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EC179 Managing Livestock Manure to Protect Environmental Quality

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Managing Livestock Manure to Protect Environmental Quality

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Foreword

Managing Livestock Manure to Protect Environmental Quality

Proper utilization of livestock manure is a major environmental concern. Livestock manure has typically been considered a ‘waste product’ of livestock production. A more accurate name for this material is a ‘recycled resource’ from the production of livestock. By managing livestock manure, the producer has a second chance to utilize the nutrients that have already been paid for but not fully utilized by the animal. Collecting, containing, and properly spreading livestock manure will incur additional costs for the producer. However, these costs can be offset or justified by the producer in terms of the yield enhancement and nutrient credits that occur when manure is utilized as a resource.

This book covers the land application part of manure management. With increasing regulations, the livestock producer needs to understand the scientific principles that affect manure transformations and how to use these principles to manage the manure for maximum fertilizer value with minimal environmental impact. Improved land application of manure is one part of the solution, but we suggest that the producer evaluate the quantity of nutrients arriving on the farm as feed, animals, and fertilizer compared to the total that is exported. Achieving a nutrient balance will reduce potential environmental hazards often associated with animal agriculture.

As the producer begins to think of manure as a resource, rather than as a waste product, it is critical that one understands what quantities of nutrients are available and what effect different manure storage and handling practices have on the nutrient availability of the recycled resource. This publication explains the basic principles related to manure nutrient utilization. In addition, sources and management of odors generated on livestock facilities will be discussed. While odors from livestock production are unavoidable and currently unregulated by the Nebraska Department of Environmental Quality (NDEQ), they have been the driving force behind recent changes in environmental laws.

Nebraska state law and regulations require specific plans and recordkeeping in order to operate a permitted livestock feeding operation. This book explains land application principles and procedures and is a companion publication to a series of workbooks that contain suggested worksheets, forms, and other publications that assist with compliance of Nebraska land application regulations.

1
Chapter

Water and Air Quality Issues

Relevant Federal and State Legislation

The federal Clean Air Act Amendment of 1990 (CAAA) has provisions of importance to producers of agricultural products. Although protecting air quality has inherent implications for livestock and poultry health as well as profitability, the language of air quality is derived principally from environmental regulations designed to protect public health and the use and enjoyment of private property. Public health concerns relating to gases and aerosols (and, to some extent, their associated odors) are expressed in ambient air quality standards, emissions permits and nuisance legislation.

The federal Water Pollution Control Act of 1972, Public Law 92-500 (PL92-500), was passed so that the effectiveness and speed of implementation of water pollution controls could be improved. This was to be accomplished by increasing Federal responsibility of establishing water quality standards and providing for greater involvement in their implementation and enforcement. The objective of PL92-500 and its subsequent amendments and revisions is to restore the chemical, physical and biological integrity of the Nation's waters. To achieve this objective, PL92-500 set a goal of no discharge of pollutants into the Nation's waters by 1985. The Nation's waters are defined to include wetlands, intermittent streams as well as conventional lakes, ponds, rivers, streams, and territorial seas.

The federal Clean Water Act (CWA) of 1977 amended PL92-500 providing more easily attainable water quality goals and time frames. The CWA strengthened PL92-500's basic requirement that point sources of pollutants (industry, municipalities, and some livestock operations) obtain permits that specify the allowable amount and constituents that can be discharged and a method for achieving no discharge compliance. The permits are known as the National Pollutant Discharge Elimination System (NPDES).

In 2003, the U.S. Environmental Protection Agency (EPA) issued revised rules for NPDES permits required of CAFOs. At the time of this writing, EPA revisions to the 2003 rules, following a court challenge, have not all been finalized. The 2003 rules will expand significantly the types of animal feeding operations (AFOs) that need an NPDES permit beyond the open lot facilities commonly permitted previously. It is likely that, under the final rule, all

FIGURE 1.1

All livestock and poultry producers have a responsibility to protect the environment.

AFOs above certain sizes (see *http://www.lpes.org/cafo/02FS_Permit.pdf*) with outdoor storage of manure (including stacked manure) or that apply manure on land managed by the AFO will be classified as a CAFO and thus need an NPDES permit. Final rules should be published during the summer of 2007.

The new CAFO regulations also require that the NPDES permit include a Nutrient Management Plan (NMP) that addresses nine facility design and land application issues (see *http://www.lpes.org/cafo/20FS_Nutrient.pdf*). The nutrient management plan is a critical expectation for maintaining an "Agricultural Stormwater Exemption" on manured fields. Failure to obtain this exemption could result in any runoff or erosion from manure fields being classified as a "Point Source" and subject to greater regulatory liability. Development and implementation of an NMP will be critical to all permitted livestock operations.

Environmental Stewardship

Most producers are familiar with the benefits of stewardship of our soil resources. Reduced tillage, contour farming, terracing, and other stewardship practices have produced a dramatic improvement in agriculture's soil resources. If livestock and poultry production operations are to survive and thrive, similar principles and attitudes of stewardship must be applied to manure management as well. Good stewardship is fundamental to the preservation of our air, water, and land resources. Manure should not just be thought of as a waste product, but rather as a resource. Proper utilization of manure as a resource can be very beneficial. Benefits of manure use include improved soil physical properties and reduced fertilizer purchases. However, improper use can have dire environmental consequences that put air, water, and soil resources at risk.

Principles of Environmental Stewardship

The following principles of environmental stewardship will help livestock and poultry producers remain viable while protecting the environment's water and air quality.

1. **Awareness of environmental risks:** The potential for adverse environmental impact varies from one operation to another due to differences in animal concentration, weather, terrain, soil type, and a host of other conditions. An assessment of potential risks is beneficial in helping to identify critical environmental risks specific to an operation, and is the key to any good stewardship program.

2. **No point source discharge:** Livestock and poultry production systems should be managed to not allow discharges from animal housing, open lots, and manure storage facilities. The animal industry is unique in its 'no

FIGURE 1.2

Livestock and poultry production systems are regulated by a strict "no discharge" policy relating to manure handling and storage facilities.

discharge' standard. Very few industries or municipalities are required to comply with such regulations. Decisions related to timing and site selection of land application should be made to minimize the risk of discharges.

3. **Balance in the use of nutrients:** Nitrogen (N) and phosphorus (P) are both essential nutrients for all life forms. However, in excess, they can contaminate water resources. Animal production systems must maintain a balance between the nutrients arriving at livestock/poultry operations (through purchased feed and fertilizer) with the nutrients leaving the operation (crop production, animals, or animal products). An excess of nutrients arriving on farms can result in an accumulation that poses environmental risk to water resources.

4. **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 utilization while minimizing the risk of runoff and leaching of the nutrients.

FIGURE 1.3

Injecting manure into the soil reduces odor and helps maintain good neighbor relations.

5. **Be a good neighbor:**
The by-products of animal production create several potential nuisances including odors, flies, noise, dust and others. A producer must be fully aware of these potential problems and the degree of concern they may cause to neighbors. If technology and management strategies are available to reduce or eliminate these nuisances, such strategies should be implemented. Where such options do not exist, producers may need to consider alternatives to offset these nuisances.

6. **Know the rules:** Federal, state, and local governments are setting minimum standards. Good stewardship requires knowledge of, and compliance with, current regulatory requirements. However, most regulations often establish a minimum standard for environmental management, whereas good stewardship often requires higher standards than the minimum regulatory requirements.

7. **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 environmental issues. Livestock expansion should occur only in areas that have adequate land bases for manure nutrients and sufficient separation distances between neighbors, surface water, and groundwater. As facilities increase in size, so must the degree of management and responsibility.

Understanding Water Quality Issues

Manure contains four primary contaminants that impact water quality: nitrogen, phosphorus, bacteria and other pathogens, and organic matter.

Nitrogen

All living things require nitrogen, the fundamental building block of protein, for growth and survival. Livestock and poultry only use part of the protein in their feed rations for the production of meat or other animal products. The remaining protein is excreted as nitrogen in manure in the form of urea (in urine), and organic nitrogen (in feces).

When manure is applied to land, the soil's aerobic environment converts common manure nitrogen forms to nitrate. Nitrate is highly soluble in water. When levels of residual nitrate become high and water moves through the soil profile, leaching can occur and cause contamination of water. There are several health concerns related to consumption of high-nitrate water. Infants and pregnant women are at greatest risk. Foremost is that nitrate contamination of drinking water restricts the oxygen in the bloodstream in infants under the age of six months, causing methemoglobinemia (blue baby syndrome). In addition, there are other less well-documented health impacts. The U.S. Environmental Protection Agency (EPA) has set a maximum contaminant level (MCL) of 10 parts per million (ppm) for nitrate in public water supplies.

Ammonium in surface water also represents an environmental risk to animals and wildlife. In most natural surface waters, total ammonium concentrations greater than 2 mg/l exceed the chronic criteria for fish.

Ammonium and organic nitrogen forms found in manure are likely to be transported with surface water runoff and erosion. These forms of nitrogen are unlikely to leach through soils. 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. Ammonium can also be converted to ammonia and transported by volatilization and deposition processes.

Phosphorus

Phosphorus is another nutrient that is essential for plant growth and development. It plays many critical functions, the primary one being the storage and transfer of energy through the plant. In confined livestock production systems, supplemental phosphorus is often essential for bone development and optimum animal performance. Commercially mined, phosphorus is a limited

Figure 1.4

Phosphorus in surface waters can promote eutrophication.

resource with approximately 40 years' supply remaining in the United States. Thus, better use of manure phosphorus provides an increasingly important alternative to commercial fertilizers.

Phosphorus transported from agricultural lands to surface waters can promote eutrophication — an abnormal growth of algae and aquatic weeds in surface waters. Eutrophication is one of the leading water quality issues facing the nation's lakes and reservoirs today. As this organic material decays, oxygen levels in the water decline, which can be detrimental to fish populations. Euthrophic surface waters may also experience blooms of cyanobacteria, which can kill livestock and pose health hazards to humans.

Phosphorus stored in soils is primarily fixed to soil minerals (iron, aluminum, and calcium) or to organic matter (living soil bacteria, crop residue, and partially decayed organic matter). Thus, soil erosion is the primary transport mechanism of particulate phosphorus to surface water.

Soil water also contains a small amount of dissolved phosphorus essential for plant uptake. Because the balance among the various phosphorus pools is heavily in favor of the organic and soil mineral forms, phosphorus leaching is rarely an issue. However, as soil phosphorus increases, phosphorus in runoff and erosion entering surface water become greater concerns.

Pathogens

Pathogens, typically microbes (e.g., bacteria, viruses, protozoa, fungi) or parasitic worms, are organisms capable of causing infection or disease in other organisms, including humans, wild and domestic animals, and plants. Several pathogens naturally occur in livestock and poultry manure and under certain circumstances may pose a risk to human health.

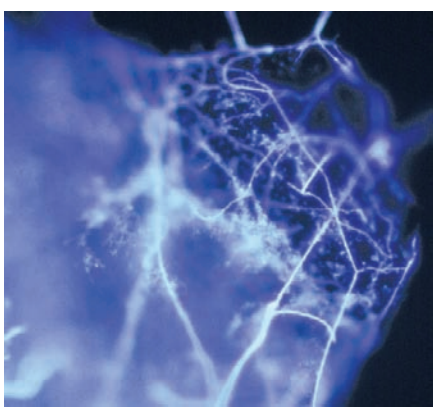


FIGURE 1.5

Soil and dust particles are often colonized by fungal hyphae (white filaments in image); spores and bacteria are also found on dust particles.

Protozoa: Many parasites are commonly found in and disseminated with manure, including *Cryptosporidium*, and *Giardia*. With respect to transmission to humans, *Cryptosporidium parvum* and *Giardia lamblia* are the two protozoa shed in animal manure of greatest concern. They are parasites that cause severe diarrhea, nausea, fever, vomiting, and fatigue in humans. In healthy humans, the infections from either organisms are usually self limiting and do not pose serious health risks. However, the risk can be much greater for the very young, the elderly, and those with immune suppressed systems (e.g., patients receiving chemotherapy, AIDS patients, and organ transplant recipients). Some protozoa, specifically *Cryptosporidium*, can survive high levels of chlorine.

Bacteria: There are several bacterial pathogens shed in livestock manure capable of causing disease in humans, including the common food-borne pathogens *Escherichia coli* O157:H7, *Salmonella*, *Listeria*, and *Clostridium*. However, unless a water supply is directly contaminated with feces containing the bacteria, the risk of human infection from bacteria in manure is relatively low. Most pathogenic bacteria can be killed with common water disinfectants such as chlorine if water contamination is suspected.

Viruses: Livestock and poultry shed several viruses in manure, but typically these viruses are not directly transmitted to humans. Influenza viruses in swine are an exception.

Parasitic worms: Parasitic worms can be disseminated in manure and survive for long periods in the absence of an animal host. These parasites are primarily a health risk for livestock, causing several different diseases in cattle and sheep.

Fungi: Many fungi, including both animal and plant pathogens, survive well and are naturally dispersed in animal manure. The enzymes found in manure may activate some fungal resting spores. Application of non-composted manure to crop production fields can result in increased crop disease.

FIGURE 1.6

Some fungal structures can survive passage through animal digestive systems and produce spores that are dispersed in the air from manure.

Manure management to reduce pathogen populations: Pathogens are most likely to be transported to water through 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. Pathogens usually do not move through soil profiles and reach groundwater because of the filtering capabilities of soil. Exceptions to this occur adjacent to poorly maintained well casings.

Most human pathogens do not multiply outside their host but can survive from a few days to several months depending upon environmental factors including temperature, moisture, pH, and oxygen. Composting livestock manure for several weeks prior to application to the land significantly reduces the risk of exposure to these pathogens. The high temperatures ($\geq 130^{o}$ F) attained during the composting process kills most unwanted pathogens and parasites. Many pathogens and parasites survive well in manure; consequently, the composting process reduces the pathogen populations.

Organic matter

Organic matter in manure from undigested feeds can be a valuable environmental resource if managed properly, or an environmental pollutant if managed poorly. Manure is rich in organic carbon, which offers positive benefits to the soil including:

- being the primary energy source for an active, healthy soil microbial environment.
- being an important stabilizer of soil nutrients, especially mobile forms of nitrogen. Agronomic application of nitrogen applied as manure is less likely to leach than nutrients applied as inorganic fertilizers. Most manure nutrients are temporarily stabilized as soil microbial biomass.
- contributing to improved soil structure, which contributes to improved water infiltration and greater water-holding capacity, benefiting crops, soil erosion, and nutrient retention.

Soil organic matter is an excellent indicator of the soil's productivity. In the Midwest, soil organic matter has been reduced by 50 to 70 percent since the virgin soils were first placed into crop production over 100 years ago. Long-term studies have shown that manure application can reverse the decline in organic matter. Conservation of organic carbon in manure and return of that carbon to the soil may someday play a role in addressing global warming issues due to carbon dioxide and methane accumulation in the atmosphere.

FIGURE 1.7

Long-term studies have shown that manure application can reverse the decline in organic matter.

If manure is allowed to discharge to a water body or runoff 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. If this occurs in an aquatic environment, fish kills may occur. Manure, silage leachate, and waste milk can be 50 to 250 times higher in degradable organic matter 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). Organic matter, like pathogens, phosphorus, and ammonia, is transported to water primarily by surface water runoff. Rarely does organic matter leach through soils.

Organic matter is unlikely to be transported in sufficient quantities to nearby surface waters unless one of the following situations occurs:

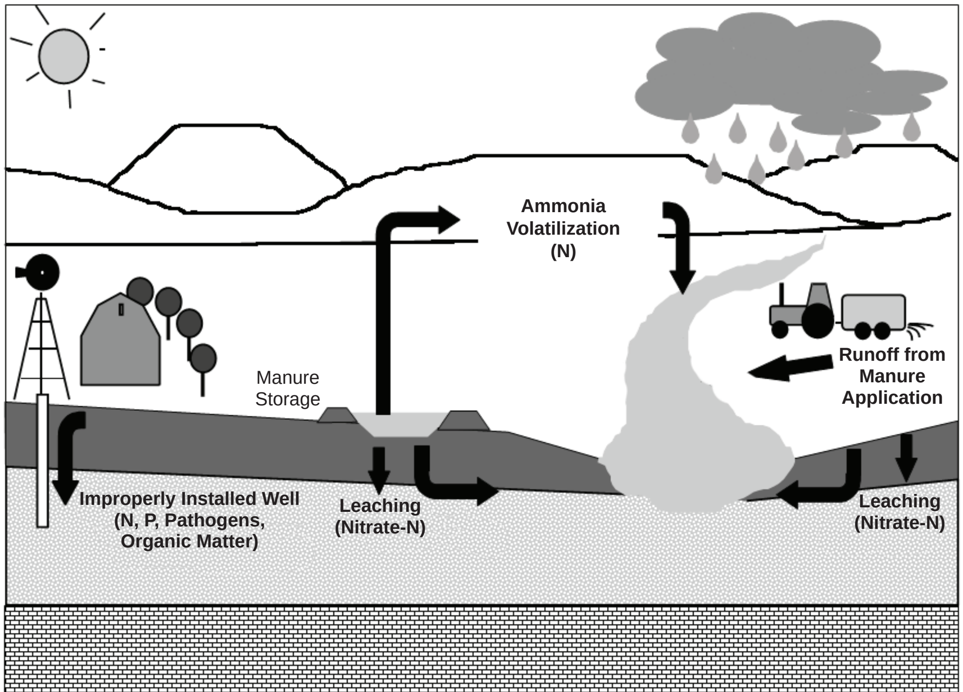
- a direct discharge from livestock housing, manure storage, open lot, or other facility is allowed to enter surface water drainage.
- a catastrophic failure such as an earthen storage break or the continuous application by an irrigation system on the same location.

• significant rainfall occurs shortly after surface application of manure.

• significant application is made on frozen or snow-covered soils in proximity to surface water.

How Do Contaminants Get Into the Water?

Water quality can be degraded by contaminants contained in manure, from water used at milking centers, from silage leachate, and simply from open lot runoff. These potential pollutants typically follow one or more possible pathways to water *(Figure 1.8)*.



Modified from Figure 1-4 in the Livestock and Poultry Environmental Stewardship (LPES) Curriculum.

FIGURE 1.8

Common pathways for manure contaminants to reach surface water and groundwater.

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 can travel with surface water runoff and through soil erosion. Problems associated with phosphorus, pathogens, ammonia, and organic matter most commonly are associated with runoff and/or erosion.

Leaching: Dissolved contaminants such as nitrate will leach through the soil when the soil moisture exceeds its water-holding capacity. Most contaminants in manure and other by-products (organic matter, pathogens, and typically phosphorus) are filtered by the soil and generally 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, soluble contaminants such as nitrate may move beyond a crop's root zone and contaminate groundwater.

***Well casings*:** Well casings 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 manure contaminants to move to groundwater.

***Ammonia volatilization and deposition*:** Ammonia volatilizes from manure storage, lagoons, open lots and land applications without incorporation. Once volatilized, most ammonia is re-deposited 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 deposition rates that threaten vitality and growth in local ecosystems. In the United States, coastal areas are often adversely affected by atmospheric ammonia deposition.

The five major contaminants associated with livestock and poultry by-products, their environmental risk, and common pathway to water are summarized in *Table 1.1*.

Table 1.1

Environmental risk and common pathways of water contaminants.

Potential Contaminant	Environmental Risk	Most Common Pathway to Water
Nitrate	Methemoglobinemia	Leaching
Ammonium	Fish kills	Surface water runoff
Phosphorus	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
Modified from Table 1-3 in the LPES Curriculum		

Understanding Air Quality Issues

The handling and storage of manure associated with confinement livestock and poultry systems generates a wide range of air-borne contaminants including ammonia, carbon dioxide, hydrogen sulfide, and methane. These contaminants are dispersed in gases, aerosols, and dusts. The occurrence and concentration of individual contaminants vary substantially with animal species and type of confinement facility. In addition to chemical contaminants, potentially allergenic and pathogenic microbes can be dispersed in aerosols and dusts associated with manure handling and storage. Air-borne contaminants can have direct and indirect effects on human health, the environment, and the social impacts of communities.

Impact on health and communities

Odor nuisance to neighbors of livestock and poultry operations is a common source of discontent within communities and these concerns should be taken seriously. It is often the cause of opposition to new or expanding facilities, as well as heightened scrutiny of other environmental issues. Recent research suggests that neighbors have strong emotional reactions to livestock-related odors. These reactions can impact psychological and physiological health resulting in significantly greater anger, confusion, tension, depression, and fatigue in populations living near intensive livestock operations.

Physiological responses to odorous compounds are not well understood but appear to be limited in nature. Reports suggest that odors may elicit respiratory problems with nausea, vomiting, and headaches. Although some compounds associated with odor (hydrogen sulfide and ammonia) are toxic in high concentrations, neighbors of livestock operations are rarely exposed to toxic levels. It is unclear if long-term, low-level exposure to compounds can impact the health of neighboring residents. A consensus among health professionals does not exist at this time.

