your storage to unexpectedly reach capacity. Your response should be to prevent the release of wastes. Depending on your situation, this may or may not be possible, but suggested responses to this type of problem include:

- Add soil to the berm to increase the elevation of the dam.
- Planned emergency utilization of manure by pumping onto fields at acceptable rates.
- Stop all additional flow to the storage (waterers).
- Call a pumping contractor.
- Make sure no surface water is entering the storage.
- Consider maintaining some grassland near the storage for emergency manure application.

These activities should be started when your lagoon has exceeded the temporary storage level as defined for the lagoon. Waiting for the lagoon to reach the freeboard level may result in spills as you never know when the pumping equipment will malfunction. Start early!

Potential runoff from application field. This situation could result from unexpected rains during field application of manure. Again, the response is to prevent the release of wastes to neighboring areas. Possible solutions include:

- Immediately stop additional waste application.
- Create a temporary diversion or berm to contain the waste on the field.
- Incorporate waste to prevent further runoff.

Hurricanes and tropical storms. These severe storms are unpredictable in nature, and depending on their intensity, they can cause a great deal of damage to an area. They normally occur from June 1 to November 30 and can produce tornadoes and cause severe flash flooding. Tropical storms and hurricanes can also deliver large amounts of rainfall in very short periods of time. Areas that are prone to these storms should prepare for their possibility months beforehand. Before the hurricane season begins, temporary storage levels in lagoons and storage basins should be as low as possible. Be prepared for multiple storms. In September 1999 many livestock producers in the coastal regions of North Carolina, South Carolina, and Virginia received over 30 inches of rainfall from two hurricanes and one tropical storm.
Regardless of their size, hurricanes should be respected! The National Hurricane Center issues a hurricane watch when there is a threat of hurricane conditions within 24-36 hours. Hurricane warnings are issued when hurricane conditions (winds of 74 miles per hour or greater) are expected in 24 hours or less.

Seasonal heavy rainfall. From year to year, many areas of the county may receive periods of high rainfall that may be atypical of long term averages. These wet periods may delay crop planting, thus manure removal from storage facilities exceeding the design storage capacity of the structure. In these situations discuss your options for manure removal with your comprehensive nutrient management planner, technical specialist and design engineer. Remember, it is probably better to pump manure nutrients when they are not needed than to risk overtopping and lagoon failure.

Flooding. Several floods in the mid-west and eastern states have shown the vulnerability of livestock facilities located in or near floodplains. Before the floodwaters begin to rise, you should consider several items:

- Will the farm be isolated due to road flooding?
- How many days of protected feed storage is on the farm?
- How will animals be evacuated from the farm?
- How will animal mortalities be managed? Is an upland site dedicated if burial is the preferred option?
- Which is at a higher risk of flooding - buildings, manure storage, feed storage or mortality disposal sites?

Pollution in Progress

In this type of situation, the storage or waste handling system is actively leaking. Your main goals here are to stop the flow and minimize the impact of the leak on the environment.

Leaking or broken pipe, pit wall, or lagoon berm. These leaks may be seepage or flowing wastes. Response will depend on the level of the impact from the leaking waste (is it on your property or off?). Possible solutions include:

- Stop flow into pipe, pit, or lagoon.
- Prevent additional leaking of material by turning off recycle flushing system and irrigation pumps; closing valves controlling outflows; and preventing siphon effect.
- Dig a holding area or construct a berm to contain waste waters.
- Repair defective component.

Lagoon problems may require the consultation of an individual experienced in the design and installation of lagoons for permanent repair measures.

Tankwagon leak or overturn. There is a good chance that this emergency will be off your property and may include personal injuries (e.g., automobile accident). If there are injuries in any livestock waste emergency, they take precedence over all other responses. Once injury response is taken care of, limiting the environmental impact becomes the main goal in responding to this type of emergency. Possible solutions include:

- Stop additional spill of material.
- Contain material that has spilled.
- Begin clean-up procedures.
- Contact appropriate agencies if waste is on or off your property or there is surface or ground water impact.

Pollution Discovered After the Fact

This situation occurs when a leak or spill is discovered several days after it occurs. There is a potential for increased environmental impact due to the late discovery of waste leakage. Response should be swift in order to minimize damage as much as possible. Responses should include:

- Stop additional leakage.
- Contain spilled wastes.
- Attempt application of spilled wastes on cropland.
- Notify agencies and local authorities.
- Assess environmental impact of fish kill, surface water pollution, well or ground water impact, and amount of waste released and for what duration.

Components of Emergency Action Plans

While every emergency is different, response actions should be similar. As stated earlier, human health and injuries take precedence and should be dealt with first. Also, you should never put someone in life threatening or risky situations as part of your response plan. These following steps should provide a framework for developing your plan.

1. Eliminate the source. Depending on the situation, this may or may not be possible.

2. Contain the spill and minimize manure movement off the farm or downstream.

3. Assess the extent of the spill and note any obvious damages.

- Did the waste reach any surface waters?
- Approximately how much was released and for what duration?
- Any damage noted, such as employee injury, fish kills, or property damage?
- Distance and direction to nearest neighbor or town or public well of the release?
- Did the spill leave the property?
- Does the spill have the potential to reach surface waters?
- Could a future rain event cause the spill to reach surface waters?
- Are potable water wells, spring, or groundwater recharge areas in danger?

Review any actions that were taken to contain or minimize the spill or discharge.

4. Contact appropriate agencies.

State law requires that "Whenever, because of an accident or otherwise, any toxic or taste and color producing substance, or any other substance which would endanger downstream users of the waters of the State or would damage property, is discharged into water, or is so placed that it might flow, be washed, or fall into them, it shall be the duty of the person in charge of such substances at the time to forthwith notify the Environmental Protection Division in person or by telephone of the location and nature of the danger, and it shall be such person's further duty to immediately take all reasonable and necessary steps to prevent injury to property and downstream users of said water." This means that you must notify the EPD as soon as possible. Your phone call should include: your name, facility, telephone number, the details of the incident from item 2 above, the exact location of the facility, and the location or direction of movement of the spill, weather and wind conditions, what corrective measures have been undertaken, and the seriousness of the situation.

GEORGIA STATEWIDE NUMBER FOR REPORTING SPILLS IS: 800-241-4113

If spill leaves property and enters surface waters where health could be in danger, call local Emergency Medical Services (EMS) or fire department. Instruct EMS to contact local Health Department if necessary. If none of the above works, call 911 or the Sheriff's Department and explain your problem to them. Ask them to contact the agencies as listed above.

5. Clean-up the spill and make repairs.

Perform any modifications that were recommended by the Department of Natural Resources and technical assistance agencies or professional engineers to rectify the damage, repair the system, and reassess the manure management plan to ensure the problem will not happen again in the future. The emergency action plan must include provisions for emergency spreading or transfer of manure from all storage structures in the system. This may include emergency pumping or spreading (to prevent overtopping of a storage structure) during periods when the soil or crop conditions are not conducive to normal spreading or application. You should contact the Department of Natural resources or local soil and water conservation district for guidance to apply manure in this instance. You should consider which fields are best able to handle the manure and wastewater without further environmental damage. Application rates, methods, and minimum buffer distances must all be addressed. If transferring waste to another location for application, consider the limitations that may be involved with the transfer of waste to that site and application considerations at that location.

Creating a Community Response Plan

When an emergency arises you may need the assistance of neighboring farmers, fire departments or other county services. Communities have developed and are encouraged to develop Community Response Plans that assist livestock producers in the event of manure spills or catastrophic animal deaths. These plans allow livestock producers to review or develop the components of their farm's Emergency Action Plan with the assistance of neighboring livestock producers and farmers as well as community emergency response personnel. Collectively, this process gives producers the opportunity to find out who in the community (producers, farmers or community services) owns equipment that may be available locally to use in the event of a manure spill. Large equipment that may be necessary to respond to and clean up a manure spill include graders, bulldozers, back hoes, front-end loaders, portable electric generators, portable diesel pumps and irrigation pipe, vacuum tank wagons, and dump trucks.

As with most emergencies, it is always better to be prepared than to "test" a response plan during an actual emergency. Several communities have taken this lesson to the farm. Mock "spills" have to be conducted to train Manure Spill Teams and test the effectiveness of a community's response plan. Livestock producers, farmers, volunteer fire departments, county health department and local police or sheriff office work together to form the Manure Spill Teams. These exercises are not meant to address every possible type of spill or area that may be affected by a spill. Rather these drills allow the Manure Spill Team (or responding agencies or groups) to work together, develop communication protocols and establish general procedures that will need to be implemented to protect human health, minimize environmental impact, and foster a quick clean-up.

Post-Spill Assessment and Reporting

State law requires that "Whenever, spills occur which would endanger downstream users of the waters of the State or would damage property, it shall be the duty of the person in charge at the time to notify the Environmental Protection Division (EPD) in person or by telephone of the location and nature of the danger, and it shall be such person's further duty to immediately take all reasonable and necessary steps to prevent injury to property and downstream users of said water." This means that you must notify the EPD as soon as possible. Your phone call should include: your name, facility, telephone number, the details of the incident from item 2 above, the exact location of the facility, and the location or direction of movement of the spill, weather and wind conditions, what corrective measures have been undertaken, and the seriousness of the situation.

THE GEORGIA STATEWIDE NUMBER FOR REPORTING SPILLS IS: 800-241-4113
THE STATE OPERATIONS CENTER IN ATLANTA IS: 404-656-4300

On permitted operations, the reporting requirements will be specified in the permit. In most cases, reporting of spills or any other non-compliance that would endanger human health or the environment is required by telephone within 24 hours and in writing within five working days of the discharge. The reports will need to include:

- Description of the discharge including its cause, flow path, receiving water body, and an estimate of the amount discharged.
- Time and location of discharge
- Analysis of discharge for chemical and biological parameters or valid reasons for not sampling
- Steps taken or planned to reduce, eliminate, and prevent the recurrence of the discharge.

Assessments or "follow-up" reports give you and the regulatory agency an opportunity to reflect and learn from the events that lead up to the spill and those actions that were taken following the spill. Some of the questions you should consider answering in the report are listed below.

- Assess the extent of the spill and note any obvious damages.
- Did the waste reach any surface waters, wetlands, tile drains or wells?
- Approximately how much manure was released and for what duration?
- Any damage noted, such as employee injury, fish kills, habitat degradation or property damage?
- Response to spill.
- When and where was the spill contained?
- What measures were taken to avoid additional contamination?
- Did a technical specialist or any local group assist in the clean-up?
- What specific corrective actions are necessary to repair any damage to your storage structure, manure transfer or application equipment to prevent another spill?
- Can you determine the cause of the spill or discharge?
- If appropriate, were signs present of the condition before the accident occurred?
- When were local and state agencies contacted notifying them of the spill?
- Did a representative of the state water quality agency or health department respond to the notification? List names, titles and agencies.
- Were you given and "special" instructions from state or local representatives?

Developing an Emergency Action Plan

Every farm should have an Emergency Action Plan, although they are even more important on farms that store liquid manure or slurry. On animal feeding operations where CNMP's are required, these plans should be a part off the CNMP. This plan is your first response to spill even before it occurs. Simple things, such as collecting phone numbers and listing hazardous chemicals on the farm, will shorten the response time in the event of an emergency. Whether the emergency is a lagoon breach, fire, flood or overturned spreader your emergency action plan should help you prepare to reduce the risk to you, your coworkers, the farm and to the environment.

At the end of this chapter there are two emergency action plans that can be implemented on your farm. The first is a "simple" emergency action plan example that all farms could use. The second focuses on liquid manure and spill prevention and should be used in conjunction with the first on operations with liquid systems. Review them both before preparing your own. Use these examples to prepare a plan that will be used on your farm. These templates can be modified as you see fit to tailor it to your operation. Extension employees, NRCS specialist, and consultants should also be able to assist you with development of these plans if necessary.

Once completed, this plan should be available and understood by all employees at the farm. The main points of the plan (order of action) along with the relevant phone numbers should be posted by all telephones at the site. A copy should also be available in remote locations or vehicles if the land application sites are not close by the facility office. It is the responsibility of the owner or manager of the facility that all employees understand what circumstances constitute an imminent danger to the environment or health and safety of workers and neighbors. The employees should be able to respond, and have the authority to initiate containment and cleanup activities, during emergencies as well as notify the appropriate agencies of conditions at the facility. Lastly, post emergency contact phone numbers by every phone on the farm.

Manure Spills, Accidents and Discharges .... real stories, real issues.

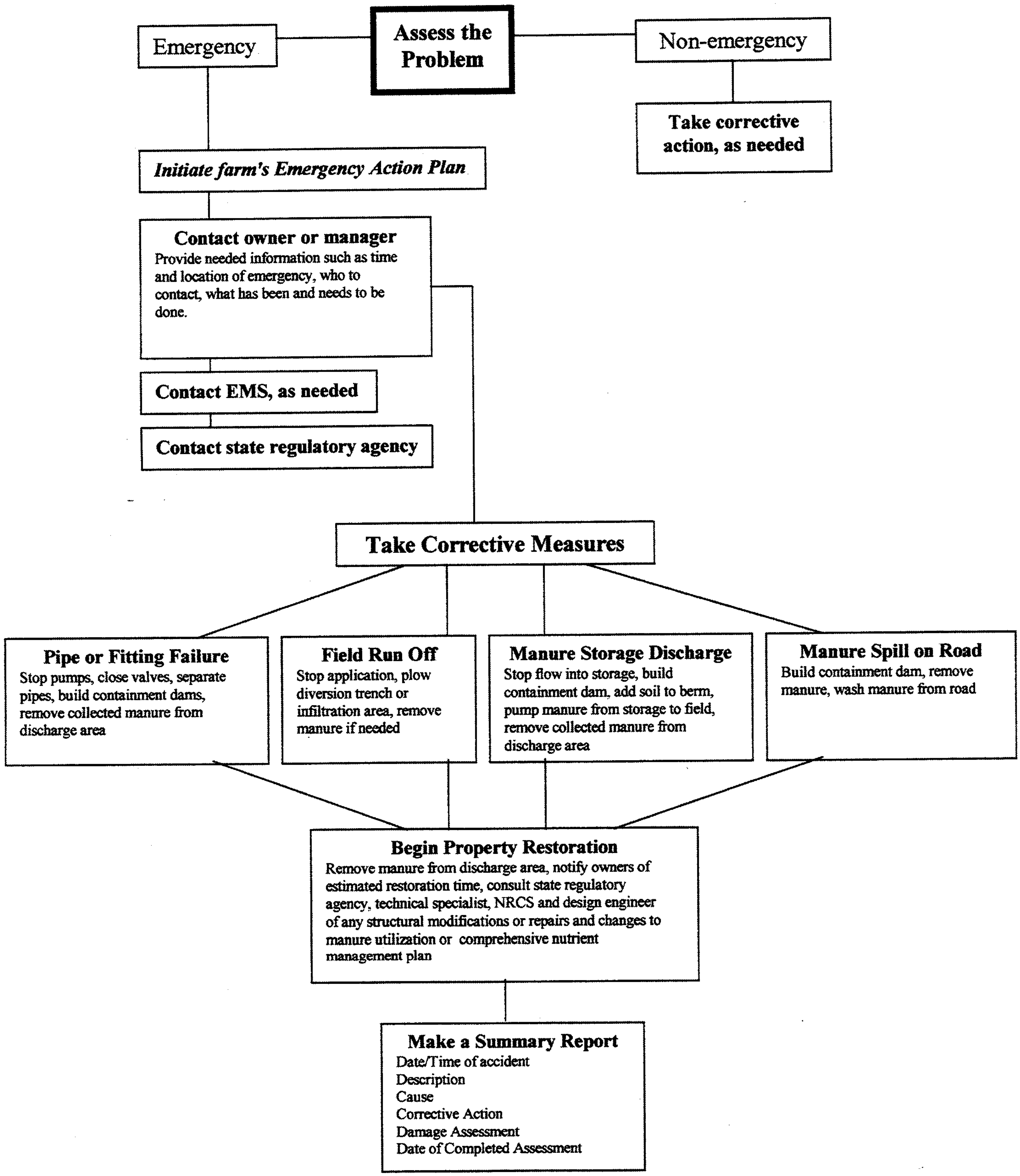
Learning from the mistakes in the past gives us the opportunity to make appropriate changes in the future. The following is a collection of case studies that reviews several manure spills that have occurred on livestock operations. These are real events and unfortunately they are not the only examples of manure discharges and spills into our surface and ground waters.

As you read these case studies of real farms, ask yourself:

- Was the manure spill an accident?
- What could have been done to prevent this spill from happening?
- Could this happen on my farm?
- Would I know how to handle or have the resources to address a similar spill on my farm?
- Do I have an emergency action plan if a spill occurs?
- Would an Emergency Action Plan have been helpful?

Typical Steps in Responding to Manure Spill or Discharge

Adopted from the NPPC Environmental Assurance Program



Case Study #1

.... *Equipment Failure*

Location: Ontario, Canada
Operation: Swine

Background:

- A portable irrigation system was laid out over a stream to reach a field for the application of swine lagoon effluent.
- When the pump was turned on, a section of pipe over the bridge became disconnected.
- The farmer wired the pipes back together then continued the manure application.
- No attempt was made to collect the effluent released into the stream.
- The farmer had never notified regulators of the incident two days after the event occurred.

Result:

- Lagoon effluent leaked from the separated pipes and flowed directly into the stream below.
- Fish were killed in the creek downstream of the spill.

Response:

- Ontario investigators confirmed the spill had caused the fish kill in the creek.
- Charges were laid onto the farmer citing a lack of 'due diligence' and 'failure to notify' regulatory authorities in a timely manner.

Action:

- No further action was taken by the farmer.
- The farmer was convicted and fined.

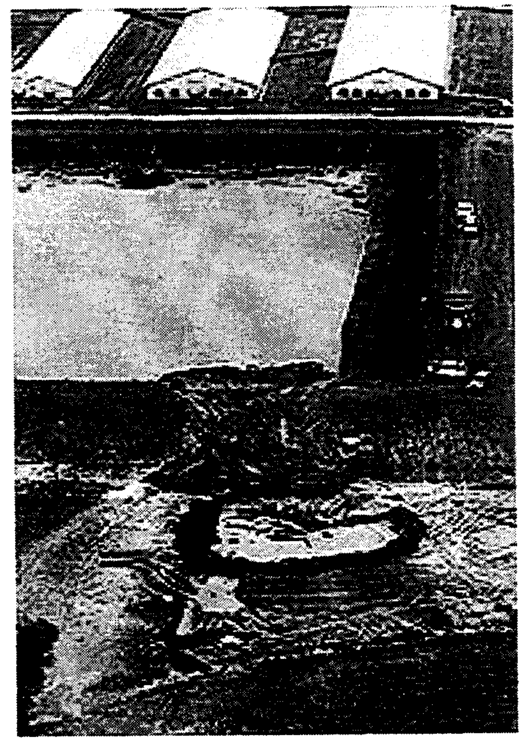
How Could this Spill have been Avoided?

- Use a section of flexible pipe to carry manure over streams and bridges.
- Monitor the pipeline during application.
- Be prepared to shut down immediately if a problem develops by having manpower and radios on hand.
- Notify the appropriate state and local authorities as soon as possible.

Case Study #2

.... Improper Modification of Storage Structure

Location: Southeastern North Carolina
Operation: Swine



Background:

- 7.3 Acre lagoon exceeded its temporary liquid storage
- Irrigation equipment was not on site nor was sufficient land cleared for application if a pump and equipment was available
- Approximately a week before the spill, farm workers improperly installed a pipe in the lagoon embankment
- Rainwater from a tropical storm ponded above then scoured out the embankment near where the pipe was installed
- The lagoon breached releasing lagoon effluent and sludge

Result:

- Over 22 million gallons of effluent and sludge were discharged into a river nearby.
- Approximately 4,000 fish were killed in the river downstream of the spill.

Response:

- Television and print media reported the lagoon spill all over the state and country. The spill was reported in newspapers as far away as Den Hague, Netherlands.
- State water quality investigators confirmed the spill had caused the fish kill in the creek..
- Charges were laid onto the farmer for violating state water quality standards.

Action:

- The farm was required to depopulate until repairs were made to the lagoon, irrigation equipment was purchased and sufficient land application field were cleared and planted.
- The farmer was convicted and fined.
- Repairs and land clearing were completed approximately one and a half years after the lagoon breach.

How Could this Spill have been Avoided?

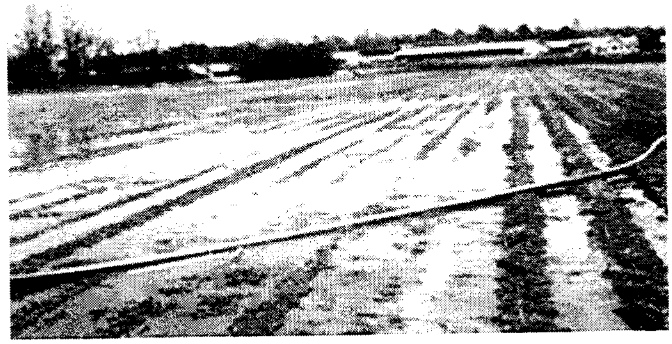
- Consult and follow plans provided by NRCS or a professional engineer before installing any pipe or electrical line on a lagoon embankment
- Ensure trenches on embankment are dug in a "V" shape and backfill soil should be mechanically tamped. Excess soil should be placed over the backfilled trench to allow for any settling.
- Ensure land application fields are cleared and planted prior to populating a new farm or delivering manure to a new storage basin or lagoon.
- More frequent inspections by farm personnel, technical specialists and regulatory agencies.
- Implementation of Emergency Action Plan and notification of spill to local emergency services

Case Study #3

... Over Application of Manure

Location: Southern, Ohio
Operation: Dairy

Background:



- The gasoline powered drive engine on a travelling gun irrigation system ran out of fuel while the irrigation pump was still running
- Excessive amounts of liquid manure were applied to a level untilled field

Result:

- Manure leached down to a tile system and drained into a open drainage ditch
- The water quality was impaired by low dissolved oxygen levels downstream in the drainage ditch and adjoining stream
- The farmer observed discolored water and foam discharging from the field tile into the open drain

Result:

- State water quality officials responded to an anonymous call
- Water samples were taken to identify the source of contamination
- Discolored water and foam were found discharging from a field tile outlet into the drainage ditch
- The dairyman was charged with applying manure at a rate that exceeds his manure utilization plan and for violating the water quality standards of the state.

Action:

- No further action was taken by the farmer.
- The farmer was convicted and fined.

How Could this Spill have been Avoided?

- Check engine fuel and oil levels before each "pull" on a travelling gun irrigation system
- Delay manure application until field tiles stop flowing
- Inspect irrigation systems during application events. Ensure drive engines and turbines are operating.
- Check soils for their "antecedent" moisture condition before selecting application rates and pumping duration
- Postpone irrigation of manure and wastewater until drainage from tile drains cease.

Case Study #4

.... Lack of Storage Capacity

Location: Southeastern Virginia
Operation: Poultry Layer

- An 8,500-gallon tanker was hauling sludge from a poultry layer lagoon to an application site three miles from the farm.
- The tanker failed to check for on-coming train as it crossed a railroad track beside the application field.
- A slow moving train severed the tanker, releasing the high strength sludge into a ditch.
- The startled but unharmed driver immediately contacted company supervisors and the local fire department.

Result:
- Lagoon sludge released from the tanker flowed directly into a nearby stream.
- Fish were killed in the stream downstream of the spill.

Response:
- Supervisors from the sludge application contractor contacted state water quality agents.
- The soil was placed into the stream to contain the spilled sludge and contaminated water. Vacuum tanker, already on site, pumped and applied the material to the application field.
- The spill was confirmed to have caused a fish kill in the stream.

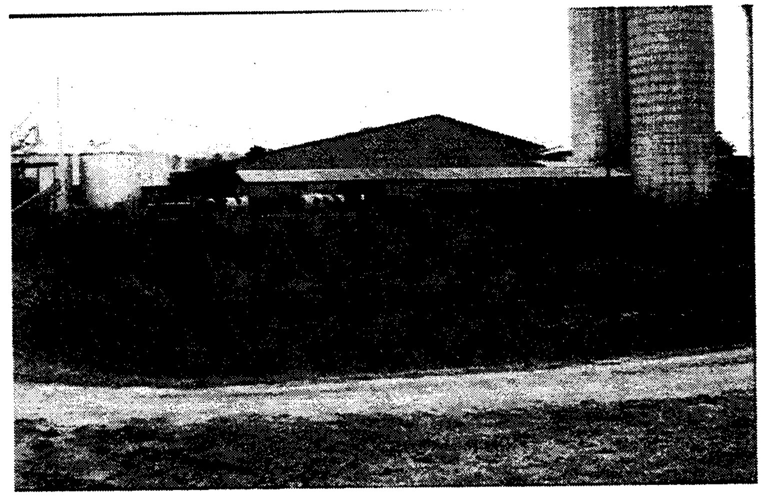
Action:
- The contractor received only a warning due to the company's quick response to mitigating the spill.

How Could this Spill have been Avoided?
- Special care should be taken when transporting manure and sludge in on public roads.
- Minimize transport of manure in areas of high traffic, high speeds or railroad crossings.

Case Study #5

.... *Lack of Storage Capacity*

Location: Southern Pennsylvania
Operation: Dairy



Background:

- Farm's manure storage basin was overflowing into a field
- An irrigation gun and tank wagon was used to apply manure on a bottomland field of wheat stubble
- Application occurred in the evening and at night in November, following several days of rain and snow
- Application rates of 7,200 gal/acre were reported, but were believed to be higher by investigators

Result:

- Manure from the overflowing storage basin entered a nearby field tile system which drained into a ditch that crossed the property line, and then into a stream on the neighbor's property
- Liquid manure entered the ditch via a tile blowout and open catch basins, eventually contaminating two in-stream ponds on the neighbor's property

Response:

- State water quality officials were informed by the producer and investigated the following day
- Water samples were taken identifying the source of contamination
- The producer was charged with failing to provide adequate storage and discharging manure into surface waters

Action:

- The stream was temporarily dammed to prevent further movement of manure laden water downstream
- The producer pumped contaminated water from the stream and applied onto adjacent fields under the supervision of state investigators
- Producer paid a fine with no contest

How Could this Spill have been Avoided?

- Ensure adequate storage to allow flexibility in application due to weather
- Do not apply manure when soil is nearly saturated from snow or rain
- Inspect fields regularly, especially before manure application, to ensure tile blowouts are repaired
- Monitor tiles during and after manure application
- If a problem occurs, notify your state water quality agency as soon as possible.

G1: General Emergency Action Plan

Farm Name:
Owner/Operator: **Phone Number:**
2nd Contact Person if owner/operator is not available:
Name: **Phone Number:**
Permit Number (if applicable):
Size and type of operation:

Fire Emergency Response Information
Farm Fire Protection District:
911 Coordinates for farm:
Electrical Power Company Name:
Electrical Power Company Phone Number:
Is there a disconnect between the meter base and the buildings? Y N
If so, where?
Size of Electrical Service:
Do you have a standby alternator? Y N
Give the location (sketch preferable) of electrical panels in buildings:

Propane Company Name:
Propane Company Phone Number:
Location and size of propane tanks:

Other fuels and locations:

Are there hazardous materials stored in facilities: Y N
If yes, provide the location(s) and list of materials:

(If you have any medical conditions the EMS personnel should know about, please list them below):
Name: Condition:
Name: Condition:
Name: Condition:

Emergency Action Plan Checklist

As part of this plan, the following is made available and each employee is trained and aware of the following procedures.

- ☐ **Emergency Phone Number List Posted at Each Phone**: An emergency phone notification list, *which includes telephone number of the operator, local offices for fire dept, sheriff dept., EMS, Public Health Office, State Water Quality Agency and State Dept of Agriculture.*

- ☐ **General Farm Information Sheet** and **Facility Map**: *Draw facility layout including location of: telephone locations, location of shutoffs for water, electric, natural gas and propane tanks, re-cycle systems, schematic of waste management system, pumping pits,* ***areas of no entrance without assisted breathing devices****, hazardous materials, ingress/egress for emergency vehicles, identity of immediately adjacent landowners with emergency phone numbers.*

- ☐ **Location of Pre-Arranged Emergency Supply Equipment and Supplies**: List of equipment owners, phone numbers and location of individuals and equipment that may be used in an emergency.

- ☐ **Runoff Retention Plan**: Instructions detailing the **ACTION PLAN** to be taken in an emergency involving runoff of contaminanted water that may result from fire or other emergency. *Maps of the facility and surrounding areas including drainage patterns and locations of spoil materials for forming emergency dikes, location of surface waters, waterways, wells, and any other environmentally sensitive areas should also be included.*

- ☐ **Fire Emergency Information and Response Plan**

- ☐ **Power Outage Information**

- ☐ **Personal Information and Medical Emergency Response Procedures**: *Any medical conditions you or your farm personnel may have that emergency medical personnel should be made aware (i.e., diabetes, heart or respiratory problems, medications, etc.).*

G2: Emergency Action Plan (Liquid Manure)

The following is posted, clearly by every phone on farm:

IF There is an EMERGENCY.......

1) **Shut off all flow into storage area or lagoon or going out to land application areas**

2) **Assess the extent of the emergency and determine how much help is needed**

3) **Contact Farm Supervisors**

Name:	Phone #:
Name:	Phone #:

4) **Give supervisor the following information:**
   Your name
   Description of Emergency
   Estimates of the amounts, area covered, and distance traveled from manure storage
   Whether manure has reached ditches, waterways, streams or crossed property lines
   Any obvious damage: employee injury, fish kill, or property damage?
   What is being done, any assistance needed

5) **Contact state environmental protection division, contractors, emergency officials, technical specialists and media, as needed.**
   a) Georgia Environmental Protection Division-
      i) SPILL REPORTING: 800-241-4113
      ii) LOCAL OFFICE Phone______________

b) Local County Health Department		Phone______________
c) Pumping-	Name__________________	Phone______________
d) NRCS-	Name__________________	Phone______________
e) Extension Office-	Name__________________	Phone______________
f) Consultants-	Name__________________	Phone______________

Provide directions that anybody can direct someone to the site by telephone.

Build a containment dam downstream of discharge area, then progressively build additional dams upstream

- Add soil to the berm of the manure storage area/basin
- Remove manure from the discharge area with a trash pump if necessary

Pump manure and wastewater from the manure storage to lower the volume in basin

Complete Post-Emergency Assessment and Documentation or other State reporting requirements.

Pre-arranged Emergency Response Agreements

List any arrangements made with other producers to share personnel and/or equipment and supplies and land access during an emergency.

Pre-arranged land access agreements

Contact #1 ____

Contact #2 ____

Location of Pre-Arranged Emergency Supply Equipment and Supplies

Available 24 hours a day. Include phone numbers and primary contacts. Put list in the order you want equipment operators contacted. Copy posted in each animal building on site, in site office and owners residence. Preferably posted by a phone or main doorway if no phone.

Owner	**Phone**	**Location**
Irrigation Pumps		
Dozer/Track Loader		
Backhoe		
Vacuum Slurry Tank		

Post-Emergency Assessment and Documentation

1.) Assess the extent of the spill and note any obvious damages.
    Did the waste reach any surface waters?
    Approximately how much was released and for what duration?
    Any damage noted, such as employee injury, fish kills, or property damage?

2.) Contact appropriate agencies:
Reporting a Release of Livestock Waste from a Lagoon

a) Reports of releases to surface waters, including to sinkholes, drain inlets, broken subsurface drains or other conduits to groundwater or surface waters, shall be made upon discovery of the release, except when such immediate notification will impede the owner's or operator's response to correct the cause of the release or to contain the livestock waste, in which case the report shall be made as soon as possible but no later than 24 hours after discovery.

b) The report required under subsection (a) shall be given to the State Water Quality Agency by calling: *(800) 241-4113*

Contents of Report
The report should include, as a minimum, each of the following to the extent that it is known at the time of the report:

a) name and telephone number of the person reporting the release;
b) county, distance and direction from nearest town, village or municipality of the release;
c) an estimate of the quantity in gallons that was released, and an estimate of the flow rate if the release is ongoing;
d) area into which the release occurred (field, ditch, stream, or other description) and apparent environmental impacts of the release;
e) time and duration of the release;
f) the names and telephone numbers of persons who may be contacted for further information;
g) dangers to health or the environment resulting from the release;
h) actions taken to respond to, contain and mitigate the release; and
i) name of facility and mailing address.

3.) Implement procedures to prevent similar occurrences. Seek professional assistance if problem is berm or structure related.

DOCUMENTATION OF CLEAN-UP EFFORTS

All responses to emergencies should be documented and kept with the manure management plan. This documentation should include all agency and local authority contacts made during the response phase. This information can be used to assess response to the emergency, prepare for future problems, and train employees.

Review of Essential Information

An Emergency Action Plan is a basic, yet through, common sense plan that will help you make the right decisions in an emergency.

You should have an Emergency Action Plan because:

- accidents will happen,
- writing the plan requires you to plan for emergencies
- it makes you more likely to remember appropriate responses during emergencies
- they minimize environmental and human health impacts
- it is required as part of a CNMP
- it is a great pollution prevention strategy.

The format for an Emergency Action Plan consists of the following five steps:

1) Eliminate the source
   Shutting down pumps, building diversions or berms, closing valves, repairing leaks
2) Contain the spill
   Building berms, diversions, dams, or basins
3) Assess the extent of the spill and note damages
4) Contact appropriate agencies
5) Clean up and make repairs
   Modifications and plans for prevention of future accidents.

The most important part of a plan is preventing spills from occurring in the first place.

Prevention measures include regular inspection, monitoring and record keeping, automatic cut-offs, and secondary containment.

Three types of emergencies are imminent pollution (where you know its coming), pollution in progress (actively occurring), and pollution discovered after the fact.

In an emergency situation, human health and well being takes precedence. It should always be assessed first and corrective actions should not put human well being in jeopardy.

In the event of a spill or manure release that could endanger downstream users of water of the State or could damage property, Georgia law requires that you notify the Environmental Protection Division of the Georgia Department of Natural Resources.

Post Spill assessment and reporting is important because it is required by law, it helps you examine your response, determine causes and assess damages, and should lead to plans for prevention in the future.

All employees of the farm should be made aware of the emergency action plan and it should be posted in a visible location, preferably near the phone.

Community and neighbors should be made aware of emergency response plans. They can provide access to needed emergency equipment, provide access to property that may be needed for corrective action, help you in plan development, and make you aware of additional resources in your community.

11

Mortality Management

Lesson 51 — Mortality Management

By Don Stettler, USDA Natural Resources Conservation Service

Intended Outcomes

The participants will be able to

- Explain why timely management of mortality is important.
- List the different methods for managing mortality.
- List the advantages and disadvantages of different methods for managing mortality.
- Explain conceptually the sizing of mortality composting facilities.

Outline

I. Introduction
II. Rendering
III. Composting
A. Composting principles
B. Dead animal composting
C. Composter operation
D. Compost end use
IV. Incineration
V. Sanitary Landfills
VI. Burial
VII. Disposal Pits
VIII. Regulatory Compliance Issues
Appendix A. Livestock Mortality Rates (Percentage)
Appendix B. Procedures for Sizing of Structures and Windrows for Composting Animal Mortalities using Universal Sizing Equations
—Worksheet for Determining Compost Bin or Windrow Volume Requirements
—Equations for universal sizing of composting bins and windrows

Activities

Estimate

- Composter bin volume requirements.
- The size of a manure storage facility.

Time Required: 2 hours

PROJECT STATEMENT

This educational program, Livestock and Poultry Environmental Stewardship, consists of lessons arranged into the following six modules:

- Introduction
- Animal Dietary Strategies
- Manure Storage and Treatment
- Land Application/Nutrient Management
- Outdoor Air Quality
- Related Issues

The project team appreciates the financial assistance of the U.S. Department of Agriculture and U.S. Environmental Protection Agency's Ag Center in the development of this educational program.

Introduction

Animals dying because of disease, injury, or other causes routinely happens in the day-to-day operation of any confined livestock operation. The magnitude of this mortality can be significant. The mortality rate is generally highest for newborn animals because of their vulnerability. For example, a typical rate for newborn pigs is 10%, but for older finishing hogs, it is only 2% (Table 51-1). For poultry, the mortality rate varies by type (Table 51-2).

