A Code of Practice for

The Management of Greenhouse Nutrient Discharges

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Horticulture™ New Zealand

Sustainable Farming Fund
www.maf.govt.nz/sff

Contents

1. Preface

The development of *A Code of Practice for The Management of Greenhouse Nutrient Discharges* has been funded by the Ministry of Agriculture and Forestry's Sustainable Farming Fund, Horticulture New Zealand's Fresh Tomato Product Group, Horticentre (formally Veg-Gro Supplies Ltd), Fertiliser Manufacturers' Research Association and Northern Flower Growers' Association. Unitec New Zealand was the consultant to the project and contracted by the stakeholders to develop this Code of Practice.

Consultation in relation to the Code has been extensive. During its two-year development phase the Industry working party fine-tuned the document in response to a detailed review process.

This Code is designed for the management of nutrient solution associated with the soilless production of vegetable and flower crops in modern greenhouses. It does not address other types of horticulture, including protected crops grown in soil. The Code is founded on the principles of sustainable management and incorporates current world best practice and the requirements of the Resource Management Act 1991.

Research data from New Zealand shows that it is possible for the greenhouse industry to adopt procedures that allow the release of the nutrient solution in a way that does not add to nitrogen pollution of streams or ground water. These techniques are described in the Code. They involve capturing the solution and then releasing it when conditions are suitable. By following these procedures, the development team believes, the soilless greenhouse industry can operate at as high a level of environmental safety as any other primary industry. A non-prescriptive approach has been adopted as it provides for the safe, effective and responsible release of the nutrient solution from soilless systems on a site-specific basis.

The Code is intended to be a living document and it is expected to undergo practical evaluation and review. A training programme has been developed to ensure advisors and end users are provided with sufficient guidance in the use of the Code to achieve its objectives.

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2. The Purpose and Approach of the Code

A Code of Practice for The Management of Greenhouse Nutrient Discharges provides a framework and tools to assist growers in their management of nutrient solution in protected cropping operations.

Growing plants in soilless horticulture is unique in that the release of the nutrient solution can be controlled, as the plant is grown in a channel, block, bag or pot. The nutrient solution is mixed in a tank and then circulated in sealed pipes direct to the plant. After the nutrient solution moves past the root zone the surplus is either collected, sent back to the mixing tank and reused, or is released.

Release or recirculation decisions for nutrient solution are based on a complex set of criteria, including plant needs, solution quality, climatic conditions and production requirements, and on the size of the storage tank. All installations need to release some nutrient solution at some time.

The release of nutrient solution, if not appropriately managed, will result in adverse environmental effects, including increased nitrate concentrations in groundwater and nutrient enrichment of surface water.

In this Code no specific annual limit for nitrogen has been set as the amount of nitrate leached from any one site depends on a range of soil, plant, animal and weather factors. This differs from some current council regulations for the application of fertilisers and effluent to pasture.

The Code provides a practical and flexible approach allowing the grower to make decisions based on individual conditions prevailing at the time of application, the scale of the operation and selecting the best methods for preventing or minimising the adverse effects on the environment.

Growers should also consider the level of technical expertise required, the effects of the discharge on the environment, the financial implications and whether or not the options in the Code can be successfully implemented.

The Code's conservative guidelines for nitrogen application of no more than 30kg N/ha to a release site over a three week period ensures minimal adverse effects of the release of nutrient solution.

Growers need to be aware of, and to meet, the requirements of regional council plans, which may include conditions under which such applications must occur, including maximum volumes of nitrogen that may be applied. The methods in this Code provide growers with the tools to meet these requirements.

The Resource Management Act 1991 (usually called the RMA) requires regional councils to manage the adverse effects of discharges of contaminants. When released, nutrient solution is classed as a discharge of a contaminant as the solution will usually contain nitrate that may leach through the soil to either groundwater or surface water. Refer to Appendix C for more details on the RMA requirements.

The purpose of this Code is to provide best management practices for managing nutrient solution that is surplus to the requirements of the soilless system, so that any solution released has minimal effects on the environment. Thus the Code incorporates the results of recent nitrogen leaching research conducted in New Zealand. The RMA includes '*best practicable option*' as a mechanism which Councils may choose to use for preventing or minimising the adverse effects on the environment from contaminants. Refer to Appendix C ii) for the definition of '*best practicable option*' from the RMA. Best practicable option and best management practice are similar, in that they both focus on the most efficient and effective way to manage an issue.

The Code of Practice is designed to:

- Assist in maintaining access to international markets and be a part of quality assurance programmes; e.g. New Zealand Gap (the New Zealand Fresh Produce Approved Supplier Programme), EUREPGAP.
- Assist and improve the decision-making process required to maintain economic viability.
- Develop sustainable practices specific to a grower's situation while ensuring responsibilities are fulfilled under the RMA, including when it is environmentally safe to release nutrient solutions from soilless horticulture.
- Help growers meet their responsibilities under the RMA as regional councils develop and implement regional plans.

3. The Code and the Resource Management Act

The Resource Management Act 1991 (RMA) is the legislation that sets out how the environment should be managed by providing a framework for the management and use of air, land and water. This section provides an overview of the RMA and shows the relationship between the RMA and the management of nutrient solutions.

The RMA has an overall purpose of sustainable management, part of which includes people having a duty to avoid, remedy or mitigate any adverse effects their activities may have on the environment. Refer to Appendix C for relevant sections of the Act.

The RMA is implemented by regional, district and city councils or, (in the case of Gisborne, Tasman, Marlborough and Nelson) unitary authorities, who may develop plans to address the matters specified in the RMA. The councils also consider resource consent applications by assessing the extent to which an activity meets the requirements of the RMA and their plans, to ensure that any adverse effects are adequately addressed.

The RMA gives different responsibilities to the various councils. These include the following -
Regional councils have responsibility for environmental matters; e.g. discharges to air, land and water and water allocation and water quality.
District and city councils have responsibility for land use including subdivision, noise, hazardous substances.
Unitary authorities have responsibility for both the regional and district council functions.

Therefore a grower may need consents from different councils, or a number of consents for different activities. For instance: a greenhouse grower may require a land use consent from the district council and a water take consent and a discharge consent from the regional council.

Council plans set out if an activity is classified as permitted, controlled, discretionary, non-complying or prohibited, depending on the adverse effects that may result from the activity. Generally, if an activity is not permitted in a plan a resource consent will be required. Permitted activities may have conditions attached to them that are required to be met by users to enable the activity to be a carried out as a permitted activity. A council may monitor permitted activities to ensure that the requirements of the permitted activity are being met.

The release to the environment of nutrient solution from soilless horticulture, whether to land or water, is classified as a discharge of a contaminant to the environment under the RMA and is included as a land and water issue managed by regional councils. Discharges of contaminants into the environment are restricted under the RMA and need to be addressed in regional plans. Refer to Appendix C

A contaminant is defined in the RMA as:

“Includes any substance (including gases, liquids, solids and micro organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar or other substances, energy or heat:

a) When discharged into water changes or is likely to change the physical, chemical or biological condition of the water; or
b) When discharged onto or into land or into air, changes or is likely to change the physical, chemical or biological condition of the land or air onto or into which it is discharged.”

The relevant regional plan sets out the conditions a grower must meet when releasing nutrient solution to ensure that the release does not create adverse effects. These requirements will vary from region to region. For instance: in some cases resource consent may be needed if the volume of the nutrient solution being released is beyond a certain permitted level. Growers need to ensure that they are aware of the requirements in their own region, and either comply with their regional council’s permitted rules or obtain a resource consent for the release of nutrient solution.

The Code provides tools to assess the impacts of the disposal of nutrient solution because assessing the effects of the release of nutrient solution is an important step in being able to meet and address council requirements. A resource consent may require specific conditions to enable the discharge to occur and it is important that growers meet such requirements.

A consent application should give information on how the solution will be managed and how any adverse effects of the disposal will be reduced, avoided or mitigated. Usually councils have a form to be completed with the application which sets out the information that needs to be provided as part of the consent. If more than one consent is being sought the council may want to consider all applications together.

Advice on obtaining a resource consent can be found on websites from the Ministry for the Environment and regional councils. It may be necessary, and of benefit, to seek professional advice and assistance with a consent application.

Links to websites that may be useful can be found on www.hortnz.co.nz under ‘links’.

4. Stage A – Minimising Nutrient Discharges

Soilless systems increase productivity and allow greater control of possible impacts on the environment.

Older soil based systems and some replacement systems such as sawdust and pumice bags allow the water and nutrient to run directly through the soil or out of the bottom of the bag. In fact this is encouraged as continual drainage reduces the potential for water logging of soil.

However, increasingly in soilless systems, plants are placed into channels where the solution runs back into a central mixing tank. This is more difficult to achieve with container growing (e.g. blocks, buckets or pots) where the solution must emerge from the container and be in contact with the outside environment before being collected and recycled back into the mixing tanks.

In most soilless greenhouse systems some nutrient solution is periodically released. This is because many crops benefit from a moderate addition of fresh water (at least 5% per day) to the solution. Often systems are cleaned and all the solution replaced between crops. Sometimes when unmanageable disease invades crop roots a solution is released. These scheduled and unplanned releases must meet the normal requirements of the Code for nutrient release.

The basic principle for this part of the Code is:

- Design the greenhouse system so that as little solution as possible requires releasing

The volume and frequency of the release of the nutrient solution depends largely on -

- The engineering design of the system
- The quality of the input water e.g. concentration of elements such as chlorine, sodium
- The quality of the fertilisers e.g. contaminants such as cadmium in the commercial fertiliser
- The type of medium used
- The ability to keep the water free of diseases, through using additives e.g. fungicides, and treatment of the water while the plants are growing

Specific actions to limit the need to release nutrient solution include:

- Using water off the greenhouse roof. It may be less contaminated with elements, but sometimes more contaminated with pathogens, than water from many aquifers
- Ensuring there are no leaks in the pipes
- Using lined dams or ponds
- Diverting water that drains out of plant containers and channels back into the mixing tank
- Using high quality aquifer water
- Maintaining the hygiene in recirculation systems through avoiding contact with the soil and diseased plants
- Treating water:
    - To control pathogenic fungi
    - To remove contaminants from water e.g. sodium, iron, algae
- Using high purity fertilisers

You provide INFORMATION on the SYSTEM DESIGN

Records - Minimising Nutrient Discharges

Record the details and management methods used in each greenhouse using the following guide.

Greenhouse Name or Number	**Property name**
Crop information	e.g. crops grown and annual sequence

Greenhouse data

Greenhouse details	e.g. area, construction
Rooting environment and media	Specify e.g. bag, bucket, pot, rockwool, pumice, sawdust, other – Give details
Irrigation method	Specify e.g. top-dripper, top-sprinkler, capillary, NFT type, other Give details – water application rate, drippers/pot
Water source	e.g. roof, stream, aquifer, municipal, dam, other, Include proportion of water from each source and annual volume used total

Tanks and storage

Raw water storage	e.g. ponds - lined/unlined/covered/uncovered, tanks, other
Drain tanks	For return of solutions
Mixing tanks	
Treatment tanks	
Tanks for return of solution	
Storage tanks for solution to be disposed of	

