Workshop on Environmental Phosphorus Issues and Animal Production

TUESDAY, FEBRUARY 22
9:00 am to 4:00 pm

Sponsored by University of Nebraska Cooperative Extension

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Nebraska Cattlemen, Nebraska Pork Producers Association,
Nebraska Corn Growers Association, Nebraska Farm Bureau,
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WORKSHOP ON ENVIRONMENTAL PHOSPHORUS ISSUES AND ANIMAL PRODUCTION

Objectives

A one-day forum focused on phosphorus–related issues facing the livestock industry will be implemented for the purpose of:

1) Introducing current information relative to water quality concerns, management options, and regulatory directions;
2) Establishing collaborations towards future solutions among livestock industry, supporting agribusiness, university, and regulatory organizations;
3) Initiating an evaluation of future public policy needs for Nebraska.

Agenda

Topic	PROPOSED SPEAKER	TIMING
Understanding the Phosphorus Issue Roy Frederick (moderator)		**9 am**
Welcome and Introductory Comments - prefer focus on economic issues	Roy Fredericks	10 minutes
Overview of Phosphorus Issues in U.S.	Peter Kleinman, USDA-ARS at Penn State	30 min.
Phosphorus Impact on NE Watersheds	John C. Holz, School of Natural Resources, UNL	15 min.
Regulatory/Policy Trends Relative to Phosphorus	Ralph Summers, Region 7 EPA	15 min.
A Livestock Producer's Challenges when Addressing Phosphorus Issues	Jeff Albers	15 min
Questions of Morning Speakers		
Break		10:45 AM
Role of Animal Feeding Programs in Phosphorus Management Don Beerman (moderator)		**11 am**
Phosphorus Concentration Issues in NE's Livestock Industry	Rick Koelsch, BSE at UNL	15 min.
Feeding Program Options for Addressing Phosphorus Issues (ruminants)	Terry Klopfenstein, Animal Science at UNL	15 min.
Feeding Program Options for Addressing Phosphorus Issues (non-ruminants)	Mike Brumm, Animal Science at UNL	15 min.
Corn Breeding Options for Improved Phosphorus Utilization	Steve Soderlund, Optimum Quality Grain	15 min.
Role of Corn Processing Industry on Phosphorus Feeding Issues	Todd Milton, Animal Science at UNL	15 min.
Options for Removing P from a Waste Stream	Dennis Schulte (BSE at UNL)	15 min.
Lunch		12:30 pm
Questions of Morning Speakers		1:30 pm

Agenda (continued)

Topic	POTENTIAL SPEAKER	TIMING
Role of Manure Management in Phosphorus Management Ken Cassman (moderator)		**1:45 pm**
Managing Phosphorus in Cropping Systems - Overview of Research - Trends in NE Soil P Status - Trends in Commercial & Manure P Use - Soil P Runoff Risk Factors	Dan Walters, Agronomy at UNL and Bahman Eghball, USDA ARS Scientist at UNL	40 min.
Tools for Judging Phosphorus Environmental Risk	Mike Kucera, Resource Conservationist at NRCS	15 min.
Overview of Comprehensive Nutrient Management Planning Process for Nebraska	Charles Shapiro, UNL Agronomist	15 min.
	Questions of Afternoon Speakers	
Identification and Summarization of Critical Issues/Solutions Ken Cassman (moderator)		**3 pm**
Stakeholders Perspective*	Bill Dickey, Tom Gustafson, Greg Ibach, Dennis Heitman, and Senator Ed Schrock .	5 min presentations by each panelist followed by 20 min panel discussion
Summarization of Key Issues and Future Needs	Ken Cassman	15 min
Adjourn 4 pm		

Planning Team
Jeff Albers, cattle producer
Troy Bredenkamp, Nebraska Cattlemen
Bill Dicke, Cattlemen's Consulting
Bahman Eghball, USDA ARS Agronomist
Rick Koelsch, Biological Systems Engineering, UNL
Ron Lindquist, Minnesota Corn Processors, Inc.
Todd Milton, Animal Science, UNL
Pete Poppert, Cattlemen's Consulting
Rick Stock, Cargill Corn Milling
Ken Wurdeman, Nebraska Corn Development, Utilization & Marketing Board

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OVERVIEW OF PHOSPHORUS ISSUES IN THE U.S.

WHAT'S THE PROBLEM?

Phosphorus is an essential nutrient for plant and animal growth and therefore is vital to crop and livestock production. Phosphorus limits biological productivity in most freshwater bodies, making it the primary agent of "eutrophication." Eutrophication, the natural process of nutrient enrichment, akin to aging, has been linked to a variety of adverse ecological and human health impacts, ranging from increased growth of undesirable algae, to fish kills, to human illness. Although eutrophication can occur naturally over centuries, human activities can accelerate eutrophication in a matter of only decades (Sharpley, 2000).

In the past, phosphorus pollution was attributed to "point sources," such as sewage treatment plants and factories. As a result, efforts to control phosphorus pollution were focused primarily on removal of phosphates in detergents and improved filtration and treatment of industrial effluent. Despite great advances in point source phosphorus control, eutrophication continues to be the most widespread water quality problem of U.S. surface waters (U.S. Environmental Protection Agency, 1996).

Non-point sources of phosphorus, such as runoff from agricultural fields, roads, septic systems, suburban lawns, and even forests, are cited as major contributors to accelerated eutrophication. Not surprisingly, non-point sources are much more difficult to identify and control than point sources.

WHY THE PROBLEM?

The question often arises as to how farms, particularly livestock operations, have evolved from being sinks of phosphorus, where improvements in soil fertility were needed for production, to sources of phosphorus, where excess nutrients are lost to the environment. While the answer is quite complex, much of today's agricultural phosphorus problems may be attributed to large on-farm nutrient imbalances: more phosphorus enters the farm in feed and fertilizer than leaves in crops, livestock, and other products (e.g., eggs and milk). This imbalance has evolved over time, as agriculture has become more specialized, with feed and livestock production increasingly segregated, even on a regional basis. Table 1 illustrates phosphorus balances for farms representing a variety of farming systems, showing the large excesses in phosphorus that can occur.

Table 1. Phosphorus Balance for Various Farming Systems.

	----------Farming System----------			
P	Crop[1]	Dairy[2]	Poultry[3]	Hogs[4]
Input	----------kg P/ha/yr----------			
Fertilizer	22	11	0	0
Feed	0	22	1,540	106
Output	-20	-15	-408	-67
Balance	***+2 (10%)***	***+18 (55%)***	***+1,131 (73%)***	***+39 (37%)***

Adapted from Lanyon and Thompson (1996) and Bacon et al. (1990).
[1]30-ha cash crop farm growing corn and alfalfa.
[2]40-ha dairy farm with 65 dairy holsteins, 5 dry cows, and 35 heifers.
[3]12-ha poultry farm with 74,000 layers.
[4]30-ha hog farm with 1,280 hogs and manure export of 45 kg P/ha/yr.

In most livestock operations, the majority of the phosphorus that remains on farms is applied to soils, where it accumulates over time. Although most soils have a large capacity for "fixing" phosphorus in forms

that reduce the mobility of phosphorus in the environment, long-term additions eventually overwhelm this finite fixation capacity (also referred to as "sorption capacity").

Due to the imbalance of phosphorus imports and exports on farms, significant concentrations of phosphorus accumulate in manure-amended soils over time. Even when best management practices (BMPs) are used to guide farmer's nutrient management decisions, phosphorus is generally ignored and manure is applied to soils to meet crop nitrogen requirements, thereby minimizing nitrate leaching to groundwater. However, because of the high phosphorus content of manure compared to nitrogen, nitrogen-based management results in the addition of phosphorus above levels needed by crops.

To illustrate this point, Figure 1 shows trends in soil test phosphorus concentrations related to different manure application intensities. These data are derived from a soil in Oklahoma with a "medium" soil test phosphorus ranking. Such as soil would typically receive approximately 40 kg P/hectare/yr for corn production. Note that most of the phosphorus accumulates in the surface of the soil, where it is vulnerable to removal by either runoff or leaching.

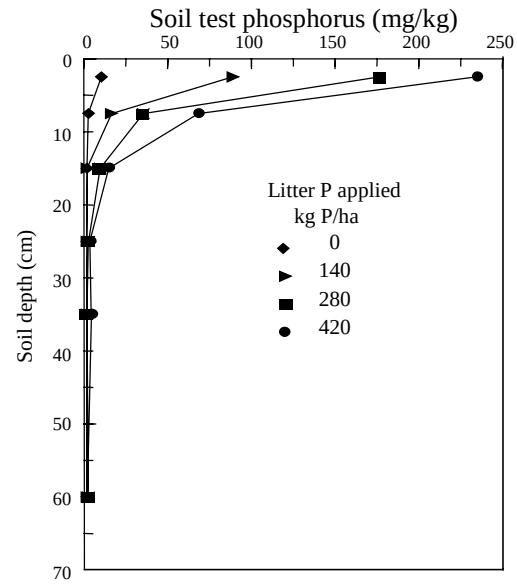

Figure 1.
Effect of poultry litter application on soil test phosphorus concentration in the profile of a Ruston fine sandy loam.

THE LOSS OF PHOSPHORUS FROM AGRICULTURAL LANDS

Phosphorus is removed from agricultural lands by two processes which occur in the field: surface runoff and subsurface leaching. In reality, these can be vague terms that describe extremely dynamic processes. For instance, surface flow can infiltrate into a soil during movement downslope, move laterally as subsurface "interflow," and reappear as surface flow.

The loss of phosphorus from agricultural lands occurs in sediment-bound and dissolved forms. Sediment phosphorus includes phosphorus associated with mineral particles and organic matter, and accounts for more than 90% of the total phosphorus of most soils. Sediment phosphorus eroded during surface flow events typically constitutes 60-90% of phosphorus transported in runoff. As a result, erosion control represents the first step in limiting phosphorus losses from agricultural land.

Even when sediment phosphorus loss is controlled, however, the loss of dissolved phosphorus may represent a serious environmental concern. Dissolved phosphorus is released from soil and plant material, and is usually immediately "bio-available" (sediment phosphorus is usually not immediately bio-available, although it can become bio-available over the long-term), making dissolved phosphorus the

fraction of greatest concern relative to eutrophication.

The release of dissolved phosphorus occurs when rainfall or irrigation water interact surface soil, plant material, or surface applied manure before leaving the field as runoff or leachate. Generally only the upper 1-2 inches of the soil surface serve as the source of dissolved phosphorus in runoff and leachate. Notably, runoff from grass, forest and non-cultivated soils carries much less sediment phosphorus, and is dominated by dissolved phosphorus.

As soil phosphorus increases, the potential for dissolved phosphorus release to runoff and leachate (leaching water) also increases (Figure 2). This highlights one of the crucial issues facing phosphorus management at the moment: how much phosphorus is too much? Because the nature of the relationship between soil phosphorus and runoff/leachate phosphorus is soil specific, research is required to ensure that local contexts are considered when addressing this question. Such research is currently the focus of the National Phosphorus Project (Sharpley et al., 1999a).

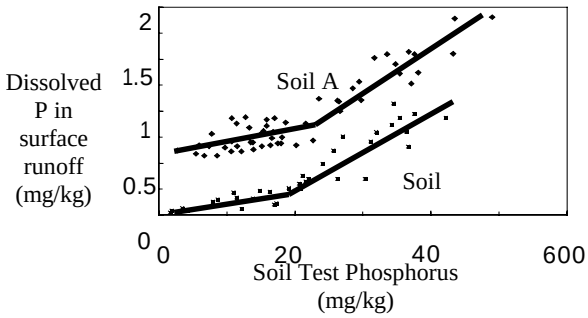

FIGURE 2. Relationship of soil test phosphorus to dissolved phosphorus in runoff for soils of differing texture (Soil A is Sandy Loam, Soil B is Silt Loam).

REMEDIATION

The overall goal to reduce phosphorus losses from agricultural lands must ultimately be grounded in an increased phosphorus use-efficiency, balancing phosphorus inputs in feed and fertilizer, as well as managing the level of phosphorus in the soil. Reducing phosphorus loss may be brought about by source and transport control strategies. As mentioned above, we have generally been able to reduce the transport of phosphorus from agricultural land in erosion. Much less attention has been directed toward source management and the control of dissolved phosphorus losses in surface runoff.

Source Management.

1. Manipulation of dietary phosphorus intake by animals, carefully matching dietary phosphorus inputs to livestock requirements, may help balance farm phosphorus input and output in livestock operations.

2. Enzyme additives (e.g., phytase) for livestock feed that will increase the efficiency of phosphorus uptake from grain during digestion are available and may reduce the phosphorus content of manure.

3. Low-phytate corn for feed has the potential to decrease the concentration of phosphorus in manure. Development of other crops with reduced phytate phosphorus is underway.

4. Commercially available manure amendments, such as slaked lime or alum, can reduce ammonia (NH_3) volatilization, leading to improved animal health and weight gains; reduce the solubility of phosphorus in poultry litter by several orders of magnitude; and decrease dissolved phosphorus in surface runoff. In addition, inexpensive coal-combustion byproducts,

such as fly ash, may immobilize phosphorus when added to soils without reducing the availability of the immobilized phosphorus to crops.

5. A mechanism should be established to facilitate movement of manure from surplus to deficit areas. In Delaware, a local poultry trade organization has established a "manure bank" network that puts manure-needy farmers in contact with manure-rich poultry growers. Even so, there is a need to develop a means to ensure the biosecurity of any manure transportation network that is developed.

6. Composting and pellitizing may also be considered as a management tool to improve manure distribution. Although this tends to increase the phosphorus concentration of manures, the volume is reduced and thus, transportation costs are less. Additional markets may be available for these materials.

7. There is interest in using some manures as sources of “bioenergy.” For example, dried poultry litter can be burned directly or converted by pyrolytic methods into oils suitable for use to generate electric power. Liquid wastes can be digested anaerobically to produce methane which can be used for heat and energy.

Transport Management.

1. Phosphorus loss via surface runoff and erosion may be reduced by conservation tillage and crop residue management, buffer strips, riparian zones, terracing, contour tillage, cover crops and impoundments (settling basins).

2. Conversion from furrow irrigation to sprinkler to drip irrigation significantly reduces irrigation erosion and runoff. Furrow treatments such as straw mulching and use of polyacrylamides (PAM) will also reduce in-furrow soil movement.

3. Most of these practices are generally more efficient at reducing sediment phosphorus than dissolved phosphorus. The impact of remedial measures to help improve poor water quality is often slow, as phosphorus stored in lake and stream sediments can provide a long-term source of phosphorus in waters even after inputs from agriculture are reduced. Therefore, immediate action is needed to reduce future problems.

4. None of these measures should be relied on as the sole or primary practice to reduce phosphorus export from agriculture.

Targeting Remediation.

Threshold soil phosphorus levels are being proposed to guide phosphorus management recommendations. In most cases, agencies which need these levels hope to uniformly apply a threshold value to areas and states under their domain. However, it is often too simplistic to use threshold soil phosphorus levels as the sole criterion to guide phosphorus management and phosphorus applications.

For example, adjacent fields having similar soil test phosphorus levels but differing susceptibilities to surface runoff and erosion, due to contrasting topography and management, should not have similar restrictions on phosphorus use and management. Also, it has been shown that in some agricultural watersheds, 90% of annual phosphorus export comes from only 10% of the land area during a few relatively large storms. Therefore, threshold soil phosphorus values will have little meaning unless they are used in conjunction with an

estimate of a sites' potential for surface runoff and erosion.

