5-178

CONSERVATION INNOVATION GRANTS
Final Progress Report

Grantee Name: Washington State University	
Project Title: Development and Integration of a National Feed Management Education Program and Assessment Tools into a Comprehensive Nutrient Management Plan (CNMP)	
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Period Covered by Report: September 2005 thru December 2008	
Project End Date: 9 08	

Summarize the work performed during the project period covered by this report:

Project Objectives - The three primary project objectives identified were:

1) **Develop a two-tier tool for assessing the impacts of feed management practices on whole farm nutrient balance for a) animal nutritionists and b) NRCS staff and TSP advisors,**

2) **Develop the content of a Feed Management chapter for the NRCS Agricultural Waste Management Field Handbook (AWMFH), and**

3) **Develop and implement an education program targeting integration of feed management into a CNMP.**

Proposed Specific Outcomes were:

1) **Develop educational materials that are applicable at the national level**

2) **Provide training for NRCS staff, agricultural professionals, and technical service providers (TSPs) in feed management concepts and practices that minimize import of nutrients to the farm, and**

3) **Provide training in the use of computer models and software for strategic ration balancing, whole farm nutrient balance, and nutrient excretion estimates based upon feed and animal performance inputs, and**

4) **Develop a chapter for the NRCS Agricultural Waste Management Field Handbook (AWMFH) on Feed Management.**

Describe significant results, accomplishments, and lessons learned. Compare actual accomplishments to the project goals in your proposal:

Outcomes 1, 2, and 3 - Education materials to assist with the understanding of CPS 592 Feed Management, feed management plan development and implementation tools, and a decision aid tool were developed (Feed Nutrient Management Economics software – FNMP$).

Workshops have been conducted in the states of Washington, California, Texas, Maryland, Nebraska, Pennsylvania, and Wisconsin. Collaborating states with these trainings included: Idaho, Oregon, Virginia, Indiana, Iowa, and Minnesota.

In addition, the national CNMP training program led by Iowa State has incorporated our Feed Management project material into their curriculum.

Approximately 70 individuals have become certified thru the American Registry of Professional Animal Scientists organization to be feed management planners.

All outreach materials can be found at:

http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp

http://www.puyallup.wsu.edu/dairy/nutrient-management/software.asp

Outcome 4 – A final draft of the AWFMH for Feed Management accompanies this report.

Describe the work that you anticipate completing in the next six-month period:

While the funding for this project has ended, the interest and implementation activities are continuing. Training workshops are scheduled in 2009 for the states of California, Pennsylvania, and Maryland. The project team is available to work with individual states with adoption of CPS 592 Feed Management. In addition, the American Registry of Professional Animal Scientists continues to provide the exam process for certifying that a nutritionist is qualified to develop a nutrient management plan.

A major emphasis will be placed on completing the poultry, swine, and beef materials. The Feed Management chapter for the AWFMH will be complet by September 2008. In addition, we are converting a decision aid tool called Feed Management Nutrient Planning Economics (FNMP$) from Excel to an Access data base format. Efforts to provide training for nutritionists and TSPs will continue.

In the space below, provide the following in accordance with the Environmental Quality Incentives Program (EQIP) and CIG grant agreement provisions:

a. A listing of EQIP-eligible producers involved in the project, identified by name and social security number or taxpayer identification number;

b. The dollar amount of any direct or indirect payment made to each individual producer or entity for any structural, vegetative, or management practices. Both biennial and cumulative payment amounts must be submitted.

c. A self-certification statement indicating that each individual or entity receiving a direct or indirect payment for any structural, vegetative, or management practice through this grant is in compliance with the adjusted gross income (AGI) and highly-erodible lands and wetlands conservation (HEL/WC) compliance provisions of the Farm Bill.

Not applicable

Nutrient Tracking through Animal Diets and Feed Management
Primary authorship – Al Sutton, Purdue University

INTRODUCTION

Purpose and Scope

Feed management is managing the quantity of nutrients fed to livestock and poultry for their intended purpose. This involves development of diets that supply the quantity of available nutrients required by livestock and poultry for maintenance, production, performance, and reproduction. Supplying nutrients in excess of an animal's requirement results in additional nutrients being excreted. In many circumstances confined livestock and poultry operations find themselves under a whole farm nutrient imbalance. In this scenario, there are more nutrients being imported on the farm than is being exported from the farm or utilized by current cropping rotations. As a result, soil saturation with various nutrients, especially phosphorus (P), or excess losses of nitrogen (N) can have a deleterious impact on the environment through runoff, soil erosion and leaching. Phosphorus losses from soil emptying into surrounding fresh water bodies can lead to eutrophication (Carpenter et al., 1998; Correll, 1999; Sharpley et al., 1994). Nitrate leaching from soil into drinking waters can lead to fatalities in humans (Cameron et al., 1996) and livestock (Rasby et al., 1988). Anaerobic degradation of manure or other organic matter sources (animal mortality, spoiled feed) from the operation can cause air quality pollution from the emission of ammonia and other nitrogenous compounds, sulfurous compounds, volatile organic compounds that often are odorous, and can cause green house and acid rain effects.

The NRCS Conservation Practice Standard (CPS) (Code 592) (Feed Management) was developed with the purpose of supplying the quantity of available nutrients required by livestock and poultry for maintenance, production, performance and reproduction; while reducing the quantity of nutrients, especially N and P, excreted in manure by minimizing the over-feeding of these and other nutrients. As a result of fulfilling this purpose, the livestock and poultry operations can improve the whole farm nutrient balance and minimize the threat of nutrients from manure impacting water and air quality. In addition, using proper feed management practices may improve net farm income by feeding nutrients more efficiently. The aim of this chapter is to outline various aspects of animal nutrition, feed formulation and feed management practices to enhance nutrient efficiency, reduce nutrient excretion and potentially improve net income from livestock and poultry farms. This chapter will present general background information about animal nutrition and feed management practices plus outline the development of a feed management plan (FMP) to meet CPS 592. For further detailed information on specific subject matter, consult the fact sheets at the following websites http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.nrcs.usda.gov/technical/standards/nhcp.html; http://www.extension.org/animal+manure+manageemnt; http://www.fass.org/page.asp?pageID=131 and the resource list at the end of the chapter.