Water treatment **SEE FACT SHEET 1, page 10**

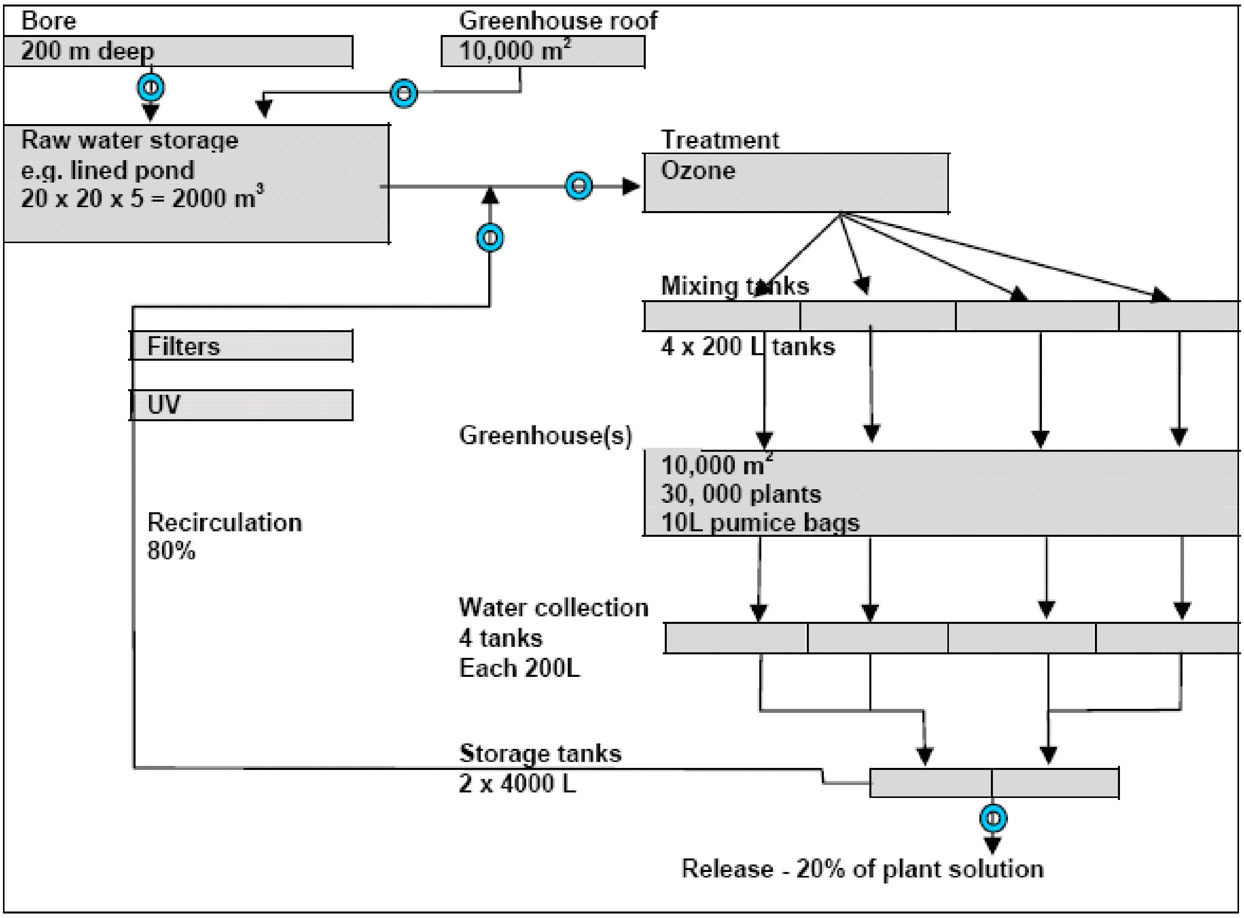
Raw water	
Mixed water	
Return water	

System diagram showing all pipes and tanks

Draw a diagram of your system on a separate page

Example of data required:
- Raw water tank
- Return tank / drain tank
- Water treatment
- Mixing tanks
- Distribution to plants
- Collection after solution passes the plant
- Storage of surplus solution
- Volumes of tanks
- Flow meters ◎
- How the solution is released, e.g. uncontrolled, 1 - 2 x/year, regular – daily/weekly, leaks, overflows

An example of a system diagram



Fact Sheet 1 Water Treatment

There are numerous methods of treating the raw irrigation water and nutrient solution. The prime purpose is to remove pathogens. The treatment methods include -

1. Ozonation

Ozone has been used for over 100 years for sterilising drinking water. It is now widely used for municipal and wastewater, in the beverage and food industry, in swimming pools as well as in horticulture. New Zealand experience suggests that it is more beneficial to treat source water rather than the re-circulating solution.

In soilless horticulture, ozone:

- kills pathogenic bacteria, fungi and viruses in raw water or in nutrient solution
- leaves no residue
- is the strongest oxidising (sterilising) agent available
- flocculates soluble iron and manganese in bore water, possibly causing some bore water to be unsuitable for circulating systems
- adds oxygen to water

Ozone is very unstable so it must be produced on site.

Ozonation requires five steps:

1. Filtering the solution to reduce the organic load
2. Air preparation or oxygen production
3. Ozone generation
4. Ozone diffusion to introduce ozone gas into water. Ozone is applied in a separate contact vessel,–where the ozone action takes place. Ozone concentration quickly declines
5. Venting of surplus ozone

Sterilised water or nutrient solution is almost free of ozone by the time it reaches plant roots, causing no damage and not affecting beneficial micro-organisms living on crop roots.

2. Ultra-violet (UV) sterilisation

Ultra-violet radiation has become one of the most popular water disinfection methods for advanced greenhouse horticulture. It is very effective, safe and convenient.

UV, an invisible and very hazardous type of radiation, does not directly kill but it damages the DNA of living organisms. UV-C with a wavelength of between 200 and 280 nm is germicidal, 254 nm is most effective.

When water flows past a UV-C source, any pathogen in the water is destroyed, provided it receives a sufficient dose. The UV-C source is several, long, tube-shaped lamps placed inside quartz sleeves, all placed in stainless steel housing. Water flows alongside the sleeves.

The UV dose received by the pathogens in the water depends on physical factors. The water needs to be as clear as possible. This involves coarse filtration of plant parts and other debris, and secondly, fine filtration of smaller (ideally down to 10 micron) particles. Even the finest filtration cannot remove dissolved solids - these include organic molecules and iron chelate.

UV transmission in the solution is measured by a spectrophotometer. Transmission needs to be at least 20%. Since some solution has transmission below 10%, dilution with clear raw water is needed before UV sterilising proceeds.

There are many different guidelines for the amount of UV required for sterilisation. The standard for horticulture needs to be much higher than for human drinking water. Current recommendations include:

- 100 mJ/cm^2 UV-C for water without virus but containing fungi and bacteria
- 150 mJ/cm^2 UV- C for water containing Pepino Mosaic Virus
- 250 mJ/cm^2 UV-C for water containing other viruses.

The design of a UV sterilising system needs to consider:

- the flow rate water
- the strength of UV lamps,
- the penetration of UV radiation
- the thickness and turbulence of water

3. Filtration with slow sand filters

Slow sand filters (misleadingly called 'biofilters') have become a common water treatment technique to remove Phytophthora and Pythium but not other pathogens.

They are effective, reliable, practical and economic, either used alone or in combination with UV.

A slow sand filter:

- Is based primarily on a mechanical action. It consists of four parts from top to bottom:
    - a water layer
    - a filter bed
    - a drainage system
    - a flow control system
- Has a much lower flow rate and much finer sand than a normal sand filter
- Is much larger, more prone to clogging and needs more maintenance than a normal sand filter.

New alternatives to sand, such as lava and rockwool, are being tested as a filter material. Rockwool can remove Fusarium as well as Pythium and Phytophthora. In Europe slow sand filters are used in conjunction with UV for the removal of virus.

4. Heating / sterilising

This can control all pathogens in water or nutrient solution.

The standard method of heat treatment was to heat solution to 95 °C for 30 seconds.

However, a lower peak temperature (85-90°C) gives perfect control provided the exposure time is longer; e.g.

- 90 °C for 2 minutes
- 87 °C for 2½ minutes
- 85 °C for 3 minutes

Source water and solutions contain large amounts of calcium. Heating causes calcium to precipitate and form scale on the heat exchangers. Scaling increases as temperature increases and is very severe at 100 °C.

Water or solution to be sterilised is:

1. Collected in a tank,
2. Filtered by a simple filter
3. Pumped into the sterilising system
4. Nitric acid is added to lower the pH and reduce scaling.
5. Heating is generally done in two steps:
    a. In the first heat exchanger, the incoming water is preheated to about 80 °C (by using the heat from step 7)
    b. In the next heat exchanger, the incoming water is heated to peak temperature
6. The water then flows through a long line where the peak temperature is maintained for the required time and disinfection takes place.
7. Treated water is cooled down to an acceptable temperature (e.g. 30 °C) through the first heat exchanger.

5. Stage B – Collection and Storage

In modern soilless systems most of the solution is returned to mixing tanks for recirculation.

The basic principles for this part of the Code are:

- All solution should be returned to a central storage where it is recirculated or else stored until it is released for reuse or disposal
- The system should be maintained in a sound condition
- Released nutrient solution should be able to be stored until application sites are in a suitable condition to receive the solution
- Storage should be kept at the lowest possible level to allow for times when conditions limit release
- Details of released nutrient solution (volumes and concentrations of nutrients, particularly nitrogen), should be recorded regularly.

Records – Collection and Storage

You PLAN for and SET UP SYSTEMS for collection and storage before they are needed

Storage capacity

The principles for collection and storage require that released nutrient solution shall be able to be stored until application sites are in a suitable condition and that storage shall always be kept at the lowest possible level to allow for when conditions limit release.

Generally there should be sufficient storage to hold 2 to 3 weeks discharged solution in winter or 1 weeks discharged solution in summer, whichever is the largest.

The following information must be collected and recorded and kept for at least 5 years

1. Raw water analysis – lab reports - *You are required to have at least 1 test per year*
   Refer to Stage C vii page 24

2. Released solution analysis – lab reports - *You are required to have at least 1 test per year*
   Refer to Stage C vii page 24

3. Nitrate concentration determined with the electronic meter or Merckoquant® test strips (www.merck.co.nz)
   - *You are required to test each release batch*
   Refer to pages 18 and 32

4. Calculation of volume of solution to be stored for release
   Refer to page 13

5. Calculation of nitrogen to be released
   Refer to page 18

For Formulae and Conversion Tables, and Abbreviations and Definitions – refer to Appendices A and B on pages 41 - 46

Calculation of volume of solution to be stored for release SEE FACT SHEET 2, page 15

Water Release and Storage Indicator

	Plant solution m^3	Release %	Typical volume (**m^3**) of storage required for a 1 ha greenhouse **m^3**				
			For 1 day	For 1 week	For 1 month	For 2 months	For 4 months
Formulae			**plant solution x release % ÷ 100**	**day rate x 7**	**day rate x 30**	**day rate x 60**	**day rate x 120**
Example: Average day	29 m^3	30	8.7	61	261	522	1044
		20	5.8	41	174	348	696
		10	2.9	20	87	174	348

Use your own data to complete the following table:

	Plant solution m^3	Release %	Volume (**m^3**) of storage required for your greenhouse area **m^3**				
			For 1 day	For 1 week	For 1 month	For 2 months	For 4 months
Average day							
Winter day							
Summer day							

			Total property storage required m^3
Example:	**Multiply the 1 months storage (m^3) by the greenhouse area**	174 m^3 x 3 ha	522
Your data:	**Multiply the 1 months storage (m^3) by the greenhouse area**	m^3 x ha	

Note: Plant solution is the total volume of water used in a day by the plants.
The calculation for released solution is described in Fact Sheet 2.

Calculation of nitrogen to be released

Step 1

Get a laboratory analysis of the nitrogen content of the solution and then convert it to ppm.

	Lab result	g N in 1 m^3 water	ppm
a)	1 ppm (parts per million) total-N	1.0	1
b)	1 mg total-N / litre	1.0	1
c)	1 mg nitrate (NO_3^-) / litre	0.23	0.23

Step 2

Calculate the amount (kg) of nitrogen to be a released in any batch

- Use data from solution analyses
- Back up the laboratory test with Merckoquant® test strips (or electronic meter) for each release

Write in the nitrate-N. For nitrite-N and ammonium-N use results from the solution analysis or data from previous analyses

←

Convert the nitrate to nitrate-N, nitrite to nitrite-N, and ammonium to ammonium-N.
(Fact Sheet 5 page 31 & Appendix A page 41)

←

Merckoquant® test strips give both nitrate and nitrite concentrations. They do not test for ammonium which requires a laboratory test.

For example:

Nitrate-N = 185
Nitrite-N = 5
Ammonia-N = <u>10</u>
Total-N = 200

	Total N (ppm)		Water released in any batch (m^3)		N released (g)		Convert N to kg		N released (kg)
Example	200	x	300	=	60,000	÷	1000	=	60
Use your average data		x		=		÷	1000	=	
Use summer data		x		=		÷	1000	=	
Use your winter data		x		=		÷	1000	=	

To do this calculation you need –

- ○ Laboratory tests of release water – especially for nitrate-N
- ○ Water meter on release tanks
- ○ Merckoquant® test strips

This calculation does not calculate the water volume released.
This is done in the Application Record Sheet page 25.
See also Fact Sheet 7 pages 39 - 40 and Appendix D page 49

Fact Sheet 2 Nutrient Solution Release Related to the Season

The **nutrient solution** in a soilless system can be split into two parts -

1. The solution used by the plant – **plant solution**

   The water and nutrients in this solution are used by the plant for structural growth (of roots, stems and leaves), evapotranspiration, and crop (leaf, flowers or fruit) production.

2. The solution released from the system – r**eleased solution**

   It contains both water and nutrients – both are addressed in the Code.

Calculating released solution as a percentage of plant solution

The calculation used in the Code is for released solution as a percentage of plant solution, as it is the best indicator of the proportions of water and nutrients used by the plant.

If a property uses 100m^3 of solution in one day and releases 33m^3, the volume of solution used by the plants is 67 m^3. The percentage of released solution compared to plant solution used

$$= \frac{33 \ x 100}{67 \ x 1} = 50 \ \%$$

Instead some calculate released solution as a percentage of total solution. This is misleading because this calculation always gives a lower value. For the example above the answer is 33%.

$$= \frac{33 \ x 100}{100 \ x 1} = 33 \ \%$$

	Released Solution Percentage						
% of plant solution	**5.3**	**11**	**25**	**43**	**50**	**67**	**100**
% of total solution	**5**	**10**	**20**	**30**	**33**	**40**	**50**

For every m^2 of a modern tomato greenhouse, plant growth normally requires around 2 ml of nutrient solution for each J/cm^2 of radiation. Up to an extra 1 ml/m^2 has been applied to allow for conductivity control and to dilute unwanted nutrients in the solution.

Thus a total of up to 3 ml/m^2 solution can be applied for each J/cm^2 of radiation. The extra solution is released. If 1 ml/m^2 is released the calculated release rate is 50%.