FIGURE 1.9

Odor nuisance from livestock operations is a common source of discontent within communities and should be taken seriously.

Source of contaminants

Over 160 volatile compounds are found in gaseous emissions from confinement facilities. Many of these volatile compounds contribute to odors and raise concerns about human health, while others, including methane and carbon dioxide, may contribute to global warming. Some community concerns and regulatory efforts have focused on individual gases while others have focused on the general issue of odor.

Metabolic processes within the gastrointestinal track of livestock and anaerobic degradation of manure generate most of these 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 methane and carbon dioxide, which are odorless. When in balance, these anaerobic processes eliminate odorous compounds. However, in manure storage or overloaded anaerobic treatment lagoons, acid-forming and methane-forming processes are not in balance, resulting in an accumulation of VFAs.

Sulfate-reducing bacteria found in anaerobic environments convert sulfate to hydrogen sulfide and other sulfur-containing compounds that contribute to odor. Hydrogen sulfide alone is not a significant source of odor, but is of public health concern; exposure to concentrations of 2,000 ppm for a few minutes can be fatal. Long exposures at 300 ppm have also caused deaths. Such high concentrations of hydrogen sulfide are more likely to collect in confined spaces such as manure pits. Ambient air regulations in Nebraska specify that hydrogen sulfide concentrations cannot exceed 0.1 ppm (30-minute average), or 10 ppm (1-minute average). Research at the University of Nebraska-Lincoln suggests that hydrogen sulfide emissions from feedlots are unlikely to exceed regulatory limits.

Ammonia is released in large quantities by livestock production systems. Anaerobic lagoons may lose more than two-thirds of the nitrogen in manure as ammonia. Open lots for livestock production will volatilize roughly half of the nitrogen, primarily as ammonia. The main problem associated with ammonia relates to its deposition on land and water and its chemical combination with other aerial compounds to produce particulate matter that causes haze and may contribute to health concerns.

Odor characterization

Odorous volatile compounds are commonly considered to be a nuisance by many neighbors of confinement facilities. A neighbor's determination of odor nuisance is related to physical factors (frequency, intensity, and duration of odor experience) and social factors (past experience with agriculture, relationship with the producer, and appearance of the livestock or poultry operation). Odor is defined in terms of four factors (FIDO factors):

- Frequency – how often does the odor occur?
- Intensity – how strong is the odor?
- Duration – how long does the odor persist?
- Offensiveness – to what extent does the odor offend individuals exposed to it?

The four FIDO factors are not independent; they interact in predictable ways. For example, although the actual intensity of two different odors may be equal, the offensiveness of one odor may increase the ability of a person to sense it, while that same person may be relatively insensitive to the other less offensive odor. The most commonly cited odor parameter is intensity, defined as the number of volume dilutions (volumes of odor-free air added to a unit volume of odorous air) required to reduce the odor to a level that is barely detectable by 50 percent of a group of human panelists exposed to the odor under controlled conditions.

Sources of odor

For new facilities, odor management is first and foremost an issue of site selection. Choosing locations that take into account prevailing winds and neighbors is important. In established livestock operations, proper manure handling, moisture management, and dust control can eliminate many odor complaints.

FIGURE 1.10

Manure storage structures are often mistaken for lagoons. This debris basin allows solid manure to settle for ease in collection and manure application.

Lagoons are typically designed for the anaerobic digestion process. An anaerobic lagoon is a structure that is designed to treat and store manure. A properly designed and operated anaerobic lagoon should not produce the odors that a manure storage facility often emits. Manure storage structures are often mistaken for lagoons. A manure storage facility is a structure designed to store manure and effluent generated from a livestock operation.

Health issues

In addition to odorous compounds, dust emissions from animal confinement facilities are gaining greater attention due to their ability to serve as a carrier of odorous compounds and microbes with the potential to impact the health of facility workers and neighbors.

Fungi are naturally found in livestock and poultry operations and are a legitimate concern. Several species infect and cause disease in humans ranging from dermatitis to invasive diseases of the lung that are sometimes fatal. In addition, some fungi produce toxic compounds called mycotoxins that can produce pneumonia or disrupt the function of target organs such as the kidney,

FIGURE 1.11

Dust emissions from animal confinement facilities serve as a carrier of odor and micro-organisms that can impact the health of workers and neighbors.

liver, and spleen. As with bacteria, the exposure risk is much higher within the production facility and decreases at distances from the facility. Unlike bacteria, treatment for fungal infections is more difficult. Although predisposition is not required for infection to occur, modern medical practices, such as treatment with antibiotics, corticosteroids, and immunosuppressive drugs predispose humans to infection by fungi.

How Do Contaminants Get Into the Air?

Airborne emissions from animal production systems originate from three primary sources: manure storage and treatment facilities, animal housings, and land application activities *(Figure 1.12)*. The movement or dispersion of airborne emissions from animal feeding operations (AFOs) are affected by topography, prevailing winds, and orientation. Generally, plumes from odorous sources are more intense under stable atmospheric conditions. This means on calm, cool days the odor plume will be very intense just downwind of the source. Conversely, unstable conditions, such as a warm day or windy conditions, tend to disperse and dilute air emissions.

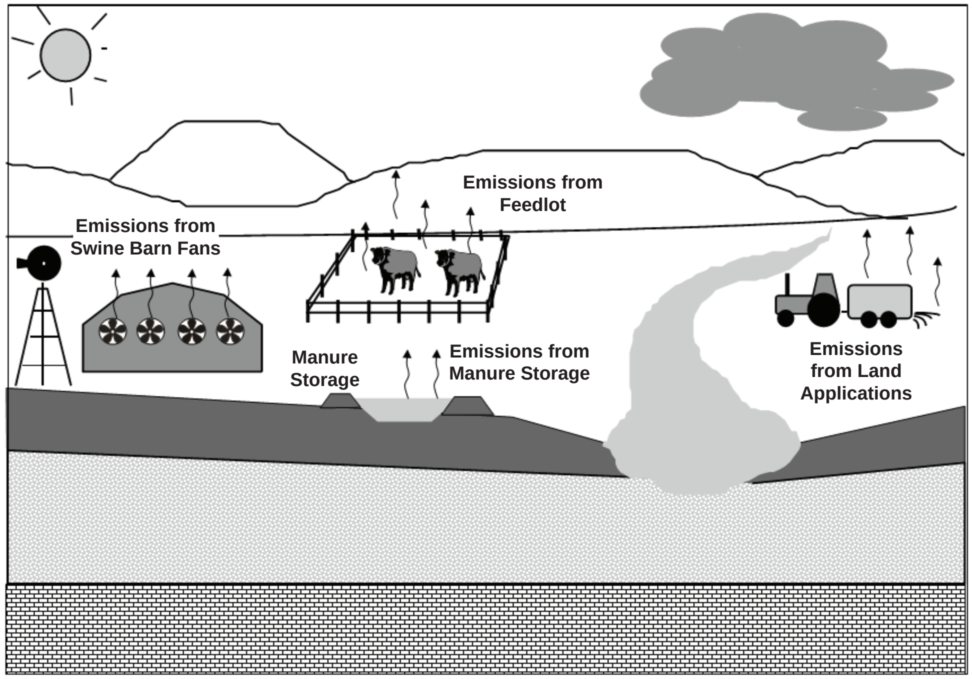


FIGURE 1.12

Common pathways for manure contaminants to pollute the air.

Issues of Local Concern

The previous discussion introduced many 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, or from 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. These priorities should be considered in your livestock operation's future environmental stewardship efforts.

Manure: Waste Product or Valuable Resource?

There are problems with manure, but generally these are manageable. Manure is also a potentially valuable resource. In addition to fertilizer cost savings, manure is a soil amendment with medium- to long-term effects. Its value as an amendment is often difficult to estimate but is partly reflected in increased yields with manure applied compared with fertilizer application alone. Yield increases can be dramatic on once-eroded, fine-textured soils, low organic matter soils, and sandy soils. Soil structure and soil aggregate stability are often improved, resulting in improved water infiltration, less runoff and erosion, and increased water-holding capacity. Some manures have a liming effect. Information about factors affecting the value of manure and a worksheet for estimating the dollar value of manure are available in *Calculating the Value of Manure for Crop Production* NebGuide G1519. These calculations can also be done with a software tool, *Nebraska Manure Value Calculator,* available at *cnmp.unl.edu/cnmpsoftware2.html#Calculator*.

Portions of this chapter were taken from Livestock and Poultry Environmental Stewardship curriculum, Lesson 1 authored by Rick Koelsch, University of Nebraska, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, *Copyright 2001*.

2
Chapter

Comprehensive Nutrient Management Planning in Nebraska

Comprehensive Nutrient Management Planning (CNMP) initiated by the United States Department of Agriculture (USDA) and EPA expands on the idea of nutrient management planning by addressing six key manure and nutrient management components. The CNMP takes a more systematic approach to reduce nutrient loads in manure from livestock facilities and asks the producer to consider alternatives in livestock feeding and the storage, handling, and distribution of manure. This approach has the potential to reduce total manure nutrient load, in addition to managing the manure produced. The six components are:

- Manure handling and storage
- Land application
- Site management
- Recordkeeping
- Feed management
- Other utilization options

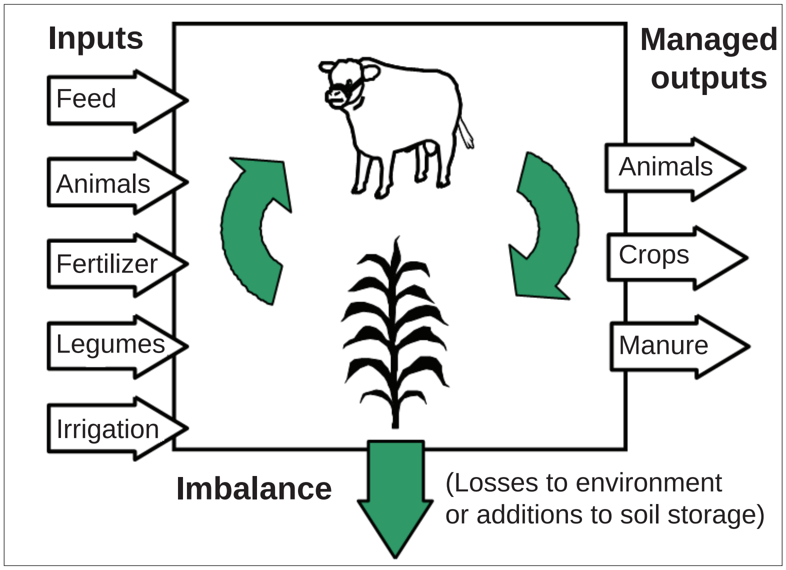
Nebraska livestock producers must comply with Nebraska state regulations in Title 130, administered by the Nebraska Department of Environmental Quality (NDEQ). In conjunction with representatives of the livestock industry, fertilizer and chemical industry, crop consultants, agency personnel and University specialists, a Nebraska CNMP process was developed to define the planning, implementation, and review steps of a CNMP. *Figure 2.1* shows the framework for the plan.

FIGURE 2.1

Nebraska Comprehensive Nutrient Management Plan.

Whole-Farm Nutrient Balance

One way to determine whether there is a need for a change in management practices is to conduct a whole-farm nutrient balance analysis. A whole-farm nutrient balance analysis determines if excess nutrients are being stored on

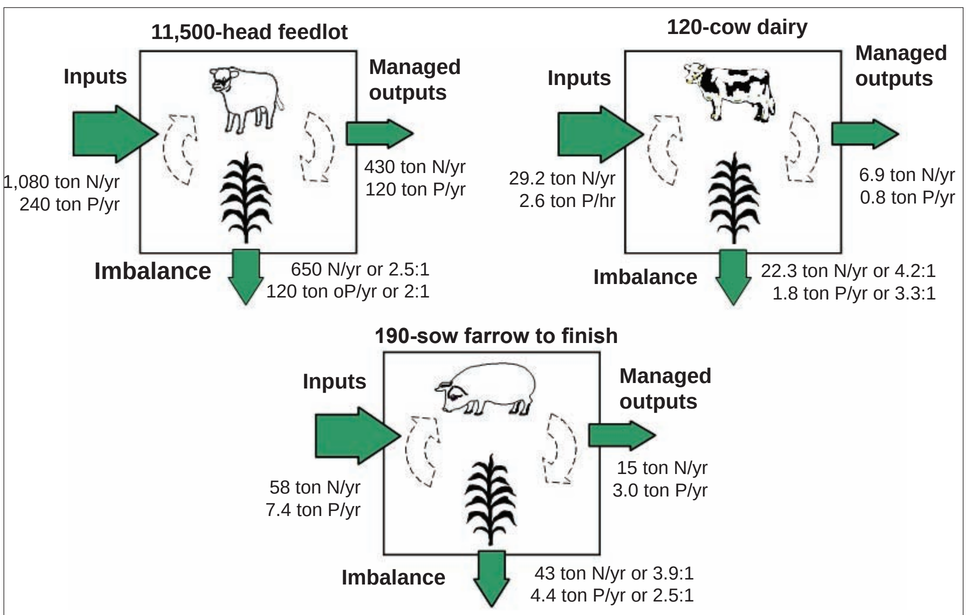


Modified from Figure 2-3 in the LPES Curriculum.

FIGURE 2.2

Whole-Farm Nutrient Balance.

the farm *(Figure 2.2)*. Understanding the whole-farm nutrient balance, as well as the sources of nutrient inputs and losses, is critical to identifying a nutrient management strategy for reducing an imbalance and achieving an environmentally sustainable operation. (For detailed information on the whole-farm nutrient balance, see Lesson 2 of the LPES Curriculum.) The input/output whole-farm nutrient balance analysis process includes listing the nutrients that arrive on the livestock farm in the form of feed, fertilizer, irrigation water, animals, or nitrogen fixed by legumes. The nutrients that leave the farm as marketed products are called managed outputs, such as animals and crop products. Any imbalance between input and managed outputs will either be added to soil reserves (perhaps adding to future environmental risks) or lost directly to the environment. Since the results will be different, it is important that this analysis be conducted for both nitrogen and phosphorus *(Figure 2.3)*.



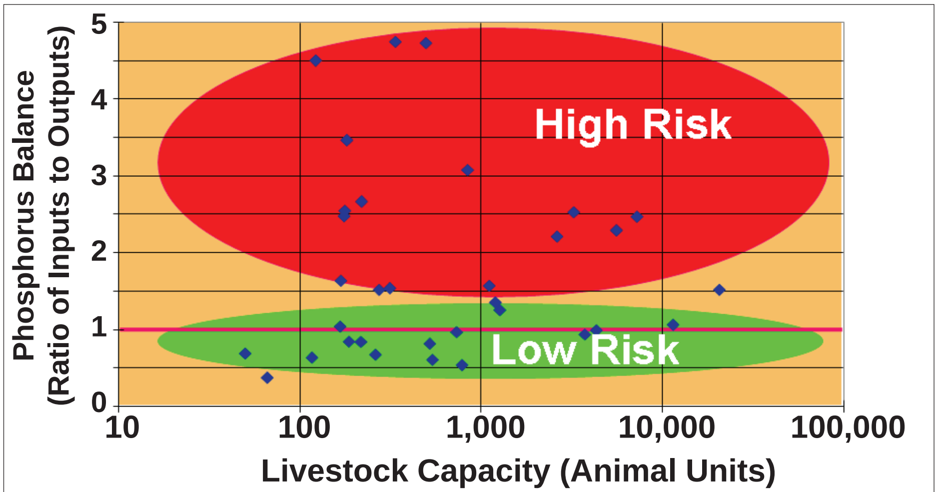
Modified from Figure 2-4 in the LPES Curriculum.

FIGURE 2.3

Typical nutrient imbalance observed for different livestock systems.

Observed imbalances for sample farms

The ideal situation is when the quantity of a nutrient input equals the managed output quantity. This indicates that the farm is utilizing all of the imported nutrients. A ratio of inputs to outputs greater than one indicates an accumulation of nutrients on the farm. It is usually a precursor to environmental risk but may occur when soils are seriously depleted or herds are being increased. *Figure 2.3* shows the nitrogen and phosphorus balance for some typical farms. In all cases the inputs are greater by a factor of at least twice the outputs. This indicates that feed and fertilizer inputs need to be adjusted. Alternatively, to bring the farm into balance, more land needs to be acquired or the manure has to be transferred to other sites.

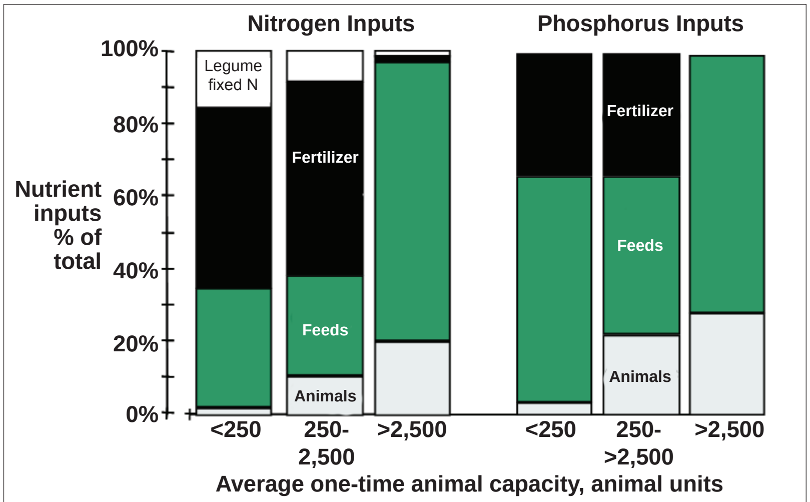


Modified from Figure 2-5 in the LPES Curriculum.

FIGURE 2.4

Phosphorus balance versus size for 33 Nebraska livestock operations.

In a study of 33 livestock operations in Nebraska, size of operation did not affect the input:output ratio *(Figure 2.4)*. High and low risk operations were found in any size class. *Figure 2.5* shows the proportion of inputs by contribution class (legumes, fertilizer, feeds and purchased animals) for both nitrogen and phosphorus. When a producer calculates this information for an operation, the manager can decide which of these categories can be adjusted so the input numbers will achieve a balance with nutrient exports.



Modified from Figure 2-6 in the LPES Curriculum.

FIGURE 2.5

Relative sources of nitrogen and phosphorus inputs with different-sized Nebraska livestock operations.

Estimating balance

Before attempting to calculate the balance, there is a worksheet that can be completed to determine if a particular operation may be at risk *(Table 2.1)*. If one or more risk factors are identified, an actual calculation of the whole-farm nutrient balance is suggested. The actual calculation of the balance requires data on purchased inputs and sales of outputs. Calculating the balance for a number of years and averaging is preferable to a one-year snapshot.

TABLE 2.1

Environmental Stewardship Assessment. Indicators of a possible imbalance that may exist on your farm (check those that apply). Even one "yes" response indicates that potential for nutrient imbalances is high.

Yes	**No**	**Don't Know**	
(check those that apply)			
			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 one acre of cropland is available per animal (1,000 lbs. of live weight), and no manure is transported to off-farm users.

Modified from Table 2-1 in the LPES Curriculum.

Strategies for attaining nutrient balance

Fertilizer is a common major source of inputs for both nitrogen and phosphorus in operations under 2,500 animal units (AUs) *(Figure 2.5)*. If manure is land-applied, every effort should be made to credit the manure nutrients and reduce purchased fertilizer inputs. Purchased feed is the second largest source of nitrogen inputs for the under 2,500 animal unit operations and the largest source for the over 2,500 animal unit operations. Feed is commonly the largest source of phosphorus for most livestock operations. It is important that both the protein (nitrogen source) and phosphorus levels be monitored and compared to the recommended feeding levels. It may be particularly difficult to reduce phosphorus in the diet when feeding by-products that have enriched levels of phosphorus, such as ethanol and corn gluten by-products.

Supplemental phosphorus additions to swine diets can be reduced by feeding low phytic acid corn or by feeding phytase-treated feed. Feeding phytase has been shown to decrease phosphorus levels in manure by 20 to 40 percent. This reduces the purchased phosphorus input total and moves an operation closer to the 1:1 balance goal. On an on-farm trial in Holt County, Nebraska, diet reformulation and phytase supplements were demonstrated in a 1200-head swine finishing barn. *Figure 2.6* shows the decrease in manure phosphorus. The reduction in manure phosphorus and the change in diet reduced the acres needed to utilize all the manure phosphorus by about one-third. The acres needed to spread the produced manure were reduced when feeds were reformulated to meet dietary requirements and phytase was used *(Figure 2.7)*. Reformulated diets may also reduce feed expenses.