Definitions of Nutrition and Feed Management Terms

Nutrition terms

1. Nutrient – any chemical element or compound in the diet that supports reproduction, growth, lactation or maintenance of life processes.
2. Six classes of nutrients – water, proteins and amino acids, carbohydrates, lipids, vitamins, and minerals. These nutrients support cellular needs for water, fuel, structural constituents (skin, muscle, bone, nerves, fat), and metabolic regulation.
3. Enzyme – an organic catalyst. It speeds or slows a chemical reaction without being used up in the reaction.
4. Essential nutrients – nutrients that are required in the diet because they cannot be synthesized within the body in sufficient amounts to satisfy metabolic needs.
5. Feedstuff – any material made into or used as feed.
6. Diet – a mixture of feedstuffs used to supply nutrients to an animal.
7. Ration – a daily supply of feed.
8. Macrominerals – essential mineral that are required in relatively large amounts (i.e. Calcium, Phosphorus, Magnesium, Sodium, Potassium).
9. Microminerals/trace elements – essential minerals that are required in smaller quantities (i.e. Zinc, Iodine, Selenium, Copper, Iron, Manganese).
10. Apparent digestibility – the percentage of a feed nutrient that is digested and absorbed from the gastrointestinal tract, as indicated by nutrient intake minus fecal nutrient output.
11. Rumen – the largest of the four stomach compartments in the adult ruminant. The site of active microbial digestion.
12. Ruminant – an animal with a functional rumen compartment in the stomach plus three other compartments. A cud-chewing animal.
13. Non-ruminant- an animal that has a simple stomach.
14. Roughage – A feed low in digestible energy and high in fiber.

Feed management terms

1. Dry matter (DM) – the portion of a sample remaining after water has been removed.
2. Crude protein (CP) – the content of nitrogen in a sample multiplied by the factor 6.25 to provide an estimate of the protein content of a sample.
3. Ether extract (EE) – composed of fats and fatty acid esters.
4. Ash – residual minerals remaining after all combustible material has been burned off in a furnace.
5. Crude fiber (CF) – structural carbohydrates of plants (i.e. hemicellulose, cellulose, and lignin)

Units of Measure

Example 1. Dry matter (DM) and Ash

Initial sample weight = 100 g
Sample weight after drying (100°C) = 50 g
Sample weight after furnace ashing (600 °C) = 10 g
% DM = 50%
% Ash = 10%
(Sample weight after drying/initial sample weight) x 100 = % DM

(Sample weight after furnace ashing/initial sample weight) x 100 = % Ash

Example 2. Crude protein (CP)

Protein consists of 16% nitrogen (N); therefore 6.25 times the amount of nitrogen in the sample would equal the total amount or 100% of the protein in the sample.

Weight of sample = 100 g
Amount of N in sample = 3000 mg/kg
% CP = 18.75%

[(amount of N in sample x 6.25)/weight of sample] x 100 = % CP

Example 3. Apparent digestibility

Nutrient intake (NI) = 20 g
Fecal nutrient output (NO) = 5 g
Apparent digestibility (%) = 75%

[(NI – NO)/NI] x 100 = Apparent digestibility (%)

Nutrient Flow on Livestock Farms

Within a whole farm context, nutrients can be recycled through manure nutrients and utilized as a fertilizer resource through crops that can be consumed by animals for the production of meat, milk and eggs (Figure 1). However, depending upon the crop rotation and land available for crop production, there may be a significant imbalance of nutrients. If the total import of nutrients (i.e. animals, purchased feed, commercial fertilizer, legume N, irrigation water nutrients) are greater than the managed export of nutrients in the form of animals sold (meat), milk and eggs, plus crops sold off-farm and manure transported off-farm, then there will be a nutrient imbalance with an accumulation in the soil or losses of nutrients off-farm through runoff, leaching and gaseous losses. Gaseous losses are difficult to control and estimate therefore, these nutrient losses will be difficult to include in nutrient balances. Whole farm nutrient balance (WFNB) on a farm that can be estimated is determined with the equation:

Nutrient balance = nutrient inputs – managed nutrient exports

In all livestock and poultry operations, much of the purchased nutrients imported on the farm is as feed. Depending upon the numbers of animals grown, the land base and crop production of the operation, import of feed N (as crude protein in the diet) and P is generally much greater than other nutrient import sources (i.e. commercial fertilizer, legume N, irrigation water nutrients). Therefore, development of a FMP is critical to reduce excess excretion of nutrients, and to provide a WFNB that will not result in a significant accumulation and losses of nutrients from the operation to the environment. Figure 2 shows another example of the flow of N on a dairy operation in a whole farm context.

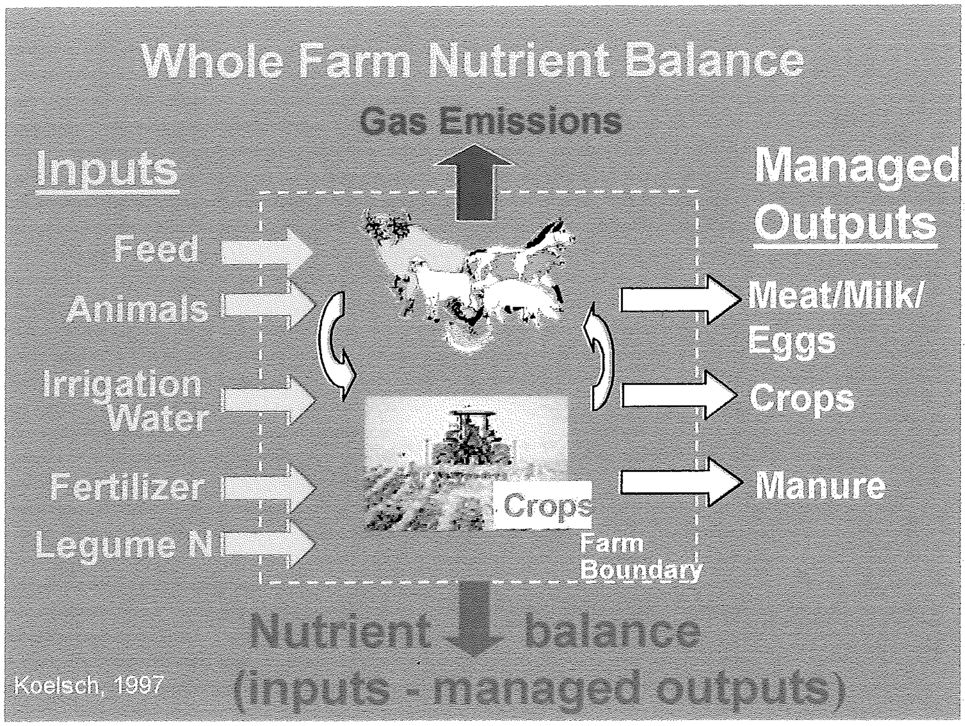

Figure 1. Whole Farm Nutrient Balance based on nutrient inputs minus managed outputs (adapted from Koelsch and Lesoing (1999)).