Solution use and the season

Due to seasonal changes in light intensity and photoperiod, the volume of nutrient solution used by the plant changes throughout the year.

The 31 year average (1972 to 2003) global (outdoor) light intensity for Pukekohe is –

	Joules/cm^2/day
Summer - highest 10% days	3,270
Summer average – weeks 40 to 17	**1865**
Year – average	1,467
Winter average – weeks 22 to 35	**800**
Winter - lowest 10% days	256

Average global yearly radiation	535,455 ***J/cm^2***

The graph at the end of this Fact Sheet shows the estimated daily volume of released solution for different seasons over the range of possible release rates.

Soil moisture through the year

There are two distinct soil moisture periods in many areas of New Zealand; one where the soil is dry and the other where the soil is wet.

A simulation of daily soil moisture deficits in the Pukekohe over 6 years (1999 to 2005) showed –

1. The **wet soil period** (weeks 22 to 35 of the year) when soils stay wet (at or near field capacity) for long periods. Over a **four month** period there are often only a few times to release solutions according to the Code.

2. The **dry soil period** (weeks 40 to 17) where soils are dry (at a high Soil Moisture Deficit) for most of the time. Solution can be irrigated throughout this period according to the Code, except when heavy rain occurs. The soil may stay wet for up to **two weeks**.

Storage requirements and the season

The principles of the Code mean that released solution shall be able to be stored until application sites are in a suitable condition.

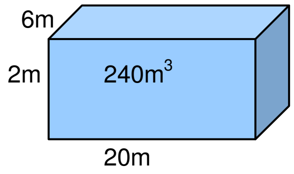
Two calculations are made for each period; one is 50% release rate to cover installations which have a high release of solution, and the other is 10% release rate to cover installations which have a low release of solution.

The wet soil period

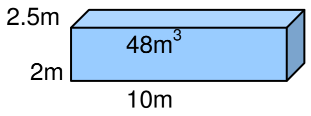
On an average winter day tomato plants in a one hectare greenhouse use 16 m^3 of plant solution. At a release rate of 50% the greenhouse releases 8 m^3 of solution and at a release rate of 10% the greenhouse releases 1.6 m^3 of solution. (On a very dull cold day in winter the plants use only about 5 m^3 plant solution).

The volume for 1 months storage at a 50% release rate is 240 m^3 (30 days x 15 m^3 x 50%) and at a 10% release rate is reduced to 48 m^3.

Storage for wet soil period – 50% release rate



Storage for wet soil period– 10% release rate

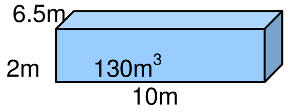


The dry soil period

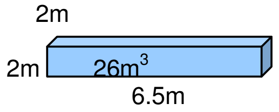
On an average summer day tomato plants in a one hectare greenhouse use 37 m^3 of solution. At a release rate of 50% the greenhouse releases 19 m^3 of solution and at a release rate of 10% the greenhouse releases 4 m^3 of solution. (On an extremely hot summer day the plants use as much as 65 m^3 solution/ha).

The volume for 1 weeks storage at a 50% release rate is 130 m^3 (7 days x 37 m^3 x 50%) and at a 10% release rate is reduced to 26 m^3.

Storage for dry soil period– 50% release rate



Storage for dry soil period– 10% release rate



These calculations are for mature plants. Often crops are replaced in winter. Empty greenhouses or small plants use less water and have a reduced storage requirement.

Total solution release

Often a system is cleaned between crops and the solution replaced. Sometimes when unmanageable disease invades crop roots, a solution has to be released quickly. Both these scheduled and unplanned releases must meet the normal requirements of the Code for nutrient release.

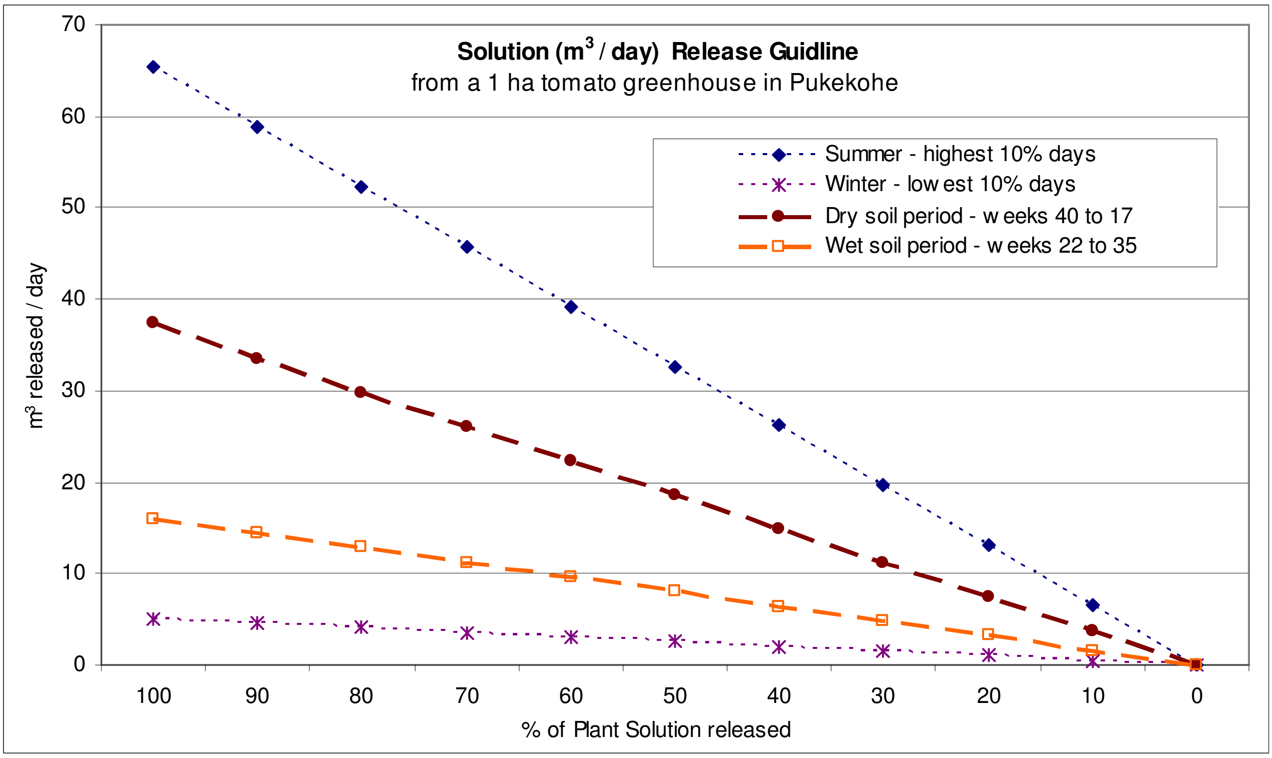
Storage is needed to hold the contents of all the tanks and the circulating solution until disposal site conditions are suitable.

Water release and media

The volume of water released is least when water quality is best.

With poor quality water the daily release from rock wool is often 30 – 40% of plant solution, and from pumice 40 – 100%.

In NFT systems using clean water there is not normally a daily release, while water containing contaminants might have a low daily release of 5% of plant solution.

Solution (m^3 / day) Release Guidline
from a 1 ha tomato greenhouse in Pukekohe
Summer - highest 10% days
Winter - lowest 10% days
Dry soil period - weeks 40 to 17
Wet soil period - weeks 22 to 35
m^3 released / day
70
60
50
40
30
20
10
0
100
90
80
70
60
50
40
30
20
10
0
% of Plant Solution released

6. Stage C – Land Application

The **basic principles** for this part of the Code, which consider only the release of the nitrogen and water content of the solution, to land based sites are:

- There should be sufficient land allocated on the release site to take into account the plants' ability to absorb the applied nitrogen, allow for all sources of nitrogen, seasonal variations and time for plants to absorb the nitrogen
- The water should be used or disposed of in a way that enhances plant growth and does not overload the soil
- Water should be applied to recharge the root zone, but not enough to result in drainage or runoff
- No application should be made over any of the seven sensitive areas listed in **Fact Sheet 3 - B d**, page 26
- Released water should be spread evenly over the application area
- Water and nitrogen applications should be recorded and kept

Nitrogen is the most environmentally significant nutrient in surplus nutrient solutions. Nitrogen transported by either leaching or runoff may pollute both ground and surface water. This Code focuses on techniques that prevent or limit this occurring.

Other nutrients are not addressed in the Code at present. Phosphorus also affects the environment. It mainly enters water bodies attached (adsorbed) onto soil particles; little is leached. When the Code is followed for nitrogen application, application of phosphorus will be undertaken in a way that maximises uptake of by plants and prevents runoff, preventing phosphorus entering water bodies.

Growers should find a site where surplus solutions can be reused to provide water and nutrients for plant growth. Suitable uses for sites considered in this version of the Code are -

- Pasture harvesting; e.g. silage and hay
- Pasture grazed by animals
- Crops – annual and permanent
- Catch crops

Other uses, not considered here, include -

- Turf – instant lawn, sports turf
- Forest
- Constructed and harvested wetlands
- Growing coppicing trees for ethanol production or firewood
- Using media with a high C:N ratio such as sawdust beds
- Nitrogen digesters
- Denitrification beds and filtration systems

i) Release sites

The process for selecting a release site is - SEE FACT SHEET 3, page 26

1. Identify the potential release sites
2. Describe potential release sites
3. Draw a sketch diagram (plan) of the release sites, get a photo or GIS map from your territorial or regional authority, or use the site map from your quality assurance programme e.g. EUREPGAP or New Zealand Gap (NZ Fresh Produce Approved Supplier Programme).

Describe or show -

1. Potential release areas
2. Soil types – texture, drainage ability, infiltration rate
3. Ground water depth – in wet and dry periods
4. Contour – slopes, areas where solution could flow across boundaries
5. Sensitive areas – streams, flood prone areas, wetlands, ponds etc
6. Ground cover – permanent, current cover on cropping areas
7. Riparian strips – buffer zone distance

ii) Application methods for released solution

The most suitable systems in order are -

- Set sprinklers
- Movable sprinklers e.g. travelling irrigators and K line
- Truck and trailer for small volumes but application is not very even

Other application systems such as drippers and border irrigation can be used, but require more care as they are likely to take solutions below the root zone.

iii) Application criteria

1. Solution should be spread evenly over the designated application area so that heavy rates leading to spot leaching or runoff do not occur

2. The grower should present a report on the application area and system, which should confirm that a suitable site and soil are available for application of released solutions. It should also:
    i. meet the requirements of this Code
    ii. be able to take the assessed volume of released solution at all times
    iii. be owned or leased by the grower, or be a neighbouring property where a contract makes it available when required

3. The grower should present a design report giving -
    a. EITHER application specifications (from the irrigation supplier) showing compliance with standard procedures and application rate (mm/h) related to soil texture and slope
    b. OR an application uniformity test (from an irrigation engineer) showing compliance with the Irrigation Code of Practice and the Irrigation Evaluation Code of Practice.

Unplanned releases due to events such as disease must meet the criteria in the Code

iv) Release - Evaluation of Risk at Site

On this page you assess the suitability of a site.

Record the details for each disposal site using the following guide.
Draw a sketch plan for each site **SEE FACT SHEETS 3, 4, 5, 6, 7, pages 26 - 40**

Site Address	**Property** – owner/occupier	**Area** – ha

Ground cover

Pasture or Crop	e.g. pasture or crops grown and annual sequence Example: It was in pasture for five years. Then it went from potatoes to onions and greens. Current crop is cabbage. It will then return to pasture.
Quality of ground cover	Example: Soil is bare for long periods during onion and potato cropping

Soil

Soil description	Describe topsoil and subsoil – texture, structure Example: Topsoil: 15 cm deep, dark brown, a silty clay loam, crumbly and easy to cultivate Cracks when dry Subsoil: pale brown with slight mottling, a clay, very sticky
Slope / contour	Example: It is on a very slight slope towards a stream that only flows in winter Erosion risk is very low
Water infiltration rate	Include soil structure - see Fact Sheet 4 Example: Gentle slope - clay loam with strong structure - 13 mm/h maximum application rate
Water Holding Capacity	See Fact Sheet 4, and Appendix E Example: High capacity
Drainage	See Fact Sheets 3 and 7, and Appendices D and E Example: Drainage is slow especially in winter

Weather

Rainfall	Annual rainfall Example: 1200 mm
Rainfall distribution	List times when heavy rain is possible and periods where rainfall exceeds ET. See Fact Sheets 3 and 7 Example: NE rains are likely in autumn. Rainfall is greater than ET from April to October

Constraints

Sensitive areas	e.g. streams, wetlands and their distance Example: Stream on downwind side already pollute Neighbours' irrigation pond on boundary
Mitigating factors	Example: Riparian strips have just been established Owner of property has joined the local land use group

Evaluation

Nitrate Leaching Risk	see Fact Sheet 3 Example: high risk in late winter – score 4 High risk also in autumn during NE rain, or sometimes in summer

Nitrogen Loading

Calculate the amount of nitrogen to be applied per hectare in one application.
This Code specifies a maximum of 30 kg N/ha in a three week period, up to a maximum of 150kgN/ha/year (up to 200kgN/ha/year can be applied to some soils, see your Regional Council).

