Code of Practice for Nutrient Management

August 2014
Version 1.0

Horticulture™ New Zealand

Nutrient Management Code of Practice

Contents

INTRODUCTION

Why this Code of Practice for Nutrient Management

Purpose and scope

This Code of Practice is designed for growers to understand and implement good and best management practices for nutrient management, particularly nitrogen, and to assist where resource consent is required from Regional Council. It is anticipated that this Code will be a resource for council staff and other regulators when considering what growers can do to reduce nutrient losses. As it is the operation that will require resource consent the Code is written to address the whole operation but it is recognised that some management practices need to be assessed at the paddock level and combined to provide an operation overview.

This Code of Practice for Nutrient Management sits alongside the 'Erosion and Sediment control guidelines for vegetable production – Good Management Practices' which sets out methods and practices to manage soil loss through surface water runoff and soil erosion. Phosphorous binds to soil particles so managing soil loss will also manage loss of phosphorous. Appropriate use of phosphorous is important to ensure efficient use of Nitrogen. Where practices in this COP for Nutrient Management interface with soil management practices reference is made to the 'Erosion and Sediment control guidelines for vegetable production – Good Management Practices'.

Background

The management of nutrients in horticultural operations is crucial to the sustainable production of high quality vegetables. The use nutrients is essential for both plant growth and plant quality. Getting the right mix of micro and macro nutrients for the crop is critical and is influenced by many factors including the weather, the previous crop and soil nutrient status including residues in the soil. Crop growth may also be affected by pH and the availability of irrigation. Given the multiple variables there is no 'one size fits all' and decisions and actions taken will vary between operations. Therefore it is important that assessment of risks and decisions are made on sound principles of nutrient management throughout each stage of the production cycle.

There is potential for nutrient to be lost to the crop and move to water, either by leaching to groundwater or by overland flow to surface water. Nutrients in water can cause a range of problems and adversely affect water quality. It is in the grower's interest to maximise the use of N so that productivity is optimised whilst minimising the impact on the environment.

Regional Councils have a responsibility under the RMA to manage discharges to water, and this includes the nutrients that move from a crop to water, commonly known as non-point source discharges or diffuse discharges, because the discharge is not from a distinct point – such as the end of a pipe.

Measuring and quantifying non-point source discharges is difficult. Models, such as Overseer, can be used to predict the discharge based on a range of parameters, such as: climate, soil type, fertiliser applied, irrigation, crop type/rotation and topography.

There are a range of management practices that can be used to reduce the potential for non- point source discharges of nutrients. Increasingly Councils are seeking that growers implement good management practices. This Code of Practice sets out a range of good and best management practices that can be adopted by a grower to reduce the potential for nutrient loss and may be used to assist with applying for resource consent for discharges of nutrients from the operation. A checklist is included in Appendix 2 to collate the management practices that have, or will be adopted by the operation, verified by an independent consultant which could be used as part of a resource consent application.

Good and best management practices provide a framework for continuous improvement.

Good management practices (GMP) are described as an entry level practice that all growers could expect to undertake to manage nutrients.

Best management practices (BMP) are advanced mitigation options that often require significant investment which may present a barrier for uptake, especially for smaller growers.

Best management practices should not be compulsory but should be recognised as potentially providing advanced mitigation options for nutrient management. However all growers need to demonstrate that the management practices used are based on sound principles of nutrient management.

This code is based on the best information available at this time but as new technology and practices become available and understanding of both the issues and mitigation methods improves the GMP and BMP will require updating.

How to use this Code of Practice

The Code is based on a risk assessment approach with five steps:

1. Understanding how nutrients loss occurs and the potential risks
2. Having appropriate information on which to base decisions to address the risk
3. Assessing the risks within a specific situation
4. Identifying and implementing appropriate management practices to address the identified risks
5. Maintaining records to verify how the management practices have been implemented.

The good and best management practices are grouped according to the stage of the crop cycle

- Pre planting
- Planting
- Post planting
- Harvesting and Post-harvest

In addition there are some general good management practices that can be used across all stages of the crop cycle, such as being NZGAP accredited, and training of operators.

A grower needs to select management practices that are appropriate to the scale and intensity of the operation to maintain productivity while minimising the effects on the environment and which could reasonably be adopted without significant impact on the profitability of the business. Given that there is a wide range in scale and intensity of operations and multiple variables of crops, rotations, rainfall, topography and soil type it is not possible to provide a single prescription that fits all operations. However this Code however presents a range of possible tools which should be assessed by the grower to determine the most appropriate in particular circumstances for their operation

1. Risk based approach to nutrient management

There are a number of steps that are important in a risk based approach to a growing operation and nutrient management.

1. Understanding how nutrients move through soil and water and the potential risks
2. Having appropriate information on which to base decisions to address the risk
3. Assessing the risks within a specific situation
4. Identifying and implementing appropriate management practices to address the identified risks
5. Maintaining records to verify how the management practices have been implemented.

This diagram is a summary of each step with the details provided below.

Risk based approach to nutrient management

1. Understand how nutrient loss occurs and potential risk

Knowledge of movement of nutrients through soil and water

Factors contributing to nutrient loss

2. Information to help decision making

Soil tests

Paddock history

Crop history

Rotation and crop selection

Rainfall

3. Assessing the risk

Using the risk template identify the risk for each contributing factor

Determine the level of risk for the operation

4. Identify and implement GMP's and BMP's to address risks

Pre-planting

Planting and Ground Preparation

Post planting

Harvest and post-harvest

Other BMP's and GMP's

5. Maintaining records

Records should be kept to verify actions taken

2. Step 1: Understanding how nutrient loss occurs

Knowing how nutrients are lost from the soil to water is important in terms of understanding why nutrients, particularly nitrogen, need to be actively managed. This involves an understanding of the nitrogen cycle, plant requirements and the factors that contribute to the movement of nutrients through the soil.

