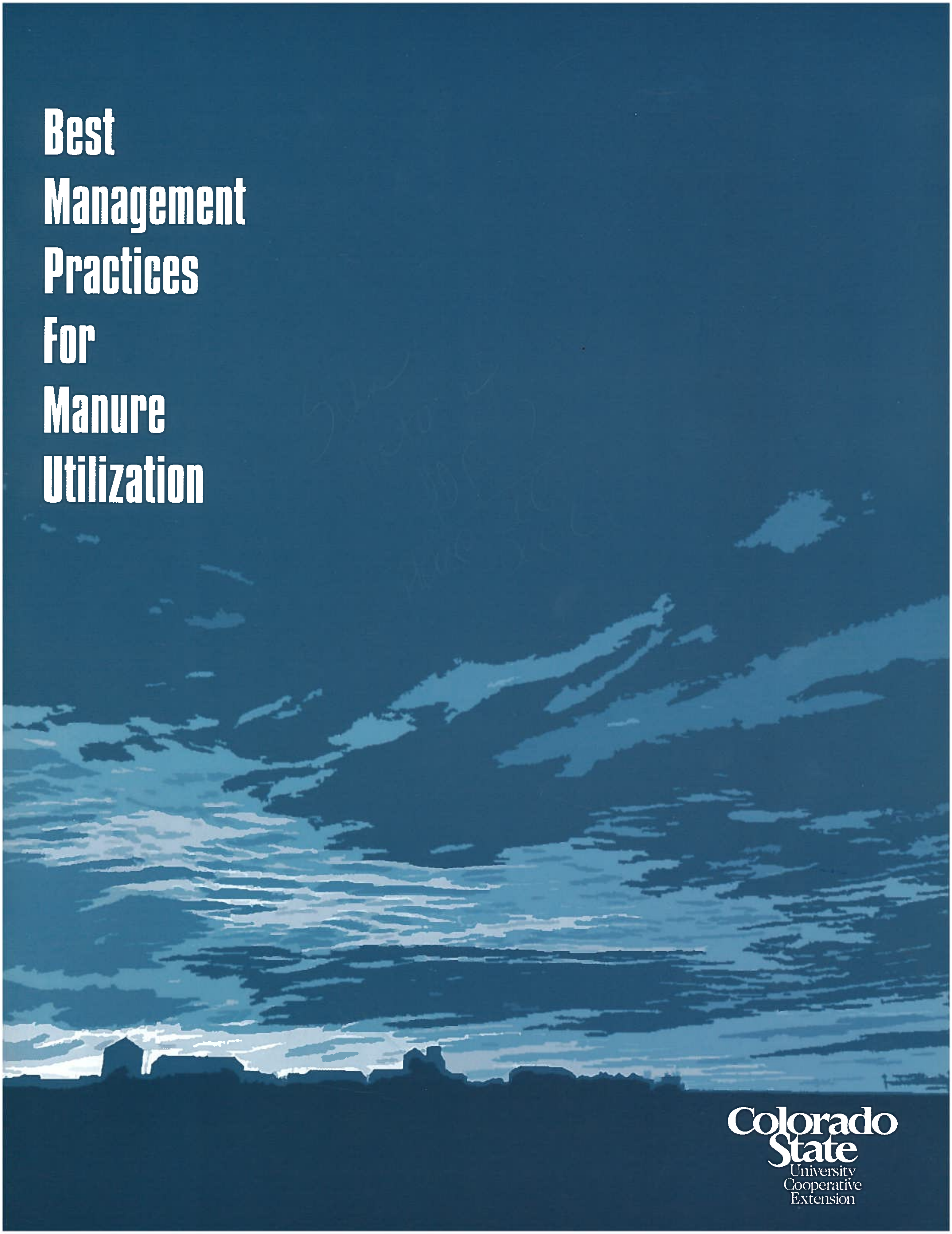
Best Management Practices For Manure Utilization



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In association with: Colorado Department of Agriculture and the Agricultural Chemicals and Groundwater Protection Advisory Committee

The authors and the Colorado Department of Agriculture gratefully acknowledge the extensive input and leadership of the Agricultural Chemical and Groundwater Protection Advisory Committee, representing production agriculture, agricultural chemical dealers and applicators, the green industry and the general public.

With cooperation from: Colorado Department of Public Health and Environment
USDA Natural Resource Conservation Service
Colorado State University Department of Soil and Crop Sciences

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Layout and Design by: Colorado State University Publications and Printing

Published by Colorado State University Cooperative Extension in Cooperation with Colorado Department of Agriculture.

1,000 9/99

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Bulletin 568A

Colorado State University Cooperative Extension

Best Management Practices for Manure Utilization

Livestock manure and effluents are rich in plant available nutrients which can be valuable assets to crop producers. However, they also can be a source of both ground and surface water contamination if handled improperly. Livestock manure contains significant quantities of N, P, and K, and smaller amounts of nutrients such as Ca, Mg, Mn, Zn, Cu, and S. Manure that is properly applied to cropland increases soil fertility, improves soil physical properties, and saves fertilizer costs. Liquid effluents are composed primarily of water and have less impact on soil physical properties, but they also contain nutrients and other constituents that must be managed properly.

The primary constituents of animal waste that may cause water quality problems include pathogenic organisms, nitrate, ammonia, phosphorous, salts, heavy metals, and organic solids. Nitrate (NO_3) is the most common ground water pollutant from fields that receive excessive rates of manure. Ground water monitoring has shown that NO_3 contamination can be a problem in the vicinity of confined livestock feeding operations. Runoff from feedlots or manured fields can also degrade the quality of surface water.

In Colorado, state law prohibits any direct discharge of manure or animal wastewater to either surface or ground water. Concentrated swine operations are subjected to air and water quality provisions that among other things, require an approved nutrient management plan as a component of the operating permit. These nutrient management plans are used to document that confined feeding operations apply wastes at agronomic rates and in a manner which does not adversely impact air or water quality. The Colorado Confined Animal Feeding Operations Control Regulation mandates that producers who confine and feed an average of 1000 or more "animal units" for at least 45 days per year ensure that no water quality impacts occur by collecting and properly disposing of animal manures, as well as stormwater runoff. Smaller feeding operations that directly discharge into state waters or are located in hydrologically sensitive areas may also fall under this regulation. Animal feeding operations are directed to employ Best Management Practices (BMPs) to protect state waters.

This publication is intended to provide general recommendations and BMPs to assist in the sound management of animal waste as a nutrient source for crops. These BMPs are necessarily general, as they cover operations utilizing manure from a variety of feeding operations. This document is not intended to establish guidance to meet any specific regulatory program in Colorado governing the application of animal waste and is not a substitute for compliance with local, state or federal regulations. Table values for manure characterization given in the document are for planning purposes in lieu of documented site-specific values.

Nutrient Management Planning

Sound management practices are essential to maximize the agronomic and economic benefits of manure while reducing the risk of adverse environmental consequences. Livestock producers do not intentionally put water quality at risk. The problems that occur are usually a result of inattention due to the need to focus limited management time on herd health and production. Virtually every regulatory and voluntary manure management approach now calls for producers to develop a Nutrient Management Plan. This plan documents approximately how much manure is produced and how it will be managed. At the core of these plans is the concept that manure will be applied at "agronomic rates" to crop lands.

Table 1. Animal unit equivalency factors for Colorado.

Livestock Type	Animal Unit Equivalency Factor	CAFO Threshold Number
Slaughter and Feed Cattle	1.0	1,000
Horses	1.0	1,000
Mature Dairy Cattle	1.4	750
Swine (>55 lbs.)	0.2	5,000
Sheep	0.2	5,000
Turkeys	0.02	50,000
Chickens (broiler or layer)	0.01	100,000

For young stock, less than 50% of adult weight, reduce the above factors by one-half.

The **agronomic rate** is a nutrient application rate based upon a field-specific estimate of crop needs and an accounting of all N and P available to that crop prior to manure (and/or fertilizer) application. Implicit within the agronomic rate concept is an application rate that does not lead to unacceptable nutrient losses. The agronomic rate is not something that can be directly obtained from a textbook or tables. Rather, it must be evaluated for each farm and field. Knowledge of manure or effluent nutrient content and residual soil nutrients is critical to determining how much can be safely applied so that the agronomic rate is not exceeded. While producers were encouraged in the past to fertilize for maximum crop yields, now they must also consider the environmental risk of nutrient losses in determining how much manure to apply. By knowing the relationship between manure nutrient content, residual soil nutrients, and crop needs, wise decisions can be made such as where to spread manure, how much to spread, and on which nutrient to base the application rate.

