Guidelines for developing a Nutrient Management Code of Practice for your industry, region or farm.

CRACKING THE NUTRIENT CODE

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The Guidelines in Brief

A report of the National Land and Water Resources Audit (*Australian Agriculture Assessment 2001)* provides an assessment of the losses of nutrients from farming systems. The report identifies the need for a higher level of attention to be paid in Australian agriculture to nutrient status, monitoring and tracking changes in all farming systems.

Nutrients are essential for healthy plant and animal production, and nutrient inputs are often required to enhance productivity. However if nutrients are poorly managed the consequences are very undesirable, both environmentally and economically.

A Nutrient Management Code of Practice can help farming industries to maximise the efficient use of nutrients in their systems, which will in turn:

- minimise environmental impact, and
- increase production efficiency.

Because every industry and every region in Australia is exposed to different nutrient management risks, it would be difficult to prepare a Nutrient Management Code of Practice to suit them all. Instead, the Fertilizer Industry Federation of Australia Inc. (FIFA) has prepared '*Cracking the Nutrient Code'*, a set of guidelines to help individual industries and regions develop their own specific Nutrient Management Codes of Practice.

Through the development of industry or region specific Nutrient Management Codes of Practice, the guidelines promote the use of management practices which result in the best possible production outcomes whilst protecting the environment. Three guiding principles, which form the basis of sustainable nutrient management decisions and practices, are essential components of a Nutrient Management Code of Practice. These are:

- Awareness and Understanding of the Risks
- Employing the Nutrient Management Tools Available
- Adopting a System of Continuous Improvement.

The guidelines benefit from the extensive nutrient management experience within the fertilizer industry and provide you with the tools to develop and implement a Nutrient Management Code of Practice for your industry, region or farm. Input has also been sourced from specialists in environmental management systems, and the guidelines are developed on the basis of the principles of the International Management Systems Standard ISO 14001.

Good luck 'Cracking the Nutrient Code'

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SECTION 1

'Cracking the Nutrient Code' Guidelines

1. *'Cracking the Nutrient Code'* Guidelines

1.1 Context for the Guidelines;

An adequate supply of food is essential for the existence of humankind. Plants also require an adequate food supply in the form of plant nutrients. Productive soils must be able to supply an adequate level of plant nutrients to support crop and pasture growth.

Soil fertility in modern-day agriculture is part of a dynamic, ever-changing system. Plant nutrients are constantly being "imported" and "exported" from the farm in the form of plant and animal products. Even in the best-managed agricultural systems with efficient nutrient cycling, net losses in produce sold from the farm are inevitable. This means that the addition of plant nutrients in the form of fertilizers is necessary to maintain or enhance a soil's productive capacity.

Mineral fertilizers are the principal source of applied plant nutrients. However, organic materials such as processing waste from plant and animal products, animal manure and sewage sludge are also important sources of nutrients. Legumes grown for grain, pasture or as green manure crops, which are returned to the soil, provide additional nitrogen sourced from the atmosphere.

Whatever form of nutrient is used to improve soil fertility or supplement plant growth, it is essential that the farm management system takes into account the potential impact of the nutrients added to the system. Inefficient management of nutrients is undesirable, both economically and environmentally.

There is a growing awareness of off-farm impacts of fertilizer use, particularly as this relates to catchment environmental quality, and a recognition of the lack of information on nutrient use efficiency as it impacts upon Australian agriculture. Farm managers need to be able to demonstrate that they are managing nutrients to minimise environmental risks, and in doing so, will reap the benefits of more efficient production.

Why are these guidelines so important?

The management of nutrients in agriculture has the potential to impact upon the wider community as well as having important commercial and trade implications. The Australian community will require that agricultural industries demonstrate that they are implementing *best practice* nutrient management for production and environmental sustainability. Increasingly, access to many high value markets requires compliance with Quality Assurance Programs and/or Environmental Management Systems.

The Fertilizer Industry Federation of Australia Inc. (FIFA) recognises that best practice for the effective management of nutrients will vary depending on a whole range of factors including:

- soil type,
- climatic pattern, and
- cropping/pasture system.

It is therefore difficult to develop a comprehensive Nutrient Management Code of Practice that fits all situations. Some key agricultural industry sectors have already developed, or are developing, industry specific Codes of Practice as a method of communicating best practice and allowing each industry to self regulate its activities. FIFA has prepared these guidelines to help individual industries, regions and farms to develop their own specific Nutrient Management Codes of Practice.

1.2 How to use the Guidelines

The guidelines should be used in the following way:

- Read about the guidelines in **Section 1**
- Learn how to develop a Nutrient Management Code of Practice in **Section 2** by following seven steps:
  1. Know what to look for
  2. Evaluate current activities and practices
  3. Consider the environmental context
  4. Evaluate and prioritise risks and impacts
  5. Identify best management practices
  6. Foster a process of continuous improvement
  7. Identify appropriate nutrient management tools
- Select the most appropriate tools for implementing and monitoring best practice from the Nutrient Management Toolbox in **Section 3**
- Insert your newly developed nutrient management Code of Practice, alongside those of other industries or catchments in **Section 4**
- Make sure your Code is implemented by referring to **Section 5**

1.3 Who should use the Guidelines?

The guidelines have been developed for use by:

- Farmer organisations
- Industry organisations
- Research organisations
- Resource management organisations
- Local, state and federal government departments
- Landcare and Catchment Management Groups

to assist in the development of Nutrient Management Codes of Practice for an industry or region. However, the principles can just as easily be adopted by an individual farm manager to develop a nutrient management plan for the farm.

1.4 Outcomes of using the Guidelines

If you follow the process outlined in the guidelines, you will be able to produce a Nutrient Management Code of Practice for your industry or region. A Code of Practice can help those involved in your industry, or farming in your region, to maximise the efficient use of nutrients in their systems, which will in turn:

- minimise environmental impact, and
- increase production efficiency.

SECTION 2

Developing a Nutrient Management Code of Practice

2. Developing a Nutrient Management Code of Practice

2.1 What makes a good Code of Practice?

An effective Code of Practice must:

- be specific enough to be useful, without being prescriptive or inflexible
- be based on good research and factual data
- have the support of the end-user
- meet regulatory requirements where these are in place
- have provision for training, monitoring, audit and review systems, and
- be recognised and implemented.

The guidelines are designed to help you produce a Nutrient Management Code of Practice with these characteristics.

2.2 *'Cracking the Nutrient Code'* – Principles and Process

The aim of a Nutrient Management Code of Practice is to provide a framework for the adoption of sustainable nutrient management practices. Sustainable nutrient management practices are those which maintain or enhance:

- the economic viability of agricultural production;
- the natural resource base; and
- other ecosystems which are influenced by agricultural activities.

'Cracking the Nutrient Code' adheres to three guiding principles, which form the foundation of sustainable nutrient management.

Table 1: Three Principles of Sustainable Nutrient Management

Principle	Description
① **Awareness and Understanding of the Risks**	❑ Change is only possible when stakeholders become aware of the major issues and identify where their activities are creating risks ❑ Once understood, the risks and impacts associated with nutrient management can be strategically managed
② **Employing the Nutrient Management Tools Available**	❑ The most appropriate technology and management techniques should be employed to provide an informed basis for nutrient decisions and activities ❑ Use of monitoring tools to confirm the effectiveness and efficiency of nutrient decisions and activities.
③ **Adopting a Process of Continuous Improvement**	❑ A cycle of planning, doing, monitoring and improving ensures that practices are continuously getting better

Preparation of a Nutrient Management Code of Practice follows the steps outlined in Figure 1. These steps enable the developers of a Code to understand nutrient management risks, to examine current practices in their environmental context, to identify the nutrient management risks and impacts which are most important in their situation, and to identify the best management practices to minimise these risks.

Figure 1: The steps to "Cracking the Nutrient Code"

Know What to Look For

- **Understanding & Awareness**

  5 Risk Categories
- **Leach** (leaching)
- **Load** (nutrient loading)
- **Run** (run-off)
- **Blow** (air borne losses)
- **Mine** (mining soil nutrient by non-maintenance strategies)

Evaluate Current Practices

- **Document current Operational and Agronomic activities**
- **Link to 5 Risk Categories**

Consider the Environmental Context

- **Under what environmental conditions are Operational & Agronomic activities occurring**
- **Identify sensitive environmental areas**

Prioritise the Nutrient Management Risks

- **Evaluate the likelihood and consequence of Risks from Operational and Agronomic activities**
- **Rank using the Nutrient Management Risk Calculator**

Identify Best Management Practices

- **Identify Best Management Practices to address medium, high and very high risks**
- **Select appropriate Nutrient Management Tools to implement and monitor best practices**
- **Foster a process of continuous improvement**

2.3 Knowing what to look for

The first guiding principle for sustainable nutrient management involves "Understanding and Awareness" of the issues.

The first step to 'Cracking the Nutrient Code' ensures that there is an awareness of all potential nutrient management risks. Nutrient management risks are defined as the chance of an unfavourable consequence, for production or for the environment, resulting from nutrient inputs or outputs, e.g. production risks may be the loss of yield potential or failure to achieve a satisfactory quality, environmental risks may be the possible pollution of water ways or the build up of heavy metal impurities in the soil.

The Nutrient Management Risk Matrix (Section 2.11) classifies nutrient management risks into five categories - Leach, Load, Run, Blow and Mine risks. Check out the Glossary (Section 7) for definitions of the categories and study the Nutrient Management Risk Matrix to gain an understanding of what to look for.

2.4 Evaluate Current Activities

Given an understanding of the potential nutrient management risks, thinking about current practices helps to focus in on key risks and improvement opportunities. Nutrient management activities can be broken up in two main areas - operational activities and agronomic practices.

Operational activities are considered first. Consider each major activity and step involved in the transport, storage, handling and application of fertilizer.

Table 2: Nutrient Management Risks associated with Operational Activities

Activity	Possible Concerns	Relevant Risk Categories
Bulk & bag transport of fertilizer and other nutrient sources	Spill of product, damage of product, safety risk for other road users (slippery), stormwater, soil and ground water contamination risk	Run, Leach, Load, Blow
Loading and unloading of fertilizer and other nutrient sources	Spills to ground, loss and damage of product, safety risk for employees (slippery), surface water, soil and ground water risk, safety risk from ingestion by farm animals or wildlife, dust released creating air quality risk and loading of nutrient in surrounding areas	Run, Leach, Load, Blow
Storage of bulk fertilizer in bulk bays, silos and other areas	Poorly designed facilities or absence of suitable facilities leading to damage and loss of product, storm water, soil and ground water contamination. Air quality may also be impacted. Poor housekeeping relating to clean up of transfer areas	Run, Leach, Load, Blow
Storage of liquid fertilizer	Inadequate storage facilities, including bunding, leading to loss of product to ground and subsequent storm water, ground water, soil and air quality impacts	Run, Leach, Load, Blow
Broadcast spreading and band application of fertilizer or other nutrient sources	Uneven application of nutrients across intended area due to poor equipment calibration and operator skill leading to inadequate supply in some areas and excessive loading in others. Surface water and ground water impacts possible. Spreading in unsuitable climatic conditions. Non-target application to areas such as waterways and native areas.	Run, Leach, Load, Blow
Application via irrigation	Application efficiency, calibration of equipment. Overhead irrigation in unsuitable climatic conditions. Poor control of tailwater in furrow irrigation systems. Contamination of water source from pump backflow during fertigation.	Run, Leach, Load
Application via direct injection (e.g. anhydrous ammonia)	Lack of equipment calibration, application in inappropriate conditions	Run, Leach, Load

Then consider each major agronomic activity, and the potential nutrient management risks associated with it.

Table 3: Nutrient Management Risks associated with Agronomic Activities

Activity	Possible Concerns	Relevant Risk Categories
Nutrient Application Rate	Application rate is greater than the nutrient required for maximum crop production, except where capital applications are required. Application of different nutrient elements is not balanced. Application rate is less than nutrient removal in produce, or below the level required for maximum economic yield.	Leach, Load, Mine
Nutrient Application Timing	Nutrients not available during peak demand periods. Mobile nutrients applied at times when uptake is low, and rainfall is high.	Run, Leach, Mine
Nutrient Form	Inappropriate application of slow-release or highly soluble nutrient forms. Application of acidifying compounds to acid soils. Use of products with high levels of impurities.	Leach, Load, Mine
Nutrient Placement	Nutrients placed where they are inaccessible to plant roots. Band placement is too concentrated. Injection of anhydrous ammonia is too close to surface.	Leach, Load, Blow
Disposal of animal manures	Over-application of nutrients to small areas. Heavy metal accumulation. Microbial contamination of produce.	Run, Leach, Load
Growth of legume species	Failure to utilise fixed nitrogen. Increased soil acidification.	Leach, Load

Begin to create a Nutrient Management Plan by recording the most important Operational and Agronomic activities associated with your industry, region or farm into the two tables in Section 2.13.

2.5 Consider the Environmental Context

This step involves taking stock of the environment in and around the areas intended for fertilizer storage, handling and application to identify those places potentially impacted by nutrient management practices.

The following table provides a list of possible environmental targets requiring consideration when making nutrient management decisions.