The diagram below shows the major pathways of nitrogen cycling in soil air and water. The aim of this code is to minimise the losses of nitrogen to water without increasing the losses to the air or reducing productivity. Understanding the factors affecting the uptake of N by crops and those affecting cycling in the soil is vital to achieve these aims.

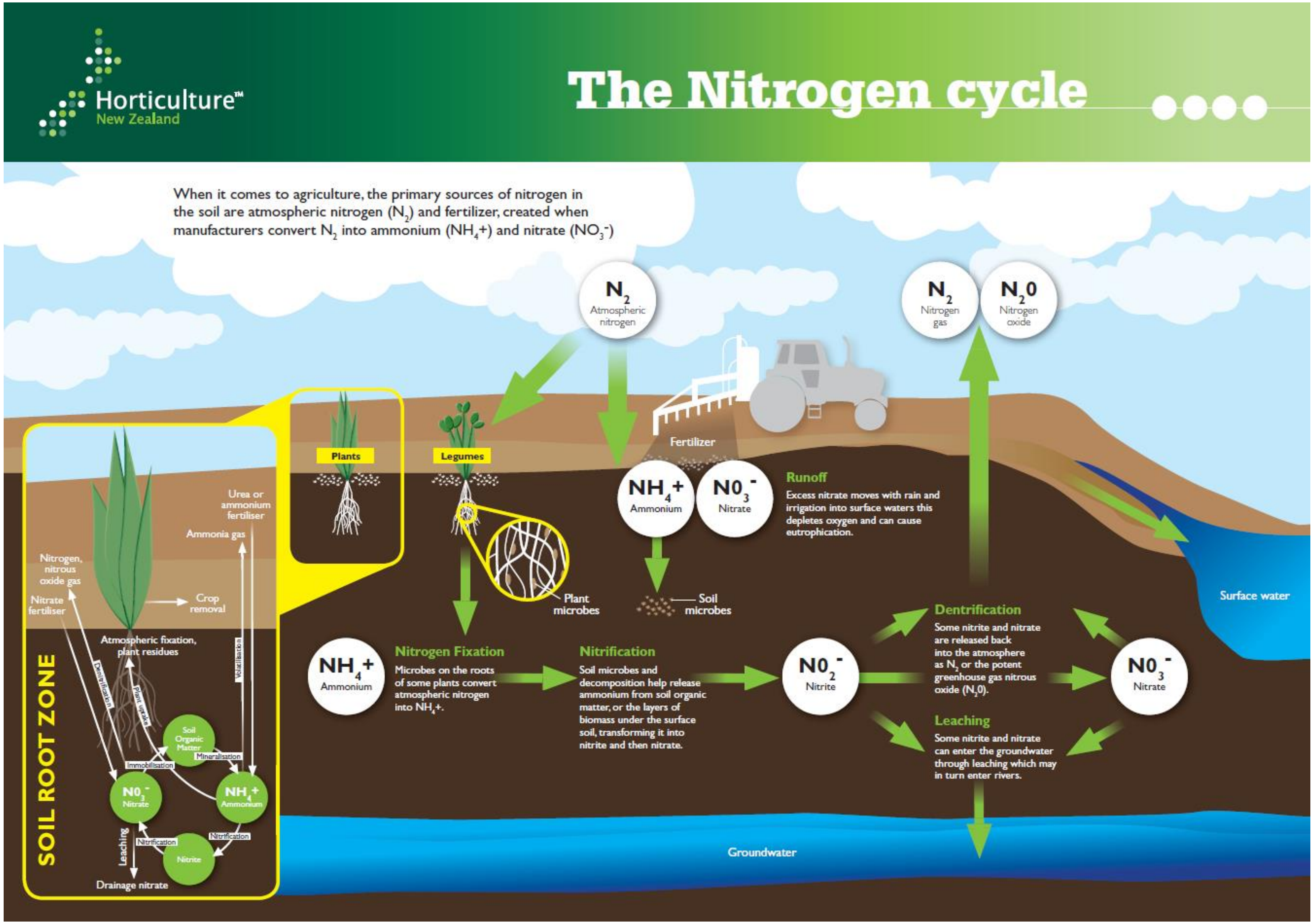
Inputs to the soil part of the nitrogen cycle include:

- Nitrogen fixation when some plants (such as legumes) have microbes on their roots that convert nitrogen in the air to ammonium in the soil. This then goes through the nitrification process and is converted to nitrates.
- Mineralisation of N from soil organic matter. As organic matter levels increase the amounts of N mineralised can increase.
- Mineralisation of N from incorporated crop residues. Some crops, such as brassica, contain large amounts of N.
- Grazing animals and applications of slurry and manures.
- Fertiliser applications. If applied in excess of crop requirement can be lost to air or water.

Nitrogen losses to the plant include:

- Leaching. This is the major process by which nitrogen is lost to ground water. It occurs where mineral N is present in soils out of reach of growing crops where drainage occurs.
- De-nitrification. This is a microbial process where microorganisms use nitrate, which is a form of nitrogen that is biologically available, and they convert it back to nitrogen gas or nitrogen oxide.

Nitrate leaching losses are due to the level of drainage combined with the level of nitrate in the soil and therefore are most likely to occur from winter crops.