Long-range planning is fundamental to optimizing manure benefits while minimizing environmental concerns. The basic elements of a **nutrient management plan** are:

1. Estimates of manure and waste water production on the farm
2. Farm maps which identify manure stockpiles and lagoons, potential application sites and sensitive resource areas
3. Cropping information and rotation sequence
4. Soil, plant, water, and manure analyses
5. Realistic crop yield expectations
6. Determination of crop nutrient needs
7. Determination of available nutrient credits
8. Recommended manure rates, timing, and application methods
9. Plans for operation and maintenance of manure storage and utilization. Documentation of any manure to be sold, given away, or used for purposes other than as a soil amendment.

If animal feed rations are modified to reduce nutrient content or volume of the waste as part of the management strategy, this also should be documented as part of the waste management plan. Advances have been made in recent years in feed formulation for reducing N and P excretion without reducing rate of gain. The "ideal protein concept" is a feeding method for monogastrics in which crude protein levels are reduced and amino acids are supplemented in order to reduce N excretion. For reduction of phosphorus excretion, adding phytase to the diet has been shown to increase P availability to hogs and chickens. Most of the research on nutritional approaches to reducing manure nutrient excretion has been done on monogastrics, but research is in progress on cattle feeding methods for this purpose.

Nutrient management plans are no longer just a good idea: they are essential for documenting proper stewardship and regulatory compliance. This publication is designed to help producers develop their own nutrient management plans in a relatively simple format. However, technical assistance is also available to producers from their local Certified Crop Adviser (CCA), Cooperative Extension agent or USDA NRCS conservationist.

Manure Handling and Storage

Livestock feedlots, manure stockpiles, runoff storage ponds, and treatment lagoons represent potential point sources of ground water contamination. Research has shown that active feedlots develop a compacted manure/soil layer, which acts as a seal to prevent leaching. When cleaning pens, it is very important to avoid disturbing this seal. Workers need to be trained to correctly use manure loading machinery to maintain a manure pack on the surface.

In addition to maintaining the integrity of the "hard pan" under feedlot pens, it is critical to create and maintain a smooth pen surface that facilitates proper drainage and runoff collection. Pens should be designed with a 3 percent to 5 percent slope for optimum drainage. Low spots and rough surfaces should be filled and smoothed during pen cleaning.

Abandoned feedlots have a large potential to cause NO_3 leaching as the surface seal cracks and deteriorates. For this reason, pens need to be thoroughly cleaned and scraped down to bare earth prior to abandonment. Revegetation of the old pens is also important to help absorb excess soil nutrients and prevent erosion.

Manure stockpiles should be located a safe distance away (at least 150 ft.) from any water supply and above the 100-year flood plain unless flood proofing measures are provided. Grass filter strips or sediment basins can be used to reduce solids and nutrients in runoff. For land with a slope of greater than 1 percent, plant a strip of a dense, sod-forming grass such as smooth brome or pubescent wheatgrass at least 20 to 50 feet wide around the downhill side of any feedlot or manure stockpile to filter potential contaminants in runoff water. More precise filter strip seeding recommendations may be obtained from the local USDA-NRCS office.

Liquid Effluent and Runoff Collection and Storage

Storm water and wastewater runoff from feedlots can contain high concentrations of nutrients, salts, pathogens, and oxygen-demanding organic matter. Preventing storm water from passing across the feedlot surface by installing terraces or diversion channels above the feedlot is a BMP that can significantly reduce the volume of wastewater. Decreasing the active lot area can also help reduce the contaminants moved by storm water.

The criteria for waste water treatment lagoons and holding ponds is stricter than for runoff containment ponds. Runoff containment ponds are necessary for large feeding operations to hold excess wastewater until it can be land applied or evaporated. These should be constructed on fine-textured soils (such as silty clays, clay loams, or clay) with a lining of soil compacted to a

Liquid waste holding structure

minimum thickness of 12 inches with an additional 18-30 inches of soil cover above the compacted soil. On coarse textured or sandy soils it may be necessary to import bentonite clay or use synthetic liners or concrete. Seepage is required to be less than 0.25 inch/day if the pond contains runoff only. However, if the pond stores process wastewater, the seepage requirement is 0.03 inch/day. New holding facilities must be designed to contain the runoff from a 25-year, 24-hour storm event and should be located above the 100-year flood plain and at least 150 feet down gradient from any well. Do not site storage ponds or treatment lagoons in areas with a high water table (within 10 ft. of the bottom of the pond). The local USDA-NRCS office can provide help with pond or lagoon design.

Manure Treatment

There are numerous options for treating or processing manure such as composting, solid separation, aeration, anaerobic digestion, and constructed wetlands. A growing number of producers have become interested in manure treatment systems as a way to reduce volume and odor and enhance the value and acceptance of manure. Careful evaluation of the economic feasibility of a manure treatment system and discussion with a professional engineer is recommended before implementing a new treatment system.

Cleaning pens

Composting is a biological process in which microorganisms convert organic materials, such as manure, into a soil-like material. During composting, some N is lost from the manure as NH_3 gas. Most of the remaining N is tied up within stable organic compounds which will become slowly available to plants after soil application. Composted manure has less odor and is easier to haul and store than raw manure because the volume and weight can be reduced by as much as 50 percent.

Solid separation is a viable treatment for wastewater from milking parlors or hog operations. Settling basins or vibrating screens are used to remove solids from the wastewater resulting in reduced odor and less lagoon loading. This treatment requires an investment in equipment and maintenance, but improves the ease of handling the wastewater.

Aeration of wastewater storage ponds increases the oxygen level in wastewater and reduces odors. Aeration can be achieved through mechanical means or through gas exchange with the air in large, shallow ponds. The disadvantages of aeration include high energy costs for mechanical aeration and additional maintenance expense.

Anaerobic digestion is another treatment option in which manure is digested to produce energy for farm use or possibly for sale to a local power company. This treatment can require a large start-up investment and high maintenance, but significantly reduces manure odors because the treatment vessel is enclosed to capture gases. Maintenance costs can be offset by the use of the energy produced by the combustion of the gases.

Constructed wetlands can be a useful manure treatment option because of high nutrient use of wetland plants and the denitrification process which transforms nitrate into gaseous nitrogen forms. The disadvantages include construction costs, the need for solid separation prior to wetland treatment, and the need to manage the wastewater discharged from the wetland.

Developing a Nutrient Management Plan (NMP)

Worksheets to help develop a nutrient management plan can be found near the end of this publication. They are provided as a starting place to help producers establish sound manure management. Developing a plan is just the beginning. Implementation of the plan and follow up are required to best manage your operation.

NMP Section 1. Nutrient and Land Inventory

Producers should start by calculating an estimate of total annual manure production at their operation so that they can determine how much cropland is needed for long term application. There are several ways to develop this information; one method is described in the steps below. Another method is to actually weigh the manure removed during pen cleaning. If your land base is inadequate to safely utilize the total nutrients produced, arrangements should be made to apply the manure off-site.

Steps for determining nutrient inventory from manure production include:

1. Determine the average weight and number of livestock kept annually at the facility.
2. Determine annual manure production on a per animal basis. (Tables 2 and 3 give estimates on an AU basis.)
3. Multiply average annual manure production times average number of animals to get total manure production.
4. Use manure analysis or Table 4 to estimate nutrient content of manure.
5. Multiply total manure production by nutrient content per unit of manure to determine annual nutrient production.

Table 2. Solid manure production by livestock calculated on a wet weight basis at the time of land application.

Animal Type	Manure Production	Manure Moisture Content
	(lb./day/1000 lbs. of animal)	(% at time of spreading)
Dairy		
Lactating Cow	18.5	46
Dry Cow	17.6	46
Heifer	16.9	46
Beef		
Feeder, yearling (750-1100 lb.)		
High forage diet	10.1	32
High energy diet	8.7	32
450-750 lb.	11.2	32
Cow	10.7	32
Veal	2.8	46
Swine		
Nursing/nursery pig (0-40 lbs.)	21.6	51
Grower (40-220 lbs.)	12.9	51
Replacement gilt	6.7	51
Sow (gestating)	5.1	51
Sow (lactating)	12.2	51
Boar	3.9	51
Poultry		
Layer	25.2	40
Pullet	19.0	40
Broiler	33.3	40
Turkey	18.2	40
Horse	14.1	22
Sheep	14.5	31

These values are adapted from the USDA Agricultural Waste Management Field Handbook or represent data from Colorado sampling. Manure production and moisture will vary with animal age, feed ration, breed and handling.

Table 3. Liquid swine manure production on a wet weight-basis.*

Swine Type	Manure Production (gal/ day/1000 lbs. of animal)
Nursing/nursery pig (0-40 lbs.)	12.8
Grower (40-220 lbs.)	7.5
Replacement gilt	4.0
Sow (gestating)	3.3
Sow (lactating)	7.2
Boar	2.5

* These numbers do not include wash water or storm water that may be added to holding facilities.