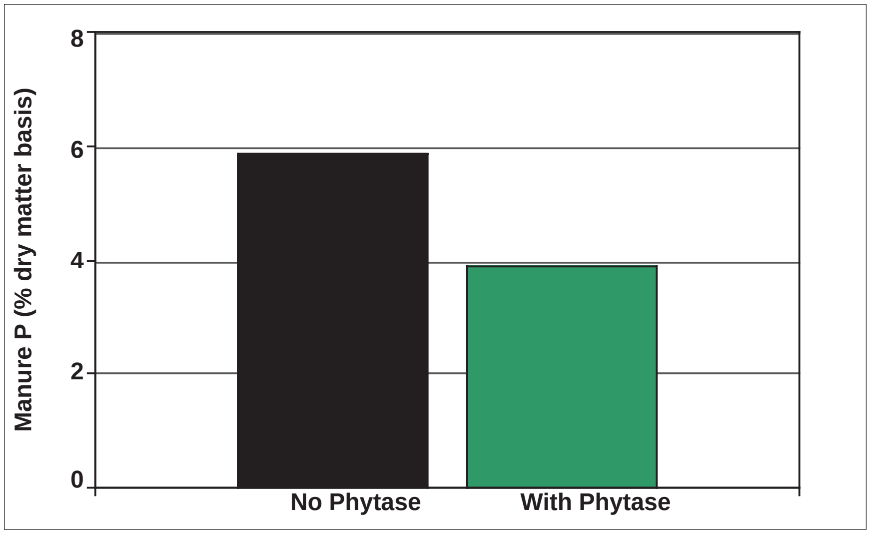


FIGURE 2.6

Effect of phytase addition to feed on phosphorus in manure.

Exporting manure

Another management technique to improve nutrient balance is to increase the amount of manure exported from the farm. Manure can be given away or sold. There are a number of documented successes in Nebraska of manure marketing. It may be necessary to begin with a below cost or subsidized manure marketing program to establish its value for neighbors and customers. As this value is established among neighboring crop producers, manure may be sold at its agronomic value. While there may be a cost to manure exporting, it may be less costly than other manure management options. Evidence of adequate available land for manure application is required before a permit is approved by NDEQ.

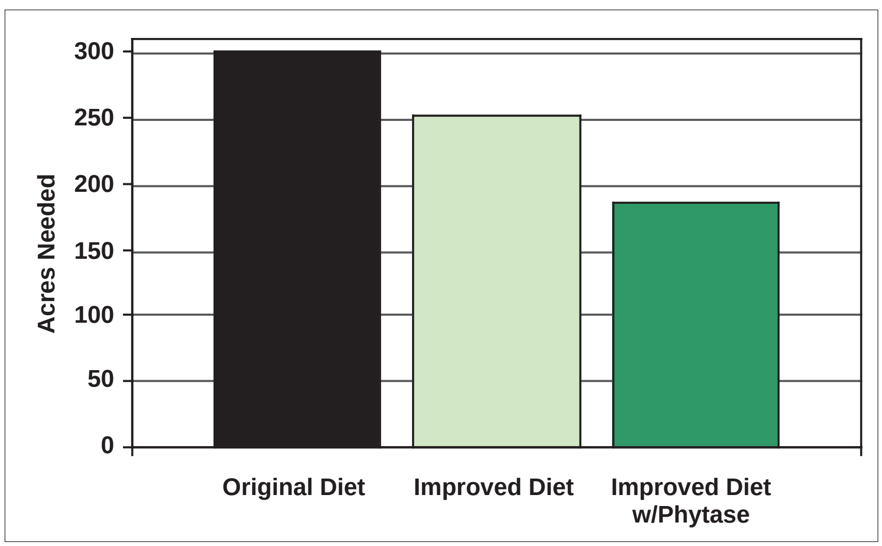


FIGURE 2.7

Annual acres needed to supply 70 pounds P_2O_5 per acre from a 1200-head swine finishing barn with improved diet and use of phytase.

Manure treatment

Manure treatment is another option to help with nutrient balance, but it is costly and technically complex. Research is being conducted on anaerobic digestion, precipitation of phosphorus with other by-products, mixing with lime slurry, liquid-solid separation, and composting. Composting is the simplest and most cost-competitive treatment option at this time. Other alternatives include methane generation to capture a valuable energy source, treating the manure with alum to sequester the phosphorus so it would not be as likely to run off the land, and changing nitrogen in manure to ammonia or nitrogen gas (preferred) for release into the atmosphere.

Portions of this chapter were taken from Livestock and Poultry Environmental Stewardship curriculum, Lesson 2 authored by Rick Koelsch, University of Nebraska, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, *Copyright 2001*.

3
Chapter

Manure Nutrient Dynamics

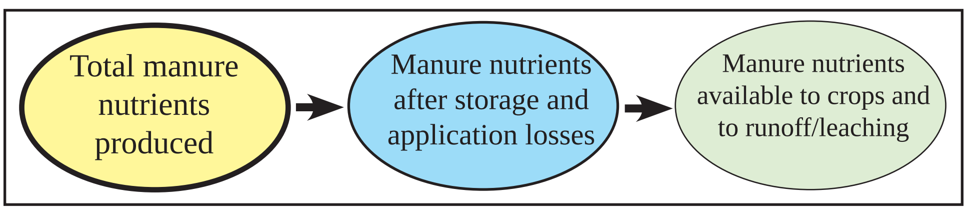
Nutrients in manure are potentially valuable resources for the management of soil fertility, but these nutrients are potential pollutants as well. Only 10 to 40 percent of the nutrients consumed by animals may end up in the marketed product; the rest is excreted in feces and urine. Manure contains all nutrients needed by plants, but nitrogen and phosphate generally have the most agronomic significance in Nebraska. They are also potential contaminants of water resources. This chapter focuses on nitrogen and phosphorus, and also addresses concerns of salt in manure.

Manure nutrient dynamics can be considered in three stages *(Figure 3.1)*.

- Manure nutrients are produced in feces, urine and other agricultural byproducts associated with an animal feeding operation. The quantity of nutrients produced varies with livestock type as well as the animal ration.
- Manure nutrients are lost during manure handling, storage, treatment, and application.
- Manure nutrients become available in the soil for crop uptake or are lost as potential pollutants.

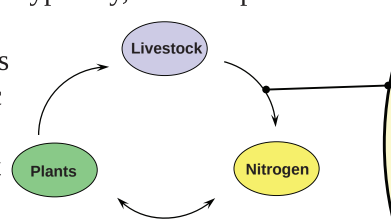
FIGURE 3.1

Three stages of manure nutrient dynamics.



The Nitrogen Cycle

Animal rations contain significant amounts of nitrogen, a major component of protein. Typically, 60 to 80 percent of manure nitrogen is in organic forms, with most of the remaining in the form of ammonium. Organic nitrogen in feces is in complex molecules associated with undigested food. These molecules are decomposed by



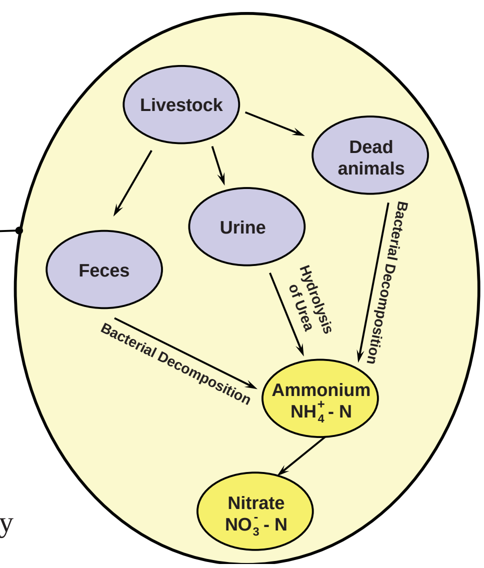


FIGURE 3.2

The manure nitrogen cycle.

bacteria and the organic nitrogen is transformed to ammonium (*Figures 3.2* and *3.3*). Organic nitrogen in urine is in the form of urea, which undergoes hydrolysis, producing ammonium. Organic nitrogen in dead animals also is transformed to ammonium. These transformations begin immediately upon excretion and continue during manure storage and handling, and after land application. The transformation of nutrients from organic to inorganic forms is called mineralization.

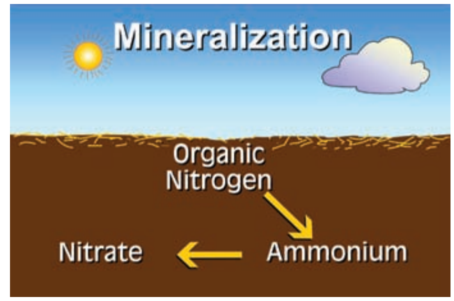


FIGURE 3.3

The mineralization process of the manure nitrogen cycle.

Ammonium and ammonia exist in a state of equilibrium and their relative concentrations depend on temperature, aeration, and pH. Ammonium is a cation that is adsorbed by soil particles. Ammonia is volatile and easily lost to the atmosphere *(Figure 3.4)*. Losses of manure nitrogen through volatilization vary with manure handling, storage, and application methods. Some volatilized ammonia eventually returns to the land after ammonia reacts with water molecules in the air. Some of this nitrogen may be deposited in water bodies as well.

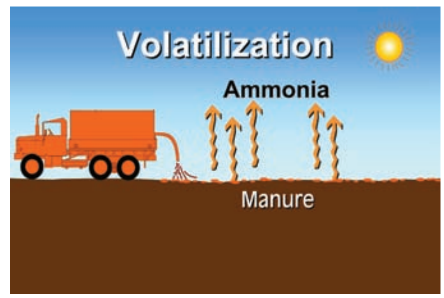


FIGURE 3.4

The volatilization process of the manure nitrogen cycle.

Nitrate and nitrite are typically at low levels in manure but after land application much of the manure nitrogen is eventually transformed to nitrate through oxidation of ammonium, also known as nitrification *(Figure 3.5)*. Some nitrate may be lost through leaching *(Figure 3.6)* or to denitrification *(Figure 3.7)* when the soil is water-logged.

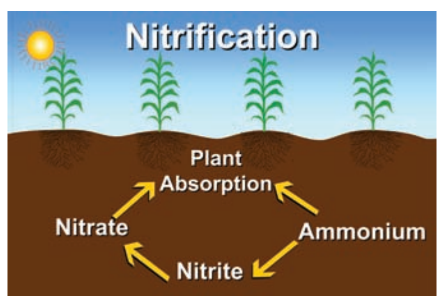
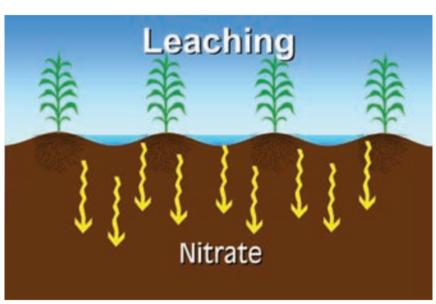
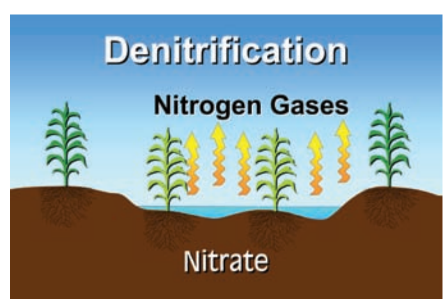


FIGURE 3.5

The nitrification process of the manure nitrogen cycle.

Plants take up nitrogen from the soil as ammonium and nitrate. Animals eventually consume plant products, completing the manure nitrogen cycle. Other plant parts die and are decomposed by microorganisms to produce ammonium.





FIGURES 3.6 AND 3.7

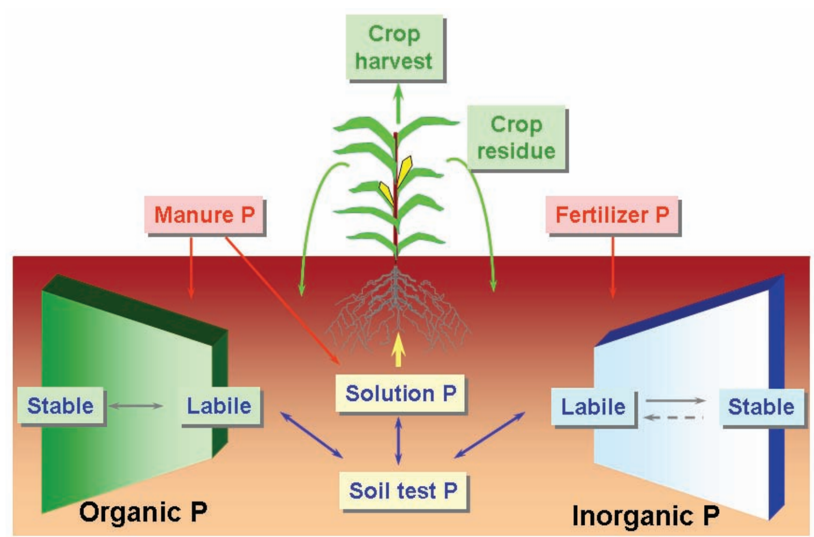
The leaching and denitrification processes of the manure nitrogen cycle.

The Phosphorus Cycle

Animal manures contain both organic and inorganic forms of phosphorus. When manure mineralizes, organic phosphorus becomes inorganic phosphorus in solution and is available to plants *(Figure 3.8)*. Some organic phosphorus is transformed to inorganic form shortly after application but other phosphorus will remain in organic form. Soil organic phosphorus consists of labile and stable fractions. The labile fractions will be mineralized after a short time while the stable fractions may remain in organic form for years.

FIGURE 3.8

As manure is mineralized, organic phosphorus becomes inorganic phosphorus in solution, which is plant-available.



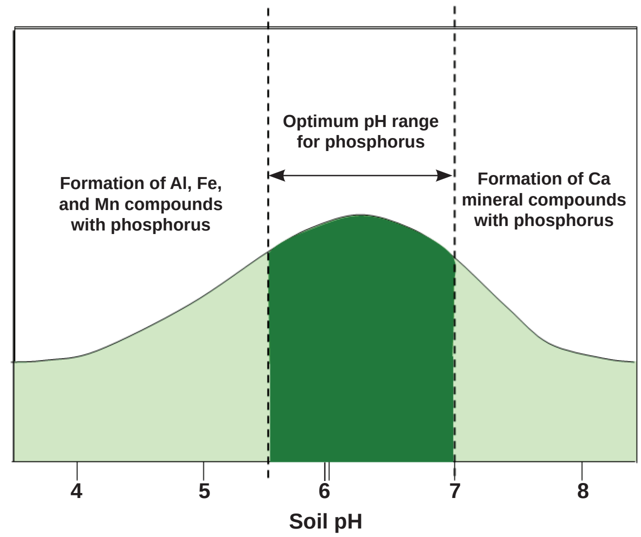
Modified from Figure 34-2 in the LPES Curriculum.

Solution phosphorus is in the form of anions that react with cations such as iron, aluminum, and calcium to become attached phosphorus and unavailable to plants. Attached phosphorus may be loosely bonded (labile phosphorus), or tightly bonded in the soil (non-labile or stable phosphorus). The rate of reaction of dissolved phosphorus anions and compounds formed depends on soil pH *(Figure 3.9)*. A greater proportion of the total soil phosphorus is likely to be bioavailable, or labile phosphorus, between pH 5.5 and 7.0 than at higher or lower pH.

At low soil pH, dissolved phosphorus quickly reacts with soluble iron, aluminum, and manganese to form precipitates, or it is adsorbed by hydroxides of iron and aluminum and by other clay minerals. Under

FIGURE 3.9

Soil phosphorus as affected by soil pH.



Phosphorus or Phosphate?

Phosphorus content in soil, plants, and animal rations is expressed as phosphorus (P) content but phosphorus in fertilizers and manure intended for land application is expressed as phosphate (P_2O_5).

- To convert P to P_2O_5 concentration, multiply by 2.29.
- To convert P_2O_5 to P, multiply by 0.44.

moderately acid conditions, chemical precipitation of phosphorus is unlikely, but much dissolved phosphorus becomes adsorped. At high pH, dissolved phosphorus reacts with calcium to precipitate as calcium phosphate. The potential for phosphorus adsorption also increases as the clay content of soil increases.

With repeated application of manure, available soil phosphorus can become excessive with high potential for runoff. Soil phosphorus leaches very slowly, but when the water table is high and the soil is sandy, leaching of phosphorus to groundwater may be of concern.

Other Nutrients in Manure

Potassium (K) and other nutrients essential for plant growth are supplied in manure. Some nutrients and heavy metals may reach toxic levels with repeated high rates of application. Heavy metals could be of greater concern when manure from animals that have consumed feeds containing heavy metals is applied directly to grazing land. However, heavy metals normally are not in animal manures unless the animals have been fed supplemental feeds that include zinc, copper, or selenium. Feedlot manure often contains significant amounts of calcium carbonate and can have a liming effect on acidic soils.

Calcium carbonate (lime) is a common additive to livestock diets. Manure can contain between one and four percent calcium carbonate, depending on the diet formulation. One way to account for the liming effect of manure is to monitor the pH of the soil over time. The pH of manured soils should increase, or become more basic. Used in conjuction with a good liming plan, the amount of agricultural lime needed can be reduced on manured fields.

A more direct way to determine the amount of calcium carbonate in manure is to test it for effective calcium carbonate (ECC), which is a commercial fertilizer test. Request an ECC test which will report the amount of calcium carbonate equivalent in the manure.

For example, assume a feedlot manure sample test returns two percent calcium carbonate. If the manure was applied at 25 tons/acre and the manure was 20 percent moisture, the equivalent lime application would be 800 pounds (20 tons of dry manure/acre). In this example, one ton of dry manure contained 40 pounds of available lime. Therefore, if the producer’s soil test showed a 2,500-pound lime requirement, he would only need a 1,700-pound application after the manure application.

Salts in Manure

Manure may contain high levels of soluble salt. High rates of manure application can result in soil salt levels which are detrimental to crop growth. Another concern may be salts in effluents applied to growing crops through sprinkler irrigation systems with the salts burning the plant tissue. Total salt concentration is measured by electrical conductivity (EC).

Crops vary in tolerance to salt in soils *(Table 3.1)*. Barley has a very high level of tolerance to soluble salts with an expected yield loss of 10 percent at an EC reading of 10 mmho/cm. On the other hand, corn has a low level of tolerance and suffers a 10 percent yield loss at an EC reading of 3 mmho/cm. Soil is considered to be saline when soil EC is 4 mmho/cm or greater.

If effluent that is to be applied to a crop through a sprinkler irrigation system has an EC greater than 6 mmho/cm, there is potential for leaf burn and the effluent should be diluted to prevent salt damage to the plants.

Estimating soluble salt concentration in manure.

- Divide EC (mmho/cm) by 15 to estimate soluble salt concentration as **percent of manure.**
- Multiply EC (mmho/cm) by 640 to estimate soluble salt concentration as **parts per million of manure.**
- Multiply by 2 the sum of the percentages of potassium, calcium, magnesium, and sodium to estimate soluble salt concentration as **percent of manure.**

TABLE 3.1

Salt tolerance level and soil electrical conductivity (EC) values at which 0, 10, and 50 percent crop yield reduction occurs.

Crop	Tolerance level	0	10	50
		% Yield Reduction		
		Soil electrical conductivity (mmho/cm)		
Barley	Very High	8	10	18
Sugar Beets	Very High	7	9	15
Wheat	High	6	7	13
Soybean	Medium	5	5	7
Sorghum	Medium	4	5	11
Alfalfa	Low	2	3	9
Corn	Low	2	3	6
Dry Beans	Low	1	2	4

Manure Nutrient Losses

Manure nutrients are lost during manure handling, storage, treatment, and application. Manure nitrogen is especially vulnerable to volatilization when ammonium is transformed to ammonia. Losses of phosphorus and potassium are primarily due to runoff and erosion.

Losses from storage and treatment facilities

Nutrient losses vary with types of manure storage and treatment facilities *(Table 3.2)*. Losses of manure phosphorus and potassium are minimal with some manure handling systems, but considerable phosphorus and potassium may be lost from open feedlots to runoff and leaching. Manure nitrogen losses are relatively higher in open feedlots and with poultry manure on shavings or sawdust, and relatively less with bottom-loaded slurry storage and pits under slatted floors.

FIGURE 3.10

Agitation increases nitrogen losses.

TABLE 3.2

Nutrients remaining in manure after storage and treatment losses.

Manure storage/treatment system	N	P*	K*
	(% remaining in manure)		
Open lot or feedlot	50	95	70
Manure pack under roof	70	100	100
Bottom loaded slurry storage	85	100	100
Top loaded slurry storage	70	100	100
Pit beneath slatted floor	75	100	100
Poultry manure in pit beneath slatted floor	85	100	100
Poultry manure on shavings or sawdust	50	100	100
Compost	70	100	100
One-cell anaerobic treatment lagoon	20	35	65
Multi-cell anaerobic treatment lagoon	10	35	65

*Remaining P and K will be found in settled solids, lagoon sludge, or runoff water.