How animals are managed has a major affect on the mortality rate. For example, the mortality rate in dairy animals is reduced by providing proper nutrition to help prevent metabolic problems, such as milk fever; by gentle handling; and by culling cows before they become infirm. The mortality rate for dairy calves is highly influenced by colostrum management. A University of California–Davis study found that calves not receiving colostrum had an increased risk of dying 74 times greater than calves receiving colostrum by the recommended method. These findings suggest that an excellent beginning to managing mortality is to care for livestock in ways that minimize it. However, regardless of how well livestock are cared for, there will be mortality and it must be managed.

Catastrophic mortality can occur when an epidemic infects and destroys the majority of a herd or flock in a short time or when a natural disaster, such as a flood, strikes. There may also be incidences when an entire herd or flock must be destroyed to protect human health. For example, the slaughter of chickens in Hong Kong in late 1997 was deemed necessary to prevent transmission of H5N1 flu virus to humans. A prudent manager of a livestock facility will have a contingency plan for dealing with a catastrophic mortality event.

The focus of this lesson will be on managing what is considered normal, day-to-day mortality. However, several of the methods discussed may also be used for managing catastrophic mortality if scaled to accommodate it. Planning for a catastrophic mortality event should include the study of regulations because they often specify what methods may be used. Planning and preparation for catastrophic mortality may also include locating and reserving a site for disposal and having insurance to cover the cost involved.

. . . an excellent beginning to managing mortality is to care for livestock in ways that minimize it.

Table 51-1. Mortality rate for swine.

Animal Type	Mortality, %
Newborn pigs	10
Nursery pigs	2–3
Sows	6
Boars	1
Finishing hogs	2

Table 51-2. Mortality rate for poultry.

Poultry Type	Average Mortality Rate During Flock Cycle, %
Layer	
hen	14
pullet	5
Broiler	
breeder pullet	5
breeder hen	11
breeder male	22
roaster	8
Turkey	
hen	6
light tom	9
heavy tom	12

Mortality must be managed for at least three reasons:
(1) Hygienic
(2) Environmental protection
(3) Aesthetics

Mortality must be managed for at least three reasons:

(1) Hygienic. Timely removal and appropriate handling of dead animals can prevent other animals in the operation from becoming ill and may prevent spread of the disease to other operations. This is especially true for the removal of those animals that have succumbed to contagious disease.

(2) Environmental protection. Nutrients and other contaminants that are released as the dead animal decomposes can be carried away in run off or leached to groundwater resources.

(3) Aesthetics. Perhaps those who work on the farm or ranch may be come accustomed to the sight of dead animals. However, visitors and others may find it very offensive and use it as a basis for judging the level of management being given the operation even though this may be unfair.

In the past, dead animals were frequently taken to a remote area, allowing carcasses to decompose and be eaten by scavengers. This practice is now illegal in virtually all of the United States. In addition, it is a highly irresponsible method and may encourage the spread of disease from one operation to another. It may also contribute to both surface and groundwater contamination.

Acceptable ways for managing mortality include

- Rendering
- Composting
- Incineration
- Sanitary landfills
- Burial
- Disposal pits

Of these methods, only the rendering and composting methods recycle the nutrients, a concept that has been promoted since Lesson 1 of this training.

Although incineration, sanitary landfills, burial, and disposal pits may be acceptable methods from an environmental protection viewpoint, they are disposal methods, and in essence, waste the nutrients. In the following paragraphs, each of the acceptable methods will be discussed, beginning with rendering.

Rendering

Use of rendering services recycles the nutrients contained in dead animals, most often as an ingredient in animal food, especially for pets. The primary disadvantage of rendering is that the dead animals must be preserved or promptly transported to a rendering plant. This disadvantage has been intensified in recent years by a reduction in the number of facilities that provide rendering services. The outbreak of "mad cow disease" in the United Kingdom (UK) in 1986 has led to restrictions on how rendered products may be used in the United States. More properly described as Bovine Spongiform Encephalopathy (BSE), it is a degenerative brain disease that ultimately results in animal death. BSE is a member of the transmissible spongiform encephalopathy (TSE) group of diseases and is manifested as behavioral, gait, and postural changes, usually beginning with apprehension, anxiety, and fear. A TSE commonly known as scrapie has significantly affected the U:S. sheep industry. In the United States, cases of scrapie also have been reported in goats. Similar diseases, for example, the Creutzfeldt-Jakob disease, have surfaced in humans. These diseases have also been reported in mink, cats, deer, and elk. To date, no cases of BSE have been diagnosed in the United States. The process used by U.S. renders helps prevent a UK-type of epidemic. To further reduce the potential of BSE introduction into U.S. domestic herds, the Food and Drug Administration has rules that prohibits the use of ruminant byproducts in the production of feed for ruminants.

If the dead animals are not preserved, they must be transported to a rendering facility within 72 hours, minimizing decomposition. For rendering to be feasible, therefore, a rendering plant providing frequent pickup must be in close proximity. Proper bio-security measures must be utilized to minimize the spread of disease from farm to farm by rendering plant vehicles and personnel. These measures include transporting dead animals within 24 hours of their death and designating an area outside the perimeter of the facility for pickup by rendering personnel. The designated area to store dead animals must maximize sanitation and discourage scavengers.

An alternative to on-farm storage is cooperative dropoff locations where a number of producers can leave dead animals. This approach eliminates many of the problems associated with on-farm storage and the need for rendering personnel to come onto the farm. It is also advantageous to the render because the mortality for pickup will be more convenient and the mortality amount more constant because the daily variation will be smoothed when averaged over several operations.

The need for frequent pickup for transport to a rendering plant or dropoff location can be minimized by preservation of dead animals to prevent decomposition. Preservation allows the dead animals to be stored on the farm until amounts are sufficient to warrant the cost of transport for rendering. Freezing and fermentation are the two general methods that can be used for preservation.

Freezing requires the obtaining and operating of appropriate refrige ration equipment that is sealed against weather and air leakage. In some parts of the country, large custom-built or ordinary freezer boxes are used to preserve dead animals until they can be picked up and delivered to the rendering plant. Custom-built boxes or units are usually free standing with self-contained refrigeration units designed to provide temperatures between 10 and 20°F. Freezing is an expensive method of managing mortality. It does not eliminate active pathogenic microorganisms. However, the transfer of pathogen or other harmful microorganisms between farms has not been a problem. Those who use the method find it useful as a way of reducing or eliminating potential pollution and improving conditions on the farm.

Fermentation involves grinding the dead animals into 1-inch or smaller particles while adding carbohydrates such as sugar, whey, molasses, or corn. Adding bacteria may also speed fermentation. Fermentation produces volatile fatty acids and causes a decline in pH to below 4.5, which preserves the nutrients in the dead animals. The decrease in pH during fermentation inhibits further decomposition and inactivates many pathogenic microorganisms.

In summary, the rendering mortality management method has the following advantages and disadvantages (Table 51-3).

Use of rendering services recycles the nutrients contained in dead animals. ...The primary disadvantage of rendering is that the dead animals must be preserved or promptly transported to a rendering plant.

Table 51-3. Mortality management by rendering.

Advantages	Disadvantages
1. Conserves nutrients contained in the dead animals 2. Minimal capital investment unless preservation is used 3. Low maintenance	1. Increases sanitary precautions to prevent disease transmission 2. Storage of animals is required until pickup 3. Fees charged for pickup 4. Rendering service may not be available

Composting ... is essentially the same process as natural decomposition except that it is enhanced and accelerated by mixing organic waste with other ingredients in a manner that optimizes microbial growth.

Composting

Composting principles

Composting is the controlled aerobic biological decomposition of organic matter into a stable, humus-like product, called compost (Figure 51-1). It is essentially the same process as natural decomposition except that it is enhanced and accelerated by mixing organic waste with other ingredients in a manner that optimizes microbial growth.

The compost pile will pass through a wide range of temperatures over the course of the active composting period (Figure 51-2). As the temperature varies, conditions will become unsuitable for some microorganisms while at the same time become ideal for others.

Initially, as the microbial population begins to consume the most readily degradable material in the compost pile and grow in size, the heat generated by the microbial activity will be trapped by the self-insulating compost material. As the heat within the pile accumulates, the temperature of the compost pile will begin to rise. As the pile temperatures increase, the pile will become inhabited by a diverse population of microorganisms operating at peak growth and efficiency. This intense microbial activity sustains the vigorous heating that is necessary for the destruction of pathogens, fly larvae,

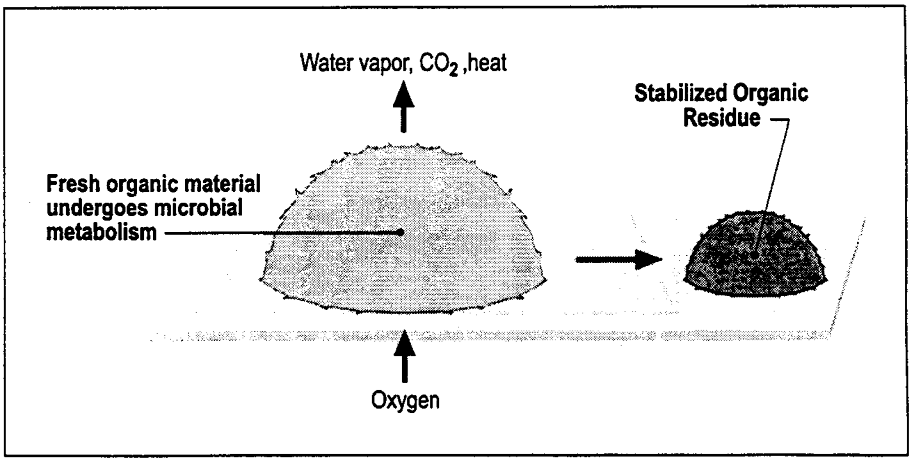


Figure 51-1. Composting process.

and weed seeds. The diversity of the microbial population also allows the decomposition of a wide range of material from simple, easily degradable material to more complex, decay resistant ones such as cellulose. The temperatures will continue to rise and peak between 130 to 160°F. Once this peak is reached, microbial activity begins to decrease in response to a depletion in readily degradable material or excessively high temperatures that are detrimental to their function. Efficient composting requires that the initial compost mix have

- A balanced source of energy (carbon) and nutrients (primarily nitrogen), typically with a carbon:nitrogen (C:N) ratio of 20:1 to 40:1.
- Sufficient moisture, typically 40% to 60%.
- Sufficient oxygen for an aerobic environment, typically 5% or greater.
- A pH in the range of 6 to 8.

These compost mix characteristics must be maintained throughout the composting process as well.

The proper proportion of the material to be composted combined with amendments and bulking agents is commonly called the compost mix or the "recipe" (Figure 51-3). A composting amendment is any item added to the compost mixture that alters the moisture content, C:N, or pH. Crop residue, leaves, grass, straw, hay, and peanut hulls are examples of the material suitable for use as a compost amendment. A bulking agent, such as wood chips,

Efficient composting requires that the initial compost mix have
- **A balanced source of energy and nutrients ...**
- **Sufficient moisture ...**
- **Sufficient oxygen for an aerobic environment ...**
- **A pH in the range of 6 to 8.**

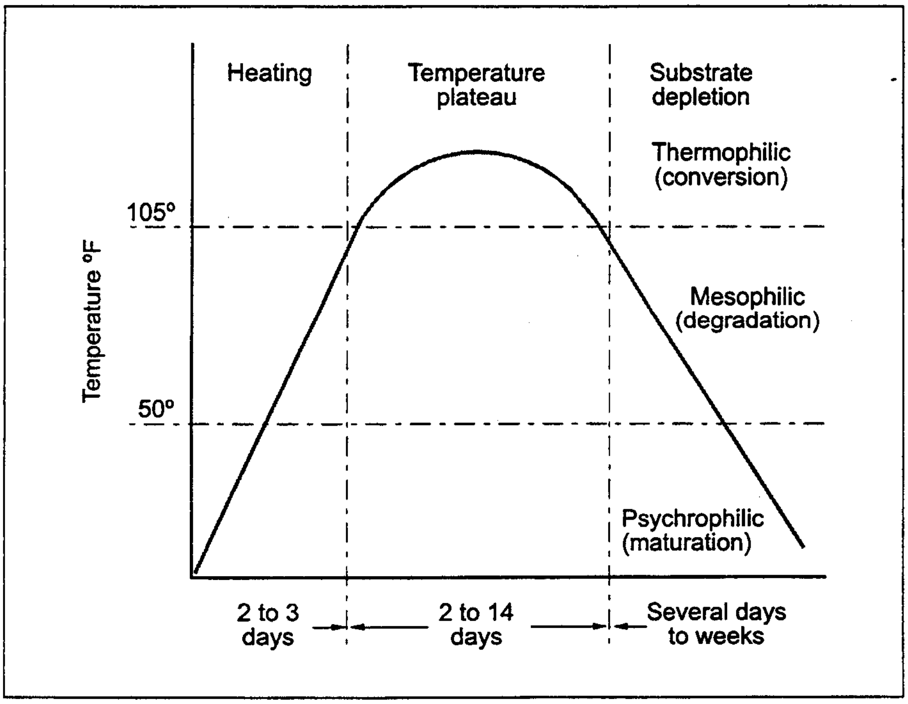


Figure 51-2. Compost temperature ranges.
Source: Agricultural Waste Management Field Handbook, Part 651, p. 10-55.

A number of methods are used to compost organic wastes including
- Passive composting pile
- Windrow
- Passively aerated windrow
- Aerated static pile
- In-vessel

is used primarily to improve the ability of the compost to be self-supporting or have structure and to allow internal air movement. Some bulking agents may alter the moisture content and/or C:N ratio. This type of material would serve as both an amendment and a bulking agent.

Recipe recommendations are available for composting many types of organic wastes. However, when it is necessary to determine the recipe from scratch, the characteristics of the waste, amendments, and bulking agents must be known. The characteristics that are the most important in determining the recipe are moisture content, carbon content, nitrogen content, and C:N ratio. If any two of the last three components are known, the remaining one can be calculated. The determination of the recipe is normally an iterative process of adjusting the C:N ratio and moisture content by adding amendments. If the C:N ratio is out of the acceptable range, then amendments are added to adjust it. If this results in high or low moisture content, amendments are added to adjust the moisture content. The C:N ratio is again checked, and the process may be repeated. After a couple of iterations, the mixture is normally acceptable.

A number of methods are used to compost organic wastes including
- Passive composting pile
- Windrow
- Passively aerated windrow
- Aerated static pile
- In-vessel

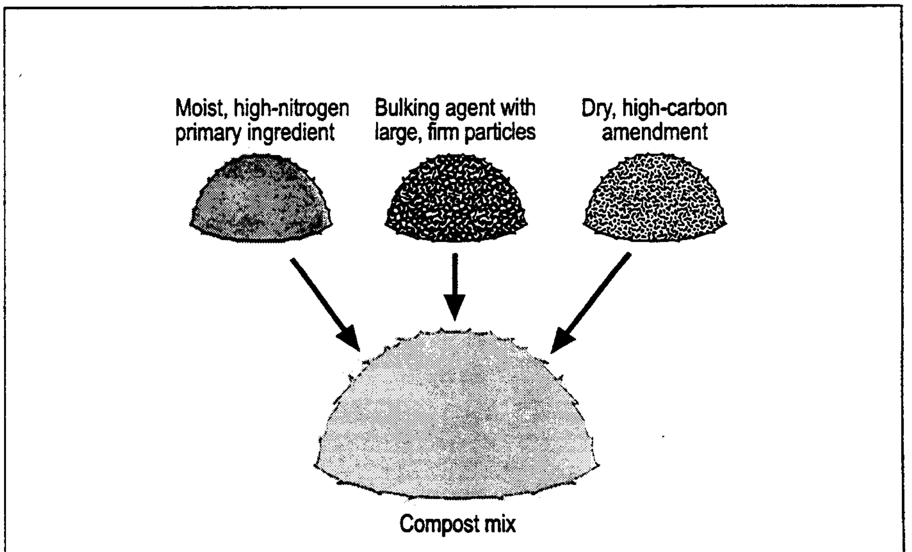


Figure 51-3. Components of the compost mix.

Dead animal composting

Dead animal composting generally employs the in-vessel method using composting bins (Figure 51-4). Dead animals may also be composted using the windrow or passive composting pile methods, the preferable methods for composting larger dead animals.

As already emphasized, organic wastes are generally blended into a homogenous mix having the appropriate C:N ratio, pH, oxygen, and moisture to facilitate efficient decomposition. Dead animal composting, however, requires a different approach. For dead animal composting, the carcasses and amendments are layered into the pile, and no mixing is done until after the high-rate phase of composting has occurred and the dead animals are fully decomposed. For that reason, the initial pile in which dead animals are

Dead animal composting... requires a different approach. ... the carcasses and amendments are layered into the pile, and no mixing is done until after the high-rate phase of composting has occurred and the dead animals are fully decomposed.

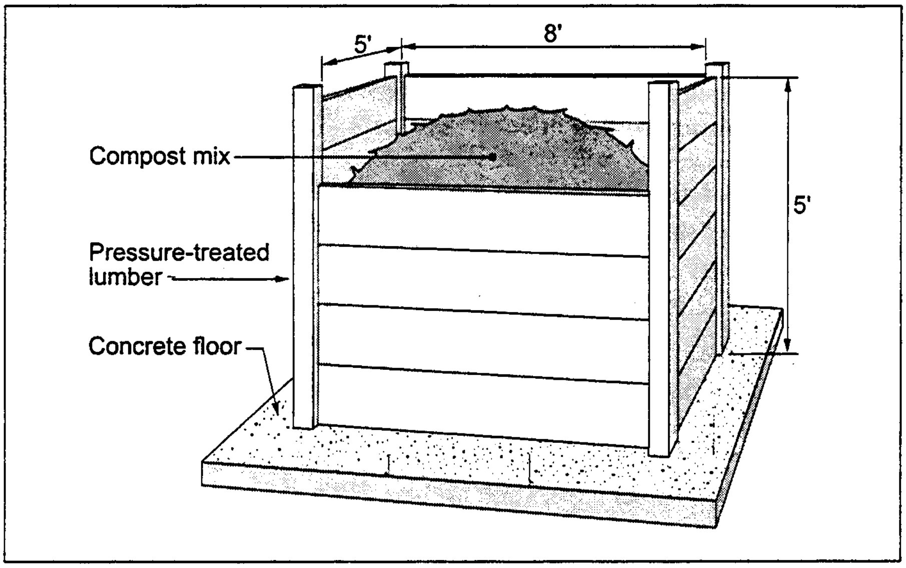


Figure 51-4. Compost bin.
Source: Agricultural Waste Management Field Handbook, Part 651, p. 10-59.

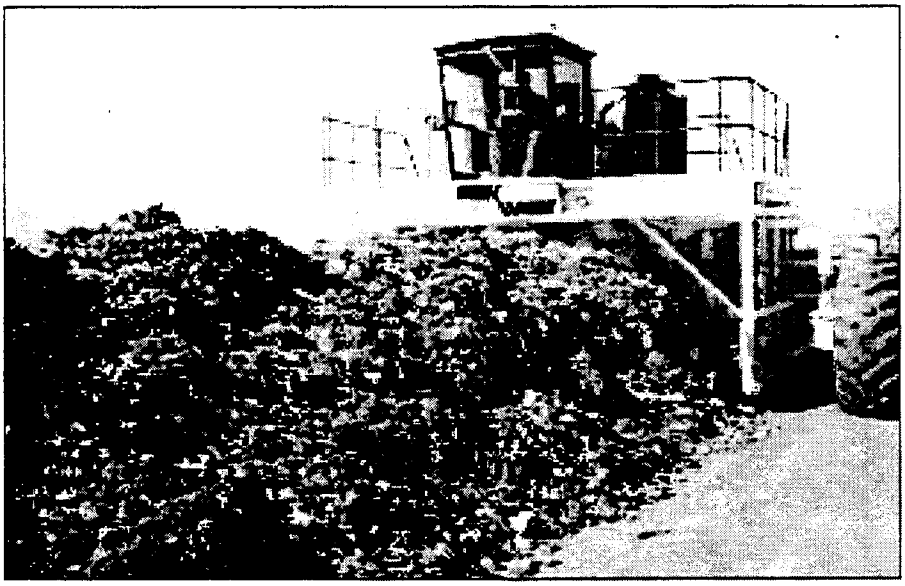


Figure 51-5. Windrow.

composted is an inconsistent, nonhomogeneous mixture. Figure 51-6 illustrates how two amendments, straw and chicken litter, are layered with dead broiler poultry in bin composting. Regulations in some states do not allow including chicken litter in the compost mix. Where chicken litter is not allowed, dead animals can be composted with sawdust as the only amendment. However, where use of chicken litter is allowed and it is conveniently available, its use will allow the compost process to be more efficient because the C:N ratio is adjusted.

Composting mortality can be likened to aboveground burial in a biomass filter with the pathogens killed by high temperatures.

Composting mortality can be likened to aboveground burial in a biomass filter with the pathogens killed by high temperatures (Figure 51-7). At least one foot of biofilter should be provided between the dead animals and the sides of the bin or the outside surface of the windrow. For large animals, this distance should be increased to two feet. The composting process for mortality is shown schematically in Figure 51-8.

For bin composting, a permanent structure, such as bins constructed of treated lumber or concrete within a pole-frame building with concrete floors (Figure 51-9), is the most desirable. This type of facility offers easier overall operation and management especially during inclement weather and for improved aesthetics. Some states may require that composters be roofed and/or be located on impermeable surfaces, such as concrete or compacted clay. Consult the Natural Resources Conservation Service, Extension Service, MidWest Plan Service, or Northeast Regional Agricultural Engineering Service for composter plans that will meet your needs.

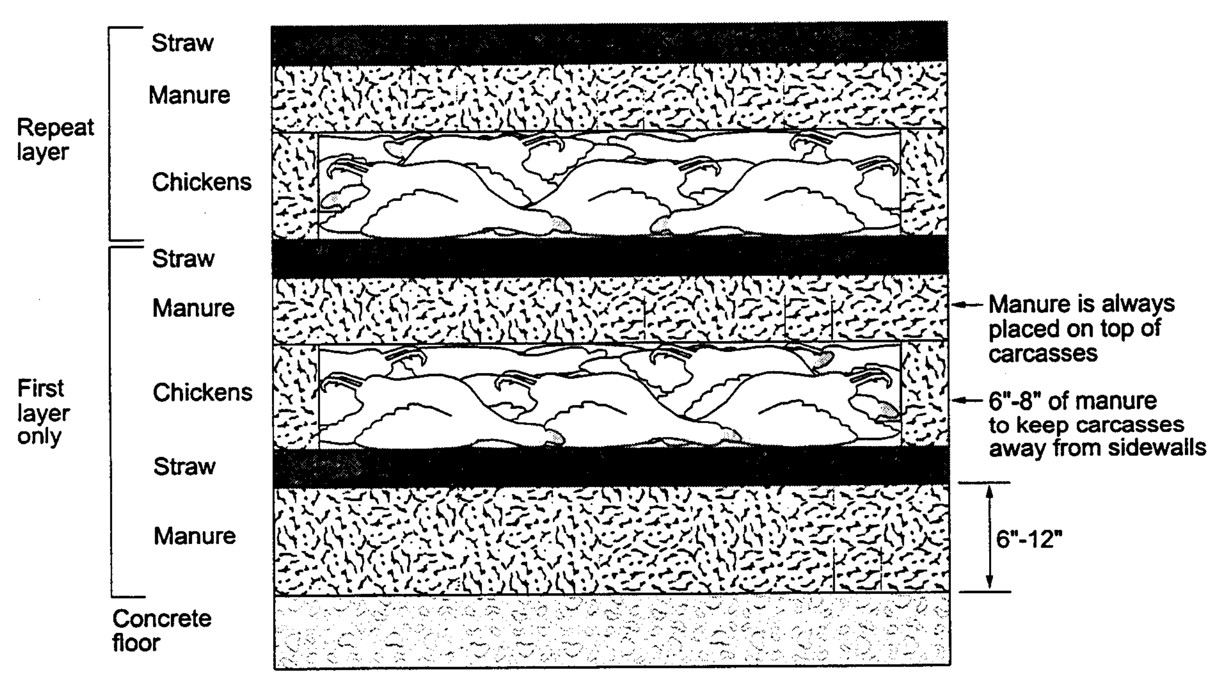


Figure 51-6. Initial layering of the mix for composting dead broiler chickens.
Source: Agricultural Waste Management Field Handbook, Part 651, p. 10-61.

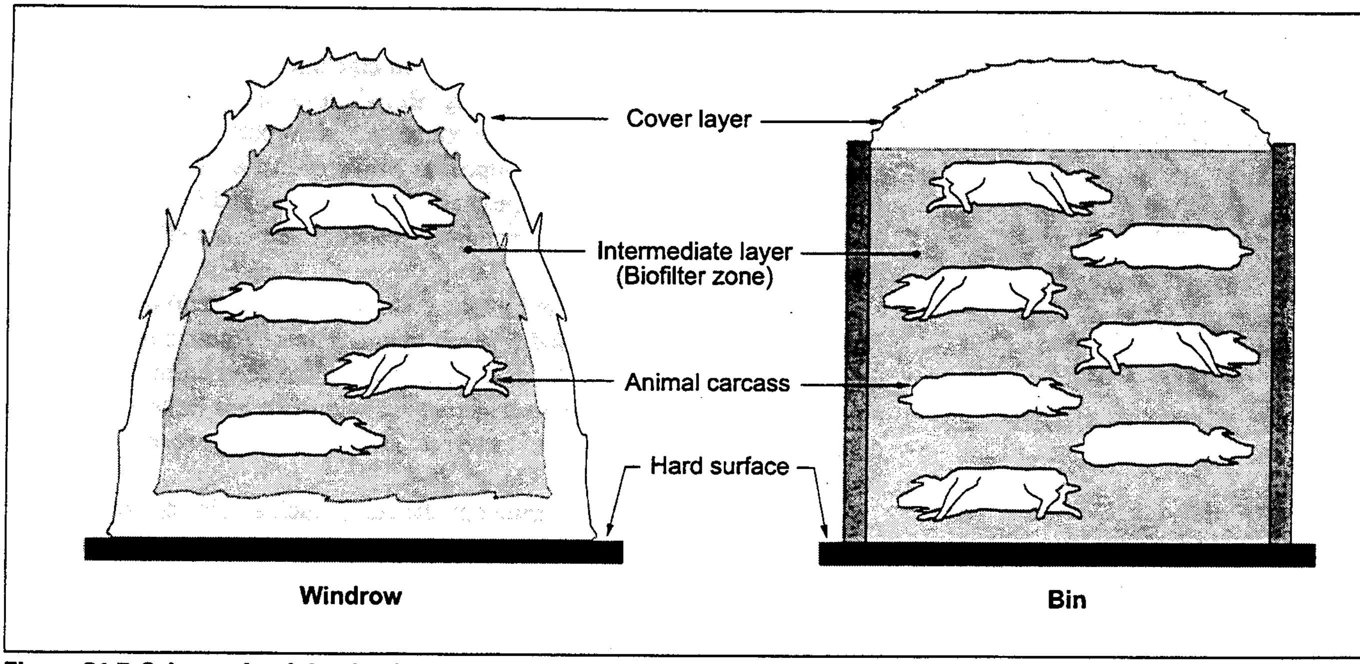


Figure 51-7. Schematic of dead animal composting using a windrow or bin.

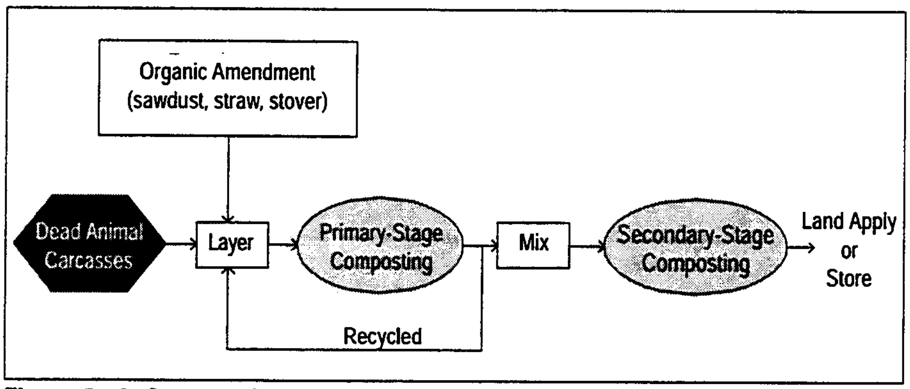


Figure 51-8. Composting process schematic.

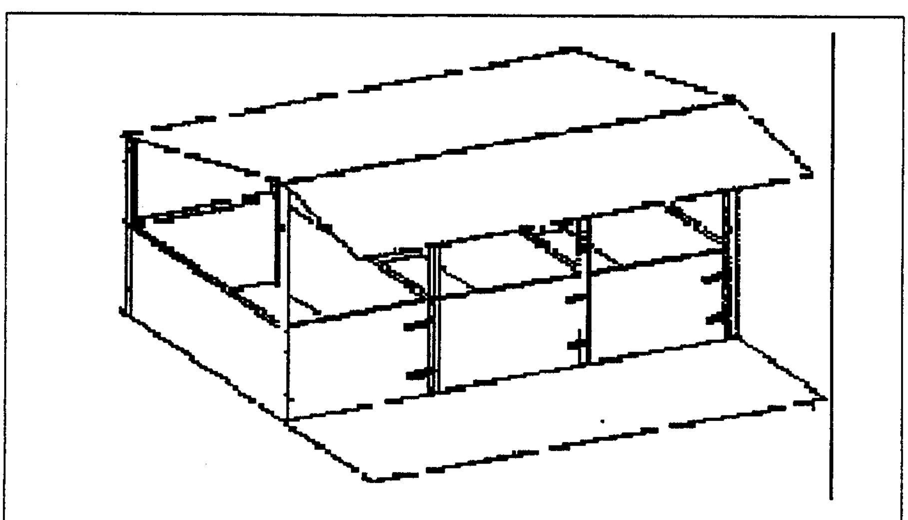


Figure 51-9. Composting building.

Consult the Natural Resources Conservation Service, Extension Service, MidWest Plan Service, or Northeast Regional Agricultural Engineering Service for composter plans that will meet your needs.

Temporary bins can also be constructed with bales of low-quality hay or straw (Figure 51-10). This type of construction is less expensive and provides the flexibility, such as the number of bins and their location, that a permanent structure would not. When the need arises, bale bins can also be used along with a permanent structure facility to provide additional composting capacity. Straw bale composters, for example, could be used for catastrophic mortality.

The correct sizing of the composting facility is critical for its successful operation and depends on the size of the animals and the amount of material to be composted on a daily basis. Proper sizing makes the management and operation of the composting process easier. For example, composting facilities that are undersized can lead to problems with odor and flies. Sizing is fairly easy, using the universal sizing procedure. The steps of this procedure are given in Table 51-4. It is applicable to the sizing of either bins or windrows and for any type of dead animal.

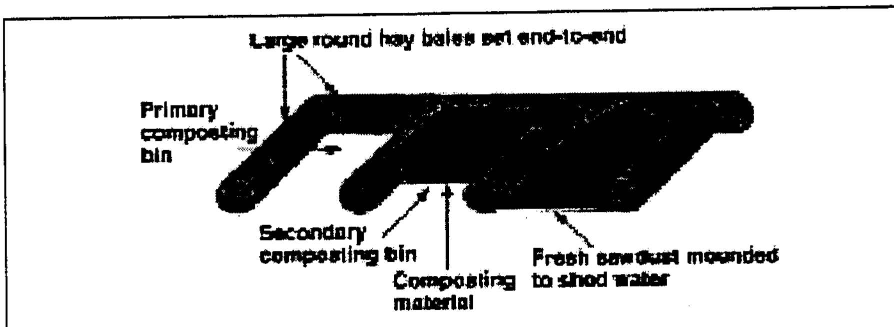


Figure 51-10. Straw bale composter.

Proper sizing makes the management and operation of the composting process easier.

Table 51-4. Universal sizing procedure.

Step	Description
A	Determine the average daily weight of animal carcasses to be composted.
B	Determine the composting cycle times for the **"design weight"** to be composted in each windrow or bin. 1. Primary cycle time (days) = 5.00 x (design animal weight, lb)$^{0.5}$, minimum time ≥10 days 2. Secondary cycle time (days) = 1/3 Primary cycle time, minimum time ≥ 10 days 3. Storage time (days) = Year's maximum period of time between land applica tion events. Must be in keeping with the timing requirements of the nutrient management plan.
C	Determine the needed composter volumes. 1. Primary composter volume (ft^3) = 0.2 x Average daily loss (lb/day) x Primary cycle time (in days) 2. Secondary composter volume (ft^3) = 0.2 x Average daily loss (lb/day) x Secondary cycle time (in days) 3. Storage volume (ft^3) = 0.2 x Average daily loss (lb/day) x Storage time (days)
D	Determine the dimensions of the compost facility including bin dimensions and number of bins or windrow size and area requirements.
E	Determine the annual sawdust requirement for the composting system. Annual sawdust needs (yd^3/yr) = Annual loss (lb/yr) x 0.0069.

[1]Adapted from Ohio Livestock Mortality Handbook 1999.

Step A—Determine the weight of the animal carcasses to be composted. Use farm records for building capacity, animal sizes, and livestock production values and loss records when possible or use the mortality table developed for the various livestock species. Table 51-5 is an example of a mortality table for poultry. Determine the average daily death loss for each growth stage on the farm. Then estimate both the pounds of mortality produced by the operations in one year using "average weight" and the average daily loss in pounds per day to be composted. For species such as cattle or sheep where the majority of mortality occurs during a short period such as during lambing and calving, the average daily loss needs to be determined on the shorter period rather than the entire year.

Step B—Determine the composting cycle times for the "design weight" to be composted in each windrow or bin. The time for primary composting as well as the needed composting volume increases as the animal weight increases. An operation with different growth stages should evaluate the feasibility of using segregated bins or windrows. For mature cattle or horses, the preferred approach is to place each individual mortality in a pile on a composting pad. Separate facilities are recommended for animals in the following weight ranges:

- Less than 50 lb
- 50 to 250 lb
- Greater than 250 lb

The following equations may be used to determine the composting times required for bins:

1. Primary cycle time (in days) = 5.00 x (design animal weight, lb)$^{0.5}$, minimum time ^{3} 10 days
   The "design animal weight" used in the equation for determining the primary cycle time is usually taken as the weight of the largest individual animal to be composted.
2. Secondary cycle time (in days) = 1/3 Primary cycle time, minimum time ^{3} 10 days
3. Storage time (in days) = Years maximum period of time between land application events. Must be in keeping with the timing requirements of the nutrient management plan. For example, if the longest period of time during the year when land application cannot be made is from October 1 to March 30, the storage time required is 6 months or about 180 days.

Step A—Determine the weight of the animal carcasses to be composted.

Step B—Determine the composting cycle times for the "design weight" to be composted in each windrow or bin.

Table 51-5. Poultry mortality rates.

Poultry Type	Avg. Weight, lb	Loss Rate, %	Flock Life, days	Design Weight, lb
Broiler	4.2	4.5-5	42–49	4.5
Layers	4.5	14	440	4.5
Breeding Hens	7-8	10-12	440	8
Turkey, females	14	5-6	95	14
Turkey, males	24	9	112	24

Step C—
Determine the composter volumes.

Step C—Determine the composter volumes. The following equations are used to determine the needed composter volumes (ft^3).

1. Primary composter volume (ft^3) = 0.2 x Average daily loss (lb/day) x Primary cycle time (in days)
2. Secondary composter volume (ft^3) = 0.2 x Average daily loss (lb/day) x Secondary cycle time (in days)
3. Storage volume (ft^3) = 0.2 x Average daily loss (lb/day) x storage time (days)

Step D—
Determine the dimensions of the compost facility, bin dimensions, and windrow size or number of bins.

Step D—Determine the dimensions of the compost facility, bin dimensions, and windrow size or number of bins. For a bin system, the minimum front dimension should be 2 ft greater than the loading bucket width. A minimum of two primary bins is required. An alternative to individual secondary bins is an area or areas large enough to accommodate the contents of the primary bins. Secondary bins/areas are generally directly behind the primary bins.

