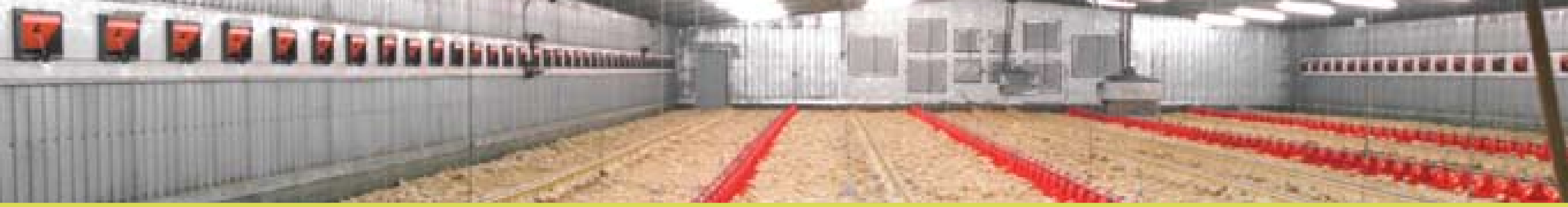


Chapter 6.
NUTRIENT MANAGEMENT PLANNING

This chapter explores:

- features of a nutrient management plan
- managing nutrients in manure
- nutrient use efficiency
- field assessment
- soil and manure sampling
    - interpreting manure test results
- manure inventory
- crop nutrient replacement

Your crops require adequate nutrients and conditions to produce your target yields. Some of these nutrients are supplied through the soil, but additional nutrients might need to be provided through the application of commercial fertilizer, manure, compost or crop residue. However, the application of excess nutrients poses a threat to the environment. Matching nutrient levels to crop demand protects the environment and maximizes the benefit of supplying valuable nutrients to your crops.

Manure and compost can provide many benefits to crops and the soil if handled properly. Manure is a source of plant nutrients. As well, its application to the land can improve soil tilth, structure and water-holding capacity, especially for poor quality soils, coarse-textured soils, soils low in organic matter or degraded soils. However, if manure application is not properly managed, excess nutrients may be applied to agricultural land, affecting soil and water quality. Manure is also a source of nitrogen gases, including ammonia and nitrous oxide (a greenhouse gas), which can be released during application, reducing air quality.

Nutrient management planning is not simply an accounting exercise. Although the paperwork of keeping records and calculating application rates is necessary, you also need to know where, how and when to apply nutrients for maximum benefit to crops and least impact on the environment. In other words, you need to ensure that what you planned is actually happening.

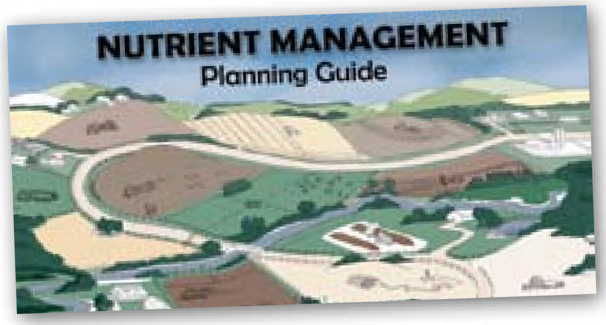
Nutrient management planning aims to optimize crop yield and quality, minimize fertilizer input costs, effectively use manure and compost, and protect soil, water and air quality. It focuses on applying the right amount of the nutrient-containing product in the right place at the right time. This involves setting realistic target yields, choosing the correctly balanced blend of nutrients, placing the nutrients as close to the growing plant as possible without damaging the plant, and applying the nutrients as close as possible to the time when the plants are actively growing.

Nutrient management planning uses a balanced fertility perspective, considering the amounts of all nutrients in the soil and the crop's requirements. Balanced fertility involves calculating and applying the appropriate amount of each nutrient, rather than basing recommendations on only one nutrient. A slight deficiency in one nutrient can affect the plant's ability to take up another nutrient. This results in unused nutrients that may be susceptible to leaching, runoff or gaseous losses.

ALL AGRICULTURAL OPERATORS in Alberta must manage nutrients in accordance with the standards in the *Agricultural Operation Practices Act* (AOPA).

Balanced fertility results in a well-fed crop, which produces a healthier, more extensive root system able to explore a greater area in search of nutrients and water. This results in more efficient extraction of nutrients and water, and because a higher yield is produced with the same amount of water, crop water use efficiency is improved.

Balanced fertility management also reduces erosion potential. The crop grows faster so the soil surface is covered more rapidly, protecting it from wind and water erosion. In addition, more biomass is produced so more crop residues can be left behind to protect against erosion.



For more information on nutrient management planning, get the Nutrient Management Planning Guide from the Publications Office of Alberta Agriculture and Rural Development (ARD) or download it from www.agriculture.alberta.ca.

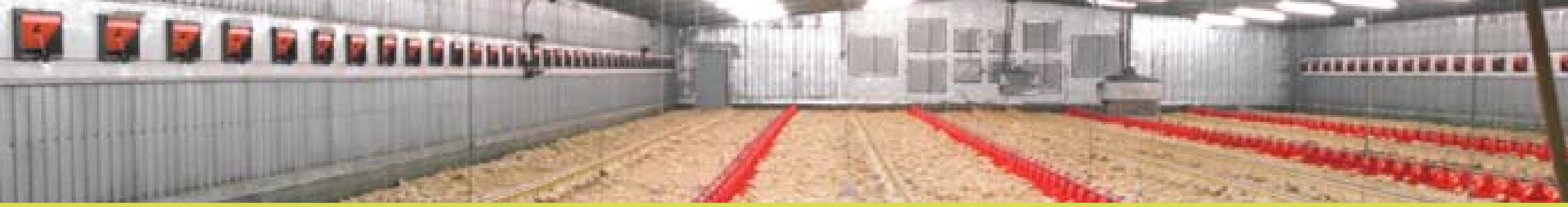
A TYPICAL NUTRIENT MANAGEMENT PLAN IN ALBERTA CONSISTS OF THE FOLLOWING COMPONENTS:

1. Field (or site) assessment – includes soil test information, area, soil texture, estimated length and grade of any slopes, problem soil conditions (e.g. solonetzic soils) and limiting physical features such as environmentally sensitive areas (e.g. water bodies).
2. Manure inventory – includes estimated nutrient content (from lab analysis or standard values), estimated manure volume(s) and desired information about the animal population or the operation (e.g. number of animals, phase of production, housing and feeding system, etc.).
3. Nutrient application plan – includes information about manure application and incorporation methods, equipment calibration, planned crop rotation, cropping system, crop fertility requirements, planned manure and commercial fertilizer application rates, nutrients applied from all nutrient sources, timing of application and incorporation.
4. Land management plan – includes information on production practices and other control systems to reduce post-application nutrient losses.
5. Record keeping system – includes a system of record keeping, and if required, a system that complies with the AOPA record keeping requirement for manure handling, application and transfer.