Anaerobic treatment of manure results in considerable loss of nitrogen, mostly in the form of ammonia due to volatilization. During anaerobic digestion of manure, organic matter in the liquid decomposes and is emitted as methane gas and carbon dioxide. Much of the particulate matter, including phosphorus and potassium compounds, settles to the bottom. Some of the liquid with low nutrient and organic matter content is regularly removed to maintain the storage capacity of the lagoon while the sludge is left to accumulate at the bottom of the lagoon. The phosphorus and potassium in anaerobic lagoons is potentially recoverable by removing the sludge, but this generally is not done more than once every 15-25 years to avoid interruption of the anaerobic decomposition process.

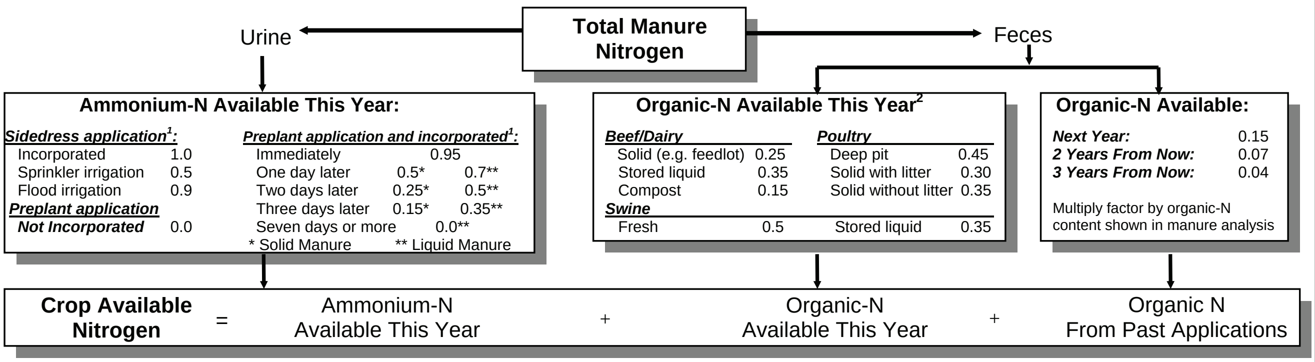
Composting accelerates the decomposition of organic matter, yielding a less bulky and more stable organic product. A significant amount of ammonium is lost during composting as ammonia is either released to the atmosphere or inorganic nitrogen is tied-up in stable organic compounds.

TABLE 3.3 (BELOW)

Availability factors for manure nitrogen.

Ammonium available following application

When manure is not incorporated, significant nitrogen losses can occur following land application due to volatilization of ammonia. This is especially true for liquid effluents, which have greater concentrations of the total nitrogen in ammonium form. If manure is immediately incorporated, little or no ammonium is lost *(Table 3.3)*, but 100 percent can be lost without incorporation. On hot and windy days, 100 percent of the ammonium can be lost within two days following surface application.



[1] *Incorporation can be accomplished by tillage or by a 0.50 inch or greater rainfall.*
[2] *Organic-N availability assumes spring seeded crops such as corn and soybeans. For winter or spring spring manure applications prior to planting small grains, multiply organic-N availability factor by 0.7.*

Manure Nutrients — crop-available or pollutant?

Mineralization of nutrients and crop availability

Plants take up nutrients in inorganic forms. Ammonium and nitrate in manures are immediately available to crops. Organic material needs to decompose to allow mineralization of nutrients to inorganic forms that plants can use. Manure type affects the rate of mineralization, often due to differing carbon:nitrogen ratios. Poultry manure typically has a low carbon:nitrogen ratio compared to cattle or swine manure, and has a high rate of mineralization. Litter or bedding in manure will slow decomposition and mineralization of the nutrients. Nutrients in anaerobically-treated manure will mineralize relatively quickly. Incorporated manure will decompose faster than if left on the soil surface.

A major part of organic nitrogen is not available in the season of application. About 25 percent of organic nitrogen in solid manure from beef feedlots is typically available in the year of application. Organic nitrogen continues to be

Potassium or Potash?

Potassium content in soil, plants, and animal rations is expressed as potassium (K) content but potassium in fertilizers and manure intended for land application is expressed as potash, or more correctly, potassium oxide (K_2O).

- To convert K to K_2O concentration, multiply by 1.2.
- To convert K_2O to K, multiply by 0.83.

Figure 3.11

Incorporated manure will decompose faster than manure left on the soil surface.

mineralized in subsequent years, releasing approximately 12 percent and 5 percent of the organic nitrogen applied in the second and third years, respectively, after application. Mineralization of nitrogen from compost is slow as the composting process results in the formation of stable organic compounds that resist decomposition.

Much of the manure phosphorus is in dissolved inorganic forms and crop available until phosphorus ions are fixed by calcium or iron (in most Nebraska soils). Calcium and iron phosphate are only slowly available to plants.

Plant availability of other nutrients in the year of application is given in *Table 3.4*.

Table 3.4

First-year availability (percent of total nutrients applied) for several nutrients in all manure types.

Nutrient	% Available
Phosphorus	70
Potassium	90
Sulfur	40
Micro-nutrients	70
Calcium and Magnesium	70

Crop removal of nutrients

Removal of nutrients by grain and forage crops is related to yield *(Table 3.5)*. Harvest of 200-bushel corn removes approximately 140 pounds nitrogen, 60 pounds P_2O_5 and 40 pounds of K_2O. Alfalfa and soybean can derive much of their nitrogen from the atmosphere. Biological nitrogen fixation is inhibited when soil nitrogen levels are high and the crops will obtain a major part of the required nitrogen from the soil. Alfalfa is able to capture nitrate which has leached beyond the rooting zone of annual crops.

Table 3.5

Average nutrient removal by grain or forage crops.

Nutrient Removal by Crop			
Crop	**N**	**P_2O_5**	**K_2O**
Grain (lbs/bu)			
Corn	0.7	0.3	0.2
Grain sorghum	0.9	0.4	0.3
Oats	0.6	0.2	0.2
Soybean	3.5	0.8	1.3
Wheat	1.2	0.5	0.4
Forage (lbs/ton)			
Alfalfa hay	46.2	9.3	44.9
Alfalfa haylage	21.8	4.9	21.4
Corn silage	9.0	3.2	7.7
Forage sorghum	9.0	3.0	9.6
From Table R-1 in EC720, Nebraska's CNMP Workbook.			

Soil phosphorus build-up

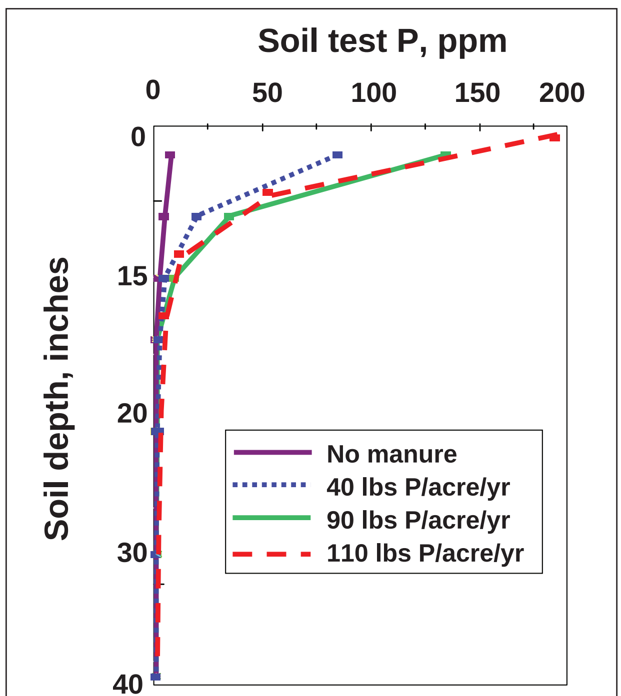
Crops typically remove two to five pounds of nitrogen for every pound of P_2O_5 in the harvested product *(Table 3.5)*. In contrast, slurry and solid manures typically supply 0.9 to 1.5 pounds of nitrogen for every one pound of P_2O_5; the ratio contained in liquid manures is similar to that of crops. Applying manure to meet the nitrogen requirement of plants often results in excessive application of phosphorus. Application of manure to supply 200 pounds/acre of nitrogen may supply about 130 pounds/acre P_2O_5 in beef manure or about 200 pounds/acre P_2O_5 in swine or poultry manure.

FIGURE 3.12

Nutrients are removed by grains and forage.

Soil phosphorus losses to water bodies

Agricultural byproducts are the greatest contributor of phosphorus to surface waters in much of Nebraska. In order to minimize the transport costs for manure disposal, manure is often applied to land at excessive rates near the animal feeding operation. Repeated applications of manure to meet nitrogen needs can result in an increase in soil phosphorus levels that may pose significant risk of surface water contamination *(Figure 3.13)*. Phosphorus levels in the upper surface soil are likely to be much higher following manure application than the average for soil sampled to an 8-inch depth. This is especially true if manure is not well incorporated into the soil. As available soil phosphorus levels increase beyond the critical value for crop yield, the potential for phosphorus loss increases *(Figure 3.14)*. Several factors contribute to the potential for phosphorus loss from land to water bodies.



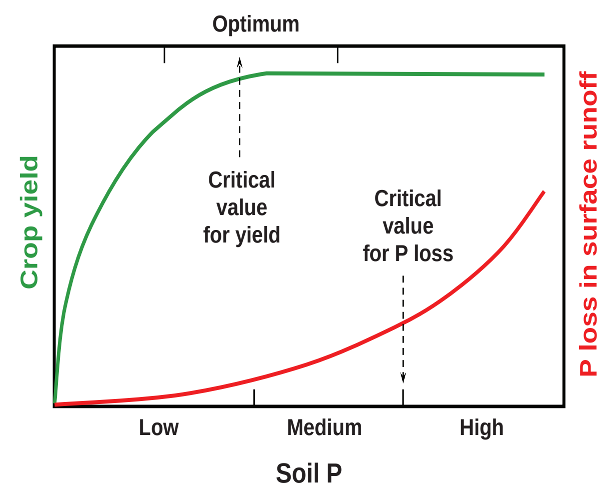
Modified from Figure 34-3 in the LPES Curriculum.

FIGURE 3.13

Soil test phosphorus increases with repeated applications of manure.

FIGURE 3.14

Soils have a critical phosphorus level for optimum crop growth and a critical value above which the potential for phosphorus runoff greatly increases.



Modified from Figure 34-14 in the LPES Curriculum.

The potential loss of phosphorus to runoff and erosion is affected by soil phosphorus level and management and is increased when:

- soil test phosphorus increases *(Figure 3.13)*;
- more phosphorus is applied in manure or fertilizer than required by crops; and,
- applied phosphorus is not incorporated.

The potential for phosphorus loss varies with phosphorus transport factors, including:

- soil erosion which removes both dissolved and attached phosphorus;
- water runoff which carries plant available phosphorus to surface waters;
- irrigation runoff, especially with furrow irrigation; and
- distance to a water flow channel, stream, or water body.

4

Chapter

Inventory

The Nebraska CNMP process outlined in Chapter 2 starts with an inventory of the physical assets on the livestock or poultry operation. Detailed information is needed about the capacity of the confinement areas, the land available for manure application, and the equipment available to distribute and apply the manure. This information is used in other sections to develop strategic, annual, and odor management plans.

Inventory of Animals

The Nebraska Department of Environmental Quality's Title 130 requires permitted operations to state the maximum one-time animal capacity of the livestock operation and provide related information about those animals for the purpose of classifying an AFO as a Small, Medium, or Large CAFO *(Table 4.1)*.

TABLE 4.1

AFOs are classified as Small, Medium, or Large according to the following species animal numbers.

Circle the number of animals in your AFO.			
Species	**Large**	**Medium**	**Small**
Beef cattle	1,000 or more	300 to 399	less than 300
Veal	1,000 or more	300 to 999	less than 200
Mature Dairy Cattle	700 or more	200 to 699	less than 200
Dairy heifers	1,000 or more	300 to 999	less than 300
Swine (55 lbs or more)	2,500 or more	750 to 2,499	less than 750
Swine (less than 55 lbs)	10,000 or more	3,000 to 9,999	less than 3,000
Turkeys	55,000 or more	16,500 to 54,999	less than 16,500
Laying hens or broilers [1]	30,000 or more	9,000 to 29,999	less than 9,000
Laying hens [2]	82,000 or more	25,000 to 81,999	less than 25,000
Chickens except laying hens	125,000 or more	37,500 to 124,999	less than 37,500
Ducks [1]	5,000 or more	1,500 to 4,999	less than 1,500
Ducks [2]	30,000 or more	10,000 to 29,999	less than 10,000
Sheep or lambs	10,000 or more	3,000 to 9,999	less than 3,000
Horses	500 or more	150 to 499	less than 150

[1] Only applicable to poultry operations with liquid manure systems
[2] Other than a liquid manure system

Inventory of Available Land for Manure Applications

The purpose of preparing an inventory of all land application sites is to determine whether the land is suitable to receive manure applications, what environmental risks might be present, and whether there is sufficient land available for the manure volume produced. Each land application site should be identified by a legal description and name. The number of acres on each site should be noted. The soil type and slope of each application site should be noted. Cropping and cultural practices should be recorded at each application site. A documented yield history will help determine the crop utilization of nitrogen from animal manure. Depth to groundwater as well as the distance to the nearest body of water down gradient of the application site should be determined.

A base-line soil test phosphorus level should be determined for each application site through soil testing. This will enable the producer to monitor and manage increases of phosphorus on the application site.

Inventory of Community Sites Regarding Water and Air Quality Issues

At a minimum, for permitted CAFOs in Nebraska, maps or aerial photos are required for the nutrient management plan that must include:

- location and legal description of all planned waste application areas to be utilized by the operation;
- location of any setbacks or buffers; and
- location and extent of any surface water or wetlands within the boundaries of the field, as well as location and extent of any surface water within 200 feet of the field.

In addition, a CAFO must provide scaled drawings of the production area, topographic maps, or equivalent. Each drawing or map must show:

- the spatial location and extent of the animal feeding operation and livestock waste control facilities, including the various components of the facility such as areas designated for stockpiling, composting, or for temporary holding of dead animals, and the area immediately adjacent;
- the location and entire extent of any drainage area controlled or diverted by the operation, including the area immediately adjacent to such area with the runoff flow directions indicated;
- the source of the animal feeding operation's water supply, all other wells, and the location of any wetlands or surface water within the boundaries or immediately adjacent to the facility;
- the topography or clearly defined runoff flow direction in and around the operation and facilities; and
- a United States Geological Survey Quadrangle Map(s) or equivalent scaled topographic maps showing the geographic location of the animal feeding operation and the area extending 2,000 feet from the operation, including the location of all known wells, surface water bodies, homesteads, and businesses that, at the time of permit application, lie within 2,000 feet of the facility.

Inventory of Manure Handling Equipment

Each piece of manure handling equipment used in the manure management system should be described and its purpose and capacity defined. All of the equipment should be identified with the manure storage system it is used with. The equipment list should include not only equipment which is owned but also any equipment that might be hired or rented to handle the manure. The loading, hauling, and pumping capacities of the manure handling equipment should be noted to ensure that the equipment can adequately manage the quantities of solids and liquids that are produced by the livestock operation. Having this information is vital, not only for the present operation, but also to help plan for any future expansion of the livestock operation.

FIGURE 4.1

An inventory should be kept of all manure handling equipment with its purpose and capacity defined.

5
Chapter

Strategic Plan

The strategic plan explains how the animal feeding operation will account for manure produced and applied in an agronomically sound way. This plan is required for producers to obtain an operating permit from NDEQ. The issues relevant to land application include: calculation of manure nutrients produced, estimation of land requirements, implementation of the plan, and management of the land application of manure. Specific plans for manure application and rate determination are required. Excess manure that will not be applied to the producer's land needs to be accounted for by transfers to off-farm users. This may be done through land application agreements. Planning is necessary to utilize the manure nutrients produced and to minimize costs associated with manure management. Once a permit is granted, the maintenance of that permit is covered in the Annual Plan.

FIGURE 5.1

Manure should be applied in an agronomically sound way.

If a livestock facility has a lagoon or holding pond, a plan is needed for sludge removal. Two additional plans are required for a permit application: a site abandonment plan and an emergency response plan.

Quantities of Manure and Nutrients Produced

Typical nutrient excretion values for different livestock types are presented in *Table 5.1*. For example, nitrogen and phosphorus excreted in a 10,000-head beef cattle operation, turning animals twice a year, is estimated to be:

$$\text{Excreted-N} = 10{,}000 \text{ head capacity} \times 2 \text{ turns/yr} \times \frac{\textit{55 lbs}}{\textit{finished animal}} = 1{,}100{,}000 \text{ lbs N/yr}$$

$$\text{Excreted-P} = 10{,}000 \text{ head capacity} \times 2 \text{ turns/yr} \times \frac{\textit{17 lbs}}{\textit{finished animal}} = 340{,}000 \text{ lbs } P_2O_5\textit{/yr}$$

These values vary dramatically between farms. The amount of distiller grain in rations greatly affects nutrient excretion.

Nutrient concentration in manure varies with the ration as high levels of protein or nutrients will result in more nutrient excretion. Phosphorus in swine manure can be reduced by reducing supplemental phosphorus and by adding phytase to improve the digestibility of grain phosphorus.

TABLE 5.1

Manure and nutrient excreted for livestock and poultry, based upon typical animal performance and dietary characteristics in 2002. Actual excretion will vary with diet and animal performance. Harvested manure will vary from these values based upon volatilization of nitrogen and water, addition of solids from bedding and soil, and water and feed additions. The software tool, Nutrient Inventory, at http://cnmp.unl.edu/cnmpsoftware2.html, provides one method for estimating nutrients retained in harvested manure.

Manure and nutrient excreted for livestock and poultry.

	Total Solids	Nitrogen	Phosphorus as P_2O_5	Potassium as K_2O	Total Manure
Meat-Producing Animals	**(lb/finished animal)**				
Beef, finishing — corn diet	780	55	17	46	9800
Beef, finishing — 40% DGS[1] in diet	780	82	32		9800
Poultry — Broilers[2]	2.8	0.12	0.08	0.082	11
Poultry — Turkey (males)[2]	20	1.2	0.82	0.68	78
Poultry — Turkey (females)[2]	9.8	0.57	0.37	0.30	38
Poultry — Duck[2]	3.7	0.14	0.11	0.082	14
Swine — Nursery pig[2]	10	0.91	0.34	0.42	87
Swine — Grow-Finish[2]	120	10	3.9	5.3	1200
All Other Livestock	(lb/animal/day)				
Beef — Cow	15	0.42	0.22	0.36	
Beef — Growing Calf	6	0.29	0.13	0.23	50
Dairy — Lactating Cow[3]	20	0.99	0.39	0.28	150
Dairy — Dry Cow	11	0.50	0.15	0.40	83
Milk — Fed Cows			0.017		
Dairy — Calf	3.2	0.14			19
Dairy — Heifer	8.2	0.26	0.10		48
Dairy — Veal	0.27	0.033	0.023	0.053	7.8
Horse — Sedentary	8.4	0.20	0.066	0.072	56
Horse — Intense Exercise	8.6	0.34	0.17	0.25	57
Layer	0.049	0.0035	0.0025	0.0016	0.19
Swine — Gestasting Sow[2]	1.1	0.071	0.046	0.058	11
Swine — Lactating Sow[2]	2.5	0.19	0.13	0.14	25
Swine — Boar[2]	0.84	0.061	0.048	0.047	8.4

[1]DGS — Distillers grains with solubles
[2]If phytase is used in ration, P excretion may be 30% to 40% less
[3]Assumes milk production of 88 pounds per day

At this time, NDEQ uses default values for its determinations of total manure nutrients produced for planning purposes.

Estimating annual manure nutrients produced based on default values

Excretion numbers can be calculated using average values developed for the various animal species at specific stages in their development. EC720, *Nebraska's CNMP: Manure Application Workbook* is a resource that contains default values.

FIGURE 5.2

Annual manure nutrients produced can be estimated based on feed intake.

Estimating annual manure nutrients produced based on feed intake

Another method of calculating total manure nitrogen and phosphorus is using the whole-farm nutrient balance process. This method uses the actual feedstuffs and their associated nitrogen and phosphorus concentrations. From this, the livestock weight gain per ton of feed and nutrients retained in the livestock product are calculated and the remaining nutrients are assumed to be excreted in the manure. This method gives different results than using default values and may be more accurate, but only if the input data is of good quality. The software tool, *Nutrient Inventory,* provides an accepted method for estimating excretion of nutrients based upon ration (*http://cnmp.unl.edu/cnmpsoftware2.html*).