Preventing phosphorus loss is now taking on the added dimension of defining, targeting, and mitigating source-areas of phosphorus where high soil phosphorus levels coincide with high surface runoff and erosion potentials. This approach addresses phosphorus management at multi-field or watershed scales. Further, a comprehensive phosphorus management strategy must address down-gradient water quality impacts such as the proximity of P-sensitive waters. Conventionally applied remedies may not produce the desired results and may prove to be an inefficient and poor cost-effective approach to the problem if this source-area perspective to target application of phosphorus fertility, surface runoff and erosion control technology is not used.

A simple phosphorus index has been developed by USDA-NRCS in cooperation with several research scientists as a screening tool for use by field staffs, watershed planners, and farmers to rank the vulnerability of fields as sources of phosphorus loss in surface runoff. The index accounts for and ranks transport and source factors controlling phosphorus loss in surface runoff and sites where the risk of phosphorus movement and proximity to phosphorus-sensitive waters is expected to be higher than that of others. The index is a tool for field personnel to help identify agricultural areas or practices that have the greatest potential to accelerate eutrophication. It will identify management options available to land users that will allow them flexibility in targeting cost-beneficial remedial strategies.

INTEGRATING PHOSPHORUS AND NITROGEN MANAGEMENT AT WATERSHED SCALES

Farm nitrogen inputs can usually be more easily balanced with plant uptake than can phosphorus inputs, particularly where confined livestock operations exist. In the past, separate strategies for either phosphorus or nitrogen have been developed and implemented at farm or watershed scales. Because phosphorus and nitrogen have different chemistry and flow pathways through soils and watersheds, these narrowly targeted strategies often conflict and lead to compromised water quality. For example, manure application based on crop nitrogen requirements to minimize nitrate leaching to ground water, often results in excess soil phosphorus and enhances potential phosphorus losses in surface runoff. In contrast, reducing surface runoff losses of phosphorus via conservation tillage can increase water infiltration into the soil profile and enhance nitrate leaching.

Development of sound remedial measures should consider these conflicting impacts of conservation practices on resultant water quality. Clearly, a technically-sound framework must be developed that includes critical sources of phosphorus and nitrogen export from agricultural watersheds so that optimal strategies at farm and watershed scales can be implemented to best manage both phosphorus and nitrogen (Sharpley et al., 1999b).

SUMMARY

The overall goal of efforts to reduce phosphorus losses from agriculture, should be to balance off-farm inputs of phosphorus in feed and fertilizer with outputs in products while managing soils in ways that maintain productivity. Reducing

phosphorus loss from agricultural lands may be brought about by a suite of source and transport control strategies.

Future advisory programs should reinforce the fact that all fields do not contribute equally to phosphorus export from watersheds. Most phosphorus export comes from only a small portion of the watershed as a result of relatively few storms. Although soil phosphorus content is important in determining the concentration of phosphorus in agricultural runoff, it is likely that surface runoff and erosion potential will override soil phosphorus levels in determining phosphorus export. If water or soil do not move from a field or below the root zone, then phosphorus will not move. Clearly, management systems will be most effective if targeted to the hydrologically active source areas in a watershed that operate during a few major storms.

Manure management will have to account for site vulnerability to surface runoff and erosion, as well as soil phosphorus content, because not all soils and fields have the same potential to transfer phosphorus to surface runoff and leaching. As a result, threshold soil phosphorus levels should be indexed against phosphorus transport potential with lower values for phosphorus source areas than for areas not contributing to water export.

Consideration of all these factors will be needed to develop extension and demonstration projects that educate farmers, the livestock industry, and the general public as to what is actually involved in ensuring clean water. Development of guidelines to implement such strategies will also require consideration of the socio-economic and political impacts of any management changes on both rural and urban communities and of the mechanisms by which change can be achieved in a diverse community of land users.

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PHOSPHORUS IMPACTS ON NEBRASKA WATERSHEDS

INTRODUCTION

Nebraska's abundant water resources include nearly 400 public lakes and thousands of privately owned lakes and ponds, as well as over 1,300 natural sandhill lakes and more than 800 constructed sandpit lakes. More than 75% of the lakes and reservoirs across the Midwest have degraded water quality due to agricultural inputs of sediments and nutrients such as phosphorus and nitrogen. Nationwide, the U.S. EPA reported that more than five million acres of lakes and reservoirs are threatened or impaired by nutrients, sediments, toxins, and organic matter, primarily from agricultural pollution. The U.S. EPA estimates that more than 1,300 lakes in Nebraska alone are impaired.

THE CONNECTION BETWEEN PHOSPHORUS AND POOR WATER QUALITY

Phosphorus has long been recognized as the least abundant element in freshwater and is the key factor controlling biological productivity. Phosphorus loading has been particularly key in accelerating the degradation of surface waters throughout the Midwest and Nebraska. Symptoms of this degradation (also termed "eutrophication") include nuisance algal blooms which produce poor water clarity, noxious odors, impaired potable water supplies, dissolved oxygen depletion, fish kills, reduced recreational value, and lower property values. Excessive algal growth is the primary symptom targeted by lake and reservoir managers since its control indirectly reduces the magnitude of the other eutrophication problems.

A DEMONSTRATION OF THE IMPORTANCE OF PHOSPHORUS

A recent study that I conducted in cooperation with Dr. Kyle Hoagalnd of UNL provides a dramatic example of the key role that phosphorus plays in controlling the overall water quality of Nebraska's lakes and reservoirs. This study was conducted at a sandpit lake near Fremont, NE with extremely high levels of phosphorus which produced nearly all of the previously listed symptoms of severe eutrophication. For example, scum-forming algal blooms would typically begin in May and persist through the fall which resulted in very poor water clarity, odors, dissolved oxygen depletion, fish stress, and severely impaired recreational activities in the lake. An isolated section of this lake was treated with a chemical called aluminum sulfate (alum) which was extremely effective in stripping the phosphorus from the lakewater, but was not toxic to the algae or other aquatic organisms.

The improvements in the water quality of this sandpit lake following the reduction in phosphorus were striking. Lower levels of phosphorus in the water column resulted in a 65% decrease in the amount of algae in the lake, an increase in water clarity from 2 feet to 5.5 feet, and an increase in dissolved oxygen concentrations which increased the amount of fish habitat. These findings clearly demonstrate that phosphorus is indeed the key factor driving most of Nebraska's water quality problems.

THE STATUS OF NEBRASKA'S LAKES AND RESERVOIRS

In general, phosphorus levels in the Nebraska's lakes and reservoirs are very high and water quality in these water bodies is poor. Lakes and reservoirs are commonly classified by their phosphorus concentration into one of the four following categories: oligotrophic, mesotrophic, eutrophic, or hypereutrophic. The majority of Nebraska's lakes and reservoirs fall into the two high phosphorus categories; eutrophic and hypereutrophic. Unfortunately, high levels of undesirable algae and poor water quality are usually associated with these eutrophic and hypereutrophic lakes. Clearly, phosphorus management should be the focus of livestock and agricultural development planning if we hope to improve and maintain many of Nebraska's existing water resources.

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POLICY/REGULATORY TRENDS RELATIVE TO PHOSPHORUS

- **Water Quality Standards**

  National Strategy for Regional Nutrient Criteria

  State Water Quality Standards

- **Concentrated Animal Feeding Operations**

  Unified AFO Strategy

  EPA Regulations and Requirements

- **Total Maximum Daily Load Program**

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NATIONAL STRATEGY FOR THE DEVELOPMENT OF REGIONAL NUTRIENT CRITERIA

ABSTRACT

National Strategy. The U.S. Environmental Protection Agency is presenting a National strategy which describes the approach the Agency will follow in developing nutrient information and working with States and Tribes to adopt nutrient criteria as part of State water quality standards. The strategy presents over enrichment assessment tools and recognizes current capabilities for conducting these assessments at the regional watershed and waterbody levels. The major focus of this strategy is the development of waterbody-type technical guidance and region-specific nutrient criteria by the year 2000. Once waterbody-type guidance and nutrient criteria are established, EPA will assist States and Tribes in adopting numerical criteria into water quality standards by the end of 2003.

BACKGROUND

No current ambient criteria for phosphorus in fresh water. Presently, the only national water quality criteria in existence for phosphorus is in EPA's 1976 publication entitled *Quality Criteria for Water*. EPA presented ambient water quality criteria for nitrates, nitrites, and phosphorus. The phosphorus criterion was 0.10 ug/l elemental phosphorus for the protection of marine and estuarine waters. This criterion was based on a conservative estimate to protect against the toxic effects of the bioconcentration of elemental phosphorus to estuarine and marine organisms, and not the potential to cause eutrophication.

KEY ELEMENTS OF THE NATIONAL NUTRIENT STRATEGY

The major elements of this strategy include:

- Use of a regional and waterbody-type approach for the development of nutrient water quality criteria.
- Development of waterbody-typetechnical guidance documents (i.e., documents for streams and rivers; lakes and reservoirs; estuaries and coastal waters; and wetlands) that will serve as "user manuals" for assessing trophic state and developing region-specific nutrient criteria to control overenrichment.
- Establishment of an EPA National Nutrient Team with Regional Nutrient Coordinators to develop regional databases and to promote State and Tribal involvement.
- Development by EPA of nutrient water quality criteria guidance in the form of numerical regional target ranges, which EPA expects States and Tribes to use in implementing State management programs to reduce over enrichment in surface water, i.e., through the development of water quality criteria, standards, NPDES permit limits, and total maximum daily loads (TMDLs).
- Monitoring and evaluation of the effectiveness of nutrient management programs as they are implemented.

INFORMATION

For additional information on this National Strategy, contact Bob Cantilli, Health and Ecological Criteria Division, (4304), 401 M Street, S.W., Washington D.C., 204360 (telephone: 202-260-5546). Or view the Federal Register Notice published on June 15, 1998. The EPA Region 7 contact is Gary Welker, Environmental Services Division, 901 N. 5th St., Kansas City, KS, 66101 (telephone: (913) 551-7177). Source - *http://www.epa.gov/ost/standards/nutsi.html*

A LIVESTOCK PRODUCERS CHALLENGES WITH PHOSPHATE ISSUES

Herb Albers Feed Lots, Inc. located in Cuming County Nebraska where we maintain a 14,000 head commercial feedlot along with a farming operation. Our operation is currently third generation. Cuming County is the largest producer of hogs and cattle in Nebraska.

As with any industry, we have continued to consolidate our numbers into fewer hands, especially since the 1980's. In the 1980's, we saw people lose their land base around their operations. Consequently, we are more limited to the number of acres available to spread manure on that are producer-owned.

RADIUS AND DISTRIBUTION

I would estimate that within a five-mile radius of our feedlot only about 25% of the area available is spread with livestock manure.

In relation to Cuming County, I would estimate approximately 30%. However, we must remember that there is not a fence around the county. For example, 75% of our waste is spread in an adjoining county.

In our County, I would estimate that the amount of ground carrying a phosphorus level higher than 150 PPM, is considerably less than the amount of acres being spread. Currently we have managed to stay below this level in our operation. This is due in part to our soil sampling that we have carried out over the past 19 years. The concern that I currently have is that the same ground continues to be covered

CHALLENGES

The challenges that I see for our industry in the future are as follows. The first challenge is that manure is a very heavy moisture laden product that is very hard to transport over a long distance. The further we haul this product, the more logistical problems we face. For example, we feel 10 miles is currently our limit from an economical stand point, but when we factor in logistics, that number is cut to 5 miles.

The logistics referred to include cycle time of the spreaders. Another concern is time spent in the spreader. The longer it is on board, the more it packs into the spreader causing mechanical failure. Also a challenge is the length of time that row crop ground is available to spread on. Our goal is to put more product on more acres. The limiting factors are numerous. For one, neighbor relations must be considered. Their attitude toward manure is most often negative. Comments are made that there is too much foreign material and weed seed with the manure. Frankly, we are not seeing this as a problem because with manure we are getting a better fertility program which means a quicker canopy and better plant health. This attitude could be changed with education and demonstration plots. Another way is with regulations; the concern with this is that most people tend to shy away from regulations.

ECONOMICS OF MANURE

We feel on average, our records would conservatively reflect a 20-bushel increase in yield on corn and a 10-bushel increase on beans. I feel there is even more potential than this with proper breeding and research.

An application of manure at 16 ton to the acre will provide enough phosphorus and potassium for a 3-year period. The nitrogen levels are usually not available until the second and the third year because the ammonia nitrogen is usually volatilized off by the time it reaches the field in an open lot situation.

LAGOON AFFLUENT CHALLENGES

A challenge that is also facing us in the industry is lagoon affluent and how to properly dispose of this. The phosphate level is not very high on our samples, but salt is a concern. The problem is that the area that you can pipe this to is limited. There are not a lot on economics to this program.

We need to be looking at other alternatives to waste water handling. For instance, are there microbes that we can add on a cost beneficial basis that would reduce odor and phosphate levels to this affluent. We may also need to look at different design structures such as wet land bio filters. Further research and education is needed.

PUBLIC POLICY

As we look at public policy on all these issues that we have in relation to phosphate it becomes apparent to me that we need more education and research to be provided to both the producer and the farmer. In my opinion, to get more acres spread we need to educate farmers on the proper way to apply manure followed by a cost share program or tax credit to help move this product further off the producers' site.

The cost share program that I'm referring to would be much like the one currently in place, for farmers building terraces. Example a farmer constructs a terrace system 75% of the cost is shared by government agencies. This type of program would be beneficial to producers required to build lagoon structures.

In Cuming County, by-products have become an intrical part of cattle feeding with plants located in Blair and in Columbus. This seems likely to continue into the future. In the past, this has offered us an economic advantage. We will continue to use this product as long as there is a benefit. The downside to corn gluten is higher phosphate levels in the manure, and approximately 25% more manure being produced.

In our county, one of the major challenges to us is the new regulation being imposed by LB 1209. I would estimate that this will eventually eliminate-20 – 30%of the producers in our area.

As we can see, regulation comes at a high price. Most of these producers will be the small to mid-size operators that simply do not want to make the added investment into their operations, in the form of lagoons and additional land needed to apply waste on.

MANURE BENEFITS

One of the big advantages to manure that I have experienced, is the reduction of erosion on our fields. In fact, with proper application and management we feel the need for terracing may no longer exist. This is done through maintaining higher organic content in the soil structure, plus higher fertility levels mean more crop residue left to protect the soil. This in turn leads to better water intake properties.

NUMBER OF ACRES NEEDED FOR APPLICATION

Our data on manure output would reflect that we need to maintain 2,100 acres of crop ground to absorb the amount produced from a 12,000-head feedlot. We annually spread

700 acres and we need a 3-year rotation to keep phosphorus levels down. Crop rotation is key to making these numbers work.

As we look at phosphate management, projecting the amount of manure being produced on an annual basis would be a logical step in doing this. I did this and found the following results.

By using average dry matter intakes of feed and allocating a percent of this as bypass I came up with a projected yearly output of 14,284 tons. Currently, our actual output is 10,680 tons. When we factor in the amount of dirt present by tracking the amount required back into the yard. The actual amount of manure drops into the 7,000-ton range. However time is of the essence if we do not change attitudes soon. The problem will compound itself, because the same acres are reapplied on year after year.

CONCLUSION

The projected numbers being twice as high as the actual would lead me to speculate that the phosphorus issue is an easier one to solve than what was perceived.

In summary, I feel that we have many challenges ahead of us and we need help to make these challenges into benefits in the future. Manure should not be looked at as a liability but as an asset. It is an undiscovered asset; we should be using it as a profit center. Currently our hands are tied, we would like to spread more acres, but the ground is simply not available. The bottom line is that we need funding and a joint education program to effect change. If we can establish a cost share program with some real incentives and focus this with a long-term goal of spreading more acres. The benefits to the producer and the farmer will be great, and compliance will follow. This is the type of rural economic development that benefits everyone for generations to come.