6.1 MANAGING NUTRIENTS IN MANURE

Manure should be managed as a resource to maximize its benefits and minimize its risks. To use manure as a resource, it is important to understand its composition.

The macronutrients in manure that contribute to plant growth are nitrogen, phosphorus, potassium, calcium, magnesium, sodium and sulphur. Manure also contains micronutrients such as boron, chlorine, copper, iron, molybdenum, zinc, selenium, chromium, iodine and cobalt. Manure provides the same nutrients for crop production as commercial fertilizers, though the



challenge with manure is the forms and ratio of the nutrients are not easy to change, nor easy to match to crop requirements.

Over-application of manure can lead to problems such as contamination of water sources with nutrients and pathogens, emission of odours and greenhouse gases, nutrient loading in the soil leading to crop lodging, and salt accumulation resulting in poor yields. The two most important nutrients to consider when managing manure to reduce risks to the environment are nitrogen (N) and phosphorus (P).

6.1.1 Manure Nutrient Availability

Testing soil and manure to determine their nutrient levels is the only way to be sure about how much manure to apply. Some nutrients in manure and other organic nutrient sources such as compost are in an inorganic form, which is readily available for crop uptake; other nutrients are slowly converted from an organic form to an inorganic form.

Nutrients such as nitrogen and phosphorus are present in manure in both inorganic and organic forms. Crops can not readily absorb and use nutrients in their organic from. Nutrients in their organic form must be transformed by soil micro-organisms into inorganic forms that crops can use. The process of conversion from organic compounds to inorganic compounds happens over time. So portions of the organic nutrients are converted each year into the inorganic forms that crops can use.

The inorganic forms of nutrients are immediately available to and usable by crops (Table 6.1). In manure the primary form of inorganic nitrogen is ammonium, whereas in compost the primary form of inorganic nitrogen is nitrate. Ammonium can quickly be converted into ammonia, which is a gaseous compound that readily volatilizes, or gasses off, so it is at risk of being lost from the productive system. Nitrate-N will not volatilize, but instead this form is soluble in water and is therefore at risk of being lost via surface runoff or leaching.

The higher the ammonium content of the manure, the higher crop-available nitrogen in the manure, and the greater the risk and therefore the cost of ammonium nitrogen losses during application. Manure types such as liquid dairy, liquid swine or poultry manure have a high concentration of ammonium in the manure. This means that a higher percentage of the nitrogen is available in the year of application and this manure has the highest risk of nitrogen loss.

Table 6.1 Form and Availability of Nitrogen and Phosphorus in Manure

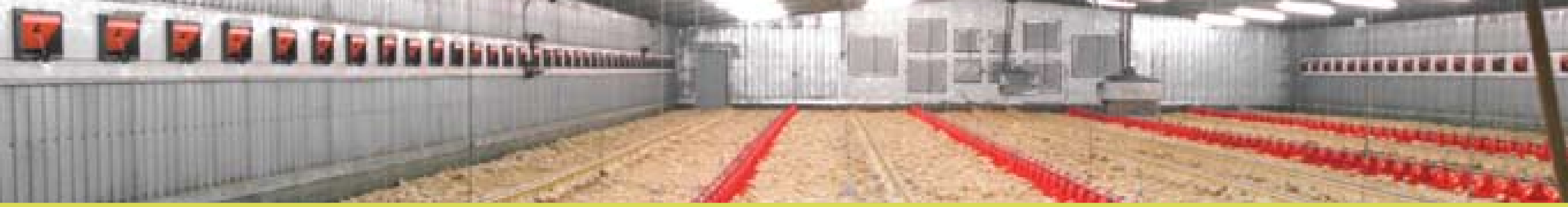
Nutrient	Form in Manure	Available 1st Year	Available 2nd Year	Available 3rd Year	Environmental Risks
Nitrogen (N)	Inorganic N •Ammonium (NH_4^+) •Nitrate (NO_3^-) Organic N	NH_4^+ + NO_3^- + 25% of organic N content (for solid manure), 40% of organic N content (for liquid manure), 30% of organic N content (for poultry manure)	12% of initial organic N content (for solid manure), 20% of initial organic N (for liquid manure), 15% of organic N content (for poultry manure)	6% of initial organic N content (for solid manure), 10% of initial organic N (for liquid manure), 7% of organic N content (for poultry manure)	• Nitrate in groundwater • Volatilization[a] of ammonia • Denitrification[b] as nitrous oxide
Phosphorus (P)	Inorganic P ($H_2PO_4^-$ and HPO_4^{2-}) Organic P	70% of initial total P content	20% of initial total P content	6% of initial total P content	• P in surface runoff (particulate and dissolved) • P leaching into groundwater

a. Volatilization is the gaseous loss of a substance (e.g. ammonia) into the atmosphere.
b. Denitrification is the transformation, under high moisture or saturated soil conditions, of nitrate to gaseous forms, which can be lost to the atmosphere.
Note: The percentages listed in the table are only estimates. The availability of nutrients from organic sources, such as manure, depends on biological processes in the soil. These processes are affected by many factors, such as temperature, moisture and soil type.

The ratio of nitrogen to phosphorus in manure varies with livestock type, feed type and ration, and manure handling system. The ratio of these nutrients in manure does not match the crop's requirements. Cattle manure, for example, may contain 1 to 2 parts of nitrogen to 1 part of phosphorus (a ratio of 1:1 to 2:1). Crops require between 3 and 7 parts of nitrogen per 1 part of phosphorus (a ratio of 3:1 to 7:1). Due to this imbalance, manure application will provide either too little or excess nutrients for optimal crop growth.

A FEW FACTS ABOUT NITROGEN AND PHOSPHORUS:

- Plants can readily use inorganic nitrogen in the form of ammonium or nitrate.
- Organic nitrogen must be transformed to ammonium (via mineralization) or nitrate (via nitrification) form before plants can use it.
- Phosphorus (P) is generally found in three forms: particulate phosphorus (P attached to sediments), dissolved phosphorus (water-soluble P) and organic phosphorus.
- Plants can readily use dissolved phosphorus.