FIGURE 5.3

Nutrient losses during storage and handling should be estimated prior to land application.

Land Requirements for Managing Manure

The main emphasis in the planning stage of a manure application program is whether or not sufficient land is accessible to manage the nitrogen (required by NDEQ) and phosphorus (which may be required in the future) in manure.

Nutrient losses during storage and handling should be estimated prior to land application. For planning purposes, default values for these losses are acceptable since actual nutrient content varies with each storage facility.

Once a permit is granted by NDEQ, nutrient requirements will be determined annually based on soil tests, manure analysis, and actual production history. Therefore, the initial calculations will be superseded by actual management and will be based on field history.

The strategic planning process is designed to estimate the manure produced and the land needed for application at an agronomic rate. The calculations required by NDEQ are designed to insure enough land. However, the calculations typically overestimate the actual acres needed on an *annual* basis. This will give the producer some flexibility on a *year-to-year* basis to make decisions suitable to conditions.

Estimating land requirement on a nitrogen basis

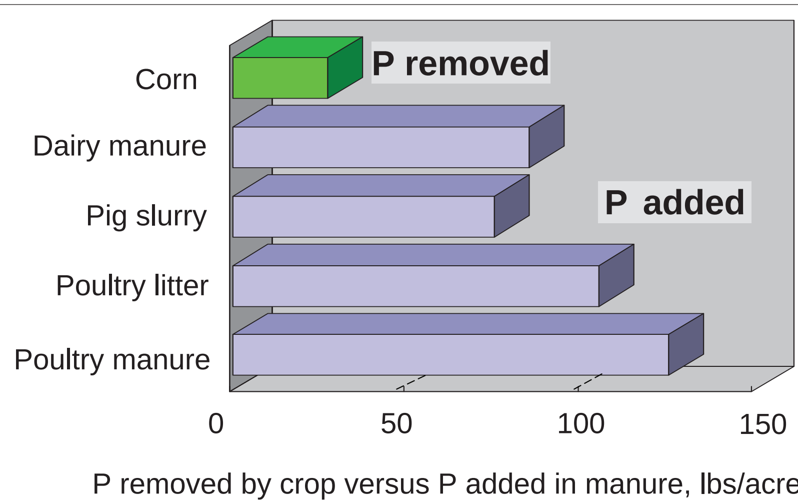
The agronomic nitrogen rate is the amount of nitrogen needed to grow and produce a crop at a certain yield level. Choice of yield level is important for these calculations and should be based on field records. Use of county averages is acceptable, but often underestimates production, resulting in increased land requirements. For legumes, such as alfalfa and soybeans, 50 percent of nitrogen removal is used, as some nitrogen is gained from symbiotic nitrogen fixation. When estimating manure nutrients available to the crop, consider that substantial nitrogen can be lost during storage and handling, and there may be significant loss of ammonium nitrogen following application. EC720, *Nebraska's CNMP: Manure Application Workbook (http://cnmp.unl.edu/landapplicationworkbook.html)*, provides useful information for determining these estimates.

One component of the calculations for determining crop-available nitrogen that is not included in the strategic planning process is the mineralization of the organic component of manure. This mineralization component accounts for differences in the amount of manure nitrogen calculated in an Annual Plan compared to that calculated in a Strategic Plan. In the Annual Plan there will usually be less available manure nitrogen than estimated in the Strategic Plan. Therefore, fewer acres are usually needed for land application than estimated in the Strategic Plan.

Assessing the potential for phosphorus runoff — the Phosphorus Index

Land application of manure can be beneficial to crop production but can result in increased risk of P loss to surface waters. When manure is applied to meet crop nitrogen needs, the amount of P applied is typically much more than the P removed in the harvest of one crop *(Figure 5.4)*. Effective January 1, 2007, operators of large CAFOs in Nebraska need to assess the risk of P delivery to surface waters from each of their designated fields by using a P index before manure can be applied. This assessment needs to be done once every five years and results need to be kept. Phosphorus indexes are tools for the assessment of the potential for P delivery from agricultural lands to surface waters. Two P indexes are approved for Nebraska — the Nebraska P Index (1998) and the recent Nebraska P Index (2005).

Both P indexes consider source and transport factors to estimate P loss to surface waters. The source factors allow assessment of the quantity and forms of P present at the site (see *Appendix Table 1* on Page 67). The transport factors allow assessment of the potential for transport of P from the site to a water body.



Modified from Figure 34-8 in the LPES Curriculum.

FIGURE 5.4

Applying manure to meet crop nitrogen needs (about 200 pounds available-N/acre for 170-bushel corn) will add much more phosphorus than corn uses annually.

The Nebraska P Index (1998) is found in the appendix of Title 130. The Nebraska P Index (2005) and the publication, *The Nebraska Phosphorus Index (2005): Background and Users Guide*, are available at *http://cnmp.unl.edu/cnmpsoftware2.html*.

The P Index was designed to be used on the basis of a whole field or management units within a field. In many fields, the risk of P loss is often considerably greater for part of a field than for the whole field, and it may be economically and environmentally advantageous to do the P loss risk assessment by zones within the fields. The P index risk scores fall into four risk levels [see Appendix *Table 1* on Page 67 for additional interpretation appropriate for Nebraska P Index (1998)].

- Low (0-2). Current practices keep water quality impairment due to agricultural P pollution low. Manure can be applied at rates sufficient to meet crop N needs.
- Medium (2-5). Delivery of agricultural P may cause some water quality impairment and consideration should be given to alternative conservation and P management practices. Manure can be applied at rates sufficient to meet crop N needs.
- High (5-15). Phosphorus loss from the field causes much water quality impairment. Remedial action, such as alternative conservation measures or P management practices, is recommended. Manure can be applied, but P applied should not exceed crop P removal. Manure can be applied to meet a crop's N need in one or more applications duirng a five-year period, but P applied should not exceed crop removal during that five-year period.
- Very High (>15). Impairment of water quality is extreme and remedial action is urgently recommended. Phosphorus application should be discontinued. Improved conservation measures should be implemented.

Management for reducing phosphorus losses: The most effective management principle is to apply no more phosphorus than the crop needs over a set time period. If manure is to be applied every three years, then the manure phosphorus load should not exceed the three-year removal rate, unless the soils are extremely low in phosphorus at application time. Application of manure on a nitrogen basis every year should be avoided on any sensitive site with a high Phosphorus Index.

The decision of whether or not to incorporate manure is a problem without a perfect solution. Surface-applied manure will allow more soluble phosphorus to run off in a moderate rainfall event. Research has shown that water soluble phosphorus movement will increase without incorporation. However, with no incorporation, the increased crop residue and manure covering will reduce erosion and the movement of phosphorus which is attached to soil particles. Tillage will reduce water soluble phosphorus in runoff but will increase sediment attached phosphorus.

Physical structures to hold water in settling basins and behind dams will decrease soluble phosphorus reaching surface water. A combination of not applying manure near streams and waterways; reduced tillage to decrease sediment loss; and water control will minimize phosphorus reaching surface waters.

In high soil phosphorus situations, choosing a crop such as alfalfa will remove more phosphorus per acre and help draw down reserves. Crops where the whole plant is harvested will remove more nutrients than crops where crop residue is returned. Near sensitive areas, perennial forages and grass filter strips provide more ground cover and reduce erosion potential.

FIGURE 5.5

Deciding whether or not to incorporate manure is a problem without a perfect solution.

An excellent Extension publication on phosphorus management is *Agricultural Phosphorus Management and Water Quality Protection in the Midwest (http://www.ianrpubs.unl.edu/sendIt/rp189.pdf).* RP 187. University of Nebraska–Lincoln Extension.

Nutrient Management Activities Plan

A permit application requires the description of the procedures to be used, the need, and timing of implementation. This section is extremely important because the operator is committing to follow specific procedures. For example, if the plan says manure will be sampled every year, then the records need to contain annual reports of manure analysis. If the soil sampling area is listed as 20-acre sub-fields, then records will need to show that this was done. The calculation of an agronomic rate for manure application and guidelines for manure and soil sampling are covered in the Annual Plan chapter.

Three major plans are needed: the soil sampling plan for each field, the manure sampling and analysis plan for each handling system, and the manure application plan for each manure handling system. This includes methods of application, priority determination of sites, calibration, setbacks, and the recordkeeping system to be used. Forms for these plans can be found in EC720, *Nebraska's CNMP: Manure Application Workbook*.

Odor Management Plan

Odor emission is of great concern to the general public. An odor management plan is required in the permit application for livestock operations with more than 1,000 animal units (Classes II, III, IV). Producers need to understand odor emission from animal housing, manure storage and handling, and land application (see Chapter 1) and available management options.

Site selection and management

Odor problems can be minimized through site selection. Find a site that is located the proper distance from neighborhoods and public places. Take into account prevailing winds in the summer when many people spend significant time outdoors. Don't locate where slope gradient will let odors 'flow' to neighbors. Try and keep housing and storage out of sight and surrounded by crops and windbreaks.

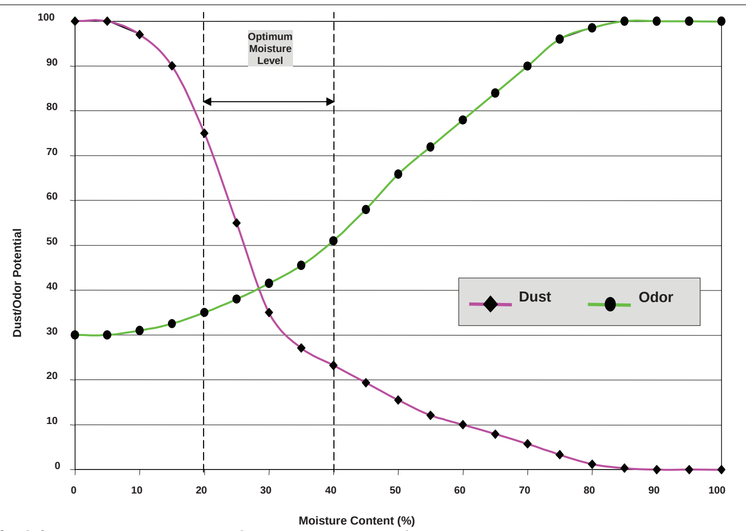
FIGURE 5.6

Make sure feedlots are well-drained and scraped frequently to minimize odor production.

With open lots, the influence of pen moisture on odorous emissions is well documented. Poor drainage and/or improper diversion structures in holding pens or feedlots favor anaerobic microbial activity. Adequate drainage is critical to avoid odors. A pen slope of three to four percent will help ensure that the surface sheds water rapidly. Research has shown that open lot moisture levels between 20 and 40 percent moisture content are best for controlling odor and dust. Lots that have below 20 percent moisture become too dry and generate dust; lots that have above 40 percent moisture produce odors that dominate emissions. Frequent manure collection is also critical, especially in feedlots. When scraping the surface of a feedlot, it is best to use equipment that leaves a smooth surface (box scrapers are excellent) to prevent standing water and the resulting odors.

Housing

When designing housing and the management of housing, consider cleanliness to be a significant factor in reducing odors. Odors cling to dust, holding the odors near ground level. All management practices that reduce dust will help with reducing odors. More fat in the feed, covers for feed equipment, and cleaning fans and areas where dust can accumulate are all management techniques that help reduce dust and odor. Windbreaks near the housing will help push odorous air up into the atmosphere and avoid movement along the ground surface.



Modified from Figure 42-1 in the LPES Curriculum.

FIGURE 5.7

Research has shown that open lot moisture levels between 20 and 40 percent moisture content are best for controlling odor and dust.

Management of the housing area to keep areas clean minimizes odors. Outdoor lots need similar housekeeping. Design and maintain open lots to encourage good drainage and rapid drying. Keep lots clean and remove manure and unused or spoiled feed. Design feed bunks to drain. Keep grass cut around feedlots, provide good drainage from feedlots, keep dust down on access and feeding roads, and use windbreaks to hide line of sight to pens.

Livestock waste control facility (LWCF)

The LWCF can be a source of odor. Anaerobic lagoons, manure storage (including underbarn pits), or a sediment basin are types of LWCFs. An anaerobic lagoon is designed to treat and store manure. A properly designed and operated lagoon should not produce the odors that a manure storage often emits and should not require agitation. A lagoon should never be completely emptied except for sludge removal, and then it should only be pumped down to the permanent pool marker. A manure storage structure is designed to store manure from a production facility for a period of time and is routinely emptied. Covering a manure storage is an option that will help minimize odors. Sediment basins collect runoff from feedlots and should be allowed to drain completely and be cleaned regularly to minimize odors.

Land application considerations for reducing odor

Discuss manure application with your neighbors. Plan applications to coordinate with their outdoor events and minimize impact from odors. If neighbors know about the manure application ahead of time, they may be less likely to be offended.

When emptying a pit or manure storage facility, agitation is necessary to have a uniform material. Agitate and land-apply between 8 a.m. and 4 p.m. on warm, sunny days when wind direction does not impact neighbors. The optimum time to apply manure is in mid- to late-morning when the air is warming and rising; avoid evening applications. When applying manure, management processes that minimize mixing of air and manure are helpful. Immediate incorporation with injectors, knives, or tillage implements will reduce odors. Drop hoses are better than broadcast sprayers.

FIGURE 5.8

Large guns that direct water and effluent into the air with high pressure will produce more odor.

Effluent can be applied by irrigation equipment and the same principles apply. Large guns that direct water and effluent into the air with high pressure will produce more odor than low pressure drop nozzles under the crop canopy. Use only the effluent from lagoons and apply when the lagoon is functioning well (summer and fall). Lagoons 'turn' in the early spring as biological processes restart. At this point, odors may be worse and the effluent should not be irrigated onto fields.

Emerging technologies should be monitored since this area is being researched and new management tools may prove very useful. In addition, public education and communications need to be practiced continually. The goal is to use all available technology to minimize odors, or if odors are unavoidable that they are produced at a time when their effect on neighbors will be minimized.

Having a specific plan and recording its implementation will be very useful if anyone ever questions the intent and procedures of a specific operation.

Additional Required Plans

Operation and maintenance plan

The livestock producer will need to document how the storage and runoff facilities will be maintained and operated over the year. Title 130 states that a plan will include a schedule for monitoring of available waste storage capacity, comprehensive inspections, security of drain valves, waste removal procedures, maintenance procedures and recordkeeping plans related to the storage facility. When designing new facilities, a professional engineer can help set up these plans and determine minimum pumping depths and maximum storage depths.

Tip

Clean water diversions can eliminate or minimize unnecessary volumes of clean water from the manure management system.

- Place diversions uphill or around facilities.
- Gutter buildings to divert rainfall.
- Maintain waterers.
- Keep diversions mowed.

Sludge and sediment management plan

In the case of anaerobic lagoons where liquid is pumped off annually and sludge builds up at the bottom, a plan is needed to utilize the sludge when it is removed. Most lagoons are designed for a 20- to 25-year life. When best management practices are used, there is minimal agitation during the annual pumping. A microbial population is established that metabolizes most of the organic material that settles to the bottom. The remaining material is rich in phosphorus and nitrogen.

EC720, *Nebraska's CNMP: Manure Application Workbook*, assumes 65 percent for the proportion of total phosphorus that settles and needs to be managed as sludge. This will result in significant phosphorus to distribute. The phosphorus in the sludge will be higher in concentration than in other manures so it will be more economical to transport over longer distances. Fields far away from the storage site can be used for this material. If these sites are not vulnerable to phosphorus transport they can have more than one year of phosphorus needs applied at one time. Alternatively, this material can be sold or given to others. It needs to be accounted for in the permit application.

FIGURE 5.9

A plan should be made for the sludge and sediment removal in a lagoon.

FIGURE 5.10

Proper steps from the closure plan should be followed when abandoning a manure storage structure.

Closure plan

A plan is needed to outline the steps that would be taken in case the livestock production area is closed. The specific plan will be dependent on the housing and storage system. Annual scraped cattle yards need a different plan than a lagoon. Cattle yards may contain sufficient nitrogen that cropping them without commercial fertilizers should be possible for several years. Lots may need to be scraped and the scrapings applied like manure. The plan for this needs to be written and included with the permit application.

Emergency response plan

Leaks and equipment failure have created emergencies in the past either due to equipment failures, operator error, or natural disasters. Having a plan to remedy the situation will allow a quicker and more effective response. This plan is required in a permit application and makes economic and management sense. For each potential problem the producer needs to outline the initial containment steps, who is to be informed, and what equipment is available to repair the problem. NDEQ requires notification by telephone and in writing for certain emergencies.

Disposal of dead amimals

Proper planning for livestock death losses will help minimize the risk of environmental contamination. Disposal methods include rendering, burial, incineration and composting. With fewer rendering plants available and concerns over water contamination from burial and the costs associated with incineration, composting may provide an alternative means for disposal of mortality losses. Properly done, composting offers a practical, economical, and environmentally friendly way to utilize livestock mortalities, and recycle the nutrients contained in the animal carcass.

6

Chapter

Annual Crop Nutrient Management Plan

An annual crop nutrient management plan is needed to ensure an adequate supply of nutrients to sustain profitable crop production, and to balance nutrient inputs (including manure) with crop nutrient needs. Title 130 of the NDEQ requires that a permit application include a nutrient management plan with manure sampling and analysis procedures, soil sampling and analysis procedures, and planned land application rates, methods, and frequencies.

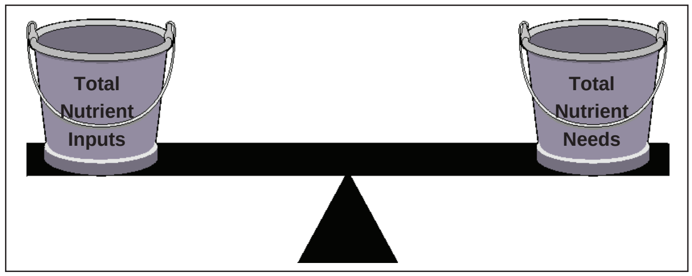


FIGURE 6.1

Crop-available nutrients should equal crop nutrient needs.

The Strategic Plan covered in the previous chapter describes how the land and manure are going to be sampled, while the Annual Plan implements that plan and associates manure application with specific fields. The annual crop nutrient management plan has four required and two recommended components:

- nitrogen management plan
- soil testing
- manure nutrient analysis
- manure application
- phosphorus management plan (recommended)
- action plan and records (recommended).

Planned activities for some components are likely to be similar from one cropping season to the next, but each should be reviewed and revised annually to adjust for current conditions. Nitrogen inputs must be matched with crop nitrogen needs for each growing season because of the possibility of excess nitrate-nitrogen leaching to groundwater. Manure applications may provide phosphorus for several years provided the surface soil phosphorus does not accumulate to levels that cause unacceptable chances of phosphorus loss to surface water.

Nitrogen Management Plan

Manure should be applied so it does not exceed the crop nitrogen requirements, according to NDEQ Title 130. Consequently, producers need to determine the total nitrogen requirement for the planned crop, and then decide how and when to apply that amount of nitrogen. All of the nitrogen may be derived from manure, or producers may desire to apply commercial nitrogen

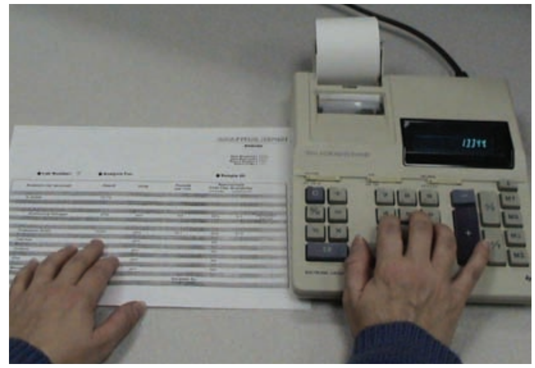


FIGURE 6.2

Manure analysis reports are used to plan proper application rates.

fertilizer prior to or at planting, or as a sidedress application. Remember to allow nitrogen credit for sources such as soil residual nitrate-N, preceding legume crops and nitrate in irrigation water.

Once nitrogen credits and nitrogen applications from commercial fertilizer are subtracted from the crop nitrogen requirement, the remainder can be supplied from manure. A laboratory analysis of the manure source is helpful in determining the manure application rate. A lab analysis will provide the amount of ammonium, nitrate, and organic nitrogen in the sample. Nitrate-N will be 100 percent available the year of application, although nitrate-N levels are usually quite low in manures. Ammonium-N can be 100 percent available if manure is incorporated immediately or injected. If manure is broadcast and not incorporated, the ammonium-N would be unavailable due to ammonia volatilization to the atmosphere. Organic-N availability will depend on the manure source. If manure is to be applied in successive years, credit also needs to be given for nitrogen mineralization from previous years' manure application. For more information to calculate manure nitrogen credits, see Appendix *Tables 4* and *5* on Page 70.