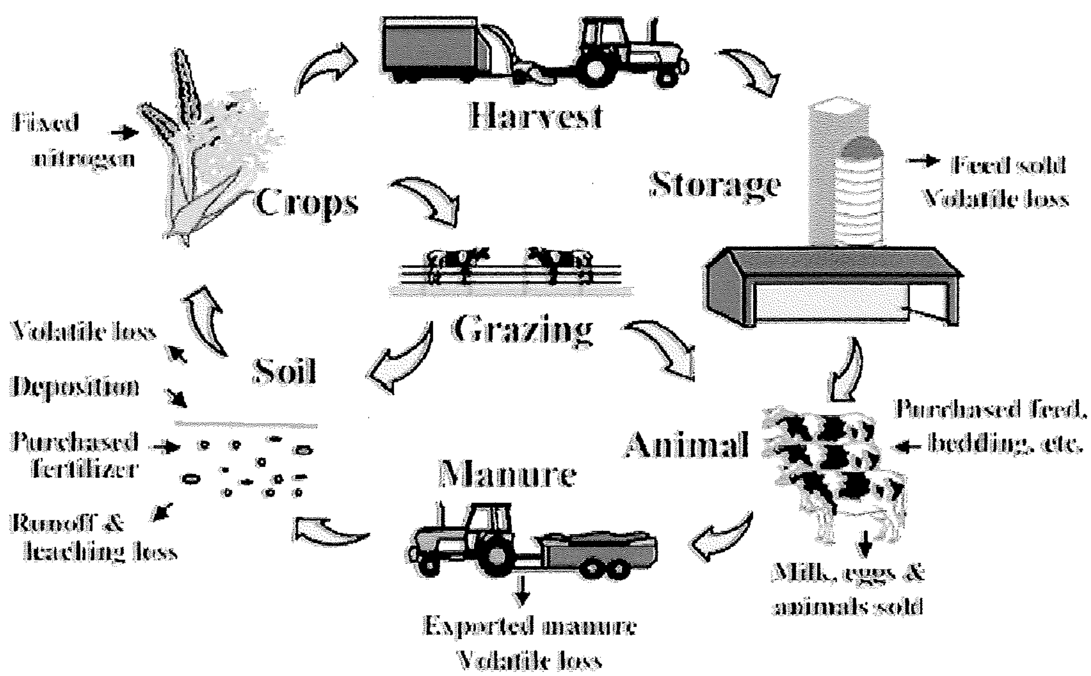

Figure 2. Major nitrogen flows in animal production within the farm and between the farm and its environment (Rotz, 2004).

Developing a Feed Management Plan

A systematic 5-step development and implementation process for the Feed Management Practice Standard is shown in Figure 3. The steps of the flow diagram were chosen to coincide with the sections of the Feed Management Practice Standard.

The first step focuses on defining the purpose(s) for considering the Feed Management Standard on a particular farm to: 1) feed to minimize excess nutrients in manure while maintaining production, performance, and reproduction, or 2) feed to improve net farm income by feeding more efficiently. Key participants at step 1 would be the producer, the nutrient management planner, and NRCS staff.

The second step of the flow diagram focuses on identifying the conditions where the practice applies and making an initial assessment of the opportunity for the full development of a FMP. The conditions where the practice applies as noted the in CPS 592 include:

1) Whole farm imbalance
2) Soil nutrient build-up
3) Land base not large enough, or
4) Seeking to enhance nutrient efficiencies.

After defining the condition(s) for use of the CPS 592, an opportunity checklist is then used to make an initial assessment of developing a complete feed management plan. The opportunity checklist can be found in a companion fact sheet entitled "Use of the Opportunity Checklist in Feed Management Plan Development". The Opportunity Checklist can be found in species specific versions for beef, dairy, poultry and swine (http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.extension.org/animal+manure+manageemnt). Key participants at step 2 would be the producer, the nutrient management planner, and NRCS staff.

The third step of the flow diagram focuses on the question of "how to reduce nutrients on manure used on the farm". This step will not be considered by all farms. Two major ways that a reduction in on-farm manure nutrients can be achieved is through feed ingredient and exporting manure off-farm. Making the decision to make a ration change vs. moving manure off-farm has major economic implications.

An electronic decision aid tool has been developed to assist with this decision. The tool is called Feed Nutrient Management Planner with Economics (http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.extension.org/animal+manure+manageemnt). Key participants at step 3 would be the producer, the nutrient management planner, and the nutritionist .

The fourth step of the flow diagram focuses on the development of the feed management plan. The key tool to assist with the writing of the plan is the FMP checklist. The FMP checklist can be found in a companion fact sheet entitled "Use of the Feed Management Plan Checklist in Feed Management Plan Development". The FMP checklist can be found in species specific versions for beef, dairy, poultry and swine (http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.extension.org/animal+manure+manageemnt).

A national FMP template has been developed and can be found in the companion fact sheet entitled "National Feed Management Plan Template" (http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.extension.org/animal+manure+manageemnt). Key participants at step 4 would be the producer and the nutritionist.

The fifth and final step of the flow diagram focuses on FMP implementation and monitoring. This step focuses on implementing those practices that will help achieve the purpose(s) that were selected at step 1. In addition, review dates are established so that the FMP will be utilized as an active management tool.

It is important that the outcomes of the feed management plan as it relates to manure volume and nutrient composition are communicated to the nutrient management planner as this may affect cropping recommendations. Key participants at step 5 would be the producer and the nutritionist.