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PHOSPHORUS CONCENTRATION IN NEBRASKA'S LIVESTOCK INDUSTRY

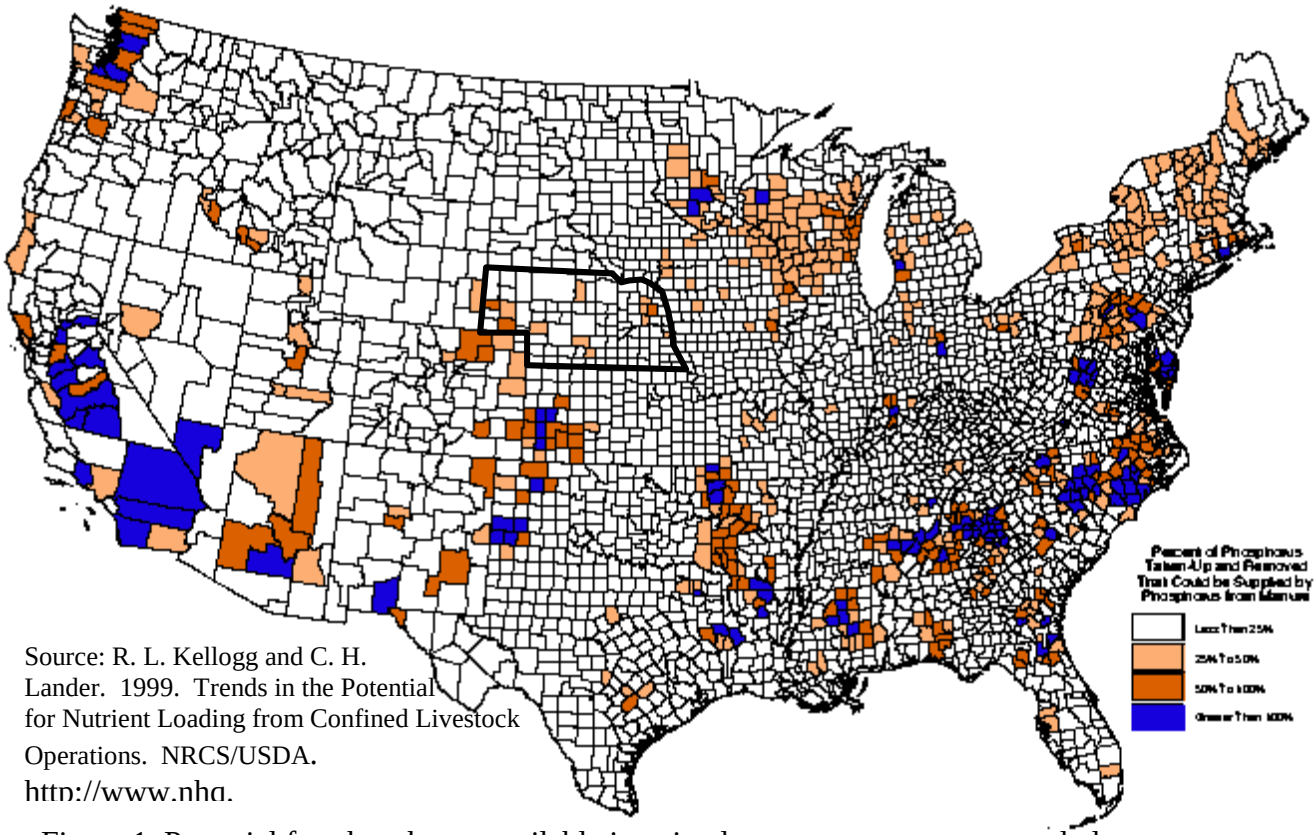
INTRODUCTION

Nutrient related water quality concerns associated with livestock production systems are generally associated with concentration of nutrients at a single location. Separation of livestock and crop production systems and concentration of livestock has contributed to this potential for nutrient concentration.

Our ability to recycle manure nutrients in a cropping program is fundamental to environmentally friendly management of nutrients in livestock systems. Manure nutrients utilized by crops will not be a water quality concern. However, there are limits to the ability of crops to recycle nutrients.

Concentration of livestock production separate from feed grain production has resulted in regional concentrations of phosphorus beyond the ability of local crop systems to recycle animal manure nutrients (Figure 1). Concentration of the poultry industry in Delaware and Eastern Maryland and the swine industry in North Carolina has produced well-publicized environmental challenges.

However, these nutrients did not originate as manure. They arrived as nutrient rich animal feeds often originating from outside the region. The shipment of feed grains from the Corn Belt to these livestock intensive regions has concentrated nutrients beyond the ability of local cropping systems to recycle those feed grain nutrients that end up in manure. Separation of feed grain and livestock production systems is an underlying cause of some of the most challenging nutrient related problems faced by the livestock industry.



Source: R. L. Kellogg and C. H. Lander. 1999. Trends in the Potential for Nutrient Loading from Confined Livestock Operations. NRCS/USDA. http://www.nhq.

Figure 1. Potential for phosphorus available in animal manure to meet or exceed plant uptake and removal for harvested crop and hay land.

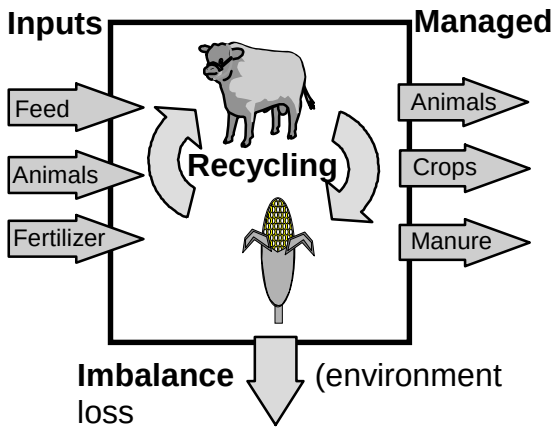


Figure 2. Nutrient flows on livestock or poultry operation

In contrast, Nebraska shows few signs of this regional concentration of nutrients. However, we are not immune to such concerns. Nutrient imbalances in Nebraska typically are a result of concentrations of nutrients on individual livestock operations as opposed to regional concentrations.

NUTRIENT FLOWS IN LIVESTOCK SYSTEMS

Nutrients are transported along multiple pathways and forms in a livestock operation (Figure 2). Phosphorus Inputs include purchased products (fertilizer, animal feed, and purchased animals). Within the boundaries of the farm, there is a "Recycling" of nutrients between the livestock and crop components as manure and animal feed. Nutrients exit a livestock operation preferably as "Managed Outputs" including animals and crops sold and possibly other products moved off farm (e.g. manure transferred to a neighboring farm).

The Imbalance between Inputs and Managed Outputs defines the magnitude of phosphorus losses to the environment (phosphorus runoff into surface water) and phosphorus additions to soil. Although not a direct loss to the environment, a growing accumulation of phosphorus in the soil adds to the risk of future environmental losses.

Nutrient imbalance can be expressed as a ratio of inputs to managed outputs. A ratio of 3 to1 suggests that for every three pounds of phosphorus entering a farm, one pound leaves as a managed product and the remaining two pounds are lost to the environment or added to the soil reserves. Livestock operations with a nutrient imbalance are an environmental risk. In contrast, operations that achieve a balance represent a potentially sustainable system.

NUTRIENT BALANCES IN NEBRASKA LIVESTOCK SYSTEMS

The nutrient balance for a Nebraska feedlot is illustrated in Figure 3. For this feedlot, the input to output ratio is 2 to 1 for phosphorus Without modifications in practice this operation will annually add most of the 120 ton phosphorus imbalance to soils managed by the livestock operation. Soil phosphorus levels will increase significantly with time.

The nutrient balance for 33 Nebraska livestock operations is illustrated in Figure 4. Many of the operations involved in this study experienced a phosphorus balance near the ideal 1 to 1 ratio while some exceeded ratios

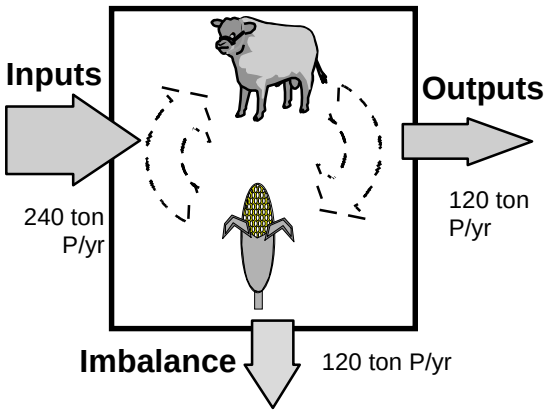


Figure 3. Phosphorus balance for 11,500 head Nebraska feedlot

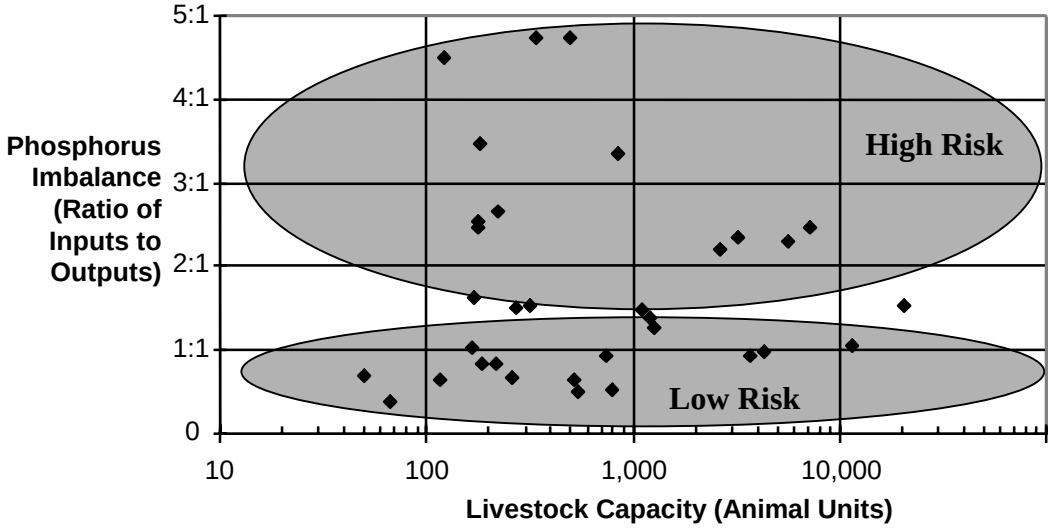


Figure 4. Phosphorus balance versus size for 33 Nebraska livestock operations.

of 4 to 1. As illustrated by this figure size of livestock operation is generally a poor indicator of the nutrient imbalance experienced by livestock operations. Similarly, the concentration of livestock per crop acre provided a poor indicator of the variation observed (not shown).

SOURCES OF PHOSPHORUS INPUTS

The source of nutrient inputs to livestock operations is important to understanding preferred management practices for reducing water quality risk. Purchased animal feeds are the most significant source of phosphorus inputs (see Figure 5). With the growing concentration of livestock and poultry, purchased animal feed is often the most significant source of nutrients even in regions that grow most animal feeds locally. Efforts to correct phosphorus imbalances must address purchased feed inputs and/or export of excess manure nutrients to off farm users.

Feed program decisions will impact phosphorus balance. For example, feeding of by-products of ethanol and corn processing typically result in finish cattle rations with excess phosphorus levels and cattle operations with higher phosphorus imbalance (Table 1). A critical review of feed programs from an environmental sustainability perspective is needed.

Table 3. Nutrient imbalance for cattle operations as influence by their use of corn processing by-products in cattle ration.

Feedlots:	P Balance
Using by-products	2.0 to 1
Not using by-products	1.1 to 1

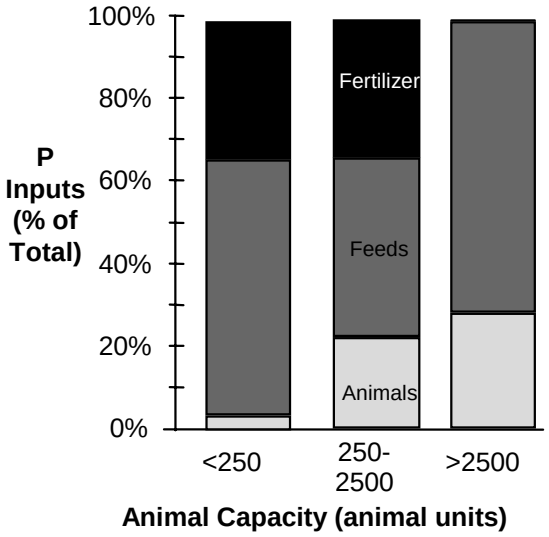


Figure 5. Source of phosphorus inputs for Nebraska livestock operations.

INDICATORS OF AN IMBALANCE

Some potential indicators of that a nutrient imbalance may be a concern for an individual livestock operation include the following:

- Soil phosphorus levels for the majority of fields are increasing with time or greater than 100 ppm.
- The majority (more than 50%) of the protein and phosphorus fed to livestock originates as purchased feed and forages.
- Less than 1 acre of cropland is available per animal unit (1000 lbs. of live weight) and no manure is transported to off-farm users.

In addition, it is possible to estimate an inventory of manure nutrient production and the crop nutrient requirements of available land to determine if adequate land is available for managing manure nutrients. A University of Nebraska software package assists with those calculations (http://www.ianr.unl.edu/manure/). A lack of available land for agronomic application of phosphorus suggests that this nutrient is being concentrated within the operation.

STRATEGIES TO IMPROVE NUTRIENT BALANCE

The solution to sustainable nutrient management on livestock systems is based upon creating a nutrient balance (either reduced nutrient inputs or increased managed outputs). Three fundamental strategies include:

Efficient use of manure nutrients in crop production. Accurate crediting of manure nutrients in a cropping program will reduce purchases of commercial fertilizer inputs and the phosphorus imbalance. This practice is especially important to livestock operations with significant crop production and substantial purchases of commercial fertilizers.

Reduced feed purchases. Feed program choices will impact nutrient balance, especially for farms purchasing significant quantities of feed from off-farm sources. Efficient utilization of purchased feed nutrients will reduce nutrient imbalances for many modern livestock systems.

3. Export of manure nutrients. Export of manure creates an additional managed output, similar to the sale of crops or livestock products. For the 11,500 head Nebraska feedlot illustrated in Figure 3, their efforts to market manure (not shown in Figure 3) have resulted in a sustainable phosphorus balance (see Figure 6). Marketing of manure moved sufficient phosphorus to off-farm uses so as to almost eliminate the potential phosphorus imbalance and prevent future buildup of soil phosphorus within this farm.

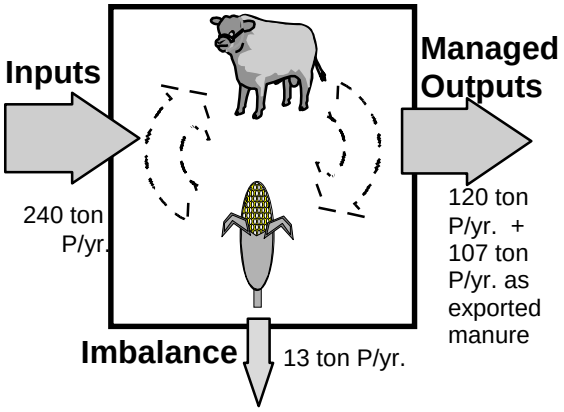


Figure 6. Phosphorus balance for 11,500 head Nebraska feedlot after crediting manure marketing program.