Horticulture™
New Zealand
The Nitrogen cycle
When it comes to agriculture, the primary sources of nitrogen in the soil are atmospheric nitrogen (N_2) and fertilizer, created when manufacturers convert N_2 into ammonium (NH_4+) and nitrate (NO_3^-)
N_2 Atmospheric nitrogen
N_2 Nitrogen gas
$N_2 0$ Nitrogen oxide
Plants
Legumes
Fertilizer
NH_4+ Ammonium
$N0_3^-$ Nitrate
Runoff
Excess nitrate moves with rain and irrigation into surface waters this depletes oxygen and can cause eutrophication.
Plant microbes
Soil microbes
Surface water
NH_4+ Ammonium
Nitrogen Fixation
Microbes on the roots of some plants convert atmospheric nitrogen into NH_4+.
Nitrification
Soil microbes and decomposition help release ammonium from soil organic matter, or the layers of biomass under the surface soil, transforming it into nitrite and then nitrate.
$N0_2^-$ Nitrite
Dentrification
Some nitrite and nitrate are released back into the atmosphere as N_2 or the potent greenhouse gas nitrous oxide ($N_2 0$).
Leaching
Some nitrite and nitrate can enter the groundwater through leaching which may in turn enter rivers.
$N0_3^-$ Nitrate
Groundwater
SOIL ROOT ZONE
Urea or ammonium fertiliser
Ammonia gas
Nitrogen, nitrous oxide gas
Nitrate fertiliser
Crop removal
Atmospheric fixation, plant residues
Denitrification
Plant uptake
Volatilisation
Soil Organic Matter
Immobilisation
Mineralisation
$N0_3^-$ Nitrate
NH_4+ Ammonium
Leaching
Nitrification
Nitrification
Nitrite
Drainage nitrate

Excessive amounts of N lost by leaching or runoff will affect the quality of ground and surface waters. Too much nitrogen in these waters causes eutrophication where excess algae is grown due to the nitrogen in the water. As the algae dies and decomposes it uses up the available oxygen depleting the water of oxygen available to support other life such as fish.

Matching N supply with N demand is key to reducing the potential for nitrate leaching.

In order to get good crop yields, growers need to make sure that they have enough nitrogen for crops to be able to build the frame that enables the marketable part of the crop to be grown. Without a sufficient and timely supply of nitrogen, it is hard to achieve the production of high yields of good quality produce. One of the issues with vegetable crops is that they are relatively inefficient at nitrogen uptake particularly if they are shallow rooted and are grown with wide row spacings. Additionally some crops, especially brassicas, un-harvested crops or low yielding crops can leave large amounts of crop residue behind. Management of these residues can be difficult as the best practices to minimise N losses from them might lead to carry over of diseases into subsequent crops.

Fertilisers give growers a tool to be able to optimise production. However

- If too much fertiliser is used; or
- If the fertiliser applied does not match crop needs; or
- If fertiliser is used at the wrong time of year when soils are saturated;

It is possible for that nitrogen fertiliser to be lost either leaching down through the soil profile, or it can be converted through to nitrogen gas, creating a loss of productivity.

Growers can manage and reduce potential for nitrate leaching by identifying contributing factors and the risk of potential losses and adopting good and best management practices set out in this Code to minimise or reduce the risk.

Contributing factors to nutrient losses

This section lists a number of factors that can contribute to the risk of nitrogen losses. These factors often operate in combination. For instance: whilst rainfall can lead to larger amounts of N loss the risks of N loss by leaching are higher on well drained moisture retentive soils.

- **Rainfall** – increased rainfall increases leaching risk, particularly on lighter well drained soil. High winter rainfall increases the risk, particularly on bare or fallow soils.

- **Irrigation** – Like rainfall, excessive irrigation can increase the risk of leaching, but using best practice irrigation management can decrease the risk of leaching.

- **Soil type** – The soil type influences the ability of nutrients to move through the soil profile. Lighter sandier soils are more prone to leakage.

- **Paddock history** - Land which has been in long term grass or has received repeated applications of organic manure can increase nitrogen supply, which should be taken into account when deciding on fertiliser recommendations.

- **Previous crop planted and residual N in the soil** – Vegetable crops can leave large amounts of N at harvest. Crops such as brassicas tend to leave smaller amounts of mineral N but can leave large amounts of N in leafy residues. Nitrogen from these residues can be lost, if this is not managed or mitigated through use of a cover crop or the next crop. Cultivation, replanting and using less N can assist with managing these risks.

- **Crops being grown** – Vegetable crops are grown in wide rows and can be shallow rooted leading to an increased risk of N losses by leaching if fertiliser applications are excessive or are not timed to match crop demand.

- **Crop yield and quality** – markets demands around quality may require increased nitrogen input during growing

- **Intensity of cropping** – the risk of N loss will increase with intensity of vegetable cropping especially with sequential cropping, unless inputs and management processes are not adapted to manage these risks.

- **Topography** – sloped ground will increase risk of surface water runoff and wind erosion, particularly post-harvest compaction

- **Type of Fertiliser** the type of fertiliser applied to the soil can affect nutrient uptake by the plant and leaching

- **Timing of nitrogen application** – the application of fertilisers should be split and matched to crop needs, applications should never exceed crop requirement especially in the winter.

- **Fertiliser Placement** – Vegetable crops are often in wide rows, placed fertilisers may be more effectively utilised by younger crops.

- **Applications of organic manures -** Use of poultry, mushroom, pig, dairy effluent or manures prior to winter present a risk for leaching and need to be taken into account in the N balance for the crop.

- **Pest and disease** – may cause yield and crop losses, these will contribute to nitrogen in soils if not harvested and left on the paddock

- **Animals in the rotation** – If there are animals as a part of the rotation then the N on the paddock from the stock needs to be included in N calculations.

- **Ground preparation and planting methods** – Run off and over cultivation (fines tighter on surface) present risks to exit the paddock. Direct drilling and reduced tillage will reduce risk and less air will be generated therefore these will be less carbon released to the atmosphere.

3. Step 2: Information to help decision making

Decision making is based in adequate information. This information will be used to identify the extent to which the contributing factors outlined above are relevant to an operation.