Table 4: Environmental Targets and Relevant Nutrient Management Risks

Environmental Targets	Description	Relevant Risk Categories
Groundwater	Depth, quality, potential for nutrients to impact need review. Ground water may be a medium for further transport of nutrients, impacting other targets downstream, e.g. water pumped for stock or human use, water discharging into rivers.	Load, Leach, Run
Surface water bodies such as rivers, streams, lakes and dams	Distance from areas intended for fertilizer storage, handling and field application	Run, Blow, Load, Leach
Soils	Soil type, inherent fertility	Load, Mine, Leach, Run, Blow
Neighbouring crops and land owners	Sensitive neighbouring crops and landholder considerations need reviewing to ensure no non-target application of nutrients.	Run, Blow, Leach
Biodiversity – Native Fauna and Flora	Proximity of areas intended for fertilizer use to areas of native vegetation, sensitivity of those areas to fertilizer	Run, Blow, Leach
Air	Potential emissions of greenhouse gases such as carbon dioxide (CO_2) and nitrous oxide (N_2O)	Load
Farm produce	Microbial contamination from organically derived fertilizers and soil amendments. Concentration of heavy metals above maximum limits (MLs)	Load

2.6 Prioritise Nutrient Management Risks

Having identified the nutrient management risks associated with current activities and their environmental context, the next step is to evaluate the importance of each of these risks.

This is achieved by considering two things:

- What is the **likelihood** that an activity could have a Leach, Load, Run, Blow or Mine impact?
- How significant are the potential **consequences** of this activity on the environment?

For each current activity, use the Nutrient Management Risk Calculator (Section 2.12) to rank the five risk categories as low, medium or high based on the likelihood of occurrence and the significance of potential consequences. Risks that fall in the red area should be given high management priority.

The questions contained in Appendix 1 will help you determine the ranking to be given to each nutrient management risk for agronomic practices. Once determined, enter the risk rankings for each activity in the Nutrient Management Plan.

2.7 Identify Best Management Practices

Now that the nutrient management risks applicable to your region or industry have been assessed, best management practices need to be identified, and in some cases developed, to minimise these risks.

Some suggested risk management strategies are outlined in Appendix 2. Other information on best management practices for minimising nutrient management risks is available from many sources. Check out the further reading suggestions, and contact list in Section 6. In the Nutrient Management Plan, detail the best management practices that will assist in managing key risks.

The best management practices identified in the Nutrient Management Plan now form the basis of a Nutrient Management Code of Practice for your industry, region or farm.

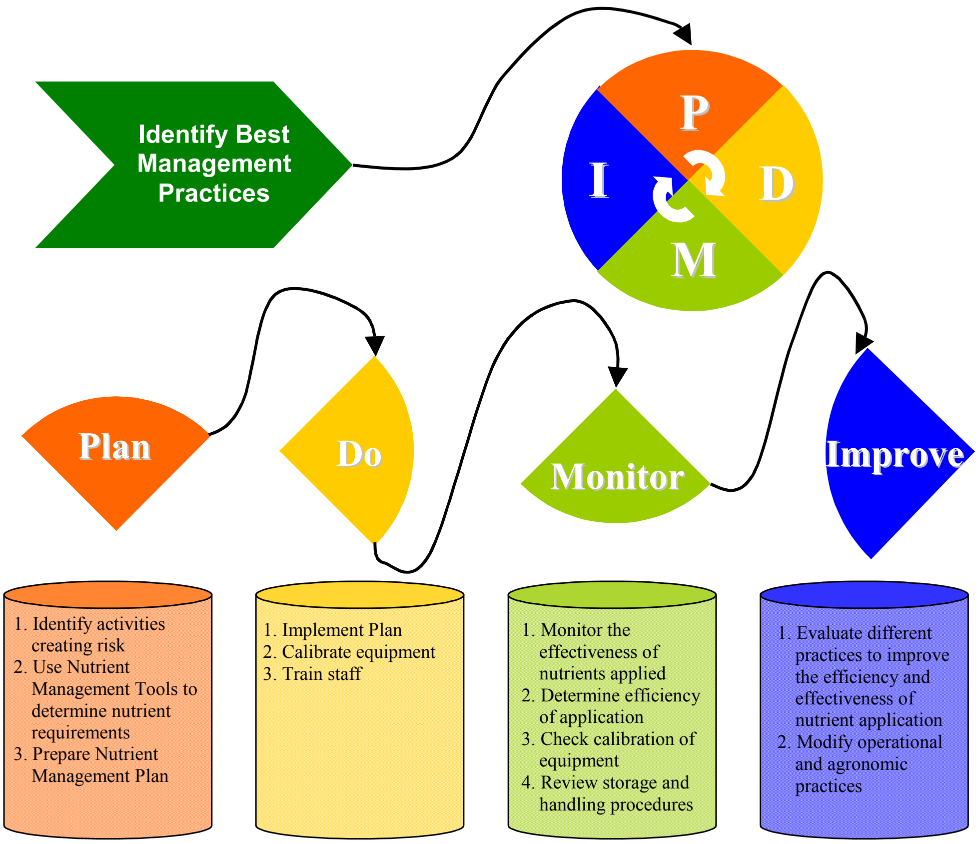
However, the process doesn't finish here. In some instances, best management practices have not yet been developed or tested. For this reason it is important for managers to adopt a process of continuous improvement to ensure that nutrient management is continually getting better.

2.8 Foster the Process of Continuous Improvement

Integrating the management of environmental and production risks into best practices can be a challenging task, and it is unusual to get them right first go. Many managers already employ continuous improvement approaches to problem solving and day-to-day management activities. Developers of a Nutrient Management Code of Practice should provide information that will allow managers to adopt a process of continuous improvement. In this way a Code of Practice is no longer a static document, but a vehicle for learning.

There are four steps in any continuous improvement process: Plan, Do, Measure and Improve.

Figure 2. The Process of Continuous Improvement



The following information could be included in a Nutrient Management Code of Practice to assist managers in the adoption of a Continuous Improvement Process.

PLAN

Nutrient management planning involves considering yield and quality targets, the production and soil fertility history, environmental risks, and operational requirements, prior to carrying out activities. With this knowledge, a plan can be formulated to achieve the production objectives in an environmentally responsible manner.

Use of appropriate Nutrient Management Tools is strongly recommended for planning fertilizer application. Information on techniques and technologies to assist in this process are available in the Nutrient Management Toolbox.

DO

Implement the activities as planned, keeping detailed record of activities as they are carried out. Ensure that training is available and undertaken.

MONITOR

Measurement is all about assessing how well planned activities went and identifying those areas where things could be improved. Remember the old saying, “you can not manage what you do not measure.”

Below are some readily measured performance indicators that can be used to assess performance in managing each of the environmental risk areas. It is important to have benchmarks against which these indicators can be judged. Some of these indicators are explained further in the Nutrient Management Toolbox, or check out the Further Reading list for other sources of information.

Key measures for Leaching Risks:

- Water use efficiency of the crop / pasture
- Soil moisture data from irrigation scheduling information
- Water table depth
- Volume of water the tile drain pump moves
- Nutrient concentration of water from test well / tile drain
- Rainfall
- Soil texture

Key measures for Load Risks:

- Heavy metal concentration in produce compared to maximum limit (ML)
- Heavy metal concentration in fertilizers
- Mineral concentration in farm produce
- Incidence of metabolic disorders in the herd e.g. grass tetany
- Nutrient concentration in soil
- Incidence of water logging when soil temperature is above 10°C
- Microbial organism count on farm produce

Key measures for Run Risks:

- Water use efficiency of the crop / pasture
- Volume of surface water leaving the farm
- Incidence of weed growth or algal blooms in farm and nearby waterways
- Visual assessment of soil loss / displacement from production areas

Key measures for Blow Risks:

- Ground cover
- Visual evidence of fertilizer fines drift at application

Key measures for Mine Risks:

- Nutrient budget for the major nutrients (nutrient exports from the farm compared to the nutrient imports)
- Soil and/or plant analysis on fertility monitoring sites over time and mineral composition of produce leaving farm

Most Quality Assurance programs and Environmental Management Systems require some form of external audit or assessment. The audit report will often identify areas for improvement that can be included in procedures to manage risks.

IMPROVE

Where measured indicators reveal that nutrient management risks are not being effectively managed, room for improvement exists. This step utilises the learning from previous plans, activities and measurements to formulate a revised plan. Revision of past plans will ensure that future activities achieve greater effectiveness and further reduce the impacts on the environment.

2.9 Identify Appropriate Nutrient Management Tools

Nutrient management tools are the techniques and technologies which enable both the implementation and the monitoring of best management practices. Developers of Nutrient Management Codes of Practice should indicate appropriate tools to assist in the implementation of their Code.

The Nutrient Management Toolbox in Section 3 provides information about several important nutrient management tools. Using the Toolbox and/or other sources of information, detail the most appropriate nutrient management tools for implementing and monitoring the best practices identified in the Nutrient Management Plan.

2.10 Writing the Code

When writing the Code, particular attention must be paid to the use of words such as “should", “shall” and “will” which are used to emphasize differing levels of obligation on users.

The three terms are normally used as follow:

Will	- Means a legal requirement
Shall	- Means an obligation, with virtually no exceptions
Should	- Means strongly recommended

2.11 Nutrient Management Risk Matrix

Risk	Description	Processes/Principles	Potential Consequences
Leach	Water carrying dissolved nutrients or particles (soil or organic matter) moving beyond the root zone	Application of nutrients at rates greater than soil nutrient holding capacity and/or plant requirements Application of nutrients at times when leaching potential is greatest Inefficient irrigation management strategies Spills and loss of containment of fertilizers from transport, storage and handling facilities leading to a concentrated migration of nutrients into soil or surface and ground waters	Nutrient loading and contamination of ground water potentially making it unsuitable for stock and domestic purposes Soil acidification from nitrate leaching Loss of valuable nutrients from the plant root zone
Load	Application and accumulation of nutrients and undesirable substances Application or loss of nutrients to non targeted areas	Undesirable impurities accumulating in the soil e.g. cadmium in mineral fertilizers or microbial contaminants from organic fertilizers Imbalances in plant nutrition Imprecise application techniques Inappropriate use of organic fertilizers Spills and loss of containment in transport, storage and handling of fertilizers Liberation of greenhouse gasses such as carbon dioxide and nitrous oxide to the atmosphere	Uptake of harmful substances/impurities in farm produce Mineral imbalance in produce Poor produce handling & storage characteristics Microbial contamination of produce / livestock Nutrient loading in operational areas, contaminating soil and leading to potential point source impacts Negative impact on soil quality Possible contribution to depletion of the ozone layer and global warming
Run	Storm and surface water run-off carrying nutrients	Surface water leaving the farm paddocks (or transport, storage and handling facilities) carrying dissolved nutrients or nutrients associated with soil and organic material e.g. nitrogen & phosphorus Application of nutrients at times when run-off risk is greatest Direct application of fertilizers to water ways	Algal blooms Contamination of surface water making it unsuitable for uses such as stock and domestic purposes Soil fertility decline
Blow	Air quality impacts associated with fertilizer handling, application and emissions arising from soil	Dust emissions in handling and application of mineral or organic fertilizers Ammonia escape from transport, storage and application equipment Wind erosion of soil due to inadequate plant cover	Poor air quality Ammonia toxicity in people, plants and animals Soil fertility decline
Mine	Decline in soil fertility due to net export of nutrients in produce without replacement	Export of nutrients in produce greater than nutrients being replaced Burning or removal of crop residues Soil organic matter decline Soil acidity increasing	Soil fertility decline Loss of soil organism bio-diversity Loss of enterprise flexibility Poor nutritional quality of produce or pasture

2.12 Nutrient Management Risk Calculator

Nutrient Management Risk Calculator		**Environmental Consequence**		
		Low *An event **unlikely** to cause damage to environment, **has minimal potential** for effect/impact outside immediate application area &/or reversible.*	**Medium** *An event, which **has the potential** to cause damage or harm, **reversible, with the possibility of causing impact** in the surrounding environment/ecosystem.*	**High** *A **significant** event **with the potential** to cause **damage or harm** to the environment both to the **immediate area** and in **the surrounding environment/ecosystem**, difficult to reverse, and **is likely to cause alarm in the community**.*
Likelihood of Occurrence	**Low** *Unlikely to occur (< 25% probability)*	**Low Nutrient Management Risk**	**Low Nutrient Management Risk**	**Medium Nutrient Management Risk**
	Medium *Likely to occur (25 – 75% probability)*	**Low Nutrient Management Risk**	**Medium Nutrient Management Risk**	**High Nutrient Management Risk**
	High *Will occur often (> 75% probability)*	**Medium Nutrient Management Risk**	**High Nutrient Management Risk**	**Very High Nutrient Management Risk**

2.13 Nutrient Management Plan

Operational Activities

Operational Activity	Risk Category	Environmental Risk Assessment			Best Management Practices	Tools
		Likelihood	Consequence	Risk Ranking	Detail here the best management practices that will assist in managing key risks	Detail here the nutrient management tools suitable for implementing and monitoring best management practices.
	Leach					
	Load					
	Run					
	Blow					
	Mine					
	Leach					
	Load					
	Run					
	Blow					
	Mine					
	Leach					
	Load					
	Run					
	Blow					
	Mine					
	Leach					
	Load					
	Run					
	Blow					
	Mine					

Agronomic Activities

Agronomic Activity	Risk Category	Nutrient Management Risk			Best Management Practices Detail here the best management practices that will assist in managing key risks	Tools Detail here the nutrient management tools suitable for implementing and monitoring best management practices.
		Likelihood	Consequence	Risk Ranking		
	Leach					
	Load					
	Run					
	Blow					
	Mine					
	Leach					
	Load					
	Run					
	Blow					
	Mine					
	Leach					
	Load					
	Run					
	Blow					
	Mine					
	Leach					
	Load					
	Run					
	Blow					
	Mine					

SECTION 3

The Nutrient Management Toolbox

3. The Nutrient Management Toolbox

There are many tried and tested techniques which can be employed to improve nutrient management, and therefore to minimise nutrient management risks, both production and environmental.

Many of these techniques have been available for some time, however their value in managing nutrient management risks has not been fully acknowledged.