Feed Management Development and Implementation Flow Chart

Activity	Who is Involved
Step 1) Determine the purpose specific to the farm	Step 1) Nutrient Management Planner and Producer
Step 2) Identify where practice applies and assess the opportunity for adoption of 592 standard	Step 2) Nutrient Management Planner and Producer
Step 3) Evaluate the economics of making ration change vs. transporting manure	Step 3) Nutrient Management Planner, Producer and Nutritionist
Step 4) Feed Management Plan Development	Step 4) Producer and Nutritionist
Step 5) Feed Management Plan Implementation and Monitoring	Step 5) Producer and Nutritionist

Figure 3. Five steps for development of a feed management plan for livestock and poultry operations.

Role of technical service providers (TSP)

Conservation planners, nutrient management planners and certified feed management TSP have a key role in determining if feed management practices and development of a FMP can help livestock and poultry producers reduce WFNB concerns or improve the likelihood of increasing profitability. The TSP needs to work with consulting nutritionists in the development of the FMP and help with the implementation especially if EQIP monies are available for FMP. Figure 4 shows the relationships and role of the TSP with the nutritionist in consultation with the livestock or poultry producer in the development and implementation of the plan. Opportunity check lists and feed management plan checklists for the TSP and nutritionist, respectively, are available to determine if development of a FMP is warranted and will have an impact on the WFNB of the operation.

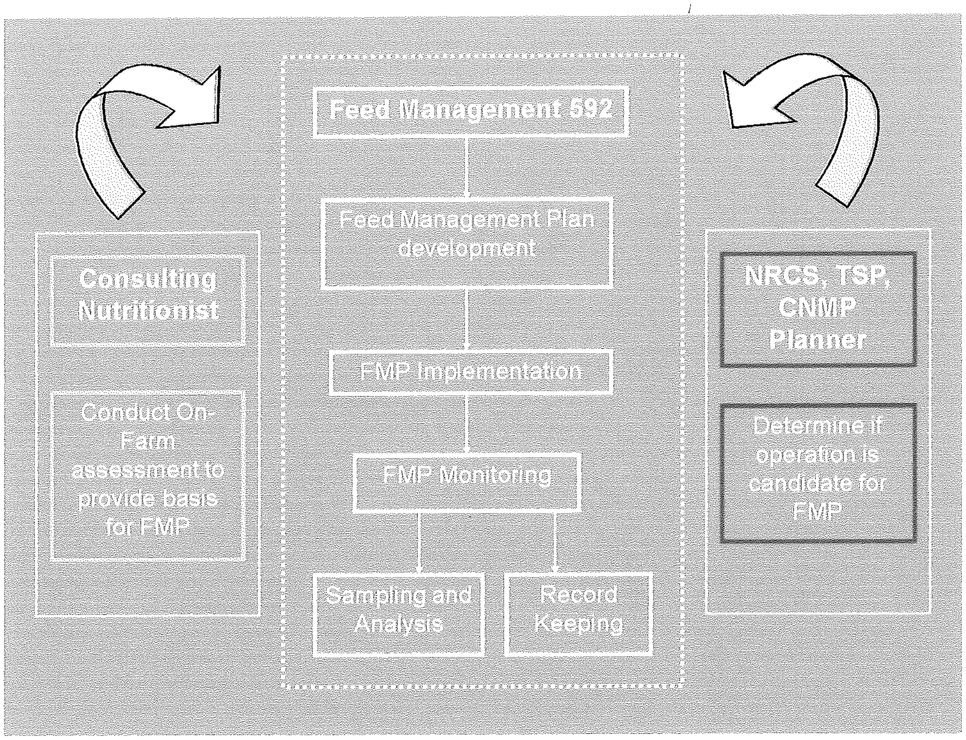

Figure 4. Role of a technical service provider and a consulting nutritionist in the development, implementation and monitoring of a feed management plan for an animal production operation. (Harrison, et al, 2007).

General Nutrition Principles

There are six classes of nutrients: proteins, carbohydrates, fats, minerals, vitamins and water. The roles of certain feed ingredients in a diet can be divided into groups according to how they function in the body. For instance, corn generally provides the greatest source of carbohydrates (for energy) and soybean meal is used primarily as a protein source. The regulatory nutrients include vitamins, water, minerals, and proteins. The structural nutrients also include water, minerals, proteins as well as fats. The nutrients that primarily supply energy are fats and carbohydrates but proteins can be used for energy also.

Protein (N)

Protein is made up of amino acids which are called the "building blocks" of muscle. Chemically, protein contains nitrogen, carbon, hydrogen, oxygen and some contain sulfur. Typically, nitrogen in protein is approximately 16% of the protein molecule therefore to convert nitrogen in feeds to a crude protein equivalent is N x 6.25. Specific levels and ratios of amino acids are required by the animal to grow, reproduce, produce milk and eggs, therefore, nutritionists try to formulate diets to contain the correct ratios and levels of the amino acids. This is especially important for pigs and poultry. For sheep, beef cattle and dairy cattle, non-protein nitrogen such as urea can be consumed and the amino acids will be created in the digestive system by microorganisms to meet the needs of the animal.

Carbohydrates (energy)

Carbohydrates comprise the largest proportion of livestock rations for providing energy and bulk in the diet. The carbohydrate fraction of plant feedstuffs comprises up to 70 and 80% of the dry matter of forages and cereal grains, respectively (Kellems and Church, 2002). Chemically, carbohydrates contain carbon, hydrogen and oxygen. Glucose, lactose, galactose, maltose, sucrose, and starch are the main components of carbohydrates that provide energy; however, the ruminant animal can create volatile fatty acids in the digestive system from specific carbohydrates that can be used for energy. These carbohydrates that are used in plant and cereals for structural purposes are cellulose, hemicelluloses and lignin.

Fats (energy)

Fats and oils provide additional energy in the diet and aids in the absorption of vitamins. Chemically, fats contain carbon, oxygen and hydrogen but they can be arranged in a triglyceride form with different length fatty acid units. The energy value of fats is 2.25 times more potent compared to carbohydrates.

Minerals (Ca, P, K, Na, Cl, Mn, Mg, Fe, Cu, Se)

Minerals are important for structural integrity, and are critical components for maintaining the ionic balance and metabolic activity of the animal. Inorganic sources of minerals are often added to diets to provide the correct level of biologically available sources of minerals and to balance levels of minerals that are in other feed ingredients in the diet.

Vitamins (A, D, E, K, B-complex)

Vitamins are provided in small quantities for animal diets to assist in metabolic activities in the animal. Certain vitamins can be synthesized in animals, however, commercial vitamin mixes are added to the diet for those not synthesized and because normal plant feed sources do not contain sufficient amounts available to the animal.