6.1.2 Managing Nutrient Losses and Risks

The plant nutrients in manure that are of greatest environmental concern are nitrogen and phosphorus. Losses of nutrients such as nitrogen and phosphorus from the soil through erosion, leaching or gaseous emissions can have serious environmental impacts as well as economic impacts through the direct loss of valuable nutrients and through the cost of replacing nutrients that have been lost.

Nitrogen and phosphorus behave in different ways once applied to the soil. Nitrogen in nitrate (NO_3^-) form moves easily with water. As a result, it can move across the soil surface with runoff or it can be leached below the root zone as water infiltrates and could eventually enter the groundwater. Nitrogen in ammonia (NH_3^-) form can gas off the soil surface to the atmosphere. Organic nitrogen is moved from the soil surface with soil erosion events.

Phosphorus, on the other hand, binds tightly to soil materials and does not move as readily with the soil water unless there are high phosphorus levels in the soil. As a result the most common pathway for phosphorus to enter water is through soil erosion. In situations with high soil phosphorus concentrations the amount of dissolved and unbound phosphorus increases in the soil solution, leading to increased phosphorus movement in water solution.

Many factors influence the potential movement of nitrogen and phosphorus to surface and groundwater including:

- soil type, texture and slope
- proximity of the nutrient to surface and groundwater
- soil fertility levels
- manure application and land management practices.

Factors that influence nutrient movement off a field need to be assessed on a site-by-site basis to determine their relative importance. So, for example, where soil phosphorus levels, as determined by soil tests, are high and erosion potential is high, the risk of phosphorus contamination of surface water from manure application is also high. In fact, the high risk may only apply to a portion of the field that is directly connected to the watercourse or water body. So management practices may be implemented in portions of the field to address the areas of higher risk.

For groundwater to be contaminated there must be both a source of nitrate in the soil and the opportunity for transport down the soil profile. Nitrate may be present in the soil from nutrients applied and not used during the crop year or from fertilizers or manure applied after crop harvest. Ammonium-nitrogen can volatilize to the air as ammonia gas if the manure is surface-applied, but when incorporated into warm, well aerated soil it's converted to nitrate quickly; the process is slower in cool, wet soils. Organic nitrogen must be mineralized to ammonium and then converted to nitrate, so this process generally proceeds slowly. The rate of all nutrient conversion processes depends on the temperature, so manure applied in the summer is much more likely to be converted to nitrate than manure applied in the late fall.

During the growing season usually crops are removing more water than is being added as precipitation, so normally there is no leaching or downward movement of nitrates. During the fall or after crop harvest, there are no growing plants to use any remaining nitrates and the amount of precipitation can be greater than evaporation, so water can move down through the soil profile, increasing the risk of nitrate leaching.

The rate of water movement down through the soil depends on the soil porosity. Gravel and sand soils are more porous than silt and clay soils. Shallow soils over bedrock provide less protection for groundwater, because contaminants aren't being filtered once they reach the fractures in bedrock.

To reduce nutrient losses by wind and water erosion:

- Leave some of last year's crop residue on the soil surface and reduce tillage. This increases water infiltration and reduces nutrient losses due to erosion.
- Include perennial forages in the rotation to increase infiltration, reduce the impact of wind and water on the soil, reduce nutrient losses, and take advantage of deep-rooted crops to harvest nutrients from deep in the soil profile.
- Establish grassed waterways in erosion-prone areas to slow water movement from the field and trap soil particles.
- Plant trees for windbreaks, reduce field widths or use strip cropping to reduce the distance wind travels in crossing unprotected fields.
- Build a runoff control basin or an embankment across a depression to slow water movement, trap sediments and reduce gully erosion. Slower water movement encourages organic matter, sediments and nutrients in the water to settle out or be trapped by surface residue.

Generally, surface-applied manure is susceptible to movement of nutrients in surface runoff.

To reduce nutrient losses from surface-applied manure by surface runoff:

- Apply manure as close as possible to the time of the crop's need, when crops are actively growing, in the spring for spring-seeded annual crops, and before seeding fall cereals.
- Inject or incorporate the manure as soon as possible.
- Do not apply manure if heavy rain is predicted within 24 hours after manure application.
- When a high amount of nitrogen is required by a crop, split the total amount required into two-thirds manure and one-third mineral fertilizer. Apply mineral fertilizer later in the season.
- Leave a buffer zone around lakes, streams and wells that meets or exceeds AOPA's setback requirements. Do not apply manure or commercial fertilizer to the buffer.
- Do not apply manure to frozen or snow-covered ground.

6.1.2.1 Nitrogen

Generally, the environmental risks associated with inorganic nitrogen are losses to water sources through leaching and surface water runoff or losses to air through denitrification and volatilization.

To reduce ammonium (NH_4^+) nitrogen losses into the air through volatilization:

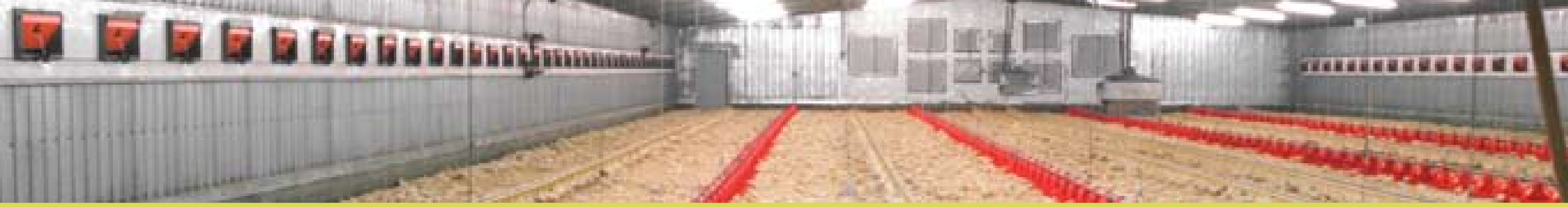
- Apply manure on humid and/or cold, non-windy days.
- Inject the manure or incorporate manure as soon as possible.

To reduce nitrate (NO_3^-) nitrogen losses to the air through denitrification:

- Avoid manure application in low, wet areas, where water can pool.
- Apply manure just before seeding, so nutrients can be used while plants are actively growing.