Key information includes:

- Knowing your paddock (Paddock history and selection)
- Knowing your crops and rotation (Crop Selection)

Knowing your paddock (Paddock history)

- Soil type:
  - Is the soil poorly moderately or well drained?
  - What is the soils water holding capacity, Organic matter level, pH?
  - Are there any soil limitations such as compaction that might limit yield potential?
- Available nutrients in soil
  - Have assessments of P K Mg and any problematic trace-elements been made?
- Rainfall:
  - Amount of winter rainfall/drainage
- Previous history: What has been the:
  - cropping intensity
  - fertiliser applications
  - frequency of high residue vegetable crops or grassland (Continuous cereals will contribute the least input.. The previous crop, particularly if it left large quantities of leafy residues, will have a large influence on available N)
- Available N – assessed with reference to paddock history or by assessment of soil mineral N in intensive market garden rotations.
- Irrigation –has the paddock irrigation available as this will effect nutrient use efficiency and yield expectation.
- Erosion risk – in certain circumstances the growing of certain vegetables may not be recommended

Knowing your crops and rotation (Crop Selection)

- Crop:
  - Which is the next crop to be planted.
  - When is it likely to be planted and harvested? (Some crops might be better suited from an environmental point of view but not appropriate because of rotational considerations affecting sensitivity to pests, disease and weed control.)
- Desired yield level.
- The desired plant population – which is dependent on a variety of factors – usually a compromise between yield and soil maintenance or disease pressure – wide rowed crops may need special attention.
- Market constraints – which might affect harvesting.
- Nutrient requirements – what are the amounts required during the growing cycle so that for instance N supply can be matched with crop demand.

Rotation is influenced by a number of variables:

- The previous crop, crop history including the degree of crop residue
- The degree of soil borne disease
- The degree of compaction in the paddock
- Access to irrigation
- Seasonal variations – such as degree of susceptibility to frost, adequate drainage, ability to irrigate

These factors will influence crop selection and management.

Soil testing

<u>3-5 yearly soil tests</u>

Three – five yearly soil tests are designed to measure nutrients such as phosphorous, magnesium and potassium. The

<u>Deep N Testing</u>

Deep N testing is a method of soil sampling for total nitrogen found below the root zone. It is a way of finding out whether the target application of nitrogen has been utilised by the plant or not. It aids the production of high yields because it provides the opportunity to variably apply nutrients according to the nutritional requirements of plants, based on the levels of residual nitrogen and other essential nutrients in the soil. It involves driving a pipe to 300 mm and 600 mm depths at random intervals within a cropped paddock. The results are then tested at an accredited laboratory for a range of nutrients.

4. Step 3: Assessing the risks

Use the information from Step 2 to assess the risk of nutrient losses, based on the extent of risk for each of the contributing factors identified in Step 1.

Contributing factor	**Assessing extent of risk**	**Level of risk**
Soil moisture	Applications of N when soils that are saturated - high risk. Applications when soils are not saturated – lower risk *Note*: It is important to assess the soil moisture status before an application to ensure that the potential for leaching is minimised. Use of foliar applications can reduce the risk	
Irrigation	Use of irrigation – high risk *Note*: Risk can be reduced by ensuring that irrigation is used to maintain soil moisture at target levels and applications of N timed accordingly.	
Soil type	Light soils – High risk Medium soils – Medium risk Heavy soils – Low risk	
Paddock history	Quantities of N applied not based on fertiliser recommendations or assessment of crop residues – high risk Applications take into account fertiliser recommendations and crop residues to ensure that appropriate levels of N are applied - lower risk	
Previous crop planted and residual N in the soil	High residue crop – high risk Crop failure or lower than anticipated yield – high risk Removal of previous residue – lower risk	
Crops being grown	Shallow root vegetables – higher risk	
Crop yield and quality	Nitrogen is used to achieve desired yield and quality. Inappropriate or excessive use can create quality issues and increase the risk of leaching – high risk	
Intensity of cropping	Repeated cropping – higher risk	
Topography	Sloped ground – higher risk of run off	
Plant uptake of nitrogen	Low plant uptake - high risk High plant uptake - lower risk *Note:* There are a range of factors that contribute to the plant uptake of nitrogen and hence reduce the N in the soil able to be leached – e.g time of years, growth stage, type and form of nitrogen, rooting depth. The combination of factors need to be assessed to determine uptake for each crop.	
Timing of nitrogen application	High level of base dressing at planting – high risk Applications split and matched to crop needs – lower risk	
Fertiliser application methods	Broadcast application – higher risk Application only to the row – reduced risk Foliar applications – low risk	
Applications of organic manures	Organic manures applied but not taken into account for N balance – High risk Organic manures applied but taken into account for N balance – Lower risk	
Pest and disease	Crop failure or lower than anticipated yield due to pest and disease – high risk	
Animals in the rotation	Animals included in the rotation – higher risk No animals – lower risk	
Ground preparation and planting methods	Direct drilling and reduced tillage – lower risk Presence of fines post cultivation – higher risk	
Compaction	Compacted soil will prevent roots being able to penetrate and access nitrogen. Compacted soil presents a higher risk.	
TOTAL		**L:** **M:** **H**

5. Step 4: Identifying and implementing appropriate management options to address the identified risks

After identifying the nature and degree of the risk of losses of nutrients a grower needs to make decisions about what management practices could be adopted and implemented to address the risks.

A range of management practices have been identified as assisting to reduce losses of nutrients. These can be good management practices (GMP's) or Best Management Practices (BMP's).

Management practices based on each stage of the crop cycle:

- Pre planting
- Planting
- Post planting
- Harvest and post-harvest

A number of generic management practices that can apply across all crop cycles are also identified.

The management practices are grouped according to:

- Nutrient management
- Irrigation management.

The mix of management practices chosen by a grower will be an outcome of the risk assessment, the major contributing factors for the site specific situation, and the ability of the operation to adopt practices in an economically sustainable manner.

There is a checklist in Appendix 2 which a grower can use to identify the GMP's and BMP's that will be adopted and implemented in respect of the operation. The checklist may form part of a resource consent application. Provision is made for the checklist to be reviewed by an independent consultant prior to lodging with the consent application.

<u>Pre-planting</u>

The pre-planting stage is critical in how the potential risk of nutrient loss is managed.