Water

Approximately one half to two thirds or the body mass for adults and up to 90% of the body mass of newborn animals is water (Pond et al., 1995). There are typically two major functions of water: 1) component in body metabolism and 2) factor in controlling body temperature. Some of the biological functions of water include aiding digest transport through the gastrointestinal tract, and solvent in blood, tissue fluids, secretions and excretions.

Access to water may occur through several different avenues. One major source of water intake is through free access to drinking water (Table 1). Poor water quality will negatively impact the animal's intake and therefore reduce animal performance. Water quality can be compromised by high levels of salts, nitrates, sulfates, fluoride, pathogenic microorganisms, algae, pesticides, dissolved solids, and industrial compounds that may be polluting the water supply (EPA, 2006; Kellems and Church, 2002; Hairston and Stribling, 1995). Secondly, water can be consumed through the water content of ingested feedstuffs. For example, an animal consuming 20 lb of corn silage per day has the potential to consume 13 to 15 lb of water per day (Kellems and Church, 2002).

Table 1. Expected water consumption of various classes and species of adult livestock in a temperate climate[a].

Animal	Liters/day
Beef cattle	22-66
Dairy cattle	38-110
Sheep and goats	4-15
Horses	30-45
Swine	11-19
Chickens	0.2-0.4
Turkeys	0.4-0.6

[a]Pond et al., 1995.

Classification of Feeds

Feeds are also classified based upon their chemical characteristics (National Research Council, NRC). For instance forages or roughages, commonly fed to cattle and sheep, have more than 18% fiber. Energy feed sources, such as cereal grains, have less than 20% protein and less than 18% fiber. Protein supplements, such as soybean meal and various byproduct sources, have greater than 20% protein and less than 18% fiber. Minerals, vitamins, and additives are specific for the nutrient you need in the diet for specific functions in the animal. Example feed ingredients for each class of feeds are shown below in Table 2..

TABLE 3–4 Classes of Feeds According to the NRC System, Their Traits and Examples		
Class	**Trait(s)**	**Examples**
1—Dry forages or roughage	> 18 percent fiber	Hay, straw, seed hulls, fodder, stover
2—Succulent forages or roughage	> 18 percent fiber	Pasture, green chop, cannery residues
3—Silages	> 18 percent fiber	Wholeplant grain crops, wilted or low-moisture grasses or legumes
4—Energy feeds	< 20 percent protein and < 18 percent fiber	Cereal grains, milling byproducts, roots and tubers, brewery byproducts
5—Protein supplements	> 20 percent protein and < 18 percent fiber	Animal byproducts (meat scraps) Marine byproducts (fish meal) Avian byproducts (hydrolized feathers) Plant byproducts (soybean meal, cottonseed meal, linseed meal, corn gluten meal)
6—Mineral supplements	Guaranteed analysis	Steamed bone meal Dicalcium phosphate Iodized salt Trace mineralized salt
7—Vitamin supplements	Guaranteed potency	Vitamin A acetate Vitamins A, D, E B-complex vitamins
8—Additives	Specific	Antibiotics (chlortetracycline, oxytetracycline, tylosin) Coloring materials Flavors Hormones Medicants

Source: Adapted from National Academy of Science publications.

Vitamins also serve important catalytic functions in plants as well as in animals, promoting nutrient formation, tissue growth, and reproduction. Their presence in the plant means that harvested plants and plant products are sources of these vital nutrients.

Table 2 – Classes of Feeds According to the NRC System, Their Traits and Examples

Digestive Processes

The initial digestive process involves the intake of feed ingredients provided to meet the maintenance, production, and reproduction requirements of the animals involved. The requirements for production are affected by stage of growth and the type of production (e.g., meat, milk, eggs) involved. How well the animal can retain nutrients for productive purposes depends upon the availability of the nutrients in the diet, absorption, metabolism and retention and ultimately, the excretion of nutrients. The quantity of nutrients excreted by animals is affected by three main factors: (1) the amount of dietary nutrients consumed, (2) the efficiency with which they are utilized and retained by the animal for growth and other functions, and (3) the amount of normal metabolic losses (endogenous). In other words, the amount of excreted nutrients can be expressed as:

Nutrients excreted = Nutrient intake - Nutrients utilized + Nutrients from endogenous sources

The primary way to reduce the amount of nutrients excreted by animals is to decrease the amount that is consumed and increase the efficiency of utilization (digestibility, absorption and retention) of the dietary nutrients for formation of the product.

The goal of efficient and productive feeding of animals, within economic and environmental constraints, is to provide essential available nutrients for maintenance and production with minimal excess amounts.

Nutrients in feeds can vary considerably and not all nutrients in feeds are available to the animal. Therefore, any means of increasing the digestibility or availability of nutrients will increase the potential for animal use and retention, and reduce the amount of the nutrients excreted. There is increasing interest today in using enzymes, genetically modified feed ingredients and feed processing technologies to enhance the availability of nutrients to meet the specific animal needs and reduce excretion of nutrients. In addition, a routine feed analysis program is imperative so diets can be formulated and periodically adjusted to meet but not exceed nutrient requirements of the animal.

Feed Management Systems

Feeding farm animals involves a series of diets with all nutrients required for maintenance, growth, reproduction and production of products (meat, eggs, and milk). While different feeding systems are utilized, the most common approach is to use diet formulation to combine exact quantities of feed ingredients into a total mixed ration (TMR) for delivery to the animals. The TMR is presented before meat-type (broiler) chickens, layer (egg-producing) chickens, turkeys, ducks and growing pigs constantly, whereas, the TMR is delivered to dairy cows and fattening cattle generally two to three times per day. Breeding herd animals are generally fed once or twice daily.

Feed Formulation

Formulation of diets involves combining various available, economical sources of feed ingredients into a ration that animals will consume, digest and utilize the nutrients to meet the nutrient needs of the animal for maintenance or productive purposes. The individual responsible for ration formation should be aware and understand the concepts of nutrition, the animal's production status, and the physical and chemical composition of various available feedstuffs. The National Research Council (NRC) has developed nutrient requirements for all species of animals which can be used as a reliable tool for ration formulation for a particular stage of production. It is also possible to obtain animal nutrient requirements from extension or university publications. These may provide modifications to nutrient requirements depending on regional differences in environment, animal or feed conditions.