In addition, emerging technologies are changing the way we measure and manage nutrients. For example, remote sensing technologies allow us to map the spatial variability in crop and pasture production and some soil parameters across a paddock, thereby giving us a better indication of the environmental context in which nutrients must be managed.

The following sheets provide information on some important nutrient management tools which are easily accessible to managers. Further information can be sought from the sources indicated.

Soil Testing

3.1 Soil Testing

What is it?

Soil testing evolved from the need to assess the capacity of soils to support plant growth and is based on the premise that pools of soil nutrients can be extracted and the size of the pool related to plant growth. The use of soil testing has grown rapidly in the past decade in response to resource management requirements and productivity needs.

How can it be used in nutrient management?

Soil testing can be used as a nutrient management tool to:

- help diagnose reasons for poor plant performance which may be preventing the efficient use of nutrients
- predict the fertilizer requirement needed to match nutrient supply with crop demand, and
- monitor changes in soil fertility.

More Details

Effective soil testing relies on the proper conduct of three activities:

1. soil sampling
2. laboratory analysis
3. interpretation of results

Sampling

The results from laboratory analyses can be misleading if the sample analysed is not representative or appropriate for the area being tested. A sample should be taken so that:

- each sample is a composite of 25-30 individual cores or sub-samples
- it represents one soil type or management zone only and is taken only from those parts of the area which are typical of the whole area. Changes in vegetation and slope may indicate a change in soil type. Avoid unusual areas such as stock camps, old fence lines or headlands
- cores are taken to a depth appropriate to the purpose

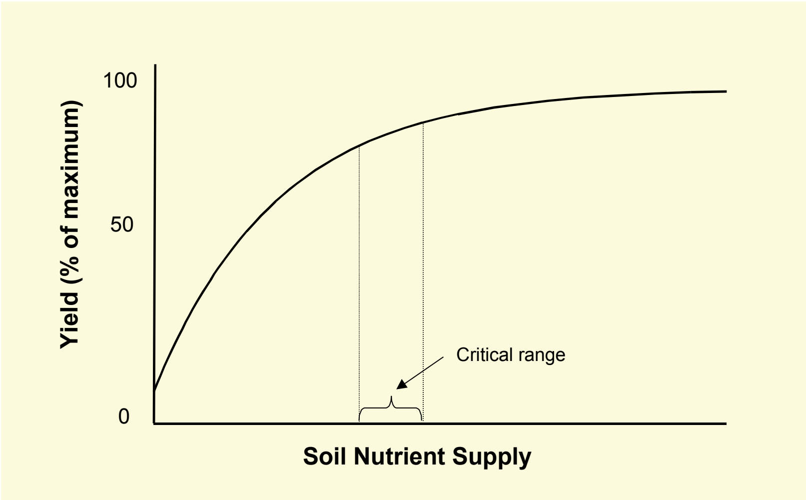
The results of laboratory analyses can also be affected by the timing of sample collection and the handling of samples after collection. Variation in soil fertility from season to season can be considerable and if soil testing is used as a monitoring tool samples should be taken at the same time each year. After collection samples should be kept cool and shaded and forwarded to the laboratory as soon as possible. Fully detailed sampling and handling procedures are usually provided by soil testing services and laboratories, and should be carefully followed. Additionally, detailed requirements for soil sampling and sample handling are set out in Chapter 3, *Soil Analysis an Interpretation Manual* (see Further Reading in Section 6, Other Resources).

Laboratory Analysis

Most laboratories offer a suite of analyses to suit different industry needs. There are many different analytical techniques used worldwide, most of which attempt to measure the size of the soil nutrient pools accessible to plants. It is important that the laboratory use the analytical technique for each nutrient which is appropriate to your soil type and industry. Some specialty laboratories provide analysis of heavy metal content of soils.

The major agricultural soil testing laboratories in Australia are accredited by the Australasian Soil and Plant Analysis Council (ASPAC) and the National Association of Testing Authorities (NATA). This accreditation ensures that the laboratory analysis of samples can be performed with accuracy because the required controls and documentation are in place.

Interpretation of Results
Accurate results of laboratory analyses are of little use unless calibrated against plant growth.   Plant growth response curves are usually the result of years of experimentation with a particular soil type and crop combination at a range of soil nutrient levels (see figure). The level of soil nutrient content required for near maximum production (or critical range) is defined by the response curve.



Plant growth response curve, showing the critical range in soil nutrient supply for near maximum yield.

Recommendations for nutrient management from the results of soil analyses should be made considering many other factors such as:
- availability of the nutrient in the unsampled part of the root zone based on local knowledge
- soil buffering capacity
- the supply of nutrients from mineralisation of soil organic matter
- variation in plant demand, due to plant species, variety, quality and yield targets or carrying capacity
- financial considerations

Interpretation and recommendation should always be carried out by a trained agronomist.

Further Reading
- Soil Analysis: an Interpretation Manual
- The Australian Soil Fertility Manual, Chapter 8
- Incitec Nutrient Advantage: A Qualitative Guide to Soil Sampling (2001)

3.2 Plant Tissue Testing

What is it?

Plant tissue testing involves the sampling of plant parts, chemical extraction to determine their nutrient concentration, and the relation of this to plant production.

How can it be used in nutrient management?

The information plant tissue testing provides on the nutrient status of plants can play an important role in nutrient management by:

- identifying plant nutrient deficiencies, toxicity or production limitations where no visible symptoms occur
- determining if applied nutrients have been taken up by plants
- predicting nutrient problems likely to affect crop production between sampling and harvest
- allowing the calculation of nutrient export in hay or produce, or the dietary intake by animals
- providing information on the variation in plant demand for nutrients with time

Some Details

As with soil testing, plant tissue testing depends on reliable sampling, analytical and interpretation procedures.

Sampling

Plant tissue should be collected from many plants to produce a representative sample. Samples can be taken randomly or from permanent monitoring sites or transects, depending on the nature of the crop and purpose of the test.

Plant nutrient composition varies with plant age and plant part, variety and weather conditions. For many crop and pasture species a standard plant part and plant age are used for monitoring nutrient deficiencies and so samples should be taken using these guidelines. Samples should not be taken if the sampled crop or pasture is under stress due to circumstances other than nutrition, for example if suffering drought, disease or waterlogging stress. Samples are best taken early in the day.

Plant tissue should be stored in paper bags, either cooled or dried immediately after collection, and forwarded to the laboratory as soon as possible. Documentation including notes on the prevailing weather conditions, plant growth stage, plant symptoms, fertilizer history, pesticide and herbicide control programs and previous land use should be filed for later reference when the laboratory result is received.

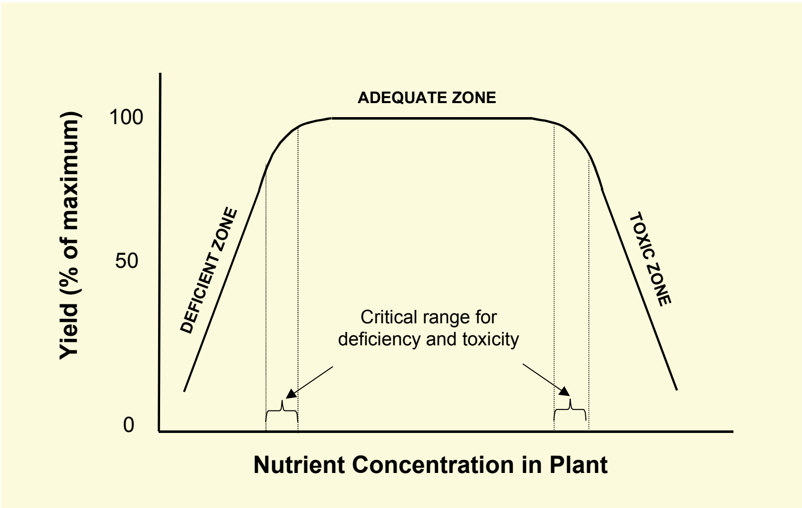
Detailed information on sampling procedures is available in Chapter 3, 'Plant Analysis: an Interpretation Manual' (see Further Reading in Section 6, Other Resources)

Laboratory Analysis

Laboratory analysis usually consists of a chemical digestion of the dried and ground sample, and measurement of the concentration of nutrient in the digest solution. As with soil analysis, most commercial laboratories undertaking plant tissue analysis are accredited through the Australasian Soil and Plant Analysis Council Inc. (ASPAC) and the National Association of Testing Authorities (NATA) to ensure the quality of results.

Interpretation
Plant nutrient concentration can be related to current yield (for diagnostic purposes) or to final yield (for predictive purposes) to produce a nutrient response curve (see figure). To avoid deficiencies, the nutrient concentration of plants should be maintained slightly higher than the 'critical range' required for near maximum production. Concentrations much higher than the critical range can indicate excess availability of nutrients, and in some instances impending toxicity.

Many factors can influence critical nutrient concentrations and the interpretation of plant analyses. For this reason plant analyses should be interpreted by trained agronomists.



Plant nutrient concentration response curve.

Other Measures of Plant Nutrient Status
Other tests for plant nutrient status are available but are not as widely used as the analysis of dried tissue concentrations. Sampling and analysis of plant sap can be used to assess the immediate availability of nutrients. This is in contrast to analysis of dried tissue concentrations, which are an assessment of the accumulation of nutrients over some time. Sap analysis requires careful calibration for the crop and conditions in which it is used but can then be used to identify nutrient shortages or oversupply, or to monitor the results of nutrient applications.

Subtle changes in leaf colour can be related to changes in plant nutrient status. Technology has allowed the quantification of leaf colour through measurements of transmission or reflectance of radiation, or the fluorescence of chlorophyll. Probably most useful is the technique of near infrared (NIR) reflectance spectroscopy. NIR reflectance has been successfully correlated with nutrient status in a range of crops.

Further Information

- Plant Analysis: an Interpretation Manual
- Australian Soil Fertility Manual: Chapter 8
- Incitec Nutrient Advantage: A Guide to Sampling Plant Material for the Most Reliable Results (2001)

3.3 Water Testing

What is it?

Water testing involves the sampling of streams, bores or dams to determine the suitability of water for its intended use.

How can it be used in nutrient management?

The chemical, physical and biological properties of water may affect the health of plants that use the water, the uptake of heavy metals by plants and the physical structure and chemical fertility of the soil to which it is applied. Information from water testing can help avoid a number of potential problems:

- Saline irrigation water contributes to increased plant uptake of cadmium from the soil.
- High chloride levels in irrigation water may adversely affect the quality of chloride sensitive crops.
- Water from some bores may contain high salt levels that in turn can adversely affect soil structure.
- The amount of dissolved nutrients in irrigation water needs to taken into account in determining total nutrient application rates.

More Details

A number of water quality factors can be assessed in the laboratory including the pH, the conductivity, the concentration of specific ions, and the presence of specific chemical compounds or micro-organisms.

Sampling

Water samples can be taken directly from the body of water (stream or dam) or if a pump is used, from the first outlet along the supply line. A representative sample is normally made up of a number (say 5) of small volume sub-samples (say 100 - 200 mL) taken from a large body of water to make up a sample which represents (chemically, physically and biologically) the whole body of water which is of concern or interest.

Where the water is used for irrigation or piped for livestock or domestic purposes, the simplest approach is to let the pump do the sampling. When water is drawn from an underground source, i.e. a bore or well, this is often the only way to sample. Allow the pump to run for sufficient time to flush out water which has been in the pipe, then take samples at time intervals of 5 - 10 minutes, from the first off-take point, e.g. tap, trough, or sprinkler head.

Where available use the sample bottle provided by the testing laboratory or a suitable container, that is strong and durable, so that it will not break in transit and that the cap does not leak once the cap is secured. Rinse the bottle at least 4 times with the water to be sampled, then fill to the top with as little air as possible remaining and seal tightly.

Samples for specific ions often require a ‘preservative’ to be added to prevent precipitation or other chemical activity that might give a false reading. For some analyses it is also important to keep samples cool and away from light. Check with the laboratory for specific sample handling instructions.

Interpretation
Most water quality parameters have been calibrated with plant growth to allow the interpretation of water testing results. For example, salinity classes for irrigation water are outlined in the table below.

Salinity classes for irrigation water

Conductivity (μS/cm)	Salinity Class
<650	Low salinity water, suitable for use on all crops except tobacco with all methods of water application, with little probability of a salinity problem developing
650-1300	Medium salinity, suitable for use on all but very low salt tolerant crops. Water can be used if a moderate amount of leaching occurs. Plants with medium salt tolerance can be grown, usually without special practices for salinity control. Sprinkler irrigation with the more saline waters in this group may cause leaf burn on salt-sensitive crops, especially at higher temperatures in the daytime when evaporation may be high.
1300-3000	High salinity water, suitable for use on medium and high salt tolerant crops only. Water should not be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required.
3000-5000	Very high salinity water, suitable for use only on high salt tolerant crops. For use soils must be permeable, free draining and water must be applied in excess to provide considerable leaching
5000-8000	Extremely high salinity water, generally unsuitable for irrigation unless soils are permeable, well drained and crops are of very high salt tolerance.
>8000	Too saline for irrigation

Further information

Incitec Nutrient Advantage Water Sampling Guide (2001)

Water sampling standards and guidelines are available from Standards Australia.

ASINZS 5667.1: 1998. Guidance on the design of sampling programs, sampling techniques, and the preservation and handling of samples.

AS/NZS 5667.4: 1998. Guidance on sampling from lakes, natural and man-made.

AS/NZS 5667.5: 1998. Guidance on sampling of drinking water and water used for food and beverage processing.

AS/NZS 5667.6: 1998. Guidance on sampling rivers and streams. AS/NZS 5667.11: 1998. Guidance on sampling of ground-waters.

Cadmium in potatoes - managing the risk from saline irrigation water
CSIRO Land and Water/CRC for Soil and Land Management

Maximum Economic Production with Maximum Environmental Care

3.3 Maximum Economic Production with Maximum Environmental Care

What is it?