Total all manure nutrients from the various sources on your farm to get an estimate of farm total nutrient production (Worksheet 1 is provided at the end of this document as a template for these records). This figure will be compared to estimated crop utilization figures on Worksheet 3.

Estimating the volume of liquid swine manure produced at large confined feeding facilities is confounded by the addition of fresh water to the system for flushing waste from the animal housing units. Documented, operation-specific numbers or Table 3 can be used to estimate the volume of swine manure production on a liquid basis. To estimate total liquid waste water available for land application, add the volume of fresh water used for flushing purposes to the calculated manure volume. This should give you total wastewater volume (excluding runoff) before any evaporation or digestion occurs. Evaporation figures for Colorado are available from local USDA-NRCS offices.

Calculation 1. Estimation of total annual nutrient production from a solid manure handling system.

Example 1a: Beef Feedlot Manure

Example Feedlot has 2500 head on average year-round. The cattle come in weighing 500 lbs. each and leave weighing 1200 lbs. each. They are fed a grain diet.

Step 1: Calculate average animal weight

(500 + 1200)/2 = 850 lbs./head

Step 2: Obtain table value for manure production (Table 2)

8.7 lb/day/1000 lbs. of animal (feeder, high energy diet)

Step 3: Calculate total annual manure production for operation

Multiply table value by average animal weight divided by 1000.

8.7 lb/day/1000 lbs. of animal x 850 lbs. = 7.4 lbs. manure/day/animal

Multiply by the number of days on feed/year.

7.4 lbs. manure/day x 365 days/year = 2,700 lbs. manure/year/animal

Multiply by the number of head fed/year.

2,700 lbs. manure/year x 2500 head = 6,750,000 lbs. manure/year.

Convert lbs. to tons by dividing by 2000.

$$\frac{\text{6,750,000 lbs. manure /year}}{\text{2000 lbs./ton}} = \text{3375 tons manure /year}$$

Step 4: Obtain manure analysis (Table 4):

23 lb. N /ton

24 lb. P_2O_5 /ton

Step 5: Calculate total annual nutrient production:

23 lb. N /ton x 3375 tons/yr. = 77,625 lb. N/yr.

24 lb. P_2O_5 /ton x 3375 tons/yr. = 81,000 lb. P_2O_5/yr

Calculation 1b. Estimation of nutrient production from a liquid manure handling system.

Example 1b: Swine Liquid Waste

Example feeding operation has 5000 head on average year-round. The pigs come in weighing 50 lbs. each and leave weighing 250 lbs. each. They are fed a grain diet.

Step 1: **Calculate average animal weight**

(50 + 250)/2 = 150 lbs./head

Step 2: **Obtain table value for liquid waste production** (Table 3)

7.5 gal/day/1000 lbs. of animal

Step 3: **Calculate total annual manure production for the operation**

Multiply table value by average animal weight divided by 1000.

7.5 gal/day/1000 lbs. of animal x 150 lbs. = 1.125 gal manure/day/animal

Multiply by the number of days on feed/year.

1.125 gal manure/day x 365 days/year = 410 gal manure/year/animal

Multiply by the number of head fed/year.

410 gal manure/year x 5000 pigs = 2,050,000 gal manure/year.

Convert to 1000 gal by dividing by 1000

$\frac{2{,}050{,}000 \text{ gal manure/year}}{1000 \text{ gal}}$ = 2,050 thousand gal manure/year

Step 4: **Obtain liquid manure analysis** (Table 4):

36 lb. N/1000 gal

27 lb. P_2O_5/1000 gal

Step 5: **Calculate total annual nutrient production:**

36 lb. N /1000 gal x 2,050 thousand gal/year = 73,800 lb. N/yr.

27 lb. P_2O_5/1000 gal x 2,050 thousand gal/year = 55,350 lb. P_2O_5/yr

Step 6: **Adjust for N loss as ammonia from system** (Table 5)

73,800 lb. N/yr. x 50% volatilization

= 36,900 lb. N/yr.

Determining Land Needs for Long Term Manure Utilization

One of the first steps in developing a long term nutrient management plan is to determine if adequate land is available for utilization of the manure and effluent produced. If the land base is determined to be inadequate, arrangements must be made to reduce manure production or find alternatives to overapplication. To estimate the minimum land base required, you need to know the annual manure production of your facility and have a manure sample analyzed for total N, P, and K. Then calculate the best estimate of annual nutrient removal on a per acre basis. For this calculation, use conservative estimates of annual crop nutrient removal and assume that all N and P in the manure is crop available unless you are using liquid effluents with known N volatilization rates. Total manure production divided by acceptable application rates (tons or gallons per acre) will give an estimate of the land base needed for safe manure utilization (Calculation 2). This is not the same calculation as is used for determining the agronomic rate of application for a specific field for a specific year.

Table 4. Approximate nutrient composition of various types of animal manure at time of land application.*

Type of manure		Moisture Content	Total N	NH_4-N[a]	P_2O_5	K_2O
		%	lb./ton			
Solid handling systems						
Swine		82	10	6	9	8
Beef		32	23	7	24	41
Dairy Cattle		46	13	5	16	34
Sheep		31	29	5	26	38
Chickens	Without litter	55	33	26	48	34
	With litter	25	56	36	45	34
Turkeys	Without litter	78	27	17	20	17
	With litter	71	20	13	16	13
Horses	Without bedding	22	19	4	14	36
		%	lb/1,000 gal			
Liquid Handling Systems[b]						
Swine	Liquid pit	96	36	26	27	22
	Single-stage anaerobic	99	7	6	2	7
	Two-stage anaerobic	99	4	3	2	7
Beef	Lagoon[c]	99	4	2	9	5
Dairy Cattle	Liquid pit	92	24	12	18	29
	Lagoon[c]	99	4	2	4	10
Poultry	Liquid pit	87	80	64	36	96

[a] Ammonia fraction can vary significantly across time and systems. Numbers given are for planning purposes only; manure analysis is needed to accurately determine ammonia fraction.
[b] Application conversion factor: lb/1,000 gal x 27.15 = lb./acre inch.
[c] Includes runoff water.
* These values are derived from the USDA Agricultural Waste Management Field Handbook, 1992 and are modified with data collected from Colorado feeding operations when possible. Nutrient composition of manure will vary with age, breed, feed rations, and manure handling.

Total N in manure is used to calculate an estimate of safe long term solid manure application rate because all of the applied N that is not lost to leaching or volatilization will eventually become available to the crop. Liquid wastes such as swine effluent can have a large loss component due to ammonia volatilization. Long term planning for effluent applications should include conservative volatilization estimates to allow for uncertainty and lower than expected crop nutrient uptake (See Table 5).

Phosphorus Based Manure Planning

While manure applications in Colorado are most often based on crop N needs, in certain situations it is more appropriate to base manure rates on crop P requirement and manure P content. Phosphorus is known to cause surface water degradation, even at very low concentrations. When P from runoff enters lakes and streams, it accelerates the growth of algae and other aquatic weeds. As these plants flourish, oxygen and light become limiting to the survival of more desirable species and the natural food chain is disrupted. Excessive manure applications to cropland have been shown to result in P movement to water and subsequent degradation.

Manure management plans should consider P loading when runoff from a field is likely to enter sensitive water bodies. In addition, if the soil test shows that extractable P is in the "high" or "very high" range and P movement is likely, manure should be applied at rates based on crop P removal. For planning purposes, all of the P in the manure should be considered crop available in these cases. The consequence of P based management for a producer is that more land is required to safely utilize the manure.

Site Assessment

The final aspect of the land and resource inventory is an assessment of the manure storage and utilization sites. Site maps of the farm and feeding operation are an important part of any nutrient management plan. Obtain aerial maps from your local NRCS office or develop your own maps if necessary. Identify manure storage facilities, fields receiving manure, and any wells, surface water or shallow ground water. These maps can help you identify sensitive resource areas such as surface water bodies that might receive runoff from your farm. Appropriate BMPs such as buffer areas, set backs, reduced application rates, or application timing limitations may be identified as a part of these maps.

To determine the pollution potential at your site, the following questions need to be considered:

Manure and wastewater storage site evaluation

1. Is the soil texture coarse (sandy with low amounts of clay)?
2. Is the depth to ground water less than 50 feet in the vicinity of manure storage?
3. Have recent well water analyses indicated that local ground water NO3-N levels are increasing?
4. Is the horizontal distance of the feedlot to surface water bodies (creeks, ponds, drainage ditches, etc.) or wellheads less than 150 feet?
5. Does runoff from the feedlot surface leave your property?
6. Does seepage from runoff storage ponds exceed .25 in/day?
7. Does seepage from lagoons exceed .03 in/day?
8. Is manure stored within the 100 year flood plain?
9. Do runoff storage ponds lack the capacity to handle runoff volumes from a 25 year, 24-hour storm?