For example:

Nitrate-N = 185
Nitrite-N = 5
Ammonia-N = <u>10</u>
Total-N = 200

	total N (ppm)		Solution released (m^3)		N released (g)		Convert N to kg		N released (kg)		Area (ha)	=	kg N/ha
Example	200	x	300	=	60,000	÷	1000	=	60	÷	2	=	30
Typical day Use your average data		x		=		÷		=		÷		=	
Summer day Use summer data		x		=		÷	1000	=		÷		=	
Winter day Use your winter data		x		=		÷	1000	=		÷		=	

If 2 ha of land are available you have reached the maximum rate of 30 kg N/ha and may not apply nutrient for another 3 weeks.

If 5 ha of land are available you have not reached the maximum rate of 30 kg N/ha – you have decreased the potential for leaching.

Check that your calculation meets all the requirements of the Code
See Fact Sheet 5 page 31

For Formulae and Conversion Tables, and Abbreviations and Definitions – refer to Appendices A and B on pages 41 - 46

v) Disposal area needed

Hectares (ha) needed to meet the **30** kg N/ha standard for a single application

		m^3 - volume of solution for disposal on any day												Application depth
		2	5	10	20	50	100	150	200	300	500	1000	2000	mm/ha
Solution concentration - ppm N	50	0.003	0.008	0.02	0.03	0.08	0.2	0.3	0.3	0.5	0.8	1.7	3.3	**60**
	100	0.007	0.017	0.03	0.07	0.17	0.3	0.5	0.7	1.0	1.7	3.3	6.7	**30**
	150	0.010	0.025	0.05	0.10	0.25	0.5	0.8	1.0	1.5	2.5	5.0	10.0	**20**
	200	0.013	0.033	0.07	0.13	0.33	0.7	1.0	1.3	2.0	3.3	6.7	13.3	**15**
	250	0.017	0.042	0.08	0.17	0.4	0.8	1.3	1.7	2.5	4.2	8.3	16.7	**12**
	300	0.020	0.050	0.10	0.20	0.5	1.0	1.5	2.0	3.0	5.0	10.0	20.0	**10**
	350	0.023	0.058	0.12	0.2	0.6	1.2	1.8	2.3	3.5	5.8	11.7	23.3	**9**
	400	0.027	0.067	0.13	0.3	0.7	1.3	2.0	2.7	4.0	6.7	13.3	26.7	**8**
	500	0.033	0.083	0.17	0.3	0.8	1.7	2.5	3.3	5.0	8.3	16.7	33.3	**6**
	600	0.040	0.1000	0.20	0.4	1.0	2.0	3.0	4.0	6.0	10.0	20.0	40.0	**5**

Note:

1. Consider nitrogen application rates and irrigation rates separately as each of them can be the more important factor in nitrogen leaching.
2. All area values in this table consider only the nitrogen application guidelines of the Code.
3. When **nitrogen concentrations in the released solution are low**, water application rates can be high enough to leach nitrogen. Use a water budget, as described in Fact Sheet 7 page 39, to calculate the correct water application rate.

Costs of disposal

SEE FACT SHEET 6, page 38

The value of unused nutrients in solution represents a considerable cost. For a 1 ha property the costs of released nitrogen may be in the order of $6000 a year for a 20% release rate, and $15,000 a year for a 50% release rate.

You check the site just before release

SEE FACT SHEETS 3 and 4

vi) Release - Assessing Risk One Day Before Application

Assess the risk of leaching and runoff

Put a cross ☒ *against any statement that applies*

	High Risk	Moderate risk	Low risk
Drains	☐ Flowing	☐ Stopped within 1 week	☐ Stopped over a week ago
Season	☐ Going into a wet Season	☐ Going into a dry season	☐ Drought period
Rain	☐ Heavy rain forecast within 1 week	☐ Only showers forecast	☐ No rain forecast
Soil	☐ Deep cracks	☐ Shallow cracks	☐ No cracks
Ground cover	☐ Bare soil	☐ < 30% ground cover	☐ Plant cover over 70%
Plants	☐ Weak roots	☐ Moderate roots	☐ Strong dense roots
Rate of growth	☐ Slow or no plant growth	☐ Moderate growth rate	☐ Fast growth period
Stock	☐ Heavily grazed pasture < 25 mm height	☐ Stock removed 2 weeks before	☐ No stock

If **ANY** crosses are in this column – the **risk of leaching is high.** Do not apply solution to soil Store solution until soil conditions are suitable	If **ANY** crosses are in this column – the **risk of leaching is moderate.** You may apply solution with special care and by following remedial actions such as planting cover crops. See Fact Sheet 5	If **ALL** the crosses are in this column – the **risk of leaching is low** Release nutrient solution according to the Code of Practice

vii) Records

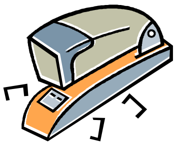
Record full water analyses

	Raw water analysis	Comments on significant results
	Dates	*You should have at least 1 lab test/year*
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

	Released solution analysis	Comments on significant results
	Dates	*You should have at least 3 lab tests/year*
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

You must keep analyses for at least 5 years -

- to be able to assess past management practices and make decisions
- to be able to provide data for surveys monitoring nitrogen leaching



Application Record

Use one form for each site
You can copy this form or use your own format

Site Address	**Property – owner/occupier**	**Area – ha**

Application Dates	2.11.05			

Ground cover

Type of cover	Pasture			
% cover	high cover			
Rate of growth	fast growth			

Stock

Stock type	Steers			
Stocking rate – su/ha	4			

Soil conditions

Soil water	Drying fast			
Soil temperature	Warm			
Drains	Dry			
Number and type of cracks	Just starting			

Weather

Before & after application	Hot and Dry Then Windy			

Rain

Before application	Nil			
After application	22 mm in 2 days			

ET

Ave of 5 days before	3			
Ave of 5 days after	4			
Tensiometer before	35			
Tensiometer after	Falls to 20			

Constraints

Sensitive areas	Nil			
Mitigating factors	Soil into drying phase			

Water volume

m^3 applied	2000			
water meter readings				

Nitrogen applied

Merckoquant® test ppm	100			
kg/ha	10			
Other sources	old crop roots 10			
Total N applied	20			

Nitrate Leaching Risk - Circle See Assessing Risk Sheet and Fact Sheet 3	High Medium [✓ Low]	High Medium Low	High Medium Low	High Medium Low

Fact Sheet 3 Assessing Site Suitability

Leaching is only possible when water drains through soil pores or through cracks in dry soils

Estimating soil drainage from soil appearance

The best assessment of the long term soil drainage qualities of a particular area is local experience and the appearance of the top 500-800 mm of the soil:

- Warm brown colours and an abundance of healthy roots indicate free drainage.
- Grey coloured soil, especially in the lower layers indicates slow drainage
- A mixture of greys with rusty-coloured mottles indicates alternating free and slow drainage especially in winter

Estimating soil conditions from weather records

When rainfall (plus irrigation) exceeds evapotranspiration, soils are too wet to receive nitrogen containing nutrient solutions.

A Monthly data

Water balances indicate the times of the year when water is likely to drain through the soil, and therefore the risk of nitrate being leached. Data for Albert Park Auckland and Lincoln Canterbury (graphed at the end of this Fact Sheet) shows that, on average, rainfall exceeds evapotranspiration from April to October at both sites. Similar data for other places in New Zealand are tabulated in Appendix D.

B Daily data

To estimate the daily irrigation requirements (and the volume of water you can release onto a site) you can use a water budget described in Fact Sheet No 7. Local newspapers usually publish actual rainfall and evaporation data.

What to watch out for

a) Slow drainage or slow water infiltration rates at the soil surface cause water to run off the soil surface increasing erosion and the transfer of nutrients to surface waters.

b) While it is reasonable to assume that nitrogen is not lost from dry soils, an exception is possible with clay soils which develop deep cracks as they dry. Animal slurries applied to such soils have appeared from drainage outfalls within hours of application.

c) Other things to consider include -
   - Soil type – texture, drainage ability, infiltration rate
   - Ploughing which speeds up soil OM breakdown and so accelerates potential nitrogen leaching
   - Ground water depth – in wet and dry periods
   - Contour – slopes, areas where solution could flow across boundaries
   - Ground cover – permanent, cropping
   - Riparian strips – buffer zone distance

d) Sensitive areas
   Application shall not be made over:
   - permanently wet areas e.g. hollows/springs
   - streams, waterways
   - flood prone areas
   - natural wetlands
   - drinking water bores and intakes
   - open drains
   - ponds, irrigation ponds, lakes

Leaching risk

An estimate of the risks of nitrate being leached from soils is made by using an index based on rainfall and the drainage characteristics of the soil (this is derived from the more commonly used sulphate leaching index).

Nitrate leaching indices in slow and free draining soils and at different rainfalls

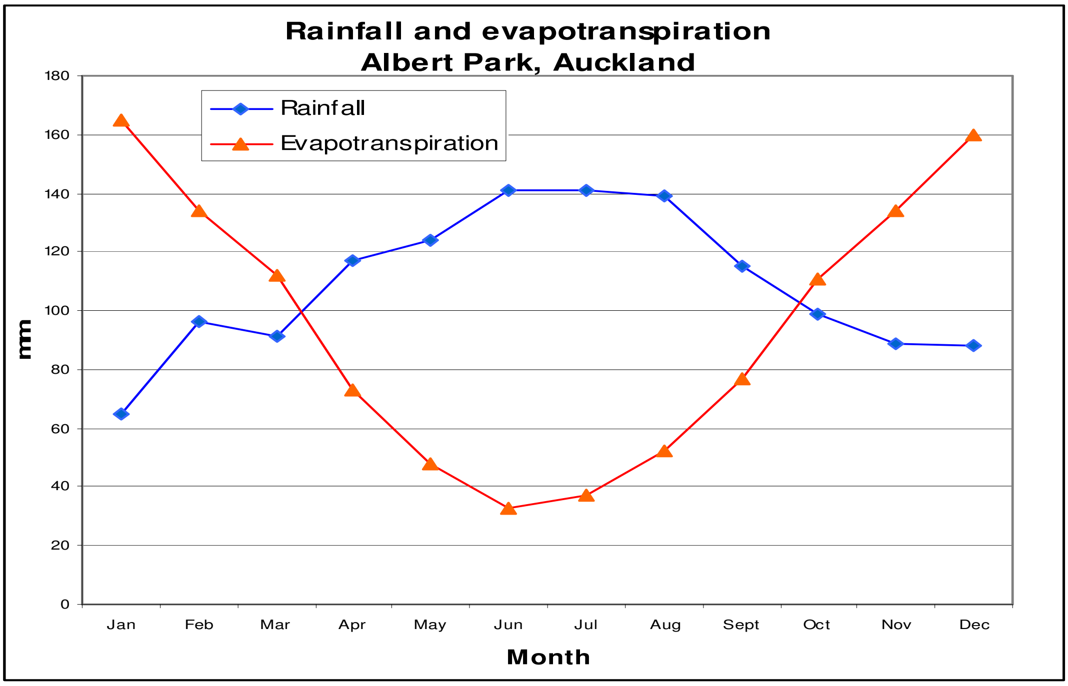
Annual rainfall (mm)	Slow drainage	Free drainage
<500	2	3
500-750	3	4
750-1500	4	5
>1500	5	6
Irrigated land	4	5

The interpretation of the leaching indices in the table –
2 = no leaching
3 = slight winter leaching
4 = severe winter leaching
5 = complete winter and some summer leaching
6 = complete winter and severe summer leaching

The times when solutions can be applied to sites with leaching indices of 4, 5 or 6 are likely to be limited to periods of below average rainfall or summer.

Slow draining soils include clay soils, especially those with low organic matter, silt loam soils and soils with compact subsoil. Free draining soils include sandy soil and loam soil with high organic matter and strong structure.