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FEED PROGRAM OPTIONS FOR ADDRESSING PHOSPHORUS ISSUES FACING BEEF FEEDLOTS

BIOLOGICAL IMPORTANCE

Phosphorus is an important nutrient in animal growth that has numerous functions in cattle. Phosphorus is predominant in bone (80% of body reserves) as hydroxyapetite crystals leading to bone strength and structure. The other 20% of P in the body is in soft tissues and functions include DNA and cell structure, enzymes and enzyme kinetics, and energy storage as ATP. Clearly, P is absolutely essential and arguably one of the most important minerals to all mammals.

Despite this importance, not many applied feeding studies have been performed to accurately define requirements for typical feedlot cattle weighing between 500 and 1250 lbs and consuming high-energy (i.e. grain) diets. Therefore, extrapolations have been made from studies with either non-ruminants or very young calves (<500 lbs) consuming low-energy diets. As a result, P requirements may be overestimated and subsequent formulations are exceeding animal requirements. All excess P supplied to animals above the requirement will be excreted in the feces (predominant) or may spill into the urine. Regardless, accurate estimates of requirements is crucial to managing this environmentally challenged nutrient and ensuring optimum performance without negative consequences.

REQUIREMENTS ARE IMPORTANT

When discussing feeding programs, two issues were historically important in terms of knowing the requirement. They were 1) optimizing performance and 2) not supplementing too much P due to expense of the mineral P sources. An emerging issue is now to accurately formulate diets too not overfeed P. An important consideration is that once the requirement has been met, additional P has no value to the animal or to the producer. In fact, excess P is eventually a detriment to the environment (and producer) because P supplied above the requirement accumulates in manure.

MAINTENANCE REQUIREMENTS

Animal requirements for P are based on the functions of P in the body. Cattle require P for maintenance of P in body stores as well as P for gain of tissues, either bone or soft tissues. The maintenance requirement consists of endogenous P that undergoes turnover and is secreted primarily in saliva (Wadsworth and Cohen, 1972). Once P is secreted into the GI tract via saliva, it may eventually be excreted in the feces despite originating from body stores and NOT from the diet. Therefore, maintenance requirement has been estimated in previous trials by accounting for this endogenous P pool excreted in feces. The 1996 NRC Nutrient Requirements of Beef Cattle predicts maintenance requirement as .73 g of absorbed P per 100 lbs of body weight. With feedlot cattle weights ranging from 600 to 1250 lbs, then absorbed P requirements for maintenance alone would range from 4.4 to 9.1 grams per day. If an animal is consuming 20 lbs of DM per day, then .05 to .1% of diet DM is required to meet maintenance requirements. This requirement needs to be met to replenish P that undergoes turnover in both bone and soft tissues.

Unfortunately, P absorption in the small intestine is not 100%, suggesting that more than the 4.5 to 9 grams is required per day for maintenance. There are ranges of absorption efficiencies reported in the literature from 50 to 90%. NRC assumes that 68% of P from the diet is absorbed which is probably a

conservative estimate. Assuming 68% absorption, 6.6 to 13.2 grams per day is required in the diet depending on animal weight. These estimates are equivalent to .07 to .15% if animals consume 20 lbs of DM.

REQUIREMENTS FOR GAIN

Cattle gaining 300 to 600 lbs or more during the feedlot finishing phase require P for the bone and soft tissue gain. With that in mind, NRC (1996) predicts the P required for gain as 3.9 grams for every 100 grams of protein gained per day which is based on how much P accumulates over that weight range (Ellenberger, 1950). Predicting P requirements as a function of gain seems logical because if steers are gaining more lbs per day, then P gain would also increase. Given energy intakes of feedlot cattle, retained protein varies from 150 to 190 grams per day for gains of 3.2 to 4.0 lbs per day. For example, if a steer is retaining 180 grams of protein, then P requirement for gain is 7 grams per day. Similar to maintenance requirement, assuming 68% absorption efficiency, total P required in the diet for gain is 10.3 grams per day. Combining the 10.3 grams for gain with 6.6 to 13.2 grams for maintenance, results in a total P requirement of 17 to 23.5 grams of P per day in the finishing diet. Estimating a low DM intake of 20 lbs per day (most conservative), then .19 to .26 % of diet DM as total P is required by the animal.

Most typical, grain finishing diets contain more than .26% without added P in supplements, therefore mineral P addition isn't necessary to ensure optimal animal performance. In the previous examples with maintenance and gain requirements, all figures were conservative, i.e. low intake (20 lbs), relatively high protein retention (180 grams), and poor absorption coefficient (68%). On average, NRC recommendations are lower than typical feedlot diet P concentrations (.35%; Hoechst-Roussel, 1996). Numerous reasons nutritionists cite to support fortification of P include: NRC predictions aren't accurate, variation in ingredient analysis, safety margin on mixing and formulation, and perceived differences in types of cattle. However, given the previous scenarios developed here, diets are more than adequate when feeding grain finishing diets without supplemental P. There is also growing evidence that NRC predictions may overestimate, not underestimate requirements for P (Erickson et al., 1999).

ABSORPTION ISSUES

One important factor in determining how much P should be provided in finishing diets is the absorption coefficient. As discussed, the NRC assumes 68%. If this efficiency increases, then less P would need to be provided and conversely if this estimate is too high, then some cattle may be underfed P. Playne (1976) summarized five studies with steers on grain-based diets and the average digestibility of dietary P was 74.3% ± 3.7. For this reason, the NRC is conservative to ensure that P supplied in the diet is sufficient to maximize performance.

Phytate P is commonly discussed when focusing on P absorption in animal diets. Phytate P is an organic complex that must be hydrolyzed and the phosphate released before the animal can absorb the mineral. Phytate can be hydrolyzed by phytase enzyme from microbes (naturally-occurring) or commercial production (by microbes). Given that phytase is a common enzyme to microbes, numerous studies have illustrated complete hydrolysis of phytate P by rumen fluid incubation (> 90%) and balance method in the animal (94 to 99%; Morse et al., 1992). Subsequently, essentially all the P in corn, corn byproducts, roughages, etc. that would contain phytate P is available for absorption by cattle. With non-ruminants, phytase enzyme either needs to be supplemented in the diet, or excess P supplemented in the diet as inorganic mineral supplements to meet the animal's requirement.

In feedlot animals, supplementing mineral P isn't a concern due to microbial phytase and the animal's ability to then utilize P in corn, roughage, etc. Utilizing phytate P is an advantage for feedlot cattle in terms of dietary formulation of P. However, due to the large number of studies in non-ruminants illustrating the need for supplemental mineral P, there is still skepticism as to how much organic P cattle may utilize.

CONSEQUENCE OF DECREASING P

We conducted a two-year study to determine the impact of decreasing dietary P to NRC-recommended levels on P excretion and P in manure. The control diet contained typical concentrations of P (.36 to .41% of DM) and the NRC-recommended level contained .22 to .29% P and was formulated to not exceed the requirement. Animal gains in the four experiments was not influenced by dietary P. Subtle differences existed between diets for feed efficiency and were a function of replacing corn with corn bran. Corn bran contains lower energy and lower P than corn and was fed to meet the decreasing P requirement over the course of the feeding period. If corn wasn't replaced with corn bran, then P would have been fed above the NRC-predicted requirement.

Feeding the lower P diet decreased P intake by 4.5 lbs (51%) per steer for the two yearling experiments and 5.1 lbs (41%) for the two calf experiments. Because animal gains were unaffected, P excretion was decreased by the same amount as P intake. When manure was corrected for P in the pen soil, P removed in manure was decreased 59% (3.4 lbs) for the yearling experiments and by 38% (4.3 lbs) for the calf experiments (Erickson et al., 2000).

WHAT IS THE REQUIREMENT?

Because the NRC requirement estimates are based on some dated studies (Ellenberger, 1950; Tillman et al., 1959), we have conducted a P requirement study with yearlings (>850 lbs) and are currently studying requirements of finishing calves this spring (600 lbs). In the yearling study, we fed 5 different concentrations of P, .14,.19, .24, .29, and .34% of diet DM. Gains and feed efficiency were unaffected by P concentration in the diet or grams of P fed (Erickson et al., 1999). Grams of P fed ranged from 16 to 36 across those concentrations. Using the NRC equations for these cattle and actual performance data, the predicted P requirement was .20% or 22.5 grams per day. Because P can be stored in bone and then mobilized to ensure adequate P for soft tissues, we isolated the phalanx bone (lower leg) at slaughter as well as a rib bone. Bone characteristics were unaffected across all P levels fed suggesting that none of the animals were mobilizing P from bone stores, thus the P fed must have been adequate. The yearling steers in this study were relatively large (> 850 lbs) and therefore P requirements would be lower than weaned calves entering feedlots in Nebraska. Therefore, we are currently conducting a similar study with newly received calves that will be fed for approximately 180 days until slaughter. Hopefully this study will give more insight into this important area. The key to the yearling study is that the requirement was lower than concentrations of P fed. As nutritionists, we needed to utilize some unique, non-typical feedstuffs to obtain a high-energy diet that contained only .14% P. These ingredients would not be possible in current feeding situations but the results reinforce the conclusion that supplemental P above what is provided in the basal corn diet is unnecessary.

SUMMARY

P is a critical nutrient that continuously undergoes turnover in the bone and soft tissues. This requirement is in grams per day, yet formulations are in terms % of diet DM. To ensure requirements are met, then you must have a good estimate of DM intake. Also, how efficiently P is absorbed in the

intestine can have an influence on requirement estimates. However, given current information on P requirements, the NRC predictions seem at least adequate to meet feedlot cattle requirements. Therefore, because NRC predictions suggest that no supplemental mineral P is required, supplementation strategies should be adjusted to remove all P from supplements. Typical grain finishing diets should contain enough P (>.25%) without mineral P in supplements. If P analysis of grain suggests that P in the entire diet is lower than .25%, then NRC recommendations can be used to meet the animal's requirement.

The most important consideration for feeding programs dealing with P is that all P fed above the requirement will be excreted. The excess P then must be dealt with at a cost to the producer and the environment. Historically, not supplementing P was incorrectly believed to cost the producer in terms of lost performance. However, not supplementing P may save the producer some costs due to both the mineral supplement cost and the environmental cost of P and spreading that P across crop acres. At present, the best management practice would be to remove all P from supplements and utilize P from what is provided from basal ingredients of corn, corn byproducts, and roughages.

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REDUCING PHOSPHORUS CONTENT IN SWINE MANURE

The majority of swine diets in Nebraska and much of the United States are formulated using corn/milo and soybean meal as the primary energy and amino acid sources. While very cost effective for lean growth, use of these ingredients in typical swine diets results in large amounts of undigested phosphorus being excreted in the feces.

The majority of the phosphorus in corn/milo and soybean meal occurs as phytic acid. The salts of phytic acid are typically described as phytates. In general, phytate phosphorus accounts for 65-70% of the total phosphorus in these feed grains. Pigs lack the necessary enzyme (phytase) to cleave the organic bonds of phytates during the digestion process. Thus, phosphorus in feed grains in the phytate form is undigested and excreted in the feces (Table 1).

For years, swine nutritionists formulated swine diets with the knowledge of this unavailable phosphorus problem. Inorganic phosphorus sources (generally mono or dicalcium phosphate) were added to the diet as sources of digestible phosphorus. Nutrient recommendations specified a total % P in the diet with the assumption that feed grains such as corn and soybean meal would be the primary dietary ingredients and these ingredients would have large amounts of undigestible (unavailable) phosphorus.

However, in recent years, advances in research have led to a true understanding of the phosphorus requirement of pigs during all phases of growth and production. The requirement is now given in nutrition guides as the requirement for available phosphorous as a percentage of the diet. Current University of Nebraska recommendations for phosphorus in grow-finish and breeding herd diets are given in Tables 2 and 3.

Recently, a commercial source of the phytase enzyme has become available for addition to swine and poultry diets. Derived from bacteria, addition of this phytase source to swine diets has improved the availability of the formerly unavailable phosphorus in feed grains such as corn and soybean meal.

Swine diets using corn and soybean meal can now be formulated to meet the digestible phosphorus needs of pigs utilizing phytase and reduced amounts of mono or dicalcium phosphate. In addition to having equal pig performance, pigs fed diets formulated with phytase and reduced amounts of inorganic phosphorus have a 20 to 40% reduction in the amount of phosphorus excreted in the manure (Table 4).

While effective in reducing the phosphorus excretion of pigs, phytase currently costs more than inorganic phosphorus sources, limiting its use by pork producers. However, a second phytase source is expected to be available this summer, with expectations of a price decrease. Phytase also does not withstand the heat associated with pelleting of swine diets, further limiting it application unless specialized equipment is installed in the feed mill. Both manufactures of phytase are pursuing research to solve the heat stability problem so a wider range of producers can utilize phytase in swine diets.

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Table 1. Total and available phosphorous contents of commonly used swine feed ingredients (as-fed basis).

	Phosphorus, %	
	Total	Available
Corn		
High lysine	.20	.03
High oil	.23	.04
Yellow dent	.26	.04
Milo	.28	.06
Oats	.34	.10
Soybean meal		
Dehulled	.69	.17
Solvent	.62	.24
Wheat, hard	.37	.18

Table 2. University of Nebraska Dietary Phosphorous Recommendations, % of Diet.

	45 to 80 lb	80 to 130 lb	130 to 190 lb	190lb to slaughter
Available P,%	.29	.22	.19	.16
Total P,%	.58	.51	.47	.43

Table 3. University of Nebraska Breeding Herd Phosphorous Recommendations, % of Diet.

	Breeding gilt	Gestation	Lactation
Available P, %	.40	.49	.49
Total P, %	.65	.75	.75

Table 4. Potential of phytase for reducing phosphorus in swine manure of 180 lb pigs[a]

Item	Estimated Requirement	With Phytase
Dietary phosphorus, %	.40	.30
Phosphorous intake, gm/d[b]	12.4	9.3
Phosphorus retained, gm/d[e]	4.0	4.0
Phosphorus excreted, gm/d[d]	8.4	5.3
Reduction in P excretion, %		37%

[a]From Cromwell, G. L. 1991. *Feedstuffs*, Oct. 7. pp 14-16.
[b]Assumes 820 g (1.80 lb) daily gain and 3.1 kg (6.8 lb) daily feed intake.
[c]Assumes 5 g phosphorus retained per kg body weight gain.
[d]Includes 2 g per 100 kg body weight endogenous phosphorus.

CORN BREEDING OPTIONS FOR IMPROVED P USE

During the past several decades, confined animal feeding operations (AFOs) have experienced substantial expansion. Manure generated by these livestock operations is generally disposed on land as fertilizer. Traditionally, manure application rates have been based on nitrogen requirements of crops resulting in phosphorus fertilization rates that exceed crop removal of phosphorus. The nitrogen-to-phosphorus ratio in corn grain is about 6-to-1, while that in manure from monogastric animals, such as poultry and swine, is about 3-to-1. This combination of factors often results in phosphorus surpluses in soils, which can result in a buildup of phosphorus in soils and subsoil of cropland surrounding confined AFOs. Once the "binding" sites in the soil are saturated with phosphorus, additional phosphorus is more soluble and may leach down the soil profile to reach the water table or run off into surface water.

Because of the environmental hazards caused by excess phosphorus entering streams, lakes, and other surface waters, legislative bodies in countries around the world have begun to pass laws that require reduction of total phosphorus applied per land area. In some cases, these new pieces of legislation have made it increasingly difficult to continue livestock production.