Choosing feed ingredients for ration formulations may focus on developing least cost rations or the most predicted profitable ration based upon productivity. In some cases, the impact of ration formulation on nutrient excretion is not considered. However, with the development of a FMP, nutrient excretion is identified as another important consideration when formulating rations.

Maintaining the nutritional quality of feed ingredients can be difficult. Feedstuff quality can be altered by physical or genetic differences. Physical differences include the amount and type of soil nutrients available during plant growth, temperature, water supply, length of photoperiod and light intensity, cultivation practices, plant maturity at harvest, and storage. Genetic variety also plays a significant role in determining the nutrient composition and quality of a feed ingredient.

Improvements in genetic selection have allowed for novel nutrient dense plant variety development. An example of this are a nutrient enrich corn that contains approximately 30% more lysine, 50% more total sulfur-containing amino acids, 18% more threonine, and 6% more metabolizable energy than a normal corn variety. Another example is a low phytic acid corn with the benefit of containing approximately 75% available P compared to yellow dent corn at about 12% available P. Low phytic acid corn in broiler diets resulted in a 50% reduction in phytate-bound dietary P translating in a 20% reduction in fecal P excretion compared to birds fed the yellow dent corn diet. Similar genetic changes in chemical composition are also available for soybean varieties. Because of such feed ingredient variations a subsample of each ingredient should be analyzed for nutrient composition prior to diet formulation. This feed management practice allows optimization of the ration to the animal's nutrient requirements. Many states have university or commercial laboratories specializing in feed analysis. Computer software programs are available for more accurate diet formulation.

Feed Storage, Handling, and Processing

Feed ingredient quality

Feed ingredient quality (grains, forages, fat, minerals and vitamins) is a critical part of animal nutrition. Therefore good storage facilities and conditions are vital. However, the quality of the grains and forages starts with a good initial quality product at harvest. To ensure properly stored grain in bins, high moisture grains need to be dried to at least 14% moisture for long term storage and no more than 16% moisture for winter storage. Grain temperatures should not exceed 82°C or there will be some browning, evidence of decreased lysine availability, therefore, an adequate fan system for cooling is desirable in some climates. Fat should not be stored at temperatures above 60° C, with 49° C being most ideal. Antioxidants extend the time period before rancidity of the oil starts. Vitamin stability varies greatly among vitamins, depending on conditions they are exposed to and storage time. Storage of the vitamin premixes should be in a cool, dark, and dry place.
Moisture, visible and ultraviolet light, heat, and contact with certain trace minerals are the most common factors that reduce vitamin stability.

Pelleting

Pelleting of diets is an effective way to improve feed efficiency (generally 4 to 6%) for all phases of swine and poultry production (Wondra et al., 1995; Szabo, 1988). The improved feed efficiency is due to: 1) a slight reduction in feed wastage and 2) a slight improvement in digestibility of the diet because the steam heat of the pelleting process gelatinizes some of the starch, thereby increasing the susceptibility area of the diet to digestive enzyme hydrolysis. A side benefit to pelleting the diet is a 10 to 15% reduction in dry matter and N excretion caused by the reduced wastage and improved feed efficiency and digestibility. On the negative side, pelleting does increase the cost of feed.

Grinding

Fine grinding of feed is effective in improving feed utilization and decreasing dry matter, N, and P excretion. By reducing the particle size, the surface area of the grain particles is increased allowing for greater interaction with digestive enzymes. Cereal grains with hard seed coats (grain sorghum, barley, and triticale) have the greatest improvements in digestibility by processing, but even the processing of corn is of economic benefit. When particle size is reduced from 1,000 to 400 µm, dry matter and N digestibility increase by approximately 5 to 6% (Wondra et al., 1995; Hale and Thompson, 1986). As particle size is reduced from 1,200 to 600 µm, dry matter and N excretion are reduced by 20 and 24%, respectively. The recommended particle size is between 650 and 750 µm for swine and poultry. Reducing particle size further increases the energy costs of grinding and reduces the throughput of the mill below the economic returns for finer grinding as well as increasing the incidence of stomach ulcers in pigs (Healy et al., 1994). Ruminants require larger particle sizes because there is a rumen stimulation factor required to provide good health of the rumen. The particle size can vary depending upon the source or type of diet fed and the performance required of the animal.

Fermentation

Silage is the product of forages or a whole plant cereal (corn silage) with a higher moisture level that have been chopped and placed in storage structures that can exclude oxygen so that the forages can undergo acid fermentation. Anaerobic microorganisms metabolize sugars and produce volatile fatty acids that reduce the pH of the forages, eventually stop the fermentation process and preserve the forages until it is fed to ruminants. Storage structures used to preserve the forages include bunker silos, upright silos (either glass-lined steel or concrete) or sealed plastic bags. Important components for high quality silage require the proper maturity and moisture level of the forages at harvest, compaction of the material during filling of the storage structure to exclude oxygen, and sealing of the storage structure when the structure is full.

Other processes

Extrusion, micronization and steam-flaking are examples of other processes designed to reduce the particle size, break the seed coat or change the chemical structure of the feed ingredient to improve nutrient or energy digestion and/or improve the ability of enzyme activity on the feed resource. In most cases, these processes improve nutrient utilization and efficiency results with less nutrient excretion.

Feed Management Schemes

Recommended feeding management practices for a particular operation may include considering processing options (discussed previously), implementation of grouping strategies, including grouping by gender and increasing the number of production groups, appropriately adjusting diets based on climatic factors, and minimizing feed wastage.

Grouping – Place animals of similar ages, weights and/or production levels together so that more specific rations can be developed with a minimal chance of overfeeding nutrients.

Phase feeding – Use multi-phase feeding versus minimal phase feeding. Phase feeding provides a series of diets that are formulated to more closely meet the nutrient needs of the animal at a particular stage of growth or production (Henry and Dourmad, 1993). Dividing the growth period into several periods with a smaller spread in body weight, milk production or egg production status allows producers to provide diets that more closely meet the animal's nutrient requirements and significantly reduces nutrient excretion and wastage.

Gender (Split-sex feeding) – Place animals of the same gender together. Split-sex feeding divides the animals by gender so that diets can be formulated to meet the special nutrient needs of each sex.