Step E—Determine the annual amount of sawdust required for the composting.

Step E—Determine the annual amount of sawdust required for the composting. The following equation estimates the total annual amount of fresh sawdust needed. In practice, it is recommended that up to 50% of the fresh sawdust needs be met with finished compost. The equation allows for a 1-foot sawdust base in the bin on which to begin placing the dead animals, 1-foot of sawdust between layers, 1 foot of sawdust clearance between the dead animals and the sides of the bin, and a 1-foot cover depth. Of course, if values different than these are used in the construction of the pile, either more or less sawdust will be required.

Annual sawdust needs (yd^3/yr) = Annual loss (lb/yr) x 0.0069

The universal sizing procedure sizes the facilities. It does not prescribe the materials or recipe. The recipe used to compost mortality depends on the raw material that is available and especially on the material that is available onfarm. The recipe may also depend on what state and county regulations allow. For example, some states do not permit the use of chicken litter as an amendment in the recipe for composting dead animals. In these states, it is necessary to compost without chicken litter even though it is an effective amendment and may be readily available at low cost. Composting is a combination of art and science. Therefore, it is necessary to adjust the recipe using trial and error until the desired results are achieved.

Straw can be used instead of or to replace a portion of the volume of sawdust computed in the universal sizing equations. Sawdust generally provides superior structure to the compost pile. However, if sawdust is not available or is very expensive, it may be advantageous to use straw. The straw used must yield the same compressed volume as the sawdust to provide clearance and cover equal to that of sawdust. Straw will generally compress to over one-half its loose volume. For this reason, straw must be chopped and initially layered to twice its desired final depth.

Chicken litter can be used to replace a portion of the sawdust, if regulations permit, to improve the C:N ratio of the pile and enhance the compost process. Up to two-thirds of the required sawdust can be replaced with

Given: A broiler operation. The operation's nutrient management plan does not allow land application between September 1 and March 30 or 210 days. Flock cycles occupy the facility 365 days per year.

Required: Compost bin volume requirements using the universal sizing method.

Solution:

Step A—Determine the weight of animal carcasses to be composted.
From farm records, it can be determined that the average daily loss (ADL) is 30 lb/day. A design mortality weight (W1) of 3 lb will be assumed.
Annual loss = ADL x 365
= 30 x 365
= 10,950 lb/yr

Step B—Determine the composting cycle times for the "design weight" to be composted in each windrow or bin.
Primary cycle time (days) = 5.00 x (design animal weight, lb)$^{0.5}$, Minimum time ^{3} 10 days
= 5.00 x (3)$^{0.5}$
= 8.7 days < 10 days Use 10 days.
Secondary cycle time (days) = 1/3 Primary cycle time, Minimum time ^{3} 10 days
= 1/3 x 10
= 3 days < 10 days. Use 10 days.
Storage time (days) = Year's maximum period of time between land application events.
= 210 days (from nutrient management plan)

Step C—Determine the needed composter volumes.
Primary composter volume (ft^3) = 0.2 x Average daily loss (lb/day) x Primary cycle time
= 0.2 x 30 x 10
= 60 ft^3
Secondary composter volume (ft^3) = 0.2 x Average daily loss (lb/day) x Secondary cycle time
= 0.2 x 30 x 10
= 60 ft^3
Storage volume (ft^3) = 0.2 x Average daily loss (lb/day) x Storage time (days)
= 0.2 x 30 x 210
= 1,260 ft^3

Step D—Determine the dimensions of the compost facility, bin dimensions, and windrow size or number of bins.
Any dimension that is acceptable to the producer and will provide the volume requirement for primary and secondary composter volumes and the storage volume is acceptable. A building to store the finished compost and fresh sawdust should be considered.

Step E—Determine the annual sawdust required for the composting.
Annual sawdust needs (yd^3/yr) = Annual loss (lb/yr) x 0.0069
= 10,950 x 0.0069
= 76 yd^3/yr
Assuming that 50% of the sawdust needs will be met by using finished compost, the annual sawdust need is 76 x 50% = 38 yd^3/yr.

chicken litter. Studies have shown that dead broiler chickens can be successfully composted with only chicken litter (McCaskey 1994).

Composter operation

The compost pile must be monitored and the appropriate adjustments made throughout the composting period to sustain a high rate of aerobic microbial activity for complete decomposition with a minimum of odors as well as maximum destruction of pathogens. A convenient and meaningful compost parameter to monitor is temperature; it is an indicator of microbial activity. By recording temperatures daily, a normal pattern of temperature development can be established. Deviation from the normal pattern of temperature increase indicates a slowing of or unexpected change in microbial activity. Temperatures should begin to rise fairly steadily as the microbial population begins to develop. If the temperatures do not begin to rise within the first several days, adjustments must be made in the compost mix. A lack of heating indicates that aerobic decomposition has not been established. This state can be caused by any number of factors such as a lack of aeration, inadequate carbon or nitrogen source, low moisture, or low pH. Poor aeration is caused by inadequate porosity that, in turn, can result from material characteristics or excessive moisture.

A convenient and meaningful compost parameter to monitor is temperature; it is an indicator of microbial activitity.

Specific guidelines for the operation of a compost facility include

- Use only approved plans to construct compost facilities.
- Remove mortalities daily from housing facilities.
- Shape piles and windrows so that precipitation will run off.
- Add fresh carbon amendment to outside of the pile for biofilter and to absorb leachate and odors.
- Monitor the compost pile temperature. To eliminate pathogens, an average temperature greater than 122°F must be achieved throughout the compost for at least 5 days during either the primary or secondary composting stages or as the cumulative time with temperatures greater than 122°F in both stages.
- Leave primary compost in the bin until the temperature reaches its maximum and then shows a steady decline for one week. Use care to avoid short circuiting the primary cycle time.
- Mix and aerate the compost by moving the compost to the secondary bin.
- Store stabilized compost until it can be applied in accordance with the timing prescribed by the nutrient management plan or prepared for sale to others.

Compost end use

The primary final use of finished compost is for land application. While the main value of applying compost to land is to improve the soil's structure and water-holding capacity, compost does contain many nutrients. These nutrients are generally not present in the same quantities per unit of volume as inorganic fertilizer. For this reason, a high-rate application of compost will be needed to meet crop nutrient needs. Regardless, the application rate must be based on soil testing and compost nutrient content testing and be applied in keeping with a nutrient management plan.

The advantage of using compost as a fertilizer is that it releases nutrients slowly, usually under the same warm, moist soil conditions required for plant growth. Thus, nutrient release is matched with plant uptake, resulting in a more efficient utilization of nitrogen and a decreased potential for nitrogen leaching. While the potential for leaching still exists when conditions are suitable for nutrient release from the compost, there is no plant growth to use the nitrogen. This can occur, for example, in early fall after crops have been harvested, but there is still adequate soil moisture and temperature for nutrient release.

In summary, the composting method for managing mortality has the following advantages and disadvantages (Table 51-6).

Table 51-6. Mortality management by composting.

Advantages	Disadvantages
1. Conserves nutrients contained in the dead animals	1. High initial cost
2. Low odor	2. Labor intensive
3. Environmentally safe	3. Regular monitoring and maintenance is required
4. No need to store dead animals	4. Cropland required for utilization of finished compost

Incineration

Incinerating dead poultry and small animals is biologically the safest disposal method. The residue from properly incinerated mortality is largely harmless and does not attract rodents or insects. On the other hand, it may be slow, require fuel and expensive equipment, and generate nuisance complaints from particulate air pollution and odors even when highly efficient incinerators are used. Incineration generally requires an air pollution permit, and as such, requires that the unit meet state agency regulations. Local regulations may also require an installation permit. Therefore, incineration is not a casual or inexpensive undertaking. Barrels or other homemade vessels are unsatisfactory burners and may have serious consequences if they result in air pollution or unpleasant odors.

Incinerating dead poultry and small animals is biologically the safest disposal method.

Commercial incineration units fired with gas or oil burners are available (Figure 51-11). When selecting an incinerator, consider its sturdiness and the type of controls. The unit selected should be able to operate under heavy loading conditions and withstand high operating temperatures. Consider purchasing a unit with automatic timer controls that shut off the fuel supply after predetermined time because of the convenience they provide in operating the unit.

The incinerator's capacity should be based on animal size and the expected daily mortality rate. The incinerator should be sited in a convenient location that will avoid potential problems and be downwind of livestock housing, farm residences, and neighbors. In most situations, the incinerator should be housed and placed on a concrete slab to extend its life. Maintenance costs include the replacement of expendable parts and grates every few years. The incinerator unit may need to be replaced or completely overhauled every 5 to 7 years.

To summarize, the incineration method for managing mortality has the following advantages and disadvantages (Table 51-7).

Table 51-7. Mortality management by incineration.

Advantages	Disadvantages
1. Sanitary 2. Final except for ashes wasted	1. Nutrients contained in the dead animals is 2. Initial cost 3. Fuel costs 4. Equipment operation and maintenance costs 5. Potential air quality impairment

The incinerator should be sited in a convenient location that will avoid potential problems and be downwind of livestock housing, farm residences, and neighbors.

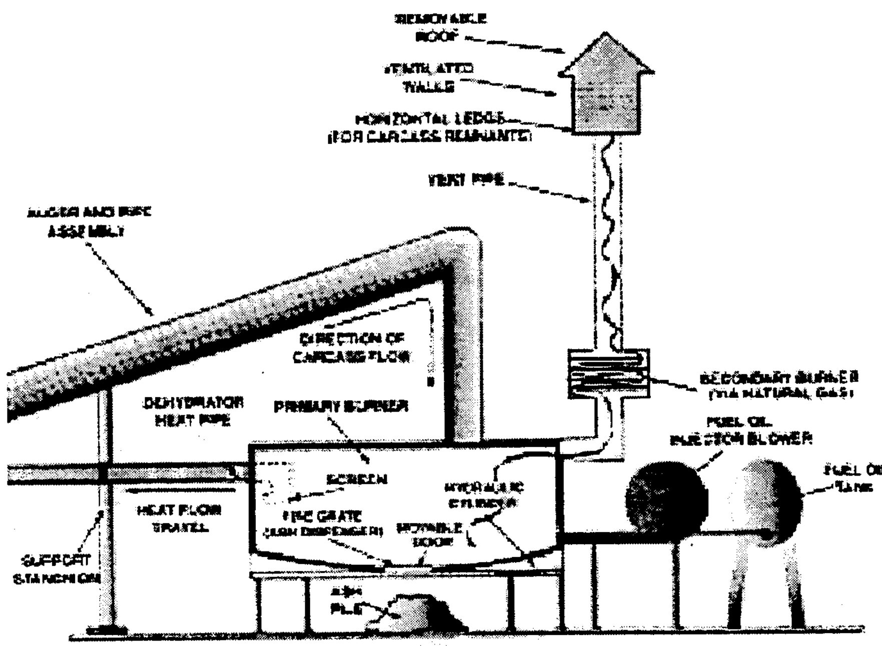


Figure 51-11. Incineration system.
Source: Severincinerator, Global WasteTransformation, Inc., Adairsville, GA.

Sanitary Landfills

Sanitary landfills are engineered burial facilities for disposal of solid waste (Figure 51-12). They are located, designed, constructed, and operated in a manner that will contain the solid waste so it will not cause a present or potential hazard to public health or to the environment. Generally, most landfills are operated under the authority of a local government that controls what can or cannot be disposed of in the landfill. To minimize the environmental hazard, hazardous material is not allowed to be disposed of in a landfill. Because of the difficulty of siting and constructing new landfills, material that can be managed with alternative methods are oftentimes excluded to preserve space. Solid waste often banned for this reason includes large home or industrial appliances and tires.

In some areas, disposal of dead poultry and/or animals in a sanitary landfill is permitted. This may be one of the simpler methods of disposal if a landfill is near the livestock facility. Because not all landfills will accept dead animals, however, arrangements with the landfill operator should be made in advance. In addition, some states require special licenses to transport dead animals. Regardless, carcasses should be hauled in a leakproof, covered container and/or vehicle.

In summary, the sanitary landfill method of managing mortality has the following advantages and disadvantages (Table 51-8).

Because not all landfills will accept dead animals ... arrangements with the landfill operator should be made in advance.

Figure 51-12. Sanitary landfill.

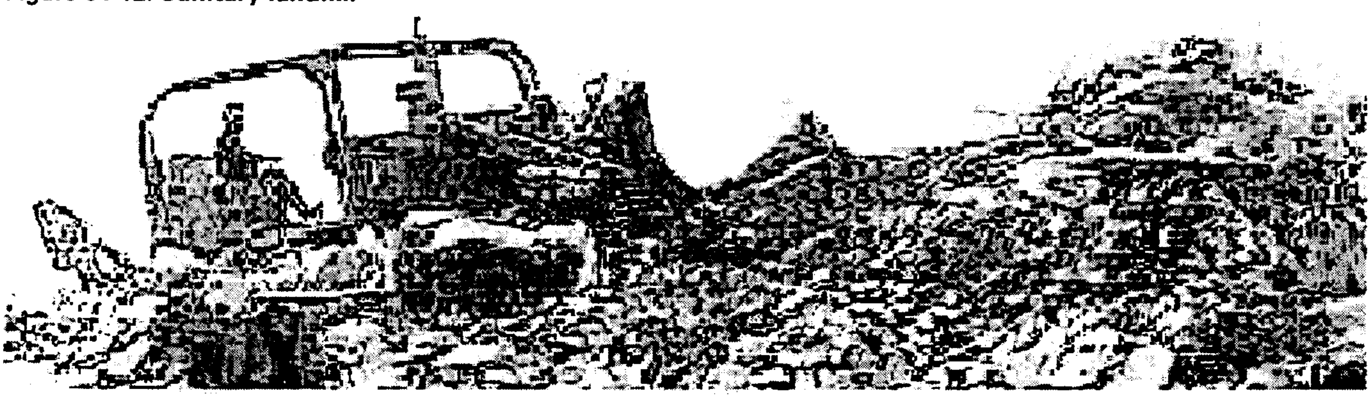


Table 51-8. Mortality management using sanitary landfills.

Advantages	Disadvantages
1. Simplicity	1. Nutrients contained in the dead animals are wasted.
2. No capital investment	2. Few landfills accept dead animals.
3. No maintenance	3. Transportation costs
	4. Not permitted in many areas

Where regulations allow burial, there are generally strict siting requirements.

Burial

Burial is a common method of handling dead animals. This method involves excavating a grave or pit, filling the bulk of the excavation with dead animals, and then covering them with soil until the grave or pit is filled. The fill over the dead animals should be heaped to allow for settling. In time, the carcasses will decompose. In cold climates, burial is difficult when the ground is frozen.

At some locations, regulations may allow disposal by burial only for a massive die-off. For this reason, it is important to contact the appropriate regulatory agency for assistance and/or guidelines if this method is under consideration for day-to-day mortality. Where regulations allow burial, there are generally strict siting requirements. Common siting requirements include locating the burial

- Where it will not create an actual or potential public health hazard.
- In soils having a moderate to slow permeability.
- Where there is a specified minimum separation distance from wells and surface water bodies.
- Where there is no evidence of a seasonal high-water table above the bottom of the grave/pit.
- Outside the 100-year floodplain.

Sites that have permeable soils, fractured or cavernous bedrock, and a seasonal high-water table must be avoided.

Construction requirements for burial graves or pits limit the depth to less than 8 feet and demand that the sides of the excavation be sloped to a stable angle. If burial is used, it is important to protect the site from scavengers and rodents before and after burial. For poultry, a 12-inch compacted soil cover is considered minimum with 24 inches being the recommended depth. For larger animals, the cover depth should be at least 36 inches of compacted soil. The completed burial should be seeded with grass to prevent erosion. Check with local officials for specific regulations.

In summary, the burial method of managing mortality has the following advantages and disadvantages (Table 51-9).

Table 51-9. Mortality management using burial.

Advantages	Disadvantages
1. Capital limited to land and excavating equipment	1. Nutrients contained in the dead animals are wasted. 2. Increases sanitary precautions to pre vent disease transmission. 3. Storage of carcasses until burial may be necessary. Difficult if ground is frozen 4. Land area becomes significant for large operations 5. Impossible when ground is frozen

Disposal Pits

Of the methods discussed, disposal pits are the least desirable method for managing mortality from an environmental protection perspective. This method differs from burial because the dead animals are placed in a lined pit (Figure 51-13) rather than an unlined grave. Dead animals may take a long time to decompose in a disposal pit because of limited aeration. For this reason, there may be a high potential for groundwater contamination. Where permitted by regulations, disposal pits should be considered only if soil conditions will protect the groundwater and there is adequate separation distance from drinking water supplies. The requirements for siting disposal pits are very similar to burial. In addition, disposal pit sites should be located on sites with 5% or greater slopes to ensure good surface drainage, minimizing infiltration.

Disposal pits are constructed of concrete blocks, treated lumber, or poured-in-place concrete. The bottom of the pit should be soil covered with several inches of crushed-rock gravel. The pit requires a cover made of reinforced concrete with an opening (filling port) large enough for the mortality. This opening must have a lid that can be secured to seal the pit when it is not in use.

In summary, the disposal pit method of managing mortality has the following advantages and disadvantages (Table 51-10).

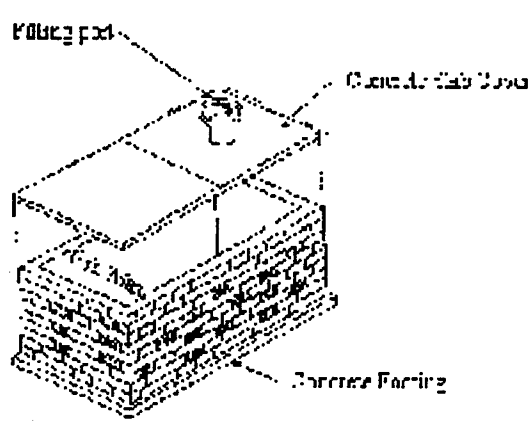


Figure 51-13. Disposal pit.
Source: Agricultural Waste Management Field Handbook, Part 651, p. 10-78.

Where permitted by regulations, disposal pits should be considered only if soil conditions will protect the groundwater and there is adequate separation distance from drinking water supplies.

Table 51-10. Mortality management using disposal pits.

Advantages	Disadvantages
1. Simplicity	1. Nutrients contained in the dead animals are wasted. 2. Exacting soil and drainage conditions are required. 3. Satisfactory location may not be convenient to facilities. 4. Possibility of environmental hazards 5. Not permitted in many areas

Regulatory Compliance Issues

Regulations relating to livestock and poultry mortality vary from state to state. Most, if not all, states require timely management. It is essential that you research the regulations for your state and locality. You may use Table 51-11 as a checklist for conducting research on the different aspects of mortality management.

Table 51-11. Regulatory compliance issues applicable to your livestock or poultry operation.

What agency(s) is (are) involved in administrating regulations related to livestock/poultry mortality?	___ U.S. EPA___ State___ Local List Name, Address, phone number	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Do regulation require that an agency be notified if death is caused by certain infectious diseases?	Yes _____ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Do regulations vary based upon size of the livestock/ poultry operation?	Yes, facilities for managing mortality are required for operations having more than ________(number) for ________ (type of livestock/poultry) No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Are methods (burial, incineration, composting, etc.) of attending to livestock/ poultry mortality specified by regulation?	Yes, the approved methods are No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Is there a time limit for attending to livestock/poultry mortality?	Yes, the time limit is No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Are plans and specification for mortality facilities required to be approved prior to construction?	Yes _____ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Are there restrictions or licenses required to transport dead livestock/poultry away from property?	Yes, a license is required ________ The restriction are No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Is certification required to operate a composter?	Yes, a certification is required ______ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Do regulations require mortality composters to be constructed with floors, roofs, and of rot-/rust-resistant building materials?	Roofs (Yes or No) ________________ Floors (Yes or No) ________________ Rot-/rust-resistant building material (Yes or No) _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Do regulations limit the location of burials of mortality to locations with certain characteristics such as separation distance to wells and streams, depth to water table, property lines, and occupied buildings?	Yes _____What are the requirements? No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Do regulations specify cover depth for burial?	Yes, the depth of cover required is _____ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Do regulations require that an approved incinerator be used?	Yes _____ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Does incineration require a air quality permit?	Yes _____ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know
Are there special requirements should catastrophic die-off occur?	Yes _____ No _____	____ Yes ____ No ____ ____ Not Applicable ____ Don't Know

Appendix A

Poultry and Livestock Mortality Rates

Poultry

Poultry Type	Average Weight, lb	Mortality Rate, %	Flock Life, days	Design Weight, lb
Broiler	4.2	4.5-5	42-49	4.5
Layers	4.5	14	440	4.5
Breeding Hens	7-8	10-12	440	8
Turkey, females	14	5-6	95	14
Turkey, males	24	9	112	24

Swine

Growth	Average Weight, lb	Mortality Rate,%			Design Weight, lb
		Low	Average	High	
Birth to Weaning	6	< 10	10-12	> 12	10
Nursery	24	< 2	2-4	> 4	35
Growing-Finishing	140	< 2	2-4	> 4	210
Breeding Herd	350	< 2	2-5	> 5	350

Cattle/Horses

Growth Stage	Average Weight, lb	Mortality Rate,%			Design Weight, lb
		Low	Average	High	
Birth	70-130	< 8	8-10	> 10	130
Weanling	600	< 2	2-3	> 3	600
Yearling	900	< 1	1	> 1	900
Mature	1,400	< 0.5	0.5-1	> 1	1,400

Sheep/Goats

Growth Stage	Average Weight, lb	Mortality Rate,%			Design Weight, lb
		Low	Average	High	
Birth	8	< 8	8-10	> 10	10
Lambs	50-80	< 4	4-6	> 6	80
Mature	170	< 2	3-5	> 8	170

Source: Ohio Livestock and Poultry Composting Handboo, December 1999.

Appendix B

Worksheet for Determining Compost Bin or Windrow Volume Requirements

Name: ______________________________ Location ____________________

Step A—Determine the weight of animal carcasses to be composted.

Average daily loss (ADL) ____________ lb.
Design mortality weight (W1) ____________ lb.
Annual loss = ADL x 365 = (__________) x 365 = ____________ lb.

Step B—Determine the composting cycle times for the "design weight" to be composted in each windrow or bin.

Primary cycle time (days) = 5.00 x $(W1)^{0.5}$ = __________- x (______________)$^{0.5}$
= ________________ days (If less than 10 days, use 10.)

Secondary cycle time (days) = 1/3 primary cycle time, minimum time ³ 10 days
= 1/3 x (_______)
= ______________ days (If less than 10 days, use 10.)

Storage time (days) = Year's maximum period of time between land application events.
= ______________ days (from nutrient management plan)

Step C—Determine the needed composter volumes.

Primary composter volume (ft^3) = 0.2 x ADL x primary cycle time
= 0.2 x ________ x __________ = _______ ft^3

Secondary composter volume (ft^3) = 0.2 x ADL x secondary cycle time
= 0.2 x ________ x __________ = _______ ft^3

Storage volume (ft^3) = 0.2 x ADL x storage time (days)
= 0.2 x ________ x __________ = _______ ft^3

Step D—Determine the dimensions of the compost facility, bin dimensions, and windrow size or number of bins.

Step E—Determine the annual sawdust required for the composting.

Annual sawdust needs (yd^3/yr) = annual loss (lb/yr) x 0.0069
= ____________ x ____________
= __________________yd^3/yr

Equations for universal sizing of composting bins and windrows

$T_1 = 5 \times W_1^{0.5}$ — days
≥ 10 days

$V_1 \geq 0.2 \times ADL \times T_1$ — ft^3

$T_2 = 1/3 \times T_1$ — days
≥ 10 days

$V_2 \geq 0.2 \times ADL \times T_2$ — ft^3

T_3 = storage — days
= Year's maximum period of time between land application events in keeping with the timing requirements of the nutrient management plan

$V_3 \geq 0.2 \times ADL \times T_3$ — ft^3
Annual sawdust needs = ADL x 0.0069 — yd^3/yr

Where
ADL = average daily mortality (lb/day)
W_1 = design mortality weight (lb)
T_1 = Primary cycle time (days)
V_1 = Primary compost bin or windrow volume (ft^3)
T_2 = Secondary cycle time (days)
V_2 = Secondary compost bin or windrow volume (ft^3)
T_3 = Storage period (days)
V_3 = Storage volume requirement (ft^3)

About the Author

This lesson was prepared by Donald L. Stettler, Environmental Engineer, USDA Natural Resources Conservation Service, National Water and Climate Center, Portland, Oregon. He can be reached at this e-mail address:
dstettler@wcc.nrcs.usda.gov

References

T.A. McCaskey, Dead Bird Composting, February 15, 1994.

Glossary

Aeration. The process by which the oxygen-deficient air in compost is replaced by air from the atmosphere. Aeration can be enhanced by turning.

Aerobic. An adjective describing an organism or process that requires oxygen (for example, an aerobic organism).

Amendment. *See* Composting amendment.

Anaerobic. An adjective describing an organism or process that does not require air or free oxygen.

Bacteria. A group of microorganisms having single-celled or noncellular bodies. Bacteria usually appear as spheroid, rod-like, or curved entities but occasionally appear as sheets, chains, or branched filaments.

Bin composting. A composting technique in which mixtures of material is composted in simple structures (bins) rather than freestanding piles. Bins are considered a form of in-vessel composting, but they are usually not totally enclosed. Many composting bins include a means of forced aeration.

Bulking agent. An ingredient in a mixture of composting raw material included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw). The terms "bulking agent" and "amendment" are commonly used interchangeably.

C. Chemical symbol for carbon.

Carbon-to-nitrogen ratio (C:N ratio). The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.

Cellulose. A long chain of tightly bound sugar molecules that constitutes the chief part of the cell walls of plants.

Compost. A group of organic residues or a mixture of organic residues and soil that have been piled, moistened, and allowed to undergo aerobic biological decomposition.

Composting. Biological degradation of organic matter under aerobic conditions to a relatively stable humus-like material called compost.

Composting amendment. An ingredient in a mixture of composting raw material included to improve the overall characteristics of the mix. Amendments often add carbon, dryness, or porosity to the mix.

Degradable material. Material that breaks down quickly and/or completely during composting is highly degradable. Material that resists biological decomposition is poorly or even nondegradable.

Disposal pit. A method for managing mortality that involves placing dead animals in an excavated hole or pit that is lined equipped with a cover. It is considered the least desirable method for managing mortality.

Grinding. Operation that reduces the particle size of material. Grinding implies that particles are broken apart largely by smashing and crushing rather than tearing or slicing.

Humus. The dark or black carbon-rich relatively stable residue resulting from the decomposition of organic matter.

Incineration. A method for managing mortality that involves burning dead animals with a very hot flame, reducing them to ashes. It is considered the most environmentally benign method for managing mortality.

In-vessel composting. A diverse group of composting methods in which composting material is contained in a building, reactor, or vessel.

Land application. Application of compost, manure, sewage sludge, municipal wastewater, and industrial wastes to land either for ultimate disposal or for reuse of the nutrients and organic matter for their fertilizer value.

Leaching. The removal of soluble material from one zone in soil to another via water movement in the profile.

Litter, poultry. Dry absorbent bedding material such as straw, sawdust, and wood shavings that is spread on the floor of poultry barns to absorb and condition manure. Sometimes the manure-litter combination from the barn is also referred to as litter.

Microorganism. An organism requiring magnification for observation.

Moisture content. The fraction or percentage of a substance comprised of water. Moisture content equals the weight of the water portion divided by the total weight (water plus dry matter portion). Moisture content is sometimes reported on a dry basis. Dry-basis moisture content equals the weight of the water divided by the weight of the dry matter.

Mortality. Animals that die prematurely because of disease, injury, or other causes.

N. Chemical symbol for nitrogen.

Organic matter. Chemical substances of animal or vegetable origin, consisting of hydrocarbons and their derivatives.

Pathogen. Any organism capable of producing disease or infection. Often found in waste material, most pathogens are killed by the high temperatures of the composting process.

pH. A measure of the concentration of hydrogen ions in a solution. pH is expressed as a negative exponent. Thus, something that has a pH of 8 has ten times fewer hydrogen ions than something with a pH of 7.The lower the pH, the more hydrogen ions present, and the more acidic the material is. The higher the pH, the fewer hydrogen ions present, and the more basic it is. A pH of 7 is considered neutral.

Porosity. A measure of the pore space of a material or pile of material. Porosity is equal to the volume of the pores divided by the total volume. In composting, the term porosity is sometimes used loosely, referring to the volume of the pores occupied by air only (without including the pore space occupied by water).

Recipe. The ingredients and proportions used in blending together several raw materials for composting.

Rendering. A method for managing mortality that converts the dead animals into useful products, such as pet food and fertilizer.

Sanitary landfill. An engineered burial facility for disposal of solid waste that is located, designed, constructed, and operated in a manner that will contain the waste so it will not cause a present or potential hazard to public health or to the environment.

Shredding. An operation that reduces the particle size of material. Shredding implies that the particles are broken apart by tearing and slicing. *See also* Grinding.

Structure, of composting mix or raw material. The ability to resist settling and compaction. Structure is improved by large rigid particles.

Universal sizing procedure. A method for determining the size of compost bins and windrows that is based on the average daily mortality.

Windrow. A long, relatively narrow, and low pile. Windrows have a large exposed surface area that encourages passive aeration and drying.

Index

FUNDING
This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture; the U.S. Environmental Protection Agency, National Agriculture Assistance Center; and the University of Nebraska Cooperative Extension, University of Nebraska-Lincoln, under Cooperative Agreement Number 97-EXCA-3-0642.

Georgia Department of Agriculture
Swine Mortality Disposal
Guy Selph

Purpose: To prevent the spread of infectious, contagious, and communicable diseases from dead animals.

Authority: Dead Animal Disposal Act (O.C.G.A. Sec. 4-5) passed 1969. Rules of the Georgia Department of Agriculture (Chapter 40-16-2) adopted April 1970 and amended May 1984 and October 1985.

I. Definition of Dead Animal:

Carcass, parts of carcass, effluent blood, intestinal or stomach content, and waste material involved in handling the carcass of farm livestock including but not limited to swine, cattle, poultry, equine, sheep, goats, ratites, etc.

II. Violations:

a. To abandon dead animals on personal, private or public land;
b. To properly dispose of dead animals on another person's property without his permission;
c. To dispose of dead animals in a city or county landfill without making arrangements with the city of county officials for proper disposal;
d. To abandon dead animals in wells or open pits on personal, private or public land.

III. Methods of Disposal:

a. Incineration or Burning

(1) Within twelve (12) hours of death or discovery;
(2) Entire carcass reduced to ashes;
(3) Under conditions approved by the U.S. Environmental Protection Agency and the Georgia Environmental Protection Division.
(4) Special conditions (emergency) approved by State Veterinarian on case-by-case basis.

b. Burial

(1) Within twelve (12) hours of death or discovery;
(2) At least three (3) feet below ground level;
(3) No more than eight (8) feet deep;
(4) Three (3) feet of soil on top.

c. Rendering

(1) Within twelve (12) hours of death or discovery;
(2) Longer than twelve (12) hours if refrigerated or frozen.

d. Composting

(1) Approved by State Veterinarian;
(2) NRCS standard or equivalent.

e. Others

(1) Risk assessments for the spread of disease performed by the Georgia Department of Agriculture personnel, and
(2) Approved by State Veterinarian on case-by-case basis.

IV. Transportation:

a. Georgia Department of Agriculture may prohibit transportation of dead animals;
b. Dead animals must be transported in leak-proof trucks.

V. Penalty for violations:

Violation of Laws and Rules is a misdemeanor and punishable as such.

Georgia Department of Agriculture Proposal:

Mass graves (disposal pits) for swine can be designed, constructed, and maintained in a manner approved by the Department of Agriculture. Department of Agriculture personnel must first conduct a site assessment for soil suitability. Modeled after the successful poultry mortality pit disposal guidelines.

Georgia Department of Agriculture

Capitol Square • Atlanta, Georgia 30334-4201

Tommy Irvin
Commissioner

RULES
OF
GEORGIA DEPARTMENT OF AGRICULTURE
ERADICATION, CONTROL AND SUPPRESSION OF ANIMAL AND POULTRY DISEASES

CHAPTER 40-16-2
DEAD ANIMALS

TABLE OF CONTENTS

40-16-2-.01 Purposes of the Regulations. Amended. In order to halt the spread of infectious, contagious, and communicable disease from the carcass of any animal which has died or been killed, Rules are hereby promulgated controlling the disposal of livestock carcasses.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Purposes of the Regulations" was filed on April 1, 1970; effective April 20, 1970. Amended: Authority changed. Filed May 2, 1984; effective May 22, 1984. Amended: Rule repealed and a new Rule of the same title adopted. Filed October 3, 1985; effective October 23, 1985.

40-16-2-.02 Definitions. Amended. The following words of terms shall have the meaning set forth herein when used in these Rules and Regulations:

(a) The term "Department" shall mean the Department of Agriculture.

(b) The term "Commissioner" shall mean the Commissioner of Agriculture.

(c) Dead Animals are defined as:

(1) Carcasses or parts of carcasses of those animals which are considered farm livestock, including poultry, equine, and

(2) It shall further include any effluent, blood, intestinal or stomach contents and all necessary waste material involved in handling such carcasses.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Definitions" was filed on April 1, 1970; effective April 20, 1970. Authority changed. Filed May 2, 1984; effective May 22, 1984.

40-16-2-.03 Disposition of Dead Animals. Amended.

(1) No person shall abandon on his own land any animal which has died or has been killed.

(2) No person shall dispose of such dead animals, or parts thereof as defined above, on another person's land without having his permission to bury, as defined elsewhere in these regulations.

(3) No person shall dispose of any dead animal in a city or county landfill without their approval.

(4) Under no conditions shall dead animals be abandoned in wells or open pits of any kind on private or public land.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Disposition of Dead Animals" was filed on April 1, 1970; effective April 20, 1970. Amended: Rule amended and Authority changed. Filed May 2, 1984; effective May 22, 1984. Amended: Filed October 3, 1985; effective October 23, 1985.

40-16-2-.04 Livestock Market and Slaughter Plants. Amended.

(1) Public Livestock Sales Markets shall have a means for disposal of dead livestock as approved elsewhere in these rules and regulations by the Department. Such facilities are not required where rendering trucks can adequately service such markets; such service to be rendered so that dead livestock can be disposed of within the time limits established in these regulations.

(2) Livestock slaughter establishments shall be subject to the same rules and regulations as in #1 above.

Authority O.C.G.A. Art. 1, Secs. 4-4 and 4-5. Administrative History. Original Rule entitled "Livestock Markets, Slaughter Plants, Garbage Feeders" was filed on April 1, 1970; effective April 20, 1970. Amended: Title changed to "Livestock Markets and Slaughter Plants" Ruled amended and Authority changed. Filed May 2, 1984; effective May 22, 1984.

40-16-2-.05 Methods of Disposal of Dead Animals. Amended. Methods which may be used for the disposal of dead animals are incineration, burial, rendering, composting and acid fermentation, provided each method is carried out in the following manner:

(a) Incineration: Incineration shall be under U. S. Environmental Protection Agency and Georgia Environmental Protection Division approved conditions, with incinerators meeting Agency and/or Division's approval standards and maintained as such. Incineration shall be within twelve (12) hours after death or discovery of the carcass, whichever is later, and the entire carcass must be reduced to ashes in the incineration process.

(b) Burial: Carcasses which are buried, must be buried at least three (3) feet below the ground level but no more than eight (8) feet and have not less than three (3) feet of earth over the carcass. Burial must be completed within twelve (12) hours after death or discovery of the carcass.

(c) Rendering: Carcasses disposed of by rendering must be delivered to the rendering plant within twelve (12) hours after death or discovery of the carcass, and must be processed as soon as possible. The twelve (12) hours will be waived provided carcasses are refrigerated or frozen until delivered to the rendering plant.

(d) Composting: The procedure for composting of poultry must be approved by the State Veterinarian's office upon written request by the grower describing the procedure used and the facilities involved. Composting will be approved provided it is used in conjunction with another approved method. Composting is approved only for handling the normal daily mortality of broiler, layer or breeder operations. The procedure used must be one approved by the Commissioner.