In many situations, maximising economic production while minimising environmental loading of nutrients is possible by virtue of the inherent buffering capacity of the soil. The degree of management intensity required to maintain this compatibility will depend on the buffering capacity of a particular soil type for a particular nutrient.

How can it be used in nutrient management?

The soil's buffering capacity will:

- indicate which nutrients are more vulnerable to loss from the system
- indicate which nutrients can be managed more flexibly (e.g. a high soil buffering capacity means that nutrient applied in one year will be available in subsequent years with little risk of loss to the environment)

More Details

The objective of any agricultural enterprise is sustainable profitability through judicious application of inputs, and use of the natural resource base.

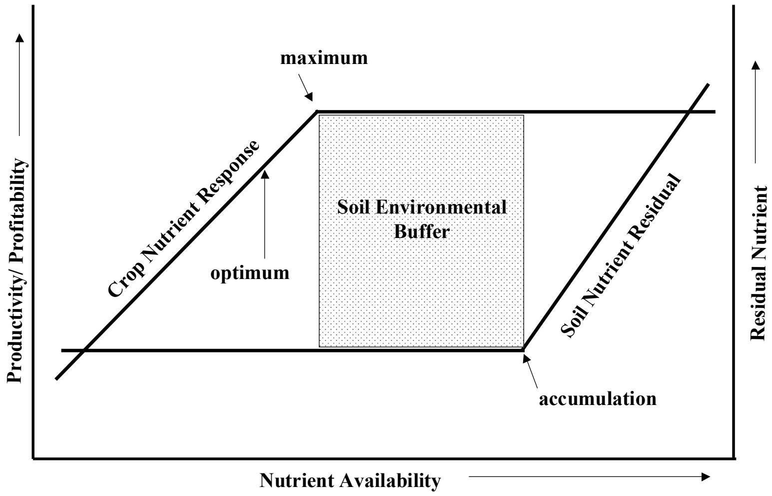
Achieving agricultural sustainability depends on an interaction of agronomic, environmental and social factors. Many criteria can be used to evaluate whether a management system is delivering maximum economic production with maximum environmental care. For example, is the system able to:

- maintain short-term profitability as well as sustained economic viability
- maintain or enhance soil productivity
- provide long-term environmental quality
- maximise efficiency of resource use e.g. soil, water, sunlight, nutrients
- ensure food safety, quality of life and community viability

Although substantial quantities of nutrients have been applied to Australian agricultural land there is evidence that soil nutrient depletion is occurring for some nutrients in some important agricultural regions. This is signified by the difference between nutrient consumed by agricultural enterprises and that exported in produce. Some leakage or losses of nutrients occur, even in the best-managed systems and these losses should be replaced to avoid nutrient depletion.

The sustainability of a nutrient program in the long-term and the potential for off-site nutrient loading can be related to the management activities carried out on the soil and the resilience of the soil (soil environmental buffer capacity).

The soil environmental buffering capacity is specific for a particular nutrient and soil and indicates whether productivity and profitability of an agricultural pursuit is likely to be compatible with environmental limitations imposed by the soil's ability to buffer against nutrient loading or depletion.



Crop response and soil residual as soil nutrient availability increases. Because of the ability of the soil to store nutrient, it acts as an environmental buffer against nutrient loss. The buffering capacity will differ with individual soil types and nutrients.

Generally, economically optimum rates of nutrient addition occur in the range 85 to 95 % of maximum yield. In soils that have a reasonable buffering capacity these rates of nutrient addition are unlikely to cause loading but may lead to nutrient decline. Applying nutrient to match removal is another practice that is unlikely to cause nutrient loading or decline in the long–term, but both these practices may lead to short term decline or loading due to variability in production resulting from climatic variability.

If nutrient addition is at rates that are continually in excess of crop removal, the potential for off-site movement is dependent on the environmental buffering capacity of the soil.

Further Information

Australian Agricultural Assessment 2001, National Land and Water Resources Audit, C/- Land and Water Australia (2001).

Raun, W. R and Johnson, G. V. 1995, Agronomy Journal, 87:827-34

3.4 Nutrient Budgeting

What is it?

Nutrients move onto a farm in a number of ways including in irrigation or rainwater, and in fertilizer, and move out of a farm in produce and through losses such as in soil erosion or nutrient leaching. Nutrient budgeting is the process of keeping a balance sheet of nutrient inputs and outputs for a paddock, a farm or a region.

How can it be used in nutrient management?

Nutrient budgeting can be used as a nutrient management tool to:

- monitor the movement of nutrients in and out of the farm, and also from one part of the farm to another (e.g. in preserved feed)
- help identify nutrient loss pathways which need to be managed
- determine the ultimate nutrient balance
- highlight where positive nutrient balances may be contributing to Load risks
- determine the amount of fertilizer input required where negative nutrient balances may be contributing to Mine risks

More Details

Nutrient budgeting requires the quantification of many different nutrient movement paths. These include:

Nutrient Outputs

- Nutrients contained in produce – grain, hay, milk, meat, wool.
- Nutrient leaching below the root zone
- Nutrient loss in run-off, including nutrients associated with eroded soil particles
- Nutrient loss through soil fixation (P, K) or immobilisation (N, S)
- Nutrient loss to the atmosphere from volatilization and denitrification
- In grazing systems, nutrient loss through transfer in dung or urine to stock camps, yards or laneways.

Nutrient Inputs

- Nutrient in mineral fertilizers
- Nutrient in organic fertilizer, soil amendments, feedlot waste, other imported manures or by-products
- Nutrient in purchased feed (grain, hay, silage, brewer's grain)
- Nutrients contained in purchased stock
- Nutrients released from soil fixation sites, or mineralised from organic matter
- Nutrients in irrigation water and rainfall

For some of these factors, standard nutrient content of materials (e.g. grains) can be used to quantify inputs or outputs, and in other cases researchers have quantified typical nutrient movement rates. For some factors, however, an educated guess must be made, or a measurement taken. A *nutrient movement monitoring* program will help to improve estimates of nutrient inputs and outputs over time.

Computer programs or worksheets that assist in the calculation of nutrient balances are available for some industries.

Movement of nutrients within the farm or paddock
Even where a nutrient balance is calculated for a certain area, an estimation should be made for the internal nutrient movements within that system. For instance on the farm scale, always harvesting hay from one paddock and feeding it out in another will lead to a transfer of nutrients. Similarly, reapplying dairy effluent or other by-products such as crop trash, to just a small part of the farm will lead to a build up of nutrients in that area. On a paddock scale, the gate end of a pasture paddock is likely to receive more dung and urine than the end furthest from the gate. Over time this will lead to a considerable nutrient gradient from one end to the other.

Using the nutrient balance to make decisions
Ensuring that the nutrient budget is in balance will, in the long term, maintain soil fertility at its current level. If the amount of soil nutrient is adequate for production, then maintaining this level is desirable. However, if the amount of soil nutrient is below the critical range for maximum production, simply balancing the nutrient budget will maintain production at a less than efficient level. Similarly, if the amount of soil nutrient is far greater than that required for maximum production, replacement may not be required and added nutrients may be at risk of loss to the environment.

It is apparent that nutrient budgeting must be used in conjunction with *soil testing* and the principles of *maximum economic production with maximum environmental care*.

As in all budgeting and planning there is a degree of error and the system/plan needs to be measured and monitored to ensure success. A regular soil plant and water testing program is the best method. On pastoral enterprises, the same paddocks should be measured to check nutrient levels are reaching the set targets and not exceeding those targets with potential offsite effects. Cropping and intensive grazing farmers have the potential to utilise some of the precision agriculture techniques with yield monitoring or detailed production records. This information can be used to ensure additional inputs into areas of high yield to replace additional nutrient removal and/or corrective action on areas of lower yields.

Further Information

- Australian Soil Fertility Manual Appendix 1
- State Departments of Agriculture or Primary Industry
- Decision support programs developed by various research organisations

3.5 Land Capability and Suitability Assessment

What is it?

Land evaluation is the classification of land units based on either their *capability* of being used for general agriculture, or their *suitability* for a specific use such as the production of a particular crop.

How can it be used in nutrient management?

Land capability and suitability classifications give information about a land unit which can assist in nutrient management by:

- Indicating what the maximum level of land use intensity should be for any land unit
- Indicating areas which are susceptible to nutrient management risks
- Identifying the attributes of a land unit which limit its suitability for a particular land use, and which therefore must be managed

More Details

Land suitability and capability assessments are important in determining the long-term sustainable productivity for current production technique and technology. Capability refers to general fitness of land for agricultural production, whereas suitability refers to fitness for a specific land use (e.g. autumn potato production).

Governments have recognised the importance of land that is capable of sustaining long-term agricultural practice for present and future commodities and are legislating to protect this finite resource at a national and state level.

The type of land use possible in a given area is determined to a large degree by the natural resources of the area, e.g. climate, geology, landform, soil, vegetation. Most agricultural land use involves the growth of crops, trees or pastures. Soil is the base medium for the growth of plants supplying water, nutrients, oxygen, and anchorage, and thus it is not surprising that the nature of the soil is a major determinant of land use.

The steps involved in land evaluation are:

1. Determine the requirements of the land use and limitations.
2. Decide which of the limitations are relevant to the particular land use in the study area, e.g. erosion, climate, drainage, flooding, infiltration, nutrient availability, soil physical, biological and chemical attributes.
3. Choose which land attributes are to be used in a particular study to measure or estimate each relevant limitation.
4. For each limitation, decide critical values of diagnostic attributes to rank the effects of the limitation in terms of increasing degree of severity for the land use.
5. Allocate an overall land suitability or capability class.

Classification
The outputs of land capability and suitability assessments differ:

Land Capability Classes

Class I	Land suitable for all agricultural and pastoral use
Class II	Land suitable for all agricultural use with slight restrictions
Class III	Land suitable for all agricultural use with moderate restrictions
Class IV	Land primarily suited to pastoral use but may be used for occasional cultivation with careful management
Class V	Land which in all other characteristics would be arable but has limitations which, unless removed, make cultivation impractical or uneconomic
Class VI	Land which is not suitable for cultivation but is well suited to pastoral use
Class VII	Land which is not suitable for cultivation but on which pastoral use is possible
Class VIII	Land which has such severe limitations that it is unsuited for either cultivation or grazing

Land Suitability Classes

Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production
Class 2	Suitable land with minor limitations which either reduce production or require more than simple management practices of class 1 land to maintain economic production
Class 3	Suitable land with moderate limitations which either further lower production or require more than those management practices of class 2 land to maintain economic production
Class 4	Marginal land, which is presently considered unsuitable due to severe limitations
Class 5	Unsuitable land with extreme limitations that preclude its use

Local land capability/suitability assessment information may be a good starting point for catchment groups and individual growers to evaluate the environmental risk of current nutrient management practices and determine the most applicable remediation practices.

Further Information

For more information on land capability and suitability for your area contact your state government department of agriculture or natural resources.

3.6 C.R.A.F.T.

What is it?

C.R.A.F.T. is an easily remembered acronym that highlights the fertilizer application factors over which a manager has control. It stands for:

- **C**hoice of fertilizer product
- **R**ate of application
- **A**pplication technique
- **F**requency of application
- **T**iming of application

How can it be used in nutrient management?

Carefully considering each of the C.R.A.F.T. elements can ensure that fertilizer application practices are designed to meet production and environmental objectives. Managing the product, rate, application technique, frequency and timing of application can ensure that nutrients are available where, when and in the correct amount required by plants. This will improve the efficiency of nutrient use and minimise the potential for nutrient loss.

More Details

Choice of fertilizer product

A wide variety of fertilizer products is available in the market place. The suitability of a product for a given situation is determined by:

- which nutrients and how much of each nutrient it contains
- form or chemical species of the nutrients in the product
- effect on other products (e.g. can it be blended or tank mixed?) or equipment (e.g. is it corrosive?)
- impurities which may be contained in the product
- physical nature of the product (e.g. particle sizing)
- solubility or release rate of the product
- application and handling equipment required.

The labelling requirements of fertilizer vary by state. In general, suppliers are required to provide the chemical analysis and form of the nutrients in the product on the bag tag or delivery docket in the case of bulk loads. More detailed product information is often available from suppliers on request.

Rate of application

The rate of fertilizer application for a particular situation should be based on the rate of nutrient required by the plants.

$$\text{Fertilizer rate (kg/ha)} = \frac{\text{nutrient rate (kg/ha)} \times 100}{\text{Fertilizer analysis (\%)}}$$

In determining nutrient rates, consider the results of:

- Soil and plant tissue analyses
- Nutrient budgets
- Crop type, yield/quality/stocking rate targets
- Water availability and future weather patterns

- Local fertilizer trials / knowledge
- Previous crop and fertilizer history
- The need for Maintenance or Capital applications (refer to the Glossary)

Application method
Application method will determine the accessibility of applied nutrients. Different placement methods can ensure that nutrient is immediately available to rapidly growing plants (e.g. banded below the seed at planting), or is metered out over a lengthy growing period (e.g. fertigation). Placement will also affect the degree of interaction between the fertilizer and the soil, which is particularly important where nutrients can become unavailable due to reactions with soil minerals (e.g. phosphorus fixation) or organic matter (e.g. nitrogen immobilisation).

Common options for fertilizer placement include:
- Surface broadcast application
- Surface broadcast and incorporated
- Banded into the soil at various band widths and depths
- Surface banded
- Fertigation
- Foliar application

The best placement method will differ between nutrients and with individual situations. For example, applications to crops generally require more accuracy and precision than applications to intensive pastures where a continual redistribution of nutrients by the grazing animals frequently occurs.