THE NUTRITIONAL SIGNIFICANCE OF PHYTATE PHOSPHORUS

One of the reasons for the high P levels in the feces of mono-gastric animals is that most (up to 80%) of the P in feed grains and oil seed meals is stored as phytic acid (phytate-P). Phytate-P is indigestible for monogastric animals since their digestive tracts lack the enzyme phytase, which releases P from the phytate ring (Figure 1).

Phytate-P complex also binds other nutritionally important minerals such as calcium, cobalt, copper, iron, magnesium, manganese, selenium, and zinc. Because these cations, when bound by phytate, are not absorbed by animals, they pass into the waste and potentially contribute to their buildup in soils receiving heavy manure applications. There is also some evidence that the phytate-P complex interacts with amino acids, potentially limiting their digestibility as well.

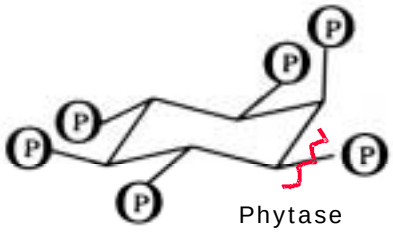


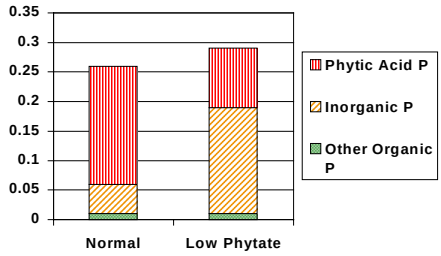
Figure 1. Phytate molecule showing site of cleavage by phytase enzyme.

Ruminant animals are believed to fully utilize phytate P because rumen microbes produce phytase. However, there is evidence that ruminant waste also contains significant levels of phosphorus. This is largely due to the fact that dietary phosphorus levels often exceed nutrient requirements even though no supplemental phosphorus is added to the ration.

Corn's phytate is present in the germ, while in soybeans the phytate is contained throughout the seed. Phytate is involved in several roles in the seed, including maturation, initiation of dormancy, and as a source of P and cations for use during germination.

Strategies for increasing phosphorus availability. There currently are two methods to overcome poor nutritional availability of P in grains fed to swine and poultry. The first, and most common for swine and poultry producers, is to add inorganic phosphates

Figure 2. Forms of Phosphorus in Corn



and/or animal byproducts to the feed. This approach does not address phytate-P content of the diet and presents consequences that are two-fold. First, supplementing P represents an added expense to the producer. Second, animals excrete the un-degraded phytate-P.

The second approach is to release the P from phytate with the addition of commercially produced phytase enzyme to the feed. The enzyme is active in the stomach of the animal and the released P is absorbed in the small intestine.

Adding phytase enzyme to feed increases P availability in corn from 15% to 43% in swine (Cromwell et al., 1993). Phytase enzyme decreases P excretion in monogastric animals by 15 to 35% when the diets are formulated to account for the increased available P. In a recent study utilizing this technology, Virginia researchers estimated that the reduction in phosphorus excretion reduced the land area required for waste lagoon liquid disposal by 27 percent.

Although phytase has the potential to reduce the amount of P excreted in the manure, some concerns do exist with this approach; such as the cost of phytase application equipment, the potential instability of the phytase enzymes, and the possibility of inconsistent distribution of phytase enzyme throughout the ration.

PLANT BREEDING APPROACHES

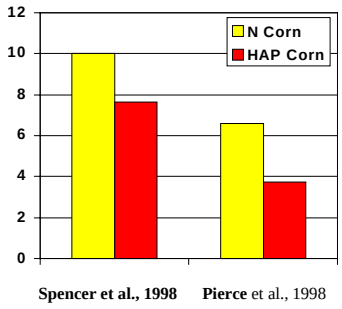
Low Phytate-P Corn. An alternative approach to adding phytase enzyme to the diet is to manipulate the way P is stored in the grain seed. In 1992, Dr. Victor Raboy, a USDA-ARS scientist discovered a non-lethal corn mutant (*lpa-1*) that stored most of its seed P as phosphate rather than as phytate-P (Raboy et al., 1994). Total P content in this mutant corn was the same as found in normal corn, but there was a 56% reduction in phytic acid P (Figure 2). Phosphorus in the seed not stored as phytic acid is present as inorganic P. These mutants offer potential genetic resources for addressing nutritional and environmental issues caused by poor availability of P in corn. Pre-commercial corn hybrids are currently being evaluated in animal feeding studies.

Animal Research Studies. To date, the results of two bioavailability, two digestibility, and four growth trials have been reported for pigs fed Low Phytate-P corn. These studies indicate that a greater amount of phosphorus is available to animals through Low Phytate-P corn than typical corn.

Cromwell et al., 1998; and Spencer et al., 1998a evaluated the bioavailability of P from normal yellow corn and Low Phytate-P corn utilizing slope ratio technique in 15 kg and 9 kg pigs, respectively. From these trials it appears that the bioavailability of P in Low Phytate-P corn is approximately 70%, and bioavailability of P in normal yellow corn is approximately 15%.

Pierce et al., 1998 reported increased digestibility of P by 31% and reduced P excretion by 13% from feeding Low Phytate-P corn. Spencer et al., 1998 and Pierce et al., 1998 reported that pigs fed Low Phytate-P corn digested significantly more dietary P and reduced P excretion by 24 to 43%, respectively (Figure 3). These results support

Figure 3. Phosphorus Excretion g/day



the conclusion that less supplemental P is required and less P is excreted when Low Phytate-P corn is fed to pigs.

Utilizing the previously cited data, pig growth trials have been conducted to test the practical application of Low Phytate-P corn in pig diets (Pierce et al., 1998, 1999; Spencer et al., 1998b; and Veum et al., 1998). In these trials, diets were formulated with either normal yellow corn or Low Phytate-P corn to the same available P concentrations. All other nutritional parameters were held constant. These trials found that using Low Phytate-P corn, reduced the need for supplemental P in the diet and reduced P excretion up to 40%.

Similar results have been reported in studies utilizing poultry. Increased concentration of available phosphorus in Low Phytate-P corn is utilized effectively by broiler chicks (Ertl et al., 1998; Kersey et al., 1998). Bird growth performance, bird health and carcass quality, were similar between broilers fed either typical corn or Low Phytate-P corn, with or without phytase supplementation (Huff et al., 1998 and 1998). Other research with broilers indicated that body weights and feed efficiency were improved with Low Phytate-P corn-based diets compared to those fed typical corn diets (Saylor et al., 1999). For laying hens, egg production and feed consumption were similar between hens fed typical corn and those fed Low Phytate-P corn-based diets (Scheideler et al., 1999).

Low Phosphorus Content Corn. An alternative solution for reducing the phosphorus content in livestock waste would be to reduce the total P content in the feed ingredients fed. This strategy may be particularly useful for reducing P in ruminant manure. To date we are unaware of any active plant breeding programs dedicated to reducing the P content in corn. It has been demonstrated that the total P content in corn can range from .20%-.38% based on growing conditions, hybrid selection, and soil fertilization programs. Thus, selective breeding programs to select corn hybrids for low P content corn could potentially reduce the P level in corn.

It is known that most of the phosphorus in corn grain is associated with the germ. Thus, selection for hybrids that have lower germ to endosperm ratio would potentially reduce the P level in the kernel. Germless mutants, having aborted embryos, have been identified which could potentially be used in breeding programs. Since the embryo is responsible for seed germination, the resulting seed would be infertile. There may be several transgenic approaches which could either eliminate embryo development, reduced P uptake in the plant or reduced P transport into the seed. However, such techniques are still in experimental development.

Issues related to plant breeding solutions for improving P bioavailability or reduced P content of corn. Low Phytate-P corn has been shown too effectively improve P bioavailability and reduce P excretion from monogastric specie. However, wide- scale product commercialization may still be several years away. Product release must consider many criteria; including, yield, area of adaptation, disease and pest resistance, as well as nutritional and environmental value of these products before commercial

introduction. While the livestock and poultry markets appear receptive to this technology, there are still many questions that remain unanswered. How do we establish the environmental value? How will members of the value chain share the value? In addition, systems to assure identity preservation of Low Phytate-P grain will be required for large-scale adoption by integrated livestock and poultry companies.

The development of corn having low P content may be a plausible solution for reducing P content in livestock (particularly ruminant) waste; however, it is not a trait that is currently under commercial development. Development of these products would be expensive, time consuming and would compete with other commercial trait development resources. The use of transgenic approaches may offer future technical solutions but may encounter social resistance.

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ROLE OF THE GRAIN PROCESSING INDUSTRIES ON PHOSPHORUS FEEDING ISSUES

GRAIN PROCESSING AND BYPRODUCT PRODUCTION

Corn and other grains can be processed to produce starches, oils, sweeteners, ethanol and other products. In addition to the products produced for human and industrial uses, several types of byproducts are produced in the wet and dry milling process. These byproducts are commonly referred to as corn milling byproducts. The major byproducts produced and utilized by the cattle feeding industry in Nebraska are wet corn gluten feed, corn steep liquor and wet distillers grains. Thus, there is a strong symbiotic relationship between the grain processing and the cattle feeding industries.

Wet corn gluten feed and steep liquor are byproducts of the corn wet milling process. In the wet milling process, corn is placed in large steep tanks to be soaked for 2 to 3 days in a mixture of warm water and sulfur dioxide. The liquid separated from this process is combined with condensed distillers solubles and commonly called steep liquor, which is partially dehydrated and fed to cattle or combined with corn bran, a component generated later in the milling process, to produce wet corn gluten feed. The steeped grain is coarsely ground allowing the germ to be harvested for subsequent extraction of the corn oil. The remaining grain fraction is then finely ground and separated into starch, gluten (corn protein) and corn bran (the outer layer of the corn kernel). The starch is converted into sweeteners, ethanol, or marketed as corn starch. The gluten protein is dried and marketed as a supplemental protein source, typically for pet food. The bran fraction, with the addition of corn steep liquor, is marketed as wet corn gluten feed. Wet corn gluten feed can be dried and sold as dry corn gluten feed. However, all of the corn gluten feed produced in Nebraska is marketed in the wet form.

Wet distillers grains is a byproduct of the dry milling process. In the dry milling process, dry grain (usually corn and sorghum grain in Nebraska) is ground and then combined with water to form a mash. Yeast are added to the mash to convert the starch (by fermentation) into ethanol. The ethanol is then distilled and the remaining mash is called distillers grains. Distillers solubles (the liquid fraction remaining after distillation) are partially dried and added back to the distillers grains. This product is commonly called wet distillers grains plus solubles, and is normally fed to feedlot cattle in Nebraska.

Approximately 190 million bushels of grain are processed annually by the 5 dry milling (ethanol) and 2 wet milling (sweeteners and ethanol) plants in Nebraska. The grain milling industry and the cattle feeding industry represent the two largest users of corn, consuming 16 and 20%, respectively, of Nebraska's corn production. The production of wet corn gluten feed, steep liquor and wet distillers grains totals about 1.2 million tons (dry matter basis) from these grain processing enterprises annually.

BYPRODUCT NUTRIENT COMPOSITION

A summary of commonly fed wet byproducts from the grain processing industry is provided in Table 1. In general, byproducts from the grain milling industry have 2 to 3 times more phosphorus than the native grain. However, these products are only fed at 20 to 50% of the diet dry matter. The reason for this increased phosphorus is simply a concentration issue. As starch and other components of the grain (oil, protein, etc) are harvested, the remaining

fractions become more concentrated in the byproducts produced. The impact of this increase on total dietary phosphorus concentration will be discussed later. Although phosphorus concentration is higher than the grain itself, the byproducts also contain higher concentrations of crude protein and several essential minerals (like calcium and potassium). These increases are actually a benefit to the cattle feeder. Wet and dry milling byproducts primarily replace corn grain and some forage (alfalfa hay or corn silage) in finishing diets. Because wet and dry milling byproducts are higher in protein and minerals than corn, the supplemental amount of these nutrients is decreased. Therefore, the cost of these supplemental nutrients can be omitted from finishing diets.

Table 1. Composition of grain byproducts

Item	Corn[a]	WCGF[a]	Steep[a]	WDG[a]
DM[b], %	85	40 - 60	45 - 55	30 - 40
CP[b], %	8 - 9	15 - 24	30 - 40	25- 35
P[b], %	.2 - .3	.5 - 1.2	1 - 2.2	.4 - .80

[a] Corn= dry corn grain; WCGF= wet corn gluten feed; Steep= corn steep liquor; WDG= wet distillers grains.

[b] DM= dry matter; CP= crude protein; P= phosphorus

EFFECTS OF FEEDING BYPRODUCTS ON RATION COMPOSITION AND ANIMAL PERFORMANCE

Due to the higher concentration of phosphorus, the total dietary phosphorus concentration is increased when wet and dry grain milling byproducts replace corn grain and forage in finishing diets. The magnitude of this increase is dependent on the amount of byproduct(s) included in the diet. A typical dry-rolled corn finishing diet contains .30 to .35% phosphorus. If a byproduct contained .8% phosphorus, replacing 25% (dry matter basis) of the corn in the diet with this byproduct would result in a total dietary phosphorus concentration of about .4%. Based on the experiments conducted by Erickson et al. (2000 Nebraska Cattle Report), dietary phosphorus concentrations of .25% of the diet dry matter is adequate for feedlot cattle. Additionally, these experiments suggested that any additional phosphorus in the diet increased the phosphorus concentration in the manure. In their experiments (Erickson et al., 2000), decreasing the dietary phosphorus concentration from .36 to .24% of the diet dry matter decreased calculated phosphorus excretion by approximately 60% in feedlot cattle. Admittedly, the feeding of grain byproducts often results in increased dietary phosphorus content and subsequently increased phosphorus in the manure. Calculations provided by Koelsch (2000 Nebraska Beef Report) suggest that the land requirement for managing phosphorus from cattle fed a diet containing .22% phosphorus would increase 60% if the dietary phosphorus concentration was .45% of the diet dry matter.

Although phosphorus is an issue with the use of grain milling byproducts, utilizing these products in feedlot diets has a very significant impact on animal performance. Table 2 summarizes data from 14 controlled research trials and demonstrates the improvements in feedlot performance when a portion of the corn in the diet is replaced with either wet corn gluten feed or wet distillers grains.

Table 2. Improvement in feedlot performance above corn control diets when grain milling byproducts replace corn grain		
Improvement[a], %	WCGF[b]	WDG[b]
Feed intake	.03 - 5.4	1.8
Daily gain	.4 - 11.4	8.0
Feed conversion	.3 - 5.1	11.5
Byproduct Net Energy Value		
NEg[c], Mcal/cwt	.70 - .80	.80 - .90
Increase over corn, %	0 - 14	14 - 28

[a] Improvement in performance relative to dry-rolled corn control diets.

[b] WCGF= wet corn gluten feed; WDG= wet distillers grains.

[c] NEg= Net energy for gain calculated from feed efficiency data from controlled research trials.

Some of the improvement in animal performance observed with the use of grain milling byproducts is a result of reducing the incidence and severity of acidosis in feedlot cattle. Also, these grain milling byproducts may have a greater impact on animal performance during weather stresses. Wet and dry milling byproducts replace starch, the primary cause of acidosis, with highly digestible fiber. These improvements in performance often enhance the profitability of cattle feeders. The improvements in animal performance from Table 2 suggest that cattle feeders can increase net returns by an average of $20/animal when byproducts are used in the diet, assuming that ration cost is not changed. Nebraska finishes approximately 4.8 million cattle annually. About one-half of these cattle (2.4 million head) are fed wet and/or dry milling byproducts in their ration. If the average improvement is $20/head, then the value of these grain milling byproducts is 48 million dollars to the cattle feeding industry.