Climate – Adjust diet to meet specific climate conditions, i. e., temperature, wind, precipitation or adjust the building climate to optimize nutrient utilization.

Wastage – Minimize spillage of feed and water into the manure management system. There are a variety of feed and watering systems that can be used with variable impacts on feed and water spillage. Wet-dry feeders for swine generally will reduce the volume of water spillage and the volume of liquid manure for storage by 30 to 50% primarily due to much less water wastage.

Diet Manipulation Factors

Diet formulation and ingredient selection considerations (discussed in more detail in fact sheets at http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.extension.org/animal+manure+manageemnt) include formulation based on feed available nutrients, use of growth promotants, genetic factors, use of specialty feeds and additives and water supplies.

Available nutrients – If the biological availability of nutrients in feed ingredients is known, diets can be formulated more accurately from feed ingredients to supply needed nutrients and reduce excess nutrient excretions.

Genetics – Knowing the genetic capability of the animals producing meat, milk and eggs, is critical so that adjustments can be made for diet formulation to provide adequate nutrients. Feed intake levels and responses to environmental conditions, i.e., climate, disease pressure, housing system are important also for formulation adjustments.

Growth promoters – Antibiotics, enzymes, probiotics and other feed additives that are growth promoters or enhance the health of animals will increase feed efficiency and animal productivity. Growth promoters can reduce nutrient excretion by increasing nutrient utilization.

Specialty feeds – Providing specific feed ingredients (e.g. high oil corn, nutrient dense corn, low phytate corn and soybeans) helps achieve a proper balance or increased availability of nutrients.

Water supplies – Water supply sources can make a significant contribution to mineral intakes of the animal. Routinely analyze water sources and account for any contribution of minerals from drinking water when making necessary adjustments to the diet formulation.

Supplemental Phosphorus – Reduce supplemental P and add phytase to swine and poultry diets to reduce P excretion. Remove all supplemental P in beef cattle diets and most of the supplemental P in dairy cattle diets to reduce P excretion.

Crude Protein – Reduce dietary protein content and add supplemental amino acids to swine and poultry diets; reduce protein and select N sources for cattle that can be absorbed more effectively. Each of these practices will reduce N excretion.

Dietary Adjustments

Table 3 provides a summary of "potential" reductions in the excretion of nutrients with dietary and/or feeding management adjustments mentioned above for livestock and poultry. It should be noted that these potential effects are not, however, additive. For more specific information see the FASS Fact Sheets (http://www.fass.org/page.asp?pageID=131)and the NRCS Technical Notes (http://www.nrcs.usda.gov/technical/ECS/nutrient/documents.html) in this series related to the specific animal species.

Table 3. Potential reduction of nitrogen and phosphorus excretion from feed management practices.

Strategy*	Nitrogen reduction (%)	Phosphorus reduction (%)
Formulation closer to requirement	10-15 (non-ruminants) 10-25 (ruminants)	10-15 (non-ruminants) 10-30 (ruminants)
Reduced protein/AA supplementation (non-ruminants)	10-25 (poultry) 20-40 (swine)	----
Protein manipulation (ruminants)	15-25	---
Use of highly dig. feeds	5	5
Phytase/low P (non-ruminants)	2-5	20-30
Selected enzymes	5	5
Growth promotants	5	5
Phase feeding	5-10	5-10
Split-sex feeding	5-8	---

*Fineness of grind/pelleting the diet from 1000 microns to 700 microns for swine can reduce manure excretion by 20-25% and N excretion by 5%. Use of chelated and organic minerals for swine (zinc, copper, selenium) can potentially reduce these mineral excretions by 15-50%.

Impact of diet on volume of manure (excreta) generated

The volume of manure generated depends upon the digestibility of the feed ingredients, especially dry matter, the intake of the animal, and the type and amount of fiber in the diet. The more digestible or degradable the dry matter is to microbiological and physical break down, the lower volume of solids that will be excreted. Conversely, if fiber is added to the animal's diet in increasing amounts, generally, there will be an increased bulk or volume of solids excreted.

The composition of the diet has an impact on the amount of urine excreted. If a reduced crude protein diet with supplemental amino acids is fed to swine, less water is consumed by the pig and lower amounts of urine excreted. Conversely, if higher dry roughage diets are fed to ruminants, more water is consumed by the animal that is excreted through urine. If higher salt concentrations are in the ration, greater water consumption results by the animal. Feeding high moisture forages to ruminants will reduce water consumption.

Impact of diet on composition of manure (excreta) generated

As expected, diet composition has a significant impact on the composition of excreta generated. Important dietary factors affecting manure excretion are: composition, quality and maturity of the individual feed ingredients; nutrient availability of the feed components; levels and ratios of specific nutrients; enzymes, feed additives, antibiotics and other growth promoters in the diet; and processing methods used for ration preparation. In addition to these factors, the chemical form of nutrients excreted can be affected by diet composition. For example, addition of fiber to swine diets will increase the amount of organic N in manure compared to ammonium N. Similarly, if phytase is fed to swine or poultry, without concomitant reductions in inorganic P and/or feeding well above the P required by the animal, the proportion of water soluble P will increase in the excreta. Phytase is a synthetic enzyme added to non-ruminant diets that releases bound forms of P normally found in feed ingredients such as corn and soybean meal. This bound form of P becomes available for the animal to utilize and reduces P excretion. High concentrate diets fed to cattle will increase the amount of soluble carbohydrates excreted compared to cattle fed high forage diets.

Excess nutrients will be excreted if they are added to the diet significantly above the nutrient requirements of the animal at a specific phase in the life cycle of the animal. Therefore, reducing this overage of nutrient formulation can have a significant impact on reducing nutrient excretion.

Impact of diet on gas emissions from manure

Animal production facilities are a point source for various airborne contaminants. Odorous and gas emissions are generated by livestock and poultry manure decomposition (i) shortly after excretion, (ii) during storage and treatment, and (iii) during land application (Bicudo et al., 2002). The generation and potency of odor and gases are influenced by weather conditions, time, species, housing strategy, manure handling systems, feed type, and general management scheme. Various control strategies are currently being explored to reduce the generation of airborne contaminants, including dietary modification.