Manure utilization site evaluation

1. Do you lack sufficient land to use all of the nutrients in manure produced on your farm?
2. Do any fields receiving manure have greater than a 1% slope and little surface residue?
3. Do any fields have a history of more than 5 consecutive years of manure application?
4. Is excess water from irrigation or precipitation available for runoff or leaching?
5. Is manure applied at rates greater than the agronomic rate?
6. Is there surface water or a well immediately downhill from any field which receives manure?
7. Has it been more than one year since you soil sampled to determine nutrient levels in fields where manure will be applied?

If the answer to any one of these questions is yes, or if you are unsure about the answer, manure storage or application at your site may degrade water quality. The local USDA-NRCS office can help you answer questions you are unsure about. Your nutrient management plan should address any problem areas identified in the questions above. Manure rates may need to be adjusted downward and all appropriate BMPs

Table 5. Approximate nitrogen lost as ammonia during handling and storage.

System	Estimated NH_4-N Loss
	——————%——————
Solid	
Daily scrape and haul	15-35
Manure pack	20-40
Open lot	40-60
Liquid	
Lagoon	70-80
Anaerobic pit	15-30
Above-ground storage	10-30

Source: MWPS-18, Livestock Waste Facilities Handbook

Calculation 2. Determining land base for long-term manure disposal based on crop N needs.*

Example: Feedlot applies manure to corn harvested for grain. Average yield is 175 bu/acre. Using estimated N removal from Table 6 and Calculation 1a data:

1) Crop nutrient removal (from Table 6):
   175 bu corn/acre x 56 lb./bu = 9,800 lb. grain/acre on harvest dried basis.
   9,800 lb. grain/acre x 1.6% N in dry harvested grain = 158 lb. N removed/acre
2) Land needs (from Calculation 1a):
   77,625 lb. N from manure production / 158 lb. N removed /acre = 491 acre minimum land base

* This calculation does not determine the agronomic rate of application because it assumes no volatilization, leaching or other N losses or credits.

Table 6. Nutrient content of the harvested part of selected Colorado crops.

Crop	Dry weight	Typical yield*	N content in harvested material	P content in harvested material
	lb./bu	unit/A	% (harvest dry weight basis)**	
Grain crops				
Barley	48	80 bu.	1.8	0.34
		2 tons straw	0.8	0.11
Corn	56	165 bu.	1.6	0.28
		3.5 tons stover	1.1	0.20
Oats	32	60 bu.	2.0	0.34
		1.5 tons straw	0.6	0.16
Rye	56	30 bu.	2.1	0.26
		1.5 tons straw	0.5	0.12
Sorghum (dryland)	56	60 bu.	1.7	0.36
		3 tons stover	1.1	0.15
Wheat (dryland)	60	40 bu.	2.1	0.62
		1.5 tons straw	0.7	0.07
Oil crops				
Canola	50	35 bu.	3.6	0.79
		3 tons straw	4.5	0.43
Soybeans	60	35 bu.	6.3	0.64
		2 tons stover	1.5	0.22
Sunflower (dryland)	25	1,100 lb.	3.6	1.71
		2 tons stover	1.5	0.18
Forage crops				
Alfalfa		4 tons	2.3	0.22
Big bluestem		3 tons	1.0	0.85
Birdsfoot trefoil		3 tons	2.5	0.22
Bromegrass		3 tons	1.9	0.21
Alfalfa-grass		4 tons	1.5	0.27
Little bluestem		3 tons	1.1	0.85
Orchardgrass		4 tons	1.5	0.20
Red clover		3 tons	2.0	0.22
Reed canarygrass		4 tons	1.4	0.18
Ryegrass		4 tons	1.7	0.27
Switchgrass		3 tons	1.2	0.10
Tall fescue		4 tons	2.0	0.20
Timothy		3 tons	1.2	0.22
Wheatgrass (dryland)		1 ton	1.4	0.27

Adapted from the USDA Agricultural Waste Management Field Handbook.

* Typical yields are for irrigated production unless noted otherwise.

** Nutrient contents are on a harvest dried basis and do not need to be corrected for moisture content except for silage and haylage.

lb. P x 2.3 = lb. P_2O_5

employed where water resources are at risk. Additionally, it may be helpful to periodically test wells near livestock operations and manured fields for NO_3 and bacterial contamination to determine if management practices are sufficiently protecting water quality.

NMP Section 2. Determination of Agronomic Rates for Crop Production

Determine agronomic rate of manure or effluent application for each field by assessing crop nutrient needs, available nutrient credits, and nutrients in the manure. Worksheet 2 at the end of this document is provided as a template for this portion of your nutrient management plan. Fill out one copy of Worksheet 2 for each field. An explanation of each section is provided below.

Field Information

Each field has specific nutrient requirements that will vary from year to year. Begin your determination of agronomic rates by filling out 1 copy of Worksheet 2 for each field that receives manure. Note the soil texture or soil name of each field. Sandy soils may require special consideration to avoid nutrient leaching. Clay soils may be more prone to runoff. These considerations are important in a sound nutrient management plan. Previous crop grown is important because you may need to add more nutrients to help with residue breakdown or less nutrients due to N-fixation, depending on the rotation sequence. Manure applications from the previous year can also supply significant amounts of nutrients in the current year due to the mineralization process. To complete your records, attach the most recent soil and manure analysis reports to the field information sheet.

Table 6. Nutrient content of the harvested part of selected Colorado crops. (continued)

Crop	Dry matter	Typical yield*	N content in harvested material	P content in harvested material
	%	tons/acre	——— % ——— (harvest dry weight basis)**	
Silage crops				
Alfalfa haylage	50	10 wet/5 dry	2.8	0.33
Corn silage	35	20 wet/7 dry	1.1	0.25
Forage sorghum	30	20 wet/6 dry	1.4	0.19
Oat haylage	40	10 wet/4 dry	1.6	0.28
Sorghum-sudan	50	10 wet/5 dry	1.4	0.16
Sugar crops				
Sugar beets		20	0.2	0.03
Turf grass				
Bluegrass		2	2.9	0.43
Bentgrass		2	3.1	0.41
Vegetable crops				
Bell peppers		9	0.4	0.12
Beans, dry		1	3.1	0.45
Cabbage		20	0.3	0.04
Carrots		13	0.2	0.04
Celery		27	0.2	0.09
Cucumbers		10	0.2	0.07
Lettuce (heads)		14	0.2	0.08
Onions		18	0.3	0.06
Peas		2	3.7	0.40
Potatoes		14	0.3	0.06
Snap beans		3	0.9	0.26
Sweet corn		6	0.9	0.24

Adapted from the USDA Agricultural Waste Management Field Handbook.
* Typical yields are for irrigated production unless noted otherwise.
** Nutrient contents are on a harvest dried basis and do not need to be corrected for moisture content except for silage and haylage.

Soil, Manure, Water and Plant Sampling and Analysis

A current soil test is needed for each field receiving manure or effluent to determine residual soil NO_3, extractable P and soil organic matter content. Soil sampling for agronomic rate determination should occur once a year. More frequent sampling may be needed to track N utilization and movement in the soil profile. Shallow soil samples (1 foot or less) are needed to evaluate crop P, K and other nutrient needs. Deeper rootzone soil samples (generally 4 to 6 ft. deep) should be collected after crop harvest and prior to any manure or effluent application to evaluate residual soil NO_3. Soil sampling below the active rootzone (>6 ft. for most annual crops, >10 ft. for hay crops) may be needed occasionally to document that nutrients are not leaving the crop rootzone. To get a good, representative soil sample, it is recommended that a minimum of 1 soil core per 10 acres or at least 10 cores on fields 40 acres or smaller be collected to form the composite sample for each depth increment. Samples should be thoroughly mixed and either air-dried or delivered to the lab immediately.

In situations where effluent or manure is applied in the fall after crop harvest, NH_4 in the animal waste may not be converted to NO_3 prior to spring soil sampling. Additionally, fields with long manure histories may also have a significant amount of NH_4 in the rootzone due to increased mineralization rates. NH_4 is available to crops and should be credited as part of the N budget in these particular situations.

Table 7a. Suggested nitrogen application rates for irrigated corn grain (175 bu/A), based on soil NO_3-N and organic matter content.

Soil NO_3-N (ppm)*	Soil Organic Matter (%)		
	0 - 1.0	1.1 - 2.0	>2.0
	———Fertilizer rate (lb. N/A)———		
0 - 6	210	185	165
7 - 12	160	135	115
13 - 18	110	85	65
19 - 24	60	35	15
>24	10	0	0

* Average concentration of NO_3-N (ppm) in 0 to 2 ft soil layer.
Add or subtract 1 lb. N/A for every bushel above or below 175 bu/A.
This table uses the formula:
N rate = 35 + [1.2 x yield goal (bu/A)] - [8 x ppm soil NO_3-N] - [0.14 x yield goal x %O.M.].