Frequency of Application
The best way to ensure that added nutrients are used most efficiently by plants and are not at risk of loss to the environment, is to match nutrient availability to plant demand over time. Annual crops, perennial crops and pastures all have different patterns of nutrient demand over time, and this pattern should be understood by the nutrient manager.

When applying mobile nutrients such as nitrogen or potassium, small rates of fertilizer applied frequently during the growth cycle of a crop or pasture is often preferable to one large application. However, crops and pastures usually have short periods of rapid nutrient demand and so a larger application at that time will be required. Fertigation systems provide the most flexibility in applying nutrients to meet plant demand, however regular top-dressing or side-dressing of fertilizer can have a similar effect, provided that sufficient moisture is available to move nutrients into the soil.

Timing of application
The timing of fertilizer application may be important relative to factors such as plant stage of growth / nutrient uptake demand, rainfall / irrigation, soil and air temperature. Applying fertilizer well before the plant will take up the nutrient exposes it to losses. Fertilizer often requires water to move it to a site where is can be taken up by plants and, in the case of nitrogen, where it is protected from gaseous losses. Therefore, timing of fertilizer application in relation to irrigation or rainfall can be critical.

Application of fertilizer in relation to soil and air temperatures is also important. For example, applying nitrogen fertilizer to ryegrass when soil temperatures are less than 4°C is likely to be ineffective in stimulating pasture growth rates as ryegrass stops growing at soil temperatures below 4°C. If it will be some time before the ryegrass starts to grow again and take up the nitrogen fertilizer, the nitrate may be subject to leaching losses.

3.7 Equipment Calibration and Maintenance

What is it?

Nutrient application equipment must be calibrated so that nutrient application rates and placement can be controlled. Maintenance of equipment to keep it in good working order such as cleaning, oiling and replacing worn parts will ensure that it's performance can be predicted.

How can it be used in nutrient management?

Calibration and maintenance of equipment will ensure that nutrient applications are carried out as intended in a nutrient management plan.

More Details

Calibration of Equipment

Most manufacturers supply information about how to calibrate equipment. If more accurate calibration is required, this can be achieved by one of the following methods:

Method 1:

Measure the distance covered (D) in metres to apply a known quantity (Q) in kg of fertilizer (e.g. 50 kg).

Method 2:

Remove the delivery hoses from the application tynes and collect and weigh the fertilizer in kg (Q) applied over a measured distance (D) in metres (e.g. 50 metres).

The application rate in kg/ha, for either method, can then be calculated as follows

$$\text{Application Rate (kg/ha)} = \frac{10\,000 \times Q\ (\text{kg})}{D\ (\text{m}) \times W\ (\text{m})}$$

where W = width of the applicator in metres.

For row crop planters, W is the (number of rows) x (row spacing).

Where it is necessary to change the setting on cog or chain drives, the following cog size calculations can be used:

Wheel Cogs:

$$\text{Number of teeth required} = \frac{\text{Required Rate (kg)} \times \text{Present Number of Teeth}}{\text{Present Rate (kg)}}$$

Outboard Cogs:

$$\text{Number of teeth required} = \frac{\text{Present Rate (kg)} \times \text{Present Number of Teeth}}{\text{Required Rate (kg)}}$$

NOTE: Calibration must be carried out under normal operating conditions (speed, gear, engine load), with the implement in the ground, to avoid variations in wheel slip.

Care of application equipment
Follow equipment manufacturers' recommendations closely. Clean bins, augers and applicators after use and oil where recommended.

Most fertilizers are corrosive to steel. Ammonium nitrate and muriate of potash are corrosive to brass.

Many factors influence how corrosive a fertilizer is, e.g. its pH; its hygroscopicity (or tendency to absorb moisture), the presence of free acids, and whether it is an ionic compound (and if so, the types of ions it forms). Additives and coatings are often added to fertilizer to reduce its hygroscopicity. The critical relative humidity of some common fertilizers is shown in the table below. The lower the figure, the more likely the product is to absorb atmospheric moisture.

Critical Relative Humidity of some fertilizer products

PRODUCT	CRH (at 30^{o}C)
Urea	70-75
Ammonium nitrate	55-60
Ammonium sulfate	75-85
Diammonium phosphate (DAP)	65-75
Monoammonium phosphate (MAP)	70-75
Triple superphosphate (TSP)	75-85
Single superphosphate	80-85
Potassium chloride (Muriate of potash)	70-80
Potassium nitrate	80-85
Potassium sulfate (Sulfate of potash)	75-80
Nitrophosphate (12-5-14-2MgO)	60-65

Accreditation of application equipment
The spreading capabilities of broadcast fertilizer application equipment can be tested for several different products and accredited under the Accu-Spread® system, part of the Australian Fertilizer Services Association *FertCare* program. Developed by the University of Melbourne, Accu-Spread® testing can often identify adjustments which improve the accuracy and bout width (distance between runs) of a machine. Accu-Spread® accreditation ensures a minimum standard of spreading accuracy on the certified machine.

Further Information

- Australian Soil Fertility Manual, Chapter 13.
- Australian Fertiliser Services Association Codes of Practice, *FertCare* Accreditation Modules Manual

Paddock Records

3.8 Paddock Record keeping

What is it?

Paddock records include details of operations carried out, stock movements, results of soil, plant tissue and water analysis, irrigation and rainfall records, targeted and actual yield or stock production, imported feedstuffs, manures or effluent, fertilizer application rates, times and spatial variation.

How can it be used in nutrient management?

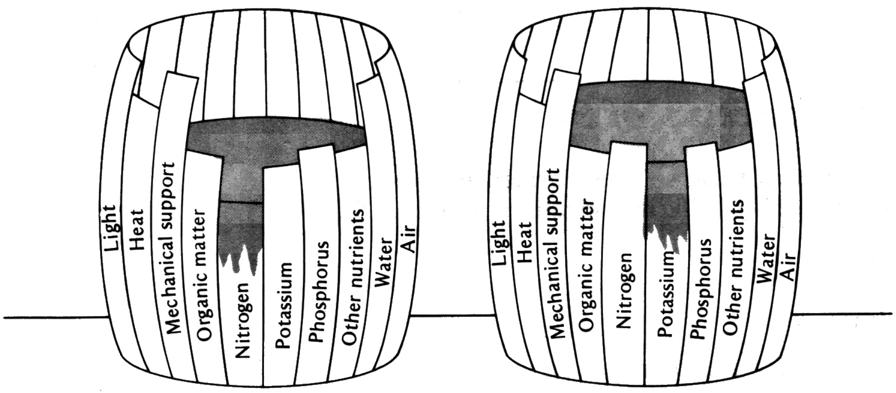
Record keeping of any sort serves many purposes but chief amongst them is:

- A systematic approach to identifying and solving ongoing problems
- A reminder of the influences of seasonal variations
- As a means of measuring progress or lack of it, over time
- To serve as a tool that might unlock additional information when required at some point in the future
- As a tool to undertake a regular critique of your own farming practices
- As a tool to demonstrate that you have taken steps to overcome various problems

In nutrient management, good paddock records can assist in calculating nutrient budgets, calculating nutrient and water use efficiency, identifying areas of a field which have varying productivity, refining production targets, and in predicting future nutrient requirements. Good records can also be used to demonstrate that nutrients have been managed for the best production and environmental outcomes.

More Details

In 1840 Justus von Liebig introduced the theory of the most limiting production factor, which is often described using the analogy of a barrel. Crop or pasture production can only reach the potential provided by the most limiting resource, or the lowest plank in the barrel. Consequently the other resources are not being used in the most efficient way. As the most limiting factor is improved, another factor will become inhibitory. His theory is just as relevant today in considering nutrient management.



Production will only reach the level provided by the most limiting resource, with other resources being utilised to less than optimum efficiency. Improving the level of the most limiting resource will raise the productive capacity and make more efficient use of other resources. Good paddock records can help to identify the most limiting resource (from Brady 1999, see Further Reading, Section 6).

Good paddock record keeping can assist managers to identify and resolve the most limiting factors in their system and therefore use their other resources more efficiently. For example, nutrient availability, rainfall and soil factors may dictate a particular yield potential for a paddock, however this yield potential is not being achieved. Paddock records including the results of soil and plant tissue tests and comments on plant visual symptoms may indicate that supply of a micro-nutrient (e.g. zinc) may be less than required by plants. Test strips or trials can confirm suspected limiting factors. Finally, overcoming the micro-nutrient deficiency will lift production and will ensure that other nutrients such and N and P are used more efficiently.

When keeping paddock records, accuracy and attention to detail will pay off. For example if soil tests are to be taken, accurate positioning of the sample sites will aid in interpreting the results against yields, soil types, incidence of frosts, water logging etc. In monitoring programs good records will also allow future sampling in the same positions so that variation is due to management over time and small scale changes, rather than large scale variation across the paddock. Modern technology involving the use of positioning by satellite will become an invaluable tool in achieving accurate positioning, but if that technology is not accessible or affordable, good records using paddock landmarks and measurement from those will serve to allow relocation of the sites within a few metres.

To best collect information from the field, memory joggers and suitable equipment, need to be prepared. A vehicle kit consisting of pencil, paper (hopefully formatted with headings and prompts), and a rough diagram or map of the area drawn from aerial photographs or some other means of over-viewing the landscape. Any form of test kit, sample bag, positional marker, permanent marker, stakes with coloured ribbons tied to them, sampling device, etc will help, as will some form of established routine as managers should be regularly repeating monitoring processes on many occasions throughout the year. Any piece of information could prove invaluable at some point in the future and should be recorded. For example noting where the machinery broke down and had to be repaired causing a four hour delay, may result in some change in depth of planting or loss of calibration.

Regular photographic records will also help identify subtle changes, and managers should photograph their paddocks on key occasions. Also, regular and close inspections of crops and pastures will increase awareness of anomalies such as herbicide residues, low areas that are subject to water-logging, insect, fungal or animal damage that may later become less visible but which may influence the final outcome. Managers need to establish and maintain an intimate knowledge of their paddocks.

Further Information

- Local TOPCROP, ProGraze or WoolPro Co-ordinator

3.9 Precision Agriculture

What is it?
Precision Agriculture is a term which has been used to describe the use of emerging technologies to manage the spatial variation inherent in agricultural and pastoral land.

How can it be used in nutrient management?
Nutrient availability and yield potential varies widely across individual paddocks. The ability to more closely measure and manage nutrient availability will allow the better matching of nutrient supply and plant requirements across the paddock landscape, resulting in the more efficient use of available nutrients.

More Details
For many farms, there is considerable variability in soils and plant yield within a paddock, resulting from natural variability and human interactions. In modern farming, equipment has been developed to manage ever larger paddocks as single, homogenous units and the ability to respond to variability within these paddocks has diminished.

Precision Agriculture (PA) or Site Specific Crop Management (SSCM) is an attempt to identify and analyse the varying soil characteristics, climate and other crop production factors, at multiple locations within paddocks, sometimes on a continuous basis. This information has the potential to enable farm managers to match the application of inputs and agronomic practices with soil properties and crop requirements as they vary across a paddock. The desired result is improvement in the efficiency of input allocations, maximisation of production capacity and minimisation of adverse environmental impacts.

Core technology which has facilitated the development of PA utilises the **Global Positioning System** (GPS) which provides accurate land-based, aerial or marine navigation information. Various data acquisition methods, including local, real-time sensors and remote sensing systems, have been linked to GPS, to allow the compilation of maps illustrating various aspects of field variability. Data storage devices, such as **Geographic Information Systems** (GIS) have allowed the storage and retrieval of data to be achieved. **Decision Support Systems** (DSS) are able to access this data and provide expert analysis functions producing information which is then more user-friendly for decision making. **Variable Rate Treatment** (VRT) may then be attempted, using control maps developed from the DSS and based on spatially referenced field information, the whole process being controlled automatically.

The GPS has the practical application that it identifies specific sites and allows them to be revisited. Thus, just as graziers can identify individual animals using ear tags and tattoos, GPS users can identify individual sites within a paddock and assess crop production on a per site basis rather than on a whole paddock basis. The ability to return to a specific point in a paddock also allows the farmer to practice site specific management of a crop.

The objective of PA data acquisition systems is to collect information that will assist in the interpretation and management of variability within the paddock or field. A variety of crop and soil sensors are being developed, some of which are commercially available. They include crop yield sensors, soil organic matter and nitrate sensors. Yield monitors for grain crops are typically attached to the clean grain elevator on the harvester. Yield mapping, remote sensing and intensive soil sampling can all be used to quantify and characterise the within-paddock variability. Variable Rate Application Technology (VRT) is an all-encompassing term for equipment designed to allow the rate of farm inputs to be controlled with precision and varied while the machine is in operation.

PA demands accurate, rapid and economical methods to obtain reliable information on the variability of soils, particularly within small scale areas. Normal laboratory methods are often too slow, tedious and costly to develop the amount and type of information required to gain the maximum benefit from PA and the formulation of site specific management decisions.

The interim approach between the current methods of soil testing and the future requirements for site-specific management systems, is based on “Zone management” or “Patch management”. In this process, paddocks are divided into smaller zones based on relatively easily measured factors such as areas of similar yield as shown in yield maps, or surface reflectance and digital elevation models. Sampling is then carried out within the zones.

Those farmers who are involved in GPS and GIS systems for managing their farming operation should seek specialised advice on the most appropriate sampling methods to suit their operation and to help them keep abreast of any new developments in this field.

The implementation of PA will be greatly enhanced by the development of real-time, field-deployed continuous soil sensors which perform soil measurements “on-the-go”. Such instruments would produce immediate results, as well as many other benefits.

Soil sampling equipment which collects, packs, marks the sample position with a record on the GPS, and labels samples is an early step in the evolution of automated sampling and analysis systems.