(e) Acid Fermentation: Carcasses disposed of by acid fermentation must be subject to the fermentation process within twelve (12) hours after death or discovery of the carcasses. The procedure must be approved by a letter of permit from the State Veterinarian's Office.

Authority O.C.G.A. Sec. 4-5-1 et seq.

40-16-2-.06 Poultry Carcass Disposal. Amended.

(1) The premises of each person growing poultry for himself or others, including turkeys, commercial eggs, hatching eggs and broilers for commercial purposes is hereby quarantined upon the placing of any dead poultry carcass (when death results from other than in connection with the slaughter thereof) in other than a disposal pit or incinerator approved by the Commissioner of Agriculture. Such quarantine shall not be applicable to any person growing poultry who provides and maintains a method of disposal of dead poultry who provides and maintains a method of disposal of dead poultry carcasses that has been approved by the Commissioner of Agriculture as satisfactory to him to prevent the spread of disease.

(2) To aid in the enforcement of the laws of this State, and these regulations, the Commissioner of Agriculture shall issue to each person growing poultry, for himself or others, a certificate of compliance with the provisions of the laws relating to disease prevention and these regulations, when the grower:

(a) Provides and maintains a disposal pit of a size and design adequate to dispose of dead poultry carcasses wherein all dead poultry carcasses are disposed of in a manner approved by the Commissioner of Agriculture to prevent the spread of disease; or

(b) Provides and maintains a method of disposal of dead poultry carcasses that has been approved by the Commissioner of Agriculture as satisfactory to him to prevent the spread of disease.

(c) The Commissioner shall determine the form and contents of the certificate issued to the grower. The certificate shall be numbered and shall be valid until cancelled or revoked by the Commissioner. The violation of any of these regulations shall be sufficient grounds for the revocation or cancellation, revocation or suspension of the certificate provided herein or the license of the poultry processing plant, after notice and hearing.

(d) Disposal pits or incinerators shall be constructed in a manner and be capable of providing a method of disposal of dead birds poultry carcasses in a manner to prevent the spread of disease. Each pit shall be utilized in such a manner as to dispose of the contents thereof effectively. Disposal pits shall be of a design and constructed in a manner approved by the Commissioner. The top of the poultry pit should be of solid construction with all sides covered (sealed with sufficient soil to prevent the entry of rodents, insects and rainwater and the exit of odors). The top should have a tight fitting lid or cap to prevent the entrance of flies. The pit should be located a minimum of 100 feet from wells and water supplies and it should be covered in a manner to allow surface water to drain away from water supplies.

(e) Use of incineration, rendering, composting, and acid fermentation, as set forth in Rules40-16-2-.05 (a), (c), (d), and (e), may be used for disposal of poultry carcasses under restrictions stated, provided it is done in a manner to prevent the spread of disease.

(f) No poultry processing plant shall purchase poultry from any poultry grower unless the grower shall submit proof, prior to purchase or delivery, of compliance with provision of these regulations. Receipt by the purchaser of the number of the certificate issued by the Commissioner of Agriculture to the grower shall be sufficient compliance with the regulation. The invoice or other writing executed by the processing plant in connection with each purchase of poultry shall have the certificate number of the grower written or otherwise indicated therein.

Authority O.C.G.A., Arts. 2 and 6 of Sec 26-2, Authority O.C.G.A. 4-5-1 et seq.

40-16-2-.07 Transportation of Diseased Animals. Amended.

(1) At his discretion, the Commissioner of Agriculture may prohibit the hauling or transportation of the body effluent and/or parts of any dead animals. If such is the case, disposal by burial at the premises where found is mandatory.

(2) Dead animals must be transported in leak-proof trucks by a person licensed to traffic in dead livestock. At his discretion, the Commissioner, or his authorized representatives can order dead animals to be delivered directly to a rendering works with no diversion enroute, so as to prevent a rendering truck from going to other farms on a "route" when he has on board animals which have died from an infectious, contagious, or communicable disease.

Authority O.C.G.A. Sec.4-5. Administrative History. Original Rule entitled "Transportation of Dead Animals" was filed on April 1, 1970: effective April 20, 1970. Amended: Rule amended and Authority changed. Filed May 2, 1984; effective May 22, 1984.

40-16-2-.08 Interstate Transportation of Dead Animals. Amended.

(1) Dead animals and/or parts thereof (except green salted hides), shall not be allowed to enter the State of Georgia except by written permit issued by the Georgia Department of Agriculture, Atlanta, Georgia 30334.

(2) Exceptions to this provision are: licensed research institutions, accredited colleges or state colleges and universities; and departments of municipal governments may transport and/or receive dead animals for research or investigational purposes only.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Interstate Transportation of Dead Animals" was filed on April 1,1970; effective April 20, 1970. Amended: Rule amended and Authority changed. Filed May 2, 1984; effective May 22, 1984.

40-16-2-.09 Penalty for Violation. Amended. Any person, firm, partnership or corporation violating the provisions of this act, or any rule or regulations made pursuant thereto, shall be guilty of a misdemeanor and upon conviction thereof shall be punished as provided by law.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Penalty for Violation" was filed on April 1, 1970; effective April 20, 1970. Amended: Authority changed. Filed May 2, 1984; effective May 22, 1984.

40-16-2-.10 Effective Date. Amended. These rules and regulations shall become effective 20 days after filing with the Secretary of State in accordance with the rules of the Administrative Procedures Act.

40-16-2-.11 Conflicting Rules and Regulations Repealed. Amended. All rules and regulations and parts in conflict with these rules and regulations are hereby repealed.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Conflicting Rules and Regulations Repealed" was filed on April 1, 1970; effective April 20, 1970. Amended: Authority changed. Filed May 2, 1984; effective May 22, 1984.

40-16-2-.12 Severability. Amended. Each of these regulations contained herein, is adopted individually, and without reference to each other, and if any one or more of said regulations is declared invalid, it shall not affect the validity of any other regulation.

Authority O.C.G.A. Sec. 4-5. Administrative History. Original Rule entitled "Severability" was filed on April 1, 1970; effective April 20,1970. Amended: Authority changed. Filed May 2, 1984; effective May 22, 1984.

12

Emissions from Animal Production Systems

Emissions from Animal Production Systems

John W. Worley

Table of Contents

Chapter 1: The Science of Odors and Emissions

In the past, airborne emissions were considered only a minor drawback for livestock and poultry production operations. However, with the trend toward larger, more concentrated production sites, odors and other airborne emissions are rapidly becoming an important issue for all animal producers. Shifting population distributions; the unwillingness of many to tolerate odors, gases, and dust emitted from animal production; and the economic importance of animal agriculture in the United States all contribute to the urgent need for stakeholders to find adequate solutions to this problem. A prerequisite to good solutions is a thorough understanding of the problem.

Emissions and Health

Very little information is available on the direct impact of airborne emissions on human health. However, some human health complaints are being made based on certain emissions like odor. A North Carolina study (Schiffman 1995) reported that people living near hog facilities who were exposed to odors experienced more tension, depression, anger, fatigue, and confusion than a group of residents not exposed to hog odors. Another study in Iowa (Thu, et al. 1997) found a higher frequency of mainly respiratory health symptoms in people living within 2 miles of a 4,000-head swine operation compared to a control group in an area with no intensive livestock operations. A different North Carolina study (Wing and Wolf, 1999) found similar results when surveying residents of three rural communities: one a non-livestock area, another with cattle (about 300 dairy cows) operations, and a final area that contained a 6,000-head pig unit. Certain respiratory and gastrointestinal health symptoms (runny nose, sore throat, excessive coughing, and diarrhea) were reported more often in the livestock (mostly hog) communities. Also quality-of-life factors like not wanting to open windows or going outside during pleasant weather were similar in the control (non-livestock) and cattle areas but much lower for residents living in the hog community. Finally, many individuals and/or grass- roots organizations claim negative effects have occurred due to odor and other airborne emissions from livestock operations (Hudson 1998).

Airborne Emissions from Animal Production Systems

Type of emissions: Odor emissions from animal production systems originate from three primary sources: manure storage units, animal housing, and land application of manure. Table 1 summarizes identified odor sources and animal species for justifiable complaints in a 1982 study in a United Kingdom (U.K.) country (Hardwick, 1985). Almost 50% of all odor complaints were traced back to land application of manure, about 20% were from manure storage units, and another 25% were from animal buildings. Other sources included feed production, processing centers, and silage storage. Between the three animal species, pigs were identified as the source of slightly more than half of the complaints (54%), with cattle and poultry being the source of 20% and 24% of the complaints, respectively. Even though these findings are from the U.K. and are nearly 20 years old, general observations in this country seem to agree with this distribution of odor sources. However, with the increased use of manure injection for land application in certain parts of the country and longer manure storage (and larger manure storage structures), there may be a higher percentage of complaints in the future associated with manure storage units and animal buildings.

Table 1. Number and source of odor complaints received during a one-year period in a United Kingdom country

Odor Source	Pigs		Cattle		Poultry		Total	
	No.	%	No.	%	No.	%	No.	%
Buildings	224	22	65	18	163	36	452	25
Slurry storage	169	17	98	28	78	17	345	19
Slurry spreading	526	52	122	34	190	42	838	46
Animal feed production	84	8	4	1	11	3	99	5
Silage storage	10	1	68	19	8	2	86	5
Total	1,013		357		450		1,820	
Percent	56		20		24			100

Source: Hardwick, 1985

Most of the odorous compounds that are emitted from animal production operations are by-products of anaerobic decomposition/transformation of livestock wastes by microorganisms. Livestock wastes include manure (feces and urine), spilled feed and water, bedding materials (i.e., straw, sunflower hulls, wood shaving), wash water, and other wastes. This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. The by-products of microbial transformations depends, in a major part, on whether it is done aerobically (i.e., with oxygen) or anaerobically (i.e., without oxygen). Microbial transformations done under aerobic conditions generally produce fewer odorous by-products than those done under anaerobic conditions. Moisture content and temperature affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as by-products of animal waste decomposition. Kreis (1978) developed one of the earliest lists of volatile compounds associated with decomposition of cattle, poultry, and swine wastes. He listed 32 compounds reported to have come from cattle wastes, 17 from poultry wastes, and more than 50 compounds from swine wastes (Kreis, 1978). O'Neill and Phillips (1992) compiled a list of 168 different compounds identified in swine and poultry wastes. The compounds are often listed in groups based on their chemical structure. Some of the principal odorous compounds, individual and as groups, are ammonia, amines, hydrogen sulfide, volatile fatty acids, indoles, skatole, phenols, mercaptans, alcohols, and carbonyls (Curtis, 1983). Carbon dioxide and methane are odorless.

Some of the gases that are emitted have implications for global warming and acid rain issues. Among these gases are ammonia and non-odorous gases such as methane and carbon dioxide. European countries have instituted strict ammonia emission limits in recent years. It has been estimated that one third of the methane produced each year comes from industrial sources, one third from natural sources, and one third from agriculture (primarily animals and manure storage units). Although animals produce more carbon dioxide than methane, methane contribution to the greenhouse effect is estimated at 15 times that of an equal amount of CO_2

Dust is another airborne emission concern that is difficult to eliminate from animal production units. It is a combination of manure solids, dander, feathers, hair, and feed. It is typically more of a problem in buildings that have solid floors and use bedding as opposed to slatted floors and liquid manure. Dust concentrations inside animal buildings and near outdoor feedlots have been measured and range from 1 up to 10 mg/m^3 (Curtis, 1983). However, dust emission rates are mostly unknown from animal production sites.

Pathogens are yet another airborne emission concern for animal production operations. Although pathogens are present in buildings and manure storage units, they typically do not survive aerosolization well, but some have been transported by dust particles.

Flies are an additional concern from certain types of poultry and livestock operations. The housefly completes a cycle from egg to adult in 6 to 7 days when temperatures are 80 to 90°F. Females can produce 600 to 800 eggs, and larvae can survive burial at depths up to 4 feet. Adults can fly up to 20 miles. These facts verify that large populations of flies can be produced relatively quickly if the correct environment (moisture and nutrients as when manure is stored) are provided. Studies have shown that flies proliferate in areas not trod by animals. To prevent flies, special care should be taken to keep spoiled feed and manure from under feeders and waterers, under fences, and other areas that the animals do not reach. Compost piles make excellent fly habitat if not managed correctly.

Airborne Emission Movement or Dispersion

The movement or dispersion of airborne emissions from an animal production site is difficult to predict and is affected by such factors as topography, prevailing winds, and building orientation. Odor plumes decrease exponentially with distance (Brembery 1994), but long distances are needed if no odors, gases, or dust are to be detected downwind from a source. A number of models are being developed to more accurately predict setback distances from livestock operations based on animal units (Schauberger and Piringer 1997) or actual emission values (Jacobson, et al. 1999).

Prevailing winds should be considered so facilities are sited to minimize odor transport to close or sensitive neighbors. For many existing facilities, this is impossible. For those situations, odor reduction techniques may be needed to reduce the odor emission rate or disperse odors faster and more effectively before they reach a sensitive neighbor or individual.

There is ample evidence that rural air quality issues have become a major concern in the siting of animal production units. A variety of livestock and poultry producers, from various areas of the United States, have reported difficulty in obtaining permits to construct new or expand existing livestock operations due to RAQ complaints from neighbors. Odors typically lowered property values of residential homes although one study in Minnesota actually reported a slight appreciation of real-estate values near livestock production units. Another often mentioned concern is the reduced value of land near livestock and poultry units for outdoor recreational activities.

In a 1999 survey of states by the North Dakota Attorney General's office, a total of 31 states reported various types of airborne emission regulations. Many of these states either exempt or chose not to enforce the regulations for agricultural operations. Most states and local units of government deal with this issue through zoning or land use ordinances. Typically, certain setback distances are required for a given size operation or for land application of manure. Also, setbacks from lakes and public waterways are common. A few states (for example, Minnesota) may have an ambient gas concentration (H_2S in the case of Minnesota) standard at a property line that may impact animal agriculture. Another possibility is an odor standard that only a few states have adopted (North Dakota, Colorado, Wyoming, and Missouri) that is again measured at the property line. Gas and odor standards are difficult to enforce since gases and especially odor are hard to measure on-site with a high degree of accuracy.

Measuring Outdoor Air Quality Components

Olfaction: the sense of smell: The sense of smell is complex. The basic anatomy of the human nose and olfactory system is well understood. Odorous compounds are detected in a small region known as the olfactory epithelium located high in the rear of the nasal cavity.

Odors evoke a wide range of physiological and emotional reactions. Odors can be either energizing or calming. They can stimulate very strong positive or negative reactions and memories. The development of aromatherapy illustrates how important smells can be to people.

The power, complexity, and our limited understanding of the sense of smell make olfaction a challenging field. Even though humans can detect over ten thousand different odors, they are sometimes simply categorized as being either pleasant or unpleasant. They are often described using terms like floral, minty, musky, foul, or acrid. The large number of recognizable odors and the general terms used to describe them make it difficult to measure and describe odors consistently and objectively.

Most odors consist of a mixture of many different gases at extremely low concentrations. The composition and concentration of the gas mixture affects the perceived odor. To completely measure an odor, each gas would need to be measured. Some odorous gases can be detected (smelled) by humans at very low concentrations (Table 2). The fact that most odors are made up of many different gases at extremely low concentrations makes it very difficult and expensive to determine the exact composition of an odor.

Odor vs. Gas Measurement: Two general approaches are used to measure odor: either measure individual gas concentrations or use olfactometry. Both approaches have strengths and weaknesses. Future developments will hopefully close the gap between the two approaches.

The specific individual gaseous compounds in an air sample can be identified and measured using a variety of sensors and techniques. The results can be used to compare different air samples. With good sensors and proper techniques, valuable information about the gases that emanate from a source can be collected and evaluated. Gas emission rates and control techniques can be compared rigorously. Regulations can be established to limit individual gas concentrations.

The gas measurement approach has some weaknesses when used to measure and control odors. The greatest weakness of the gas measurement approach is that there is no known relationship between the specific gas concentrations in a mixture and its perceived odor (Ostojic and O'Brien, 1996). As a result, controls based on gas concentrations may reduce specific gas emissions but not adequately address the odors sensed by people downwind of a source.

The key advantage of olfactometry is the direct correlation with odor and its use of the human's highly sensitive sense of smell. Olfactometry also has the advantage that it analyzes the complete gas mixture so that the contribution of each compound in the sample is included in the analysis. There are different olfactometry techniques. Data collected by different techniques can be neither combined nor directly compared.

Table 2. Odor threshold for select chemicals often found in livestock odors.

Chemical	Odor Threshold, ppm
Aldehydes	
Acetaldehyde	0.21
Propionaldehyde	0.0095
Volatile Fatty Acids	
Acetic acid	1.0
Propionic acid	20.0
Butyric acid	0.001
Nitrogen containing	
Methylamine	0.021
Dimethylamine	0.047
Trimethylamine	0.00021
Skatole	0.019
Ammonia	46.8
Sulfur containing	
Methanethiol	0.0021
Ethanethiol	0.001
Propanethiol	0.00074
t-Butythiol	0.00009
Dimethy sulfide	0.001
Hydrogen sulfide	0.0072

Source: Kreis 1978.

McFarland (1995) reviewed many of the current olfactometry techniques being used for odor measurement and concluded that dynamic forced-choice olfactometry appears to be the most accepted method. Olfactometry suffers from a lack of precision compared to some of the sophisticated chemical sensors available. The lack of precision in olfactometry is due in part to the variability in each person's sense of smell and their reaction to an odor. Also, olfactometry does not identify the individual compounds that make up the odor. Even though olfactometry has limitations, it still is the best technique available for directly measuring odors at this time.

Gas Measurement Methods: Many analytical methods measure individual gas concentrations in the air. The following section briefly describes some of the more common methods used to measure select gases in the air around livestock facilities. Some measuring techniques give a single instantaneous reading at a specific place and point in time. Another measurement using the same method some time later will probably give a different value. A series of instantaneous readings can be used to indicate how a gas concentration fluctuates. Some people combine individual readings and report average concentrations. Other measuring techniques sample air for several minutes or more and give an average concentration over the sampling period. When comparing results, it is important to recognize that instantaneous readings will vary more and have higher and lower individual readings than average readings over a sampling period.

Technique precision or detection limit is an important measurement characteristic. Some devices or methods have an accuracy of ± 1 part per million (ppm). Others may only be accurate to ± 20 ppm. Devices with greater precision can be used to detect small differences in

concentrations that less precise devices cannot detect. However, devices with greater precision usually cost more.

Patches: Patches are single-use pieces of cardboard or plastic coated with a chemical that changes color when exposed to the gas being measured. Both the amount of time exposed and the amount of color change are important. Patches give an integrated or average value but are not very precise. They can be hung in a space, worn by workers, or combined with small fans for different applications. Hydrogen sulfide patches are the most commonly used patches in livestock odor work.

Tubes-Indicator and Diffusion: Indicator tubes are available to measure a wide range of gases. To take a reading with an indicator tube (a sealed glass tube), the tips on both ends of the tube are broken off, and the tube is attached to a hand-held pump. The pump pulls a known amount of air through the tube. The media in the tube reacts and changes color with select gases in the air sample. A scale on the tube is used to measure the amount of media that reacted with the gas and indicates the concentration. Indicator tubes give nearly instantaneous readings, but they come with limited scales, and precision is around 10% of the full-scale reading on the tube. They cost around $5 each, and the hand-held pump costs from $100 to $250.

Diffusion tubes that provide an average concentration are also available for some gases. To take a reading, one end of the tube is opened and the tube is hung in the space to be monitored. Some known time later, usually six to eight hours, a reading is taken by noting the amount of media that changed color. The amount of color change in the tube and the time exposed are used to calculate an average concentration over the sampling time. Tubes cost around $8 each.

Jerome® Meter: The Jerome® meter is a portable electronic device for measuring hydrogen sulfide concentrations. It samples the air for several seconds to give a nearly instantaneous reading. The meter can measure hydrogen sulfide concentrations down to 3 parts per billion (ppb). It detects hydrogen sulfide concentrations by measuring the difference in the electric resistance of a gold leaf cover metal strip, which is exposed to the air sample. Jerome® meters cost around $10,000.

MDA-Single-Point Monitor: The MDA s-p m is used to monitor ambient air concentrations of individual compounds over extended periods of time. The units use the Chemcassette® Detection System. The cassette tape reacts, causing a color change, with the chemical being monitored. The color change is measured and used to indicate the gas concentration in the ambient air. MDA monitors can be used to measure ambient hydrogen sulfide concentrations between 2 and 90 ppb over 15-minute periods. Units with different electronics and cassettes can be purchased to monitor other gases. Units cost around $7,000.

Electronic Sensors: A number of different electronic sensors are available for measuring gas concentrations. Their method of action and precision vary. Some units have multiple gas sensors. Some units are used in the safety field to monitor gas concentrations and sound alarms if safe concentrations are exceeded in confined spaces. Many of these units cannot measure gas concentrations at levels needed for odor monitoring.

Gas chromatograph/Mass spectrometer: A gas chromatograph-/-mass spectrometer (GC/MS) is generally considered a research laboratory device. It can be used to both identify and measure gas concentrations. Very small air samples are injected into a carrier (nitrogen or

helium) gas stream passing through a GC/MS column. The column adsorbs and desorbs the chemicals in the air at different rates to separate them. After separation, the carrier gas stream with the separated chemicals passes through a detector. The detector output signal identifies the chemical and the amount in the sample. Portable units to do field research are now available.

Odor Measurement and Description: An Introduction to Olfactometry:

Various techniques measure and describe odors,. which can be characterized by the following five different characteristics or dimensions that add to the complete description of an odor:

(1) Concentration
(2) Intensity
(3) Persistence
(4) Hedonic tone
(5) Character descriptor

Odor concentration and intensity are the two most common odor characteristics measured. The other three–persistence, hedonic tone and character descriptors–are commonly viewed as more subjective characteristics. As subjective characteristics they do not lend themselves to objective measurement for scientific or regulatory purposes.

Concentration: Two odor concentrations (thresholds) can be measured: detection threshold and recognition threshold. They are usually reported in odor units (ou). Odor units are dimensionless numbers and are defined as the volume of dilution (non-odorous) air divided by the volume of odorous sample air at either detection or recognition.

The detection threshold concentration is the volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can correctly detect a difference compared to non-odorous air. At the detection threshold, a trained panelist just begins to detect the difference between odorous and non-odorous air. This is the most common concentration determined and reported.

The recognition threshold concentration is the volume of non-odorous air needed to dilute a unit volume of odorous sample air to the point where trained panelists can barely recognize the odorous air. The difference between detection and recognition thresholds can be illustrated with an analogy using sound and a person in a quiet room with a radio. If the radio is turned down so low that the person cannot hear the radio, the radio is at a level below detection. If the volume is increased in very small steps, it will increase to a point where the person will detect a noise. This volume corresponds to the detection threshold. The person will not be able to recognize the noise, whether it is music or people talking. If the volume is again increased in small steps , it will increase to a point where the person will be able to recognize that the noise is either music or people talking. This volume corresponds to the recognition threshold.

Intensity: Intensity describes the strength of an odor sample and is measured at concentrations above the detection threshold. It changes with gas or odor concentration. Intensity can be measured at full-strength (i.e., no dilution with non-odorous air) or diluted with non-odorous air. In either case, it can be measured against a five-step scale using n-butanol, a standard reference chemical (ASTM, 1988). To learn the scale, trained panelists sniff containers

of n-butanol at different concentrations in water (Table 3). They then are presented diluted or full-strength (diluted is always presented first) odorous air samples that they rate against the n-butanol scale.

Table 3. Odor intensity reference scale based on n-butanol.

Intensity Category		Equivalent Head Space Concentration of N-Butanol in Air, (ppm)*	Mixture of N-Butanol in Water, (ppm)
0	No odor	0	0
1	Very light	25	250
2	Light	75	750
3	Moderate	225	2250
4	Strong	675	6750
5	Very strong	2025	20250

* Based on air temperature of 20.3 °C.

Odor Measurement Devices and Techniques

Electronic nose: The term "electronic nose" describes a family of devices, some commercially available, that measure a select number of individual chemical compounds to measure the odor". The devices use a variety of methods for measuring the gas concentrations. Researchers have and continue to evaluate these devices. To date, they have not successfully correlated livestock odors with the output of commercial or current research electronic noses.

Scentometer: The scentometer, developed in the late 1950s (Barnebey-Cheney 1973), is a hand-held device that can be used to measure odor levels in the field.. It is a rectangular, clear plastic box with two nasal ports, two chambers of activated carbon with air inlets, and several different sized odorous air inlets. A trained individual breathes through the scentometer. All of the odorous air inlets are initially closed so that the inhaled air must pass through the activated carbon and is deodorized. The individual begins sampling by opening the odorous air inlets one at a time until an odor is detected. The number and size of open holes is used to calculate the dilution-to-threshold concentration. Portability and relatively low cost are some advantages of scentometers (Barnebey-Cheney, 1992). However, the scentometer is not known for high accuracy (Jones; 1992).

Dynamic, triangular forced-choice olfactometer: Most laboratories measuring odors from agricultural sources use a dynamic, triangular forced-choice olfactometer to determine detection and recognition threshold concentrations. These are designed to be operated in accordance with ASTM Standard E679-91 and proposed European Standard ODC 543.271.2:628.52 (Air Quality Determination of Odour Concentration by Dynamic Olfactometry). Standardized procedures and four hours of panelist training are used to achieve repeatable olfactometer results. Panelists are required to follow strict rules which help them use their sense of smell to obtain consistent results and develop a professional attitude about their work.

A dynamic, triangular forced-choice olfactometer presents three air streams to the trained panelists. One of the air streams is a mixture of non-odorous air and an extremely small amount of odorous air from a sample bag. The other two air streams have only non-odorous air.

Panelists sniff each air stream and are forced to identify which air stream is different (i.e., has some odor) than the other two non-odorous air streams. Initially, panelists must guess which air stream is different because the amount of odorous air added is below the detection threshold. In steps, the amount of odorous air added to one of the air streams is doubled until the panelist correctly recognizes which air stream is different. The air stream with the odor is randomly changed each time. The detection threshold is the non-odorous airflow rate divided by the odorous airflow rate at the time the panelist correctly recognizes which air stream is different. A panel of eight trained people is normally used to analyze each odor sample.

Field Sniffer: The term "field sniffer" refers to a trained panelist who determines odor intensity in the field. The panelists calibrate their noses with the n-butanol intensity scale mentioned above before going into the field to sniff. This calibration is done as a group so consistent intensity levels are established among the individual sniffers. Between readings, they use charcoal filter masks to breathe non-odorous air and thus avoid nasal fatigue. At specified times, the field sniffers remove their masks, sniff the air, and record the air's intensity. The results are used to validate odor dispersion models.

Dust and Pathogen Measurements

The measurement of dust concentrations in and near animal facilities is typically performed using gravimetrical methods. This is accomplished by weighing a collection filter before and after a known quantity of sample air is passed through the filter inside or near the animal unit. The results are generally given in units of mg of dust per cubic meter of air (mg/m^3). Certain filters are designed to collect all of the dust and are reported as total dust concentrations, while a certain device collects only particles small enough to enter the human respiratory system, which are reported as respirable dust. Another method of dust measurement is electronic particle counters. These devices report the number (not mass/weight) of particles per volume of air ($particles/m^3$). Often these instruments can categorize dust into particle diameter, which is beneficial in assessing the livestock/poultry and human health risks. Finally, pathogens can be collected in the air either directly on agar plates in a device like an "Anderson Sampler" or trapped in a liquid by an "All Glass Impinger" and then placed on petri dishes in the laboratory. After incubation, the colony-forming units are counted with the results usually reported as the number of colony-forming units per volume of air.

References

ASAE, 1994. Control of Manure Odors. ASAE EP379.1. Agricultural Engineers Yearbook of Standards. American Society of Agricultural Engineers. 546-547.

Axel, R. 1995. The molecular logic of smell. *Scientific American*. October. 154-159.

Bremberg, B., 1994. Livestock and the Environment: Law and Policy Aspects of Odor In TIAER.

Fulhage, C. 1995. Composting dead animals. In *New knowledge in livestock odor, an International Livestock Conference*, Oct. 16,17, & 18, 194-195. Iowa State University, Ames.

Hanna, H.M., D. Bundy, J.C. Lorimor, S.K. Mickelson, and S.W. Melvin. 1999. Effects of manure application equipment on odor, residue cover, and crop. ASAE Paper No. 991062. St. Joseph, Mich.

Hardwick, D.C. 1985. Agricultural problems related to odour prevention and control. 21-26.-In *Odour prevention and Control of Organic Sludge and Livestock Farming*. Ed. V.C. Nielsen, J.H. Voorburg, and P. L'Hermite. Elsevier Applied Science Publishers, New York.

Hogsette, J.A., 1998. Fly breeding in livestock manure. Presented at Manure Management Hn Harmony With the Environment and Society Conference, Feb 10-12, 1998. West North Central Region of the Soil and Water Conservation Society, Ankeny, IA.

Hudson, K.A., 1998Rural residents' perspectives on industrial livestock production: a patchwork of rural injustice. Presented at Manure Management Hn Harmony With the Environment and Society Conference, Feb. 10-12, 1998. West North Central Region of the Soil and Water Conservation Society, Ankeny, IA.

Jacobson, L. D., D. Paszek, D. R. Schmidt, R. E. Nicolai, B. Hetchler, and J. Zhu. 1999. Odor and Gas Emissions from Animal Manure Storage Units and Buildings. ASAE paper No. 99-4004, St. Joseph, MI: ASAE.

Jansen, J. 1998. Scale lagoon system to Swedish style and hoop house models for raising swine. Presented at Manure Management Hn Harmony With the Environment and Society Conference, Feb. 10-12, 1998. West North Central Region of the Soil and Water Conservation Society, Ankeny, IA

Kreis, R.D. 1978. Control of Animal Production Odors: The State-of-the-Art. EPA Environmental Protection Technology Series, EPA-600/2-78-083. Office of Research and Development, U.S. EPA, Ada, OK.

MidWest Plan Service. 1993. Livestock waste facilities handbook, Second Ed. MWPS-18, Ames, Iowa.

McFarland, A. 1995. Odor detection and quantification. In *A review of the literature on the nature and control of odors from pork production facilities*. ed: J. R. Miner. National Pork Producers Council, Des Moines, IA.

McFarland, A. and J. Sweeten, 1994. Field measurement of ambient odors from dairy farms in Erath County, TX. Chapter V. In *Final Report: Preliminary Research Concerning the Character, Sources, and Intensity of Odors from Dairy Operations in Erath County, Texas*. Texas Institute of Appl. Env. Res., Tarleton, State University, Stephenville.

O'Neill DH, Phillips VR. 1992. A review of the control of odour nuisance from livestock buildings. 3. Properties of the odorous substances which have identified in livestock wastes or in the air around them. *Journal of Agricultural Engineering Research* 53(1): 23-50.

Schauberger, G. and M. Piringer. 1997. Guideline to Assess the Protection Distance to Avoid Annoyance by Odour Sensation Caused by Livestock Husbandry. *In Proceedings of the Fifth International Livestock Environment Symposium*. 170-178. ASAE, St. Joseph. MI.

Schiffman S., E.A. Sattely Miller and M.S. Suggs. 1995. The effect of environmental odors emanating

from commercial swine operations on the mood of nearby residents. *Brain Research Bulletin* 37(4) 369-375.

Watts, P. J. 1992. Odour measurement at a Queensland feedlot. In Odour Update '92. *Proc. of a Workshop on Ag. Odours.* MRC Report No. DAQ 64/24.

Yasuhara, A. 1980. Relation between odor and odorous components in solid swine manure. *Chemosphere* 9:587-592.

Zhang,Y. 1997. Sprinkling Oil to Reduce Dust, Gases, and Odor in Swine Buildings. August. MidWest Plan Service (MWPS) AED-42. MWPS, 122 Davidson Hall, Iowa State Univ. Ames.

About the Authors

This lesson was written by Larry Jacobson, University of Minnesota, St. Paul, who can be reached at jacob007@.tc.umn.edu and by Jeff Lorimor, Iowa State University, Ames, who can be reached at this e-mail address: x1lorimo@exnet.iastate.edu

Chapter 2: Emissions Control Strategies from Buildings and Storage Structures

Odors and gases are emitted from the buildings that house animals and poultry through ventilation fans, or by buoyancy or wind forces in naturally ventilated barns. Methods to reduce these odors and gas emissions are less well documented than either manure storage units or land application control methods. Of the three sources, buildings are believed to release a relatively constant amount of the total odor and gas emissions generated. Building emissions, combined with releases from the manure storage unit, form the "baseline" emission levels from an animal production operation. Two approaches to minimizing odors from buildings and storage structures are first, minimize the odor generation, and second, treat an odor that is generated as it exits the building. Both approaches will be discussed in this text.

General management strategies

Swine production and manure management facilities should be planned as a total system that reduces environmental impacts while promoting animal performance and worker safety. Proper adjustment of feeders to minimize spillage will also reduce odors and save money on feed. An orderly system for manure collection and storage or treatment reduces potential pockets of odor production. All surfaces on which manure may collect and on which animals are maintained should be as clean and dry as possible. Manure, wet feed, and other products that could produce odors in the building should be removed regularly. This includes dust buildup both on the inside and on the outside of buildings, but especially inside animal housing facilities and on fan housings. Dirty, manure-covered animals promote accelerated bacterial growth and the production of gases that are quickly vaporized by animal body heat. Odor from floor surfaces will be reduced if the floors are kept clean and dry. Minimizing the floor surface area on which manure can accumulate reduces the gases and odors emitted from these surfaces. All components of the production/manure treatment system should be maintained and operated in good functional order. Proper disposal of dead animals and good fly and rodent control programs are also essential.

Ventilation system: A properly designed and well managed ventilation system will keep animals and surfaces dry and thereby reduce odor emissions. Clean fans, shutters, and air inlets will improve the efficiency of the ventilation system and simultaneously prevent "odor episodes" that can occur when atmospheric conditions exist that encourage odor generation. Hanging a brush near exhaust fans will make cleaning more convenient and thus encourage it.

Relationship between dust and odor: Dust on livestock farms affects odor measurement and control in several ways. Dust particles adsorb odorous compounds. As the dust particles are carried by the wind, so is odor. Most of the dust generated on a farm comes from feed, fecal matter, hair, and in the case of poultry, from feathers and litter. Dust also comes from animal skin, insects, and other sources. Some of the dust particles, such as those from manure and feed, omit odorous compounds as a result of bacterial decomposition. Odorous dust can increase the transport of some odor compounds. Dust concentrates odorous compounds, and as a result, odorous dust can cause an intense odor sensation. An understanding of the role dust plays in concentrating and transporting odor is important if we are to develop economical methods of controlling odor because some methods of removing dust from the air are less expensive than direct methods of treating the air to remove odorous compounds.

Facility siting: Where swine facilities are located can play a significant role in whether odors become nuisance. Swine facilities should be located as far as practical from residential developments, commercial enterprises, recreational areas, or other prime areas for non-agricultural uses. A site may seem ideal with respect to transportation, feed supply, accessibility, or land ownership but may present challenges because of existing or proposed development. Where possible, production facilities should be located near the center of a tract of land large enough to allow manure to be applied to the land at agronomic rates. Pollution control and manure treatment facilities should be located as far as practical from areas of high environmental sensitivity such as drainage ditches, streams, or estuaries. Elevating buildings several feet above ground will direct surface drainage away from the building, allow good natural air circulation, and allow manure to flow by gravity to the lagoon or other treatment units.

Dietary manipulation: Data in the scientific literature documents the reduction of odor and nutrients in animal excreta or alteration of the microbial population in an animal's digestive tract as a result of diet manipulation or from adding specific, odor-reducing materials to the diet. In general, this research has shown that nutrients such as nitrogen, phosphorus, copper, and zinc can be reduced through dietary manipulation without impacting the animal's growth and health. This alone is a positive impact on environmental parameters. Dietary manipulation has also been shown in some cases to reduce the odor concentration and offensiveness of freshly excreted manure. After the storage or treatment of manures under anaerobic conditions, the positive impact of dietary manipulation on odor might not persist. However, odor controls through dietary manipulation hold promise and may revolutionize animal feeding practices within the next few-years.