Table 7b. Suggested nitrogen application rates for irrigated corn silage (30 tons/A), based on soil NO_3-N and organic matter content.

Soil NO_3-N (ppm)*	Soil Organic Matter (%)		
	0 - 1.0	1.1 - 2.0	>2.0
	——Fertilizer rate (lb. N/A)——		
0 - 6	225	200	185
7 - 12	170	145	125
13 - 18	125	100	75
19 - 24	75	50	30
>24	25	0	0

* Average concentration of NO_3-N (ppm) in 0 to 2 ft soil layer.
Add or subtract 6 lb. N/A for every ton above or below 30 ton/A.
This table uses the formula:
N rate = 35 + [7.5 x yield goal (tons/A)] - [8 x ppm soil NO_3-N] - [0.85 x yield goal x %O.M.].

Manure is an extremely variable material whether in solid or liquid form. A representative manure sample is critical for a reliable analysis. A minimum of six sub-samples should be taken and mixed together for analysis. When sampling a solid manure stockpile, remove the crust, and use a bucket auger or a sharpshooter (a narrow shovel) to core into the pile as deeply as possible. Walk around the pile, and take samples from all sides. Deliver the sample to the lab immediately or if immediate delivery is not possible, freeze the sample in a freezer-type heavy-duty plastic bag. Manure samples should be analyzed by a reputable laboratory for moisture content, total N, NH_4 and total P at the minimum. Metals, micronutrients and E.C. are also recommended analytes.

When sampling a liquid manure or wastewater, there are several ways of sampling. You can sample from the lagoon directly with a water grab sampler (be sure to walk or boat around the lagoon and get a minimum of six samples) or you can sample from a valve inserted in the irrigation line or from cups placed in the field where the effluent is irrigated onto the land. Store the sample in a plastic jar in a cooler or freezer and deliver to the lab immediately.

Irrigation water should be analyzed for NO_3 credit, especially when shallow ground water is pumped for irrigation. These lab reports, along with a current manure analysis, should be attached to your nutrient management plan. When plant tissue tests are used to determine in-season fertilizer needs, they should also accompany the plan. See Colorado State University Cooperative Extension Fact Sheet 0.520 for information on analytical laboratories.

Crop Nutrient Need

Plant nutrient need depends upon the crop, growing conditions, and actual yield. The crop rotation will determine nutrient needs and nutrient carryover from the previous crop. In some cases, such as a three year stand of alfalfa, nutrient applications are based on more than one year of production. Table 6 indicates approximate N and P content of dry harvested crops. This information can be used to estimate actual crop nutrient removal. Due to inherent inefficiencies in plant uptake, fertilization rates often include an additional amount to compensate for these losses. Tables 7 and 8 contain current Colorado State University fertilization suggestions for selected Colorado crops; information on other crops can be obtained from your local Cooperative Extension office.

Realistic Yield Expectations

The expected crop yield is the basis for determining how much N and P fertilizer will be needed. Generally, the higher the yield expectation the higher the nutrient requirement. Over-estimating potential crop yield will result in over application of fertilizer or manure. For this reason, producers are encouraged to base yield expectations on a documented 5 year field average plus an additional 5 percent for above average growing conditions. Each field should have a yield history and expectation.

Determining Total Nutrient Needs

Crop nutrient needs are determined using your yield expectations and table values for fertilizer rates or crop nutrient removal values. Most soil laboratories will also give fertilizer recommendations with soil test results. Be sure you understand the lab's fertilizer recommendation philosophy to be sure it is compatible with the production and environmental goals of your operation.

In some cases, fertilizer application rates will need to be adjusted above or below the standard table values. Examples of these situations would be 1) where high amounts of crop residue remain, increasing N need by up to 30 lb./acre, 2) where a starter fertilizer is needed due to cool soils, 3) where alfalfa is to be maintained for more than 3 years, and 4) when manure has been applied in the previous year. Other situations may exist that justify manure rate adjustments. If so, document these adjustments on your nutrient management plan.

Table 7c. Suggested nitrogen application rates for irrigated sorghum grain (80 bu/A), based on soil nitrate and organic matter content.

Soil NO_3-N (ppm)*	Soil Organic Matter % 1 - 1.0	1.1 - 2.0	>2.0
	———Fertilizer rate (lb. N/A)———		
0 - 3	75	45	25
4 - 6	50	15	0
7 - 9	25	0	0
>9	0	0	0

* Average concentration of NO_3-N (ppm) in 0 to 2 ft soil layer.
Add or subtract 12.5 lb. N/A for every 10 bushels above or below 80 bu/A.
This table uses the formula:
N rate = [1.25 x yield goal (bu/A)] - [8 x ppm soil NO_3-N] - [0.30 x %O.M.].

Table 7d. Suggested nitrogen application rates for irrigated sorghum silage (30 tons/A), based on soil nitrate and organic matter content.

Soil NO_3-N (ppm)*	Soil Organic Matter % 0 - 1.0	1.1 - 2.0	>2.0
	——fertilizer rate (lb. N/A)——		
0 - 6	230	200	180
7 - 12	190	160	140
13 - 18	150	120	100
19 - 24	110	80	60
25 - 30	70	40	20
31 - 36	30	0	0
>36	0	0	0

* Average concentration of NO_3-N (ppm) in 0 to 2 ft soil layer.
Add or subtract 9 lb. N/A for every ton above or below 30 ton/A.
This table uses the formula:
N rate = [9 x yield goal (tons/A)] - [8 x ppm soil NO_3-N] - [30 x yield goal x %O.M.]

Table 7e. Suggested nitrogen application rates for irrigated grasses (4 tons/acre), based on soil nitrate content.

Soil NO_3-N* (ppm)	Fertilizer Rate (lb. N/A)
0 - 6	185
7 - 12	160
13 - 18	135
19 - 24	110
25 - 30	85
>30	0

* Concentration of NO_3-N (ppm) in the top foot of soil. Add or subtract 40 lb. N/A for every ton/acre above or below 4 tons/A.
Use the same N rates for grass-legume mixtures containing less than 25% legumes.

Table 8. Suggested broadcast P application rates (lbs. P_2O_5/acre).*

	$NaHCO_3$-P (ppm)			
	0 - 6	7 - 14	15 - 22	>22
	lbs. P_2O_5/acre			
Corn, irrigated and dryland	80	40	0	0
Dry Beans	80	40	0	0
Sorghum	80	40	0	0
Potatoes	240	180	120	60
Sugarbeets	100	75	50	0
Sunflowers	80	40	0	0
Wheat	80	40	0	0
Alfalfa, irrigated				
new stand	200	150	50	0
established	100	75	0	0
Alfalfa, dryland				
new stand	60	40	0	0
established	45	30	0	0
Grass and grass legume mixtures				
new stand	80	40	0	0
established	80	40	0	0

* Band application rates for row crops are half of the suggested broadcast rate.

Available N and P in Manure

The total amount of N in manure is not plant available in the first year after application due to the slow release of N tied up in organic forms. Organic N becomes available to plants when soil microorganisms decompose organic compounds such as proteins, and the N released is converted to NH_4. This process, known as mineralization, occurs over a period of several years after manure application. The amount mineralized in the first year depends upon manure source, soil temperature, moisture, and handling. In general, anywhere from 15 percent to 55 percent of the organic N in manure becomes available to the crop in the first year after application depending upon climate and management factors. Nitrogen availability can be estimated as a fraction of the total N content of manure or as a fraction of the organic N content. Organic N is usually determined by subtracting the NH_4 and NO_3 from the total N content of the manure. This approach is more accurate when reliable NH_4 content and NH_3 volatilization numbers are available.

Mineralization of N from applied manure will continue to provide nutrients to the soil system for several years after application. This additional N must be accounted for in the nutrient management plan if manure will be applied again to the same field within three years. Mineralization credit for the second and third years after application should be based upon a fraction of this initial organic N content (Table 9). Alternatively, annual soil sampling for residual soil NO_3-N, NH_4-N and organic matter can be used to estimate mineralization credit in subsequent years.

Phosphorus contained in manure is usually considered to be entirely plant available in the first year after application. In reality, some fraction of the P is tied-up in forms that are not immediately available to plants. If soil test P is in the "low to medium" range and the soil is high in lime content, it may be appropriate to assume that only 80 percent of the P will be plant available in the first year.

Volatilization Losses

Surface applied manure should be incorporated as soon as possible to reduce odor and minimize nutrient loss by volatilization and runoff. The risk of surface loss is reduced by injection application under the soil surface, but loss still may occur on sloping or erosive fields. Delayed incorporation may be acceptable on level fields if erosion control or sunlight decomposition of pathogens is desired. If solid manure is not incorporated within 72 hours after application, much of the NH_4-N fraction may be lost to volatilization (Table 10). The rate of volatilization increases under warm, dry, or windy conditions.