To reduce nitrogen losses to groundwater by leaching:

- Apply manure at agronomic rates; if nitrogen builds up in the soil profile it is at risk of being lost through leaching.
- Incorporate manure to increase the contact between the soil and the manure to tie up nutrients.
- Manage irrigation water application rates to minimize the risk of nitrogen leaching.



- Avoid spreading manure in low, wet areas or field areas prone to puddling.
- Apply manure just prior to seeding, so nutrients are used while plants are actively growing; unused nitrogen is at risk of being lost through leaching.
- Grow cover crops to capture available nitrogen and other nutrients and reduce water leaching.

6.1.2.2 Phosphorus

Generally, the environmental risks associated with phosphorus are losses to surface water sources through soil erosion or movement of dissolved phosphorus with surface runoff.

To reduce phosphorus losses:

- Inject or incorporate fertilizers and manure to avoid losses by runoff in areas that are adjacent to water bodies and/or have high runoff potential.
- Apply phosphorus based on the crop's P requirements and soil P levels. Contact a crop adviser or soil laboratory for recommended P levels for each crop.
- Test soil phosphorus annually to avoid over-applying fertilizers and manure. Over-application of manure will raise soil phosphorus levels above the recommended agronomic levels, increasing the risk of P loss from soils.
- Test soils in different landscape locations (e.g. hill tops, low spots) to determine if excess levels exist in low areas where runoff collects.
- Alter cropping, nutrient or soil management practices to reduce nutrient application, increase nutrient uptake and removal, or reduce the amount of runoff that is occurring.
- Take measures to prevent soil erosion by wind and water (see erosion control options listed above).
- Design a nutrient management plan based on phosphorus for areas that are particularly vulnerable to phosphorus runoff or leaching (e.g. flood plains, steeply sloped land, land with high water tables or shallow aquifers).

6.1.2.3 Potassium

Generally, potassium is not lost from the soil or production system. The risks associated with potassium are due to the accumulation of this nutrient in the soil and eventually in the growing crop. Excess potassium (K) in feed has been observed to reduce the absorption of magnesium (Mg) in the rumen, which is an important site of Mg absorption, resulting in overall impairment of Mg absorption. Low magnesium absorption from consumed forages is the most obvious cause of tetany. Unlike calcium, there is very little magnesium stored in the bones. Magnesium needs to be supplied in cattle rations on a daily basis.

To reduce the risk for tetany development due to potassium accumulation:

- Soil test prior to applying manure to determine K status of the field.
- Apply manure and fertilizer at agronomic rates to minimize the risk of K-related Mg deficiencies in your livestock feeds.
- Use nutrient management planning combined with improved manure application practices aimed at reducing nitrogen loss to help prevent K build-up in the soil.
- Test all feeds to assess the risk of tetany.
- Prevent tetany through ration supplementation.

6.1.2.4 Micronutrients and Trace Elements

Manures are rich in crop-required micronutrients such as boron, chloride, iron, molybdenum and zinc. They are also a source of micronutrients required for animal health, including selenium, zinc, copper, chromium, iodine and cobalt. Manure type and management have direct effects on plant and animal micronutrient levels. For example, zinc, copper, selenium and manganese levels from swine and poultry manure are often 10 to 100 times higher than from dairy manure.

For soil fertility, this means that annual manure applications aimed at meeting the crop's P and N needs may result in higher than expected soil levels of certain micronutrients. Some international studies have shown a soil build-up of elements such as copper, zinc and arsenic in fields with a history of heavy manure application. Be aware that the use of micronutrient levels in livestock feed in excess of the animals' nutritional requirements could have a negative impact on soil quality in the long term.

The best practices for managing soil levels of micronutrients are:

- Manage sources of micronutrients in livestock feeds and treatments.
- Test manure and soil for micronutrient levels.
- Adjust your nutrient management plan and application if necessary to build up micronutrient levels where needed and avoid excess in other areas.

6.1.2.5 Salts

Manure can contain significant amounts of salt (in the form of sodium) that may affect soil quality. High levels of sodium in the soil can disperse soil aggregates, degrade soil structure and reduce water infiltration rates. Saline soils can reduce crop yields and limit cropping options. Management of soil salinity is crucial for sustainable crop production.

Soil salinity is measured by passing electricity through the soil. The more salts in a soil sample, the greater its electrical conductivity (EC). EC is usually expressed in deciSiemens per metre (dS/m). A change of more than 1 dS/m may indicate a soil quality problem. If the EC is more than 2 dS/m, plant growth and yield may be affected. If the EC is more than 4 dS/m, manure application should not be considered. Refer to AOPA for regulated soil EC limits.

To control salt accumulation issues:

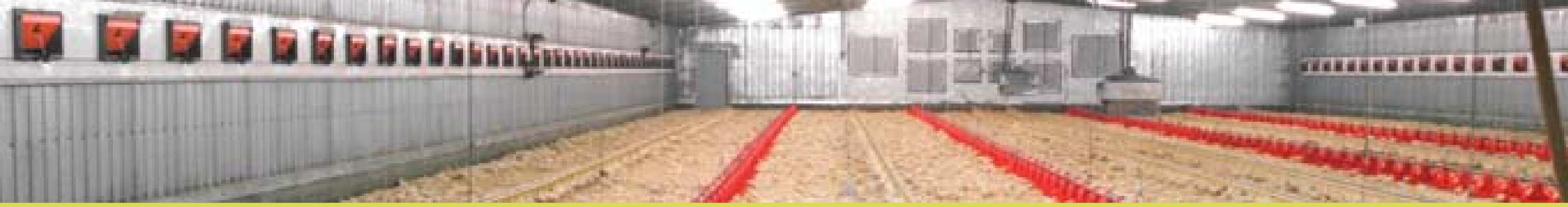
- Monitor salt levels in feed rations. (Contact a livestock nutritionist for recommended levels in feed.)
- Monitor the electrical conductivity level in soil through a soil test.
- Monitor the sodium adsorption ratio (SAR) level in soil, and do not apply manure when the SAR level is greater than 8. SAR is a measurement of sodium in relation to calcium plus magnesium. Soil SAR levels above 8 can decrease soil permeability and increase the potential for waterlogging.

6.2 NUTRIENT USE EFFICIENCY

Nutrient use efficiency refers to how well a crop uses available soil nutrients. As more nutrients are taken up and used by the crop, fewer nutrients remain in the soil to be lost or immobilized.