Management of under-floor manure pits: Control of odors from under-floor manure pits depends on the type and storage time. Manure stored longer than five days will generate more offensive gases. Undiluted liquid manure has a large odor production potential. Therefore, to reduce odors from shallow gutters with pull plugs, the manure should be removed at least once a week. Often, weekly cleaning is not a standard practice but may become so if odor control is the main objective.

One method of shallow gutter management to enhance odor control that is still being debated is the practice of using recharge water. Some facilities use clean recharge water, some recycle recharge water, and others do not recharge their gutters. Anecdotal evidence suggests that using clean or "treated" recycled recharge water may reduce odorous emissions compared to using no recharge water. Reductions are likely to be very dependent on the quality of recharge water.

Management of lagoons: One of the best ways to reduce emissions from lagoons is to properly manage the lagoon to promote healthy bacterial populations. Precharging the lagoon with dilution water before start-up, steady charging with waste rather than slug charging, and pumping or removing material from beneath the surface to avoid removal of purple sulfur bacteria are examples of good management practice. Fill pipes should empty waste below the surface to avoid stirring the surface and increasing odor emissions.

Management of manure slurry storage structures: Probably the best way to reduce emissions from these structures is to cover them, either with the natural crust that sometimes forms, with a biological cover (chopped straw, etc.) or with a synthetic cover. Biological covers

are relatively inexpensive, but add to the amount of organic matter that must be removed each year and sometimes do not hold together in windy conditions, especially on large structures. Synthetic covers cost more initially, but last longer. Total annual cost is similar for both systems. Ozonation of slurry as it enters the storage also reduces odors and helps retain nutrients by lowering bacterial activity, but its economic feasibility has not been proven at this time.

Natural windbreaks: Rows of trees and other vegetation known as shelterbelts, which have historically been used for snow and wind protection in the Midwest, may have value as odor control devices for all species and systems. Similarly, natural forests and vegetation near animal facilities in other sections of the country may serve the same purpose. These shelterbelts also create a visual barrier. A properly designed and placed tree or vegetative shelterbelt could conceivably provide a very large filtration surface (Sweeten 1991) for both dust and odorous compound removal from building exhaust air and odor dispersion and dilution, particularly under stable nighttime conditions (Miner 1995; NPPC 1996). Currently, a few studies are addressing the total impact of vegetative barriers on odor reduction from animal farms, but many people already attest to their value. Shelterbelts are inexpensive, especially if the cost is figured over the life of the trees and shrubs, but it may take 3 to 10 years to grow an effective windbreak.

It is generally felt that windbreaks reduce odors by dispersing and mixing the odorous air with fresh air, although solid research has not confirmed these effects. Windbreaks on the downwind side of animal houses create mixing and dilution. Windbreaks on the upwind side deflect air over the houses so it picks up less odorous air. Producers should avoid placing dense windbreaks so close to naturally ventilated buildings that cooling breezes and winds exchanging the air in these buildings are eliminated or greatly reduced. A minimum distance of 50 feet, or five to ten times the tree height, from a naturally ventilated building is recommended.

Bedded systems

Using solid manure systems rather than liquid manure systems is generally considered to reduce odor. Although gases and dust are emitted from solid or bedded systems, most people feel that odor from bedded systems is less objectionable than the odor from liquid systems. Using bedding/dry manure systems for animals is generally considered to be more environmentally acceptable from both water quality and outdoor air quality viewpoints.

Anecdotal evidence suggests that organic bedding such as straw, corn stalks, compost, wood chips, or newspaper may reduce odor emissions. European research seems to support the use of some type of bedding (especially sawdust) to reduce odor generation/levels in buildings and subsequent odor release or emission (Nicks et al. 1997). Relatively small bedding levels may be enough to have an effect on odor generation/emission. Until liquid systems were adapted, primarily for convenience, bedding had been used for livestock production for generations. Many dairy and poultry facilities still use dry or solid manure systems.

Hoop structures have recently become popular for some swine and dairy producers, in part due to their odor control effectiveness. They feature a deep-bedded pack system using straw or other crop residues to provide animal comfort and soak up manure liquids. Bedding availability is crucial for solid manure systems except for high-rise layer or swine houses. Hoop structure bedding requirements for finishing swine are estimated to be 200 pounds of baled corn stalks per pig marketed. MWPS Publications AED 41 and 44 give details on using bedded hoop structures for swine production.

Biofilters

Biofiltration is an air cleaning technology that uses microorganisms to break down gaseous contaminants and produce non-odorous end products. It is used successfully around the world for treating a wide range of air emissions from industrial sources. Biofiltration works well for treating odors because most odorous emissions are made up of numerous compounds at low concentrations that are readily broken down by microorganisms.

The microorganisms in a biofilter break down (i.e., oxidize) airborne volatile organic compounds (VOCs) and oxidizable inorganic gases and vapors in the odorous exhaust air. The byproducts of the process are primarily water, carbon dioxide, mineral salts, some VOCs, and microbial biomass.

Description: Figure 1 illustrates a typical, open face biofilter. Odorous air is exhausted from the building with wall or pit ventilation fans that are connected by a duct to the biofilter plenum. The plenum distributes the air evenly across the biofilter media. A supported porous screen holds the media above the plenum. As the air passes through the biofilter, the odorous gases contact the media and are absorbed onto the biofilm where they are degraded by the aerobic microorganisms.

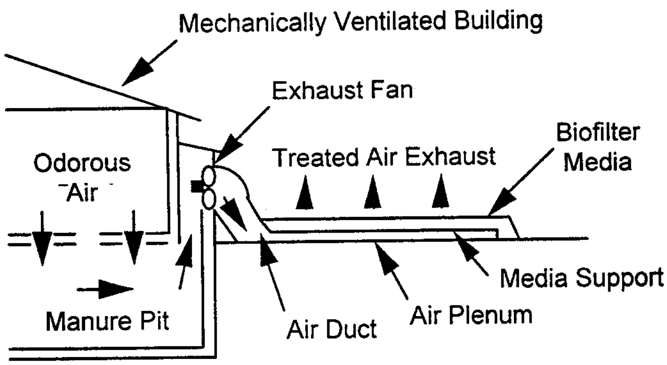


Figure 1. Typical open face biofilter layout.

Biofiltration use on livestock facilities began in Germany in the late 1960s and in Sweden in 1984 (Zeisig and Munchen 1987; Noren 1985). Biofilters on pig and calf sheds had average efficiencies around 70% (Scholtens et al. 1987). Nicolai and Janni (1997) reported an average odor reduction of 78% (minimum of 29% in April and maximum of 96% in August) from a pilot-scale biofilter built to treat air exhausted from a pit fan on a farrowing barn in Minnesota. Hydrogen sulfide and ammonia concentrations were reduced an average of 86% and 50%, respectively. The pressure drop across the media, which indicates how much the filter media restricts airflow, ranged between 0.10 and 0.19 in. of water (25 to 47 Pa). Data from a full-sized biofilter used to treat all of the ventilating air exhaust from a 700-sow gestation/farrowing swine facility were recently reported (Nicolai and Janni 1998b, 1998c). Average odor reduction was 82% over the first 10 months of operation. During the same period, average hydrogen sulfide reduction was 80% and ammonia reduction was 53%. Total pressure drop across the fans reached a maximum of 0.4 inches of water, 0.2 inches of that could be attributed to the building's ventilation inlet system.

The amortized construction and operating costs over three years for this full-sized biofilter were $0.22 per piglet produced per year. Rodent control costs were $275 per year. Additional operating costs of $125 per year included sprinkling costs and costs of operating the higher power ventilating fans (Nicolai and Janni 1998b, 1998c). In general, initial costs for a biofilter are approximately $0.10/cubic foot per minute (cfm) of ventilation air with annual operating costs of $0.02/cfm.

Recent research has led to the following recommendations concerning biofilters used to treat air from swine and dairy facilities:

- A residence time (amount of time the ventilation air is in contact with the media) of at least 5 seconds should be provided. This amount of time has resulted in 80% to 90% odor reductions; longer times do not increase this already high level of efficiency.
- The minimum depth of the biofilter media should be 10 inches.
- Fans need to be purchased with the capability of moving sufficient air exchange at a total static pressure (includes pressure drop of the barn air inlets as well as the biofilter's media) of 0.4 inches of water. When designing a biofilter, this pressure drop and its impact on the ventilating system must be considered.
- The Proper moisture control of the biofilter media is essential.
- A rodent control program is necessary.
- Vegetative growth on the biofilter surface must be limited.

Many common materials can be used for a biofilter, including dark red kidney bean straw and compost (Nicolai and Janni 1997), shredded wood and compost (50% by weight) (Nicolai and Janni 1998a, b, c), and even shredded wood and soil (50% by weight). Shredded wood is used to increase porosity, making it easier for the air to flow through the biofilter. Compost and soil are a source of microorganisms and nutrients.

Continual excessive moisture can lead to increased airflow resistance (pressure drop) and limited oxygen exchange that could create anaerobic zones. Insufficient moisture leads to drying, microbe deactivation, and channeling, which reduce contaminant removal efficiency. If present, mice and rats will burrow through the warm media in cold winter months, causing channeling and poor treatment. Rabbits, woodchucks, and badgers have also been suspected of burrowing through and nesting in biofilters. Finally, excessive vegetative growth on the biofilter surface can reduce its efficiency by causing channeling and limiting oxygen exchange. Root systems can cause plugging, and noxious weeds need to be removed before they produce seed. Excessive vegetative growth may also detract from the site's aesthetic appearance.

Summary: Biofilters effectively reduce odor, hydrogen sulfide, and ammonia emissions from mechanically ventilated livestock buildings. While simple in appearance, they are rather complex biological systems that need to be designed properly to perform well and prevent ventilation problems. Research is continuing to demonstrate their performance and to develop better design and management recommendations.

Vegetable oil sprinkling: Airborne dust, a common problem inside animal housing facilities, has been linked to both human and animal health concerns. Since suspended dust particles can and often do absorb toxic and odorous gases, the reduction of the airborne dust concentrations inside buildings will lower odor and gas emissions from these animal housing units. Research studies have shown that sprinkling various types of vegetable oil inside pig buildings will reduce indoor airborne dust levels.

Detailed information on sprinkling vegetable oils in pig barns is given in the MidWest Plan Service (MWPS) publication AED-42 (Zhang et al. 1997). Oil can be applied manually with a hand-held sprayer or automatically with a permanently installed sprinkler system. Once-a-day application is recommended. It is important to operate the oil-sprinkling equipment so the droplets are properly sized, and distributed evenly. Operating the spray nozzles within pressure and temperature limits of the suggested vegetable oils can control droplet size. The MWPS publication gives the recommended levels for such oils as canola, corn, soybean, and sunflower.

Research Data: Oil-sprinkling research (Takai et al. 1993) indicates reductions in dust levels, and in one case (Zhang et al. 1996), reduction of odorous gases like hydrogen sulfide and ammonia. Dust levels were lowered 80%, while hydrogen sulfide and ammonia concentrations were reduced 20% or 30%, respectively, in this study.

Research conducted at the University of Minnesota (Jacobson et al. 1998) showed total dust concentrations were reduced considerably by oil sprinkling. Dust levels in the oil treatment room were about 40% of the dust levels in the control room. Respirable dust levels (the fraction that reaches the human lung), however, did not follow this trend, showing similar concentrations for both the control and treatment rooms. Reasons for the inconsistent results are difficult to determine; but may be related to the fact that once-a-day sprinkling may only reduce the large particulate (feed and fecal) materials and not smaller airborne particles. Also during this same study, an average odor reduction of 60% was seen in the oil-treated room compared to a control room for a pig nursery. Oil sprinkling in the pig nursery barn did not have the same effect on individual gas concentrations. Hydrogen sulfide levels were reduced about 60%, in the rooms sprinkled with oil, but ammonia levels were unaffected by the oil treatment.

Challenges: Compared to the control room, extra labor was needed to clean the oil treatment room after each group was moved out of the building. Producers may want to add a "presoak" segment to their cleaning protocol to aid the cleanup of surfaces in these facilities, which will lead to additional wash time. To be used at the farm level, an automated system is needed to deliver the oil in the building, as opposed to using hand-held sprayers. Existing presoak sprinkling systems may potentially be modified to accomplish this with the aid of timers and appropriate nozzles.

Summary: As outlined in MWPS-42, daily sprinkling of very small amounts of vegetable oil inside an animal facility reduced the odor, hydrogen sulfide, and total dust levels of the air inside the barn and in the exhaust ventilation air. Oil sprinkling was not effective in reducing ammonia concentrations or respirable dust levels inside the treated barn.

Windbreak walls: Walls erected downwind from the fans that exhaust air from tunnel-ventilated poultry buildings are being used on more than 200 farms in Taiwan to reduce dust and odor emissions onto neighboring land. These structures, known as windbreak walls, provide some blockage of the fan airflow in the horizontal direction. They can be built with various materials covering a wood or steel frame; plywood and tarps are common. The walls are placed 10 to 20 ft downwind of the exhaust fans of tunnel ventilated barns (Figure 2).

Another variation of the windbreak wall is called a straw wall. These systems have been used in North Dakota and elsewhere. They are made with wooden structures and "chicken wire." Straw is placed inside the structures, providing a barrier to dust and other air emissions. They may also offer some filtration capability.

Windbreak walls work by reducing the forward momentum of airflow from the fans, which is beneficial during low-wind conditions, because odorous dust settles out of the airflow and remains on the farm. In addition, the walls provide a sudden, large vertical dispersion of the exhausted odor plume that acts to entrain fresh outside air into the odor plume at a faster rate than would naturally occur, providing additional dilution potential.

The data and observations taken by Bottcher et al. (1998) using scentometers at a full-scale windbreak wall site in North Carolina showed that

- Dust builds up on the wall surfaces.
- The walls redirect airflow from the building exhaust fans upward.
- When wind speeds are low and blowing from the buildings toward the lagoon, the walls move the fan airflow upward so that it blows 10 ft or more above the lagoon surface. Without the windbreak wall in place, the fan air flows directly on top of the lagoon surface.
- Dust and odor levels are greater in the airflow from the fans than they are 10 ft downwind of the windbreak wall, because the fan airflow is deflected upward.

A model study done in Iowa predicted that tall wind barriers placed around a manure storage or lagoon would reduce odor emissions (Liu et al. 1996). Anecdotal evidence suggests a swine farm located in Minnesota benefited when a steel wall was built around an earthen storage basin. Although the operating cost of windbreak walls is relatively low, periodic cleaning of odorous dust from the walls is necessary for sustained odor control, unless rainfall is sufficient to clean the walls. Installation of windbreak walls is estimated to cost at least $1.50 per pig space (e.g., $1,500 for a building that houses 1,000 pigs).

Research to evaluate windbreak walls for dust and odor control is continuing. However, it is difficult to determine the effectiveness of windbreak walls due to several factors. As wind speed and direction shift, the airflow from building fans changes direction. As a result, it is difficult to measure odor downwind. Also, windbreak walls may not be suited for animal buildings equipped with multiple fans at non-uniform locations around the building.

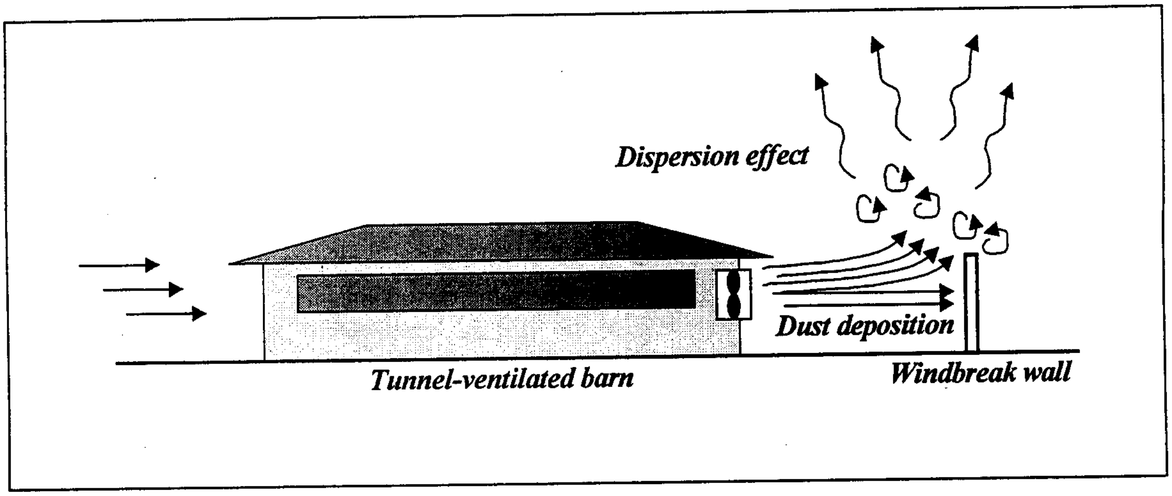


Figure 2. A tunnel-ventilated barn with a windbreak wall.

Washing walls and other wet scrubbers: Using water to scrub odorous dust, ammonia, hydrogen sulfide, and other gases from the airflow of swine building ventilation fans can be an effective method of controlling odor. Many industrial air pollution control systems use sprays of water to scrub dust, ammonia, SO_x, and NO_x from various polluting air streams. In a wet scrubber, an alkali is usually added to react with acidic pollutants. A wet scrubber design that recirculates most of the water through the system has been tested in North Carolina (Bottcher et al. 1999). This design involves a wetted pad evaporative cooling system installed in a stud wall about 4 feet upwind of ventilation fans and downwind of the pigs in a tunnel ventilated building (Figure 3).

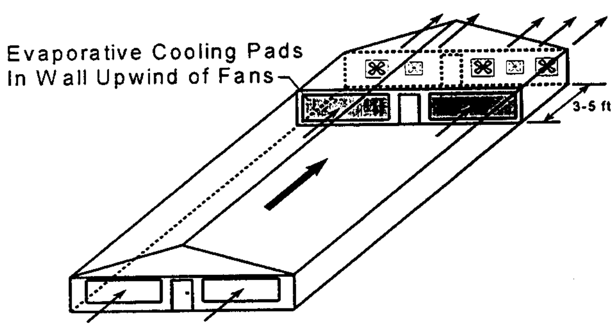


Figure 3. Evaporative cooling pad installed as a wet scrubber in a tunnel-ventilated swine building.

Source: Bottcher et al. 1999.

Recent measurements taken by Bottcher et al. (1999) show that the system can apparently reduce total dust levels as much as 65% at a relatively low ventilation rate but only by about 16% at a high airflow rate typical of maximum hot weather ventilation. Although the changes in odor levels across the wetted pad scrubber were not as great as desired at the high ventilation rate, the data does indicate a modest odor reduction, consistent with the dust reduction. These results agree with other observations that dust removal from swine building airflow is associated with odor reduction. The wetted pad wall also reduced ammonia levels in the ventilation airflow by 50% at low ventilation rates and by 33% at medium ventilation rates.

Wetted pad wall installation costs are approximately $5.70 per pig space for an 880-head finishing building (Swine Odor Task Force 1998). The main operating cost is the 1-hp water pump, which will cost about $600 annually. The wetted pad wall does not impose a significant airflow restriction on the building fans. Maintaining adequate airflow is important if a healthy indoor environment is to be provided for the animals in warm weather.

Biomass filters: Researchers at Iowa State University have tested biomass filters as a means of removing odorous dust from swine buildings (Hoff et al. 1997a). Biomass filters use the principle that dust, if removed from the ventilation exhaust stream, will capture a large portion of the odors with it. Hoff et al. (1997b) were able to demonstrate a relationship between scrubbing dust and odors in controlled laboratory experiments and in a full-scale field trial. Using inexpensive material, a biomass filter removes odorous dust from the air stream. The biomass consists of either chopped corn stalks or corn cobs (Figure 12-6), but other materials can be used. Both odor and dust levels significantly reduced: odor by up to 90% and dust by up to 80%. These reductions occurred with low resistance to airflow at cold weather ventilation rates.

Chemical additives: In some instances, chemical additives are an option for odor or gas emission control. One application where additives were shown to be effective is the addition of alum to poultry litter. Moore et al. (1995) reported on a number of products that reduced ammonia volatilization from poultry litter, including alum, which provided a 99% reduction in ammonia volatilization when 200 g/Kg (20%) was added to the litter in broiler houses. Many other additives for both liquid and solid manure are on the market. A review of products tested across the United States and Europe for ammonia reduction revealed 39 products that worked versus 18 that did not. Of the products tested for odor reduction, 22 were reported to help while 33 did not. Many products worked for only a short time. Until the mechanisms for the various products are understood so reliable performance can be predicted, the additional costs for additive products may be hard for producers to justify.

Ozonation: Ozone is a powerful oxidizing agent and a very effective natural germicide. Ozone high in the atmosphere protects the earth from solar radiation. At ground level, however, the gas can be toxic at high levels. The current OSHA permissible exposure limit for ozone is 0.1 ppm for an 8-hour, time-weighted average exposure (OSHA 1998). Ozone has been used to treat drinking water on a municipal scale since 1906, when it was installed in the treatment facilities for the city of Nice, France (Singer 1990). More than 2,000 water treatment works, primarily in France and other European countries, now use ozone for disinfecting, taste, and odor control (Tate 1991). Currently, about 100 plants in the United States and Canada use ozone

(Droste 1997). Ozone generators are sold to "freshen" the air in offices and industrial facilities. A number of commercial ozone generators are currently being sold as residential air cleaning devices.

The molecular arrangement of ozone is three atoms of oxygen (O_3). Ozone is unstable and reacts with other gases, changing their molecular structure. At low concentrations of 0.01 to 0.05 ppm, ozone has a "fresh or outdoor smell" associated with it. At higher concentrations, it begins to smell like an "electrical fire." The decomposition of ozone to oxygen is very fast. The half-life of ozone can reach 60 minutes in a cool, sterile environment and is near 20 minutes in typical conditions. In dusty animal houses, however, it may be much less. The most common products of the complete oxidation process are water vapor and carbon dioxide. Ozone reacts with and oxidizes most organic material. Thus, the relatively high level of indoor odors in livestock buildings, the ability of ozone to oxidize gas pollutants, and the potential for ozone to be rapidly depleted continue to make the ozonation of indoor air an attractive but controversial technology for reducing emissions from animal facilities.

Application in animal facilities: Only a limited number of published studies have evaluated the use of ozone for odor reduction in animal production facilities. Ozonation can potentially reduce odors in livestock facilities by killing the odor-producing microorganisms and by oxidizing the odorous metabolites. When oxidized, most compounds are reduced in odor intensity. The American Society for Heating Refrigeration, and Air-Conditioning (ASHRAE, 1989) determined that ozone is **not** an effective means of eliminating odors in ventilated air inside of buildings, but several ozone systems are on the market, and some are being tested on livestock farms with encouraging results. In a 16-month experiment, Priem (1977) found that ozone (at concentrations up to 0.2 ppm) reduced ammonia levels in a swine barn by 50% under winter ventilation conditions and by 15% under summer ventilation conditions. Researchers at Michigan State University reduced odorous compounds and disease-causing bacteria by treating swine manure slurry with high concentrations of ozone (Watkins et al. 1996). In this study, ozone was bubbled directly into fresh and stored swine manure in a continuously stirred batch reactor. Ozone concentrations of 1, 2, and 3 mg/l were used. Olfactometry determinations showed a significant odor reduction in ozonated manure samples in comparison to raw and oxygenated samples. More specifically, hydrogen sulfide concentrations were reduced slightly, while sulfate concentrations concurrently increased.

Researchers are evaluating a commercial ozone air treatment system in a tunnel-ventilated swine finishing house (Keener et al. 1999). Preliminary results suggest that a significant decrease in ammonia ($P < 0.01$) and total dust ($P < 0.02$) occurred in the ozonated building. The concentration of dust particles with optical diameters less than 1 μm were lower in the ozonated house than in the control house. However, an olfactometry panel did not measure significantly different levels of odor in the air samples from the ozonated and the control buildings. The reason for the difference between field observation and laboratory evaluation is still being investigated, but may be related to the fact that dust is removed from air samples before testing in the olfactometry lab. More testing is needed before the ozonation of lagoons or of the air inside swine facilities can be recommended.

Summary of technologies for odor control

Process/System		*Description*	*Advantages*	*Disadvantages*	*Cost*
aust air tment	*Biofilters*	**Odorous gases are passed through a bed of compost and wood chips; bacterial and fungal activity help oxidize organic volatile compounds**	**Reduces odors and hydrogen sulfide emissions effectively**	**May need special fans because of pressure drop**	**$0.50 to $0.80/pig**
st reduction	Windbreak walls	A wall made of tarp or with any other porous material is placed 10-20 ft. from exhaust fans. The walls provide some blockage of the fan airflow in the horizontal direction. Dust and odor levels downwind of the windbreaks can be lower since the plume is deflected.	May reduce dust and odor emissions effectively	Periodic cleaning of dust from the walls is necessary for sustained odor control.	$1.50/pig space of bldg capacity
	Shelterbelts	Rows of trees and other vegetation are planted around a building, creating a barrier for both dust and odors from building exhaust air. Trees can absorb odorous compounds, and create turbulence that enhances odor dispersion	May reduce dust and odor emissions effectively	It may take several years to grow an effective vegetative wind-break	$0.20/pig space of bldg capacity or more
	Washing walls	A wetted pad evaporative cooling system is installed about 1.5 m upwind of ventilation fans and downwind of hogs in a tunnel-ventilated building. Exhaust air passes through the wet pad before being pulled through the fans	Reduces about 50% of dust and 33% of ammonia at medium ventilation rate	Residence time inside the pad is very small; thus odor removal may not be highly effective.	$5.70/pig space of bldg capacity installation cost
	Oil sprinkling	Vegetable oil is sprinkled daily at low levels in the animal pens.	Helps reduce airborne dust and odors	Creates a greasy residue on the floor and pen partitions if too much oil is used	$2.50/pig space of bldg capacity
t manipulation	Phytase	Product (enzyme) is mixed into the feed	Lower P content in the manure	Not known yet	N/A
	Low-phytate corn	Use low-phytate corn for feed	Lower P content in the manure	Not known yet	N/A
	Synthetic amino-acids and low crude protein	Products are mixed into the feed	Lower N content in the manure, may reduce odor and ammonia emissions	Not known yet	N/A
	Feed additives (Yucca schidigera)	Product is mixed into the feed	May reduce odor and ammonia emissions	Not known yet	$.20/pig marketed or more
ding		Dry carbon source added to animal pens to promote comfort and soak up manure	Reduced less obnoxious odors. Works for all species	Must harvest or buy bedding, and add it throughout the year. Increased volume of manure to haul	$3.00/head capacity for swine buildings
nure additives		Chemical or biological products are added to the manure	May reduce odor and ammonia emissions	Usually questionable results.	$0.25 to $1.00/pig or more

References

ASHRAE. 1989. ASHRAE Handbook of Engineering Fundamentals. Atlanta, GA.

Bottcher, R.W. 1999. Personal communication.

Bottcher, R.W., Keener, K.M., Munilla, R.D., Parbst, K.E. and Van Wicklen, G.L. 1999. Field evaluation of a wet pad scrubber for odor and dust control. Animal Waste Management Symposium, Raleigh, NC, January 27-28.

Bottcher, R.W., Keener, K.M., Baughman, G.R., Munilla, R.D. and Parbst, K.E. 1998. Field and model evaluations of windbreak walls for modifying emissions from tunnel ventilated swine buildings. ASAE Annual International Meeting, Paper No. 984071, Orlando, FL.

Canh, TT, Aarnink AJA, Mroz Z, Jongbloed AW, Scharma JW, and Verstegen MWA. 1998.

Influence of electrolyte balance and acidifying calcium salts in the diet of growing-

finishing pigs on urinary pH, slurry pH and ammonia volatilisation from slurry. *Livestock Production Science* 56(1):1-13.

Droste, R.L. 1997. Theory and practice of water and wastewater treatment. John Wiley & Sons, New York

Hoff, S.J., Dong, L., Li, X.W., Bundy, D.S. and Harmon, J.D. 1997a. Odor removal using biomass filters. *Procs. of the 5th Intl. Symp. on Livestock Environment*, Bloomington, MN, May 29-31, 2:101-108.

Hoff, S.J., Bundy, D.S. and Li, X.W. 1997b. Dust effects on odor and odor compounds. *Procs. of the International Symposium on Ammonia and Odour Control from Animal Production Facilities*, Vinkeloord, The Netherlands, October 6-10, 1:101-110.

Jacobson, L.D., L.J. Johnston, B. Hetchler, and K.A. Janni. 1998. Odor and gas reduction from sprinkling soybean oil in a pig nursery. ASAE Paper No. 984125, St. Joseph, MI.

Keener, K.M., Bottcher, R.W., Munilla, R.D., Parbst, K.E. and Van Wicklen, G.L. 1999. Field evaluation of an indoor ozonation system for odor control. Animal Waste Management Symposium, Raleigh, NC, January 27-28.

Liu, Q., Bundy, D.S. and Hoff, S.T. 1996. The effectiveness of using tall barriers to reduce odor emission. *Procs. of the Intl. Conf. on Air Pollution from Agricultural Sources*, Kansas City~~, MO~~, February 7-9, 403-407.

Miner, J.R. 1995. An executive summary: a review of the literature on the nature and control of odors from pork production facilities. Prepared for the National Pork Producers Council, Des Moines, Iowa.

Moore et al. 1995. Listed on p. 12-13.

Nicks, B., A. Desiron, and B. Canart. 1997. Deep Litter Materials and the Ammonia Emissions in Fattening Pig Houses. In *Proceedings of the International Symposium on Ammonia and Odour Control from Animal Production Facilities. (Voermans, J.A.M. and Monteny, G. editors). Research Institute for Pig Husbandry, Rosmalen, Netherlands, 335-342.*

Nicolai, R.E. and K.A. Janni. 1997. Development of a low-cost biofilter for swine production facilities. ASAE Paper No. 974040. ASAE, St. Joseph, MI.

Nicolai, R.E. and K.A. Janni. 1998a. Comparison of biofilter residence time. ASAE Paper No. 984053. ASAE, St. Joseph, MI.

Nicolai, R.E. and K.A. Janni. 1998b. Biofiltration technology for odor reduction from swine buildings. In Proc. Animal Production Systems and Environment Conference. Iowa State University, Ames.

Nicolai, R.E. and K.A. Janni. 1998c. Biofiltration adapation to livestock facilities. In1998 USC-TRG Conference on Biofiltration. University of Southern California and the Reynolds Group, Tustin, California

Nicolai, R.E. 1998. Biofilter design information. Biosystems and Agricultural Engineering Update - 18. University of Minnesota.

Noren, O. 1985. Design and use of biofilters for livestock buildings. In V. C. Nielsen, J. H. Voorburg, and P. L'Hermite, ed. Odour Prevention and Control of Organic Sludge and Livestock Farming. Elsevier Applied Science Publishers, New York, 1985-234-237.

NPPC 1996. Practical solutions to odor problems: a satellite conference for pork producers. Notebook and video. National Pork Producers Council, Des Moines, Iowa.

O'Neill, D.H., and V.R. Phillips. 1992. A review of the control of odour nuisance from livestock buildings: Part III, Properties of the odorous substances which have been identified in livestock wastes or in the air around them. J. Agric. Eng. Res. 53:23-50.

OSHA. 1998. Table Z-1 Limits for Air Contaminants - 1910.1000, OSHA Regulations (Standards - 29 CFR), Occupational Safety and Health Administration, U.S. Dept. of Labor, Washington, D.C.

Parbst, K.E., Bottcher, R.W. and Hoff, S.J. 1998. Scrubbing parameters for odor abatement in a pilot scale testing facility. In Animal Production Systems and the Environment: An International Conference on Odor, Water Quality, Nutrient Management and Socioeconomic Issues, Proceedings Vol. II, Iowa State University, Ames, 661-666.

Priem, R. 1977. Deodorization by means of ozone. Agriculture and the Environment, 3:229-237.

Scholtens, R., J. V. Klarenbeek, and M. A. Bruins. 1987. Control of ammonia emissions with biofilters and bioscrubbers. In: V. C. Nielsen, J. H. Voorburg, and P. L'Hermite, ed. Volatile Emissions from Livestock Farming and Sewage Operations. Elsevier Applied Science Publishers, New York; 1987-196-208.

Shurson, J., M. Whitney, and R. Nicolai. 1998. Nutritional manipulation of swine diets to reduce hydrogen sulfide. A project report to the Minnesota Department of Agriculture.

Singer, P.C. 1990. Assessing ozone research needs in water treatment. J. AWWA, 82(10):78-88.

Sutton, A. L., J.A. Patterson, O.L. Adeola, B.A. Richert, D.T. Kelly, A.J. Heber, K.B. Kephart, R. Mumma, and E. Bogus. 1998. Reducing sulfur containing odors through diet manipulation. In *Proceedings Animal Production Systems and the Environment* 1998a-125-130. Des Moines, Iowa, July 19-22.

Sweeten, J.M. 1991. Odor and dust from livestock feedlots. Texas Agricultural Extension Service. College Station, 1-8.

Swine Odor Task Force 1998. Control of odor emissions from animal operations. North Carolina State University, North Carolina Agricultural Research Service.

Takai, H.; Moller, F.-; Iverson, M.; Jorsa, S.E.; and Bille-Hansen, V. 1993. Dust control in swine buildings by spraying of rapeseed oil. Fourth Inter. Livestock Environment Symposium, July 6-9. Sponsored by American Society of Agricultural Engineers (ASAE). St. Joseph, MI.

Tate, C. 1991. Survey of ozone installations in North America. *J. AWWA*, 82 (12):40-47.

Watkins, B.D., Hengenuehle, S.M., Person, H.L., Yokoyama, M.T. and Masten, S.J. 1996. Ozonation of swine manure wastes to control odors and reduce concentrations of pathogens and toxic fermentation metabolites. *Procs. of the International Conference on Air Pollution from Agricultural Operations*, Kansas City, February 7-9, 379-386.

Zeisig, H.D. and T.U. Munchen. 1987. Experiences with the use of biofilters to remove odours from piggeries and hen houses. In: V. C. Nielsen, J. H. Voorburg, and P. L'Hermite, ed. *Volatile Emissions from Livestock Farming and Sewage Operations.* Elsevier Applied Science Publishers, New York; 1987-209-216.

Zhang,Y. 1997. Sprinkling Oil to Reduce Dust, Gases, and Odor in Swine Buildings. MidWest Plan Service (MWPS) AED-42. Iowa State University, Ames.

Zhang, Y.; Tanaka, A.; Barber, E.M.; and Feddes, J.J.R. 1996. Effect of frequency and quantity of sprinkling canola oil on dust reduction in swine buildings. *Transactions of American Society of Agricultural Engineers* 39(3):1077-1081.

Zhu, J., D.S. Bundy, X. Li, and N. Rashid. 1997. Swine manure odor control using pit additives- A review. In *Proceedings of the Fifth International Livestock Environment Symposium*, 295-302.

About the Authors

This lesson was written by **Larry Jacobson**, extension engineer and livestock housing specialist, University of Minnesota, St. Paul, who can be reached at jacob007@.tc.umn.edu and by **Jeff Lorimor**, extension engineer and manure management specialist, Iowa State University, Ames, who can be reached at this e-mail address: x1lorimo@exnet.iastate.edu

Chapter 3: Emission Control Strategies for Land Application

The land application of manure from livestock and poultry facilities is the most frequent source of odor complaints from the public (Pain 1995, Hardwick 1985). Land application of manure to cropland is an important component to the long-term sustainability of animal agriculture. Manure application returns nutrients and organic matter to the soil, keeping it healthy and productive. Unfortunately, manure application to cropland does present some environmental risk. Over application of manure can lead to nitrate leaching into groundwater, phosphorus runoff into surface water, and a variety of other pollution problems. Proper manure application requires knowledge of the nutrient content of manure, the nutrient requirements for the crops, the availability of the manure nutrients, the physical limitations of the application equipment, and some understanding of the critical environmental hazards associated with manure application.

Along with water quality problems are nuisance odor concerns. Odor from manure is, in general, offensive to most people. One of the key factors in odor control is the surface area of the emitting source. The larger the surface area, the more odors are emitted. As such, manure applied on the surface of cropland presents one of the most significant sources of odor for any livestock or poultry operation. Applying manure at low rates to avoid over applying nutrients may in fact exacerbate odor problems since the manure must be spread on larger land areas.