Soil Testing

Regularly checking soil nutrient status by sampling and analysis should be part of one's crop production plans regardless of whether manure use is an option. However, soil testing is especially important with manure application to insure that excessive amounts of nutrients are not accumulating in the soil.

Soil samples should be collected to accurately reflect the nutrient status of the field. NebGuide G1740: *Guidelines for Soil Sampling*, and Extension Circular 00-154: *Soil Sampling for Precision Agriculture*, provide details on how to collect samples. It's important to collect samples for non-mobile nutrients, such as phosphorus, potassium, and pH, to a depth of 8 inches, and to collect deeper samples for nitrate-N to a depth of at least 24 inches. The most critical nutrients to monitor with regular soil sampling for manure management are nitrogen and phosphorus. Nitrate-nitrogen should be sampled before manure application and the residual nitrogen should be credited to next year's crop nitrogen requirement.

Recommended Nutrient Tests

Annually:

- Residual nitrate-N
  (*Sample depth: at least 2 ft., but preferably 3 – 4 ft.)*
- Pre-sidedress nitrate test (PSNT)
  (Sample depth: 1 ft.)

Every Four Years:
(Sample depth: 8 inches)

- pH & buffer pH
- Organic matter
- Phosphorus
- Potassium

FIGURE 6.3

Soil samples should be collected to accurately reflect the nutrient status of the field.

Another soil nitrogen test of value to livestock producers is the pre-sidedress nitrate test (PSNT). This test is based on a soil sample collected to a depth of one foot in early June, around the V6- to V8-growth stage of corn. Nitrate analysis of samples collected at this time of year accounts for nitrate which has been mineralized from soil organic matter and manure during the spring. A PSNT may better predict crop nitrogen needs for the remainder of the growing season than preplant nitrate sampling, particularly in situations where manure has been applied. Research from Iowa and other states has shown that a PSNT sample with 25 ppm nitrate-N or greater reflects an adequate nitrogen supply to meet crop needs of corn during the growing season.

Since nitrogen in soil is very dynamic, it is important in any cropping situation to closely monitor the nitrogen status of the crop. This is especially important if most or all of the required nitrogen is anticipated to come from manure. If nitrogen availability from soil and manure is less than expected (due to cool weather, excessive rain, etc.), nitrogen deficiencies may develop (yellowing of lower leaf tips and down the midrib). A regular scouting program for the field is encouraged. Assessment tools such as a chlorophyll meter or remote sensing may help detect developing nitrogen deficiency before yield potential is reduced.

Residual nitrate-N or PSNT sampling is only necessary if the crop requires significant nitrogen inputs. It is not necessary to sample for nitrogen if the crop to be planted is soybean or alfalfa.

The following gives an example of a swine producer who has a lagoon with a center pivot irrigation system. The PSNT calls for 60 lbs/acre of nitrogen to meet the corn crop's need at sidedress time. Samples of the effluent are sent to a testing lab and the results indicate that 7.9 lbs/ac-in of organic nitrogen and 44.5 lbs/ac-in of ammonium nitrogen are available. Application losses from sprinkler irrigation must now be taken into account (Appendix *Table 5* on Page 70). About 35 percent of the organic-N and 50 percent of the ammonium-N are available with sprinkler irrigation. The result is 2.8 lbs/ac-in of organic-N and 22.3 lb/ac-in of ammonium-N for a total of 25.1 lbs/ac-in. The producer can meet the crop nitrogen needs by applying about 2.5 inches of effluent per acre.

Effluent Needed to Meet Crop Nitrogen Needs

Application Availabilities:

7.9 lbs/ac-in X 35% = 2.8 lbs organic-N
44.5 lbs/ac-in X 50% = 22.3 lbs ammonium-N

Total Nutrients Applied:

2.8 + 22.3 = 25.1 lbs N/ac-in

Crop Needs:

PSNT = 60 lbs N/acre
60 lbs N/acre divided by 25 lbs/ac-in = 2.5 in

The producer should apply 2.5 inches/acre of effluent to meet crop nitrogen needs.

Samples for phosphorus determination need not be collected every year, unless required to monitor phosphorus accumulation due to manure application.

Manure Nutrient Analysis

Default values for manure nutrient concentrations are typical values, but concentrations can vary substantially from these due to the feeding program, type of animal housing, and manure handling system. Additional variation occurs within animal feeding operations due to time of year and weather conditions. It is important in an Annual Plan to accurately determine the nutrient content of manure. Therefore, it is necessary to collect representative samples at the time of land application or as close as possible to application.

FIGURE 6.4

To accurately determine the nutrient content of manure, representative samples need to be collected.

Sampling manure for nutrient analyses

Manure can be sampled from the feedlot, the manure storage pile or pit, the application spreader, or by collecting samples during application. Sampling in the field insures that losses that occur during handling, storage, and application are taken into account. The time of year and weather conditions also affect manure nutrient concentrations. Accurate determination of manure nutrient content is important for development of a good Annual Plan. Representative manure samples need to be collected at or near the time of manure application periods for each manure facility to determine nutrient contents. Refer to NebGuide G1450: *Sampling Manures for Nutrient Analysis* for more information.

FIGURE 6.5

Place solid manure samples in a resealable freezer bag.

A representative manure sample is composed of several sub-samples collected from various parts of the manure storage facility. The number of sub-samples required changes with the variability of manure. The number of sub-samples may be as few as 10 if hand-grabbing from a manure spreader or taken while pumping to load a tank spreader or through an irrigation system. Twenty sub-samples may be needed if sampling from open lots or from a liquid storage facility. Samples collected in the field during application by catching solid manure on tarps or liquid manure in pans should have eight to ten sub-samples. After sub-samples are compiled and mixed well, a sample should be put in a suitable container for shipment to a lab.

Toxic Gases from Stored Slurry Manure

(Hydrogen Sulfide, Methane, Ammonia, and Carbon Dioxide)

- Toxic gases may be released during agitation.
- Remove animals and people from the building before agitation.
- Agitate slowly at first.

FIGURE 6.6

Collect liquid manure in a plastic pail and take a sub-sample from the pail.

Tips

- Put samples of solid manure in one-quart freezer bags.
- Put samples of slurries and liquid manures in one-pint plastic bottles and fill to one inch from the top.
- Label the container with your name, the sample identification, location and date.
- Refrigerate and ship or deliver the sample as soon as possible. If delivery to the lab will be delayed, freeze the sample.
- Ship in an insulated container, such as a styrofoam-lined box.
- Avoid shipping samples on weekends.

Manure analyses

Manure organic nitrogen, ammonium nitrogen, phosphorus and water content are of greatest interest to most producers. Potassium and salt content may be important. The concentrations of calcium, magnesium, sulfur and micro-nutrients are generally of less interest.

Manure nitrogen is primarily in two forms: stable organic nitrogen and unstable ammonium nitrogen (normally nitrate-N is present in only small amounts). Organic nitrogen is slowly released over several years as the manure decomposes with 25 to 35 percent of the organic nitrogen released in the first growing season. It is estimated that 15, 7 and 4 percent of organic nitrogen become available in the subsequent 2-4 years. Ammonium nitrogen and nitrate nitrogen are immediately available to plants, but much can be lost as ammonia gas if improperly managed.

Crop availability of phosphorus and potassium in manure is more easily predicted. Seventy percent of phosphorus and 90 percent of potassium in manure are estimated to be available during the first growing season.

Results of manure analyses are typically reported as concentration (percent or ppm) for the sample as received and on a dry weight basis, as well as in pounds per unit of application. The units of application are tons per acre for solids, 1000 gallon per acre for slurries, and acre-inches for liquids. Request the laboratory to report the results in units of greatest value to the producer's situation.

FIGURE 6.7

A analysis test will indicate the nutrient content of manure.

Manure Application

The process of manure application is driven primarily by the type of manure to be applied – namely solid, slurry, or liquid. The goal with any type of application system should be to maximize the agronomic benefit from manure application and to minimize the environmental impact.

Deciding Where and When to Apply Manure

Manure should be applied to fields, and areas within fields, where it will be most beneficial to crop growth. Consider soil fertility levels in the field — will manure application increase crop yield potential? Are there areas of low fertility (low organic matter or eroded areas) that manure will help improve? Are there areas where manure has recently been applied that should be avoided? Application considerations should also include the potential for environmental impact. Will application to sloping hillsides allow opportunity for runoff into nearby streams? Maintain an appropriate buffer area around streams and wells. Do not apply manure to frozen ground unless it is relatively flat and remote from surface water.

FIGURE 6.8

Manure should be applied to fields, and areas within fields, where it will be most beneficial to crop growth.

The cost of transportation is a significant factor in manure application. The further the field is from the manure resource, the more expensive it will be to apply it to the field. The nutrient value of the manure will help offset the transportation cost by replacing commercial fertilizer input costs. Unfortunately, soils surrounding livestock facilities often have very high nutrient levels due to excessive manure application. Look for ways to reduce volume when handling manure, such as composting dry manures, or minimizing dilution of slurries with water. This will make the transport of manures over greater distances more cost-effective and allow nutrients from manures to be more effectively used on lower fertility fields.

Avoid situations that will be a nuisance to neighbors when applying manure. Try to apply when prevailing winds will carry odors away from nearby homes or businesses. Avoid application during warm, humid weather. Inject slurries rather than broadcast them on the surface. Incorporate surface-applied manures, either dry or liquid, within 24 hours after application or little odor reduction will result.

Insure Accurate Application

The first step in accurate application is to calibrate the applicator — a step often avoided by producers because of the belief that calibration of a manure applicator is not a pleasant task. However, calibration need

FIGURE 6.9

Calibrating the applicator is the first step in accurate manure applications.

not be a difficult or messy job. Accurate application also means the manure is distributed as uniformly as possible across the swath width, and that swaths are equally spaced across the field.

Injection of liquid manures allows the greatest retention of nutrients, reducing or eliminating the potential for ammonia volatilization and runoff. Injection also minimizes odor concerns. If injection of liquid manures is not possible, or if dry manure is broadcast, incorporate the manure as soon as possible.

Phosphorus Management Plan

If manure is regularly applied to cropland, phosphorus levels are generally adequate for excellent crop performance. A phosphorus management plan is useful to avoid excess levels of soil test phosphorus.

In a manure phosphorus plan, the phosphorus balance for the field after crop removal in the harvest, or harvests, following manure application is estimated. The amount of phosphorus applied is estimated from the rate of manure application and the phosphorus concentration of the manure. Other phosphorus credits, such as from fertilizer, are added to the amount applied. Crop removal of phosphorus is estimated from the yield and the phosphorus concentration of the harvested product. The difference is phosphorus added to the soil. A very general rule of thumb is that soil phosphorus levels will be increased one ppm for every 15-20 pounds of phosphate applied in excess of crop removal.

Action Plan and Records

The purpose of the action plan is for the livestock manager to communicate to employees the specifics of how manure is to be applied. The action plan ties everything together for a given year – which fields (or areas within fields) are to receive manure, how much manure should be applied and when and if it should be incorporated, as well as plans for application of commercial fertilizer. The action plan provides a brief summary of plans for the year in an easily accessible format. Great detail is not necessary – more information can be found if needed by going back to components reflected in the Annual Plan, such as manure and soil analysis, nitrogen and phosphorus management plans, etc. The Annual Plan should condense the necessary details into a useful reference that can be carried to the field.

Once manure has been applied, write down any relevant deviations from the plan before details fade from memory. See Chapter 7 for more detailed information on recordkeeping.

7 Chapter

Records and Documentation

Records allow producers to document manure application and related activities. Just as one keeps track of cash flow in a business operation, it is necessary to know where nutrients are coming from and going to in order to maximize the bottom line. Records can be used to refine estimates such as the quantity of manure produced, the nutrient contents of manure, or rates of soil phosphorus change. Finally, documenting activities is critical to a comprehensive nutrient management plan.

Title 130 requires a livestock producer to maintain records documenting implementation of a crop nutrient management plan and other facility maintenance activities. Records must be kept for five years and be available to NDEQ field inspectors, who must verify reasonable management of nitrogen. Inspectors may ask to see records of current and past manure application rates, manure analysis reports, maps of land application, soil tests, equipment application rate calibrations, as well as a record of land application training.

FIGURE 7.1

Documenting manure management activities is critical to a comprehensive nutrient management plan.

Records Required of Permitted AFOs

A permitted AFO needs to conduct routine inspections of the production area, irrigation system, and land application-related activities. Producers are encouraged to develop checklists of items to assist in completing these inspections and to provide a means of recording the results of those inspections. Examples of records checklists and sample worksheets are found in *Nutrient Management Plan: Records Checklist and Samples for Animal Feeding Operations* (*http://www.ianrpubs.unl.edu/epublic/live/rp188/build/rp188.pdf*).

FIGURE 7.2

Precipitation records are required for all facilities that maintain an outdoor manure storage or land apply manure.

TABLE 7.1

Required inspections for NPDES-permitted CAFOs in Nebraska.

Required inspections for NPDES-permitted CAFOs in Nebraska		
	Sample Form[1]	**Frequency**
Weekly inspections of all storm water diversion and runoff collection structures delivering storm water to the waste storage	Form 6	Weekly
Daily inspection at the production area of water lines, including drinking water or cooling water lines	Form 5A or 5B	Daily
Inspections of all storage facilities including storage liquid level as indicated by the depth marker	Forms 6 and 7	Weekly
Inspections prior to operation of the irrigation distribution system and the water sources protection equipment designed to prevent manure backflow to the fresh water source. In addition, regular inspections are required of land application equipment including calibration of application rates	Form 18 A, B, or C	Beginning of land application season, and as appropriate
Inspections to determine the sludge and sediment accumulation level in liquid impoundments		Annually

[1]*'Nutrient Management Plan: Records Checklist and Samples for Animal Feeding Operations' (http://www.ianrpubs.unl.edu/epublic/live/rp188/build/rp188.pdf).*

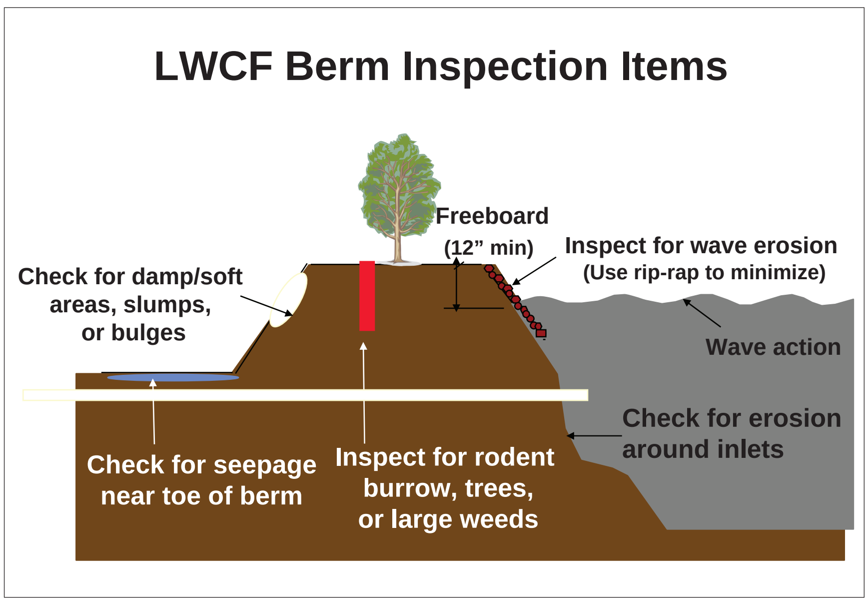


FIGURE 7.3

Inspect all LWCFs and record any major maintenance activities.

Records are also required for documenting the multiple activities within a CAFO.

Records documenting activities that are required of NPDES-permitted CAFOs in Nebraska		
	Sample Form[1]	**Frequency**
All inspections listed in *Table 7.1 (Large CAFOs only)*	See *Table 7.1*	
Depth of the manure and process wastewater in all waste storage facilities as indicated by the depth marker	Forms 6 and 7	Weekly
Any actions taken to correct deficiencies found as a result of required inspections	Forms 6 and 7	As appropriate
Records of mortalities management	Form 4	As appropriate
The date, time, and estimated volume of any overflow or discharge	Form 8	With each discharge
Expected crop yields for the land application areas	Form 13 A or B	Annually
The date(s) manure, litter, or process wastewater was applied to each field	Form 16 A, B, C, or D	For all land application events
Weather conditions at the time of application for 24 hours prior to and following application *(Large CAFOs only.)*	Form 16 A, B, C, or D	For all land application events
Results from manure, litter, process wastewater, irrigation water, and soil sampling and testing		At least annually
Basis for determining manure, litter, and process wastewater application rates	Forms 12 and 13	Annually
Results of the most recent phosphorus risk assessment for each field or field segment including the legal description, date assessed, name of person who completed the assessment, and the level of risk assessed *(Large CAFOs only.)*	Forms 9 and 10	Every 5 years, starting in 2007
Calculations that show the total nitrogen and phosphorus to be applied to each field	Forms 13 and 14	Annually
Total amount of nitrogen and phosphorus actually applied to each field	Forms 13 and 14	Annually
The method used to apply the manure, litter, or process wastewater	Form 15	As appropriate
For manure, litter, or process wastewater transferred to other persons: the nutrient analysis results and the date, recipient name and address, and approximate amount transferred	Form 23	As appropriate
Dates of inspections of equipment used to apply manure, litter, or process wastewater	Form 18 A, B, or C	As appropriate
The nutrient management plan document and the design document for all storage and runoff collection systems		Most recent permit application
[1]*'Nutrient Management Plan: Records Checklist and Samples for Animal Feeding Operations' (http://www.ianrpubs.unl.edu/epublic/live/rp188/build/rp188.pdf).*		

Table 7.2

Records documenting activities that are required of NPDES-permitted CAFOs in Nebraska.

In addition, CAFOs are required to submit reports to the Nebraska Department of Environmental Quality (NDEQ) for the following issues:

Reports to be submitted to NDEQ by NPDES-permitted CAFOs in Nebraska		
	Sample Form[1]	**Frequency**
The annual report for the previous calendar year must include the maximum number and type of animals, estimated amount of total manure, litter, and process wastewater generated, estimated amount transferred to off-farm users, number of acres for land application covered by the nutrient management plan; total number of acres under control of the operation used for land application, summary of all discharges from the production area, the name and contact information of the person who is responsible for land application and the date that land application training was last completed, a statement indicating whether the current version of the operation's nutrient management plan was developed and approved by a certified nutrient management planner; and any changes made to the nutrient management plan	Form 21	Annually by March 1
CAFOs required to install groundwater monitoring wells must report depth to groundwater prior to purging and sampling, and sample nitrate, chloride, and ammonium concentrations	Forms 6 and 7	Bi-annually typically spring and fall
Any discharge of manure, litter, or process wastewater shall be reported verbally within 24 hours of the event and in a written report to NDEQ within five days of the event	Form 8	For each discharge
[1] *'Nutrient Management Plan: Records Checklist and Samples for Animal Feeding Operations' (http://www.ianrpubs.unl.edu/epublic/live/rp188/build/rp188.pdf).*		

TABLE 7.3

Reports to be submitted to NDEQ by NPDES-permitted CAFOs in Nebraska.

The owners or authorized representatives of animal feeding operations, which have livestock waste control facilities, but which are not CAFOs shall, at a minimum:

- inspect the livestock waste control facilities at least once a month; and
- inspect any irrigation distribution system used for land application of animal manures and the water source protection equipment prior to operation, and monitor periodically while in use to ensure that the system and equipment operate as intended.

8

Chapter

Calibrations and Calculations

As part of a manure management plan, application equipment must be calibrated regularly to ensure that nutrients are being applied as accurately as possible. Knowing the application rate is important so that proper crediting of nutrients can occur. For a more thorough explanation of calibrating application equipment, see NebGuide G95-1267A: *Manure Applicator Calibration.* Charts to help in estimating application rates of solid spreaders and slurry tanks can be found in Appendix *Table 3*.

Once equipment is calibrated, to be able to apply a known rate of manure accurately, it is important to know the proper rate. This chapter includes four examples of manure rate calculations, given actual manure and soil analyses. These calculations reflect principles discussed in previous chapters of this book.

Solid Manure Calibrations

There are several methods that work to calibrate solid manure application equipment. The most important aspect is to set the machine for a specific application rate and make sure the same setting and speed is repeated on subsequent loads.

Solid Spreader Conversions:

1 bushel = 1.24 cubic feet

1 cubic foot = 0.0275 tons

Plastic sheet method for solid and semi-solid manure

Use durable plastic sheets that are 22 square feet in size. The pounds of manure collected on the sheet is equal to the tons of manure applied per acre.