Techniques to improve nutrient use efficiency include:

- Providing the required amount of available forms of nutrients when the crop needs them.
- Placing nutrients where the crop roots can access them.
- Reducing the amount of nutrients



(such as nitrate) in the soil when the crop cannot use them.

- Accounting for and managing all sources of plant-available nutrients.
- Managing other cultural practices and conditions; a healthy crop will be able to utilize nutrients more efficiently than a poor crop.

6.3 FIELD ASSESSMENT

A key step in effective manure and nutrient management is to gather information on field characteristics. Five characteristics to identify during a field assessment are:

- soil physical properties, such as soil texture and structure
- slope grade and length, especially if adjacent to water bodies
- locations of water bodies, watercourses and wells
- problematic soil conditions, such as salinity, high or low soil pH, solonetzic or eroded soils
- past and current site management, such as manure and fertilizer application history, tillage and seeding practices, crop rotation, or presence of irrigation

During the field assessment, document any features that might affect crop productivity or the ability to apply nutrients or crop protection products, and any features that affect the environmental risk associated with producing a crop on that field. Identifying field features (e.g. springs, drainage areas) is particularly important if manure applicators are unfamiliar with the site. Awareness of these features provides the applicator with an understanding of the risks and liabilities associated with the field.

6.4 SOIL SAMPLING AND TESTING

An accurate soil test, with proper soil sampling and interpretation of soil test results, is an excellent nutrient management tool. Soil variability is a major concern when trying to obtain a representative soil sample. The strategy used to sample a field can address this challenge. Information collected during a site assessment can assist in choosing an appropriate strategy for a particular field.

Soil test results provide an inventory of plant-available nutrients and other soil chemical factors important for crop production. This information gives a basis for recommending applications of additional nutrients so you can tailor your nutrient applications to the crop's needs, avoid over-application of nutrients, reduce impacts on water, soil and air quality, save money and conserve energy.

Soil testing laboratories can develop fertilizer recommendations from a 0 to 15-cm depth sample, but these recommendations make assumptions about nutrient content in deeper layers. More reliable fertility recommendations and better nutrient management decisions can be made when nutrient levels are measured at these lower depths rather than estimated (e.g. for nitrogen and sulphur). Always use the same laboratory for soil analysis to ensure that analysis procedures are the same and results between years are comparable.

Soil tests should also be used to identify any excess nutrients or salts. If excess nutrients are found, manure application rates should be adjusted so that excess nutrients are utilized and commercial fertilizer is used to supplement other nutrient requirements.

FOR DETAILED INFORMATION on soil and manure sampling, see the Nutrient Management Planning Guide available from www.agriculture.alberta.ca or the ARD Agdex factsheets on Sampling Liquid, Solid and Poultry Manure. For more specific information regarding soil sampling and AOPA, see The AOPA Reference Guide or go to www.agriculture.alberta.ca/aopa.

GENERAL SOIL SAMPLING GUIDELINES

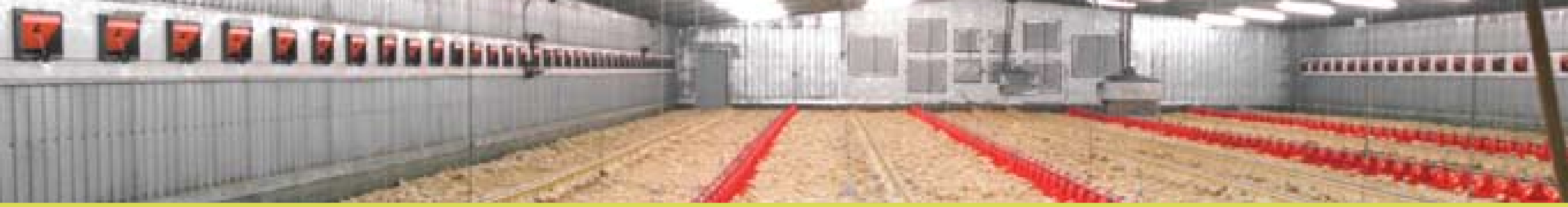
For any soil sampling strategy:

- Before sampling, consult the soil testing laboratory on lab-specific requirements for sample size, packaging and shipping, analytical options and costs. Some labs provide containers, labels and submission forms for soil samples.
- A soil sampling probe is best for taking samples. Augers can also be used but they can make it difficult to accurately separate depth intervals.
- Collect a representative sample, based on in-field variations in topography (slope), soil type, cropping management and cropping history.
- Take 15 to 20 cores for each representative bulk sample.
- Segment each core into lengths that represent depths of 0 to15 cm, 15 to 30 cm, and 30 to 60 cm.
- Separate the segmented cores by depth into clean, labelled plastic pails. Thoroughly mix the content of each pail, crushing any large lumps in the process. Avoid using metal pails to collect samples because they can alter the results of micronutrient tests.
- Take a single sub-sample (0.5 kg) for each sampling depth and submit for analysis.
- For hilly fields with knolls, slopes, or depressions, take samples from mid-slope positions to get a representative sample of the field average.
- Avoid sampling obvious areas of unusual variability such as: saline areas, eroded knolls, old manure piles, burn piles, haystacks, corrals, fence rows, old farmsteads, or any other unusual areas.
- For soils within 15 m of field borders or shelterbelts and within 50 m of built-up roads, either sample separately or avoid sampling.
- Always sample before manure or fertilizer applications.

6.5 PUT YOUR MANURE TO THE TEST

To determine an appropriate manure application rate to meet crop nutrient requirements, it is critical for you to know the manure's nutrient content. The nutrient content can be determined from book values or lab analysis. Although the best source of information is from sampling the manure from your operation, book values of nutrient content are better than not considering the nutrients in the manure at all when calculating manure application rates.

Manure nutrient composition varies widely between farms due to a host of factors such as: differences in animal species, bedding and feeding practices, and type of manure (solid or liquid). Book values may not reflect



the true nutrient composition of manure from individual farms. The only way to get reliable, farm-specific estimates of manure nutrient content is through manure sampling and analysis.

If manure is sampled annually for a 3-to-5 year period, a reliable estimate of average manure nutrient content for an operation can be established. Once historical averages have been developed, there is less need for annual sampling. However, if any component of the animal management, manure storage or handling system substantially changes, new historical averages will need to be developed.

Managers should sample manure and have it analyzed for nitrogen, phosphorus, potassium and total solids. Proper manure sampling is key to achieving a representative average of nutrient composition of the manure to be applied. For more information on sampling and analysis procedures, see the Nutrient Management Planning Guide.