Odor may last for a few hours to as much as two weeks, depending on weather conditions and the manure source. Manure that is applied beneath the soil surface (injected) or covered immediately after spreading (incorporation) eliminates most of the odor because the odorous gases must then travel up through a soil layer before being emitted into the atmosphere. The soil layer acts as both a trap for odorous gases and an aerobic treatment system, changing odorous gases into less odorous gases through microbial processes. Manure injection or incorporation also reduces manure nitrogen losses to the atmosphere by reducing ammonia volatilization. Field research suggests odor and ammonia emission reductions of 90% are attainable using shallow or deep injector manure systems versus surface application (Phillips et al. 1988).

Liquid Manure Odor Control Techniques

As indicated previously, reducing odor from the land application of liquid manure offers special challenges. Several methods of reducing odor from liquid manure land applications include incorporating the manure into the soil either during or shortly after it is spread, placing the liquid manure on the surface but in the crop canopy, or treating the manure in the storage unit before it is spread on land.

Injection and incorporation: Manure injection into the soil is the most effective way to reduce odor during the land application of untreated liquid manure (Figure 1). Table 1 shows odor dilution thresholds for various land application methods. One can see that the injection and the unmanured (control) methods have essentially the same odor units. The other common option is to simply spread liquid manure on the surface and immediately incorporate (plow or harrow methods in Table 1) into the soil. This method also reduces the odors considerably

compared to the broadcast method. However, incorporation after spreading on the surface does not result in as great a reduction as direct injection since some manure remains on the soil surface. Another study (Berglund and Hall 1987) found the odor intensity (measure of odor's strength) from surface application at 400 meters downwind was perceived to be equal to that from injection at only 50 meters. A more recent study at Iowa State University showed odor reductions from 20% to 90% by immediate incorporation of manure into the soil. This study looked at five different types of incorporation or injection devices, with all resulting in significant odor and hydrogen sulfide reductions compared to broadcast manure left on the surface (Hanna et al. 1999).

Figure 1. Injection of liquid manure into the soil.

Table 1. Odor thresholds for various land application methods.

Application Method	Odor Detection Threshold[a]
Broadcast	2818
Plow	200
Harrow	131
Inject	32
Unmanured	50

[a]Ratio of fresh air to odorous air (fresh:odorous) to dilute the odor to where it is just detectable.

The types of injectors used today include narrow tines, sweeps, disk covers, and conventional chisel plows. Besides their ability to achieve complete manure coverage for odor control, it is also important that these injector methods leave crop residue on the surface to minimize erosion and limit energy (tractor horsepower) requirements. Sweeps require more horsepower than simple tines for a given depth, but the sweeps more than compensate for this by operating at a shallower depth, permitting complete coverage. The disk covers, when set properly, require the least horsepower while still providing complete coverage, but they may also cover more crop residue. When the manure is placed on top of the soil surface and a conventional chisel plow is used for incorporation, complete coverage cannot be achieved. Thus a high level of odor control may be at the expense of higher energy requirements and the potential for greater erosion. The additional cost of manure incorporation or injection for odor control is offset somewhat by the savings in manure nitrogen. An Iowa study suggests that injecting the manure from a storage system increases costs $0.49 per year per breeding sow and $0.17 per finish hog while injecting the manure from a lagoon system increases costs $1.39 per year per breeding sow and $0.68 per finish hog (Fleming et al. 1998). However, these cost increases did not consider reduced nitrogen losses with the injection system. An Iowa survey of commercial manure applicators showed an average difference of 1/10 of a cent per gallon more for injection versus broadcast (see http://www.ae.iastate.edu/manurdir99.htm).

Drop hoses: Another method of application, used in northern European countries, is to simply place liquid manure on the surface through a series of drop hoses much like a sprayer hose or boom (Figure 2). This technique has been used to spread manure slurry (liquid manure from under barn pits) on tilled cropland and on growing crops (especially small grains), producing minimum odor and minimum potential runoff and/or erosion. The system has been used with manure tanks but could be adapted to drag hose technology on pastures or some crops such as forages. Adoption of this technology may be limited in the United States because of the prevalence of row crops and the difficulty of matching tanker tire size with rows and wheel spacing.

Pretreated manure: Treated liquid manure may be less offensive than raw or untreated manure, although this depends on the degree of treatment. Liquid manure can be treated either aerobically or anaerobically (anaerobic digestion) to significantly reduce odors. Research indicates odor reductions of 80% or more during anaerobic treatment of manure (Pain et al.1990). In such cases, manure can be surface applied or even irrigated with very little odor

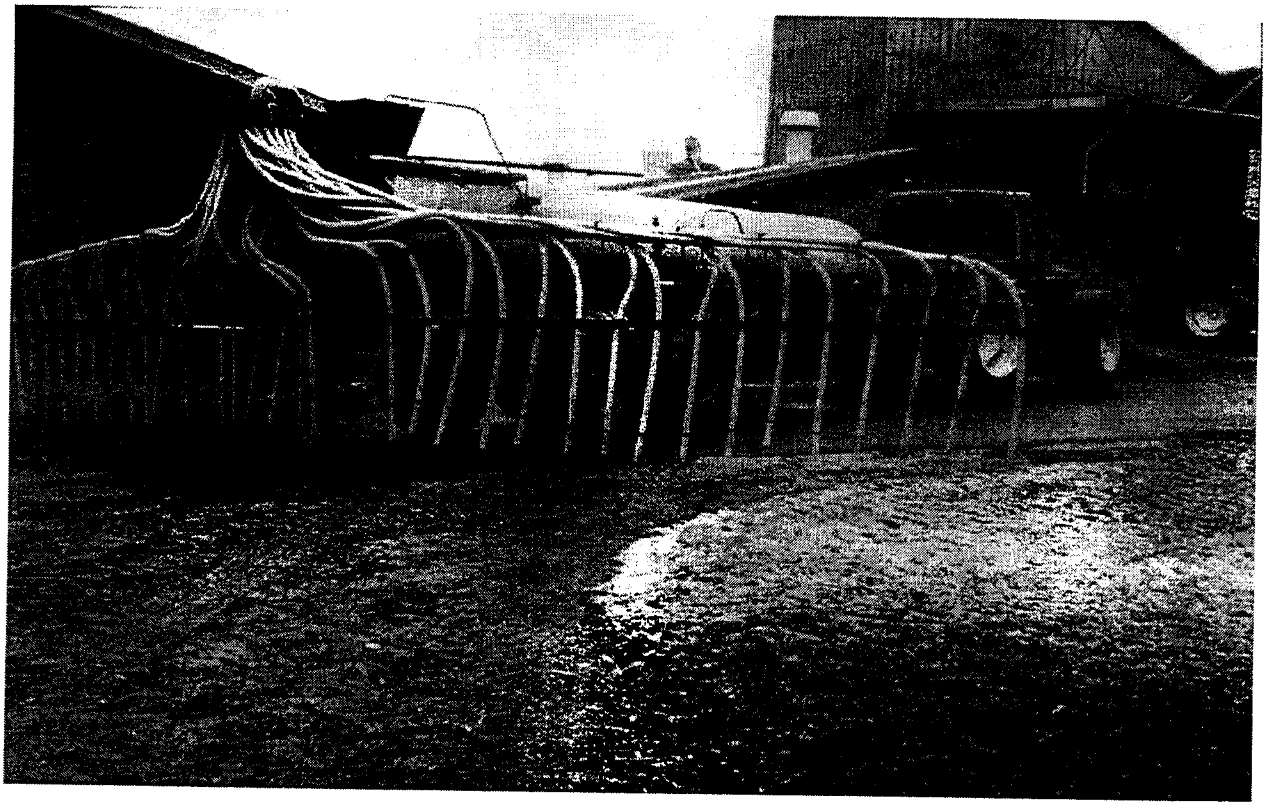


Figure 2. Drop hose liquid manure applicator.

emissions. The same can be said for solid manure that is applied frequently (hauled daily), dried, or composted since it will generate less odor during land application.

Surface application by irrigation: Applying liquid manure with irrigation (both surface and spray) systems (Figure 3) remains a popular and efficient method to distribute manure nutrients onto crop land in some sections of the United States. As mentioned previously, it can produce considerable odors if not managed properly and/or the liquid manure is untreated or has a high nutrient content. Characteristics of irrigation systems that reduce odor include use of nozzles and pressures that produce large droplet sizes, installing drop nozzles on center pivot systems, and the addition of dilution water to the liquid manure before applying.

Droplet size is of importance because of the much higher surface area per unit volume associated with smaller droplets as well as the potential for greater drift of smaller droplets. In general, larger droplets are better for odor control. Droplet size is determined by a combination of nozzle size and pressure. To overcome their tendency to drift, droplets generally must be greater than 150 microns in size, depending on wind speed. Traveling guns must operate at high pressures, but the nozzle size is large, resulting in primarily large droplets. Center pivot irrigation units have wide latitude for nozzle size and pressure combinations. To minimize droplet drift and odor emissions from irrigation and other broadcast application systems, maximize nozzle size and minimize spray pressures.

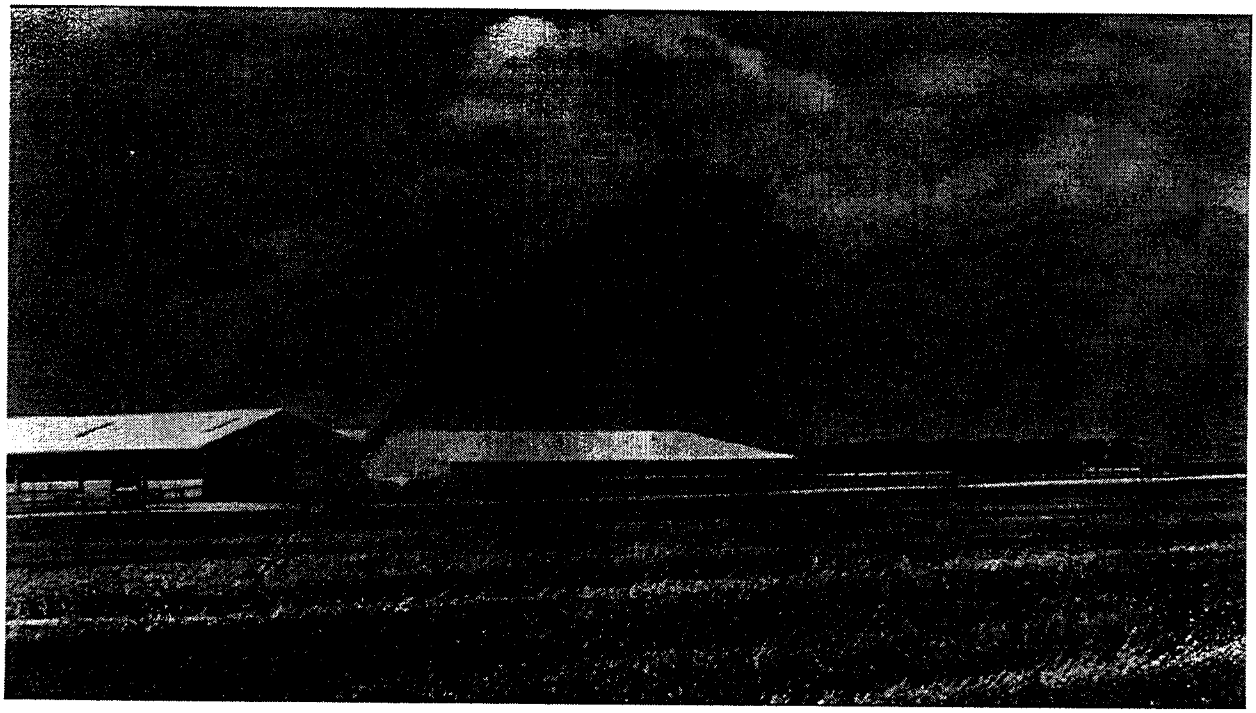


Figure 3. Spreading liquid manure with a traveling gun irrigation system.

Equipping center pivot irrigation systems with drop lines and downward spraying nozzles will reduce odors as well as reduce water evaporation. Drop lines can extend from 8 feet down to only 2 or 3 feet from the ground with appropriate nozzles and nozzle spacings to give good water distribution.

Fresh water dilution can also be used to reduce manure odors and nitrogen loss during irrigation applications. A Midwestern state (Iowa) requires a 15:1 dilution with fresh water if untreated slurry is to be irrigated. Burton (1997) reported that 3:1 fresh water additions to manure slurry reduced ammonia losses from 20% to 90%. Lagoon liquid is often mixed into irrigation water in states that commonly use irrigation for crop production. The lagoon effluent is then spread in a very dilute and greatly odor reduced manner.

Treating manure in pits: One other factor that contributes to odor and gas emission during manure application is the agitation or mixing of the manure before pumping (Figure 4). This mixing is necessary to remove the solids that have built up in the bottom of the storage and to distribute the nutrients evenly throughout the manure. Odor and gas emissions during agitation and pumping are difficult to control. The best method for reducing the impact of these odor emissions is to agitate during times when the outside air is heating (sunny clear mornings), causing the odorous air to rise and disperse.

Other techniques to reduce these emissions, such as the addition of chemical additives to the manure, are also being evaluated. Research has shown reductions in hydrogen sulfide emissions of over 90% with additions of calcium hydroxide, ferric chloride, ferrous chloride,

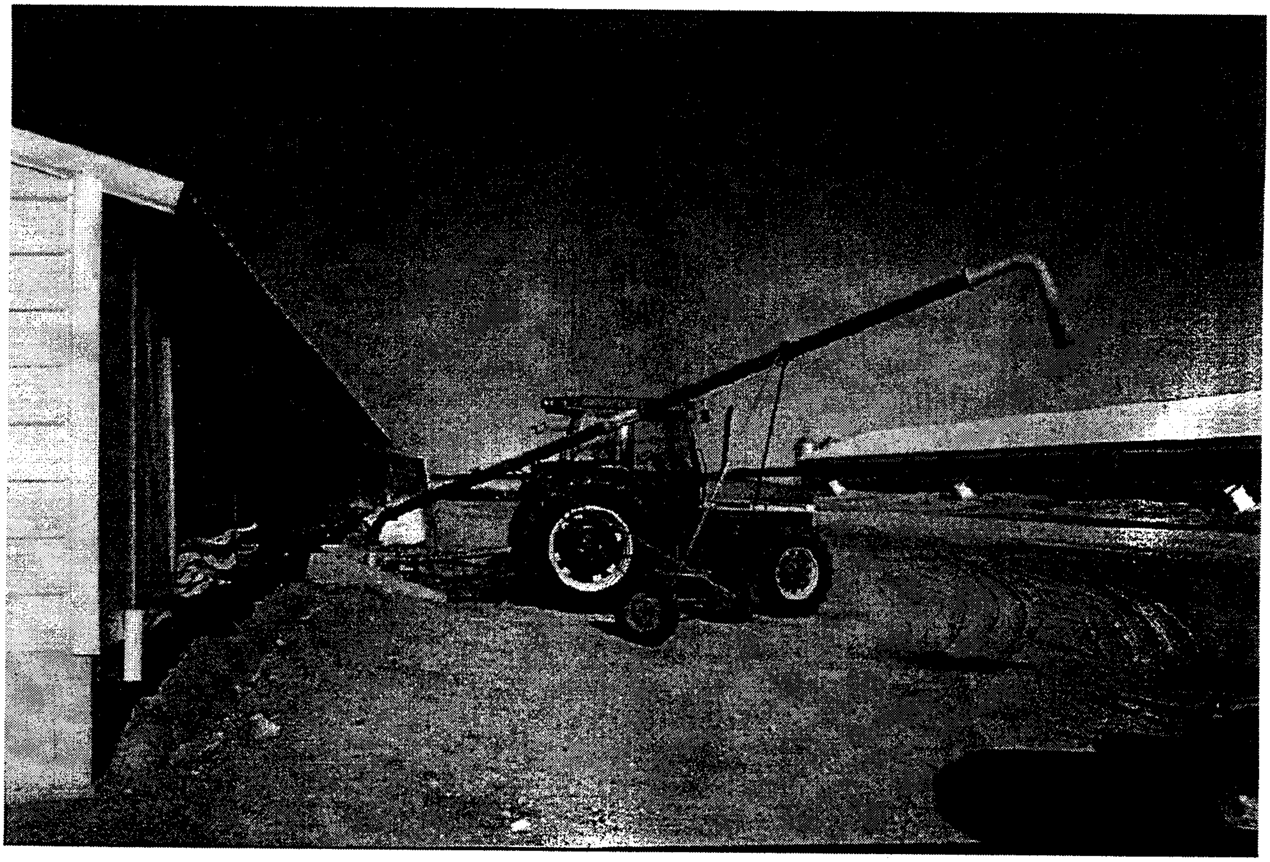


Figure 4. Agitation and pumping equipment for a deep pit manure storage under a pig-finishing barn.

ferrous sulfate, hydrogen peroxide, potassium permanganate, or sodium chlorite (Clanton et al. 1999). Although these reductions in emissions do not guarantee reductions in odor emissions, odor reductions are likely.

Solid Manure Odor Control Techniques

Technologies that reduce the odors released during land application of solid manure parallel those of liquid manure, namely, treating solid manure before it is spread and incorporating surface-applied solid manure into the soil as soon as possible after it is applied.

Incorporation: Solid manure is not injected, because unlike liquid manure, it will not flow through the pipes and tubes common to injectors. It therefore requires another pass with a disk or other tillage equipment before being incorporated into the soil. The simple recommendation is to use a tandem disk or field cultivator as soon as possible after the solid manure is spread. New equipment needs to be designed that will both apply and incorporate solid manure with a single piece of equipment or spread solid manure on grasslands.

The loading or transfer of solid manure from buildings, stacks, or storage areas can produce odor emissions. This can be a problem when solid manure is temporarily stored near

cropland and then applied after the crop is removed in the fall or before the crop is planted in the spring. One way of minimizing odors from stacked manure, however, is by covering it with plastic. Using black plastic may also help minimize fly production due to the high temperatures that occur beneath the cover.

Treatment: As with liquid manure, treating solid manure (such as composting, Figure 5) can reduce odors. Some chemical treatments can reduce gas emissions. For example, alum has been shown to significantly reduce ammonia volatilization from poultry litter (Moore et al. 1995).

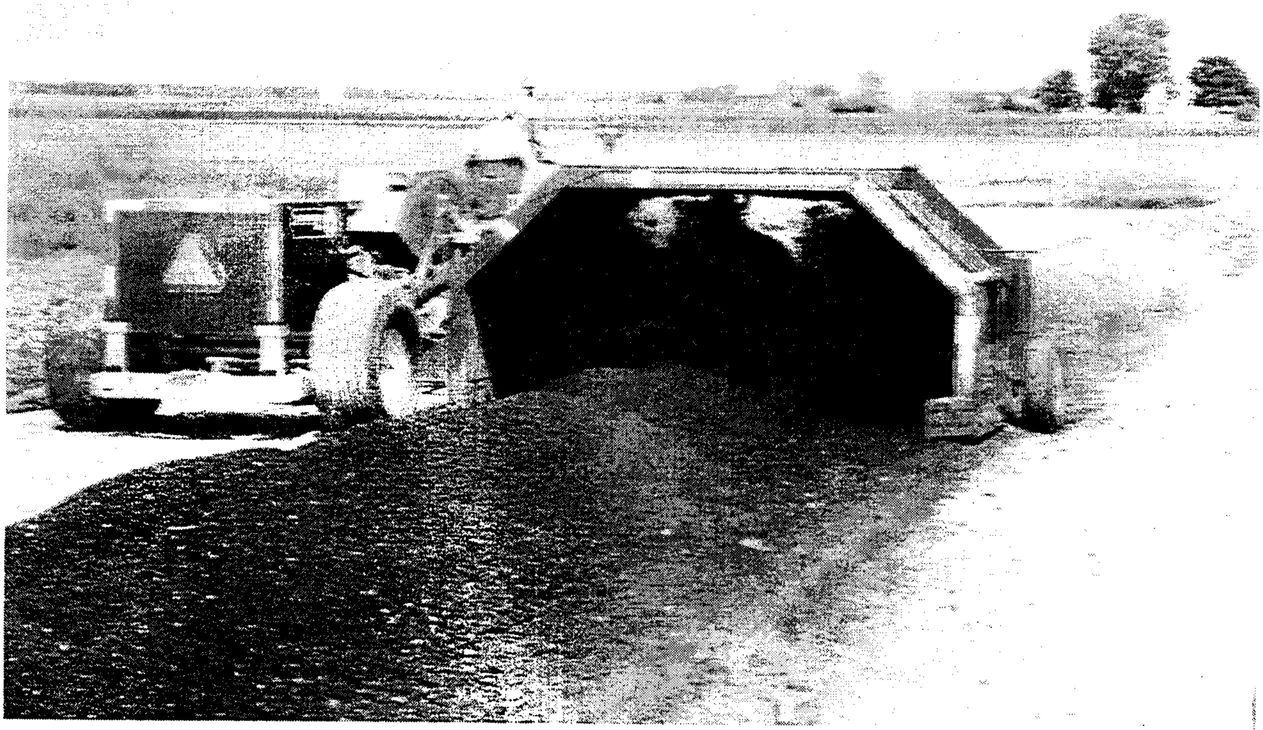


Figure 5. Mechanical turner used in composting solid manure

Time and location constraints: When applying manure, always consider wind direction especially if you are broadcasting. Select days when the wind is blowing away from neighbors and dwellings. If feasible, spread manure on weekdays when neighbors are likely to be away from their home; avoid weekends, especially Sundays and holidays. Before spreading manure, check with neighbors to be sure that they do not have a social event planned for the same day that you are planning to spread. If they do, change your plans. Finally, one of the most effective practices is simply to tell your neighbors or those who may be affected that you plan to apply manure to your farmland. Typically, people will object less if they know ahead of time and feel that they have some control or at least some input into what is happening around them.

Summary: Manure application can cause significant odor emissions. Several methods of reducing odor from both liquid and solid manure land applications include incorporating the manure into the soil either during or shortly after it is spread, placing manure on the surface but beneath the crop canopy, or treating the manure before it is spread on land. The agitation and/or loading of manure from long or short-term storage facilities will also create odors that need to be managed to avoid complaints during the application process.

References

Berglund, S. and J.E. Hall. 1987. Sludge and slurry disposal techniques and environmental problems – a review. In *Proceedings of volatile emisions from livestock farming and sewage operations workshop.* Uppsala, Sweden.

Burton, C.H. (ed.) 1997. Manure management: treatment strategies for sustainable agriculture. Silsoe Research Institute, Silsoe, Bedford, U.K.

Clanton, C.J., Nicolai, R.E., and Schmidt, D.R., 1999. Chemical additions to swine manure to reduce hydrogen sulfide losses - a laboratory study. *ASAE Annual International Meeting*, July 18-22, Toronto, Canada, Paper No. 99-4007, ASAE, 2950 Niles Rd., St. Joseph, MI.

Fleming, R.A., B.A. Babcock, and E. Wang. 1998. Resource or Waste? The Economics of Swine Manure Storage and Management. *Review of Agricultural Economics* 20:96-113.

Hanna, H.M., D. Bundy, J.C. Lorimor, S.K. Mickelson, and S.W. Melvin. 1999. Effects of manure application equipment on odor, residue cover, and crop. ASAE Paper No. 991062. St. Joseph, MI.

Hardwick, D.C. 1985. Agricultural problems related to odor prevention and control. In *Odor Prevention and Control of Organic Sludge and Livestock Farming.* ed. V.C. Nielson, J.H. Voorburg and P. L'Hermite. Elsevier Applied Science Pub. New York. pp. 21-26.

Moore, P.A., Jr., T.C. Daniel, D.R. Edwards, and D.M. Miller. 1995. Effect of chemical amendments on ammonia volatilization from poultry litter. *J. of Environmental Qual.* 24(2): 293-300.

Pain, B.F., T.H. Misselbrook, and C.R. Clarkson. 1990. Odour and ammonia emissions following the spreading of anaerobically digested pig slurry on grassland. *Biol. Wastes* 34:259-267.

Pain, B.F. 1995. Odours from application of livestock wastes to land. In New Knowledge in Livestock Odor, *Proceedings of International Livestock Odor Conference*, Ames, Iowa. 125-126.

Phillips, V.R., B.F. Pain, J.V. Klarenbeek. 1988. Factors influencing the odour and ammonia emissions during and after the land spreading of animal slurries. In *Volatile Emissions from Livestock Farming and Sewage Operations* . V. C. Nielsen, J. H. Voorburg, P.L'Hermite Elsevier Applied Science, London.

About the Authors

This lesson was written by **Larry Jacobson**, extension engineer and livestock housing specialist, University of Minnesota, St. Paul, who can be reached at jacob007@.tc.umn.edu and by **Jeff Lorimor**, extension engineer and manure management specialist, Iowa State University, Ames, who can be reached at this e-mail address: x1lorimo@exnet.iastate.edu

13

Assistance Programs and Other Resources

-Farm*A*Syst
-Clean Water Foundation Assessment Program
-NRCS Programs

The University of Georgia

College of Agricultural & Environmental Sciences
Department of Biological & Agricultural Engineering

Programs that can help Producers meet the New Regulations

Dr. Mark Risse, Biological and Agricultural Engineering

The University of Georgia Cooperative Extension Service has several resources to assist Animal Feeding Operations attempting to comply with the new regulations. These are all voluntary programs that can help you to lower your risk of non-compliance or environmental problems.

AWARE team: The overall objective of the AWARE Team is: "To facilitate awareness of animal waste issues to research scientists, Extension personnel, industry representatives, and producers and to serve as a catalyst for providing economically and environmentally sound waste utilization solutions to Georgia's animal production industry." It's web page, newsletter, and list serve are valuable sources of information.

- Newsletter: The AWARE team has a quarterly newsletter that is distributed to a mailing list of all county agents and over 300 other individuals. These newsletters are also available via the internet and are downloaded by individuals around the world. The newsletter comes out about four times a year and keeps you up to date on research, extension, and current happenings in the waste management area. This will also be your best method of finding out about field days and workshops that the team will be sponsoring. To subscribe, contact Cathy Felton at 706-542-3086.
- Webpage: All of the information that the group disseminates is available via the Internet at http://www.bae.uga.edu/outreach/aware. Our website averages over 500 visits per month and has copies of all UGA publications as well as many links to other waste management internet sites around the world.
- List Serve: Our electronic list serve is probably one of the best uses of technology by the team. This list serve allows agents or producers to send questions to a large group of people in one mailing and usually results in questions being answered quicker than normal as well as producing quite a bit of interesting discussion. To subscribe to the listserve send e-mail to listserv@listserv.uga.edu with the message "subscribe aware" in the body of the e-mail.

Environmental Assessments: There are two excellent programs that are available for you to conduct on-farm assessments. The National Pork Producers Council offers On-Farm Odor/Environmental Assessments that are very detailed. During these assessments, an assessor from both the private and public sector will visit and tour your operation and provide you with written details of changes that could be made to

Driftmier Engineering Center • Athens, Georgia 30602-4435 • (706) 542-1653 • FAX (706) 542-8806
An Equal Opportunity/Affirmative Action Institution

reduce your risk of environmental problems or odor events. Several producers have taken advantage of this program in Georgia and been extremely pleased with the feedback that they received. The Georgia Farm*A*Syst offers environmental self assessments that can be completed at your own pace or with the help of a local professional. There are a total of 15 different assessments each dealing a different area of your farm such as well protection, pesticide storage and handling, managing nutrients on croplands and pastures, and swine production. For more information on these programs contact the Georgia Pork Producers or your county agent.

Nutrient Management Planning: Comprehensive Nutrient Management plans will be required under the new regulations. The problem is that no one has really defined a comprehensive nutrient management plan. It is different than a nutrient management plan that you develop for a single field and includes other components to address the whole farm. The University of Georgia recently established a task force to specifically address nutrient management planning in Georgia. This task force will release a guide for developing these plans in the near future (currently in review). Also, the operation training and certification program will devote considerable time to nutrient management and hopefully supply enough information that you could either write your own CNMP or know what information you will need. In the immediate future, the NRCS and your county agent are the best sources of information on developing nutrient management plans, however, professional engineers, certified crop advisors, and other consultants could also assist you.

Operator Training and Certification: This program is implemented by the Georgia Department of Agriculture and the UGA Extension Service. Once certified, you will be required to obtain continuing education. The cooperative Extension service intends to offer these education opportunities on a regular basis through your county extension service. Contact the your local extension office for information on new opportunities.

Bioconversion Research and Education Center: The goal of this center is to enhance environmentally sound economic development in Georgia by strengthening the competitiveness of the state's industries through bioconversion processes such as composting and other thermal processing approaches. It focuses on waste volume reduction through processes such as composting. There are many benefits to handling swine waste as a solid rather than through lagoon type systems. This center is conducting research on these new methods and well as workshops on a continuing basis. Contact: Mark Risse at 706-542-9067

GEORGIA FARM*A*SYST PUBLICATIONS ORDER FORM

The Georgia Farm Assessment System (Farm*A*Syst) provides Georgia's farmers with information and a voluntary means to become environmentally pro-active in managing their farm to prevent pollution. Please indicate any of the assessments you would like to receive. The publications are free and will be mailed in approximately one week. Thank you for your interest.

Please indicate the number of each assessment you would like mailed.	**GEORGIA FARM*A*SYST ASSESSMENTS**
	What is Farm*A*Syst?
	Site Evaluation
	Water Quality
	Improving Drinking Water Well Condition
	Improving Drinking Water for the Rural Resident
	Improving Household Waste Water Treatment
	Management of Irrigation Systems
	Storage & Handling Practices
	Pesticide Storage & Handling
	Petroleum Storage & Handling
	Hazardous Products Storage Handling and Waste Disposal
	Fertilizer Storage & Handling
	Animal Production
	Layer Production
	Broiler Production
	Swine Production
	Dairy Production
	Beef Production
	Composting Poultry Mortalities
	Land Management
	Managing Runoff and Erosion on Croplands and Pastures
	Nutrient Management
	Managing Pests on Croplands and Pastures
	Forest Resources Management (Forest*A*Syst)
	Cotton IPM
	Pesticide Storage and Handling for Ornamental/Turf Professionals
	Managing Pesticides for Ornamental/Turf Professionals
	Other Assessments
	Overall Assessment

Please provide the following information.

NAME:______________________________ PHONE NUMBER: ______________

ADDRESS:____________________________ FAX NUMBER: ______________

____________________________ E-MAIL:______________________

Please mail this form to :

Tina Williams
College of Agricultural and Environmental Sciences
Driftmier Engineering Center
University of Georgia
Athens, Georgia 30602

or e-mail your request to twilliam@bae.uga.edu
or fax your request to (706) 542-1886 or call (706) 542-7661

NRCS Programs

Vernon Jones, USDA-NRCS, Athens, GA

Information on National Programs is available at: http://www.nrcs.usda.gov/NRCSProg.html

For more information about Natural Resource Conservation Programs and Activities go to: http://www.nhq.nrcs.usda.gov/PROGRAMS/cpindex.htm

While there are a variety of USDA programs available to assist people with their conservation needs, the following primarily financial assistance programs are the principal programs available. Locally Led Conservation groups are encouraged to contact the State Offices of the appropriate agency for more specific information about each program.

Conservation Technical Assistance (CTA)
Contact: USDA, Natural Resources Conservation Service
The purpose of the program is to assist land-users, communities, units of state and local government, and other Federal agencies in planning and implementing conservation systems. The purpose of the conservation systems are to reduce erosion, improve soil and water quality, improve and conserve wetlands, enhance fish and wildlife habitat, improve air quality, improve pasture and range condition, reduce upstream flooding, and improve woodlands.

Objectives of the program are to:

- Assist individual landusers, communities, conservation districts, and other units of State and local government and Federal agencies to meet their goals for resource stewardship and assist individuals to comply with State and local requirements. NRCS assistance to individuals is provided through conservation districts in accordance with the memorandum of understanding signed by the Secretary of Agriculture, the governor of the state, and the conservation district. Assistance is provided to land users voluntarily applying conservation and to those who must comply with local or State laws and regulations.
- Assist agricultural producers to comply with the highly erodible land (HEL) and wetland (Swampbuster) provisions of the 1985 Food Security Act as amended by the Food, Agriculture, Conservation and Trade Act of 1990 (16 U.S.C. 3801 et. seq.) and the Federal Agriculture Improvement and Reform Act of 1996 and wetlands requirements of Section 404 of the Clean Water Act. NRCS makes HEL and wetland determinations and helps land users develop and implement conservation plans to comply with the law.
- Provide technical assistance to participants in USDA cost-share and conservation incentive programs. (Assistance is funded on a reimbursable basis from the CCC.)
- Collect, analyze, interpret, display, and disseminate information about the condition and trends of the Nation&#146s soil and other natural resources so that people can make good decisions about resource use and about public policies for resource conservation.
- Develop effective science-based technologies for natural resource assessment, management, and conservation.

Conservation Farm Option (CFO)
Contact: USDA, Farm Service Agency or Natural Resources Conservation Service

The Conservation Farm Option is a pilot program for producers of wheat, feed grains, cotton, and rice. The program's purposes include conservation of soil, water, and related resources, water quality protection and improvement, wetland restoration, protection and creation, wildlife habitat development and protection, or other similar conservation purposes. Eligibility is limited to owners and producers who have contract acreage enrolled in the Agricultural Market Transition Act program, i.e. production flexibility contracts. The CFO is a voluntary program. Participants are required to develop and implement a conservation farm plan. The plan becomes part of the CFO contract which covers a ten year period. CFO is not restricted as to what measures may be included in the conservation plan, so long as they provide environmental benefits. During the contract period the owner or producer (1.) receives annual payments for implementing the CFO contract and (2.) agrees to forgo payments under the Conservation Reserve Program, the Wetlands Reserve Program, and the Environmental Quality Incentives Program in exchange for one consolidated payment.

Conservation of Private Grazing Land Initiative (CPGL)
Contact: USDA, Natural Resources Conservation Service

The Conservation of Private Grazing Land initiative will ensure that technical, educational, and related assistance is provided to those who own private grazing lands. It is not a cost share program. This technical assistance will offer opportunities for: better grazing land management; protecting soil from erosive wind and water; using more energy-efficient ways to produce food and fiber; conserving water; providing habitat for wildlife; sustaining forage and grazing plants; using plants to sequester greenhouse gases and increase soil organic matter; and using grazing lands as a source of biomass energy and raw materials for industrial products. More information can be found at the Grazing Lands Technology Institute.

Outreach and Assistance for Socially Disadvantaged Farmers and Ranchers
Contact: USDA, Natural Resources Conservation Service

Section 2501 of the Food, Agriculture, Conservation, and Trade Act of 1900 (Public Law 101-624) requires the Secretary of Agriculture to provide outreach and technical assistance to socially disadvantaged farmers and ranchers. Administration of the program was transferred to the Natural Resources Conservation Agency from the Farm Service Agency beginning in fiscal year 1997. The overall goal of the program is to increase the number of small or limited resource and minority producers and directly improve the farm income of these producers. Objectives are to make grants and enter into agreements with community-based organizations and educational institutions to provide outreach and technical assistance.

Conservation Plant Material Centers
Contact: USDA, Natural Resources Conservation Service

The purpose of the program is to provide native plants that can help solve natural resource problems. Beneficial uses for which plant material may be developed include biomass production, carbon sequestration, erosion reduction, wetland restoration, water quality improvement, streambank and riparian area protection, coastal dune stabilization, and other special conservation treatment needs. Scientists at the Plant Materials Centers seek out plants that show promise for meeting an identified conservation need and test their performance. After species are proven, they are released to the private sector for commercial production. The work at the 26 centers is carried out cooperatively with state and Federal agencies, commercial businesses, and seed and nursery associations.

Conservation Reserve Program (CRP)
Contact: USDA, Farm Service Agency

The Conservation Reserve Program reduces soil erosion, protects the Nation's ability to produce food and fiber, reduces sedimentation in streams and lakes, improves water quality, establishes wildlife habitat, and enhances forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filterstrips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. Cost sharing is provided to establish the vegetative cover practices. For additional information, see our Farm Bill page.