Average monthly rainfall and evapotranspiration

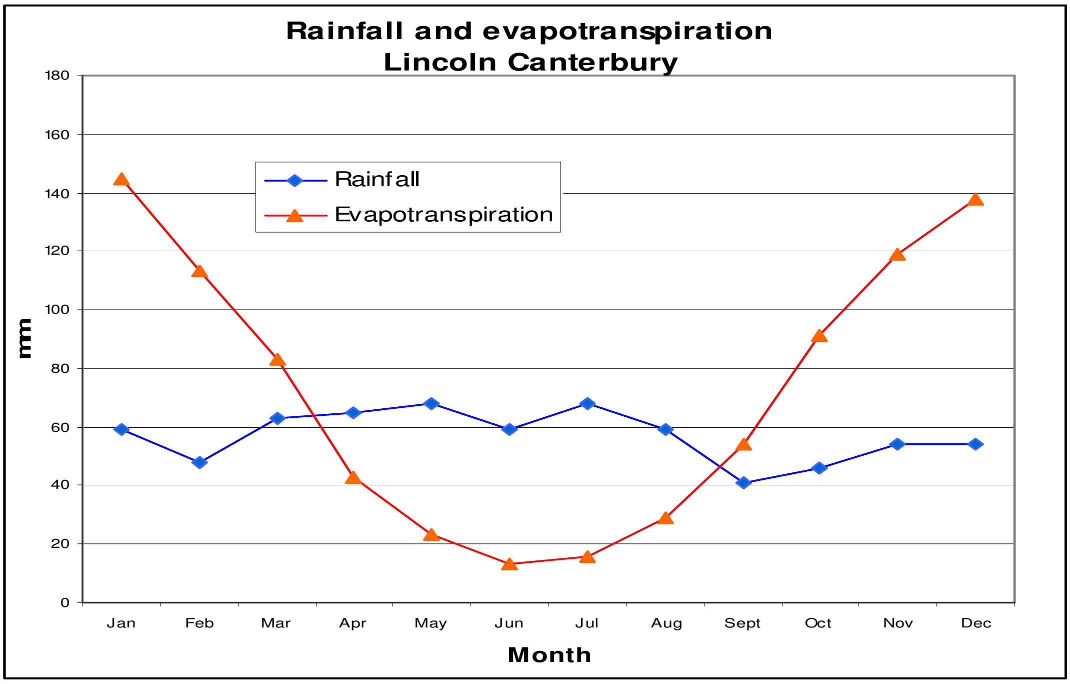


Normal soil water balance

Water short - drought	Soil being recharged with water	Soil saturated Draining of excess water	Plants use stored water	Water short

Leaching risk in normal seasons

2	3	5	2	2



Normal soil water balance

Water short - drought	Soil being recharged with water	Soil sometimes saturated and draining	Plants use stored water	Water short

Leaching risk in normal seasons

2	3	5	2	2

Fact Sheet 4 Nitrogen in Soil and Water

Nitrogen and environmental impacts

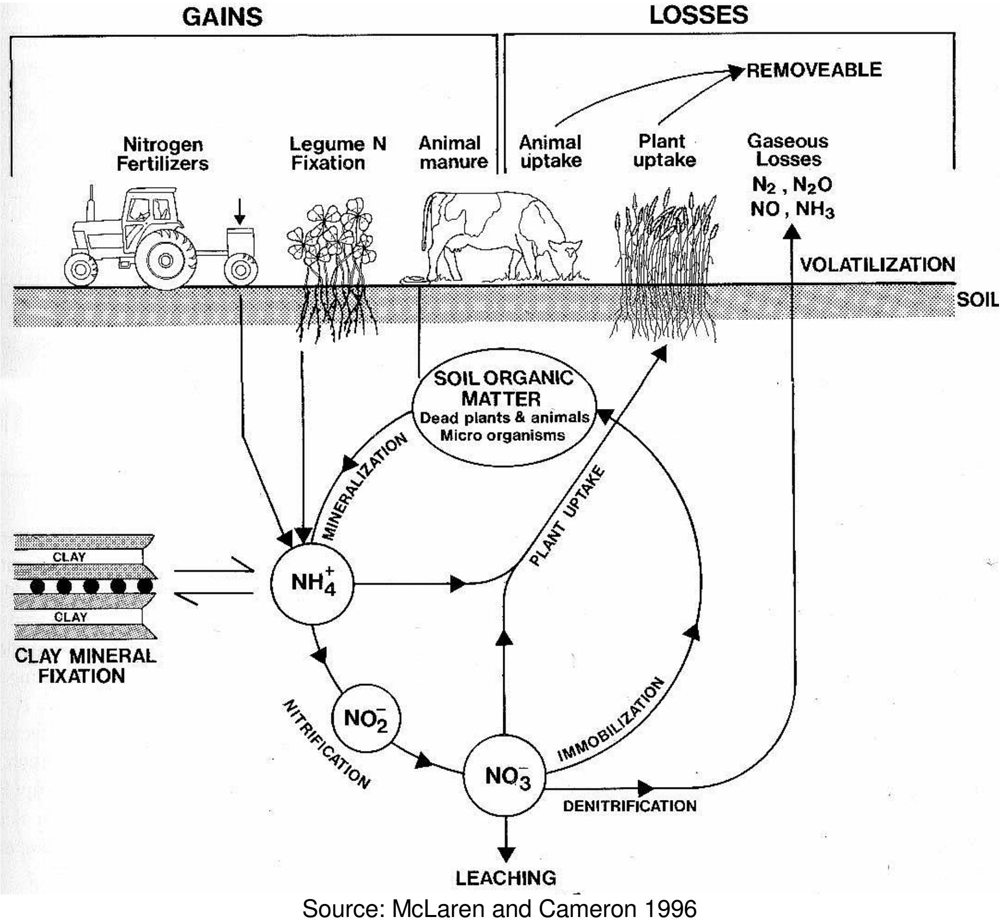
Nitrogen in released solution is a valuable nutrient and is also the nutrient most likely to cause environmental damage.

Nitrogen is the most commonly deficient nutrient in New Zealand soils. Nitrogen in released nutrient solution has the potential to be reused and to benefit pasture and crop production. Nitrogen is also the nutrient most commonly associated with water pollution and eutrophication.

Nitrogen may be present in released solution in three forms; as urea, ammonium or nitrate. Once applied to the soil, urea and ammonium are transformed into nitrate. This occurs rapidly at temperatures above 5°C but is slower at lower soil temperatures.

Nitrogen in the nitrate form is very mobile in the soil and therefore the most likely nutrient to be transferred to ground water (leaching) or surface water (runoff) and if applied irresponsibly, pollute both ground and surface waters.

It is for these reasons that nitrogen is used as an indicator of potential environmental risks when nutrient solutions are applied to land.



Source: McLaren and Cameron 1996

Nitrate content in the soil

Nitrate is both mobile and unstable.

The concentration of nitrate in the soil solution is constantly changing. At any one time, it depends on the balance between:

1. the rate at which nitrogen has been applied to the soil (as fertiliser, organic manure, animal wastes, fixation by legumes and the death of plants growing on the soil)
2. the rates at which nitrogen in organic materials is converted to inorganic forms (mineralisation) and at which these inorganic forms are converted to nitrate (nitrification)
3. the rate at which nitrate is converted into organic forms by uptake (by plants) or by incorporation into microbes (immobilisation)
4. the rate at which nitrate is washed (leached) from the surface into ground water

The rates of these processes vary independently.

For example, soil microbes continue to grow and take up nitrate in conditions (<5^{0}C) that are too cold for plants to absorb nitrate from the soil. Immobilisation is high in winter, when the soil is often warmer than the air temperature. The nitrogen is then released (mineralised) in the spring when the grass grows rapidly and the uptake rate is very high.

Nitrate leaching

The amount of nitrate leached from the surface soil depends on its concentration in the soil solution and the volume of water draining through the soil.

Nitrate moves downwards through the soil and eventually -

- reaches the ground water (shallow aquifers) or deeper aquifers
- or it moves into land-drains and then discharges to streams and enriches rivers or lakes

Enrichment of ground water and surface water by nitrate is undesirable

There is often no direct link between the amount of nitrate leached from a soil and the concentration of nitrate found in ground and surface water. This is because nitrate is diluted by water (e.g. by lateral water movement) or transformed into other forms of nitrogen.

Water movement into and through the soil

Leaching occurs only when excess water drains through the soil.

The proportion of rain or irrigation which penetrates the soil depends on soil

- texture, structure and presence of macro pores
- roughness of the surface
- the presence of vegetation
- the slope of the land
- the intensity of rain or irrigation
- soil moisture status

Estimated maximum allowable water application rates (mm/hour)
Source: NZS 5103:1973

Soil groups	Slope Gentle 0 – 8°	 moderate 9 – 12.5°	 steep over 12.5°
Sands and light sandy loams uniform in texture	**32**	**25**	**20**
Sandy loams overlying a heavier subsoil	**20.**	**17**	**13**
Medium loams to sandy clays over a heavier subsoil	**17**	**13**	**10**
Clay loams over a clay subsoil	**13**	**10**	**8**
Silt loams and silt clays	**10**	**8**	**5**
Clays	**6**	**5**	**4**
Peat	**17**	**-**	**-**

Infiltration and run off

If a soil receives water faster than it drains, the soil fills up with water, air is excluded and anaerobic (low oxygen) conditions prevent the normal functioning of plant roots and organisms. Water ponds on the soil surface or runs off sloping land, increasing the risk of erosion and the transfer of N-rich nutrient solution to surface waters. Water penetration is slow when applied to a soil with poor surface structure (a surface cap), also resulting in surface ponding and runoff. The estimated maximum application rates for a wide range of soils and slopes are given in the table on page 29.

The amount of water leaching through a soil depends on the balance between -

- the amount of water already in the soil
- the amount of water entering the soil from rain and irrigation (infiltration)
- the amount of water which is used by the crop (transpiration)
- the water evaporated from the soil surface (evaporation)

A summary of the drainage characteristics of New Zealand soils is given in Appendix E.

Water holding capacity

The ability of the soil to hold water in the pore spaces is called the water holding capacity (WHC).

This depends on the texture and structure of the soil -

a) A sandy soil, which is usually freely drained and has a low water holding capacity, will rapidly lose any excess of rain and irrigation by leaching.

b) A well-structured soil retains more water for plant-use than the sand, but once its water holding capacity is reached, excess water drains away.

c) A heavy textured soil with poorly developed structure drains more slowly than the other two examples.

Soil acidity

Leaching nitrate from the soil increases the rate at which soils become acid. This is because the leached nitrate also removes basic nutrients such as calcium, magnesium and potassium from the soil. It is therefore necessary to monitor soil pH and apply lime depending on the needs of the crops being grown.

Fact Sheet 5 Managing Nitrate in the Soil

i) Summary of recommendations

Nitrate leaching only occurs when water passes through soil
Do not apply nitrate to wet soils

1. Have release sites identified at least one month ahead of intended application.

2. Estimate the volume of water and amount of nitrogen likely to be released.

3. Where nutrient solution is applied to land which is irrigated, deduct the release volume from the additional irrigation water.

4. Where nutrient solution is applied to land which either receives N-fertiliser or is grazed, either deduct the weight of nitrogen in the solution from the weight of nitrogen in the fertiliser applied, or deduct it from the animal dung and urine, to get the total nitrogen input.

5. Do not apply nutrient solution to wet soils; wait until drains stop flowing.

6. Use local rainfall and evapotranspiration data (from tables and or local newspapers) to determine when leaching is likely to occur.

7. If more specific information is needed, use irrigation scheduling techniques (e.g. water holding capacity and water budgets) to estimate the ability of soil to retain the volume (or depth) of solution applied.

8. Identify the drainage and water infiltration characteristics of the soil of the discharge area. Be cautious when applying solution to:
    - excessively drained soils
    - badly drained soils,
    - soils with a marked surface cap
    - dry soils with deep cracks.

9. Estimate the nitrate leaching index of the soil from drainage characteristics and local rainfall.

10. Assess leaching risks on the day before planned application.

11. Apply nutrient solution to land with high plant cover (e.g. crop cover to be 75% or above)

12. Apply nutrient solution in conditions with fast plant growth - e.g. not to short grass after grazing or mowing, or crops that are growing slowly in cold weather, or are near to harvest

13. Do not apply nutrient solution to areas with just ploughed pasture or crops.

14. Consider methods to catch excess nitrate:
    - Sowing a catch crop to take up nitrogen from the soil
    - Incorporating a high C:N ratio material such as cereal straw to soak up available nitrate in the soil
    - Sow crops in the autumn (e.g. winter-growing crops), to take up nitrogen before winter rains wash it through the soil
    - Ensure that actively growing crops are present when immobilised nitrogen is re-mineralised in spring.

15. When applying nutrient solution to intensely grazed pasture:
    - The grass must be at least 50 mm high
    - Wait for at least 2 weeks after stock is removed

16. Maximum nitrogen rates for application to pasture and crops:
    - Total nitrogen application (from solution and other nitrogen sources e.g. both mineral or organic fertilisers) to be no more than 30kgN / ha per application
    - Applications to be at least 3 weeks apart

17. Consider applying a nitrification inhibitor

18. Preferably apply nutrient solution to deep-rooted crops such as wheat, rather than to those with shallow or sparse root systems – e.g. potatoes, peas, spinach

19. If applying solution to permanent plantings (orchard, amenity trees or forest) follow the general guidelines above.

20. Monitor the pH of soils receiving extra N, and apply lime when necessary.

ii) Nitrogen in released solution

a) Nitrogen tests -

- i The **annual determination** of nitrogen (nitrate, nitrite and ammonium) concentrations of both raw water and released solution can only be done in an analytical laboratory.
- ii The tests on **each release** batch are done with a specific ion electrode or Merckoquant® test strips. Specific ion electrodes only test for nitrate, the predominant nitrogen compound in released solution.

Merckoquant® test strips give an inexpensive and quick guide to the nitrate and nitrite concentration. The time taken for Merckoquant® test strips to develop colour is fastest with high concentration solutions. The concentration of the solution being tested is determined by recording the time taken for the strip which has been dipped in the solution to get to the 500 ppm colour standard. Read the concentration off this table.