To measure by the plastic sheet method:

- Take a bucket and plastic sheet and weigh them (this is the tare weight).
- Place a minimum of three plastic sheets in the application path of the spreader.
- Drive the manure spreader over the sheets at a set speed and spreader setting.
- Collect the sheets in a bucket (individually) and weigh (this is the gross weight).
- Application rate in tons/acre is the gross weight minus the tare weight.

Known spreader weight or volume

This method requires knowing the weight or volume of the manure in the spreader. This can be accomplished by weighing the spreader with a truck scale or other means. Estimating the volume in box spreaders is more difficult.

To measure spreader weight or volume:

- Weigh the spreader or estimate the volume (this is spreader capacity).
- Run the applicator in the field and measure the length and width of application.
- Use the following formula to determine the application rate:

$$\text{Application Rate (tons/acre)} = \frac{\text{spreader capacity (tons)} \times 43{,}560\ \text{ft}^2\text{/acre}}{\text{width of spread (ft)} \times \text{distance of spread (ft)}}$$

Liquid Manure Calibrations

Slurry tanks

Slurry tanks are easier to calibrate and have better application uniformity than solid manure spreaders.

To measure slurry tank applications:

- Fill tank to a known capacity or weight.
- Run the applicator in the field and measure the length and width of application.
- Use the following formula to determine application rate:

$$\text{Application Rate (gallons/acre)} = \frac{\text{tank capacity (gallons) X 43,560 ft}^2\text{/acre}}{\text{width of spread (ft) X distance of spread (ft)}}$$

Center pivots and linear systems

Application rates of center pivots and linear systems should be monitored using flow meters and known application areas.

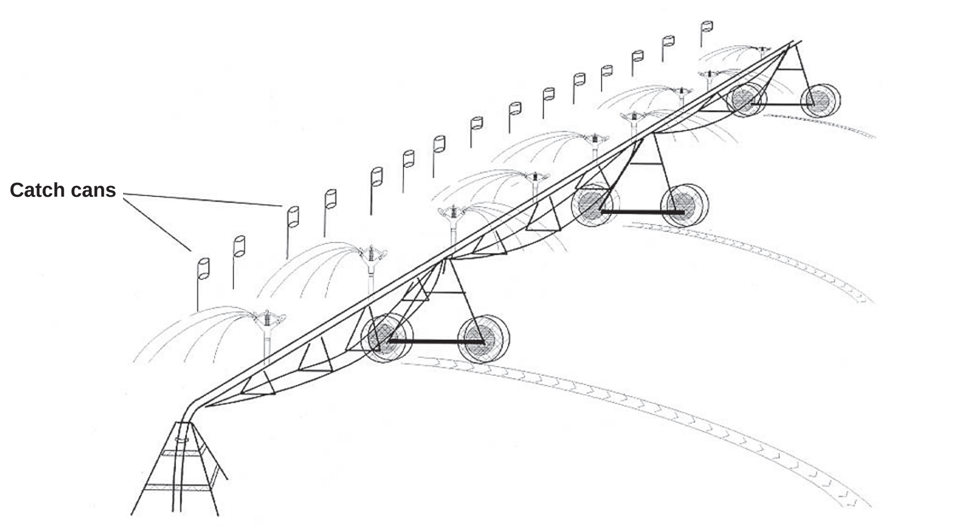
To calibrate for center pivot and linear systems:

- Begin placing catch containers beyond the first tower (center pivot only) in a line parallel to the system.
- Space catch containers 20-25 feet apart along the system's length (include any end gun coverage).
- Operate the irrigation system until it completely passes over all the catch containers.
- Record the amount in each catch container or gauge.
- Determine the Average Application Depth using the following formula:

$$\text{Average Application Depth (inches)} = \frac{\text{sum of amounts in gauges}}{\text{number of gauges}}$$

Caution:

When applying effluent with an irrigation system, a check valve must be fitted on the freshwater valve to prevent backflow of manure into the freshwater source.



From Figure 36-12 in the LPES Curriculum.

FIGURE 8.1

A typical setup of catch containers for measuring Average Application Depth for center pivots and linear systems.

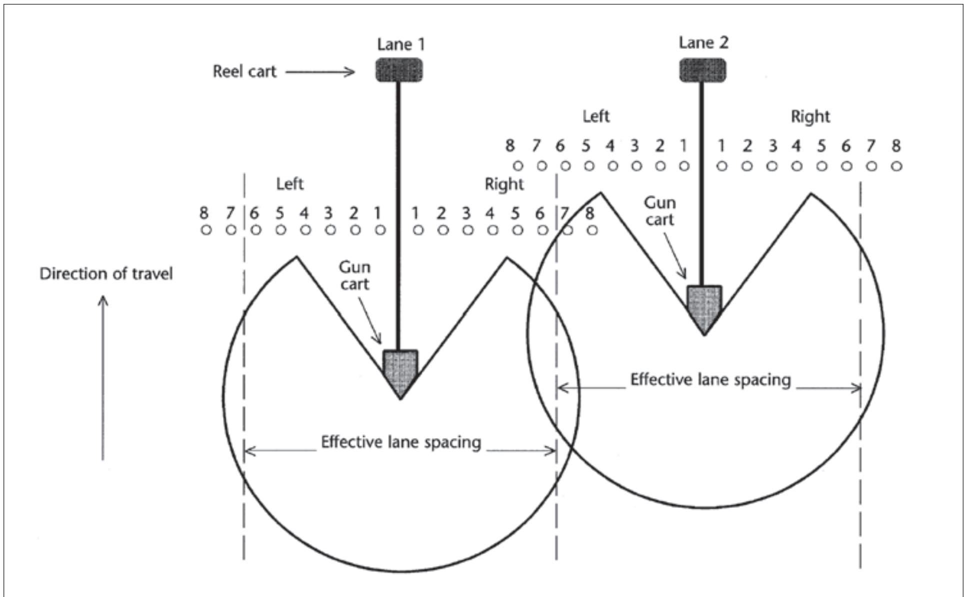
Big gun systems

To calibrate for big gun systems:

- Determine the spacing of the catch containers or rain gauges. The spacing should be 1/16 of the wetted diameter but not more than 25 feet.
- Determine the number of catch containers or gauges and lay them out, equally spaced. Place them just ahead of the sprinkler pattern in a straight line (Figure 8.2). Label the containers or gauges.
- Operate the system until the sprinkler pattern completely passes the containers or rain gauges.
- Record the amounts in each container or gauge. Identify the gauges that would be outside the effective width. This is called the overlap. Add the overlap (outside the effective lane spacing) amounts together. In Figure 8.2, this would mean adding Right 5 to Left 8, Right 6 to Left 7, Right 7 to Left 6, and Right 8 to Left 5.

$$\text{Average Application Depth (inches)} = \frac{\text{sum of amounts in gauges (after adding overlap ones)}}{\text{number of gauges}}$$

If there is a large difference between the amount in the gauges or pan depths, a uniformity problem may exist. If this is the case, consider shutting off endguns and corner units, checking for leaks, checking nozzles, screens, and recalibrating. To evaluate application uniformity or for a better explanation of calibrating land application equipment, consult *Lesson 36 of the Livestock and Poultry Environmental Stewardship Curriculum.*



From Figure 36-10 in the LPES Curriculum.

FIGURE 8.2

A typical setup of catch containers for measuring Average Application Depth for big gun systems.

The following two pages contain examples of manure analysis reports for both solid and liquid manures. They are used in the calculation examples that follow on pages 62-65.

ANALYTICAL REPORT

MANURE

Date Received 10/26/02
Date Reported 11/5/02
Report Number 2374
Report Page 1 of 2

◆**Lab Number:** 37 ◆**Analysis For:** Solid Manure ◆**Sample ID:** North

Analysis (as received)	Result	Units	Pounds per Ton	Approximate First Year Availability percentage	Approximate First Year Availability pounds per ton	
pH	7.41					
% Solids	76.6%					
Conductivity (Soluble Salts)	8.0	mmohs/cm				
Total Kjeldahl Nitrogen	15800	ppm	31.6			
Ammonical Nitrogen	712	ppm	1.4	95%	1.4	Total Available N (First Year)
Organic Nitrogen	15088	ppm	30.2	25%	7.5	8.9
Phosphorus (P2O5)	4988	ppm	10.0	70%	7.0	
Potassium (K2O)	15983	ppm	32.0	90%	28.8	
Sulfur	2718	ppm	5.4	40%	2.2	
Calcium	19714	ppm	39.4	70%	27.6	
Magnesium	4758	ppm	9.5	70%	6.7	
Sodium	2774	ppm	5.5	NA		
Zinc	345	ppm	0.7	70%	0.5	
Iron	7918	ppm	15.8	70%	11.1	
Manganese	226	ppm	0.5	70%	0.3	
Copper	54	ppm	0.1	70%	0.1	

Reviewed By:

This is a sample analysis report for solid manure. This report is used in Examples 1 and 2 on pages 62 and 63.

ANALYTICAL REPORT

MANURE

Date Receive	7/11/02
Date Reported	7/15/02
Report Numbe	1824
Report Page	2 of 4

◆**Lab Number:** 33 ◆**Analysis For:** *Liquid Manure* ◆**Sample ID:** 2 Home N Lagoon

Analysis (as received)	*Result*	*Units*	*Pounds per 1000 Gallons*	*Approximate First Year Availability* percentage	pounds/1000gal	
pH	7.7					
% Solids	4.72%					
Conductivity (Soluble Salts)	7.9	mmohs/cm				
Total Kjeldahl Nitrogen	3634	ppm	30.2			
Ammonical Nitrogen	301	ppm	2.5	95%	2.4	(Total Available N First Year)
Organic Nitrogen	3333	ppm	27.7	35%	9.7	12.1
Phosphorus (P2O5)	2147	ppm	17.8	70%	12.5	
Potassium (K2O)	2881	ppm	23.9	90%	21.5	
Sulfur	259	ppm	2.1	40%	0.9	
Calcium	880	ppm	7.3	70%	5.1	
Magnesium	428	ppm	3.6	70%	2.5	
Sodium	459	ppm	3.8	NA		
Zinc	59.3	ppm	0.5	70%	0.3	
Iron	131.7	ppm	1.1	70%	0.8	
Manganese	12.0	ppm	0.1	70%	0.1	
Copper	7.7	ppm	0.1	70%	0.0	

Reviewed By:

This is a sample analysis report for liquid manure. This report is used in Examples 3 and 4 on pages 64 and 65.

Calculating Available Nutrients in Solid Manure

Example 1: Solid Manure — Managing on a Nitrogen Basis

Corn will be grown on a field with an expected yield of 185 bu/acre. Soil test results show an organic matter level of 2.3 percent, Bray-1 phosphorus of 36 ppm, pH of 7.0, residual nitrate-N of 36 lbs/acre (3.3 ppm in 3 feet) and soluble salts of 0.33 mmho/cm. A manure test shows ammoniacal-N of 1.4 lbs/ton (of which 95 percent, or 1.3 lbs N/ton, will be available if manure is incorporated immediately), organic-N of 30.2 lbs/ton (of which 25 percent, or 7.5 lbs N/ton will be available the first year), phosphorus of 10 lbs/ton (of which 70 percent, or 7 lbs P_2O_5/ton will be available the first year).

With a soil phosphorus level of 36 ppm (Bray-1), the University of Nebraska recommendation is that no supplemental phosphorus fertilization is required to optimize yield potential for corn. From the perspective of using phosphorus most effectively, it would be best to apply manure to another field with a lower soil phosphorus level. However, there may be situations where this field is the best or only option for manure application.

Approach to Apply Manure to Meet Total N Requirement for the Current Year		
Crop N requirement *(185 bu/acre corn)*	35 + (1.2 x EY) - (8 x NO_3N ppm) - (0.14 x EY x OM) (EY = expected yield in bu/acre; *this example 185*) (NO_3N ppm = soil residual N in ppm; *this example 3.3*) (OM = percent organic matter; *this example 2.3*)	171 lb N/acre
Manure N Credit Ammoniacal-N Organic-N Total Manure-N	 1.4 lb NH_4-N/ton x 0.95 30.2 lb organic-N/ton x 0.25	 1.3 lb N/ton 7.5 lb N/ton 8.8 lb N/ton
Manure to meet crop N req.	171 lb/acre crop N req. / 8.8 lb N/ton	19.4 ton/acre
Manure P applied	19.4 ton manure x 10 lb P_2O_5/ton x 0.7	136 lb P_2O_5/acre

Application of manure at the above rate will supply all of the nitrogen for the crop grown in the year of application, plus adequate phosphorus to meet crop removal for almost three years. Annual deep soil sampling is recommended to accurately estimate fertilizer nitrogen needs in subsequent years. Accumulation of soluble salts and other nutrients at this application rate is not likely to be of concern, at least given the manure analysis shown on Page 60. However, soil tests should be taken periodically to monitor soil levels, particularly of salts, if repeated manure applications occur. Other nutrients contained in manure will further increase its value. Nitrogen and phosphorus release will occur from the organic fraction of manure for an additional 2-3 years, further increasing its value.

Economic Value of the Applied Manure in First Year		
Nutrient		**Value/Acre**
N	171 lb N/acre x $0.45/lb	$ 76.95
P_2O_5	136 lb P_2O_5/acre x $0.353/lb	$ 47.60
TOTAL		**$124.55**

Calculating Available Nutrients in Solid Manure

Example 2: Solid Manure — Managing on a Phosphorus Basis

Corn will be grown on a field with an expected yield of 185 bu/acre. Soil test results show an organic matter level of 2.3 percent, Bray-1 phosphorus of 36 ppm, pH of 7.0, residual nitrate-N of 36 lbs/acre (3.3 ppm in 3 feet) and soluble salts of 0.33 mmho/cm. A manure test shows ammoniacal-N of 1.4 lbs/ton (of which 95 percent, or 1.3 lbs N/ton, will be available if manure is incorporated immediately), organic-N of 30.2 lbs/ton (of which 25 percent, or 7.5 lbs N/ton will be available the first year), phosphorus of 10 lbs/ton (of which 70 percent, or 7 lbs P_2O_5/ton will be available the first year).

With a soil phosphorus level of 36 ppm (Bray-1), the University of Nebraska recommendation is that no supplemental phosphorus fertilization is required to optimize yield potential for corn. From the perspective of using phosphorus most effectively, it would be best to apply manure to another field with a lower soil phosphorus level. However, there may be situations where this field is the best or only option for manure application.

Approach to Provide a Three-Year Supply of Phosphorus		
Expected corn yield		185 bu/acre
3-yr crop removal of P	0.3 lb P_2O_5/bu x 185 bu/acre x 3 years	167 lb P_2O_5/acre
Manure P availability	10 lb P_2O_5/ton x 0.70	7 lb P_2O_5/ton
Manure needed	167 lb P_2O_5/acre / 7 lb P_2O_5/ton	24 ton manure/acre
Crop N requirement (185 bu/acre corn)	35 + (1.2 x EY) - (8 x NO_3N ppm) - (0.14 x EY x OM) (EY = expected yield in bu/acre; *this example 185*) (NO_3N ppm = soil residual N in ppm; *this example 3.3*) (OM = percent organic matter; *this example 2.3*)	171 lb N/acre
Manure N Credit Ammoniacal-N Organic-N Total Manure-N	 24 ton manure/acre x 1.4 lb NH_e-N/ton x 0.95 24 ton manure/acre x 30.2 lb organic-N/ton x 0.25	 32 lb N/acre 181 lb N/acre 213 lb N/acre
Fertilizer N needed	171 lb/acre crop N req. - 213 lb/acre manure N credit	(-42) lb N/acre

Application of manure at the above rate of 24 ton/acre would supply adequate phosphorus to meet crop removal at a yield of 185 bu/acre for three years. It will also provide more nitrogen than actually required by the crop in the year of application. Annual deep soil samples should be collected to determine fertilizer nitrogen requirements in subsequent years. Soil tests should be taken every four years to monitor the soil phosphorus level. Application of manure with this analysis more often than every four years will cause the soil phosphorus level to increase.

Application at this rate should not result in any significant soil accumulation of soluble salts or other nutrients.Other nutrients contained in manure will further increase its value. Nitrogen and phosphorus release will occur from the organic fraction of manure for an additional 2-3 years, further increasing its value.

Economic Value of the Applied Manure in First Year		
Nutrient		**Value/Acre**
N	213 lb N/acre x $0.45/lb	$ 95.85
P_2O_5	167 lb P_2O_5/acre x $0.35/lb	$ 58.45
TOTAL		**$154.30**

Calculating Available Nutrients in Liquid Manure

Example 3: Liquid Manure — Managing on a Nitrogen Basis

Corn will be grown on a field with an expected yield of 200 bu/acre. Soil test results show an organic matter level of 1.7 percent, Bray-1 phosphorus of 11 ppm, pH of 6.3, residual nitrate-N of 43 lbs/acre (4 ppm in 3 feet). A manure test shows ammoniacal-N of 2.5 lbs/1000 gal (of which 95 percent, or 2.4 lbs N/1000 gal, will be available if manure is injected or incorporated immediately), organic-N of 27.7 lbs/1000 gal (of which 35 percent, or 9.7 lbs N/1000 gal will be available the first year), and phosphorus of 17.8 lbs/1000 gal (of which 70 percent, or 12.5 lbs P_2O_5/1000 gal will be available the first year).

Approach to Apply Manure to Meet Total N Requirement for the Current Year		
Crop N requirement *(200 bu/acre corn)*	35 + (1.2 x EY) - (8 x NO_3N ppm) - (0.14 x EY x OM) (EY = expected yield in bu/acre; *this example 200*) (NO_3N ppm = soil residual N in ppm; *this example 4*) (OM = percent organic matter; *this example 1.7*)	195 lb N/acre
Manure N Credit Ammoniacal-N Organic-N Total Manure-N	 2.5 lb NH_4-N/1,000 gal x 0.95 27.7 lb organic-N/ton x 0.35	 2.4 lb N/ton 9.7 lb N/ton 12.1 lb N/ton
Manure to meet crop N req.	195 lb N/acre crop N req. / 12.1 lb N/1000 gal x 1000 gal	16,116 gal manure/acre
Manure P applied (total)	16,116 gal manure/1000 gal x 17.8 lb P_2O_5/1000 gal	287 lb P_2O_5/acre

Application of manure at the above rate of 16,116 gal/acre will supply all the nitrogen to meet this year's crop nitrogen needs and will supply enough phosphorus adequate to meet the crop removal in 200 bu/acre corn for about 5 years. The application will increase the soil phosphorus concentration. Manure phosphorus contributions are calculated based on the *total* amount of phosphorus in the manure, rather than that available the first year, since this amount of manure-P is of interest over several years, not just the first year after application. Annual deep soil sampling is recommended to accurately estimate fertilizer nitrogen needs in subsequent years. Other nutrients contained in manure will further increase its value. Nitrogen and phosphorus release will occur from the organic fraction of manure for an additional 2-3 years, further increasing its value.

Economic Value of the Applied Manure in First Year		
Nutrient		**Value/Acre**
N (first year)	195 lb N/acre x $0.45/lb	$ 87.75
P_2O_5	287 lb P_2O_5/acre x $0.353/lb	$100.45
TOTAL		**$188.20**

Calculating Available Nutrients in Liquid Manure

Example 4: Liquid Manure — Managing on a Phosphorus Basis

Corn will be grown on a field with an expected yield of 200 bu/acre. Soil test results show an organic matter level of 1.7 percent, Bray-1 phosphorus of 11 ppm, pH of 6.3 and residual nitrate-N of 43 lbs/acre (4 ppm in 3 feet). A manure test shows ammoniacal-N of 2.5 lbs/1000 gal (of which 95 percent, or 2.4 lbs N/1000 gal, will be available if manure is injected or incorporated immediately), organic-N of 27.7 lbs/1000 gal (of which 35 percent, or 9.7 lbs N/1000 gal will be available the first year), and phosphorus of 17.8 lbs/1000 gal (all of which will be available over a 3-year period).

With a soil Bray-1 phosphorus level of 11 ppm, the University of Nebraska recommendation is that 40 lbs P_2O_5/acre be broadcast for corn, with that application rate occurring each year over a 4- to 5-year period. This approach is the most profitable in the year of application for commercial fertilizer. With manure as a nutrient resource, it would probably be desirable to increase soil phosphorus levels above 11 ppm. Consequently, applying manure to provide close to, or perhaps slightly more than, the crop removal of phosphorus (0.3 lb P_2O_5/bu) is acceptable.