Realizing the full potential of PA will depend on progression of the range of new tools described above. However, there are significant opportunities available now, in getting started with the yield mapping technology presently available.

In order to achieve a fully automated variable rate application, the farmer must have, or have access to, a computer controlled and GPS equipped machine. More modest approaches may be used and still generate useful information on the response to differential inputs. While GPS is ideal to locate the management units, a tape measure, compass and marker pegs can suffice, but equipment to apply known and exact rates of fertilizer is essential.

Further Information

- Australian Soil Fertility Manual, Chapter 12.

3.10 Handling of Fertilizer

What is it?
The loss of product during the handling, transport, or storage of fertilizer is a potential point source of pollution, which can be effectively managed if appropriate actions are taken.

How can it be used in nutrient management?
A containment approach should be adopted for the handling and use of fertilizer. This means that during the transport, storage, and any other handling operations, operators should ensure that the fertilizer is contained within the transport vehicle or storage site so that possible adverse environmental effects from spillage are avoided.

More Details
Transport procedures
General requirements for the transport of fertilizers are:
- Bulk carriers should be such that no spillage of fertilizer can occur during transport.
- Bulk carriers should be presented in a clean condition so that no contamination occurs. Sheeting used to cover bulk product should be free from contamination.
- All bulk loads of fertilizer products should be securely covered so as to prevent any dust nuisance during transportation and to prevent moisture uptake.
- Packaged fertilizer should be transported in such a way that no damage to packages occurs and no spillage of product occurs.
- Packaged fertilizer should be protected from adverse weather such as rainfall.
- Fertilizer classified as a Dangerous Good must be transported in accordance with the relevant Transport Regulation and relevant provisions in the Australian Dangerous Goods Code.
- The relevant Transport Regulation limit on load size must be observed.
- After discharging fertilizer, the driver should ensure that all fertilizer is removed from the vehicle.

Adverse events
In the event of any spillage of fertilizer products, the driver should take immediate steps to prevent any further loss or contamination of any waterways. The driver should minimise any hazard to other road users and should ensure that no residual product remains that may pose any immediate or future threat to the environment. At the earliest opportunity, the relevant local government authority should be advised of any spillage risks to waterways, ponds, lakes, or ground water.

Storage and handling of bulk fertilizer
Fertilizer should be kept dry and free from contamination. One way of achieving this is to use a storage area with a roof, concrete floor (which includes a damp proof course), and concrete walls of sufficient height to allow front end loaders to operate effectively when loading out of storage. The floor should be designed to bear the weight of vehicles during loading and unloading.

To keep the fertilizer in the same condition during storage, it is important to control any moisture changes in the fertilizer. Fertilizer that is to be stored for a period before use should be covered with impermeable sheeting to prevent contact with moist air. The cover should be arranged so that all air movement is eliminated. Canvas tarpaulins are not suitable because they are permeable.

Impermeable sheeting placed on top of the fertilizer in the bin or silo will further protect the fertilizer from atmospheric moisture. Care is necessary to make sure that the sheeting does not get “sucked into the fertilizer” when emptying the bin.

The period for which fertilizer can be stored without covering depends on weather conditions (humidity) and the characteristics of the fertilizer (i.e. if the fertilizer is hygroscopic).

Worn auger flights will damage (grind) all fertilizers, especially coated fertilizers, and should be avoided.

Silos used for storage of fertilizer must be designed to accommodate the physical properties of the fertilizer being stored (refer to Australian Standards AS 3773 - Bulk Solids Containers Safety Requirements and AS 3744 - Loads on Bulk Solids Containers).

All bulk nitrogen fertilizers, nitrogen/phosphorus fertilizer mixtures, and compound fertilizers should be stored in sheds and covered with impermeable sheeting to exclude moist air. Storage of these products in field bins or silos is not generally recommended.

Packaged fertilizer
Any packaged (bagged) fertilizer should be stored in impermeable bags or bags with impermeable liners. If stored on open wood floors, plastic sheeting should be placed under the bags and wrapped around the whole stack.

All packaged fertilizer, including flexible intermediate bulk containers (FIBC or bulk bags) should be stored away from direct sunlight and rainfall. Fertilizer in bulk bags will compact if stored more than two high. Bulk bags should have impermeable sheeting underneath when stored on dirt or a concrete floor.

Pallets of packaged fertilizer (50 kg size, or less) should not be stored more than three high to avoid compaction and splitting of bags.

Stocks of packaged fertilizer should be rotated so that the older fertilizer is used first.

Storage times
In general, the nutrient value of fertilizer is not diminished in any way during storage. However the physical handling characteristics of fertilizers in storage are likely to be adversely affected over time.

The storage conditions, the type of fertilizer, and the physical condition of the product will determine the period for which fertilizers can be satisfactorily stored. The greater the impact of any of these factors, the shorter the safe storage life of the fertilizer.

Further Information

- Australian Soil Fertility Manual Chapter 13

Disposal of Packaging

3.11 Disposal of Packaging

What is it?
Fertilizer containers and packaging should be disposed of in a manner that ensures that there are no adverse environmental consequences arising from their disposal.

How can it be used in nutrient management?
While most fertilizer materials are handled in bulk, some products are provided in bags of varying sizes and some as liquids. As a first option, recyclable packaging should be used if available.

For all other situations, users should ensure that packaging is disposed of in a manner which minimises the risk of adverse effects on the health of people or the environment.

Particular attention must be paid to preventing woven polypropylene packaging from contaminating wool clips.

More Details
Disposal options may include:

- Alternative use (users should ensure that the container is completely empty. For liquid containers this may mean triple rinsing)
- Recycling
- Sanitary landfills – users should check with the local government authority to confirm that packaging material for fertilizers can be disposed of in landfills in their region

Further Information

- Australian Soil Fertility Manual Chapter 13
- Local Government Authority
- Environment Protection Authority

Greenhouse Gas Emissions

3.12 Managing Greenhouse Gas Emissions

What is it?

Nitrous oxide (N_2O) is a Greenhouse Gas that has an impact 310 times greater than the same quantity of carbon dioxide (CO_2). Nitrous oxide and nitric oxide (NO) are released during the nitrification of ammonia to nitrate and the denitrification of nitrate by soil microbial processes.

What can be done to minimise gaseous losses from agricultural soils?

In general terms, management strategies that increase the efficiency of nitrogen (N) uptake by crops are likely to reduce emission of N_2O to the atmosphere.

The following practices are generally accepted means of optimising the efficiency of N use:

- Avoiding excessive or untimely N inputs
- Adopting minimum or zero tillage practices (soil tillage increases the mineralization of organic matter and hence increases the soil content of NO_3)
- Avoiding water-logging through improved drainage practices and treatment of sodic soils
- Nitrogen fertilizer should be applied at optimal rates according to a fertilizer plan that takes all N sources into consideration
- Where economically feasible, the use of slow release formulations or products incorporating compounds that reduce the rate of nitrification
- Application should be timed to crop needs and development stage, when appropriate through split application
- Adjustment of fertilizer plans to correct for unexpected N losses due to heavy rains or deviations from forecasted crop development should preferably be guided by measurements with a chlorophyll meter, or similar methods
- The supply of nutrients should be balanced so that the N utilization is not hindered by deficiencies of other nutrients
- Application equipment should be monitored and adjusted to ensure precision and control of the amounts of nutrients supplied, and good physical quality fertilizers that give an even spread should be used
- The application should preferably be made by methods that minimize losses and maximize utilization, e.g. by avoiding surface application - options are soil incorporation, or band or point placement close to the roots
- Crops should be protected against pests as damage can reduce the crop's ability to utilize N
- Stubbles should be incorporated into the soil or used as a mulch, as this contributes to N immobilization
- Generally, all measures that prevent soil erosion also prevent losses of N associated with mineral and organic particles

Further Information

- Australian Soil Fertility Manual

SECTION 4

Nutrient Management Codes of Practice

4. Nutrient Management Codes of Practice

This section is available for you to insert the Nutrient Management, Fertilizer Use, or Environmental Codes of Practice of other industries or regions for reference.

A section of the Australian Fertiliser Services Association (AFSA) Code of Practice is provided as an example.

Upon completion, you can insert your own Nutrient Management Code of Practice here.

The following Codes of Practice or Guidelines which either relate to nutrient management or have sections dealing with fertilizer use have been developed in Australia:

Code of Practice for Sustainable Canegrowing
CANEGROWERS
GPO Box 1032
Brisbane Qld 4001

Optimising fertilizer and water use on irrigated pastures
Institute of Sustainable Irrigated Agriculture
RMB 3010 Cooma Rd
Kyabrum Vic 3620

Codes of Practice
Australian Fertiliser Services Association
Box 10
Glenthompson, VIC 3293

4.1 Australian Fertiliser Services Association Inc. Code of Practice for Spreading

4 – CODE OF PRACTICE FOR SPREADING

Note: There are State and Commonwealth Transport and Occupational Health & Safety Regulations which have to be observed. Ignorance of the law is no defence and all AFSA members will be familiar with them, and as a Duty of Care, will ensure that the customer is also aware of them before commencing to work for that customer. The AFSA Spreader operator will pay additional particular attention to the following.

The spreading operator will refuse any job that would result in breaching the Code of Practice or any Law or Regulation which may be applicable to the task.

ISSUE	*STRATEGY*
4.1 Weather conditions	FERTILIZER PRODUCTS WILL BE SPREAD ONLY ON THE LAND AREA CONTRACTED.
4.1.1 *Cross winds*	• The operator will not spread on areas close to boundaries if there is visible drift onto an adjacent property.
	• The operator will ask the customer if it is acceptable for dust to drift onto land other than that contracted to be spread, but still on the property.
4.1.2 *Rain*	• Where practical, the operator will not begin spreading when rain is imminent.
	• The operator will clarify with the customer what are unacceptable amounts of soil tracking off the area being spread, as well as rutting and compaction on it, and will stop spreading once rain has produced conditions where this is happening.
	• Soil tracking onto roads will be avoided where it breaches local regulations.
4.2 Run off and leaching	FERTILIZER PRODUCTS WILL BE CONTAINED ON THE LAND AREA CONTRACTED
4.2.1 *Run off into waterways*	• The operator will be familiar with, and will operate so as not to breach any State Department or other guidelines on what buffer zones to allow to minimise fertilizer and soil ameliorant run off into waterways and drains, especially in irrigation schemes, and will expect to operate within them.
	• When spreading on grassland, the operator will also take into consideration ground cover and slope to minimise run off.
	• When spreading near free water, the operator will allow for any legislated buffer zone or a minimum of a “half bout

width" *(as defined in 4.5.1),* whichever is greater.

- When spreading in irrigation bays, the operator will allow for any legislated buffer zone or a minimum of 10 meters from the end of each bay, whichever is greater.

- When spreading in dry watercourses, which have only intermittent free running water, the operator will allow for any legislated exclusion areas or in the absence of such legislation, will negotiate with the customer.

4.2.2 *Leaching into groundwater*

- The operator will be familiar with the range of fertilizer rates commonly advised in the district and will query the customer if the rate is above the upper limit.

- This will be noted on the AFSA approved Job Sheet.

4.3 Farm Hygiene

MACHINERY WILL BE "CLEAN ON / CLEAN OFF" SPREADING JOBS WHERE FACILITIES EXIST.

4.3.1 *Wash-down*

- The operator will attempt at all times to ensure that machinery (and trucks) are "clean on" to the property.

- If the customer specifically requests stringent wash-down for quarantine reasons, there will be an extra charge.

- It is the customer's responsibility to provide wash-down facilities at or near the point of entrance to the property to allow the operator to make machinery and truck "clean off' the property unless there is a prior arrangement for the operator to do this elsewhere for an additional charge.

4.4 Occupational Health

ALL FERTILIZER PRODUCTS WILL BE SPREAD ONLY ON THE LAND AREA CONTRACTED.

4.4.1 *Contact with people and livestock*

- It is the responsibility of the customer to inform the operator if there is the likelihood of there being other people (or livestock) in the vicinity of the area to be spread, and to advise those people (or owners of the livestock) of the approximate time of the spreading operation (or to move the livestock).

4.5 Occupational Safety

ALL SPREADING MACHINERY WILL UNDERGO ROUTINE MAINTENANCE AND BE OPERATED ONLY WITHIN ESTABLISHED SAFETY LIMITS.

4.5.1 *Routine maintenance after:*

- **Each Job** The operator will do the tasks listed in the AFSA *"Sunvisor Checklist Vehicle and Spreader"*

- **Each week:** The owner will organise completion of the AFSA *"Routine Checklist Vehicle and Spreader"*

- **Each year:** the owner will ensure that the vehicle and spreader are serviced according to the AFSA *"Annual*

Service Checklist Vehicle and Spreader"

- Any other items are serviced according to the manufacturers handbook using AFSA approved equipment

- After initial official accreditation under the AFSA *"Accu-Spread Protocol",* the spread pattern and spread bout width are checked using the AFSA *"Spreader Test Kit."*

4.5.2 *Safe operation*

- The operator will be familiar with the safety limits for operating the machine, and will advise the customer if the job would result in exceeding them.

- It is the responsibility of the customer to alert the operator to any known hazards when operating in a particular area.

- Varying weather conditions can alter the limits to operation in any area so the operator may need to adjust a previous decision.

4.6 Sound practice

THE **RIGHT PRODUCT** WILL ALWAYS BE SPREAD IN THE **RIGHT PLACE** AT THE **RIGHT** RATE (WHERE **"RIGHT"** IS AGREED TO BY THE SUPPLIER, THE CUSTOMER AND THE OPERATOR), AND **WITH MINIMUM ADVERSE ENVIRONMENTAL IMPACT.**

4.6.1 *Right product*

- The customer's written fertilizer order will be checked verbally with the customer and sufficient records kept to enable trace back to the depot or factory if required.