Environmental Quality Incentives Program (EQIP)
Contact: USDA, Natural Resources Conservation Service

The Environmental Quality Incentives Program provides technical, educational, and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. The program provides assistance to farmers and ranchers in complying with Federal, State, and tribal environmental laws, and encourages environmental enhancement. The program is funded through the Commodity Credit Corporation. The purposes of the program are achieved through the implementation of a conservation plan which includes structural, vegetative, and land management practices on eligible land. Five- to ten-year contracts are made with eligible producers. Cost-share payments may be made to implement one or more eligible structural or vegetative practices, such as animal waste management facilities, terraces, filter strips, tree planting, and permanent wildlife habitat. Incentive payments can be made to implement one or more land management practices, such as nutrient management, pest management, and grazing land management.

Fifty percent of the funding available for the program will be targeted at natural resource concerns relating to livestock production. The program is carried-out primarily in priority areas that may be watersheds, regions, or multi-state areas, and for significant statewide natural resource concerns that are outside of geographic priority areas. For additional information, see our Farm Bill page.

Soil Survey Programs
Contact: USDA, Natural Resources Conservation Service

The National Cooperative Soil Survey Program (NCSS) is a partnership led by NRCS of Federal land management agencies, state agricultural experiment stations and state and local units of government that provide soil survey information necessary for understanding, managing, conserving and sustaining the nation's limited soil resources.

Soil surveys provide an orderly, on-the-ground, scientific inventory of soil resources that includes maps showing the locations and extent of soils, data about the physical and chemical properties of those soils, and information derived from that data about potentialities and problems of use on each kind of soil in sufficient detail to meet all reasonable needs for farmers, agricultural technicians, community planners, engineers, and scientists in planning and transferring the findings of research and experience to specific land areas. Soil surveys provide the basic information needed to manage soil sustainably. They also provide information needed to protect water quality, wetlands, and wildlife habitat. Soil surveys are the basis for predicting the behavior of a soil under alternative uses, its potential erosion hazard, potential for ground water contamination, suitability and productivity for cultivated crops, trees, and grasses. Soil surveys are important to planners, engineers, zoning commissions, tax commissioners, homeowners, developers, as well as agricultural producers. Soil surveys also provide a basis to help predict the effect of global climate change on worldwide agricultural production and other land-dependent processes. The NRCS Soil Survey Division through its World Soil Resources Staff helps gather and interpret soil information for global use.

NRCS provides the soil surveys for the privately owned lands of the nation and, through its National Soil Survey Center, provides scientific expertise to enable the NCSS to develop and maintain a uniform system for mapping and assessing soil resources so that soil information from different locations can be shared, regardless of which agency collects it. NRCS provides most of the training in soil survey to Federal agencies and assists other Federal agencies with their soil inventories on a reimbursable basis. NRCS is also responsible for developing the standards and mechanisms for providing digital soil information for the national spatial data infrastructure required by Executive Order 12906.

Farmland Protection Program (FPP)
Contact: USDA, Natural Resources Conservation Service

The Farmland Protection Program provides funds to help purchase development rights to keep productive farmland in agricultural uses. Working through existing programs, USDA joins with State, tribal, or local governments to acquire conservation easements or other interests from landowners. USDA provides up to 50 percent of the fair market easement value. To qualify, farmland must: be part of a pending offer from a State, tribe, or local farmland protection program; be privately owned; have a conservation plan; be large enough to sustain agricultural production; be accessible to markets for what the land produces; have adequate infrastructure and agricultural support services; and have surrounding parcels of land that can support long-term agricultural production. Depending on funding availability, proposals must be submitted by the government entities to the appropriate NRCS State Office during the application window. For additional information, see our Farm Bill page.

Flood Risk Reduction Program (FRR)
Contact: USDA, Farm Service Agency

The Flood Risk Reduction Program was established to allow farmers who voluntarily enter into contracts to receive payments on lands with high flood potential. In return, participants agree to forego certain USDA program benefits. These contract payments provide incentives to move farming operations from frequently flooded land.

Forestry Incentives Program (FIP)
Contact: USDA, Natural Resources Conservation Service

The Forestry Incentives Program (FIP) supports good forest management practices on privately owned, non-industrial forest lands nationwide. FIP is designed to benefit the environment while meeting future demands for wood products. Eligible practices are tree planting, timber stand improvement, site preparation for natural regeneration, and other related activities. FIP is available in counties designated by a Forest Service survey of eligible private timber acreage. For additional information, see our Farm Bill page.

Watershed Surveys and Planning
Contact: USDA, Natural Resources Conservation Service

The Watershed and Flood Prevention Act, P.L. 83-566, August 4, 1954, (16 U.S.C. 1001-1008) authorized this program. Prior to fiscal year 1996, small watershed planning activities and the cooperative river basin surveys and investigations authorized by Section 6 of the Act were operated as separate programs. The 1996 appropriations act combined the activities into a single program entitled the Watershed Surveys and Planning program. Activities under both programs are continuing under this authority.

The purpose of the program is to assist Federal, State, and local agencies and tribal governments to protect watersheds from damage caused by erosion, floodwater, and sediment and to conserve and develop water and land resources. Resource concerns addressed by the program include water quality, opportunities for water conservation, wetland and water storage capacity, agricultural drought problems, rural development, municipal and industrial water needs, upstream flood damages, and water needs for fish, wildlife, and forest-based industries.

Types of surveys and plans include watershed plans, river basin surveys and studies, flood hazard analyses, and flood plain management assistance. The focus of these plans is to identify solutions that use land treatment and nonstructural measures to solve resource problems. Also see the Emergency Watershed Protection Fact Sheet.

Resource Conservation & Development Program (RC&D)
Contact: USDA, Natural Resources Conservation Service

The purpose of the Resource Conservation and Development (RC&D) program is to accelerate the conservation, development and utilization of natural resources, improve the general level of economic activity, and to enhance the environment and standard of living in authorized RC&D areas. It improves the capability of State, tribal and local units of government and local nonprofit organizations in rural areas to plan, develop and carry out programs for resource conservation and development. The program also establishes or improves coordination systems in rural areas. Current program objectives focus on improvement of quality of life achieved through natural resources conservation and community development which leads to sustainable communities, prudent use (development), and the management and conservation of natural resources. Authorized RC&D areas are locally sponsored areas designated by the Secretary of Agriculture for RC&D technical and financial assistance program funds. NRCS can provide grants for land conservation, water management, community development, and environmental needs in authorized RC&D areas.

Stewardship Incentives Program (SIP)
Contact: USDA, Forest Service

The Stewardship Incentive Program provides technical and financial assistance to encourage non-industrial private forest landowners to keep their lands and natural resources productive and healthy. Qualifying land includes rural lands with existing tree cover or land suitable for growing trees and which is owned by a private individual, group, association, corporation, Indian tribe, or other legal private entity. Eligible landowners must have an approved Forest Stewardship Plan and own 1,000 or fewer acres of qualifying land. Authorizations may be obtained for exceptions of up to 5,000 acres.

Wetlands Reserve Program (WRP)
Contact: USDA, Natural Resources Conservation Service

The Wetlands Reserve Program is a voluntary program to restore wetlands. Participating landowners can establish conservation easements of either permanent or 30-year duration, or can enter into restoration cost-share agreements where no easement is involved. In exchange for establishing a permanent easement, the landowner receives payment up to the agricultural value of the land and 100 percent of the restoration costs for restoring the wetlands The 30-year easement payment is 75 percent of what would be provided for a permanent easement on the same site and 75 percent of the restoration cost. The voluntary agreements are for a minimum 10-year duration and provide for 75 percent of the cost of restoring the involved wetlands. Easements and restoration cost-share agreements establish wetland protection and restoration as the primary land use for the duration of the easement or agreement. In all instances, landowners continue to control access to their land. For additional information, see our Farm Bill page.

Wildlife Habitat Incentives Program (WHIP)
Contact: USDA, Natural Resources Conservation Service

The Wildlife Habitat Incentives Program provides financial incentives to develop habitat for fish and wildlife on private lands. Participants agree to implement a wildlife habitat development plan and USDA agrees to provide cost-share assistance for the initial implementation of wildlife habitat development practices. USDA and program participants enter into a cost-share agreement for wildlife habitat development. This agreement generally lasts a minimum of 10 years from the date that the contract is signed. For additional information, see our Farm Bill page.

14

Appendix

For Official Use Only

State of Georgia
Department of Natural Resources

Registration

For Coverage Under Permit By Rule
Chapter 391-3-6-.20(4)

SWINE FEEDING OPERATIONS

☐ Existing Facility ☐ Proposed New Facility

I. FACILITY LOCATION INFORMATION

FACILITY NAME: ______________________ PHONE: ______________

MAILING ADDRESS: ______________________ CITY: ____________ ZIP CODE: __________

STREET/LOCATION ADDRESS: ______________________________________

CITY: ______________________ COUNTY: ______________ ZIP CODE: __________

II. FACILITY OWNER-OPERATOR INFORMATION

LEGAL NAME: ______________________ PHONE: ______________

ADDRESS: ______________________________________

CITY: ______________________ STATE: ______________ ZIP CODE: __________

III. SITE ACTIVITY INFORMATION

Maximum Number of Swine Weighing More Than 55 Pounds That Will Be Confined or Fed for Total of 45 Days in any 12 month Period. ______________

Describe the Swine Feeding/Growing Operation. ______________________________________

Does any other swine feeding operation adjoin this facility or utilize a common area for disposal of wastes from this facility? __________
If yes, then attach size and ownership information for the other facilities.

IV. COMMENTS

V. CERTIFICATION: I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based upon my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Printed Name: ______________________ Title: ______________

Signature: ______________________ Date: ______________

Instructions
Registration Form For Coverage Under
Permit By Rule, Chapter 391-3-6-.20(4)
SWINE FEEDING OPERATION

Who must file this Registration Form

Swine feeding operations which confine more than 750, but less than 2500 swine weighing 55 pounds or greater are not required to obtain individual wastewater permits. However, these facilities must file this registration form with the Georgia Environmental Protection Division and comply with the requirements for permit by rule under Georgia's Rules for Water Quality Control, Chapter 391-3-6-.20.

If you have questions regarding permitting of swine feeding operations, please contact the Industrial Wastewater Unit of the Permitting, Compliance and Enforcement Program at (404) 362-3280.

Where to file. Registration Forms must be sent to:

Georgia Environmental Protection Division
Permitting, Compliance and Enforcement Program
4220 International Parkway, Suite 101
Atlanta, Georgia 30354

Section I. Facility Information: Enter the facility's name, street address, mailing address, county, and telephone number. Should the facility lack a street address, describe where the facility is located in "Section IV. Comments".

Section II. Facility Owner-Operator Information: Enter the owner-operator's legal name, mailing address and telephone number.

Section III. Facility Activity Information: Provide the number of swine that will be confined at the facility and describe the feeding/growing operation.

Indicate if this swine feeding operation is associated through common ownership or common use of facilities with any other adjacent swine feeding operations. If yes, then provide size and ownership information for the associated operations.

Section IV. Comments: Provide comments as appropriate.

Section V. Certification: Provide the information requested and have the registration form signed by one of the following people:

- ♦For a corporation: by a responsible corporate officer, which means president, secretary, treasurer, or vice president of the corporation; or
- ♦For a partnership or sole proprietorship: by a general partner or the proprietor.

Summary of Requirements for Permit By Rule

1. There shall be no discharge of pollutants from the operation into surface waters of the State.

2. By October 31, 2002, new operations must have waste storage and disposal systems in operation that have been designed and constructed in accordance with Natural Resource Conservation Service (NRCS) guidance.

3. By October 31, 2001, the owner or operator shall submit to the Division a Comprehensive Nutrient Management Plan (CNMP) for the swine feeding operation. The CNMP shall be of sufficient substance and quality as to be approvable by the Division. The owner or operator shall receive the Division's approval of the CNMP by July 1, 2002, and shall begin implementing the approved CNMP not later than October 31, 2002.

4. The operation must have a certified operator by October 31, 2001. The operator must be trained and certified, in accordance with 391-3-6-.20(13).

5. New operations must be designed and constructed to handle the runoff from a 25-year, 24-hour storm event without an overflow from the storage lagoon.

6. New operations located within significant ground water recharge areas which fall within categories defined in the Georgia Department of Natural Resources Rules for Environmental Planning Criteria, Chapter 391-3-15-.02, Paragraph 3.(e) must be provided with either a compacted clay or synthetic liner such that the vertical hydraulic conductivity does not exceed 5×10^{-7} cm/sec or other criteria as determined by the Division. If it is determined that an existing lagoon is creating a ground water contamination problem, the Division may require the lagoon to be repaired.

7. New barns, new lagoons, and waste disposal systems for new swine feeding operations or for existing swine feeding operations that are expanding production shall not be located within a 100-year flood plain.

8. All existing, new, or expanding swine feeding operations with 750 to 2500 swine weighing greater than 55 pounds, must submit a registration form to the Division, on or before October 31, 2000.

For Official Use Only

State of Georgia
Department of Natural Resources

Application for a Land Application System (LAS) Permit as Required Under Chapter 391-3-6-.21(4)

ANIMAL (NON-SWINE) FEEDING OPERATIONS

☐ Existing Facility ☐ Proposed New Facility

I. FACILITY LOCATION INFORMATION (ATTACH A GOOD MAP)

FACILITY NAME: ____________________ PHONE: ____________

MAILING ADDRESS: ____________________ CITY: ____________ ZIP CODE: ____________

STREET/LOCATION ADDRESS: ________________________________

CITY: ____________ COUNTY: ____________ ZIP CODE: ____________

II. FACILITY OWNER-OPERATOR INFORMATION

LEGAL NAME: ____________________ PHONE: ____________

ADDRESS: ________________________________

CITY: ____________ STATE: ____________ ZIP CODE: ____________

III. SITE ACTIVITY INFORMATION

Maximum Number and Types of Animals That Will Be Confined or Fed for Total of 45 Days in any 12 month Period.

____

Describe the Animal Feeding/Growing Operation: ________________________________

____

____

____

Does any other animal feeding operation adjoin this facility or utilize a common area for disposal of wastes from this facility? ____________ If yes, then attach size and ownership information for the other facilities.

IV. COMMENTS

V. CERTIFICATION: I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based upon my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Printed Name: ____________________ Title: ____________

Signature: ____________________ Date: ____________

Instructions
Application for a Land Application System (LAS) Permit
as Required Under, Chapter 391-3-6-.21(4)
ANIMAL (Non-Swine) FEEDING OPERATION

Who must file this Application Form

mal (Non-Swine) feeding operations which confine more than 300 Animal Units but less than 1000 Animal Units (i.e. 300-1000 slaughter or feeder cattle; 200-700 mature dairy cattle; 9000-30,000 laying hens or broilers with a liquid manure handling system; 150-500 horses; 3000-10,000 sheep or lambs; 16,000-55,000 turkeys; or 1500-5000 ducks) must file this application form with the Georgia Environmental Protection Division under Georgia's Rules for Water Quality Control, Chapter 391-3-6-.21(4).

If you have questions regarding permitting of animal (non-swine) feeding operations, please contact the Industrial Wastewater Unit of the Permitting, Compliance and Enforcement Program at (404) 362-2680.

Where to file. Application Forms must be sent to:

Georgia Environmental Protection Division
Permitting, Compliance and Enforcement Program
4220 International Parkway, Suite 101
Atlanta, Georgia 30354

Section I. Facility Location Information: Enter the facility□s name, street address, mailing address, county, and telephone number. Should the facility lack a street address, describe where the facility is located in □Section IV. Comments□. Attach a topographic map of the area extending to at least one mile beyond property bounderies showing facility location.

Section II. Facility Owner-Operator Information: Enter the owner-operator□s legal name, mailing address and telephone number.

Section III. Facility Activity Information: Provide the number and type of animals that will be confined at the facility and describe the feeding/growing operation.

Indicate if this animal feeding operation is associated through common ownership or common use of facilities with any other adjacent animal feeding operations. If yes, then provide size and ownership information for the associated operations.

Section IV. Comments: Provide comments as appropriate.

Section V. Certification: Provide the information requested and have the application form signed by one of the following people:

- ♦For a corporation: by a responsible corporate officer, which means president, secretary, treasurer, or vice president of the corporation; or
- ♦For a partnership or sole proprietorship: by a general partner or the proprietor.

Summary of Land Application System (LAS) Permit Requirements Under Chapter 391-3-6-.21(4)

1. There shall be no discharge of pollutants from lagoons into surface waters of the State except under 25-year, 24-hour storm events.

2. New operations must have waste storage and disposal systems in operation that have been designed and constructed in accordance with Natural Resource Conservation Service (NRCS) guidance prior to beginning of feeding.

3. By October 31, 2002, existing operations shall submit to the Division a Comprehensive Nutrient Management Plan (CNMP) for the animal feeding operation. The CNMP shall be of sufficient substance and quality as to be approvable by the Division. The owner or operator shall receive the Division□s approval of the CNMP by July 1, 2003, and shall begin implementing the approved CNMP not later than October 31, 2003. New or expanding operations must receive approval of the CNMP prior to beginning or expanding of feeding.

4. Existing operations must have a certified operator by October 31, 2002. New or expanding operations must have a certified operator prior to beginning or expanding of feeding. The operator must be trained and certified in accordance with 391-3-6-.21(9).

5. New operations must be designed and constructed to handle the runoff from a 25-year, 24-hour storm event without an overflow from the storage lagoon.

6. New operations located within significant ground water recharge areas which fall within categories defined in the Georgia Department of Natural Resources Rules for Environmental Planning Criteria, Chapter 391-3-15-.02, Paragraph 3(e) must be provided with either a compacted clay or synthetic liner such that the vertical hydraulic conductivity does not exceed 5×10^{-7} cm/sec or other criteria as determined by the Division. If it is determined that an existing lagoon is creating a ground water contamination problem, the Division may require the lagoon to be repaired.

7. New barns and lagoons for new animal feeding operations or for existing animal feeding operations that are expanding production shall not be located within a 100-year flood plain.

All existing animal (non-swine) feeding operations with 300 to 1000 animal units, must submit an application form to the Division, on or before October 31, 2001. New or expanding operations should submit applications 180 days prior to beginning or expanding of feeding operations.

Please print or type in the unshaded areas only
(fill–in areas are spaced for elite type, i.e., 12 characters/inch).

Form Approved. OMB No. 2040-0086.

FORM 1 GENERAL

EPA

U.S. ENVIRONMENTAL PROTECTION AGENCY

GENERAL INFORMATION

Consolidated Permits Program

(Read the "General Instructions" before starting.)

I. EPA I.D. NUMBER

S F | T/A C | D

LABEL ITEMS

I. EPA I.D. NUMBER

III. FACILITY NAME

V. FACILITY MAILING ADDRESS

VI. FACILITY LOCATION

PLEASE PLACE LABEL IN THIS SPACE

GENERAL INSTRUCTIONS

If a preprinted label has been provided, affix it in the designated space. Review the information carefully; if any of it is incorrect, cross through it and enter the correct data in the appropriate fill–in area below. Also, if any of the preprinted data is absent *(the area to the left of the label space lists the information that should appear)*, please provide it in the proper fill–in area*(s)* below. If the label is complete and correct, you need not complete Items I, III, V, and VI *(except VI-B which must be completed regardless)*. Complete all items if no label has been provided. Refer to the instructions for detailed item descriptions and for the legal authorizations under which this data is collected.

II. POLLUTANT CHARACTERISTICS

INSTRUCTIONS: Complete A through J to determine whether you need to submit any permit application forms to the EPA. If you answer "yes" to any questions, you must submit this form and the supplemental form listed in the parenthesis following the question. Mark "X" in the box in the third column if the supplemental form is attached. If you answer "no" to each question, you need not submit any of these forms. You may answer "no" if your activity is excluded from permit requirements; see Section C of the instructions. See also, Section D of the instructions for definitions of bold–faced terms.

SPECIFIC QUESTIONS	YES	NO	FORM ATTACHED	SPECIFIC QUESTIONS	YES	NO	FORM ATTACHED
A. Is this facility a **publicly owned treatment works** which results in a **discharge** to **waters of the U.S.**? (FORM 2A)	16	17	18	B. Does or will this facility *(either existing or proposed)* include a **concentrated animal feeding operation** or **aquatic animal production facility** which results in a **discharge to waters of the U.S.**? (FORM 2B)	19	20	21
C. Is this a facility which currently results in discharges to waters of the U.S. other than those described in A or B above? (FORM 2C)	22	23	24	D. Is this a proposed facility *(other than those described in A or B above)* which will result in a **discharge** to **waters of the U.S.**? (FORM 2D)	25	26	27
E. Does or will this facility treat, store, or dispose of hazardous wastes? (FORM 3)	28	29	30	F. Do you or will you inject at this facility industrial or municipal effluent below the lowermost stratum containing, within one quarter mile of the well bore, underground sources of drinking water? (FORM 4)	31	32	33
G. Do you or will you inject at this facility any produced water or other fluids which are brought to the surface in connection with conventional oil or natural gas production, inject fluids used for enhanced recovery of oil or natural gas, or inject fluids for storage of liquid hydrocarbons? (FORM 4)	34	35	36	H. Do you or will you inject at this facility fluids for special processes such as mining of sulfur by the Frasch process, solution mining of minerals, in situ combustion of fossil fuel, or recovery of geothermal energy? (FORM 4)	37	38	39
I. Is this facility a proposed **stationary source** which is one of the 28 industrial categories listed in the instructions and which will potentially emit 100 tons per year of any air pollutant regulated under the Clean Air Act and may affect or be located in an attainment area? (FORM 5)	40	41	42	J. Is this facility a proposed **stationary source** which is NOT one of the 28 industrial categories listed in the instructions and which will potentially emit 250 tons per year of any air pollutant regulated under the Clean Air Act and may affect or be located in an attainment area? (FORM 5)	43	44	45

III. NAME OF FACILITY

C 1 SKIP

15 16 - 29 30 69

IV. FACILITY CONTACT

A. NAME & TITLE *(last, first, & title)* | B. PHONE *(area code & no.)*

C 2

15 16 45 46 48 49 51 52 55

V. FACILITY MAILING ADDRESS

A. STREET OR P.O. BOX

C 3

15 16 45

B. CITY OR TOWN | C. STATE | D. ZIP CODE

C 4

15 16 40 41 42 47 51

VI. FACILITY LOCATION

A. STREET, ROUTE NO. OR OTHER SPECIFIC IDENTIFIER

C 5

15 16 45

B. COUNTY NAME

46 70

C. CITY OR TOWN | D. STATE | E. ZIP CODE | F. COUNTY CODE *(if known)*

C 6

15 16 40 41 42 47 51 52 54

EPA Form 3510-1 (8-90)

CONTINUE ON REVERSE

CONTINUED FROM THE FRONT

VII. SIC CODES (4-digit, in order of priority)

A. FIRST		B. SECOND	
C 7	(specify)	C 7	(specify)
C. THIRD		**D. FOURTH**	
C 7	(specify)	C 7	(specify)

VIII. OPERATOR INFORMATION

A. NAME

C 8

B. Is the name listed in Item VIII-A also the owner?
☐ YES ☐ NO

C. STATUS OF OPERATOR (Enter the appropriate letter into the answer box: if "Other", specify.)

F = FEDERAL
S = STATE
P = PRIVATE
M = PUBLIC (other than federal or state)
O = OTHER (specify)

(specify)

D. PHONE (area code & no.)

C A

E. STREET OR P.O. BOX

F. CITY OR TOWN

C B

G. STATE

H. ZIP CODE

IX. INDIAN LAND

Is the facility located on Indian lands?
☐ YES ☐ NO

X. EXISTING ENVIRONMENTAL PERMITS

A. NPDES (Discharges to Surface Water)	D. PSD (Air Emissions from Proposed Sources)
C T I: 9 N	C T I: 9 P
B. UIC (Underground Injection of Fluids)	E. OTHER (specify)
C T I: 9 U	C T I: 9 — (specify)
C. RCRA (Hazardous Wastes)	E. OTHER (specify)
C T I: 9 R	C T I: 9 — (specify)

XI. MAP

Attach to this application a topographic map of the area extending to at least one mile beyond property bounderies. The map must show the outline of the facility, the location of each of its existing and proposed intake and discharge structures, each of its hazardous waste treatment, storage, or disposal facilities, and each well where it injects fluids underground. Include all springs, rivers and other surface water bodies in the map area. See instructions for precise requirements.

XII. NATURE OF BUSINESS (provide a brief description)

XIII. CERTIFICATION (see instructions)

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those persons immediately responsible for obtaining the information contained in the application, I believe that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

A. NAME & OFFICIAL TITLE (type or print)	B. SIGNATURE	C. DATE SIGNED

COMMENTS FOR OFFICIAL USE ONLY

C C

United States
Environmental Protection
Agency

Office of
Enforcement
Washington, DC 20460

EPA Form 3510-1
Revised August 1990

Permits Division

EPA

Application Form 1 - General Information

Consolidated Permits Program

This form must be completed by all persons applying for a permit under EPA's Consolidated Permits Program. See the general instructions to Form 1 to determine which other application forms you will need.

DESCRIPTION OF CONSOLIDATED PERMIT APPLICATION FORMS

The Consolidated Permit Application Forms are:

Form 1 — General Information *(included in this part)*;

Form 2 — Discharges to Surface Water *(NPDES Permits)*:

2A. Publicly Owned Treatment Works *(Reserved — not included in this package)*,

2B. Concentrated Animal Feeding Operations and Aquatic Animal Production Facilities *(not included in this package)*,

2C. Existing Manufacturing, Commercial, Mining, and Silvicultural Operations *(not included in this package)*, and

2D. New Manufacturing, Commercial, Mining, and Silvicultural Operations *(Reserved — not included in this package)*;

Form 3 — Hazardous Waste Application Form *(RCRA Permits — not included in this package)*;

Form 4 — Underground Injection of Fluids *(UIC Permits — Reserved — not included in this package)*; and

Form 5 — Air Emissions in Attainment Areas *(PSD Permits — Reserved — not included in this package)*.

FORM 1 PACKAGE TABLE OF CONTENTS

SECTION A — GENERAL INSTRUCTIONS

Who Must Apply

With the exceptions described in Section C of these instructions, Federal laws prohibit you from conducting any of the following activities without a permit.

NPDES *(National Pollutant Discharge Elimination System Under the Clean Water Act, 33 U.S.C. 1251)*. Discharge of pollutants into the waters of the United States.

RCRA *(Resource Conservation and Recovery Act, 42 U.S.C. 6901)*. Treatment, storage, or disposal of hazardous wastes.

UIC *(Underground Injection Control Under the Safe Drinking Water Act, 42 U.S.C. 300f)*. Injection of fluids underground by gravity flow or pumping.

PSD *(Prevention of Significant Deterioration Under the Clean Air Act, 72 U.S.C. 7401)*. Emission of an air pollutant by a new or modified facility in or near an area which has attained the National Ambient Air Quality Standards for that pollutant.

Each of the above permit programs is operated in any particular State by either the United States Environmental Protection Agency *(EPA)* or by an approved State agency. You must use this application form to apply for a permit for those programs administered by EPA. For those programs administered by approved States, contact the State environmental agency for the proper forms.

If you have any questions about whether you need a permit under any of the above programs, or if you need information as to whether a particular program is administered by EPA or a State agency, or if you need to obtain application forms, contact your EPA Regional office *(listed in Table 1)*.

Upon your request, and based upon information supplied by you, EPA will determine whether you are required to obtain a permit for a particular facility. Be sure to contact EPA if you have a question, because Federal laws provide that you may be heavily penalized if you do not apply for a permit when a permit is required.

Form 1 of the EPA consolidated application forms collects general information applying to all programs. You must fill out Form 1 regardless of which permit you are applying for. In addition, you must fill out one of the supplementary forms *(Forms 2 — 5)* for each permit needed under each of the above programs. Item II of Form 1 will guide you to the appropriate supplementary forms.

You should note that there are certain exclusions to the permit requirements listed above. The exclusions are described in detail in Section C of these instructions. If your activities are excluded from permit requirements then you do not need to complete and return any forms.

NOTE: Certain activities not listed above also are subject to EPA administered environmental permit requirements. These include permits for ocean dumping, dredged or fill material discharging, and certain types of air emissions. Contact your EPA Regional office for further information.

Table 1. Addresses of EPA Regional Contacts and States Within the Regional Office Jurisdictions

REGION I

Permit Contact, Environmental and Economic Impact Office, U.S. Environmental Protection Agency, John F. Kennedy Building, Boston, Massachusetts 02203, (617) 223–4635, FTS 223–4635.
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

REGION II

Permit Contact, Permits Administration Branch, Room 432, U.S. Environmental Protection Agency, 26 Federal Plaza, New York, New York 10007, (212) 264–9880, FTS 264–9880.
New Jersey, New York, Virgin Islands, and Puerto Rico.

REGION III

Permit Contact *(3 EN 23)*, U.S. Environmental Protection Agency, 6th & Walnut Streets, Philadelphia, Pennsylvania 19106, (215) 597–8816, FTS 597–8816.
Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia.

REGION IV

Permit Contact, Permits Section, U.S. Environmental Protection Agency, 345 Courtland Street, N.E., Atlanta, Georgia 30365, (404) 881–2017, FTS 257–2017.
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

REGION V

Permit Contact *(5EP)*, U.S. Environmental Protection Agency, 230 South Dearborn Street, Chicago, Illinois 60604, (312) 353–2105, FTS 353–2105.
Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.

Table 1 *(continued)*

REGION VI

Permit Contact *(6AEP)*, U.S. Environmental Protection Agency, First International Building, 1201 Elm Street, Dallas, Texas 75270, (214) 767–2765, FTS 729–2765.
Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.

REGION VII

Permit Contact, Permits Branch, U.S. Environmental Protection Agency, 324 East 11th Street, Kansas City, Missouri 64106, (816) 758–5955, FTS 758–5955.
Iowa, Kansas, Missouri, and Nebraska.

REGION VIII

Permit Contact *(8E–WE)*, Suite 103, U.S. Environmental Protection Agency, 1860 Lincoln Street, Denver, Colorado 80295, (303) 837–4901, FTS 327–4901.
Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.

REGION IX

Permit Contact, Permits Branch *(E–4)*, U.S. Environmental Protection Agency, 215 Fremont Street, San Francisco, California 94105, (415) 556–3450, FTS 556–3450.
Arizona, California, Hawaii, Nevada, Guam, American Samoa, and Trust Territories.

REGION X

Permit Contact *(M/S 521)*, U.S. Environmental Protection Agency, 1200 6th Avenue, Seattle, Washington 98101, (206) 442–7176, FTS 399–7176.
Alaska, Idaho, Oregon, and Washington.

Where to File

The application forms should be mailed to the EPA Regional office whose Region includes the State in which the facility is located *(see Table 1)*.

If the State in which the facility is located administers a Federal permit program under which you need a permit, you should contact the appropriate State agency for the correct forms. Your EPA Regional office *(Table 1)* can tell you to whom to apply and can provide the appropriate address and phone number.

When to File

Because of statutory requirements, the deadlines for filing applications vary according to the type of facility you operate and the type of permit you need. These deadlines are as follows:[1]

Table 2. Filing Dates for Permits

FORM *(permit)*	WHEN TO FILE
2A *(NPDES)*	180 days before your present NPDES permit expires.
2B *(NPDES)*	180 days before your present NPDES permit expires[2], or 180 days prior to startup if you are a new facility.
2C *(NPDES)*	180 days before your present NPDES permit expires[2].
2D *(NPDES)*	180 days prior to startup.
3 *(Hazardous Waste)*	Existing facility: Six months following publication of regulations listing hazardous wastes. New facility: 180 days before commencing physical construction.
4 *(UIC)*	A reasonable time prior to construction for new wells; as directed by the Director for existing wells.
5 *(PSD)*	Prior to commencement of construction.

[1] Please note that some of these forms are not yet available for use and are listed as "Reserved" at the beginning of these instructions. Contact your EPA Regional office for information on current application requirements and forms.

[2] If your present permit expires on or before November 30, 1980, the filing date is the date on which your permit expires. If your permit expires during the period December 1, 1980 – May 31, 1981, the filing date is 90 days before your permit expires.

Federal regulations provide that you may not begin to construct a new source in the NPDES program, a new hazardous waste management facility, a new injection well, or a facility covered by the PSD program before the issuance of a permit under the applicable program. Please note that if you are required to obtain a permit before beginning construction, as described above, you may need to submit your permit application well in advance of an applicable deadline listed in Table 2.

Fees

The U.S. EPA does not require a fee for applying for any permit under the consolidated permit programs. *(However, some States which administer one or more of these programs require fees for the permits which they issue.)*

Availability of Information to Public

Information contained in these application forms will, upon request, be made available to the public for inspection and copying. However, you may request confidential treatment for certain information which you submit on certain supplementary forms. The specific instructions for each supplementary form state what information on the form, if any, may be claimed as confidential and what procedures govern the claim. No information on Forms 1 and 2A through 2D may be claimed as confidential.

Completion of Forms

Unless otherwise specified in instructions to the forms, each item in each form must be answered. To indicate that each item has been considered, enter "NA," for not applicable, if a particular item does not fit the circumstances or characteristics of your facility or activity.

If you have previously submitted information to EPA or to an approved State agency which answers a question, you may either repeat the information in the space provided or attach a copy of the previous submission. Some items in the form require narrative explanation. If more space is necessary to answer a question, attach a separate sheet entitled "Additional Information."

Financial Assistance for Pollution Control

There are a number of direct loans, loan guarantees, and grants available to firms and communities for pollution control expenditures. These are provided by the Small Business Administration, the Economic Development Administration, the Farmers Home Administration, and the Department of Housing and Urban Development. Each EPA Regional office *(Table 1)* has an economic assistance coordinator who can provide you with additional information.

EPA's construction grants program under Title II of the Clean Water Act is an additional source of assistance to publicly owned treatment works. Contact your EPA Regional office for details.

SECTION B – FORM 1 LINE-BY-LINE INSTRUCTIONS

This form must be completed by all applicants.

Completing This Form

Please type or print in the unshaded areas only. Some items have small graduation marks in the fill–in spaces. These marks indicate the number of characters that may be entered into our data system. The marks are spaced at 1/6" intervals which accommodate elite type *(12 characters per inch)*. If you use another type you may ignore the marks. If you print, place each character between the marks. Abbreviate if necessary to stay within the number of characters allowed for each item. Use one space for breaks between words, but not for punctuation marks unless they are needed to clarify your response.

Item I

Space is provided at the upper right hand corner of Form 1 for insertion of your EPA Identification Number. If you have an existing facility, enter your Identification Number. If you don't know your EPA Identification Number, please contact your EPA Regional office *(Table 1)*, which will provide you with your number. If your facility is new *(not yet constructed)*, leave this item blank.

Item II

Answer each question to determine which supplementary forms you need to fill out. Be sure to check the glossary in Section D of these instructions for the legal definitions of the **bold faced words**. Check Section C of these instructions to determine whether your activity is excluded from permit requirements.

If you answer "no" to every question, then you do not need a permit, and you do not need to complete and return any of these forms.

If you answer "yes" to any question, then you must complete and file the supplementary form by the deadline listed in Table 2 along with this form. *(The applicable form number follows each question and is enclosed in parentheses.)* You need not submit a supplementary form if you already have a permit under the appropriate Federal program, unless your permit is due to expire and you wish to renew your permit.

Questions (I) and (J) of Item II refer to major new or modified sources subject to Prevention of Significant Deterioration *(PSD)* requirements under the Clean Air Act. For the purpose of the PSD program, major sources are defined as: (A) Sources listed in Table 3 which have the potential to emit 100 tons or more per year emissions; and (B) All other sources with the potential to emit 250 tons or more per year. See Section C of these instructions for discussion of exclusions of certain modified sources.

Table 3. 28 Industrial Categories Listed in Section 169(1) of the Clean Air Act of 1977

Fossil fuel–fired steam generators of more than 250 million BTU per hour heat input;
Coal cleaning plants *(with thermal dryers)*;
Kraft pulp mills;
Portland cement plants;
Primary zinc smelters;
Iron and steel mill plants;
Primary aluminum ore reduction plants;
Primary copper smelters;
Municipal incinerators capable of charging more than 250 tons of refuse per day;
Hydrofluoric acid plants;
Nitric acid plants;
Sulfuric acid plants;
Petroleum refineries;
Lime plants;
Phosphate rock processing plants;
Coke oven batteries;
Sulfur recovery plants;
Carbon black plants *(furnace process)*;
Primary lead smelters;
Fuel conversion plants;
Sintering plants;
Secondary metal production plants;
Chemical process plants;
Fossil fuel boilers *(or combination thereof)* totaling more than 250 million BTU per hour heat input;

Table 3 *(continued)*

Petroleum storage and transfer units with a total storage capacity exceeding 300,000 barrels;
Taconite ore processing plants;
Glass fiber processing plants; and
Charcoal production plants.