Time (seconds)	Nitrate (ppm)	Nitrate-N (ppm)
5	20,000	4600
10	7,000	1610
15	4,000	920
20	3,000	690
30	2,000	460
40	1,400	322
50	1,100	253
55	1,000	230
60	900	207
70	750	173
90	600	138
120	500	115

Time taken to reach 500 ppm colour standard:

For solutions with concentrations less than 500 ppm nitrate or 115 ppm nitrate-N (i.e. where the test strip has not turned to the 500 ppm colour standard in 120 seconds), use the calibration on the Merckoquant® test strip container. This allows estimations as low as 10 ppm nitrate or 2.4 ppm nitrate-N.

b) Estimating total nitrogen

The 30 kgN/ha allowed to be applied over a three week period is the sum of nitrogen in released solution and any other sources of nitrogen (including fertiliser, dung, urine, nitrogen releases from organic matter, green crops dug into the soil); e.g. if fertiliser nitrogen is applied at a rate of 20 kg N/ha, the amount of nitrogen in the solution must be no greater than 10 kg N /ha over the period.

This ensures that the maximum economic benefit is obtained and decreases the chances of excess nitrogen being leached. Unfortunately there is little information available that integrates all these issues.

iii) Nitrogen uptake

The recommendations in this Code are based on soil nutrient budgets. The Code does not require growers to complete any budget calculations as all the components of nitrogen budgets are included in the recommendations.

One example of a nitrogen budget, the Nitrogen Leaching Estimation calculator, is included in this section.

a) Nitrogen uptake by pasture

The annual uptake of nitrogen increases with the productivity of the pasture. Typical New Zealand figures are -

Dry Matter Production *t /ha/yr*	**kg N/ha** *at 4% N**	**Yearly N uptake averaged for 3 week periods**
10	400	23
12.5	500	29
15	600	35
20	800	46

* Note: McLaren and Cameron (1996) give levels below 4% as deficient.

Nitrogen uptake of at least 30 kg N/ha in three weeks (the standard set by the Code) occurs when dry matter production is over 12.5 t/ha.

However, production from non-irrigated grazed ryegrass pasture varies with season, rainfall and temperature and uptake is not sufficient to meet the standard for parts of the year. Annual production and nitrogen uptake is higher in the north, drier districts have low production in summer, and cooler districts have low production for much of the year (Langer 1990).

Season	DM/ha *t/ha/yr*	Seasonal growth *X conversion factor*	kg N uptake over 3 weeks
Dargaville	17.2		
Spring		X 0.30 X 40	48
Summer		X 0.33 X 40	53
Autumn		X 0.22 X 40	35
Winter		X 0.15 X 40	24
Hamilton	10.2		
Spring		X 0.44 X 40	42
Summer		X 0.25 X 40	24
Autumn		X 0.13 X 40	12
Winter		X 0.13 X 40	12
Lincoln	10.0		
Spring		X 0.43 X 40	40
Summer		X 0.28 X 40	26
Autumn		X 0.21 X 40	20
Winter		X 0.08 X 40	8

Irrigation

Irrigation of pasture reduces the effect of summer drought. At Winchmore (Canterbury), irrigation reduced the seasonal growth variability (from 19% to 10%) and almost doubled production (5.9 to 10.2 t DM/year). Well irrigated pasture has higher growth rates and thus extracts more nitrogen.

Irrigating with a nutrient solution can drive the nitrogen it holds below the root zone of the plants, so apply irrigation only to the depth of the plants' roots.

Root depth

Roots of pasture and crops growing have varying roots depths. Examples of plant root depth growing in unrestricted soil under irrigation are shown in the table.

Grazing	*cm*
Grass	30-75
Rape	45-60

Vegetables	*cm*
Cabbage	45-60
Carrots	45-60
Lettuce	15-45
Peas	45-60
Potato	60-90
Squash	60-90
Tomato	60-120

Field crops	*cm*
Barley	90-110
Lucerne	120-185
Maize	60-90
Oats	60-75
Wheat	75-110

Fruit Crops	*cm*
Apple	75-120
Citrus	60-120
Grape	45-90

- Maximum uptake is from near the surface as most feeding roots are in the top few centimetres of the soil
- Deeper rooting plants are able to extract water and nitrogen from deeper in the soil
- Shallow rooted plants (peas, spinach) extract less
- Plants with strong root systems (wheat) are more effective

Both total nitrogen applications and water volumes need to be calculated independently when nutrient solution are applied.

b) Nitrogen uptake by crops

Some crops take up nitrogen at a faster rate than pasture but because they often have a shorter life span, the annual uptake from a site may be less than pasture. Examples of crop uptake are –

Uptake for early season vegetative growth

	Uptake/day *kg N/ha*	Uptake over 3 weeks *kg N/ha*
Wheat	4	84
Soya-beans	6	126

Total uptake by plants – annual or life of crop

	Yield *t/ha*	Uptake *kg N/ha/ year*
Wheat – Grain	5.5	110
Wheat – Straw	6.0	45
Lucerne	18	500
Maize	19	330

iv) Suitable release systems

a) Pasture harvesting

In pasture harvesting; e.g. for silage and hay, non-grazed pasture is specifically used to absorb the applied nitrogen. A large amount of nitrogen is removed from the site in hay, silage or stock food. To stimulate growth nitrogen is normally applied after cutting.

If an area set aside for pasture harvesting is to have a grazing cycle, stock can be returned to the site immediately after solution application.

Examples of the amount of nitrogen that is absorbed by non-grazed pasture in one harvest of silage or hay are –

	kg N/ha	
Hay	68	(4%N in DM). Based on fresh weight 2000 kg/ha; dry matter 1700 kg/ha (= 85% DM)
Silage	18	(4%N in DM). Based on fresh weight 3000 kg/ha; dry matter 450 kg/ha (=15% DM)

b) Grazed pasture

Animal urine, especially cattle urine, is the main source of nitrate leached from grazed pastures. Use great caution when applying nutrient solution to dairy land, especially at stocking rates greater than 2 cows per hectare. Strictly adhere to the soil moisture and drainage recommendations in the Code.

Rapidly growing pasture takes up the nitrogen in urine patches. To allow time for the pasture to absorb as much nitrogen as possible, do not apply nitrogen until at least 2 weeks after the stock has been removed.

Stock can be returned to the site immediately after solution application.

c) Cropping

Take special care if nitrogen is to be applied in late autumn or winter.

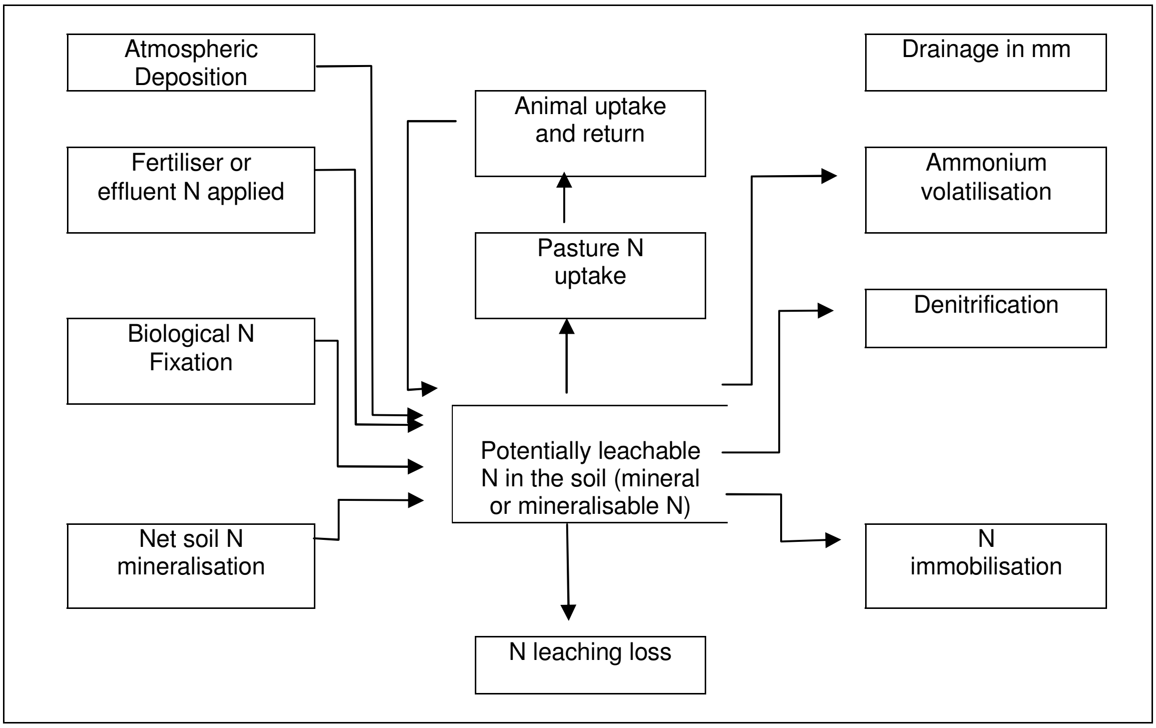
- Some crops, like winter potatoes, spinach or lettuce, conventionally receive very large dressings of fertiliser-N, which is leached in freely drained soils due to the plants inability to absorb it.
- Sow winter crops such as wheat or catch crops early (autumn or early winter) so they absorb nitrate before it is be leached during winter.
- Cereal crops residues cultivated into the soil help immobilise nitrate and decrease leaching losses.
- The organic nitrogen produced in this way is eventually re-mineralised. Crops must be sown in time to take advantage of the nitrate released (mainly in spring) and prevent it being leached.

d) Catch crops

Catch crops are grown to absorb excess nitrogen and so minimise leaching, and are then cultivated into the soil or sprayed off before the next crop is planted. They are usually planted in the autumn. It is unlikely they are economically justified for nutrient solution management unless they are also used to minimise erosion or to build up organic matter in the soil.

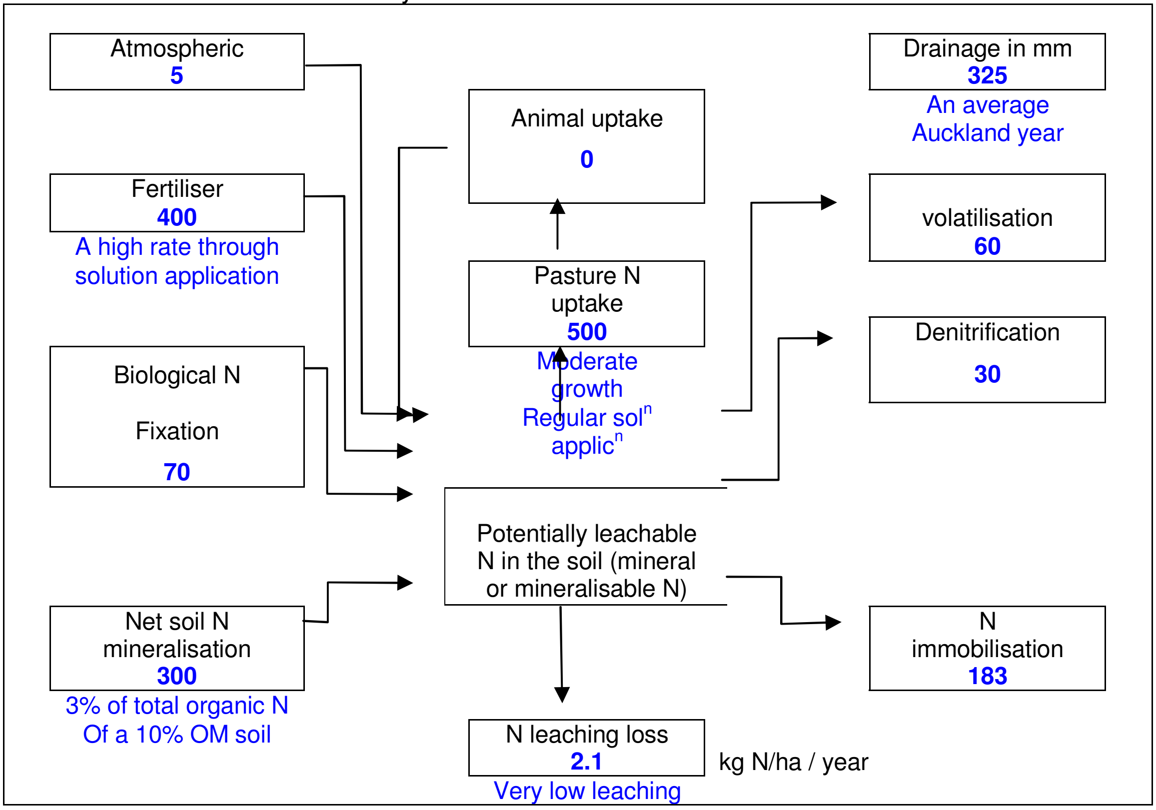
v) Assessing leaching potential

The recently developed (Di and Cameron 2003) **Nitrogen Leaching Estimation** (NLE) calculator is designed to estimate nitrogen leaching under differing conditions. The front page of the calculator is shown as follows:



a) Applying the Nitrogen Leaching Estimation Model to pasture harvesting

The nitrogen pathways for a pasture harvesting site in Auckland are illustrated in the following example. It calculates there is very low leaching even at high nitrogen application rates, as long as there is moderate pasture growth. Immobilisation also removes nitrogen from the system, and at the same time builds soil organic matter levels. It will be several years before this could lead to increased mineralisation and leaching.