This stage involves planning, collecting information and making key decisions on crop selection and rotation.

(yellow)	Good Management Practices
(green)	Best Management Practices

Management practices for the Pre-planting stage

	Management practice	Description
Paddock plan	Undertake a paddock assessment and plan to ensure that appropriate GMP's and BMP'S are selected.	The COP identifies a range of GMP's and BMP's. Selection and use of these will vary according to the nature of specific paddocks. Undertaking a paddock assessment pre-planting will assist in selecting appropriate GMP's and BMP's.

	Management practice	Description
Soil assessment	Estimate the residue from the previous crop and any carry over nitrogen such as through the crop not yielding full potential.	Previous crops leave residual N in the soil. High N vegetables are leafy, nitrogen–rich brassica crops such as broccoli, brussel sprouts and some cauliflower where significant amounts of crop debris are returned to the soil. Medium N vegetables are crops such as lettuce, leaks where a moderate amount of crop debris is returned to the soil. Low N vegetables are crops such as carrots, onions, radish, swedes and turnips where the amount of crop residue is relatively small. To be available for crop uptake the organic nitrogen must have had time to mineralise but the nitrate produced must not have been at risk of loss by leaching. Peas, clover and beans will fix N and leave it in the soil.
	Soil testing is conducted on each paddock every 3 – 5 years	Soil testing provides important information, particularly on phosphorus, magnesium, and potassium, to assist in making nutrient management and crop rotation decisions. At the very least soil testing should be undertaken on every paddock every 3-5 years and records kept.
	Soil testing uses a uniform or representative collection pattern	Sampling in a 'W' pattern will provide representative samples, covering as much of the paddock as possible but avoiding headlands or variable patches.
	Soil testing is conducted on each paddock every year when a crop is going to be planted.	Soil testing annually is a best management practice that provides a grower with more up to date information about the paddock. Nutrient management is informed by measurement. It provides the information to track previous recommendations and applications and adjust for future crops.
	Soil testing is conducted every year based on GPS mapping	Use of GPS mapping for soil testing long term provides a trend for the paddock and more consistent sampling grids.
	Nutrient levels are managed according to rainfall, *informed by deep N testing* and will match likely yield and quality goals.	Deep N testing is described in the information section above. It should be undertaken at the end of winter before spring planting to determine the level of residual N that remains in the soil from the autumn crop. Given the cost and difficulties with deep N testing it is considered that taking a representative sample and extrapolating results will enable the results to be ground trothed.
Crop selection	Choosing appropriate crops	Decide on appropriate crops for the soil and climatic conditions, taking into account rotational requirements to avoid disease carryover. Where possible, choose a crop that makes the maximum use of N from the previous crop.
Fertiliser	Plan fertiliser inputs for the crop - both base and side dressings - based on scientific evidence that is available or informed by fertiliser recommendations.	Match nutrient inputs to potential yields and crop requirements. Ensure that nitrogen is applied to meet periods of greatest demand for nitrogen. A nutrient budget should be prepared. Refer to NZGAP for details of nutrient budgets.

	Management practice	Description
	Applications of N are managed to taking into account rainfall, field capacity and soil saturation levels.	Applications of N when the soils are saturated and exceed field capacity increases the risk of leaching, particularly broadcast applications. Foliar applications present a lower risk as the application is direct to the plant, not the soil.
	Take into account any organic manures used e.g. chicken manure, mushroom compost. Ensure that timing of application does not present risk of leaching.	Organic manures provide a source of N that must be taken into account when assessing crop requirements. Consideration is also given to the timing of the applications to minimise risk of leaching.
	Take into account any animals in the rotation	Where animals have been part of the rotation then they need to be included in the nutrient budget.
	Calibrate fertiliser spreading equipment – simple method.	A simple calibration test is to apply a volume of fertiliser to a given area and confirm the spreading rate.
Fertiliser	Calibrate fertiliser spreading equipment – more complex.	Fertiliser equipment needs to be calibrated to ensure that it is spreading accurately to achieve the intended application rate. A tray test can be undertaken to confirm the volume and distribution of the spreading. Contractors who are Spreadmark registered will calibrate equipment to meet the Spreadmark requirements. Aerial applicators who are AIRCARE™ accredited will calibrate equipment to meet the AIRCARE™ requirements.
	Obtain advise from a nutrient Fertiliser Advisor or agronomist	Take advice from independent sources, especially in respect of plant requirements and uptake.
Irrigation	Plan irrigation requirements	Know you have enough water for the crop which may include pre-cultivation irrigation.

Planting

Decisions made and actions taken at planting time can influence the potential for loss of nutrients, such as soil management and cultivation and fertiliser applications at the time of planting. The ground preparation method will be determined by the soil type, crop residue and crop to be planted. Examples include power harrow, bed former, rotary hoe, ripping, ploughing.

Management practices to minimise the potential for soil movement aid in preventing nutrient loss through surface run-off or ponding. Soil compaction contributes to the potential for surface run-off so practices that avoid compaction are encouraged.

The base dressing applied at planting should be applied as per recommendations for the crop taking into account the soil test results and residual N in the soil.

Ground preparation
Refer to the Guidelines for Erosion and Sediment Control – Good Management Practices (referred to as the Erosion and Sediment Control Guidelines) for practices relating to ground preparation to avoid soil movement and surface run-off.