In summary, Nebraska is fortunate to have positive relationships in agriculture like that of the cattle feeding, grain production and the wet and dry grain processing industries. This paper will not attempt to determine the overall economic impact of each of these three sectors in Nebraska's agriculture and overall State economy; however, it should be apparent that these three segments are not mutually exclusive. Regulations or other pressures that reduce the viability of one industry would certainly have ramifications on the others.

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PHOSPHORUS REMOVAL FROM GRAIN PROCESSING WASTE STREAMS

Coproducts of the grain processing industry are often used as ingredients in animal feed, particularly for cattle production. A potential drawback to this use is that phosphorus from the grain is concentrated in the coproduct. The phosphorus-rich coproduct may become a liability to confined animal feeding operations as manure is land-applied at a time of increasingly stringent phosphorus regulations.

Other waste streams have been faced with analogous problems of phosphorus levels too high for the receiving environment. In the 1960s and 1970s the duck industry in New York was required to remove phosphorus from waters used to raise the birds (Loehr and Schulte, 1970). Sewage treatment plants are sometimes forced to remove phosphorus when eutrophication of streams and lakes are an issue. In both cases, large volume waste streams are involved and significant amounts of phosphorus-laden sludge are produced that must be handled in some fashion.

Domestic sewage and duck farm wastewater have total phosphorus levels ranging from about 5 to 50 mg/L. Grain processing waste streams have phosphorus levels several times to 100-fold that of domestic sewage. For example, Sweeten (1983) reported total phosphorus levels up to 3500 mg/L with an average of 540 mg/L for untreated whole stillage from grain sorghum processing. The characteristics of grain processing waste streams vary widely depending on the raw material, the process, and the product. Steep water from corn wet-milling contains carbohydrates, amino acids, peptides, organic acids, minerals, and may have solids contents varying from 2 to 15 percent. It is often condensed, then handled as a thick syrupy substance with a solids content approaching 50 percent. The solids content of whole stillage from the ethanol industry varies from 5 to 10 percent (Sweeten, 1983).

Phosphorus from wet-milling of corn is associated with myo-inositols (a vitamin b-like organic structure in the form of phosphate esters). One of these esters is myo-inositol hexaphosphate, also known as phytic acid or IP-6 ($C_6H_{18}O_{24}P_6$). This form reputedly is an antioxidant having cancer fighting properties. Phytate has been the subject of much research in swine and poultry nutrition because these animals lack the necessary enzymes to utilize this organic phosphorus form. A number of industrial uses of phytate, including pharmaceuticals and some in metallurgy and electroplating, are also reported. Recently, researchers at the University of Illinois discovered that phytic acid mixed and heated with corn bran, another coproduct of corn wet-milling, forms a powdery resin that has excellent sorption properties. Such starch-phytate resins also appear to have the ability to remove atrazine from aqueous solutions (Lehrfeld and Baker, 1998). Commercial use of phytic acid derived from grain products is yet to be widely developed, however.

According to Hull, et al. (1996), Sands, et al. (1986) reported that myo-inositol phosphates comprise up to eight percent of the dry weight (total solids) of corn steep water. Hull's research indicates that, while inorganic phosphorus levels in corn steep water are low (0.1 to 8.0 g/L), myo-inositil phosphate levels reached 29.4 g/L depending upon the company and where in the process

stream the sample was taken. When steep water from various locations in the process is condensed, those levels can be as high as 14.8 percent (dry weight). However, commercially available condensed corn steep water typically contains phosphorus levels nearer the bottom of that range (1.9 % on a dry weight basis, Minnesota Corn Processors Fact Sheet, 1999). Part of the challenge of phosphorus removal from grain processing wastewater involves selective removal so that other valuable ingredients are not compromised.

Removal of phosphorus from most domestic wastewater streams is typically measured in terms of the efficiency of total phosphorus (TP) or orthophosphorus (PO_4^{3-}, so-called ortho-P) removal. In many instances, these waste streams contain relatively simple inorganic ortho- or poly-phosphates as the dominant form allowing simple chemical precipitation or biological removal strategies to be successful. Schulte (1970) was able to remove up to 90 percent of the total phosphorus in duck farm wastewater through chemical precipitation with ferric chloride. Biological processes can hyperaccumulate phosphorus in microbial protoplasm to levels of 4 to 12 percent on a dry weight basis (Kiely, 1997).

The grain processing literature is not consistent in the way phosphorus is reported and rarely does it distinguish between the forms of phosphorus which exist in corn processing waste streams. However, if organic phosphorus such as phytic acid is a dominant species, as appears to be the case with corn processing wastewater, strategies other than simple chemical precipitation or bioaccumulation may be needed. Unfortunately, studies which imply that ion exchange (Hull, et al., 1996) and reverse osmosis (Sweeten, 1983) would be useful for treating grain processing wastewater do not provide the data necessary to assess their actual efficacy for phosphorus removal.

Few studies have been done with the express purpose of ascertaining the problems and opportunities for phosphorus removal from grain processing wastewaters. In general, physical-chemical treatment of stillage has met with little success (Sheehan and Greenfield, 1980). Calcium precipitation of the simpler inositol phosphate isomers appeared to concentrate inositol hexaphosphate (IP-6) and inositol pentaphosphate (IP-5) in corn steep water (Hull, et al., 1996), but only 18 to 48 percent of the IP-5 and IP-6 could be isolated that way. Lack of success using alum ($Al_2(SO_4)_3$) for chemical precipitation of phosphorus was reported by Sweeten, et al. (1983) for untreated whole stillage from ethanol production from grain sorghum.

It may be that phytate in corn steep water readily chelates with iron to form an insoluble complex, lowering the availability of inositol phosphates to precipitants such as calcium and aluminum. Hull's data indicates iron levels ranging from 0.8 to 22.9 g/L depending on the company and location in the steeping process. It would appear that additional work on chemical precipitation as a method of phosphorus removal ought to take iron chelation into account. Perhaps, ferric chloride, alone or in combination with designer polymers and coagulant aids, would be a better choice. Physical-chemical methods such as ion-exchange, electrodialysis or reverse osmosis might also be considered. Selective location phosphorus removal equipment within the corn-wet milling process might also prove to be an effective strategy.

Many questions remain to be answered before the grain processing industry can economically remove phosphorus from its coproducts. Among these questions needing attention are:

- Are there real markets for phosphorus extracts such as phytic acid?
- Is the phytic acid content of steep water sufficient to satisfy an economically significant portion of that market?
- Can phytic acid be extracted with sufficient efficiency to be economically viable?
- Does the entire grain processing waste stream have to be treated or can selective locations be identified where phosphorus removal would be most effective?
- What are the effects of phosphorus extraction on the efficacy of the remaining coproduct?
- What are the environmental impacts of the extraction process?

There is a need to examine those questions, especially should the cattle industry come under greater pressure to reduce phosphorus levels in manure.

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TRENDS IN NEBRASKA SOIL PHOSPHORUS STATUS

INTRODUCTION

Over the past twenty years, a trend in the Nebraska feedlot industry has been a reduction of feedlot numbers from over 11,000 in 1985 to 5000 today. The number of cattle on feed, however, has remained relatively stable with a concomitant increase in the size of feedlots. (Figure 1). Soil-P tests that are used for assessing plant availability, such as the widely adapted Bray-P1 test, have been shown to be well correlated with particulant-P and soluble-P in runoff and erosion from agricultural lands. The University of Nebraska Soil and Plant Analytical Laboratory (SPAL) has a historic data base of soil test values that provides information regarding trends in soil test values by county.

SOIL TEST P TRENDS

State soil test-P trends. Table 1 shows the trend in Bray P-1 soil test values form 1985 trough 1995. The probability of an economic return to phosphorus applied to Nebraska soils with a Bray P1 test above 30 ppm is very low. Statewide soil test P levels appear quite stable in that the percent of samples testing less than 15 ppm has changed very little since 1985. The percent of samples with values above 45 ppm has also remained nearly constant at about 19%. There is however, a trend toward higher P values in the 25 to 45 ppm range.

"Crop" vs. "Livestock" counties. The database was queried for a select 10 counties, five of which were predominately "crop" counties with high maize productivity (Adams, Buffalo, Filmore, Hamilton and Merrick) and five which were also major maize counties but which had high populations of cattle on feed (Colfax, Cuming, Dawson, Holt, and Scotts Bluff). Selected statistics of this subgroup of counties is presented in Table 2. These data are from the 1998 Nebraska Agricultural Statistics. The "livestock" counties had nearly 3 times the density of cattle on feed (or swine) per acre of *farm*land. Phosphorus fertilizer consumption was calculated on the basis of tons P2O5/acre of *crop*land. P fertilizer consumption/acre was slightly over 22% higher for "livestock" counties.

Soil test-P values were summarized for this subset of counties and the results are presented in Figure 2. There is a general trend toward higher soil test P values for the livestock counties with a median number of soil test P values within the 30 - 45 ppm range. The "crop" counties, in contrast, had a median number of values within the 15- 30 ppm range.

This trend implies that soil test values are rising where livestock populations are concentrated within the state. Although only a small percentage of samples (<6%) had values >100 ppm Bray P1, this is a value that presents a significant hazard to P enrichment of surface water. Wider distribution of manure, field rotation and careful monitoring of soil test P values are in order to prevent excessive soil P loading.

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Table 1. Percent of Bray-P1 soil test values in various soil-P index ranges. (Source: UNL Soil and Plant Analytical Laboratory-farm samples)

BRAY-P1 Soil Test, ppm	**YEAR**			
	1985	1990	1992	1995
	----------% of samples ----------			
<5	10	7.5	4.3	6
5.1 to 15	30	29	31.1	33.1
15.1 to 24	22	22.7	27.5	
24.1 to 29	8	7.9	9.9	19.9
29.1 to 45	3[1]	13.6	14.5	21.8
45.1 to 100		19.4[2]	12.7[2]	12.8
100.1 to 200				3.5
> 200				2.9[3]
No. of samples	4460	3409	2547	3051

[1/] No estimate of values greater than 45 ppm available for 1985.
[2/] May include values >100 since 1990 and 1992 data base only includes "values > 45".
[3/] Includes 14 samples ranging from 411 to 1158 ppm.

Table 2. Selected Agricultural Statistics for 10 Nebraska Counties. (Source: 1997-98 Nebraska Agricultural Statistics, NE Dept. Agr.)

STATISTICS	"LIVESTOCK" Counties*	"CROP" Counties**
FARM ACRES (x 1000)	3039	1875
CROP ACRES (x 1000)	1743	1516
ALL CATTLE (x 1000 head)	941	376
# Cattle / acre farm land	0.39	0.20
CATTLE ON FEED (x 1000)	1178	391
# Cattle on feed / acre farm land	0.74	0.22
SWINE (x 1000)	564	184
# Swine / acre farm land	0.24	0.10
CORN ACRES	728	1013
P-FERT. CONS. (Ton P_2O_5/yr)	23.4	19.1
Ton P_2O_5/1000 acre crop land	15.8	12.9

***"Livestock" counties** = Colfax, Cuming, Dawson, Holt, Scotts Bluff
*** "Crop" counties** = Adams, Buffalo, Filmore, Hamilton, Merrick

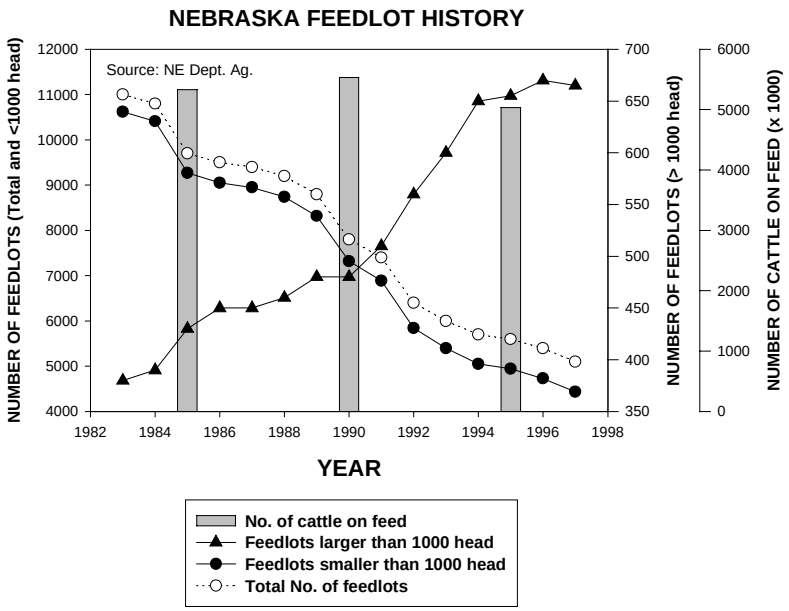

Figure 2. Feedlot number, size and cattle on feed for Nebraska, 1985-1997.

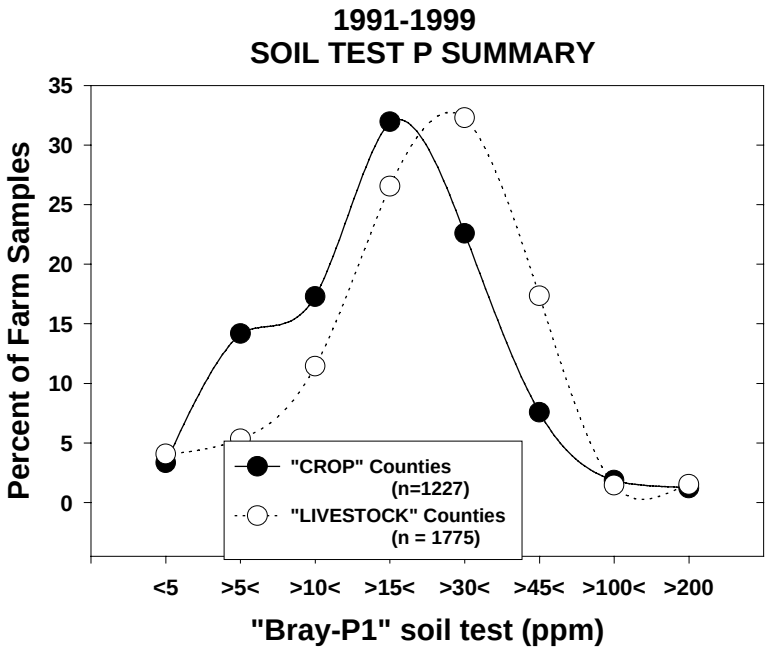

Figure 3. Trend in Bray P1 soil test values for "crop" and "livestock" counties listed in Table 2.

SOIL P RUNOFF RISK FACTORS

INTRODUCTION

Phosphorus (P) loss from agricultural landscapes is a principal cause of surface water eutrophication. Phosphorus contamination of water as the result of soil erosion and runoff is related not only to the volume of runoff and mass of sediment loss but also the complex chemistry associated with P resident in soil systems. Although soil erosion rate can be predicted with various models (e.g. RUSLE), these soil loss prediction models only predict the rate of soil movement off a particular watershed but not sediment or P delivery to a particular water body. The total sediment yield from erosion to a surface water body is usually only a fraction of soil eroded from a slope.

Assessment of the risk of surface water P contamination from any particular landmass must take into account a complex of site factors. These include potential runoff volume and sediment load (a function of erosive rain distribution, crop and land management, soil type, slope and slope length) as well as soil-P level, P management, proximity of the field to surface water bodies and presence of riparian buffer strips.