Summary of nitrogen pathways	*kg*
Total application	775
Plant uptake and losses	590
Leaching	2.1
Immobilisation by soil organisms (the balance of the N)	183

The example in a) on the previous page is set-up with some standard Auckland inputs including irrigation with nutrient solution. Calculations for three levels of pasture production follow.

i) Moderate pasture production

Moderate pasture production of 12.5 t DM/ha takes up 500 kg N/year.

- This calculation uses a high rate of nitrogen application (400 kg N/ha). The NLE Model calculates an annual low rate of leaching at 2.1 kg N/ha (as the Model is not set to distinguish small input numbers the actual leaching could be between nil and around 10 kg N/ha/year).
- The breakeven application rate (with these inputs) is calculated by the NLE to be 375 kg N/ha.
- Under practical circumstances, at the likely maximum application rate nutrient solution of 300 kg N/ha, the model calculates there is no leaching and so there is a considerable safety margin.
- The theoretical maximum application rate of 520 kg N/ha (30 kgN /ha every 3 weeks) gives an annual potential leaching at 20.5 kg N/ha.

ii) High pasture production

High pasture production of 15 t DM/ha takes up 600 kg N/year.

- The NLE model indicates there is no leaching with the same assumptions as above
- The breakeven application point is 475 kg N/ha/year.

iii) Excellent pasture production

Excellent pasture production of 20 t DM/ha takes up 800 kg N/year.

The NLE model is not designed to calculate at this level but, because of high uptake, the potential for leaching is much less and there is a far greater safety margin.

b) Applying the NLE Model grazing with dairying

When applied to grazed pastures with dairying in Auckland the NLE Model shows there is always leaching of nitrogen.

In one example with standard inputs for Auckland with light grazing of 2 cows/ha and an application of 200 kg mineral N/ha, the leaching is 21.7 kg N/ha per year.

The NLE Model shows:
- leaching is inevitable when grazing cows
- leaching accelerates with applications of mineral nitrogen
- leaching declines with reduced applications of nitrogen – at low levels there is little reduction

Mineral N fertiliser applied	**Leaching loss**	
	N conc.	**Total N loss**
kg/ha	*mg N/L*	*kg N/ha/yr*
140	5.8	18.9
150	5.9	19.2
200	6.7	21.7
250	8.2	26.5
300	10.4	33.7
400	16.9	55.0

The model also demonstrates:
- a low stocking rate (1 – 2 cows/ha) is better than a high stocking rate (3 – 4 cows/ha)
- most of the leaching is caused by the dairy cows – less is caused by mineral fertiliser nitrogen
- halving the stocking rate halves nitrogen leaching
- do not apply mineral nitrogen when organic nitrogen is applied e.g. dairy shed effluent, dairy pond sludge, pig slurry

vi) Slowing down mineralisation

a) Immobilisation

Mineralisation is the release of mineral nitrogen from organic matter in the soil. It depends on the relative amounts of carbon and nitrogen in the soil, and is slowed or even reversed (immobilised) when plant remains containing much more carbon than nitrogen are cultivated into the soil. This is due to the balance between mineralisation and immobilisation.

- When organic matter that is rich in nitrogen (e.g. clover leaves or pea straw with a C:N ratio of less than 25) is applied to the soil, the decomposing organisms quickly release nitrate into the soil solution.
- In contrast, cereal straw stubble (C:N ratio >40) does not supply enough nitrate for the growth of the decomposing organisms which then remove it from the soil solution and reduce leaching
- Woody material; e.g. sawdust, newspaper (C:N ratio >200) has an even greater effect in removing nitrate from the soil

- When nitrogen is applied to a soil containing organic matter with a high C:N ratio, the nitrate is rapidly captured by micro organisms and combined into organic forms. This protects the nitrate from being leached
- When conditions are suitable it is re-mineralised. This normally occurs in spring when plants start growing actively. They absorb the mineralised nitrate again minimising leaching losses.

b) Chemical additives

Nitrification inhibitor chemicals are applied to decrease leaching.

When nutrient solution containing urea or ammonium is applied or when organic matter is mineralising, the concentration of nitrate builds up in the soil. These chemicals slow down the rate of transformation of ammonium to nitrate and so reduce the amount of nitrate which can be leached.

They are -

- added to nutrient solution
- applied directly to the soil

Fact Sheet 6 Costs of Solution Release

Any release of a solution removes nutrients from the system which cannot be used in production. This adds to fertiliser costs. A small release (say 5%) has a small economic effect but a larger release has a very significant cost.

Annual Cost of fertilisers

In 2005, the annual cost of fertiliser for a 1 hectare crop of tomatoes is in the order of $30,000, depending on production levels and negotiated bulk rate prices.

Cost of plant nutrients	**Release rate**	**Cost of wasted nutrients**
$	%	$
30,000	5	1,500
	10	3,000
	20	6,000
	30	9,000
	40	12,000
	50	15,000
	100	30,000

Cost of released nitrogen

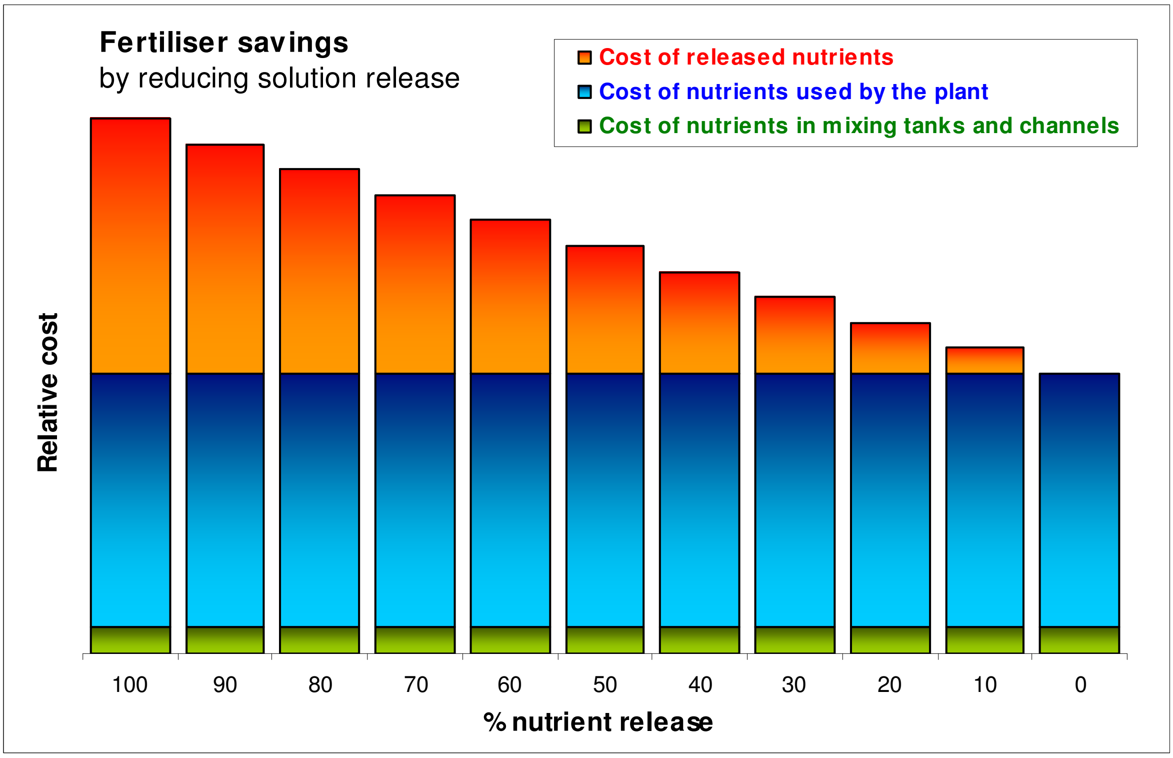
If the nitrogen content in a solution is 200ppm, every 1 m^3 released delivers 200g nitrogen to the outside environment. The cost of this is between $0.70 and $1.30/$m^3$.

Cost of N - 1 m^3 at 200 ppm

Fertiliser	% N	$/kg N	$/200 g N
Ammonium nitrate	33.5	3.50	0.70
Potassium nitrate	13.0	6.43	1.29
Calcium nitrate	15.5	4.25	0.85

The prices used are for the bulk rate and assume the fertilisers contain only the single nitrogen nutrient.

The following chart illustrates relative costs.



Fact Sheet 7 Water Budget Calculator

A water budget –

- estimates how much water is stored in the soil
- shows how quickly the soil is drying out through ET (evapotranspiration)
- indicates when plant growth is affected by water shortage
- shows when irrigation is likely to be needed to maximise growth
- shows how much water is needed to wet the root profile
- avoids over irrigation with the leaching of nutrients past the root zone

Evapotranspiration

Evapotranspiration (ET) is an estimate of the water the plant needs each day to maximise its growth. It is based on the climate – heat, sunlight, humidity and wind.

In NZ, daily ET is variable from day to day. It ranges from less than 1mm/day in winter to over 5 mm/day in summer.

When ET is converted to an irrigation rate the volume of water needing to be applied is -

1mm/day = 10 m^3/ha/day
5 mm/day = 50 m^3/ha/day

Leaching due to irrigation

In irrigation planning, the soil is allowed to dry out to a predetermined point (as shown by the Soil Moisture Deficit on the following table) and several days' water is applied at one time. If this volume is exceeded, water goes past the roots and so drives the nutrients it contains down into the ground water.

This calculation is important for the application of nutrient solution. Both the nitrogen content and the water volume must be calculated independently. In many cases a solution with a low concentration of nitrogen might not exceed the nitrogen guidelines but can exceed the irrigation guidelines.

In these cases the irrigation guidelines take precedence over the nitrogen guidelines.

Operating a water budget

A water budget estimates soil moisture deficit. It is not an exact value but an accepted best estimate.

Use the daily ET which is normally printed in local and district newspapers, to produce a water budget.

1. You must know how much water a soil holds. You get this information from an irrigation engineer. In this example the soil must loose 30 mm before plant growth slows down – this is often called the EAW (Easily Available Water) or the RAW (Readily Available Water).
2. The soil must be fully wet at the start.
3. You record the daily ET.
4. You keep a rain gauge and record daily rainfall for your property.
5. Each day you calculate the Net Change - the difference between the ET and the rainfall.
6. You assume that light rain showers, of 2 mm or less, only wet the soil surface. They do not penetrate into the root zone as the water evaporates from the soil surface.
7. You then calculate the loss of water from the soil – the Soil Moisture Deficit (SMD).
8. When the SMD gets up to the limit, you apply enough irrigation to make up the SMD. In this example you apply water when the deficit gets to 30 mm.
9. To make up for application losses you apply a little extra water e.g. apply approximately 35 mm.

Example Water Budget Calculator

Note: Most of calculations are simplified to whole numbers for easier calculations.

Property:

Year: **Month:**

Date	ET (mm)	Rain (mm)	Net change	SMD (mm)	Irrigation (mm)	Excess water	Notes
1	4		- 4	- 4			
2	3		- 3	- 7			
3	4		- 4	- 11			
4	5		- 5	- 16			
5	3	10	+7	-9			
6	2	15	+13	+4 (0)		4	The rain wets the soil. Surplus water drains through or runs off. The SMD goes to back to zero.
7	2	20	+18	+18 (0)		18	Again there is a wet day with surplus rainfall.
8	3		-3	-3			
9	2		-2	-5			
10	3		-3	-8			
11	3	5	+2	-6			
12	4	2	-4	-10			Light rain is ineffective and is not counted
13	4	1	-4	-14			Light rain is ineffective and is not counted
14	5		-5	-19			
15	5		-5	-24			
16	3		-3	-27			
17	3		-3	-30 (0)	35	0	Irrigation is required on day 17 when the SMD gets to its target level
18	3		-3	-3			
19	3		-3	-6			
20	3		-3	-9			Light applications of solution can be applied as they do not send water through the soil profile.
21	4		-4	-13			
22	4		-4	-17			
23	5		-4	-21			Heavier applications of solution can be applied - but do not apply more water than the soil can hold
24	5		-5	-26			
25	5		-5	-31 (0)	35		Solutions can be applied as irrigation
26	5		-5	-5			
27	2.2		-2.2	-7.2			
28	2.3		-2.3	-9.5			Do not apply released solution if significant rain is forecast over the next few days.
29	2.1	25	+22.9	+13.4 (0)		13.4	
30	2.1	40	+37.9	+37.9 (0)		37.9	Do not apply released solution when the soil is saturated and water is draining or running off
31	4		-4	-4			

Appendix A Formulae and Conversion Tables

Metric calculators are found on the web. Useful sites include

http://www.joshmadison.com/software/
http://www.measurement.gov.au/index.cfm?event=conversions
http://www.onlineconversion.com/

Basic Units

Prefixes

Metric units have a prefix to show its multiplication factor.