Management practices for the Planting stage

	Management practice	Description
Cultivation	Cultivate soil when conditions appropriate. Minimise soil tillage as much as practicable.	Section 3.6 of the Erosion and Sediment Control Guidelines set out good management practices for cultivation, including minimising the number of passes over a paddock and not cultivating when the soil is too wet. The aim is to reduce potential for compaction and avoid soil run-off.
	Plant a row of grain or a cover crop at appropriate intervals as a shelter belt to prevent wind erosion of soil.	Providing a shelter or cover helps reduce movement of soil through wind erosion and also manage surface run off. Examples include the use of cereals or cover crops in onions crops.
	Use contour cropping, including contour rows as a headland near creeks and drains.	Contour cropping reduces the potential for soil movement and run off, particularly adjacent to creeks and drains.
	Use riparian margins or buffer strips beside streams and drains.	Section 4.3 of the Sediment and Erosion Control Guidelines set out good practices for riparian management beside streams and drains. Riparian margins and vegetated buffers slow down the flow of water off a paddock and allow the sediment and nutrient to settle.
	Methods are used to minimise sediment runoff.	The Sediment and Erosion Control Guidelines set out a range of methods to minimise sediment run-off, based on a paddock assessment. Steps include controlling water entering a paddock, measures to keep soil in a paddock and sediment control measures for water and soil that leaves the paddock. Minimising sediment runoff will also reduce nutrient run-off.
	Manually assess soil for compaction relative to crop rooting depth and take appropriate action.	Crop root growth can be impeded by compacted soil and hence limit crop yield through limiting access to available soil moisture and nutrients. If there is a pan or compaction layer that will impeded root growth for the plant consider methods to reduce compaction, such as tine ripping.
	Assess soil for compaction using a penetrometers	Measure compaction prior to planting using penetrometers
	Adoption of new technology *e.g.* use of sub-soil aerator will allow roots deeper into soil.	New technology enables greater precision and methods to reduce potential for runoff or leaching and compaction.
Fertiliser	Nutrient applications are informed by available information or fertiliser recommendations.	A nutrient budget should be completed for the crop. This will be informed by soil testing, residual N. The crop should be fed based on yield required taking into consideration nutrients already in the soil and/or those previously applied (manure, previous crop left over).
	Fertiliser applications are applied relative to the predicted uptake levels of the plant from planting to maturity.	Fertiliser applications should match the plant requirements and stage of growth.
	Fertiliser spreading equipment is calibrated and can accurately deliver the recommended treatment.	Calibrated equipment ensures correct quantities and spread of application to the crop.

	Management practice	Description
	Crop calculators may be used if available and practical for local conditions.	Crop calculators have been developed for some crops and can be used to help inform crop nutrient requirements.
	Use improved fertiliser technology where appropriate (e.g. prills/coatings)	The nature and quality of the fertiliser influences accurate and even application. Use of fertiliser that increases accuracy is a BMP.
	Controlled traffic farming technology to increase application efficiency and soil management. Advanced farming systems that make use of GPS mapping and aerial photography.	Variable rate application based on: • Aspect • Soil type • Yield • Irrigation
	Proof of operator following management instructions for application, including avoiding spreading into water bodies	Spreader information is monitored and recorded and methods to demonstrate that the operator has applied fertiliser according to recommendations are used eg GPS.
Irrigation	Irrigators are calibrated.	Irrigation equipment is calibrated to ensure that the volume and spread of the water is evenly applied.

Post planting

The post planting stage – or growth stage of the crop presents potential for loss of nutrients, particularly where irrigation is used.

Efficient irrigation is good management practice where soil moisture frequently drops below the wilting point and where water availability and infrastructure permits. Ideally irrigation should be delivered to achieve target yield by maintaining soil moisture above the wilting point and below the soil saturation level. Inefficient irrigation or over watering provides a pathway for the movement of nutrients below the root zone of the crop or surface run-off through excess application and ponding

Application of side dressings needs to ensure that they are undertaken to maintain the nutrient levels as determined by the performance of the crop.

Management practices for the post planting stage

	Management practices	Description
Fertiliser	Side dressings used to reduce risk.	Split dressings reduce the risk of leaching and can also give more efficient utilisation of nutrients.
	Proof of operator following management instructions for application, including avoiding spreading into water bodies	Documentation is kept to demonstrate that the operator has applied the fertiliser according to instructions, such as GPS records.
Soil and plant nutrient status	Nutrient levels are managed according to rainfall, *informed by deep N testing* and will match likely yield and quality goals.	Deep N testing is described in the information section above. It should be undertaken at the end of winter before spring planting to determine the level of residual N that remains in the soil from the autumn crop.
	Leaf tests are conducted.	Leaf sample test look at levels of N, P, K and Mg and the plant. Taken regularly the results can inform nutrient requirements of the plant during its growth. Results can also inform anticipated yield.

	Management practices	Description
Irrigation	Plant growth stage dictates volume applied.	Crop uptake and potential yield considered along with the water holding capacity of the soil.
	Water is applied to maintain soil moisture between the wilting point and field capacity.	Knowledge of paddock water holding capacity and ET rate required,
	Irrigation applied allows achievement of the yield target for fertiliser applied.	Matching water to N and yield
	Irrigation efficiency is measurable at greater than 80%.	Ensuring water not wasted
	Water is metered.	Regulations require water metering and most consents require records of water used to be provided to the Council.
	On site soil moisture monitoring is conducted.	Prior to application an assessment should be undertaken to determine crop requirements.
	Irrigation is variably applied within the paddock to maximise efficiency.	Variable rate irrigation according to soil and crop type – lanes and roads not watered.
	Highly automated irrigation systems that allow more frequent applications of less water.	Use of improved irrigation technology can better match the amount of water applied to plant requirements.
	Irrigation scheduling is undertaken using a crop model or tied into a soil moisture monitoring system	Use of a crop model or soil moisture monitoring system helps ensure that the appropriate amount of water is applied for the crop and to reduce potential for leaching.