RUNOFF RISK FACTORS

Runoff and erosion potential. Water has four main pathways once it reaches the soil: infiltration, evaporation, transpiration through the plant or runoff. Water erosion is due to the dispersive action and transporting power of water *as it occurs as runoff.* Without runoff there will be no erosion. The distribution of erosive (high energy and intensity) rainfall events will vary in any given region of the country and soil erosion is very poorly correlated with total rainfall. It is highly correlated, however, with the energy and intensity (in./hr) of rainfall. Surface soil conditions that improve water infiltration and/or reduce rainfall energy (such as residue or plant cover) will decrease the risk of erosion. Therefore crop and tillage practices that are designed to provide cover during maximum erosive rainfall periods can significantly reduce the risk of P runoff. Permanent structures such as terraces and grass strips that reduce slope length and accumulation of runoff are extremely effective means for reducing P loading risk. Maintenance of vegetated buffer strips in riparian zones can reduce P loading to surface water by more than 90%.

Bioavailable P. Phosphorus losses are generally associated with two fractions, soluble-P (that which is dissolved in runoff) and particulant-P (that which is bound to sediment). The major portion of P transport to water bodies from cultivated agricultural land is usually particulant-P. Watersheds that are forested or grass covered deliver very little sediment and P loading is dominated by soluble-P in runoff. Where soluble-P is readily available aquatic plant life, the bioavailability of particulant-P will depend on particle size, P adsorption capacity and organic P content of eroded sediment.

Soil-P tests that are used for assessing plant availability (e.g. Bray P-1) have been shown to be correlated with measured particulant-P (sediment) and to a lesser extent to soluble-P (runoff) losses. To date, these agronomic P tests have been conveniently adopted to provide indices of bioavailable P although more sensitive “environmental P tests” are available. A key thing to remember is that P runoff and erosion losses are associated with the P in the extreme surface of the soil and that soil sampling strategies for assessing plant available P (0-8 inch sampling depth) are less effective in predicting P runoff risk than shallower (<1") sampling schemes.

P management. Maintenance of adequate plant available P in soils and low P runoff risk are not incompatible goals. Crop response to P applications above a Bray-P1 level of 25 ppm has a very low probability and soil-test P levels in this range generally run a very low risk of P runoff hazard. Application of manure to soil, however, poses a significant risk since manure is usually managed as a nitrogen source. When manure is applied at agronomic N rates, soil test P levels rise quite rapidly. In addition, organic P associated with manure has greater bioavailability and solubility. Reduction of P loading can be accomplished by judicious P manure management. Surface application of manure in winter should be avoided as infiltration of snowmelt and winter precipitation is prevented resulting in greater P runoff hazard. Field rotations that limit manure application to once in three years will allow for crop removal of excess P applied in the first year. Incorporation of manure resources is essential to reduce P concentration at the soil surface. Manure application does improve soil tilth and runoff volume has been shown to be reduced where manure has improved soil structure. However, total P losses can be greater even with lower runoff and sediment losses if soil test P values become excessive.

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TRENDS IN PHOSPHORUS USE IN NEBRASKA AND USDA-ARS MANURE PHOSPHORUS RESEARCH

TRENDS IN P USE

Manure, a renewable resource, contains nutrients that are needed for plant growth. Phosphorus in manure can be utilized for crop production as a substitute for synthetic fertilizer. Phosphorus in manure can also be a source of surface or ground water contamination if not used properly. Increased P concentration can lead to eutrophication of surface waters. Management systems need to be developed to utilize manure P effec-tively without adverse effects on the environment.

Each year, about 463,000 tons P is generated in swine operations, 244,000 tons in poultry houses, 173,000 tons in beef cattle feedlots, and 140,000 tons in dairies in the U.S. In Nebraska, manure generated in cattle feedlots and swine operations can substitute for 58% of the fertilizer P purchased each year (57,700 tons fertilizer). In addition to P, manure also contains N, K, micro-nutrients and organic matter. The organic matter in manure may be more valuable than nutrients it contains when manure is applied to less productive sites within a field or to degraded soils.

In Nebraska, purchase of P fertilizer peaked in 1992 and 1993 at about 30,000 tons/yr but declined to about 10,000 tons in 1997. In Cuming county where about 450,000 cattle are placed on feed each year, fertilizer P purchase declined from 900 tons in 1990 to zero in 1997 (the last yr census was available). This is an encouraging trend.

Manure marketing and brokering is becoming more common in Nebraska. Because of its nutrient and organic matter values, use of manure by crop producers is increasing. Mead Cattle Co. near Mead, NE has an active manure-brokering program. Some other feedlots are composting the generated manure and sell the composted materials to crop producers in their area. Carbon sequestration in the soil is becoming a global issue related to climate change. Manure contains significant amount of C that can be used in low organic matter or degraded soils to increase soil C level.

USDA-ARS MANURE POSPHORUS RESEARCH

Investigators: Bahman Eghball, John Gilley, Brian Wienhold, Jim Schepers, John Doran, Dennis Francis, Julie Pschold, Christopher Bauer

<u>PHOSPHORUS and N-based manure and compost application: Corn production, soil P accumulation.</u> Manure or compost applicat-ion based on N needs of corn may result in soil accumulation of P, other ions, and salt since the manure or compost N:P ratio is usually smaller than the corn N:P uptake ratio. This study was initiated in 1992 to evaluate effects of P and N-based manure and compost application on corn yield, N and P uptake, soil P level, and weed bio-mass. Composted and non-composted beef cattle feedlot manure were applied to supply N or P needs of corn for either a one or two-yr period from 1992 to 1996. Residual values of manure and compost have been determined from 1997 to present. Phosphorus-based manure or compost treat-ments also received additional fertilizer N as needed. Fertilized and unfertilized checks were also included. Manure or compost application increased corn grain yield in all 4 yr as compared to the unfertilized check. Annual or biennial manure or compost application resulted in corn grain yields

similar to those of the fertilizer treatment. Phosphorus-based manure or compost application resulted in similar grain yields to those for N-based treatments but had significantly less soil available P level after 4 yr of application. Estimated N availability was 40% for manure and 15% for compost in the first yr and was 18% for manure and 8% for compost in the second yr after application. Weed biomass was more influenced by nutrient availability than any weed seeds introduced by manure or com-post application. Manure and compost had residual values that lasted for several years.

LIMING effects. Manure and composted manure contained about 9 g $CaCO_3$ kg^{-1} resulting in application rates of up to 1730 kg $CaCO_3$ ha^{-1} in 4 years. The surface soil (0-150 mm) pH was significantly decreased with ammonium nitrate application com-pared to soil in the unfertilized check or to soil receiving manure or compost. Soil pH was significantly increased with the N-based management strategy compared with the soil original level. In contrast, 4 yr of P-based manure and compost application strategy maintained soil pH near the original level. Beef cattle feedlot manure and compost can be good sources of $CaCO_3$ for soils requiring lime addition.

PHOSPHORUS availability. In this and another (manure and compost/tillage) study, first-year P availability was 82% from beef cattle feedlot manure and 71% from com-posted feedlot manure. Phosphorus in swine manure is expected to be more plant available than beef cattle manure since a greater portion of the swine manure P is water-soluble. For practical purposes, P in swine manure can be assumed to be 100% plant available.

HIGHLY available P corn. Highly available phosphorus (HAP) corn contains a gene that changes the P form in the grain from an organic to an inorganic form. Inorganic P is more bioavailable to monogastric animals such as swine. Use of HAP corn as feed for swine has the potential to reduce the P content of manure generated by these animals. We compared crop utilization of N and P for HAP manure to that from swine fed a traditional corn diet and that as in-organic fertilizer in 1999. We also collected runoff samples at one site to assess the potential of HAP manure in reducing runoff losses of P from manured fields. Utilization of N was similar among fertility treatments and utilization of P appeared to be related to application rate when surface-applied to a no-tillage field. Dissolved P losses were lowest from HAP plots. First-year results suggest that manure from swine fed a HAP corn diet is a good N and P source and has potential for reducing environmental contamination associated with runoff from manured fields.

P LEACHING. A long-term experiment was established in 1953 in Mitchell, NE, and included manure (12 tons ac^{-1} yr^{-1}) and no manure sections to which fertilizer treatments of 0, 40, 80, 120, 160 lb N ac^{-1}, and 120 lb N ac^{-1} + 70 lb P ac^{-1} were applied annually and continuous corn was grown under irrigation. Soil samples were collected to a depth of 1.8 m in 1993 from 7 depth increments and analyzed for plant available P and P adsorption characteristics. Available P concentrations to a soil depth of 1.8 m were greater with manure application than without manure. In the no manure plots, little fertilizer P moved beneath 1.1 m soil depth, the maximal depth of the high P adsorbing calcium carbonate layer in this soil. At about similar P loading rates, P from manure application moved deeper in the soil than P from inorganic fertilizer. Possible explanations are that phosphorus from manure moved in organic forms, or chemical reactions of P occurred with compounds in manure, which may have enhanced P solubility.

P RUNOFF losses. We determined the effects of two rainfall simulation on runoff losses of P and N following a single application of manure and compost to a Sharpsburg soil having grain sorghum and winter wheat residues in 1996 and 1997. Manure and compost were applied to no-till fields at rates required to meet N or P requirements for corn production and were either left on the soil surface or disked to 8 cm. Additional experimental treatments in-cluded fertilizer application and an untreated check. Runoff concentrations of dissolved P (DP), bioavailable P (BAP), and NH_4-N in runoff were significantly greater when the soil was not disked. However, Total and particulate P were less for no-till than disked treatment. In the disked system, N or P-based manure or compost application re-sulted in DP concentration < 1 ppm (the critical concentration). Under no-till, runoff DP concentration was > 1 ppm for the N-based application, but was < 1 ppm for the P-based treatments. Total and particulate P concentrations in runoff were generally less under wheat than sorghum residue

Another rainfall simulation experiment was conducted in 1997 to evaluate the effects of narrow switchgrass hedges (~ 3 feet wide) on the transport of P and N from a field receiving beef cattle feedlot manure and fertilizer under tilled and no-till conditions. This study was conducted on a steep (12 % average slope) Monona silt loam soil near Treynor, Iowa. A rainfall simulator was used and runoff was collected from both the initial and the following wet simulations. Only 38% of the no-till plots and 63% of disked plots had any runoff during the initial 6.4 cm hr^{-1} water application. A single narrow grass hedge reduced runoff concen-trations of DP by 47%, BAP by 48%, particulate P (PP) by 38%, total P (TP) by 40%, and NH_4-N by 60% during the wet simulation on the no-till plots receiving manure, compared with similar plots with no hedges. The corresponding reductions in concentrations as a result of a grass hedge for DP, BAP, PP, TP, and NH_4-N on the disked plots were 21, 29, 43, 38, and 52%, respectively. The TP loss was 3.3% of applied P fertilizer and was 0.3% of applied manure P. Narrow grass hedges were effec-tive in reducing P and N losses in runoff from both manure or fertilizer application.

PHOSPHORUS index. Phosphorus risk assessment index was developed to identify sites vulnerable to P runoff loss. Runoff P loss data obtained from the above three field runoff experiments were used to evaluate the P index. Measured soil erosion accounted for 78% of the variability in total P loss. Total P loss was not significantly related (R^2 = 0.12) to soil erosion when annual erosion was estimated using the revised universal soil loss equation (RUSLE). Dissolved P loss was unrelated to experimentally mea-sured soil erosion but was significantly influenced by runoff amount. There was a significant correlation between total P loss and rankings based on a modified index using measured erosion (r = 0.74). The r-value between total P loss and index rankings based on Lemunyon and Gilbert's original suggestions was 0.52. Loss of dissolved P was not correlated with the index rankings. Erosion is the principal fac-tor influencing total P loss while runoff and soil P level are the primary factors affecting the transport of dissolved P loss. If erosion and runoff are accurately predicted, the P index can serve as a useful tool for iden-tifying sites where transport of P to surface water can be a potential concern.

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ASSESSING AND MANAGING PHOSPHORUS LOSS

BACKGROUND

Degradation of surface water quality from (P) in runoff and sediment is an increasing water quality concern and has been identified as one of the leading pollutants in the nations rivers, streams, lakes, and estuaries. P loss is not dependent on one factor such a P soil test values, therefore a tool such as the P-index that takes into account all factors that impact P loss and seems to be a practical approach to assess P loss and make decisions about manure application practices.

The P-index is a planning tool used to assess the relative potential of phosphorus (P) movement into surface water from one site versus another. Best management practices (BMPs) that reduce the risk of P loss can be identified and credited in the P-index.

When individual factors that impact P loss are analyzed, it is apparent that factors such as erosion and soil P test impact P loss disproportionately. Minimizing nutrient losses from manure by properly managing rate timing and method of application, and by reducing runoff and erosion is also important to maximize nutrients available for crops.

TRANSPORT

Phosphorus is transported from manure application sites by runoff and erosion. Most P is lost from a site is the result of erosion. However, when P soil test levels increase, the amount of water-soluble P in runoff water increases.

FACTORS IMPACTING P LOSS

Site characteristics/factors impacting P loss have been placed in categories and assigned a weight factor based on relative impact on P movement from the site. Categories include: erosion, runoff, soil P test levels, commercial fertilizer and organic P application rate and method, and distance to concentrated surface water runoff. Each category's weight factor is multiplied by its risk value to get a weighted risk factor for each category. All categories are rated and the overall risk rating for the site is the sum of all values (refer to Table 1).

INTERPRETING RESULTS

After multiplying the weighting factor by the risk factor for each category and totaling all values in Table 1, the sites risk rating is determined using Table 2.

Table 2 Site/Field Risk for P Loss

Total of Weighted Values	Site Risk	Site Number
<11	LOW	
11-21	***MEDIUM***	***EX***
22-43	HIGH	
>43	VERY HIGH	

Table 1. Phosphorus Index Factors (risk of P loss from the site)

P Loss Category	None (0)	Low (1)	Medium (2)	High (4)	Very High (8)	Risk Value (0, 1, 2, 4, 8)			Weight Factor	Weighted Risk Factor		
Manure application Site/Field	----	----	----	----	----	***E X***			----			
Soil Erosion	N/A	<5 tons/ac/yr	5-10 tons/ac/yr	10-15 tons/ac/yr	>15 tons/ac/yr	***2***			X 1.5	***3***		
Furrow Irrigation Erosion	N/A	Tailwater recovery, QS <6 very erodible soils, or QS <10 other soils	QS >10 for erosion resistant soils	QS >10 for erodible soils	QS >6 for very erodible soils	**---**			X 1.5	**---**		
Sprinkler Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff	Medium spray on silty soils 3-15% slopes, large sprays on silty soils >15% slope	Low spray on silty soils >15% slope, medium spray on clay soils 3-8% slopes, large spray clay soils >15% slope	Medium spray on clay soils 8-15% slope	Low spray on clay soils >15% slope	**---**			X 0.5	**---**		
Runoff Class	Negligible	Very Low or Low	Medium	High	Very High	***4***			X 0.5	***2***		
Bray P1 Soil P Test or Olson Soil P Test	---	<30 ppm <20 ppm	30-60 ppm 20-40 ppm	60-120 ppm 40-80 ppm	>120 ppm >80 ppm	***1***			X 1.0	***1***		
Commercial P fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches	Incorporated < 3 months prior to planting or surface applied during the growing season	Incorporated >3 months before crop or surface applied <3 months before crop	Surface applied >3 months before crop	**---**			X 0.5	**---**		
Commercial P fertilizer Application Rate	None Applied	<30 P_2O_5 lbs/ac	31-90 P_2O_5 lbs/ac	91-150 P_2O_5 lbs/ac	>150 P_2O_5 lbs/ac	**---**			X 0.75	**---**		
Organic P Source Application Method	None Applied	Injected Deeper Than 2 inches	Incorporated < 3 months prior to planting or surface applied during the growing season	Incorporated >3 months before crop or surface applied <3 months before planting	Surface applied to pasture or >3 months before crop	***4***			X 1.0	***4***		
Organic P application Rate	None Applied	<30 P_2O_5 lbs/ac	31-90 P_2O_5 lbs/ac	91-150 P_2O_5 lbs/ac	>150 P_2O_5 lbs/ac	***2***			X 1.0	***2***		
Distance to concentrated surface water runoff	----	>500 feet or functioning grassed waterways	200-500 feet	<200 feet	0 feet (occurs on-site)	***2***			X 1.0	***2***		
Site/Field Total	----	----	----	----	----				----	***14***		

SITE RISK & BMP GUIDELINES

LOW – This site has a LOW potential for P movement from the site. If farming practices are maintained at the current level there should be a low probability of an adverse impact to surface water resources.