Ammonia

Inefficient use of N or excess N excretion can result in increases of ammonia emission from livestock and poultry operations. Several dietary strategies including improved feed management practices (discussed previously), selective feed ingredients, and modified ration formulation have been employed to reduce excess N excretion and aerial ammonia emissions. Implementation of phase feeding or split sex feeding allows for greater matching of the diet to the growth stage of the animal Examples of impact of diet and feed management practices are feeding in a multiphase system with the potential to reduce urinary nitrogen excretion and ammonia emission in swine by 15 and 17%, respectively (van der Peet-Schwering et al., 1996).

Reducing the crude protein of the diet and supplemental synthetic amino acids to balance the correct amino acid levels and ratios on the diet for pigs and poultry will reduce N excretion and ammonia emissions. As a general rule, for every 1 percentage unit of crude protein reduction, ammonia emissions will be reduced by 8 to 10 percentage units. Addition of small amounts of fiber (5 to 10%) in the pig's diet, reduced ammonia emissions also, but there can be increase in total manure excretion. Feeding zeolite, urease inhibitors, and organic acids can also reduce ammonia emissions substantially. Reducing crude protein levels, adjusting the protein to carbohydrate (available energy generally from grains) ratio in the diet and selecting the correct protein sources have the most impact on reducing N excretion from ruminants and consequent ammonia emissions up to 50%. If by-product feeds are included in rations, they may increase the potential for ammonia emissions since in many cases the amount of protein is overfed and the protein is not utilized effectively because of the methods of by-product processing.

Hydrogen Sulfide

Hydrogen sulfide emissions primarily come from the microbial degradation sulfur-containing amino acids and mineral sulfates provided as sources of minerals in the diet. Methods to reduce hydrogen sulfide emissions are to reduce these sources in the diet and to provide alternative mineral sources which do not contain sulfur. In some geographical areas, drinking and cleaning water may contain high sulfur concentrations which add significantly to the emissions of hydrogen sulfide. Filtering high sulfur water would be required to alleviate the problem. Because of the nature of processing ethanol, high sulfur concentrations are in distiller's dry grain with solubles. Feeding this ingredient in animal diets will very likely increase the emissions of hydrogen sulfide. Therefore, when by-products are used in animal diets, there could be increased nutrient excretion and potentially gaseous emissions.

Methane

Methane emissions come from the anaerobic microbial degradation of organic matter. With swine and poultry, methane can be generated from manure storage facilities. With ruminants, the microorganisms in the rumen (first compartment of the ruminant stomach) produce methane from the forages and other carbohydrate sources in the feed and the ruminant belches or eructates the methane into the air. Feeding a low forage:high grain ration reduces methane emissions compared to a high forage:low grain ration. Addition of certain feed additives, such as monesin or rumensin to the diet will reduce methane emissions from the ruminant.

Typical Diets

Diet formulations can vary considerably depending upon the source and quality of feed ingredients and the specific nutrient needs for the genetic potential and purpose of the animal. Following are some general guidelines (ranges) of typical feeds included in a complete ration for each species.

Grains (corn) 57-74%
Protein (soybean meal) 21-35%
Supplement (vitamins, minerals, enzymes) 5-8%

Swine

NURSERY
Grains (corn, barley, wheat) 35-70
Lactose 0-5
Protein (soybean meal, dried whey, fish meal, plasma protein, spray dry blood cells) 27-52
Fat (choice white grease, soy oil) 1-6
Vitamin and mineral supplements 2-3

GROW-FINISH
Grains (corn, barley, wheat) 73-88
Protein (soybean meal) 9-23
Fat (choice white grease, soy oil) 1
Vitamin and mineral supplements 2-3

LACTATION/GESTATION
Grains (corn, barley, wheat) 70-85
Protein (soybean meal) 11-24
Fat (choice white grease, soy oil) 0-2
Vitamin and mineral supplements 4

Summary

Manure from livestock and poultry production can be effectively utilized as a nutrient resource for crop production. However, if not managed properly or if there is greater import of nutrients on a livestock or poultry operation than export of nutrients, there can be an environmental impact on water or air quality from manure produced on the farm. Feed purchase is a major import of nutrients on livestock and poultry operations. Development of a feed management plan can help reduce whole farm nutrient imbalances by reducing excess feeding of nutrients to animal or by improving the utilization to nutrients in the animal diet and subsequently excess nutrient excretion. Understanding general nutrition principles and guidelines, and implementing tools (fact sheets, computer aids, etc) can help in the development of effective feed management plans that will help reduce nutrient accumulations on the farm, environmental impacts and the requirements of the NRCS Conservation Practice Standard (Code 592) (Feed Management).

Additional Resources

Harrison, J., R. White, G. Erickson, A. Sutton, T. Applegate, R. Burns and G. Carpenter. 2007. A national feed management education program designed to impact manure composition. CD-ROM Proc. Inter. Symposium Air Qual. Waste Mgt. for Ag. ASABE Publ. No. 701P0907cd. 5 pgs. Broomfield, CO.

Klopfenstein, T., R. Angel, G. Cromwell, G. Erickson, D. Fox, C. Parsons, L. Satter and A. Sutton. 2002. Animal diet modification to decrease the potential for nitrogen and phosphorus pollution. CAST Issue Paper #21. July, 2002.

National Research Council (NRC) Requirements of Poultry, Swine, Dairy Cattle, Beef Cattle (separate publications) http://www.nap.edu/catalog.php

Livestock and Poultry Environmental Stewardship Module B Lessons 10, 11, 12, 13. http://www.extension.org/animal+manure+management.

NRCS. 1999. Comprehensive Nutrient Management Planning Technical Guidance. National Planning Procedures Handbook. Subparts E, Parts 600.50-600.54 and Subparts F, 600.75. http://www.nrcs.usda.gov/technical/afo/cnmp_guide_index/html

NRCS. 2001. Nutrient Management Conservation Practice Plan 590. Nutrient Management. http://www.nrcs.usda.gov/technical/standards/nhcp.html

NRCS 2003. Nutrient Management Technical Notes 001, 002, 003, 004, 005. http://www.nrcs.usda.gov/technical/ECS/nutrient/documents.html

NRCS. 2003. Nutrient Management Conservation Practice Plan 592. Feed Management. http://www.nrcs.usda.gov/technical/standards/nhcp.html

NRCS-CIG fact sheets. http://www.puyallup.wsu.edu/dairy/nutrient-management/publications.asp; http://www.extension.org/animal+manure+manageemnt).

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