To determine an appropriate manure application rate, know the manure's nutrient content.

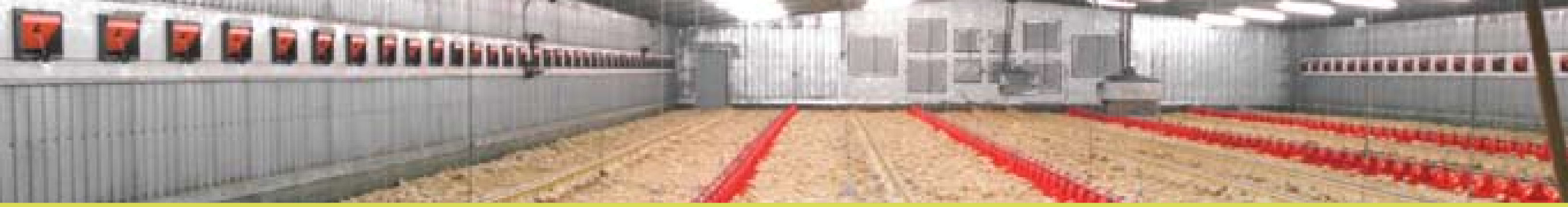
Table 6.2 Differences Between Sampling Manure Before or During Application

Parameter	Sampling Strategy	
	Sampling Before Application	Sampling During Application
Timeliness of Test Results	Manure test results can be used to calculate this year's application rates.	Cannot use analysis of samples collected during spreading to calculate this year's application rate.
Accuracy of Analysis	Manure tests may not be accurate or representative because manure is not thoroughly mixed.	Manure tests will be more reliable because sub-samples can be collected as the manure is being applied, getting a more representative sample.
Difficulty in Collection	Large equipment or agitation may be required to get a representative sample from manure storage.	Minimal time required to sample during application.
Safety	Sampling from storage facilities, especially lagoons or tanks, can be dangerous due to the risk of falling in or being overcome by gases.	Sampling from application equipment reduces the risk of falling in or being overcome by gases.

6.5.1 Recommended Practices for Sampling Manure

- Before sampling, consult the manure-testing laboratory on lab-specific requirements for sample size, packaging and shipping, turn-around times, analytical options, and costs. Some labs provide containers, labels and submission forms for samples.
- Recommended analyses for all manure samples:
  - moisture content or dry matter content
  - total nitrogen (total Kjeldahl nitrogen (TKN))
  - ammonium nitrogen (NH_4–N) (total nitrate nitrogen (NO_3–N) for compost samples)
  - total phosphorus (P)
  - total potassium (K)
- Proper sampling equipment:
  - 5-gallon plastic pail or large plastic garbage can
  - for liquid manure sampling: small collection can, pole and cup device or small bucket
  - for solid manure sampling: wheelbarrow, shovel, pitchfork, tarps and piece of plywood
  - clean, plastic bottle with a screw-on lid and several large plastic freezer bags
- Sample liquid manure during application:
  - Avoid sampling at the beginning and end of pumping, as these samples are less reflective of the manure's average characteristics than those taken midway through the pumping process.
  - Collect one sample for approximately every 1 million litres pumped.
- Sample solid manure during loading:
  - Avoid sampling from areas where moisture and bedding are considerably different from most of the pile.
- Sampling poultry litter from the production house:
  - The consistency, make-up and nutrient content of dry litter varies across the width of the production house, i.e. material from under the feeders and waterers will be different from the material along the walls. These differences must be considered when attempting to collect a representative manure sample from the litter pack in the production house.
  - There are two suggested methods for in-barn sampling of poultry litter, referred to as the 'point' method where the entire house is sampled in a zigzag pattern or the 'trench' sampling method where a trench is dug across the width of the production house.

TIP: Use only plastic buckets and bottles for manure samples. Do not use galvanized steel buckets because they can affect the results of the lab analysis for micronutrients. Do not use glass containers for sampling or shipping sub-samples due to the risk of breakage and personal injury.



IMPORTANCE OF AGITATING LIQUID MANURE

During storage, liquid manure tends to settle into different layers, each with a distinct nutrient profile. By agitating liquid manure, solids are disrupted and re-suspended, which facilitates storage emptying and improves the consistency (i.e. nutrient distribution) of the manure applied. Liquid manure can be agitated using various types of high volume pumps or propeller-type agitators. If the storage facility is large, it may be necessary to place agitators at several locations to get adequate mixing.

NOTE: Potentially lethal gases such as hydrogen sulphide (H_2S) are released when liquid manure is disturbed. Take special care to ensure adequate ventilation when there are people or animals present, and never enter a confined space where manure is present without a respirator.

Optional manure analysis could include: electrical conductivity (EC), pH, total carbon or carbon:nitrogen (C:N) ratio, chloride (Cl), sulphur (S), sodium (Na), calcium (Ca), magnesium (Mg) and micronutrients such as copper (Cu), manganese (Mn), zinc (Zn) and iron (Fe). It is usually not necessary to analyze manure for mineral constituents such as Ca, Mg, Zn and boron (B). Most manure contains significant quantities of these minerals and fields with a history of manure application are rarely deficient.

6.5.2 Interpreting Manure Test Results

Manure test results provide nutrient levels in the manure but will not provide recommended rates of manure application. Laboratories will report manure nutrient concentrations on an as-is basis in kg/tonne, lb/ton, kg/m^3, kg/1000 litres (L), lb/1000 gallons, percentages or parts per million (ppm). Manure nutrient results should be reported and used on a wet or "as is" basis because manure is spread wet.

For these measures to be useful in nutrient management planning, they must be converted into a format that the producer uses and the availability of each nutrient must be considered. The nutrients in manure exist in two forms, organic and inorganic. The inorganic forms are 100% available for crop use and in the case of nitrogen are at risk of being lost during application. The organic form must be converted by soil micro-organisms during the growing season to a form that crops can use, so only a portion of the organic form is available for crop use in a season. The manure application rate should be based on the estimated available nutrient content.

The higher the ammonium content of the manure, the higher crop-available nitrogen in the manure, and the greater the risk and cost of ammonium nitrogen losses during application. Manure types such as liquid dairy, liquid swine or poultry manure have high concentrations of ammonium. As a result these manure types have a higher percentage of the nitrogen available in the year of application and the highest risk of nitrogen loss.