Harvest and Post-harvest

	Management practices	Description
Cover crops	Use of Cover crops (greenfeed, oats, mustard, other biological activates) can reduce losses and nutrient use. "Grassing down" increases organic matter.	Use of cover crops is a management mechanism to take up nitrogen in the soil and also increase organic matter. Depending on the specific cover crop it may be ploughed back into the soil to improve soil quality and long term production or sprayed and another crop direct drilled into the paddock. There is a need to represent time in ground and yield to ensure that the cover crop doesn't leave you more N. Refer to the Guidelines for sediment and erosion control for details on cover crops.
Harvesting	Remove as much harvestable crop as possible.	In the event of a crop failure or lower than expected yield consider mitigation measures due to excess N in the soil.
Residues	Remove or incorporate crop residues where possible	Retention of crop residues increase the mineralised N in the soil and need to be accounted for. The methods to remove or incorporation of resides need to be considered, including chopping and mixing prior to ploughing, grazing off or removing.

Other practices

There are a number of good management practices that can be used across all stages of the crop cycle.

	Management practices	Description
Training	Competency and training of operators:	There are a range of operators who have a role in the crop production cycle. The success of an operation is dependent on the standard that each operator achieves. Each operator should be adequately trained to ensure that they are competent to undertake the assigned tasks accurately and efficiently. Evidence of competency should be recorded as part of the records for the operation.
Storage	Fertiliser should be stored and loaded to avoid spillages into waterbodies.	Direct inputs of fertiliser to water can occur when it is inappropriately stored and loaded adjacent to water bodies. Refer to NZGAP requirements for storage and handling.
Records	Maintain records of activities and applications undertaken.	Records are essential for assessing the results of the activities undertaken. Records are Step 5 in this COP.
Technology	More efficient machinery *e.g.* upgrade tractors with higher levels of accuracy/horsepower able to accomplish more tasks in shorter time.	Timely efficient operations avoid working in adverse conditions
	GPS used to monitor operator performance	GPS provides a record of activities undertaken.
Industry advice	Independent agronomic advice:	There are a range of advisors available to provide advice to growers. Such advice can assist in keeping up with technology and equipment and provide an independent view of the operation and changes that could be made, include rotation planning and nutrient management.
Accredited contractors/ suppliers	Spreadmark accredited contractors:	Spreadmark is a quality assurance programme for fertiliser contractors than verifies that the equipment is accurately calibrated and operating. Use of an accredited operator ensures that best practice is met Refer to www.fertqual.co.nz
Accredited contractors/ suppliers	AIRCARE™ accredited aerial operators	AIRCARE™ is a quality assurance programme for aerial operators than verifies that the equipment is accurately calibrated and operating. Use of an accredited operator ensures that best practice is met. Refer to www.aircare.co.nz
Industry programmes	NZGAP accredited:	A grower should be accredited to NZGAP or a similar quality assurance programme as a demonstration that quality systems are used, implemented and verified as part of the operation. Refer www.nzgap.co.nz

6. Step 5: Record keeping – what needs to be kept

Record keeping is required for documentation of all steps taken and can be used for verification of the management practices adopted and any changes over the crop cycle.

Accurate records are required to ensure that you are aware of all points in the farming system, the paddock history, weather events, can reference past actions with results and verify actions taken.

Records need to be kept for:

- Property information – area
- Paddock history/ rotations
- Crops sown and dates of sowing/ planting
- Fertiliser – fertiliser recommendations, quantities, composition, rates of application, locations, and dates of application
- weed sprays,
- Harvest – dates, record of quantity/ yield
- Weather – rainfall
- Operator credentials and evidence of competency
- Calibration of equipment
- Stock included in the rotation – stocking rate and timing
- Irrigation – areas irrigated and rates and timing of application

Record templates are included in Appendix 3. Records may be kept in format to meet NZGAP requirements.

Muddy boots and *Agworld* are two computer software programmes that are suitable to be used for records.

Appendix 1: Nitrogen management and Regional Council rules

The Government has developed the National Policy Statement for Freshwater Management (NPSFM) that seeks improvements in water quality and to manage over-allocation both for water quantity and quality. Regional Councils need to implement the NPSFM and this is leading to new regional rules focussed on nitrogen leaching and allocation of water.

The rules will vary depending between regional council and between catchments depending on the state of the waterbodies in a catchment and current allocation of nutrients. Where there is over-allocation then regional rules are required to reduce the nutrient load so this will require limitations on the amount of leaching permitted on farms within the catchment.

Calculating N levels in a catchments and consequent allocation of N is complex and often dependent on models to calculate catchment loads. Such loads can then be extrapolated to an on-farm N allocation.

The amount of leaching on farm is calculated by another model (such as Overseer) to establish if the farm is leaching within the limit.

The models currently available have a number of limitations and work is being undertaken to refine them so the results are more robust.

In the meantime models may be used by regional councils as tools to set limits on nitrogen leaching for farms based of what the catchment can/cannot handle and if it is considered under/fully or over allocated in terms of nitrogen.

Appendix 2: Checklist of GMP's and BMP's used

As part of a resource consent process or audit a grower may be asked to identify GMP's and BMP's that they have adopted or chosen not to adopt to manage the potential loss of nutrients. The checklist provides a means of recording the response to each GMP or BMP and the reasons for adopting or not adopting the management practice for the operation. There is a column for a consultant to review the grower response and comment on the appropriateness of the management practice and reasons given by the grower.

This checklist is organised by groupings of topic rather than crop cycle:

- Soil
- Cultivation
- Fertiliser
- Irrigation
- Other

This places all GMP's and BMP's related to each topic are grouped together with the relevant crop cycle identified.