Table 9. Approximate percent of organic N mineralized from various manure sources over three years.

Manure Source		Percent of Organic N Available 1st year	2nd year	3rd year
		———————%———————		
Beef and dairy cattle	solid (without bedding)	30-40	10-15	5-10
	liquid (anaerobic)	25-35	5-10	2-7
Swine	solid	45-55	3-8	2-7
	liquid (anaerobic)	35-45	4-9	2-7
Sheep	solid	20-30	10-15	5-10
Horse	solid (with bedding)	15-25	5-10	2-7
Poultry	solid (without litter)	30-40	10-15	5-10

Adapted from USDA Ag Waste Management Field Handbook, 1992 and other sources.

Table 10. Approximate percentage of ammonia lost to volatilization within four days after application.

Application Method	Type of Waste	Estimated NH_3 Loss to the Atmosphere*
		————%————
Broadcast without cultivation	solid	15 - 30
Broadcast with immediate cultivation	solid or liquid	1 - 5
Injection	liquid	0 - 2
Sprinkler irrigation**	liquid	25 - 65

* Values reflect loss under each application method.
** Losses vary widely depending upon conditions at time of application.
Source: MWPS-18, Livestock Waste Facilities Handbook

Volatilization losses from liquid effluents can result in large N losses, since much of the N in effluents is in the NH_4 form, which is easily converted to ammonia gas. An accurate prediction or measurement of the amount of N volatilized from liquid manures is difficult to obtain because both the application method and the ambient climate will determine the rate of flux. Additionally, accurate measurement of NH_4 content of manure is confounded by a high degree of variability in NH_4 concentration in the manure stockpile. The current scientific literature reports losses from sprinkler applied effluents from 10 percent to over 80 percent of the ammonia fraction. For planning purposes, 20 percent to 30 percent of the ammonia can be assumed lost to volatilization during cool season application, while 40 percent to 60 percent may be assumed lost from the soil surface during summer applications. The amount of loss can be reduced by prompt incorporation. In any case, post-season soil testing will provide feedback on how much N is in the soil system after the crop is harvested. If residual N in the rootzone

Calculation 3. Estimating irrigation water N credit.

Example: N credit from 17 inches of irrigation water containing 10 ppm NO_3-N

$$\frac{17 \text{ inches /A}}{12 \text{ inches/acre foot}} \times (2.7 \text{ lb. N/acre foot}) \times (10 \text{ ppm } NO_3\text{-N}) = 38 \text{ lb. N/A}$$

Table 11. Nitrogen credits for crop requirements.

N Source	N Credit
Soil organic matter*	30 lb. N per % OM
Residual soil nitrate*	3.6 lb. N per ppm NO_3-N (1 ft. sample)
Irrigation water	2.7 lb. N per acre foot x ppm NO_3-N
Previous alfalfa crop	
>80% stand	100-140 lb. N/acre
60 - 80% stand	60-100 lb. N/acre
<60% stand	30-60 lb. N/acre
Other previous legume crop	30 lb. N/acre
Previous manure or effluent	Varies by source, rate and time (Table 9)

* These credits are factored in N rates given in tables 7a - 7e and should not be used twice.

exceeds the subsequent crop N requirement, no additional effluent, manure, or commercial N fertilizer should be applied.

Nutrient Credits

Residual soil NO_3, irrigation water, soil organic matter, and previous legume crops all contribute N to the growing crop. The N contribution from these sources must be credited in order to make accurate fertilizer and manure recommendations. Use soil and water test data and the information in Table 11 to estimate these credits. In some cases, these credits may entirely satisfy crop needs and no additional manure or fertilizer is required. A starter fertilizer may be all the supplemental fertilizer that is justified in these cases in order to enhance seedling vigor if the crop is seeded in cool soils.

Irrigation water containing NO_3 can supply N to the crop since it is applied and taken up while the crop is actively growing. Water tests for NO_3-N should be taken periodically during the irrigation season to accurately calculate this credit. Multiply p.m. NO_3-N by 2.7 lb./acre foot times the amount of irrigation water consumptively used by the crop prior to the mid-reproductive stage (in acre feet) to determine lbs. N/acre applied in the irrigation water. Inexpensive quick tests are available for on-farm water testing. If a water sample is taken for laboratory analysis, it should be kept refrigerated, but not frozen, until it gets to the lab.

Legume crops can be a very significant source of plant available N due to bacterial N_2 fixation in root nodules. Plowing down a good stand of alfalfa may release more than 100 lbs. of N per acre in the first year after plowdown. The amount of N credit given for legumes depends upon the crop, stand, and degree of nodulation. A minimum of 30 lbs. of N/acre should be credited in the first year after any legume crop (Table 11).

Total all available nutrient sources from soil testing, irrigation water, legumes and any other organic amendments to determine the total nutrient credit. Due to the difficulty of accurately assessing these credits, be sure to scout fields for nutrient sufficiency during the vegetative growth stages.

Recommended Nutrient Application Rate

Once you have analyzed crop needs, nutrient credits, and manure nutrient content, you can determine manure application rates. Total crop nutrient need minus total nutrient credits will equal the recommended nutrient application rate. This can be satisfied by manure, fertilizer, or a combination of both.

In general, manure and effluent application should be avoided on frozen fields unless a site specific analysis shows that runoff will not occur. Effluent or manure should not be applied to any soil that is saturated or has a snow pack of greater than one inch. Additionally, animal waste should not be applied to soils that are frequently flooded, as defined by the National Cooperative Soil Survey, during the period when flooding is expected to occur.

Manure is most valuable as a nutrient source if it is applied as close to planting as possible. However, manure with a high salt content may affect germination and seedling growth of sensitive crops, such as beans. If fall application is necessary in order to clean out manure storage areas, try to wait until after soil temperature is less than 50°F to reduce organic N and NH_4 conversion to NO_3. If irrigation equipment is available to apply liquid manure, the best practice is to apply manure in frequent, light applications during the growing season to match crop uptake patterns and nutrient needs.

If manure is applied at the maximum rate based upon crop N needs, additional fertilizer N should not be applied. Maximum rate is based upon a one-time application. If yearly application of manure or effluent is made, lower rates

Calculation 4. Determining agronomic rate of manure application.

Example 4a. Beef feedlot manure broadcast applied and incorporated immediately

Manure application rate based upon N requirement:

Step 1: Calculate available N in manure

N content of manure = 23 lb. total N/ton including 7 lb. NH_4-N/ton (from Table 4)

Available N = 35% availability x (23 lb./total N/ton manure - 7 lb. NH_4-N/ton) + 7 lb. NH_4-N/ton (from Table 8)
= 12 lb. available N/ton manure

Step 2: Determine crop N requirement

ex. soil contains 1.5% organic matter and 6 ppm residual soil NO_2-N
N required for 175 bu corn crop = 185 lb. N/acre (from Table 7a)

Step 3: Subtract N credits from other sources.

ex. 25 lb. NO_3-N (in 2-4 foot subsoil sample)
185 lb. N required - 25 lb. subsoil N
= 160 lb. N needed

Step 4: Calculate agronomic manure rate.

= (160 lb. N/acre) / (12 lb. available N/ton manure)
= 13 tons manure/acre

Step 5: Calculate phosphorus supplied by manure (based on N rate)

13 tons manure/acre x 24 lb. P_20_5/ton manure
= 312 lb. P_20_5/acre supplied by manure

Manure application rate based upon P requirement:

Step 1: Calculate available P in manure

Total P_20_5 = 24 lb. P_20_5/ton (from Table 4)
Available P_20_5 = 80% availability x 24 lb. P_20_5/ton manure
= 19 lb. available P_20_5/ton manure

Step 2: Determine crop P requirement

ex. $NaHCO_3$ extractable P = 6 ppm (low range) and soil lime content is high
P required for 175 bu corn crop = 80 lb. P_20_5 (from Table 8)

Step 3: Determine agronomic manure rate

= (80 lb. P_20_5/acre) / (19 lb. available P_20_5/ton manure)
= 4 tons manure/acre

Step 4: Calculate nitrogen supplied by manure (based on P rate)

4 tons manure/acre x 23 lb. total N/ ton manure
= 92 lb. total N/acre supplied by manure.

Calculation 4. Determining agronomic rate of manure application, continued.