MEDIUM – This site has a MEDIUM potential for P movement from the site. There is a greater probability for an adverse impact to surface water resources than from a LOW rated site. Some remedial action such as using P management measures (i.e. filter strips, grassed waterways, application setbacks, injection or incorporation) should be taken to lessen the probability of P movement.

HIGH – This site has a HIGH potential for P movement from the site. There is a higher probability of an adverse impact to surface water than MEDIUM sites unless remedial action is taken. Soil and water conservation, as well as P management measures (i.e. P based manure application rates) should be taken to reduce the risk of P movement and probable water quality degradation.
VERY HIGH – This site has a VERY HIGH potential for P movement from the site. There is a very high probability for an adverse impact to surface water. Remedial action should be taken to reduce the risk of P movement. Soil and water conservation practices and a phosphorus management plan are needed to reduce the potential of water quality degradation.

BMPs - Best management practices utilized to reduce P loss can vary from one site to the next. Site categories that have the highest weighted risk rating are the most critical factors impacting P loss. BMPs that reduce the risk rating of these factors are the <u>most effective</u>.

BMPs can include: manure application setbacks from areas where runoff concentrates or next to streams; application method (injection and incorporation versus broadcast); timing (growing season, spring and split applications versus fall or applications on frozen/snow covered ground); and <u>soil and water conservation practices</u> such as; residue management, terraces, contouring, grassed waterways, filter strips, etc.

ADDITIONAL CONSIDERATIONS

Sites that frequently flood (more than once in two years) should be avoided as manure application sites. Most P loss occurs shortly after manure application when runoff occurs due to heavy rainfall. Phosphorus loss is significantly reduced if adequate time passes before runoff occurs. Grassed waterways are effective at removing sediment-borne P in concentrated surface water flow and filter strips are effective in reducing sediment-borne P in non-concentrated surface water flow.

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COMPREHENSIVE NUTRIENT MANAGEMENT PLANNING FOR NEBRASKA

Comprehensive nutrient management planning (CNMP) in Nebraska is in the formation stage. We are developing a common planning instrument that will provide growers and livestock producers the tools to develop a CNMP plan. Our goal is to provide a tool that will fulfill the regulatory requirements and serve as a useful guide for making management decisions.

The specific requirements for what is included in an acceptable plan has evolved over time and the requirements are expected to change in the future. In Nebraska, Title 130 contains the appropriate regulations. They are designed to follow state law and be consistent with federal standards. The most recent federal guidelines were published last year as the USDA/EPA Unified National Strategy for Animal Feeding Operations. The complete document is available on the Web at:

http://www.epa.gov/owm/finalfost.htm

The strategy lists six areas that should be included in a CNMP:

1. Feed management
2. Manure and wastewater handling
3. Land application of manure
4. Site management
5. Record keeping
6. Other utilization options.

There are four areas that Title 130 covers related to permit applications:

1. Siting of facilities
2. Design of handling and storage
3. Land application and crop nutrient management
4. Odor management planning.

Land application and crop nutrient management is primarily based on nitrogen and not phosphorus. Relevant issues related to the land application part are the following:

1. Land area
2. Crop nutrient balance
3. Soil sampling for P levels
4. Implementation and documentation plan
5. Record keeping
6. Continual training

There are a number of ways the land area calculations can be figured. Different plans may be developed depending on assumptions about planned feeding rations, manure nutrient concentration when excreted, handling and storage losses, losses after application, rates of nutrient availability, and crop use efficiencies. The end result would be plans that require different land areas for the same size animal feeding operation. The prospect of well-qualified individuals producing a wide range of plans based on the same size operation is not in the best interest of all involved. In order to produce consistent plans across Nebraska the Livestock Environmental Issues Committee (a combination of university, state government and livestock industry groups) agreed to take leadership on developing a planning document that would fulfill the following objectives:

1. Include all major players in the planning process to arrive at consensus on important assumptions and process.
2. Structure the document to meet DEQ

requirements for successful permit applications.
3. Include management decision aides to increase profit.
4. Keep the document user-friendly and of manageable size.
5. Design training aides to insure successful implementation of the instrument.

A strategic planning committee met in June 1999 and agreed on a draft structure. A draft was written and reviewed in January 2000. At this point we are working on a revised draft. Below is an outline of the present draft:

INVENTORY

The inventory organizes the resources of the operation and includes the following:

- Livestock inventory
- Manure storage description
- Land application site inventory
- Continuing education summary
- Community information
- Environmental risk assessment.

STRATEGIC PLAN

The resources listed in the inventory are compared. Estimates are made about how much land is needed to utilize manure produced. Specific plans are made for special circumstances. The strategic plan has the following sections:

- Land requirements
- Sludge management plan
- "Whole Farm" nutrient balance
- Emergency action plan
- Mortility Disposal plan
- Odor management plan
- Abandonment plan.

ANNUAL PLAN

Manure nutrient content, crop choice, yield potential and soil nutrient levels are used to develop specific manure application recommendations for each available field. Fields with high risk for phosphorus movement are identified and a plan is developed to determine how much manure will go on which fields for a specific cropping year. The process includes the following:

- Crop nutrient management plan
- Phosphorus index assessment
- Implementation or action plan.

DOCUMENTATION AND RECORDS

Actual manure application rates may differ from plans. In this section records are kept of actual application information. Changes in soil nutrient levels and manure concentrations are monitored. The following records are included:

- Nutrient status summary
- Off-farm manure transfer
- Manure analysis report
- Soil test reports
- Manure application field logs
- Land application site easements
- Application site maps
- Manure storage inspection reports.

PLAN MODIFICATION

Using results from the annual plan and the field experience the annual plan will be modified for the next season. The following two documents are included.

- Post season summary of actual N, P & K balance
- Review of past years' plan and modifications to next years' plan.

We are seeking funds to provide an

education program to teach the use of this planning instrument to consultants and ag advisors. While the first document will be paper-based, our goal is to provide this instrument electronically. This would simplify completing the various worksheets and forms.

The next draft will be field tested by potential users to insure ease of use. Plans produced in these field tests will be reviewed by DEQ to make sure the plans are complete and correct.

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PUBLICATIONS ADDRESSING LIVESTOCK ENVIRONMENTAL ISSUES AVAILABLE TO NEBRASKA CLIENTELE

Publications are available from sources listed at the end of the reference section. (Refer to number in parentheses)

Assessment/Environmental Planning

Livestock Systems Environmental Assessment. EC97-781-D. (1).

National Pork Producers Environmental Assurance Program. (7). This includes modules on:
- Neighbor Relations
- Odor and Emissions
- Manure Storage and Treatment
- Pollution Prevention Strategies
- Composting

Crop Nutrient Management

New Nitrogen Recommendations for Corn. NebFact 93-11. (1)

Fertilizer Suggestions for Corn NebGuide 74-174-A. (1).

Fertilizer Nitrogen Best Management Practices. NebGuide G94-1178-A. (1).

Using a Chlorophyll Meter to Improve N Management. NebGuide 93-1171-A. (1).

Guidelines of Soil Sampling. NebGuide 1000. (1).

Soils Home Study Course (1)

Procedures for Field Demonstrations of Nitrogen Management Practices. Extension Circular 126. (1).

Drinking Water Quality

Perspectives on Nitrates. Extension Circular 90-2502. $2. (1).

Testing for Drinking Water Quality, G89-907. (1)

Nitrate Nitrogen in Drinking Water. NebGuide G763. (1).

Understanding Groundwater. NebGuide G93-1128-A. (1).

Testing for Bacterial Safety of Drinking Water. NebGuide G90-989-A. (1).

Water Testing Laboratories. NebGuide G89-907. (1).

Drinking Water: Nitrate and Methemogloginemia. G98-1369. (1)

Water Quality and Requirements for Dairy Cattle. NebGuide G93-1138-A. (1).

Livestock Water Quality. NebGuide G 79-467. (1).

General

Livestock Systems Environmental Assessment. EC97-781-D. (1).

Livestock and the Environment Symposium Proceedings (for public policy makers). Columbus, December, 1997. (8).

Agricultural Waste Management Field Handbook. (4).

Livestock Waste Facilities Handbook. MWPS-18. (2).

Non-Point Source Pollution Management. NCA CEEP Tips. (3).

Environmental Quality in Pork Production. (7).

Most Commonly Asked Question About Pork Production and the Environment. (7)

Comprehensive Environmental Framework for Pork Production Operations. Recommendations of National Environmental Dialogue on Pork Production. (7).

Land application of manure

Liquid Manure Application Systems: Design, Management, and Environmental Assessment. NRAES-79. $30. (2)

Determining Crop Available Nutrients from Manure. NebGuide G97-1335-A. (1).

Estimating Manure Nutrients from Livestock and Poultry. NebGuide G97-1334-A. (1).

Liquid Manure Application Systems. NRAES-79. $20. (2).

Manure Applicator Calibration. NebGuide 95-1267-A. (1).

Environmental Considerations for Manure Application System Selection. NebGuide 95-1266A. (1).

Manure Nutrient Handbook. NCA CEEP Tips. (3).

Chemigation (Feedlot Runoff Disposal). NCA CEEP Tips. (3).

Insects

Insect Control Guide for Beef Cattle in Nebraska. Extension Circular 1510. (1).

Nebraska Management Guide for Control of Arthropod Pests of Livestock and Horses. Extension Circular 1550. (1).

Nebraska Management Guide for Control of Arthropod Pests of Poultry and Pets. Extension Circular 1551. (1).

Livestock Management

Dairy Housing and Equipment Handbook. Midwest Plan Service. MWPS-7. $20. (2).

Beef Housing and Equipment Handbook. . Midwest Plan Service. MWPS-6. $7. (2).

Sheep Housing and Equipment Handbook. Midwest Plan Service. MWPS-3. (2) .

Swine Housing and Equipment Handbook. Midwest Plan Service. MWPS-8. (2) .

Swine Farrowing Handbook: Housing and Equipment. MWPS-40. (2).

Manure storage/lagoons/treatment facilities

Abandonment Planning for Earthen Manure Storages, Holding Ponds, and Anaerobic Lagoons. NebGuide G98-1370-A. (1)

Sludge Management for Anaerobic Lagoons and Runoff Holding Ponds. NebGuide G98-1371-A. (1).

Lagoons for Management of Livestock Manure. EC96-779-C. (1).

Concrete Manure Storage Handbook. MWPS-36. (2).

On-Farm Composting Handbook. NRAES-54. (2).
Composting Manure and Other Organic Residues. Neb Guide G97-1315-A (1)

Milking Center Effluent

Dairy Housing and Equipment Handbook. MWPS-7. (2).
Milking Center Design conference proceedings. NRAES-66. (2).

Odor Control

Managing Livestock Odors: Principles, Farm Assessment and Planning. Extension Circular 95-745-B. (1).
Odor Controls as Affected by Nuisance Laws. NebGuide 368. (1).
New Knowledge in Livestock Odor. International Livestock Odor Conference '95. (5).
A Review of the Literature on the Nature and Control of Odors from Pork Production Facilities. $15. (6).
Sprinkling Oil to Reduce Dust, Gases, and Odors in Swine Buildings. MWPS AED42. (2).

Open lots and feedyards

Feedlot Manure Management 2000 Conference Proceedings. 1998. $10. (8)
Manure Management for Open Lot Livestock Production. (4).
Feedlot Abandonment. NebGuide. NebGuide G96-1293-A. (1).
Mound Design for Feedlots. NebGuide G73-66. (1).
Locating a New Feedlot. NebGuide G73-65. (1).
Beef Housing and Equipment Handbook. MWPS-6. (2).
Feedlot Runoff. NCA CEEP Tips. (3).
Feedlot Biological Sealing and Runoff Regulations. NCA CEEP Tips. (3).

Regulations

Title 130-Rules and Regulations Pertaining to Livestock Waste Control. (9) and (12).
Title 119-Rules and Regulations Pertaining to the Issuance of Permits Under the National Pollutant Discharge Elimination System. (9).
Guide Manual on NPDES Regulations for Concentrated Animal Feeding Operations, EPA 833-B-95-001. (11).
Guidance for Construction and Approval of Livestock Waste Control Facilities. WP-40. (9).
Application for Permit to Construct and Operate a Livestock Waste Control Facility: Open Lot Feeding. WP-41. (9).
Application for Permit to Construct and Operate a Livestock Waste Control Facility: Confined Feeding or Dairy Barn. WP-42. (9).

Web Sites

UNL Manure Matters Web Site and Newsletter
http://www.ianr.unl.edu/manure

Subscription to newly published newsletters (e-mail announcement of newsletter and web address). To subscribe:

1. Send e-mail to:
   listserv@unl.edu
2. In the message field type:
   subscribe manurematters

UNL Neb Guides Web Site
http://www.ianr.unl.edu/pubs/wastemgt/

NRCS Ag. Waste Management Handbook:
http://www.ncg.nrcs.usda.gov/awmfh.html

Odor Technologies… Iowa State University
http://www.ae.iastate.edu/odor.htm

Ag Waste Treatment Technologies…NC State Univ.
http://www.cals.ncsu.edu/waste_mgt/te.html

Manure Education and Research… Univ. of Minnesota
http://www.bae.umn.edu/extens/manure/

Publications available from...

1. Your local extension office or IANR Communications and Computing Services, 105 Ag Communications Building, University of Nebraska-Lincoln East Campus, Lincoln, Nebraska 68583-0918, (402) 472-7912 or http://www.ianr.unl.edu/pubs.
2. MWPS publications are available through your local extension office or Agricultural Engineering Plan Service, 219A LW Chase Hall, University of Nebraska-Lincoln, Lincoln, Nebraska 68583-0727 (402) 472-1646.
3. Nebraska Cattlemen, 521 South 14th Street, Suite 101, Lincoln, Nebraska 68508, (402) 475-2333.
4. USDA NRCS. Room 152 Federal Bldg., 100 Centennial Mall N., Lincoln, NE 68508
5. Iowa State University, College of Agriculture, 304 Curtiss Hall, Ames, IA 50011.
6. National Pork Producers Council, Ordering Department, P. O. Box 10383, Des Moines, IA 50306.
7. Nebraska Pork Producers, Animal Science Building, University of Nebraska, Lincoln, NE 68583-0834.
8. Rick Koelsch, 218 L. W. Chase Hall, , University of Nebraska, Lincoln, Nebraska 68583-0726 (402) 472-4051.
9. Department of Environmental Quality, Permits and Compliance Section, Suite 400, The Atrium, 1200 N Street, P. O. Box 98922, Lincoln, NE 68509-8922.
10. National Center of Agricultural Law Research and Information, 147 Waterman Hall, University of Arkansas, Fayetteville, AR 72701.
11. US EPA, Office of Water, 4203, Washington, DC 20460
12. Manure Matters Website Resources...**http://www.ianr.unl.edu/manure**