- Where appropriate, the *Order Form* will include the signature of the adviser making the recommendation.

- The operator will check with the customer that the fertilizer products to be spread are those which were ordered and if the customer has seen a copy of the entire *Label* (if bagged) or the *Material Safety Data Sheet* (if bulk) to verify that the technical specification is acceptable for the job.

- The operator will conclude the operation for applying the product by delivering to the customer for signature the final copy of the original *Order Form.*

4.6.2 *Right place*

- The proposed location should be inspected with the customer if practicable.

- If not, it is the responsibility of the customer to provide at least three independent descriptors, which will enable the operator to locate the area to be spread.

  *(Examples are distance in km. from marked road junction, **number** of gates past an unambiguous farm landmark, **aspect and visual description** of the area itself.*

- The operator will record these details on the AFSA approved Job Sheet.

  (Some operators will supply AFSA Area Markers which the customer can locate at the approach to the spreading area.).

- The operator will have access to maps of a scale appropriate to the service area which will be used for final location.

4.6.3 *Right rate*

- It is the responsibility of the customer to provide an accurate estimate of the area to be spread - this should allow for all buffer zones referred to in Section 4.2.1 (above). The operator will provide the figure for half the *Accu-Spread* bout width for the product to be spread so that the buffer allowance can be calculated.

- Before starting, the operator will examine the area to be spread to confirm the customer's estimate and where possible, both will verify this on the *Job Sheet.*

- Any disagreement will be recorded on the *Job Sheet* and the customer's area estimate will be taken as correct.

- The operator will discuss with the customer ways to rectify the situation if there is a discrepancy between the actual and estimated areas to be spread, thus changing the spreading rate.

- If this is not possible, the operator will adjust as follows: -

1. if a fertilizer shortfall is predicted, the rate of application will be reduced for the remaining area and the operator will note this on the *Job Sheet.*

2. if a fertilizer surplus is predicted, this will be noted on the *Job Sheet* and left for the customer in the dump (if on farm).

- The AFSA Certified equipment being used will have been calibrated for the four most common products and rates applicable to the customer's needs used in the district under the *Accu-Spread* protocol.

- The operator will always spread as even as is practicable given the particular circumstances of the job.

- To ensure this, checks will be made on how much of the fertilizer delivered remains, as a minimum
  (for small jobs requiring single loads) after an estimated two thirds of the area has been spread.
  (for large jobs requiring multiple loads) after an estimated *25, 50,* and *75%* of the area has been spread.

4.6.4 *With minimum adverse environmental impact*

- The operator will avoid spreading when this could damage the soil, especially by rutting and compaction.

- In assessing the area to be spread, the operator will discuss with the customer minimising the waste fertilizer in waterways and ground water and will note buffer zones on the *Job Sheet.* (See also 4.1, 4.2, and 4.3 above).

SECTION 5

Making Sure Your Code is Implemented

5. Making Sure Your Code is Implemented

5.1 Involving the Target Audience

Involvement of the target audience in developing Codes of Practice is essential to ensure that they are implemented. The target audience will be able to comment on the practical limitations to following a proposed nutrient management strategy.

Other stakeholders who will be involved in implementing the Code, or who will have to deal with the consequences of nutrient management should also be involved in the Code of Practice development process. For catchment, industry or farm focussed Codes of Practice, the stakeholders may include:

Catchment

- Local councils
- Branches of State farmer organisations
- Catchment management authorities
- Departments of Agriculture or Primary Industry
- Fertilizer distributors
- Conservation/environmental interest groups

Industry

- Growers
- Agribusiness
- Quality assurance providers
- Trade customers with quality assurance programs

Farm

- Family, including spouse and children
- Employees
- Neighbours
- Suppliers
- Buyers

5.2 Training Requirements and Implementation Assistance

The Rural Training Council of Australia (see Section 6 for contact details) has issued Training Packages for Agriculture and Horticulture. These packages include National Competency Standards and Training Guidelines for most agricultural and horticultural operations, including the use of fertilizers. When developing Codes of Practice, check the Competency Standards for the industry concerned for relevant standards and training packages.

Some industries may have developed specific training programs for farm advisers or farm managers. For example, the Cooperative Research Centre for Sugar ran a training program “Sustainable Nutrient Management in Sugar Production Short Course” which has been used by the Bureau of Sugar Experiment Stations (BSES) to develop a one day training module for farmers to help improve nutrient management practices in the sugar industry.

5.3 Raising awareness and promoting use of the Code

Codes of Practice as a means of self-regulation will only be taken seriously if a high proportion of the people, to whom a Code is targeted, actually implement the Code. This suggests that the following points be observed:

- Farmers should be made fully aware of the Code and how it will be of benefit to them.
- Government agricultural and environmental agencies and exporters, wholesalers and retailers who purchase farm produce should be made aware of the Code and its implementation program
- Fertilizer advisers must be familiar with the Code and be applying it when formulating fertilizer recommendations
- Awareness/information programs for farmers and training programs on the use and implementation of the Code for fertilizer advisers should be provided
- The level of adoption of the Code among the target audience should be measured by a survey at appropriate time intervals.

SECTION 6

Other Resources

6. Other Resources

6.1 Further Reading

Australian Soil Fertility Manual
Edited by J. Glendinning
Published by CSIRO Publishing, 2000

Soil Analysis: an interpretation manual
Edited by K.I. Peverill, L.A. Sparrow and D.J. Reuter
Published by CSIRO Publishing, 1999

Plant Analysis: an interpretation manual (2nd ed)
Edited by: D.J. Reuter and J.B. Robinson
Published by CSIRO Publishing, 1997

Soil Fertility and Fertilizers (6th ed)
J.L. Havlin, J.D. Beaton, S.L. Tisdale, W.L. Nelson
Published by Macmillan Publishing Co., 1999

The Nature and Properties of Soil (12th Edition)
N.C. Brady and R.R. Weil
Published by Prentice Hall, 1999

Managing cadmium in potatoes for quality produce: 2nd edition
CSIRO Land and Water/CRC for Soil and Land Management

Cadmium in potatoes - managing the risk from saline irrigation water
CSIRO Land and Water/CRC for Soil and Land Management

Managing cadmium in summer grain legumes for quality produce
Agency for Food and Fibre Science, QDPI Kingaroy; Natural Resource Sciences, NR&MI Indooroopilly and CSIRO Land and Water Adelaide

Nutripak - A practical guide to cotton nutrition
Australian Cotton Cooperative Research Centre , 2001

FertCare Accreditation Modules Manual
Published by: Australian Fertilizer Services Association Inc.

6.2 Contacts and Websites

Fertilizer Industry Federation of Australia, Inc
Executive Manager
Locked Bag 916
Canberra ACT 2601
www.fifa.asn.au

National Farmers Federation
PO Box E10
Kingston ACT 2604
www.nff.org.au

Rural Training Council of Australia
PO Box E10
Kingston ACT 2604
www.rtca.farmwide.com.au

National Land and Water Resources Audit
Audit Management Unit
GPO Box 2182
Canberra ACT 2612
www.nlwra.gov.au

CSIRO Publishing
PO Box 1139
Collingwood, Vic 3066
www.publish.csiro.au

Standards Australia
PO Box 5420
Sydney NSW 2001
www.standards.com.au

SECTION 7

Glossary

7. Glossary of Terms

Anhydrous Ammonia: Anhydrous means "without water". Anhydrous ammonia is a form of ammonia that is free of water, as opposed to the water solution of ammonia commonly used in household cleaning. It must be stored under pressure to maintain a liquid form and is applied by soil injection or in flood or furrow irrigation.

Blow Risk: Air quality impacts associated with fertilizer handling, application and emissions arising from soil.

Capital Application: An application rate in excess of the nutrient removal rate in any one year, aimed to rapidly increase soil nutrient levels to that required for restoration of an adequate level of soil fertility.

Contaminant: (as applies to fertilizer products) a foreign, unwanted material which has been introduced to the fertilizer product, e.g. seed, other vegetative material, residual fertilizer from a previous cargo.

Control Measures: Management controls, procedures, site infrastructure established to manage activities impacting (actual or potential) on the environment.

Environmental Impact: Any change to the environment, whether adverse or beneficial, wholly or partially resulting from activities.

Fertigation: The application of fertilizer dissolved or suspended in irrigation water.

Fixation: Processes by which nutrients or impurities are rendered unavailable by reaction with soil components. Also refers to the process by which atmospheric nitrogen is converted to plant available nitrogen by root-nodule bacteria in legume plants.

Impurities: An undesirable element or substance which occurs naturally in the raw material from which fertilizer is manufactured (e.g. cadmium and fluorine in phosphate rock), or which is synthesised during the manufacture of fertilizers (e.g. biuret in urea).

Leach Risk: Environmental risks associated with water carrying dissolved nutrients or particles (soil or organic matter) moving through the soil beyond the root zone.

Load Risk: Application and accumulation of nutrients and undesirable substances.
Application of nutrients to non-targeted areas e.g. soil, water, air or farm produce.

Macropore: Large air spaces in soils often formed by roots or small soil animals and worms. Can allow water to move rapidly downwards in the soil profile.

Maintenance application: An application rate based on the level of nutrient removed by the crop or production system, aimed to maintain the soil fertility at a constant level.

Maximum Limit (ML): means the maximum concentration of a specified contaminant or natural toxicant, which is permitted to be present in a nominated food. Usually expressed in milligrams of the contaminant or natural toxicant per kilogram of the food (mg/kg). MLs are set by the Australian and New Zealand Food Authority at levels that are consistent with public health and safety and which are reasonably achievable from sound production and natural resource management practices. Consideration is also given to Australia's and New Zealand's international trade obligations under the World Trade Organization's Sanitary and Phytosanitary Agreement and Technical Barrier to Trade Agreement.

Mine Risk: Risk of decline in soil fertility due to net export of nutrients in produce without replacement.

Non Point Source: Release of nutrients or other elements or contaminants to the environment usually at low to moderate concentrations from a large area (e.g. agriculture).

Nutrient Management Risk: The chance of an unfavourable environmental or production consequence resulting from the interaction of nutrient management activities (either operational or agronomic) in a given environment (e.g. location, soil type and weather conditions, etc).

Operational Activities: Activities involved with the transport, storage, handling and application of fertilizer products.

Point Source: Release of nutrients or other elements or contaminants to the environment from a known and concentrated source, e.g. feedlot or food processing factory.

Run Risk: Risk of storm and surface water run-off potentially carrying nutrients.

Yield Potential: The maximum yield that could be achieved, given the prevailing circumstances.

SECTION 8

Appendices

8. Appendices

Appendix 1: Sample Questions to Guide Use of the Risk Calculator

Depending on the target audience, consider these questions from an industry, regional or farm perspective.

Risk		Sample Questions
Leaching Risk	Likelihood	❑ Does the area have a high average annual rainfall, and how is it distributed throughout the year? ❑ Do soils have a light texture (i.e. sandy) and are subsoils also light textured? ❑ Do soil profiles have significant numbers of macropores / cracks which allow preferential flow through the soil? ❑ What percentage of the time is soil bare or fallow? ❑ Is water likely to be moving through the soil beyond the depth of the plant roots during crop / pasture growth cycles? (Consider irrigation method, irrigation scheduling, rainfall intensity etc.) ❑ What is the concentration of nutrients in irrigation water? ❑ What is the frequency and rate of nitrogen and phosphorus applications and are they appropriate to crop demand at the time of application? ❑ What is the current soil nitrogen and phosphorus fertility? (shallow and deep) ❑ What is the nutrient holding capacity of soils? ❑ Is the timing of the nutrient application appropriate to the irrigation practice or likelihood of rainfall? ❑ Is irrigation tailwater contained and recycled? ❑ Do mixed pastures have a significant grass component to use nitrogen produced through the decomposition of legumes? If not, have pastures been dominated by legumes for >2 years?
	Consequence	❑ What is the current quality of the ground water in the area and surrounding areas (naturally poor, already contaminated, good quality)? ❑ What is the depth to ground water (<5 metres, 5 to 20 metres, >20 metres)? ❑ What is the current and potential use of ground water in the area and surrounding areas? ❑ Is the impact of leaching able to be contained or reversed?

Risk		Sample Questions
Load Risk	Likelihood	❑ Does the material to be applied as a fertilizer or soil amendment contain impurities such as heavy metals (e.g. cadmium, lead or mercury) which may lead to accumulation in the soil or uptake by the plant in excess of Maximum Limits specified by the Australia and New Zealand Food Authority. ❑ Are concentrations of heavy metals greater than those typically present in the soil? ❑ Are soils typically sandy and acidic? ❑ Are crops irrigated with saline water? ❑ Are mineral imbalances common in produce or animals? (eg hypocalcaemia) ❑ Are fertilizers aerially applied near open watercourses or to areas not in production (e.g. lanes or yards)? ❑ Are nutrients applied in a balanced way and according to recommendations based on soil testing? ❑ Are organic fertilizers adequately composted and applied in an appropriate way to minimise microbial contamination of produce? ❑ Are effluent or waste products routinely applied to limited land areas? ❑ Are soils likely to be waterlogged when soil temperatures are above 10°C and after nitrogen fertilizer application, resulting in increased nitrous oxide emissions?
	Consequence	❑ Will the produce grown enter the human food chain and what market restrictions are in place? ❑ What is the soil reaction with excess nutrients or impurities (e.g. fixation into unavailable forms)? ❑ Are crops such as peanuts, root and leafy crops, which are most likely to exceed the maximum limit (ML) for cadmium, grown or likely to be grown in the future? ❑ Do heavy metal or other nutrient concentrations in produce approach maximum limits (MLs)? ❑ Is the impact of loading able to be contained or reversed? ❑ Are carbon credits available to account for liberated greenhouse gases?