(yellow)	Good Management Practices
(green)	Best Management Practices

Soil

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Undertake a paddock assessment and plan to ensure that appropriate GMP's and BMP'S are selected.	Pre-planting	Y / N		
Choosing appropriate crop.	Pre-planting	Y / N		
Estimate the residue from the previous crop and any carry over nitrogen such as through the crop not yielding full potential.	Pre-planting	Y / N		

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Soil testing is conducted on each paddock every 3 – 5 years.	Pre-planting	Y / N		
Soil testing uses a uniform or representative collection pattern.	Pre-planting	Y / N		
Soil testing is conducted on each paddock every year when a crop is going to be planted.	Pre-planting	Y / N		
Soil testing is conducted every year based on GPS mapping.	Pre-planting	Y / N		
Nutrient levels are managed according to rainfall, *informed by deep N testing* and will match likely yield and quality goals.	Pre-planting	Y / N		

Cultivation

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Cultivate soil when conditions appropriate. Minimise soil tillage as much as practicable.	Planting	Y / N		
Plant a row of grain or a cover crop at appropriate intervals as a shelter belt to prevent wind erosion of soil.	Planting	Y / N		
Consider contour farming *e.g.* using contour farmed rows as a headland in front of creeks and drains.	Planting	Y / N		

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Use riparian margins or buffer strips beside streams and drains.	Planting	Y / N		
Methods are used to minimise sediment runoff.	Planting	Y / N		
Manually assess soil for compaction relative to crop rooting depth and take appropriate action.	Planting	Y / N		
Assess soil for compaction using a penetrometer.	Planting	Y / N		
Adoption of new technology *e.g.* use of sub-soil aerator will allow roots deeper into soil.	Planting	Y / N		

Fertiliser

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Plan fertiliser inputs for the crop - both base and side dressings - based on scientific evidence that is available or informed by fertiliser recommendations.	Pre-planting	Y / N		
Take into account any organic manures used e.g. chicken manure, mushroom compost	Pre-planting	Y / N		
Take into account any animals in the rotation	Pre-planting	Y / N		

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Applications of N are managed to taking into account rainfall, field capacity and soil saturation levels.	Pre-planting, planning and post planting	Y /N		
Fertiliser should be stored and loaded to avoid spillages into waterbodies	All stages	Y/ N		
Calibrate fertiliser spreading equipment – simple method	Pre-planting	Y / N		
Calibrate fertiliser spreading equipment – more complex	Pre-planting	Y / N		
Obtain advise from a Nutrient Fertiliser Advisor or agronomist	Pre-planting	Y / N		
Nutrient applications are informed by available information or fertiliser recommendations.	Planting	Y / N		
Fertiliser applications are applied relative to the predicted uptake levels of the plant from planting to maturity.	Planting	Y / N		
Fertiliser spreading equipment is calibrated and can accurately deliver the recommended treatment.	Planting	Y / N		
Use improved fertiliser technology where appropriate (e.g. prills/coatings)	Planting	Y / N		
Controlled traffic farming technology to increase application efficiency and soil management. Advanced farming systems that	Planting	Y / N		

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
make use of GPS mapping and aerial photography.				
Proof of operator following management instructions for application, including avoiding spreading into water bodies	Planting and post planting	Y / N		
Crop calculators may be used if available and practical for local conditions.	Planting	Y / N		
Side dressings used to reduce risk	Post planting	Y / N		
Nutrient levels are managed according to rainfall /irrigation, *informed by deep N testing* and will match likely yield and quality goals.	Post-planting	Y / N		
Leaf tests are conducted.	Post-planting	Y / N		

Irrigation

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Plan irrigation requirements	Pre-planting	Y / N		
Irrigators are calibrated	Planting	Y / N		
Volumes applied informed by relevant factors e.g. Plant growth/ stage/ soil type/ water holding capacity and climatic conditions	Post-planting	Y / N		
Water is applied to maintain soil moisture between the wilting point and field capacity where possible.	Post-planting	Y / N		
Irrigation applied allows achievement of the yield target for fertiliser applied.	Post-planting	Y / N		
Irrigation efficiency is measurable at greater than 80%.	Post-planting	Y / N		
Water is metered.	Post-planting	Y / N		
Irrigation scheduling is undertaken using a crop model or tied into a soil moisture monitoring system	Post-planting	Y / N		
On site soil moisture monitoring is conducted.	Post-planting	Y / N		

Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Irrigation is variably applied within the paddock to maximise efficiency.	Post-planting	Y / N		
Highly automated irrigation systems that allow more frequent applications of less water are used to maximise efficiency.	Post-planting	Y / N		

Other practices

	Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Cover crops	Use of Cover crops (greenfeed, oats, mustard, other biological activates) can reduce losses and nutrient use. "Grassing down" increases organic matter.	Harvest and post harvest	Y / N		
Harvesting	Remove as much harvestable crop as possible.	Harvest and post harvest	Y / N		
Residues	Remove or incorporate crop residues where possible	Harvest and post harvest	Y / N		
Training	Competency and training of operators	Other	Y / N		
Records	Maintain records of activities and applications undertaken.	All stages	Y / N		

	Management practices	Crop stage	Grower Adoption Y/N	Rationale/reasons	Consultant comments
Technology	More efficient machinery *e.g.* upgrade tractors with higher levels of accuracy/horsepower able to accomplish more tasks in shorter time.	Other	Y / N		
	GPS used to monitor operator performance	Other	Y / N		
Industry advice	Independent agronomic advice	Other	Y / N		
Accredited contractors/ suppliers	Spreadmark accredited contractors	Other	Y / N		
	AIRCARE™ accredited aerial operators	Other	Y / N		
Industry programmes	NZGAP accredited:	Other	Y / N		

Appendix 3: Records Templates

Soil Nutrients				
Nutrient	**Date**	**Location**	**Result**	**Comment (environmental factors)**
N				
P				
K				
S				
Mg				
Ca				
Trace elements				
Other				

Plant/Tissue Analysis				
Nutrient	Date	Location	Crop and growth stage	Results

Crop	Crop growth period		Total area in crop (hectares)	Total paddock area (hectares)	No of plants per unit measure	Typical crop yield	Fertiliser type	When applied	Residual management	Any other source of nutrient	Irrigation Method: E.g. Centre Pivot	
	Planting (Date)	Harvest (Date)	Net production	Ancillary activities		E.g. 60t/ha fresh wt	E.g.: 5kg/ha DAP	Method (eg side dressing)	E.g. incorporated, grazed	Eg effluent, compost	Seasonal (mm) / (Maximum (mm)	Return Period