Crop-available Nitrogen

The term 'crop-available N' refers to the amount of manure N that is available for crop use. This value will include the amount of the organic N that comes available during the growing season plus the amount of available inorganic N in the manure less the amount of inorganic N lost during application.

Most labs provide measures of total N and ammonium-N (NH_4–N) (and for compost nitrate-N (NO_3^-)). The difference of these two parameters provides an estimate of organic N in the manure:

$$\text{Organic N} = \text{Total N} - NH_4\text{–N}$$

Ammonium-N is at risk of being lost during manure application. The amount of loss depends on the application method and moisture and temperature conditions during application. Ammonium-N losses can be estimated using Table 6.3.

Although mineralization of organic N is controlled by soil moisture and temperature conditions, it is safe to assume for solid manure that 25%, for liquid manure that 40% and for poultry litter that 30% of the organic N will be mineralized into crop-available forms in the year following application:

Available organic N (year of application) = Organic N × 0.25 (solid) or 0.40 (liquid) or 0.30 (poultry litter)

Additional organic N will be mineralized in subsequent years and can be estimated when planning future manure applications using the following equations:

Available organic N (year 2) = Organic N × 0.12 (solid) {or 0.20 for liquid}{or 0.15 for poultry litter}
Available organic N (year 3) = Organic N × 0.06 (solid) {or 0.10 for liquid}{or 0.07 for poultry litter}

Crop-available Phosphorus
Most labs only report the amount of total P in a sample. To convert the amount of reported total P into the commercial fertilizer equivalent of P_2O_5, multiply total P by 2.29. Approximately 70% of total P in manure will be crop-available in the year it is applied. At least 90% of the total P will become available over time:

Estimated crop-available P (year 1) = Total P × 0.7
Estimated crop-available P (year 2) = Total P × 0.2
Estimated crop-available P (year 3) = Total P × 0.06

Crop-available Potassium
Most labs report the amount of total K in the manure sample. To convert the amount of reported total K into the commercial fertilizer equivalent of K_2O, multiply total K by 1.2.

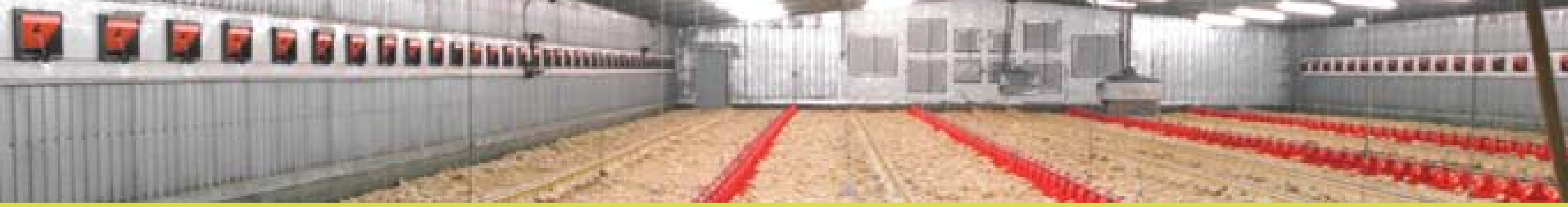
Unlike other nutrients, manure potassium (K) exists exclusively in the crop-available inorganic K^+ form. Approximately 90% of manure K is effectively crop-available:

Estimated crop-available K = Total K × 0.9

Table 6.3 Expected Ammonium Nitrogen Loss in Relation to Application Method, Timing and Weather Conditions

Application and Incorporation Strategy	Weather Conditions During Application				
	Average	Cool-moist	Cool-dry	Warm-moist	Warm-dry
Surface-applied, incorporated within 1 day[1]	25%	10%	15%	25%	50%
Surface-applied, incorporated within 2 days	30%	13%	19%	31%	57%
Surface-applied, incorporated within 3 days	35%	15%	22%	38%	65%
Surface-applied, incorporated within 4 days	40%	17%	26%	44%	72%
Surface-applied, incorporated within 5 days	45%	20%	30%	50%	80%
Not incorporated	66%	40%	50%	75%	100%
Injected	0%	0%	0%	0%	0%
Cover crop[2]	35%	25%	25%	40%	50%

1 These percentages would also apply to liquid manure broadcast (without incorporation) on bare soils.
2 These percentages would also apply to liquid manure broadcast (without incorporation) on land with residue, such as direct-seeded fields or forages.
Adapted from ARD 2004.



6.6 MANURE INVENTORY – DETERMINE MANURE PRODUCTION INFORMATION

The weight or volume of available manure should be determined prior to land application. Getting an accurate estimate of manure volume or weight is important:

- to estimate the required land base for manure utilization so nutrients are used efficiently and do not accumulate in the soil.
- to determine if you are subject to additional requirements under AOPA (e.g. if more than 500 tonnes of manure is handled).
- to estimate the time required to apply manure.

Weighing manure is the most accurate method for determining the quantity of manure applied. However, physically weighing manure may not be practical or safe, in which case the manure inventory must be estimated.

There are three options for estimating manure inventory:

1. Calculating the total volume of manure produced using book values for average manure production for each type of livestock.
   - Book values may not reflect the actual volume or weight of manure produced on a specific operation because of factors such as precipitation, feeding and bedding practices, and water conservation practices.
2. Using historical manure application records or capacity indicators in storage facilities.
   - Operations may have records documenting the volume of manure applied in the past (e.g. number of loads hauled). As long as the operation has not changed the number, management, or type of livestock, this estimate can be reliable enough for nutrient management planning. In addition, existing manure storage facilities may be equipped with capacity markers that provide easy estimates of the volume present.
3. Calculating an estimate of the pile weight or volume contained in a storage facility.
   - The weight or volume of manure in a storage facility can be estimated using direct measurements and calculations. This method can be used in the absence of historical manure application records, and is more operation-specific than using book values.