Risk		Sample Questions
Run Risk	Likelihood	❑ Does the area have a high average annual rainfall, and how is it distributed throughout the year? ❑ Is the area prone to short periods of high intensity rainfall? ❑ What is the topography of the area (e.g. flat, gently undulating, hilly)? ❑ Are soil conservation structures, such as contour banks, in place? ❑ What conservation tillage methods are being utilised (e.g. stubble mulching, minimum or zero tillage, strip cropping)? ❑ What is the level of ground cover over time? ❑ Is there likely to be surface water run-off during crop / pasture growth cycles (consider irrigation methods, irrigation scheduling, rainfall intensity, cultivation & stubble handling methods etc)? ❑ Is soil erosion likely to occur with surface run-off events? ❑ What is the frequency and rate of nitrogen fertilizer applications relative to crop / pasture demands at the time of application? ❑ Are fertilizers likely to be applied to the surface of the soil within 4 days prior to anticipated run-off events? ❑ Could fertilizers (applied dry or by fertigation) accidentally end up in waterways during application or handling? ❑ Does the irrigation system have a high potential for run-off to occur? ❑ Is the tailwater contained in surface irrigation systems?
	Consequence	❑ Is surface water run-off contained / reused on farms? What is the volume stored, how far is it from creeks, rivers etc? ❑ Is the surface water contained on farms likely to be consumed by stock or used for domestic purposes? ❑ Is the nutrient concentration of surface water leaving farms likely to be greater than the concentration in the nearby waterways at the time the water leaves the farm? ❑ What is the current and potential use of waterways? ❑ Are waterways running permanently or intermittently? ❑ Are areas adjacent to waterways vegetated, and are they able to effectively filter run-off?

Risk		Sample Questions
Blow Risk	Likelihood	❑ Are fertilizers surface broadcast and dusty in nature? ❑ Are weather conditions within acceptable limits at the time of application? (e.g. wind less than 15 km/hr) ❑ Do times of the year with high wind correspond to periods where fertilizer is applied or soil is bare? ❑ Where anhydrous ammonia is being used, has storage and application equipment been regularly tested, inspected and maintained? ❑ Are spreader operators and machines accredited under the *FertCare* program? ❑ Is application equipment calibrated and properly maintained and are trained and competent operators applying fertilizer? ❑ Are crop residues burnt?
	Consequence	❑ What is the population density and demographics in the area? ❑ How far are points of fertilizer handling and application from the nearest sensitive area e.g. houses or towns?

Risk		Sample Questions
Mine Risk	Likelihood	❑ What is the nutrient buffering capacity of the dominant soil types? ❑ Is crop nutrient removal (including crop residues if removed or burnt) greater than the nutrients applied? ❑ Are grazing management practices contributing to nutrient transfer from more productive to less productive areas (e.g. use of night paddocks or no use of back-fencing)? ❑ Are organic matter levels declining over time? ❑ Is soil acidity increasing over time? ❑ Are applied products appropriate for soil characteristics, or does soil chemistry preclude their availability (e.g. rock phosphate will not become available in alkaline soils).
	Consequence	❑ Is the current soil fertility in the optimal range or below as measured by soil testing? ❑ How much will crop or pasture production be reduced by nutrient deficiency? ❑ What is the relationship between ground cover and soil erosion? ❑ How is soil microbial activity affected by nutrient depletion? ❑ Is lime used on a regular basis to amend soil acidity? ❑ Do rotations include stubble retention, green manure crops or pasture phases to raise organic matter levels?

Appendix 2: Risk Management Strategies

Some possible causes and suggested strategies to reduce “Leach, Load, Run, Blow and Mine” risks are detailed as follows.   You may need to gather other relevant information to assist in the formulation of best management practices for a specific industry, region or farm.

Risk	Possible Causes	Suggested Strategies to Minimise Risk
Leach Risk	Inappropriate fertilizer application	❑ Consider use of decision aids listed in the *Rate of application* C.R.A.F.T., (see the Nutrient Management Toolbox, section 3.6) in order to make a better estimate of the optimum rate of nutrient to be applied ❑ Consider the soil nutrient holding capacity and do not apply rates of soluble nutrients which exceed this capacity in one application ❑ Undertake nutrient budgeting and include nitrogen input from current or previous legume species ❑ Select a less mobile nitrogen fertilizer i.e. a product containing less nitrate and more ammonium ❑ Use accredited operators and machines to broadcast apply fertilizers so that even application is achieved
	Inappropriate timing of application	❑ For mobile nutrients, consider matching plant nutrient demand over time and nutrient supply by applying small amounts of fertilizer frequently during the growth cycle of the plant rather than one large application. This can be achieved by top-dressing, side-dressing, foliar application or fertigation. ❑ When fertigating in fixed irrigation systems, inject fertilizer in the last third of the irrigation time in order to assist in keeping the nutrients in the plant root zone ❑ Avoid application of mobile nutrients to a dry soil profile well in advance of sowing ❑ Apply fertilizer when tile drains are not running ❑ Apply manures at a time when mineralised nutrients can be taken up ❑ Check weather forecast and avoid application of fertilizer if significant rainfall is expected to cause a leaching event
	Poor irrigation practices and management	❑ Improve irrigation scheduling in order to minimise water movement below the root zone of the crop ❑ On coarse textured (sandy) soils, use small frequent applications of water rather than infrequent large applications ❑ Change the irrigation method in order to have greater control over the application of water e.g. change from furrow irrigation to trickle, shorten runs in flood irrigation
	Poor choice of crop	❑ Avoid growing shallow rooted plants on coarse textured soil in high rainfall areas or where there is poor control over the amount of water applied in each irrigation i.e. flood irrigation ❑ Include a deep-rooted crop in the rotation to capture nutrient that has escaped deeper in the soil profile ❑ Ensure that the nutrient management program is balanced so that nutrients are used effectively throughout the entire rotation ❑ Coordinate the return of crop or pasture residues to the soil, so that peak nitrogen mineralisation matches rapid crop uptake

Risk	Possible Causes	Suggested Strategies to Minimise Risk
Load Risk	Fertilizer application inappropriate causing heavy metal loading	❑ Consider use of nutrient management tools in order to make a better estimate of the optimum rate of nutrient to be applied ❑ Where high application rates are used, and where the maximum limits (MLs) in farm produce may be exceeded choose fertilizers with low levels of impurities ❑ Test soils and produce to indicate current heavy metal concentrations ❑ Obtain specification for, or analyse organic amendments for heavy metal concentrations ❑ Amend soil pH. Uptake of cadmium is often greater in acidic soils ❑ Where zinc is low, more cadmium is often taken up by plants. The application of zinc fertilizer may depress cadmium uptake
	Poor choice of crop	❑ In high risk situations avoid growing crops or varieties that have a potential to violate the maximum limit (ML) for cadmium e.g. peanuts, root and leafy vegetable crops
	Inappropriate use of organic fertilizers or effluent	❑ Compost organic waste properly prior to soil application or allow sufficient time for decomposition prior to plant establishment ❑ Obtain specification for, or analyse organic amendments or effluent for nutrient content and ensure that application does not exceed plant nutrient requirement ❑ Check nutrient budget and adjust the application of other nutrients accordingly
	Nitrogen fertilizer application inappropriate causing nitrous oxide to be liberated to the atmosphere	❑ Check weather forecast and avoid application of nitrogen fertilizer if significant rainfall is expected to cause a waterlogging event ❑ In order to better match plant nutrient uptake demand over time and nutrients being applied as fertilizer, it is often better to apply small amounts of fertilizer frequently during the growth cycle of the plant rather than one large application of fertilizer ❑ Apply away from fresh crop residue e.g. deeper in the soil profile ❑ Apply in cooler periods of the year ❑ Apply using products or methods that delay nitrification
	Poor irrigation management causing water logging and nitrous oxide to be liberated	❑ Improve irrigation scheduling in order to minimise water logging of the soil ❑ Ensure that the irrigation rate is appropriate for the soil texture and stability ❑ Change the irrigation method in order to have greater control over the application of water and reduce water logging e.g. change from furrow irrigation to trickle
	Nutrient accumulation in animal traffic areas	❑ Manage stock movements and alter paddock layout to reduce time spent in high traffic areas such as laneways and watering points
	Nutrient application inappropriate causing nutrient loading	❑ Consider the use of nutrient management tools including soil analysis, to better estimate the optimum rate of nutrient for crop productivity ❑ Determine if nutrient input may be reduced by increasing uptake efficiency. Consider combinations of C.R.A.F.T., (see the Nutrient Management Toolbox, Section 3.6) ❑ Determine the phosphorus buffering capacity of the soil and ensure this capacity is not overloaded ❑ Take account of nutrient applied in irrigation water
	Poorly balanced fertilization	❑ Soil and plant tissue tests should be interpreted by a suitably qualified agronomist ❑ Apply all nutrients required to reach realistic yield goals ❑ Monitor for micro-nutrient deficiencies or toxicities
	Poor application techniques	❑ Ensure equipment is calibrated and operator is adequately trained ❑ Keep paddock records of material applied, spatially referenced if necessary

Risk	Possible Causes	Suggested Strategies to Minimise Risk
Run Risk	Fertilizer application inappropriate	❑ Check weather forecast and avoid application of fertilizer if significant rainfall is expected to cause a surface water run-off event ❑ Control and re-use tail water in flood and furrow irrigation systems whenever possible and ensure that nutrient load of recycled water is taken into account in nutrient budgets ❑ Avoid application of fertilizer when the ground is saturated ❑ Incorporate or band fertilizer rather than leaving it on the surface of the soil ❑ Consider using nutrient management tools in order to make a better estimate of the optimum rate of nutrient to be applied ❑ In order to better match plant nutrient uptake demand over time and nutrients being applied as fertilizer, it is often better to apply small amounts of fertilizer frequently during the growth cycle of the plant rather than one large application of fertilizer ❑ Leave an unfertilized buffer zone at the bottom end of flood irrigation bays when surface broadcasting fertilizer ❑ Reduce phosphorus losses below irrigated pasture's root zone and from bay surface run-off by applying phosphorus fertilizer a number of days before irrigating
	Poor ground cover management	❑ Maintain adequate ground cover to protect the soil and slow down surface run-off ❑ Use soil conservation and tillage practices which encourage infiltration of rainfall and minimise run-off, such as minimum or zero tillage, controlled traffic, strip cropping or contour banks ❑ Leave a buffer zone or develop and maintain a riparian strip where surface water drains from the paddock ❑ Reduce compaction to improve water infiltration rate ❑ Ensure that water control structures (contour banks) are well maintained on sloping areas
	Poor irrigation practices and management	❑ Match irrigation to plant needs using soil moisture monitoring, scheduling and irrigation techniques to minimise run-off ❑ Re-use surface water run-off ❑ Ensure there is no run-off for at least the first two irrigations after spreading fertilizer on pasture
	Poor storage and handling procedures	❑ Store product in a clean, dry, bunded area protected from rainfall ❑ Clean up spills immediately and dispose of as part of the nutrient management plan

Risk	Possible Causes	Suggested Strategies to Minimise Risk
Blow Risk	Fertilizer application inappropriate causing dust or drift risk	❑ Apply fertilizer when weather conditions are within acceptable limits at the time of application (e.g. wind less than 15 km/hr) ❑ Leave a buffer zone on the down wind side of the paddock ❑ Apply fertilizer when wind direction is blowing away from nearby sensitive areas e.g. open water and houses / towns ❑ Choose a fertilizer with a large, uniform particle sizing and low dust content ❑ Avoid handling fertilizer with conveying equipment that crush or grind granules ❑ Avoid aerial, broadcast and foliar application methods when conditions are not suitable ❑ Ensure application equipment is suitable and set up correctly for the prevailing weather conditions e.g. droplet size when using foliar sprays ❑ Consider use of decision aids listed in *Rate of application* C.R.A.F.T., (see the Nutrient Management Toolbox, section 3.6) in order to make a better estimate of the optimum rate of nutrient to be applied ❑ Storage of gypsum, lime and manures in the field in an appropriate location and condition to avoid movement
	Ammonia loss	❑ Ensure that application depth of nitrogen fertilizer is appropriate for soil moisture and tilth ❑ Ensure that application and handling equipment is clean and in good operational order ❑ Choose nitrogen fertilizer products, application rate, method of application, timing of application and application frequency that is appropriate for the soil and climatic conditions ❑ Avoid surface spreading of uncomposted, high N content animal manures without soil incorporation ❑ When applying anhydrous ammonia. select application equipment and soil conditions to allow rapid and complete application furrow closure (for more detailed information refer Chapter 3, Australian Soil Fertility Manual)
Mine	Failure to replace nutrients which are marginally supplied in the soil	❑ Use nutrient budgeting to determine nutrient balance at the catchment, farm or field scale ❑ Reduce non productive losses such as animal transfer, erosion and leaching but allow for uncontrollable losses in overall nutrient budget ❑ Use soil testing to determine the level of soil fertility ❑ If necessary, ensure nutrient application rates are increased to maintain soil fertility at productive levels ❑ Undertake a long-term soil monitoring program to determine soil fertility trends over time ❑ Monitor and record nutrient removal in produce leaving the farm
	Poor management of soil organic matter	❑ Undertake practices which assist in maintaining or increasing soil organic matter e.g. increased cropping frequency, stubble retention, reduced cultivation, include pasture phase / green manure crop into the rotation or application of animal manure
	Burning or removal of crop residue	❑ Resist removing crop residues for hay ❑ Budget to replace nutrients exported in hay or silage ❑ Resist burning crop ❑ Do not burn in winds which will remove ash and the nutrients it contains from the field
	Acidification	❑ Replace alkalinity exported in produce by using soil amendments such as lime or dolomite