Item III

Enter the facility's official or legal name. Do not use a colloquial name.

Item IV

Give the name, title, and work telephone number of a person who is thoroughly familiar with the operation of the facility and with the facts reported in this application and who can be contacted by reviewing offices if necessary.

Item V

Give the complete mailing address of the office where correspondence should be sent. This often is not the address used to designate the location of the facility or activity.

Item VI

Give the address or location of the facility identified in Item III of this form. If the facility lacks a street name or route number, give the most accurate alternative geographic information *(e.g., section number or quarter section number from county records or at intersection of Rts. 425 and 22)*.

Item VII

List, in descending order of significance, the four 4–digit standard industrial classification *(SIC)* codes which best describe your facility in terms of the principal products or services you produce or provide. Also, specify each classification in words. These classifications may differ from the SIC codes describing the operation generating the discharge, air emissions, or hazardous wastes.

SIC code numbers are descriptions which may be found in the "Standard Industrial Classification Manual" prepared by the Executive Office of the President, Office of Management and Budget, which is available from the Government Printing Office, Washington, D.C. Use the current edition of the manual. If you have any questions concerning the appropriate SIC code for your facility, contact your EPA Regional office *(see Table 1)*.

Item VIII–A

Give the name, as it is legally referred to, of the person, firm, public organization, or any other entity which operates the facility described in this application. This may or may not be the same name as the facility. The operator of the facility is the legal entity which controls the facility's operation rather than the plant or site manager. Do not use a colloquial name.

Item VIII–B

Indicate whether the entity which operates the facility also owns it by marking the appropriate box.

Item VIII–C

Enter the appropriate letter to indicate the legal status of the operator of the facility. Indicate "public" for a facility solely owned by local government*(s)* such as a city, town, county, parish, etc.

Items VIII–D – H

Enter the telephone number and address of the operator identified in Item VIII–A.

Item IX

Indicate whether the facility is located on Indian Lands.

Item X

Give the number of each presently effective permit issued to the facility for each program or, if you have previously filed an application but have not yet received a permit, give the number of the application, if any. Fill in the unshaded area only. If you have more than one currently effective permit for your facility under a particular permit program, you may list additional permit numbers on a separate sheet of paper. List any relevant environmental Federal *(e.g., permits under the Ocean Dumping Act, Section 404 of the Clean Water Act or the Surface Mining Control and Reclamation Act)*, State *(e.g., State permits for new air emission sources in nonattainment areas under Part D of the Clean Air Act or State permits under Section 404 of the Clean Water Act)*, or local permits or applications under "other."

Item XI

Provide a topographic map or maps of the area extending at least to one mile beyond the property boundaries of the facility which clearly show the following:

The legal boundaries of the facility;

The location and serial number of each of your existing and proposed intake and discharge structures;

All hazardous waste management facilities;

Each well where you inject fluids underground; and

All springs and surface water bodies in the area, plus all drinking water wells within 1/4 mile of the facility which are identified in the public record or otherwise known to you.

If an intake or discharge structure, hazardous waste disposal site, or injection well associated with the facility is located more than one mile from the plant, include it on the map, if possible. If not, attach additional sheets describing the location of the structure, disposal site, or well, and identify the U.S. Geological Survey *(or other)* map corresponding to the location.

On each map, include the map scale, a meridian arrow showing north, and latitude and longitude at the nearest whole second. On all maps of rivers, show the direction of the current, and in tidal waters, show the directions of the ebb and flow tides. Use a 7-1/2 minute series map published by the U.S. Geological Survey, which may be obtained through the U.S. Geological Survey Offices listed below. If a 7-1/2 minute series map has not been published for your facility site, then you may use a 15 minute series map from the U.S. Geological Survey. If neither a 7-1/2 nor 15 minute series map has been published for your facility site, use a plat map or other appropriate map, including all the requested information; in this case, briefly describe land uses in the map area *(e.g., residential, commercial)*.

You may trace your map from a geological survey chart, or other map meeting the above specifications. If you do, your map should bear a note showing the number or title of the map or chart it was traced from. Include the names of nearby towns, water bodies, and other prominent points. An example of an acceptable location map is shown in Figure 1–1 of these instructions. *(NOTE: Figure 1–1 is provided for purposes of illustration only, and does not represent any actual facility.)*

U.S.G.S. OFFICES	AREA SERVED
Eastern Mapping Center National Cartographic Information Center U.S.G.S. 536 National Center Reston, Va. 22092 Phone No. (703) 860–6336	Ala., Conn., Del., D.C., Fla., Ga., Ind., Ky., Maine, Md., Mass., N.H., N.J., N.Y., N.C., S.C., Ohio, Pa., Puerto Rico, R.I., Tenn., Vt., Va., W. Va., and Virgin Islands.
Mid Continent Mapping Center National Cartographic Information Center U.S.G.S. 1400 Independance Road Rolla, Mo. 65401 Phone No. (314) 341–0851	Ark., Ill., Iowa, Kans., La., Mich., Minn., Miss., Mo., N. Dak., Nebr., Okla., S. Dak., and Wis.
Rocky Mountain Mapping Center National Cartographic Infomation Center U.S.G.S. Stop 504, Box 25046 Federal Center Denver, Co. 80225 Phone No. (303) 234–2326	Alaska, Colo., Mont., N. Mex., Tex., Utah, and Wyo.
Western Mapping Center National Cartographic Information Center U.S.G.S. 345 Middlefield Road Menlo Park, Ca. 94025 Phone No. (415) 323–8111	Ariz., Calif., Hawaii, Idaho, Nev., Oreg., Wash., American Samoa, Guam, and Trust Territories

Item XI *(continued)*

Item XII

Briefly describe the nature of your business *(e.g., products produced or services provided)*.

Item XIII

Federal statues provide for severe penalties for submitting false information on this application form.

18 U.S.C. Section 1001 provides that "Whoever, in any matter within the jurisdiction of any department or agency of the United States knowingly and willfully falsifies, conceals or covers up by any trick, scheme, or device a material fact, or makes or uses any false writing or document knowing same to contain any false, fictitious or fraudulent statement or entry, shall be fined not more than $10,000 or imprisoned not more than five years, or both."

Section 309(c)(2) of the Clean Water Act and Section 113(c)(2) of the Clean Air Act each provide that "Any person who knowingly makes any false statement, representation, or certification in any application, . . . shall upon conviction, be punished by a fine of no more than $10,000 or by imprisonment for not more than six months, or both."

In addition, Section 3008(d)(3) of the Resource Conservation and Recovery Act provides for a fine up to $25,000 per day or imprisonment up to one year, or both, for a first conviction for making a false statement in any application under the Act, and for double these penalties upon subsequent convictions.

FEDERAL REGULATIONS REQUIRE THIS APPLICATION TO BE SIGNED AS FOLLOWS:

A. For a corporation, by a principal executive officer of at least the level of vice president. However, if the only activity in Item II which is marked "yes" is Question G, the officer may authorize a person having responsibility for the overall operations of the well or well field to sign the certification. In that case, the authorization must be written and submitted to the permitting authority.

B. For partnership or sole proprietorship, by a general partner or the proprietor, respectively; or

C. For a municipality, State, Federal, or other public facility, by either a principal executive officer or ranking elected official.

SECTION C – ACTIVITIES WHICH DO NOT REQUIRE PERMITS

I. National Pollutant Discharge Elimination System Permits Under the Clean Water Act. You are not required to obtain an NPDES permit if your discharge is in one of the following categories, as provided by the Clean Water Act *(CWA)* and by the NPDES regulations *(40 CFR Parts 122–125)*. However, under Section 510 of CWA a discharge exempted from the federal NPDES requirements may still be regulated by a State authority; contact your State environmental agency to determine whether you need a State permit.

A. DISCHARGES FROM VESSELS. Discharges of sewage from vessels, effluent from properly functioning marine engines, laundry, shower, and galley sink wastes, and any other discharge incidental to the normal operation of a vessel do not require NPDES permits. However, discharges of rubbish, trash, garbage, or other such materials discharged overboard require permits, and so do other discharges when the vessel is operating in a capacity other than as a means of transportation, such as when the vessel is being used as an energy or mining facility, a storage facility, or a seafood processing facility, or is secured to the bed of the ocean, contiguous zone, or waters of the United States for the purpose of mineral or oil exploration or development.

B. DREDGED OR FILL MATERIAL. Discharges of dredged or fill material into waters of the United States do not need NPDES permits if the dredging or filling is authorized by a permit issued by the U.S. Army Corps of Engineers or an EPA approved State under Section 404 of CWA.

C. DISCHARGES INTO PUBLICLY OWNED TREATMENT WORKS *(POTW)*. The introduction of sewage, industrial wastes, or other pollutants into a POTW does not need an NPDES permit. You must comply with all applicable pretreatment standards promulgated under Section 307(b) of CWA, which may be included in the permit issued to the POTW. If you have a plan or an agreement to switch to a POTW in the future, this does not relieve you of the obligation to apply for and receive an NPDES permit until you have stopped discharging pollutants into waters of the United States.

(NOTE: Dischargers into privately owned treatment works do not have to apply for or obtain NPDES permits except as otherwise required by the EPA Regional Administrator. The owner or operator of the treatment works itself, however, must apply for a permit and identify all users in its application. Users so identified will receive public notice of actions taken on the permit for the treatment works.)

D. DISCHARGES FROM AGRICULTURAL AND SILVICULTURAL ACTIVITIES. Most discharges from agricultural and silvicultural activities to waters of the United States do not require NPDES permits. These include runoff from orchards, cultivated crops, pastures, range lands, and forest lands. However, the discharges listed below do require NPDES permits. Definitions of the terms listed below are contained in the Glossary section of these instructions.

1. Discharges from Concentrated Animal Feeding Operations. *(See Glossary for definitions of "animal feeding operations" and "concentrated animal feeding operations." Only the latter require permits.)*

2. Discharges from Concentrated Aquatic Animal Production Facilities. *(See Glossary for size cutoffs.)*

3. Discharges associated with approved Aquaculture Projects.

4. Discharges from Silvicultural Point Sources. *(See Glossary for the definition of "silvicultural point source.")* Nonpoint source silvicultural activities are excluded from NPDES permit requirements. However, some of these activities, such as stream crossings for roads, may involve point source discharges of dredged or fill material which may require a Section 404 permit. See 33 CFR 209.120.

E. DISCHARGES IN COMPLIANCE WITH AN ON–SCENE COORDINATOR'S INSTRUCTIONS.

II. Hazardous Waste Permits Under the Resource Conservation and Recovery Act. You may be excluded from the requirement to obtain a permit under this program if you fall into one of the following categories:

Generators who accumulate their own hazardous waste on–site for less than 90 days as provided in 40 CFR 262.34;

Farmers who dispose of hazardous waste pesticide from their own use as provided in 40 CFR 262.51;

Certain persons treating, storing, or disposing of small quantities of hazardous waste as provided in 40 CFR 261.4 or 261.5; and

Owners and operators of totally enclosed treatment facilities as defined in 40 CFR 260.10.

Check with your Regional office for details. Please note that even if you are excluded from permit requirements, you may be required by Federal regulations to handle your waste in a particular manner.

III. Underground Injection Control Permits Under the Safe Drinking Water Act. You are not required to obtain a permit under this program if you:

Inject into existing wells used to enhance recovery of oil and gas or to store hydrocarbons *(note, however, that these underground injections are regulated by Federal rules)*; or

Inject into or above a stratum which contains, within 1/4 mile of the well bore, an underground source of drinking water *(unless your injection is the type identified in Item II-H, for which you do need a permit)*. However, you must notify EPA of your injection and submit certain required information on forms supplied by the Agency, and your operation may be phased out if you are a generator of hazardous wastes or a hazardous waste management facility which uses wells or septic tanks to dispose of hazardous waste.

IV. Prevention of Significant Deterioration Permits Under the Clean Air Act. The PSD program applies to newly constructed or modified facilities *(both of which are referred to as "new sources")* which increase air emissions. The Clean Air Act Amendments of 1977 exclude small new sources of air emissions from the PSD review program. Any new source in an industrial category listed in Table 3 of these instructions whose potential to emit is less than 100 tons per year is not required to get a PSD permit. In addition, any new source in an industrial category not listed in Table 3 whose potential to emit is less than 250 tons per year is exempted from the PSD requirements.

Modified sources which increase their net emissions *(the difference between the total emission increases and total emission decreases at the source)* less than the significant amount set forth in EPA regulations are also exempt from PSD requirements. Contact your EPA Regional office *(Table 1)* for further information.

SECTION D — GLOSSARY

NOTE: This Glossary includes terms used in the instructions and in Forms 1, 2B, 2C, and 3. Additional terms will be included in the future when other forms are developed to reflect the requirements of other parts of the Consolidated Permits Program. If you have any questions concerning the meaning of any of these terms, please contact your EPA Regional office *(Table 1)*.

ALIQUOT means a sample of specified volume used to make up a total composite sample.

ANIMAL FEEDING OPERATION means a lot or facility *(other than an aquatic animal production facility)* where the following conditions are met:

A. Animals *(other than aquatic animals)* have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period; and

B. Crops, vegetation, forage growth, or post—harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

Two or more animal feeding operations under common ownership are a single animal feeding operation if they adjoin each other or if they use a common area or system for the disposal of wastes.

ANIMAL UNIT means a unit of measurement for any animal feeding operation calculated by adding the following numbers: The number of slaughter and feeder cattle multiplied by 1.0; Plus the number of mature dairy cattle multiplied by 1.4; Plus the number of swine weighing over 25 kilograms *(approximately 55 pounds)* multiplied by 0.4; Plus the number of sheep multiplied by 0.1; Plus the number of horses multiplied by 2.0.

APPLICATION means the EPA standard national forms for applying for a permit, including any additions, revisions, or modifications to the forms; or forms approved by EPA for use in approved States, including any approved modifications or revisions. For RCRA, "application" also means "Application, Part B."

APPLICATION, PART A means that part of the Consolidated Permit Application forms which a RCRA permit applicant must complete to qualify for interim status under Section 3005(e) of RCRA and for consideration for a permit. Part A consists of Form 1 *(General Information)* and Form 3 *(Hazardous Waste Application Form)*.

APPLICATION, PART B means that part of the application which a RCRA permit applicant must complete to be issued a permit. *(NOTE: EPA is not developing a specific form for Part B of the permit application, but an instruction booklet explaining what information must be supplied is available from the EPA Regional office.)*

APPROVED PROGRAM or APPROVED STATE means a State program which has been approved or authorized by EPA under 40 CFR Part 123.

AQUACULTURE PROJECT means a defined managed water area which uses discharges of pollutants into that designated area for the maintenance or production of harvestable freshwater, estuarine, or marine plants or animals. "Designated area" means the portions of the waters of the United States within which the applicant plans to confine the cultivated species, using a method of plan or operation *(including, but not limited to, physical confinement)* which, on the basis of reliable scientific evidence, is expected to ensure the specific individual organisms comprising an aquaculture crop will enjoy increased growth attributable to the discharge of pollutants and be harvested within a defined geographic area.

AQUIFER means a geological formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring.

AREA OF REVIEW means the area surrounding an injection well which is described according to the criteria set forth in 40 CFR Section 146.06.

AREA PERMIT means a UIC permit applicable to all or certain wells within a geographic area, rather than to a specified well, under 40 CFR Section 122.37.

ATTAINMENT AREA means, for any air pollutant, an area which has been designated under Section 107 of the Clean Air Act as having ambient air quality levels better than any national primary or secondary ambient air quality standard for that pollutant. Standards have been set for sulfur oxides, particulate matter, nitrogen dioxide, carbon monoxide, ozone, lead, and hydrocarbons. For purposes of the Glossary, "attainment area" also refers to "unclassifiable area," which means, for any pollutants, an area designated under Section 107 as unclassifiable with respect to that pollutant due to insufficient information.

BEST MANAGEMENT PRACTICES *(BMP)* means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMP's include treatment requirements, operation procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

BIOLOGICAL MONITORING TEST means any test which includes the use of aquatic algal, invertebrate, or vertebrate species to measure acute or chronic toxicity, and any biological or chemical measure of bioaccumulation.

BYPASS means the intentional diversion of wastes from any any portion of a treatment facility.

CONCENTRATED ANIMAL FEEDING OPERATION means an animal feeding operation which meets the criteria set forth in either (A) or (B) below or which the Director designates as such on a case—by—case basis:

A. More than the numbers of animals specified in any of the following categories are confined:

1. 1,000 slaughter or feeder cattle,
2. 700 mature dairy cattle *(whether milked or dry cows)*,
3. 2,500 swine each weighing over 25 kilograms *(approximately 55 pounds)*,
4. 500 horses,
5. 10,000 sheep or lambs,
6. 55,000 turkeys,
7. 100,000 laying hens or broilers *(if the facility has a continuous overflow watering)*,
8. 30,000 laying hens or broilers *(if the facility has a liquid manure handling system)*,
9. 5,000 ducks, or
10. 1,000 animal units; or

B. More than the following numbers and types of animals are confined:

1. 300 slaughter or feeder cattle,
2. 200 mature dairy cattle *(whether milked or dry cows)*,
3. 750 swine each weighing over 25 kilograms *(approximately 55 pounds)*,
4. 150 horses,

CONCENTRATED ANIMAL FEEDING OPERATION *(continued)*

5. 3,000 sheep or lambs,

6. 16,500 turkeys,

7. 30,000 laying hens or broilers *(if the facility has continuous overflow watering)*,

8. 9,000 laying hens or broilers *(if the facility has a liquid manure handling system)*,

9. 1,500 ducks, or

10. 300 animal units; AND

Either one of the following conditions are met: Pollutants are discharged into waters of the United States through a manmade ditch, flushing system or other similar manmade device *("manmade" means constructed by man and used for the purpose of transporting wastes)*; or Pollutants are discharged directly into waters of the Unites 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.

Provided, however, that no animal feeding operation is a concentrated animal feeding operation as defined above if such animal feeding operation discharges only in the event of a 25 year, 24 hour storm event.

CONCENTRATED AQUATIC ANIMAL PRODUCTION FACILITY means a hatchery, fish farm, or other facility which contains, grows or holds aquatic animals in either of the following categories, or which the Director designates as such on a case–by–case basis:

A. Cold water fish species or other cold water aquatic animals including, but not limited to, the Salmonidae family of fish *(e.g., trout and salmon)* in ponds, raceways or other similar structures which discharge at least 30 days per year but does not include:

1. Facilities which produce less than 9,090 harvest weight kilograms *(approximately 20,000 pounds)* of aquatic animals per year; and

2. Facilities which feed less than 2,272 kilograms *(approximately 5,000 pounds)* of food during the calendar month of maximum feeding.

B. Warm water fish species or other warm water aquatic animals including, but not limited to, the Ameiuridae, Cetrarchidae, and Cyprinidae families of fish *(e.g., respectively, catfish, sunfish, and minnows)* in ponds, raceways, or other similar structures which discharge at least 30 days per year, but does not include:

1. Closed ponds which discharge only during periods of excess runoff; or

2. Facilities which produce less than 45,454 harvest weight kilograms *(approximately 100,000 pounds)* of aquatic animals per year.

CONTACT COOLING WATER means water used to reduce temperature which comes into contact with a raw material, intermediate product, waste product other than heat, or finished product.

CONTAINER means any portable device in which a material is stored, transported, treated, disposed of, or otherwise handled.

CONTIGUOUS ZONE means the entire zone established by the United States under article 24 of the convention of the Territorial Sea and the Contiguous Zone.

CWA means the Clean Water Act *(formerly referred to the Federal Water Pollution Control Act)* Pub. L. 92–500, as amended by Pub. L. 95–217 and Pub. L. 95–576, 33 U.S.C. 1251 *et seq.*

DIKE means any embankment or ridge of either natural or manmade materials used to prevent the movement of liquids, sludges, solids, or other materials.

DIRECT DISCHARGE means the discharge of a pollutant as defined below.

DIRECTOR means the EPA Regional Administrator or the State Director as the context requires.

DISCHARGE *(OF A POLLUTANT)* means:

A. Any addition of any pollutant or combination of pollutants to waters of the United States from any point source; or

B. Any addition of any pollutant or combination of pollutants to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft which is being used as a means of transportation.

This definition includes discharges into waters of the United States from: Surface runoff which is collected or channelled by man; Discharges through pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to POTW's; and Discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works. This term does not include an addition of pollutants by any indirect discharger.

DISPOSAL *(in the RCRA program)* means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any hazardous waste into or on any land or water so that the hazardous waste or any constituent of it may enter the environment or be emitted into the air or discharged into any waters, including ground water.

DISPOSAL FACILITY means a facility or part of a facility at which hazardous waste is intentionally placed into or on land or water, and at which hazardous waste will remain after closure.

EFFLUENT LIMITATION means any restriction imposed by the Director on quantities, discharge rates, and concentrations of pollutants which are discharged from point sources into waters of the United States, the waters of the continguous zone, or the ocean.

EFFLUENT LIMITATION GUIDELINE means a regulation published by the Administrator under Section 304(b) of the Clean Water Act to adopt or revise effluent limitations.

ENVIRONMENTAL PROTECTION AGENCY *(EPA)* means the United States Environmental Protection Agency.

EPA IDENTIFICATION NUMBER means the number assigned by EPA to each generator, transporter, and facility.

EXEMPTED AQUIFER means an aquifer or its portion that meets the criteria in the definition of USDW, but which has been exempted according to the procedures in 40 CFR Section 122.35(b).

EXISTING HWM FACILITY means a Hazardous Waste Management facility which was in operation, or for which construction had commenced, on or before October 21, 1976. Construction had commenced if (A) the owner or operator had obtained all necessary Federal, State, and local preconstruction approvals or permits, and either (B1) a continuous on–site, physical construction program had begun, or (B2) the owner or operator had entered into contractual obligations, which could not be cancelled or modified without substantial loss, for construction of the facility to be completed within a reasonable time.

(NOTE: This definition reflects the literal language of the statute. However, EPA believes that amendments to RCRA now in conference will shortly be enacted and will change the date for determining when a facility is an "existing facility" to one no earlier than May of 1980; indications are the conferees are considering October 30, 1980. Accordingly, EPA encourages every owner or operator of a facility which was built or under construction as of the promulgation date of the RCRA program regulations to file Part A of its permit application so that it can be quickly processed for interim status when the change in the law takes effect. When those amendments are enacted, EPA will amend this definition.)

EXISTING SOURCE or EXISTING DISCHARGER *(in the NPDES program)* means any source which is not a new source or a new discharger.

EXISTING INJECTION WELL means an injection well other than a new injection well.

FACILITY means any HWM facility, UIC underground injection well, NPDES point source, PSD stationary source, or any other facility or activity *(including land or appurtenances thereto)* that is subject to regulation under the RCRA, UIC, NPDES, or PSD programs.

FLUID means material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state.

GENERATOR means any person by site, whose act or process produces hazardous waste identified or listed in 40 CFR Part 261.

GROUNDWATER means water below the land surface in a zone of saturation.

HAZARDOUS SUBSTANCE means any of the substances designated under 40 CFR Part 116 pursuant to Section 311 of CWA. *(NOTE: These substances are listed in Table 2c–4 of the instructions to Form 2C.)*

HAZARDOUS WASTE means a hazardous waste as defined in 40 CFR Section 261.3 published May 19, 1980.

HAZARDOUS WASTE MANAGEMENT FACILITY *(HWM facility)* means all contiguous land, structures, appurtenances, and improvements on the land, used for treating, storing, or disposing of hazardous wastes. A facility may consist of several treatment, storage, or disposal operational units *(for example, one or more landfills, surface impoundments, or combinations of them)*.

IN OPERATION means a facility which is treating, storing, or disposing of hazardous waste.

INCINERATOR *(in the RCRA program)* means an enclosed device using controlled flame combustion, the primary purpose of which is to thermally break down hazardous waste. Examples of incinerators are rotary kiln, fluidized bed, and liquid injection incinerators.

INDIRECT DISCHARGER means a nondomestic discharger introducing pollutants to a publicly owned treatment works.

INJECTION WELL means a well into which fluids are being injected.

INTERIM AUTHORIZATION means approval by EPA of a State hazardous waste program which has met the requirements of Section 3006(c) of RCRA and applicable requirements of 40 CFR Part 123, Subparts A, B, and F.

LANDFILL means a disposal facility or part of a facility where hazardous waste is placed in or on land and which is not a land treatment facility, a surface impoundment, or an injection well.

LAND TREATMENT FACILITY *(in the RCRA program)* means a facility or part of a facility at which hazardous waste is applied onto or incorporated into the soil surface; such facilities are disposal facilities if the waste will remain after closure.

LISTED STATE means a State listed by the Administrator under Section 1422 of SDWA as needing a State UIC program.

MGD means millions of gallons per day.

MUNICIPALITY means a city, village, town, borough, county, parish, district, association, or other public body created by or under State law and having jurisdiction over disposal of sewage, industrial wastes, or other wastes, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under Section 208 of CWA.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)* means the national program for issuing modifying, revoking and reissuing, terminating, monitoring, and enforcing permits and imposing and enforcing pretreatment requirements, under Sections 307, 318, 402, and 405 of CWA. The term includes an approved program.

NEW DISCHARGER means any building, structure, facility, or installation: (A) From which there is or may be a new or additional discharge of pollutants at a site at which on October 18, 1972, it had never discharged pollutants; (B) Which has never received a finally effective NPDES permit for discharges at that site; and (C) Which is not a "new source." This definition includes an indirect discharger which commences discharging into waters of the United States. It also includes any existing mobile point source, such as an offshore oil drilling rig, seafood processing vessel, or aggregate plant that begins discharging at a location for which it does not have an existing permit.

NEW HWM FACILITY means a Hazardous Waste Management facility which began operation or for which construction commenced after October 21, 1976.

NEW INJECTION WELL means a well which begins injection after a UIC program for the State in which the well is located is approved.

NEW SOURCE *(in the NPDES program)* means any building, structure, facility, or installation from which there is or may be a discharge of pollutants, the construction of which commenced:

A. After promulgation of standards of performance under Section 306 of CWA which are applicable to such source; or

B. After proposal of standards of performance in accordance with Section 306 of CWA which are applicable to such source, but only if the standards are promulgated in accordance with Section 306 within 120 days of their proposal.

NON–CONTACT COOLING WATER means water used to reduce temperature which does not come into direct contact with any raw material, intermediate product, waste product *(other than heat)*, or finished product.

OFF–SITE means any site which is not "on–site."

ON–SITE means on the same or geographically contiguous property which may be divided by public or private right*(s)*–of–way, provided the entrance and exit between the properties is at a cross–roads intersection, and access is by crossing as opposed to going along, the right*(s)*–of–way. Non–contiguous properties owned by the same person, but connected by a right–of–way which the person controls and to which the public does not have access, is also considered on–site property.

OPEN BURNING means the combustion of any material without the following characteristics:

A. Control of combustion air to maintain adequate temperature for efficient combustion;

B. Containment of the combustion–reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion; and

C. Control of emission of the gaseous combustion products.

(See also "incinerator" and "thermal treatment").

OPERATOR means the person responsible for the overall operation of a facility.

OUTFALL means a point source.

OWNER means the person who owns a facility or part of a facility.

PERMIT means an authorization, license, or equivalent control document issued by EPA or an approved State to implement the requirements of 40 CFR Parts 122, 123, and 124.

PHYSICAL CONSTRUCTION *(in the RCRA program)* means excavation, movement of earth, erection of forms or structures, or similar activity to prepare a HWM facility to accept hazardous waste.

PILE means any noncontainerized accumulation of solid, nonflowing hazardous waste that is used for treatment or storage.

POINT SOURCE means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture.

POLLUTANT means dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical waste, biological materials, radioactive materials *(except those regulated under the Atomic Energy Act of 1954, as amended [42 U.S.C. Section 2011 et seq.])*, heat, wrecked or discarded equipment, rocks, sand, cellar dirt and industrial, municipal, and agriculture waste discharged into water. It does not mean:

A. Sewage from vessels; or

B. Water, gas, or other material which is injected into a well to facilitate production of oil or gas, or water derived in association with oil and gas production and disposed of in a well, if the well used either to facilitate production or for disposal purposes is approved by authority of the State in which the well is located, and if the State determines that the injection or disposal will not result in the degradation of ground or surface water resources.

(NOTE: Radioactive materials covered by the Atomic Energy Act are those encompassed in its definition of source, byproduct, or special nuclear materials. Examples of materials not covered include radium and accelerator produced isotopes. See Train v. Colorado Public Interest Research Group, Inc., 426 U.S. 1 [1976].)

PREVENTION OF SIGNIFICANT DETERIORATION *(PSD)* means the national permitting program under 40 CFR 52.21 to prevent emissions of certain pollutants regulated under the Clean Air Act from significantly deteriorating air quality in attainment areas.

PRIMARY INDUSTRY CATEGORY means any industry category listed in the NRDC Settlement Agreement *(Natural Resources Defense Council v. Train, 8 ERC 2120 [D.D.C. 1976], modified 12 ERC 1833 [D.D.C. 1979])*.

PRIVATELY OWNED TREATMENT WORKS means any device or system which is: (A) Used to treat wastes from any facility whose operator is not the operator of the treatment works; and (B) Not a POTW.

PROCESS WASTEWATER means any water which, during manufacturing or processing, comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, byproduct, or waste product.

PUBLICLY OWNED TREATMENT WORKS or POTW means any device or system used in the treatment *(including recycling and reclamation)* of municipal sewage or industrial wastes of a liquid nature which is owned by a State or municipality. This definition includes any sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

RENT means use of another's property in return for regular payment.

RCRA means the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act of 1976 *(Pub. L. 94–580, as amended by Pub. L. 95–609, 42 U.S.C. Section 6901 et seq.)*.

ROCK CRUSHING AND GRAVEL WASHING FACILITIES are facilities which process crushed and broken stone, gravel, and riprap *(see 40 CFR Part 436, Subpart B, and the effluent limitations guidelines for these facilities)*.

SDWA means the Safe Drinking Water Act *(Pub. L. 95–523, as amended by Pub. L. 95–1900, 42 U.S.C. Section 300[f] et seq.)*.

SECONDARY INDUSTRY CATEGORY means any industry category which is not a primary industry category.

SEWAGE FROM VESSELS means human body wastes and the wastes from tiolets and other receptacles intended to receive or retain body wastes that are discharged from vessels and regulated under Section 312 of CWA, except that with respect to commercial vessels on the Great Lakes this term includes graywater. For the purposes of this definition, "graywater" means galley, bath, and shower water.

SEWAGE SLUDGE means the solids, residues, and precipitate separated from or created in sewage by the unit processes of a POTW. "Sewage" as used in this definition means any wastes, including wastes from humans, households, commercial establishments, industries, and storm water runoff, that are discharged to or otherwise enter a publicly owned treatment works.

SILVICULTURAL POINT SOURCE means any discernable, confined, and discrete conveyance related to rock crushing, gravel washing, log sorting, or log storage facilities which are operated in connection with silvicultural activities and from which pollutants are discharged into waters of the United States. This term does not include nonpoint source silvicultural activities such as nursery operations, site preparation, reforestation and subsequent cultural treatment, thinning, prescribed burning, pest and fire control, harvesting operations, surface drainage, or road construction and maintenance from which there is natural runoff. However, some of these activities *(such as stream crossing for roads)* may involve point source discharges of dredged or fill material which may require a CWA Section 404 permit. "Log sorting and log storage facilities" are facilities whose discharges result from the holding of unprocessed wood, e.g., logs or roundwood with bark or after removal of bark in self–contained bodies of water *(mill ponds or log ponds)* or stored on land where water is applied intentionally on the logs *(wet decking)*. *(See 40 CFR Part 429, Subpart J, and the effluent limitations guidelines for these facilities.)*

STATE means any of the 50 States, the District of Columbia, Guam, the Commonwealth of Puerto Rico, the Virgin Islands, American Samoa, the Trust Territory of the Pacific Islands *(except in the case of RCRA)*, and the Commonwealth of the Northern Mariana Islands *(except in the case of CWA)*.

STATIONARY SOURCE *(in the PSD program)* means any building, structure, facility, or installation which emits or may emit any air pollutant regulated under the Clean Air Act. "Building, structure, facility, or installation" means any grouping of pollutant–emitting activities which are located on one or more contiguous or adjacent properties and which are owned or operated by the same person *(or by persons under common control)*.

STORAGE *(in the RCRA program)* means the holding of hazardous waste for a temporary period at the end of which the hazardous waste is treated, disposed, or stored elsewhere.

STORM WATER RUNOFF means water discharged as a result of rain, snow, or other precipitation.

SURFACE IMPOUNDMENT or IMPOUNDMENT means a facility or part of a facility which is a natural topographic depression, manmade excavation, or diked area formed primarily of earthen materials *(although it may be lined with manmade materials)*, which is designed to hold an accumulation of liquid wastes or wastes containing free liquids, and which is not an injection well. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons.

TANK *(in the RCRA program)* means a stationary device, designed to contain an accumulation of hazardous waste which is constructed primarily of non–earthen materials *(e.g., wood, concrete, steel, plastic)* which provide structural support.

THERMAL TREATMENT *(in the RCRA program)* means the treatment of hazardous waste in a device which uses elevated temperature as the primary means to change the chemical, physical, or biological character or composition of the hazardous waste. Examples of thermal treatment processes are incineration, molten salt, pyrolysis, calcination, wet air oxidation, and microwave discharge. *(See also "incinerator" and "open burning").*

TOTALLY ENCLOSED TREATMENT FACILITY *(in the RCRA program)* means a facility for the treatment of hazardous waste which is directly connected to an industrial production process and which is constructed and operated in a manner which prevents the release of any hazardous waste or any constituent thereof into the environment during treatment. An example is a pipe in which waste acid is neutralized.

TOXIC POLLUTANT means any pollutant listed as toxic under Section 307(a)(1) of CWA.

TRANSPORTER *(in the RCRA program)* means a person engaged in the off–site transportation of hazardous waste by air, rail, highway, or water.

TREATMENT *(in the RCRA program)* means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non–hazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

UNDERGROUND INJECTION means well injection.

UNDERGROUND SOURCE OF DRINKING WATER or USDW means an aquifer or its portion which is not an exempted aquifer and:

A. Which supplies drinking water for human consumption; or

B. In which the ground water contains fewer than 10,000 mg/l total dissolved solids.

UPSET means an exceptional incident in which there is unintentional and temporary noncompliance with technology–based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

WATERS OF THE UNITED STATES means:

A. All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;

B. All interstate waters, including interstate wetlands;

C. All other waters such as intrastate lakes, rivers, streams *(including intermittent streams)*, mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, and natural ponds, the use, degradation, or destruction of which would or could affect interstate or foreign commerce including any such waters:

1. Which are or could be used by interstate or foreign travelers for recreational or other purposes,

2. From which fish or shellfish are or could be taken and sold in interstate or foreign commerce,

3. Which are used or could be used for industrial purposes by industries in interstate commerce;

D. All impoundments of waters otherwise defined as waters of the United States under this definition;

E. Tributaries of waters identified in paragraphs (A) – (D) above;

F. The territorial sea; and

G. Wetlands adjacent to waters *(other than waters that are themselves wetlands)* identified in paragraphs (A) – (F) of this definition.

Waste treatment systems, including treatment ponds or lagoons designed to meet requirement of CWA *(other than cooling ponds as defined in 40 CFR Section 423.11(m) which also meet the criteria of this definition)* are not waters of the United States. This exclusion applies only to manmade bodies of water which neither were originally created in waters of the United States *(such as a disposal area in wetlands)* nor resulted from the impoundments of waters of the United States.

WELL INJECTION or UNDERGROUND INJECTION means the subsurface emplacement of fluids through a bored, drilled, or driven well; or through a dug well, where the depth of the dug well is greater than the largest surface dimension.

WETLANDS means those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.