FOR MORE DETAILED INFORMATION ON MANURE INVENTORY, refer to the Nutrient Management Planning Guide available from www.agriculture.alberta.ca

Table 6.4 Average Volumes and Weights of Solid Manure Production Expected from Typical Livestock Housing Systems in Alberta

Species		Daily			Yearly		
		lb	kg	cu ft	tons	tonnes	cu ft
Beef	Feeders	8.4	3.8	0.21	1.53	1.39	75
	Finishers – Open Lot	13.1	5.9	0.32	2.38	2.16	117
	Finishers – Paved Lot	19.8	9.0	0.43	3.61	3.28	156
	Feeder Calves <550 lb	3.3	1.5	0.08	0.59	0.54	29
	Cow w/Calf	17.8	8.1	0.44	3.25	2.95	159
	Cows/Bulls	16.5	7.5	0.40	3.02	2.73	147
Dairy	Tie Stall	139.7	63.5	2.66	25.5	23.12	970
	Loose Housing	146.3	66.5	2.78	26.71	24.21	1016
	Replacements	42.9	19.5	0.82	7.83	7.10	298
	Calves	2.9	1.3	0.07	0.54	0.49	26
Swine	Farrow to Finish	86.4	39.3	1.74	15.76	14.29	637
	Farrow to Wean	26.6	12.1	0.54	4.85	4.40	196
	Farrowing	21.3	9.7	0.43	3.88	3.52	157
	Weaner	2.8	1.3	0.06	0.50	0.46	20
	Feeder	8.2	3.7	0.17	1.50	1.36	61
Poultry (per 100)	Layers – Belt Cage	9.9	4.5	0.41	1.81	1.64	149
	Layers – Deep Pit	13.0	5.9	0.31	2.37	2.15	112
	Broilers	6.0	2.7	0.30	1.09	0.99	108
	Broiler Breeders	15.8	7.2	0.59	2.89	2.62	217
	Layer Breeders	11.7	5.3	0.53	2.13	1.93	192
	Pullets	6.0	2.7	0.15	1.09	0.99	56
	Turkey Hens (Light)	13.6	6.2	0.85	2.49	2.26	309
	Turkey Toms (Heavy)	19.8	9.0	1.28	3.61	3.28	468
	Turkey Broilers	11.0	5.0	0.51	0.01	1.82	186
Horses	PMU	45.8	20.8	0.92	8.35	7.57	337
	Feedlot	15.2	6.9	0.46	2.77	2.51	169
	Donkeys	7.6	3.5	0.23	1.39	1.26	84
	Mules	11.4	5.2	0.35	2.08	1.89	127
Fur Farms	Mink (per 100)	30.8	14.0	0.71	5.62	5.10	260
	Fox (per 100)	77.0	35.0	1.24	14.05	12.74	454
	Rabbits (per 100)	100.1	45.5	2.49	18.27	16.56	908
Cervid	Elk	5.8	2.6	0.14	1.06	0.96	52
	Deer	2.9	1.3	0.07	0.52	0.47	25

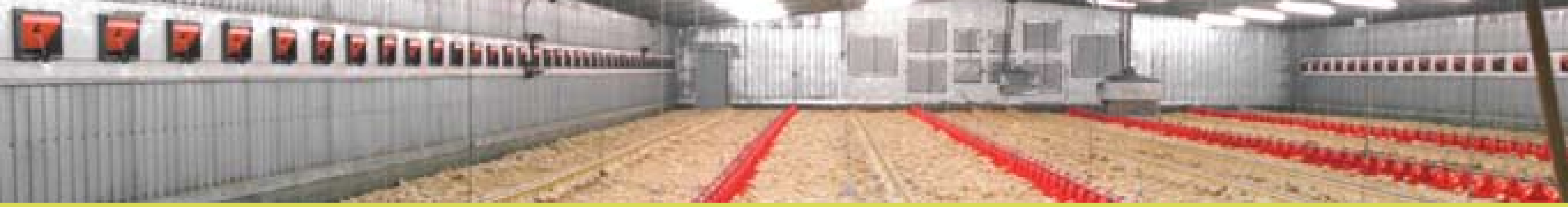


Table 6.4 Average Volumes and Weights of Solid Manure Production Expected from Typical Livestock Housing Systems in Alberta (continued from page 62)

Species		Daily			Yearly		
		lb	kg	cu ft	tons	tonnes	cu ft
Sheep	Bison	7.3	3.3	0.18	1.32	1.20	65
	Alpacas/Llamas	4.6	2.1	0.15	0.84	0.76	55
	Ewes w/Lambs	3.9	1.8	0.13	0.71	0.64	46
	Ewes/Rams	3.1	1.4	0.10	0.57	0.51	37
	Feeders	1.5	0.7	0.05	0.28	0.25	18
	Lambs	0.8	0.4	0.02	0.14	0.13	9
Goats	Meat/Milk (per Ewe)	5.9	2.7	0.19	1.08	0.98	70
	Feeders	0.6	0.3	0.02	0.10	0.09	6
	Nannies/Billies	3.1	1.4	0.10	0.56	0.51	36
Ratite	Emus	1.3	0.6	0.08	0.24	0.22	29
	Ostriches	2.4	1.1	0.15	0.44	0.40	53

Table 6.5 Average Volumes and Weights of Liquid Manure Production Expected from Typical Livestock Housing Systems in Alberta

Species		Daily			Yearly		
		gallons	litres	cu ft	gallons	cu M (tonnes)	cu ft
Dairy (* count lactating cows only)	Free Stall: Lactating Cows Only[1]	21.7	98.6	3.50	7934	36.0	1274
	Free Stall: Dry Cows	9.5	43.0	1.50	3454	15.7	554
	Free Stall: Lactating with Dry Cows Only*[2]	25.7	116.8	4.11	9381	42.6	1500
Swine (* count sows only)	Farrow to Finish *	14.4	65.7	2.31	5272	24.0	844
	Farrow to Wean *	4.4	20.2	0.71	1622	7.4	260
	Farrow Only *	3.5	15.9	0.56	1278	5.8	204
	Feeders / Boars	1.6	7.1	0.25	568	2.6	91
	Growers / Roasters	0.9	4.2	0.15	333	1.5	53
	Weaners	0.5	2.3	0.08	183	0.8	29
Poultry (per 100)	Chicken: Layers	6.0	27.1	0.95	2174	10.0	348

1 Includes milking parlour washwater of 30 L per lactating cow

2 Includes milking parlour washwater of 30 L per lactating cow (zero milking parlour washwater for dries)

Note: Dairy associated livestock is usually assumed to be solid manure production

6.7 CROP NUTRIENT REQUIREMENTS

The target yield for a given crop is an important factor in determining the amount of nutrients to be applied through manure and fertilizer. Nutrient requirements vary from one crop to another; therefore, under the same conditions, recommended application rates will be different depending on the crop. To estimate a target yield, average the yields of the previous four harvests for a given field and add 5 to 10% as an expected improvement factor.

Accurate manure application rates are based on manure and soil analyses, as well as past cropping history, past manure applications and current crop fertility requirements.