Approach to Provide a Three-Year Supply of Phosphorus		
Expected corn yield		200 bu/acre
3-yr crop removal of P	0.3 lb P_2O_5/bu x 200 bu/acre x 3 years	180 lb P_2O_5/acre
Manure P availability	17.8 lb P_2O_5/1,000 gal + 1,000 gal	17.8 lb P_2O_5/1,000 gal
Manure needed	180 lb P_2O_5/acre / 17.8 lb P_2O_5/1000 gal x 1000 gal	10,100 gal/acre
Crop N requirement (200 bu/acre corn)	35 + (1.2 x EY) - (8 x NO_3N ppm) - (0.14 x EY x OM) (EY = expected yield in bu/acre; *this example 200*) (NO_3N ppm = soil residual N in ppm; *this example 4*) (OM = percent organic matter; *this example 1.7*)	195 lb N/acre
Manure N Credit Ammoniacal-N Organic-N Total Manure-N	 10,100 gal manure/acre x 2.5 lb NH_4-N/1,000 gal x 0.95 10,100 gal manure/acre x 27.7 lb organic-N/1,000 gal x 0.35	 24 lb N/acre 98 lb N/acre 122 lb N/acre
Fertilizer N needed	195 lb/acre crop N req. - 128 lb/acre manure N credit	73 lb N/acre

Application of manure at the above rate of 14,400 gal/acre will supply adequate phosphorus to meet crop removal at a yield of 200 bu/acre for three years. If an increase in soil phosphorus is desired, then the application rate could be increased. The application of 14,400 gal/acre of liquid manure will also supply almost all of the nitrogen needed by the crop during the current growing season. Other nutrients contained in manure will further increase its value. Nitrogen and phosphorus release will occur from the organic fraction of manure for an additional 2-3 years, further increasing its value.

Economic Value of the Applied Manure in First Year		
Nutrient		**Value/Acre**
N	174 lb N/acre x $0.45/lb	$ 78.30
P_2O_5	180 lb P_2O_5/acre x $0.35/lb	$ 63.00
TOTAL		**$141.30**

Appendix Tables

Appendix Table 1. Factors Influencing P Loss

Factors	Description
Source Factors	
Soil P	As soil P increases, P loss in runoff increases.
Applied P rate	The more P (fertilizer or manure), the greater risk of P loss.
Application method	P loss increases in this order: subsurface injection, incorporated, and surface broadcast with no incorporation.
Application timing	The sooner it rains after P is applied, the greater the risk for P loss.
Transport Factors	
Erosion	Total P loss strongly related to erosion.
Surface runoff	Water has to move off or through a soil for P to move.
Subsurface flow	In sandy, organic, or P-saturated soils, P can leach through the soil.
Soil texture	Influences relative amounts of surface and subsurface flow occurring.
Irrigation runoff	Improper irrigation management can induce runoff and erosion of P.
Connectivity to stream	The closer the field to the stream, the greater the chance of P reaching it.
Proximity of P-sensitive water	Some watersheds are closer to P-sensitive waters than others (i.e., point of impact).
Sensitivity P input	Shallow lakes with large surface areas tend to be more vulnerable to eutrophication.

Modified from Table 34-4 in the LPES Curriculum.

Appendix Table 2. Management Options to Minimize Nonpoint Source Pollution of Surface Water by Soil P

Phosphorus Index	Management Options to Minimize NPS Pollution of Surface Water by Soil P
< 30 (Low)	• **Soil testing:** Have soils tested for P at least every three years to monitor build-up or decline in soil P. • **Soil conservation:** Follow good soil conservation practices. Consider effects of changes in tillage practices or land use on potential for increased P transport from site. • **Nutrient management:** Consider effects of any major changes in agricultural practices on P losses before implementing them on the farm. Examples include increasing the number of animal units on a farm or changing to crops with a high demand for fertilizer P.
30-75 (Medium)	• **Soil Testing:** Have soils tested for P at least every three years to monitor build-up or decline in soil P. Conduct a more comprehensive soil-testing program in areas that have been identified by the P Index as being most sensitive to P loss by surface runoff, subsurface flow, and erosion. • **Soil conservation:** Implement practices to reduce P losses by surface runoff, subsurface flow¸ and erosion in the most sensitive fields (i.e., reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). • **Nutrient management:** Any changes in agricultural practices may affect P loss; carefully consider the sensitivity of fields to P loss before implementing any activity that will increase soil P. Avoid broadcast application of P fertilizers and apply manures only to fields with lower P Index values.
75-100 (High)	• **Soil testing:** A comprehensive soil-testing program should be conducted on the entire farm to determine fields that are most suitable for further P additions. For fields that have excessive P, develop estimates of the time required to deplete the soil P to optimum levels for use in long-range planning. • **Soil conservation:** Implement practices to reduce P losses by surface runoff, subsurface flow, and erosion in the most sensitive fields (i.e., reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). Consider using crops with high P removal capacities in fields with high P Index values. • **Nutrient management:** In most situations, fertilizer P, other than a small amount used in starter fertilizers, will not be needed. Manure applications may be excessive on the farm and should only be applied to fields with lower P Index values. A long-term P management plan should be considered.
>100 (Very High)	• **Soil testing:** For fields that have excessive P, estimate the time required to deplete soil P to optimum levels for use in long-range planning. Consider using new soil-testing methods that provide more information on environmental impact of soil P. • **Soil conservation:** Implement practices to reduce P losses by surface runoff, subsurface flow, and erosion in the most sensitive fields (i.e., reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). Consider using crop with high P removal capacities in fields with high P Index values. • **Nutrient management:** Fertilizer and manure P should not be applied for at least three years and perhaps longer. A comprehensive, long-term P management plan must be developed and implemented.

Modified from Table 34-6 in the LPES Curriculum.

Appendix Table 3. Manure Application Guide

What is your manure application rate? From the chart below, selet the (1) spreader capacity, (2) spreader pattern length, and (3) spreader pattern width for typical manure applications. Rate per Acre = Spreader Capacity x 43,560 / (Width of Spread X Length of Spread)

Liquid manure application rate (1000's of gallons per acre)

Spread Length \ Width-->	2000 gallon tank: 10'	15'	20'	25'	30'	35'
600'	15	10	7	6	5	4
800'	11	7	5	4	4	3
1000'	9	6	4	3	3	2
1200'	7	5	4	3	2	2
1400'	6	4	3	2	2	2
1600'	5	4	3	2	2	2
1800'	5	3	2	2	2	1
2000'	4	3	2	2	1	1
2500'	3	2	2	1	1	1
3000'	3	2	1	1	1	1

Spread Length \ Width-->	2500 gallon tank: 10'	15'	20'	25'	30'	35'
600'	18	12	9	7	6	5
800'	14	9	7	5	5	4
1000'	11	7	5	4	4	3
1200'	9	6	5	4	3	3
1400'	8	5	4	3	3	2
1600'	7	5	3	3	2	2
1800'	6	4	3	2	2	2
2000'	5	4	3	2	2	2
2500'	4	3	2	2	1	1
3000'	4	2	2	1	1	1

Spread Length \ Width-->	3000 gallon tank: 10'	15'	20'	30'	40'	50'
600'	22	15	11	7	5	4
800'	16	11	8	5	4	3
1000'	13	9	7	4	3	3
1200'	11	7	5	4	3	2
1400'	9	6	5	3	2	2
1600'	8	5	4	3	2	2
1800'	7	5	4	2	2	1
2000'	7	4	3	2	2	1
2500'	5	3	3	2	1	1
3000'	4	3	2	1	1	1

Spread Length \ Width-->	3500 gallon tank: 10'	15'	20'	30'	40'	50'
600'	25	17	13	8	6	5
800'	19	13	10	6	5	4
1000'	15	10	8	5	4	3
1200'	13	8	6	4	3	3
1400'	11	7	5	4	3	2
1600'	10	6	5	3	2	2
1800'	8	6	4	3	2	2
2000'	8	5	4	3	2	2
2500'	6	4	3	2	2	1
3000'	5	3	3	2	1	1

Spread Length \ Width-->	4000 gallon tank: 10'	15'	20'	30'	40'	50'
600'	29	19	15	10	7	6
800'	22	15	11	7	5	4
1000'	17	12	9	6	4	3
1200'	15	10	7	5	4	3
1400'	12	8	6	4	3	2
1600'	11	7	5	4	3	2
1800'	10	6	5	3	2	2
2000'	9	6	4	3	2	2
2500'	7	5	3	2	2	1
3000'	6	4	3	2	1	1

Spread Length \ Width-->	4500 gallon tank: 10'	15'	20'	30'	40'	50'
600'	33	22	16	11	8	7
800'	25	16	12	8	6	5
1000'	20	13	10	7	5	4
1200'	16	11	8	5	4	3
1400'	14	9	7	5	4	3
1600'	12	8	6	4	3	2
1800'	11	7	5	4	3	2
2000'	10	7	5	3	2	2
2500'	8	5	4	3	2	2
3000'	7	4	3	2	2	1

Liquid manure application rate (1000's of gallons per acre)

Spread Length \ Width-->	5000 gallon tank: 10'	15'	20'	30'	40'	50'
600'	36	24	18	12	9	7
800'	27	18	14	9	7	5
1000'	22	15	11	7	5	4
1200'	18	12	9	6	5	4
1400'	16	10	8	5	4	3
1600'	14	9	7	5	3	3
1800'	12	8	6	4	3	2
2000'	11	7	5	4	3	2
2500'	9	6	4	3	2	2
3000'	7	5	4	2	2	1

Spread Length \ Width-->	5500 gallon tank: 10'	15'	20'	30'	40'	50'
600'	40	27	20	13	10	8
800'	30	20	15	10	7	6
1000'	24	16	12	8	6	5
1200'	20	13	10	7	5	4
1400'	17	11	9	6	4	3
1600'	15	10	7	5	4	3
1800'	13	9	7	4	3	3
2000'	12	8	6	4	3	2
2500'	10	6	5	3	2	2
3000'	8	5	4	3	2	2

Spread Length \ Width-->	6000 gallon tank: 10'	15'	20'	30'	40'	50'
600'	44	29	22	15	11	9
800'	33	22	16	11	8	7
1000'	26	17	13	9	7	5
1200'	22	15	11	7	5	4
1400'	19	12	9	6	5	4
1600'	16	11	8	5	4	3
1800'	15	10	7	5	4	3
2000'	13	9	7	4	3	3
2500'	10	7	5	3	3	2
3000'	9	6	4	3	2	2

Solid manure application rate (tons per acre)

Spread Length \ Width-->	3 ton spreader (90 bushel): 10'	15'	20'	25'	30'	35'
600'	22	15	11	9	7	6
800'	16	11	8	7	5	5
1000'	13	9	7	5	4	4
1200'	11	7	5	4	4	3
1400'	9	6	5	4	3	3
1600'	8	5	4	3	3	2
1800'	7	5	4	3	2	2
2000'	7	4	3	3	2	2
2500'	5	3	3	2	2	1
3000'	4	3	2	2	1	1

Spread Length \ Width-->	4 ton spreader (120 bushel): 10'	15'	20'	25'	30'	35'
600'	29	19	15	12	10	8
800'	22	15	11	9	7	6
1000'	17	12	9	7	6	5
1200'	15	10	7	6	5	4
1400'	12	8	6	5	4	4
1600'	11	7	5	4	4	3
1800'	10	6	5	4	3	3
2000'	9	6	4	3	3	2
2500'	7	5	3	3	2	2
3000'	6	4	3	2	2	2

Spread Length \ Width-->	6 ton spreader (175 bushel): 10'	15'	20'	25'	30'	35'
600'	44	29	22	17	15	12
800'	33	22	16	13	11	9
1000'	26	17	13	10	9	7
1200'	22	15	11	9	7	6
1400'	19	12	9	7	6	5
1600'	16	11	8	7	5	5
1800'	15	10	7	6	5	4
2000'	13	9	7	5	4	4
2500'	10	7	5	4	3	3
3000'	9	6	4	3	3	2

Solid manure application rate (tons per acre)

Spread Length \ Width-->	8 ton spreader (230 bushel): 10'	15'	20'	25'	30'	35'
600'	58	39	29	23	19	17
800'	44	29	22	17	15	12
1000'	35	23	17	14	12	10
1200'	29	19	15	12	10	8
1400'	25	17	12	10	8	7
1600'	22	15	11	9	7	6
1800'	19	13	10	8	6	6
2000'	17	12	9	7	6	5
2500'	14	9	7	6	5	4
3000'	12	8	6	5	4	3

Spread Length \ Width-->	10 ton spreader (290 bushel): 10'	15'	20'	25'	30'	35'
600'	73	48	36	29	24	21
800'	54	36	27	22	18	16
1000'	44	29	22	17	15	12
1200'	36	24	18	15	12	10
1400'	31	21	16	12	10	9
1600'	27	18	14	11	9	8
1800'	24	16	12	10	8	7
2000'	22	15	11	9	7	6
2500'	17	12	9	7	6	5
3000'	15	10	7	6	5	4

Spread Length \ Width-->	12 ton spreader (350 bushel): 10'	15'	20'	25'	30'	35'
600'	87	58	44	35	29	25
800'	65	44	33	26	22	19
1000'	52	35	26	21	17	15
1200'	44	29	22	17	15	12
1400'	37	25	19	15	12	11
1600'	33	22	16	13	11	9
1800'	29	19	15	12	10	8
2000'	26	17	13	10	9	7
2500'	21	14	10	8	7	6
3000'	17	12	9	7	6	5

Spread Length \ Width-->	14 ton spreader (410 bushel): 10'	15'	20'	25'	30'	35'
600'	102	68	51	41	34	29
800'	76	51	38	30	25	22
1000'	61	41	30	24	20	17
1200'	51	34	25	20	17	15
1400'	44	29	22	17	15	12
1600'	38	25	19	15	13	11
1800'	34	23	17	14	11	10
2000'	30	20	15	12	10	9
2500'	24	16	12	10	8	7
3000'	20	14	10	8	7	6

Spread Length \ Width-->	16 ton spreader (470 bushel): 10'	15'	20'	25'	30'	35'
600'	116	77	58	46	39	33
800'	87	58	44	35	29	25
1000'	70	46	35	28	23	20
1200'	58	39	29	23	19	17
1400'	50	33	25	20	17	14
1600'	44	29	22	17	15	12
1800'	39	26	19	15	13	11
2000'	35	23	17	14	12	10
2500'	28	19	14	11	9	8
3000'	23	15	12	9	8	7

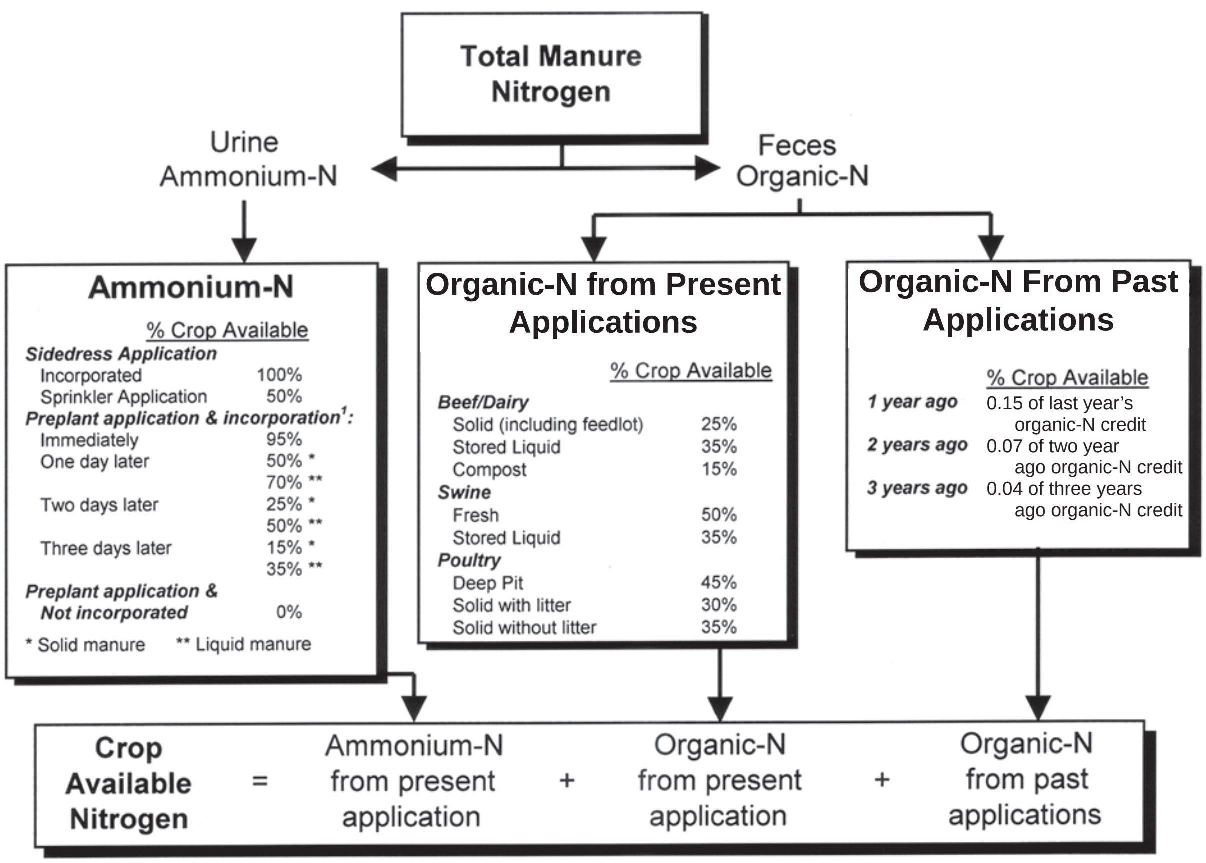
Spread Length \ Width-->	18 ton spreader (530 bushel): 10'	15'	20'	25'	30'	35'
600'	131	87	65	52	44	37
800'	98	65	49	39	33	28
1000'	78	52	39	31	26	22
1200'	65	44	33	26	22	19
1400'	56	37	28	22	19	16
1600'	49	33	25	20	16	14
1800'	44	29	22	17	15	12
2000'	39	26	20	16	13	11
2500'	31	21	16	13	10	9
3000'	26	17	13	10	9	7

Appendix Table 4. What is the nutrient content of manure?

Because of the variability of manure, a manure analysis is recommended over table values.

Species	% Dry Matter	Nitrogen			
		Ammonium-N	Organic-N	P_2O_5	K_2O
Slurry Manure (lbs of nutrient per 1,000 gallons of manure)					
Dairy	7	9	13	14	20
Beef	12	14	20	22	31
Swine	5	17	10	19	15
Layer	11	38	20	51	33
Dairy (lagoon sludge)	10	4	17	20	16
Swine (lagoon sludge)	8	8	19	52	76
Beef (runoff pond sludge)	17	10	42	40	17
Solid Manure (lbs of nutrient per ton of manure)					
Beef (dirt lot)	59	5	20	18	22
Beef (paved lot)	29	5	9	9	13
Swine	18	6	7	13	9
Dairy	22	3	8	7	9
Broiler (litter from house)	79	141	57	69	47
Layer (scrapped)	35	14	14	31	20
Turkey (grower house litter)	73	12	43	63	49
Lilquid Effluent from lagoon or holding pond (lbs per acre-inch)					
Beef (runoff holding pond)	0.3	41	4	10	203
Swine (lagoon)	0.25	50	29	17	86
Dairy (lagoon)	0.25	27	18	13	113

Appendix Table 5. What portion of the nutrients in manure is available to the crop?



Crop available P_2O_5 = P_2O_5 Manure Analysis X 0.7 Crop available K_2O = K_2O Manure Analysis X 0.8

[1] Incorporation can be accomplished by tillage or rainfall of one-half inch or greater.

See these UNL Extension publications for more information:

NebGuides

G1450	Sampling Manures for Nutrient Analysis
G1740	Guidelines for Soil Sampling

Extension Circulars

EC154	Soil Sampling for Precision Agriculture
EC720	Nebraska's CNMP: Manure Application Workbook
EC721	Nebraska's CNMP: Odor Management Plan Workbook
EC722	Nebraska's CNMP: Manure and Open Lot Runoff Storage Workbook
EC778	Application of Liquid Manures Using Center Pivots

See these other publications for more information:

Midwest Plan Service	Livestock and Poultry Environmental Stewardship Curriculum
Phosphorus Index	(under development)
MWPS-18, Section 1	Manure Characteristics
MWPS-18, Section 2	Manure Storages
MWPS-18, Section 3	Outdoor Air Quality

Web sites

Board on Agriculture and Natural Resources: http://www7.nationalacademies.org/banr/index.html
Livestock and Poultry Environmental Stewardship (LPES) Curriculum: http://www.lpes.org
Midwest Plan Service (MWPS): http://www.mwpshq.org
Nebraska Department of Environmental Quality (NDEQ): http://www.deq.state.ne.us
University of Nebraska–Lincoln Extension publications: http://www.ianr.unl.edu/pubs
UNL Manure Matters: http://manure.unl.edu
Livestock Waste Regulations — Home Study Course: http://manure.unl.edu

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Stercus Accidit
Cura Opes

Manure Happens
Manage the Resource