Example 4b. Swine effluent from a two stage anaerobic lagoon

Effluent application rate based upon N requirement:

Step 1: Calculate available N in effluent

N content of manure = 4 lb. total N/1000 gal including 3 lb. NH_4- N/1000 gal (from Table 4)

Available NH_4-N = 50% volatilization x 3 lb. NH_4-N/1000 gal effluent (from Table 10)
= 1.5 lb. available NH_4-N/1000 gal effluent

Available organic N = 1 lb. organic N x 40% mineralization (Table 9)
= 0.4 lb. available organic N

Total available N = 1.5 lb. NH_4-N + 0.4 lb. organic N
= 1.9 lb. available N/1000 gal effluent
= 52 lb. available N/acre inch*

Step 2: Determine crop N requirement

ex. soil contains 1.5% organic matter and 6 ppm residual soil NO_2-N
N required for 175 bu corn crop
= 185 lb. N/acre (from Table 7a)

Step 3: Subtract N credits from other sources.

ex. 25 lb. NO_3-N in 2-4 foot subsoil samples
185 lb. N required - 25 lb. subsoil N
= 160 lb. N needed

Step 4: Determine agronomic effluent rate.

= (160 lb. N/acre)/(52 lb. available N/acre inch effluent)
= 3 inches effluent/acre (to be applied in 2 or more applications)

Step 5: Calculate phosphorus supplied by effluent (based on N rate)

3 acre inches effluent x 2 lb. P_2O_5/1000 gal effluent x 27.15
= 163 lb. P_2O_5/acre supplied by effluent

* Multiply lb/1000 gal effluent by 27.15 to convert to lb./acre inch.

Effluent application rate based upon P requirement:

Step 1: Calculate available P in effluent

Total P_2O_5 = 2 lb. P_2O_5/1000 gal effluent (from Table 4)

Available P_2O_5 = 80% availability x 2 lb. P_2O_5/1000 gal effluent
= 1.6 lb. available P_2O_5/1000 gal effluent
= 43 lb. available P_2O_5/acre inch effluent*

Step 2: Calculate crop P requirement

ex. $NaHCO_3$ extractable P = 6 ppm (low range) and soil lime content is high
P required for 175 bu corn crop = 80 lb. P_2O_5/acre (from Table 8)

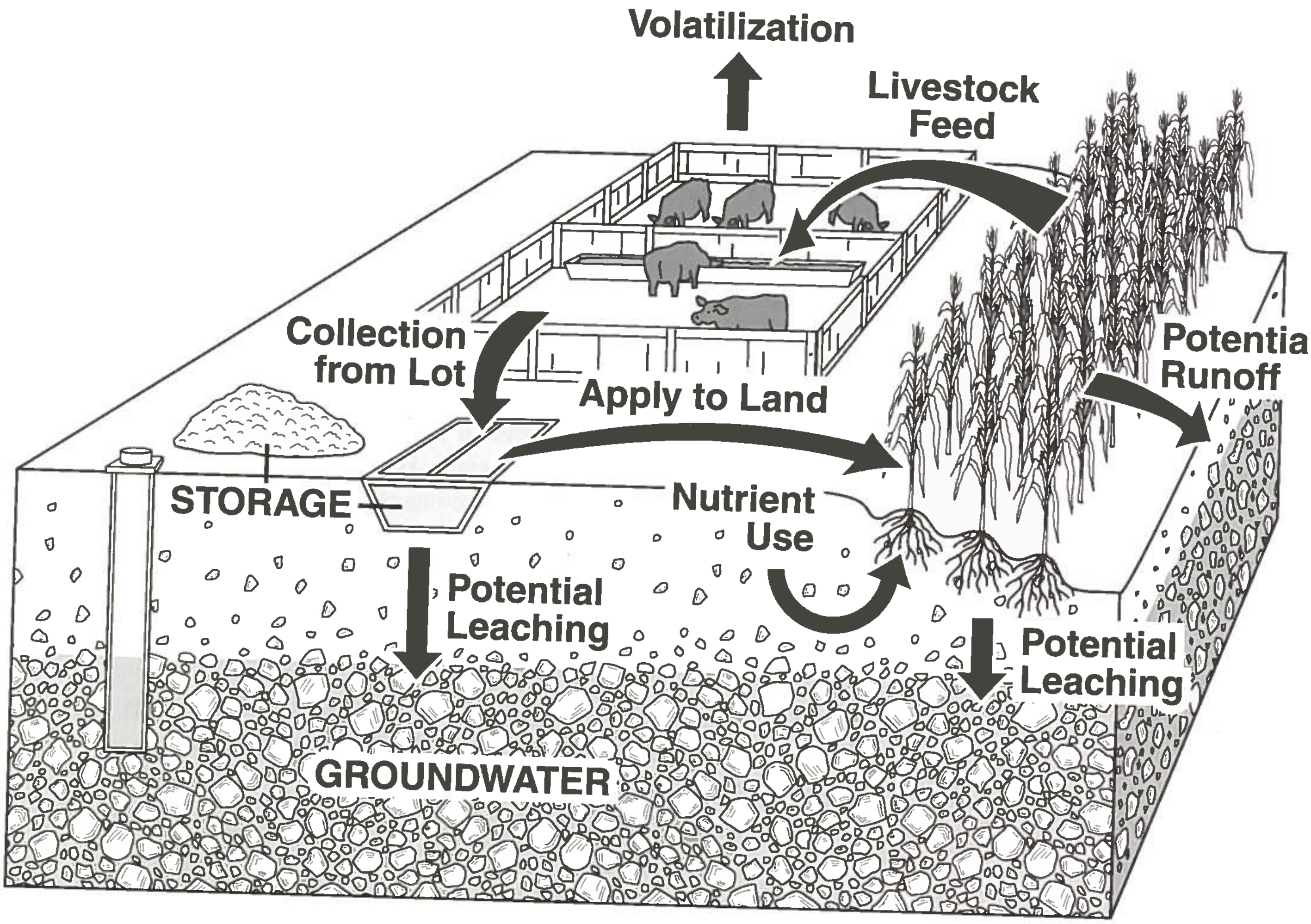
Step 3: Determine agronomic effluent rate.

= (80 lb. P_2O_5/acre) / (43 lb. available P_2O_5/acre inch effluent)
= 2 acre inches of total effluent/acre for this crop year
(To be applied in 2 or more applications)

Step 4: Calculate nitrogen supplied by effluent manure (based on P rate)

2 acre inches effluent/acre x 52 lb. available N/acre inch
= 104 lb. available N supplied by manure

* Multiply lb/1000 gal effluent by 27.15 to convert to lb./acre inch.



are recommended and annual soil sampling is needed to track soil N and P levels. If soil N, P or E.C. increases significantly over time, manure use should be discontinued until nutrients in the rootzone decline below crop response thresholds.

NMP Section 3. Nutrient Use Summary

Operation and Maintenance

Farm-wide accounting of manure and fertilizer application is the final aspect of a nutrient management plan. This is important to help document a balance between manure production and utilization. Worksheet 3 is provided to help record annual application data. After tallying total nutrient application, you can evaluate nutrient sufficiency or excess on the farm by comparing these numbers to manure production on Worksheet 1.

A number of other items should be assessed on an annual basis as a part of nutrient management planning. These include equipment calibration, soil tests, and monitoring water quality near the operation.

Accurate record keeping is an essential component of any manure management program. Keeping accurate records allows managers to make good decisions regarding manure and nutrient applications. Additionally, these records provide documentation that you are complying with state and local regulations to protect Colorado's water resources. All operators should maintain records of nutrient management plans for at least three years.

Spreader Calibration

The value of carefully calculating manure application rates is seriously diminished if manure spreaders are poorly calibrated. Proper calibration is essential in order to apply manure correctly. Manure spreaders discharge at widely varying rates, depending on travel speed, PTO speed, gear box settings, discharge openings, and manure moisture and consistency.

Calibration requires measurement of manure applied on a given area. To check spreader calibration, you must know the field size. Secondly, count the number of loads of manure applied to the field. Weigh at least three of the loads, and calculate the average weight. Finally, multiply the number of loads by the average weight, and then divide by the field acreage. This provides you the average application rate per acre for the field. Adjust the spreader or ground speed as necessary to achieve the desired rate. Remember to recheck the calibration whenever a different manure source with a new moisture content or density is applied. Using good equipment and the proper overlap distance will ensure better nutrient distribution and help avoid "hot spots" or areas with nutrient deficiency. (See Colorado State University Cooperative Extension fact sheet 0.561 for more information on spreader calibration.)

Follow Up and Monitoring

Determining agronomic rates of manure or effluent application is not an exact science. Climactic, soil, and management factors influence crop nutrient uptake, mineralization rate, volatilization and overall nutrient availability. Producers must continue to monitor crop yields, as well as soils within and below the rootzone, to determine what adjustments are needed each year in the operating plan to continue protecting water quality.

Best Management Practices for Manure Utilization

Guidance Principle: Collect, store, and apply animal manures properly to optimize efficiency while protecting water quality.

To select manure BMPs that achieve water quality goals and the greatest net returns for your operation, consider:

- most suitable practices for your site and management constraints
- need to protect sensitive resources and areas

General BMPs

3.1 Develop a nutrient management plan for your operation that includes:

1. Estimates of manure production on your farm
2. Farm maps which identify manure stockpiles, potential application sites and sensitive resource areas
3. Cropping information
4. Soil, plant, water, and manure analysis
5. Realistic crop yield expectations
6. Determination of crop nutrient needs
7. Determination of available nutrient credits
8. Recommended manure rates, timing, and application methods
9. Operation and maintenance plans

3.2 Base manure application rates on crop phosphorus (P) needs IF soil test P is in the high or very high category, the field drains to any sensitive surface water body, AND P movement is likely. In most other cases, application rates may be based on crop N needs.

3.3 Apply commercial N and P fertilizer to manured fields only when soil available N and P from manure application does not satisfy crop needs.

3.4 Cease effluent application if crop is destroyed during growing season. Plant winter cover crops to scavenge excess nutrients when crop uptake is lower than expected due to hail or other yield limitations.

3.5 Maintain nutrient management plans and actual manure and fertilizer management records on file a minimum of three years or the duration of your crop rotation, if longer than three years.

3.6 Scout fields for nutrient deficiencies/sufficiency throughout the season in order to identify and correct problems that may limit economic crop yields.

Manure Application BMPs

3.7 Incorporate manure as soon as possible after application to minimize volatilization losses, reduce odor, and prevent runoff.

3.8 Apply manure uniformly with properly calibrated equipment.

3.9 Time liquid manure applications to match crop nutrient uptake patterns in order to minimize the opportunity for NO_3 leaching on coarse textured soils. Effluent application amounts must not exceed the soil water holding capacity of the active rootzone. Several light applications of liquid manure during the growing season are better than a single heavy application.

3.10 Limit solid manure application on frozen or saturated ground to fields not subject to runoff. Liquid effluent should not be applied to frozen or saturated ground.

3.11 Create a buffer area around surface water and wells where no manure is applied to prevent the possibility of water contamination.

3.12 Plant permanent vegetation strips around the perimeter of surface water and erosive fields to catch and filter nutrients and sediments in surface runoff.

3.13 Apply manure on a rotational basis to fields that will be planted to high N use crops such as corn or forage. Long-term annual applications to the same field are not recommended, except at low rates.

Manure Collection and Storage BMPs

3.14 Locate manure stockpiles, lagoons, and ponds a safe distance from all water supply wells. Manure stockpiles, lagoons, and runoff collection ponds should be located on areas not subject to leaching and must be above the 100 year flood plain, unless adequate flood proofing structures are provided.

3.15 Inspect lagoons and liquid manure storage ponds regularly to ensure seepage does not exceed state and local restrictions.

3.16 Divert runoff from pens and manure storage sites by construction of ditches or terraces. Collect runoff water from the lot in a storage pond; minimize runoff volume by diverting runoff water from crossing the feedlot.

3.17 Clean corrals as frequently as possible to maintain a firm, dry corral surface with the loose manure layer less than one inch deep and pen moisture content between 25 percent to 35 percent. Avoid mechanical disturbance of the manure-soil seal when cleaning feedlots. Create a smooth surface with a 3 percent to 5 percent slope when scraping lots.

3.18 Scrape feedlots or manure storage areas down to bare earth and revegetate after they are permanently abandoned.

Solid manure application

Nutrient Management Plan Guidelines

1. Using **Worksheet 1**, determine the approximate nutrient inventory from manure production on your farm. If you use manure but do not produce any on your farm go to Worksheet 2.
2. Attach farm maps identifying fields receiving manure, waste storage facilities and natural resource areas of special concern, such as streams, groundwater recharge areas, wetlands, public or private drinking water wells.
3. Fill out 1 copy of **Worksheet 2** per field identifying:
    - cropping sequence
    - yield expectations
    - crop nutrient needs
    - nutrient credits
    - planned manure and or fertilizer rates
    - note any special management needed to protect natural resource areas of special concern.
4. Attach soil tests, manure analysis, irrigation water tests, and plant tissue analysis used to determine proper nutrient rates.
5. Use **Worksheet 3** to document whole farm nutrient use.
6. Attach information on feed management to reduce nutrients, manure treatment to reduce nutrient content or volume, and land management practices used to modify manure loading rates. If other manure utilization options are used, such as composting or sale to other producers, document amount of manure diverted annually.
7. Indicate who prepared forms and date them.
8. Nutrient management plan should be reviewed and evaluated annually.

Worksheet 1. Determination of Nutrient Inventory from Manure Production

Livestock Type	Average Animal Weight[1]	Average Manure Production Per Animal[2]	Average Number Animals Per Year	Total Manure Production[3]	Manure Analysis[4] Total N	Manure Analysis[4] P_2O_5	Total Nutrient Production[5] Total N	Total Nutrient Production[5] P_2O_5
		—1000 gal— or ——tons——		—1000 gal— or ——tons——	——lb/1000 gal—— or ——lb/ton——		————lb————	
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
______	______	______	______	______	______	______	______	______
Total			______	______			______	______

Notes:

Prepared by:______________________________ Date:______________

[1] Average animal weight should be based on the average over the entire year.
[2] Average production per animal should be on an as-applied basis. See Tables 2 and 3 for guidelines.
[3] Total manure production is determined by multiplying Average Manure Production per animal by the average number of animals per year.
[4] Manure analysis will be lbs of nutrients (Total N and P_2O_5) per 1000 gal or per ton. In lieu of lab analysis, use values in Table 4.
[5] Multiply total manure production by manure analysis to determine total nutrient production.

Worksheet 2. Determination of Manure Application Rates for Field: ____________

(Field ID)

1. Field information

Crop ______________ Crop year ________ Number of acres ______________

Soil name/texture ______________ Previous crop ______________

2. Nutrient need

	N	P_2O_5
	——lb./acre——	
a) Expected yield ______________		
b) Nutrient recommendations from soil test report	______	______
c) Special nutrient need above test recommendations	______	______
d) ***Total nutrient need***	______	______

3. Nutrient credits

	N	P_2O_5
	——lb./acre——	
a) Residual soil credit*	______	
b) Irrigation water credit	______	
c) Organic matter credit*	______	
d) Previous legume crop	______	
e) Mineralization from previous manure applications	______	
f) Other: ______________	______	______
g) ***Total nutrient credit***	______	______

*If not included in 2b above.

4. Recommended nutrient application rate — N — P_2O_5

a) **Total nutrient need** minus **Total nutrient credit** (lb./acre) ______ ______

b) Expected NH_3-N volatilization ______%

NH_4-N available from manure ______ lb./ton or lb/1000 gal

c) Expected mineralization ______%

Organic N available from manure ______ lb./ton or lb/1000 gal

d) Total available N ______ lb./ton or lb/1000 gal

e) Recommended manure application rate ______________

(tons/acre) or (1000 gal/acre) or (acre inch)

5. Post season follow-up

Actual crop yield ______________ Total irrigation water applied ________(inches/acre)

Supplemental fertilizers applied ________ lbs N/a Total manure applied ______________

(tons/acre) or (1000 gal/acre)

________ lbs P_2O_5 /A

Prepared by: ______________ Date: ______________

Worksheet 3. Whole Farm Nutrient Use Summary   For Crop Year: ____________

Field	Size —acres—	Crop	Recommended Nutrient Application Rate —lb/acre—		Manure Application Rate —tons/acre— or —1000 gal/acre—	Total Manure Applied Per Field[1] —tons— or —gallons—	Additional Fertilizer Applied —lb/acre—	
			N	P_2O_5			N	P_2O_5
Whole Farm Total Manure Applied								

[1] Total manure applied is calculated by multiplying field size (acres) by manure application rate.

Prepared by:____ Date:____________________

For more information about manure management or specific inquiries about BMPs, contact Colorado State University Cooperative Extension. They have publications, programs, and specialists available to help you answer questions about water quality.

Related source material from Colorado State University Cooperative Extension:

Fact Sheets:	0.500	Soil sampling
	0.501	Soil testing
	0.520	Selecting an analytical laboratory
	0.534	Fertilizing spring-seeded small grains
	0.535	Fertilizing mountain meadows
	0.537	Fertilizing alfalfa and grasses
	0.538	Fertilizing corn
	0.539	Fertilizing dry beans
	0.540	Fertilizing grain and forage sorghums
	0.541	Fertilizing potatoes
	0.542	Fertilizing sugarbeets
	0.543	Fertilizing sunflowers
	0.544	Fertilizing winter wheat
	0.546	Organic materials as nitrogen fertilizers
	0.550	Nitrogen sources and transformations
	0.560	Cattle manure application rates
	0.561	Manure spreader calibration
	1.219	Horse manure: a renewable resource
	1.220	Feedlot manure management
	1.221	Liquid manure management
	1.222	Liquid manure application to cropland
	1.223	Liquid manure application methods

Additional resources: USDA Agricultural Waste Management Field Handbook, 1992.