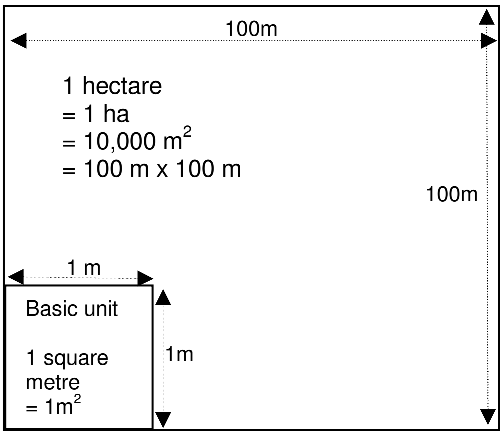
Prefix	Symbol	Times base	
giga	G	1 billion times	10^9
mega	M	1 million times	10^6
kilo	k	1 thousand times	10^3
hecto	h	1 hundred times	10^2
deka	da	10 times	10^1
-	-	1	10^0
deci	d	$\frac{1}{10}$ - the tenth	10^{-1}
centi	c	$\frac{1}{100}$ - one hundredth	10^{-2}
milli	m	$\frac{1}{1000}$ - one thousandth	10^{-3}
micro	µ	$\frac{1}{1,000,000}$ - one millionth	10^{-6}
nano	n	$\frac{1}{1,000,000,000}$ - one billionth	10^{-9}
pico	p	$\frac{1}{1,000,000,000,000}$ - one trillionth	10^{-12}

Length

Unit	Symbol	Comparison
millimetre	mm	1/1000 m
centimetre	cm	1/100 m
metre	m	
kilometre	km	1000 metres
	1 metre	≈ 3.3 feet (ft)
	1 foot	≈ 0.3 metres (m)

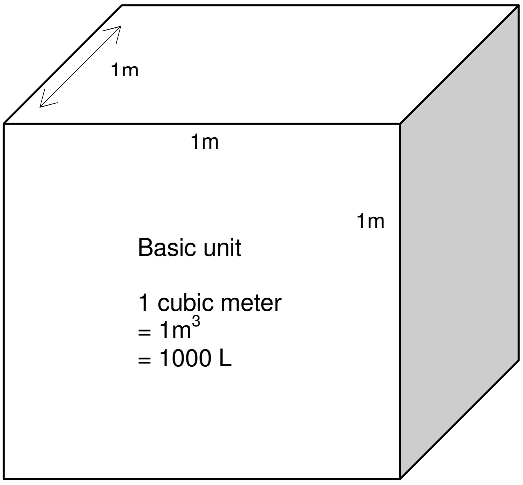
Area

Unit	Symbol	Comparison
square centimetre	cm^2	
square metre	m^2	
	ha	$10,000m^2$ = 100m x 100m
1 hectare	1 ha	2.4711 acres – approx 2.5 acres
1 acre		0.4047 ha) – approx 0.4 ha
		4047 m^2 - approx $4000m^2$
1 square yard		0.8361 m^2
1 square foot	1 ft^2	0.0929 m^2
1 square metre	1 m^2	10.7639 square feet
		1.196 square yards



Volume

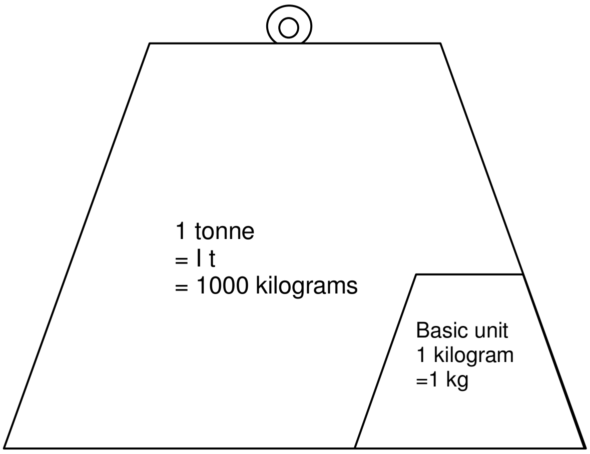
Unit	Symbol	Comparison
cubic centimetres	cm^3	or mL
cubic metre	m^3	1000 litres
millilitres	mℓ or mL	
litre	ℓ or L	1000 mL or 1000 cm^3
	1 tonne	1000 kg
	1 litre	0.22 gallons
	1 gallon	4.5461 litres (L)
	5000 L tank	5 m^3
	1000 gallon tank	4546.1 L approx 4.5 m^3



Weight (Mass)

Unit	Symbol	Comparison
microgram	μm	
milligram	mg	
gram	g	
kilogram	kg	(1000 g)
tonne	t	(1000 kg)

<	Less than
>	Greater than



Energy

Joules have replaced calories as a measure of energy

Energy is measured in **joules (J)**
One thousand joules is a **kilojoule (kJ)**
One million joules is a **megajoule (MJ)**

To convert calories to Joules
Calories x 4.1868 = Joules
Example:
30 calories x 4.1868 = 125.604 Joules

Evapotranspiration – ET See definitions in Appendix B pages 44 - 46

ET is measured in mm of water per day.

		Cold winter day	Moderate day	Hot summer day
ET - evapotranspiration	mm/day	1	3	5
Irrigation equivalent	ℓ/day/m^2	1	3	5
	m^3/day/ha	10	30	50

Ratios and proportion

ppm	parts per million	
%	parts per hundred	Percentage
C:N ratio	The proportion of carbon to nitrogen in the soil	A high number indicates the soil will immobilise (soak up) nitrogen so this it is less likely to leach
kg N/ha	kilogram's of nitrogen applied per hectare	
kg DM/ha	kilograms of dry matter produced per year over 1 hectare	Dry matter is the normal way to measure pasture growth
t DM/year	as above	
mg N/L	milligrams of nitrogen per litre	*mg/L is the same as ppm*

Solution Concentrations

Nutrient concentrations are analysed by laboratories in either of two ways –

a. as the single atom e.g. the single nitrogen atom N or elemental nitrogen. It is often written as nitrate-N to show that the nitrogen atom came from nitrate and not from another group.

b. as a group of atoms e.g. as the nitrate ion (NO_3^-) (1 nitrogen atom and 3 oxygen atoms) or the ammonium ion (NH_4^+) (1 nitrogen atom plus 4 hydrogen atoms)
These have an electrical charge – either positive or negative

It is important to distinguish between these analyses as the concentration and application rate to soil is significantly different and they act differently in the soil e.g. nitrate (and nitrate-N) is more likely to leach.

Nitrate-N	The nitrogen atoms that come from nitrate
Nitrite-N	The nitrogen atoms that come from nitrite
Ammonia-N	The nitrogen atoms that come from ammonia
Total=N	The total nitrogen atoms that come from all sources See page 18 or 21

Conversion		**Concentration of chemical group** ppm		Factor		**Nutrient N** ppm
Nitrate to Nitrogen	NO_3^- to N	870	x	0.23	=	200
Nitrite to Nitrogen	NO_2^- to N	667	x	0.30	=	200
Ammonium to Nitrogen	NH_4^+ to N	256	x	0.78	=	200

Conversion		**Concentration of chemical group** ppm		Factor		**Nutrient N** ppm
Nitrate to Nitrogen	NO_3^- to N	200	x	0.23	=	46
Nitrite to Nitrogen	NO_2^- to N	200	x	0.30	=	60
Ammonium to Nitrogen	NH_4^+ to N	200	x	0.78	=	156

Go to Fact Sheet 5 for Merckoquant® conversions from nitrate to nitrate-N.

Nutrient dilutions

Laboratory analyses for solutions including nitrogen are given in different units.
In the following table the commonly used units can be interchanged.
For example, a common strength of nitrogen in solution is 200 ppm, which is the same concentration as 200 mg/kg, 200 mg/ℓ or 200 µg/mℓ. They have just been written using different symbols.

Unit	**symbol**
parts per million	ppm
milligrams per kilogram	mg/kg
milligrams per litre	mg/ℓ
micrograms per millilitre	µg/mℓ

Appendix B Abbreviations and Definitions

(i) Abbreviations

New Zealand GAP	**The New Zealand Fresh Produce Approved Supplier Programme – New Zealand Gap provides a traceable, accountable system from crop to customer for the production of fruit, vegetables and flowers.** **It ensures best practices are in place for the production, packaging and distribution of New Zealand fresh produce, and reduces risk of health, safety and environmental issues – so customers can buy with confidence.** **Visit www.approvedsupplier.co.nz**
EUREPGAP	**A European quality control programme - EUREPGAP is a set of normative documents suitable to be accredited to internationally recognised certification criteria such as ISO Guide 65.**
NFGA	**Northern Flower Growers Association**
HortNZ	**Horticulture New Zealand**
MAF SFF	**Ministry of Agriculture and Forestry Sustainable Farming Fund**

(ii) Definitions from the Fertiliser Code of Practice

Best management practice	**In relation to fertiliser use, means the best methods to ensure that fertiliser use is a sustainable land management practice.** See RMA definitions for Best Practicable Option, Appendix C.
Fact Sheet	**A paper which summarises key information relevant to a specific topic, and which indicates where further information is found**
Fertiliser	**Any substance which is described as, or held out to be for, or suitable for sustaining or increasing the growth, productivity or quality of plants or animals through the application of essential nutrient to plants or soils (Note the full definition in 1.5)**
Risk	**The level of chance at which an event may occur**
Soil quality	**A qualitative term referring to the physical, chemical and biological attributes of a soil**
Soil test	**A procedure to estimate the nutrient status of the soil at the time of sampling**
Surface water	**Any above ground body of natural water including streams, rivers, wetlands, ponds and harbours**
Sustainable management	**Managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being, and for their health and safety while –** **a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations** **b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems** **c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment (s5 (2) RM Act)**

(iii) Definitions specific to the Code or from the Irrigation Code of Practice

Code	**A Code of Practice for The Management of Greenhouse Nutrient Discharges**
Disposal	**The method used for disposing of a waste nutrient solution**
Drainage	**Water in the soil that moves through the soil and out the bottom of the profile**
Evapotranspiration (ET)	**An estimate of the water the plant needs each day to maximise its growth, based on the climate – heat, sunlight, humidity and wind. It includes the water loss from a combined surface of vegetation and soil, evaporation of water from the soil surface, from free water on plants and transpiration by plants**
Field Capacity	**The soil water content of well-drained soils after drainage from initially saturated soils has become negligible. The macro pores of the soil are filled with air and the micro pores hold water between the soil particles**
Greenhouse	**A fully enclosed plant growing house, includes plastic and glass, with plants growing in soilless media.**
Infiltration	**Water moving into the soil and wetting the soil**
Irrigation	**The transfer of water from the water source to the designated area**
Leaching	**The removal of dissolved substances from the root zone in drainage water**
Media or rooting media	**The solid material used in soilless systems in which the roots grow. It is normally inert and all water, air and nutrients must be supplied. Today's soilless media includes bark, peat, pumice, sawdust, coco peat and rockwool.**
NFT - Nutrient Film Technique	**This soilless system is based on the flow of water down a channel without the use of significant solid medium to provide root growth or plant support (except for the block used to propagate the seedling)**
Nutrient solution or Solution	**The liquid that provides plants with water and their nutrients. The nutrient solution in a soilless system is split into two parts – plant solution and released solution.**
Nutrients	**The essential elements that plants require for growth, includes macronutrients and micronutrients (trace elements). Some nutrients become toxic to plants at high concentrations.**
N loading	**The total rate of nitrogen applied – measured in kg N/ha/year**
Plant solution	**The solution used by the plant. The water and nutrients in this solution are used by the plant for structural growth (of roots, stems and leaves), evapotranspiration, and crop (leaf, flowers or fruit) production.**
Raw water	**The water from the bore or stream before any treatment or addition of nutrients**
Recirculation	**When the nutrient solution is returned to the mixing tank to be treated and recirculated around the plants**
Release	**When solution is released from the growing system**
Released solution	**The Code calculates released solution as a percentage of plant solution**

	rather than a percentage of all the solution added to the system, as it is the true indicator of the amount of water and nutrient released.
Reuse	**When the surplus nutrient is to be used for a secondary purpose – not recirculation**
(Effective) root depth	**Average effective root depths for mature plants shall be used to determine available water holding capacity**
Runoff	**The movement of water across the surface of the soil. This causes erosion and also carries nutrients away form the site and into waterways**
Should	**Practices that should be followed and are considered mandatory to this Code**
Soilless growing	**Growing plants without the use of soil. A common synonym is hydroponics**
Soilless system or growing system	**All components of the installation - that supplies nutrient solution to plants, collects the solution and returns it to the mixing tanks**
Surplus solution	**Solution that has been used by the system but is to be released from it. This solution may be reused for secondary purposes e.g. pasture irrigation or fertilisation, or be discharged to waste. It contains both water and nutrients.**
(Available) Water Holding Capacity WHC	**The difference in moisture content between field capacity and permanent wilting point, expressed in millimetres depth of water over a specified depth of soil (usually equal to the expected effective root depth of a crop during periods of maximum water demand)**
Waste	**A nutrient solution that has no productive use**
Soil Moisture Deficit (SMD)	**A measure of the shortage of water in the soil. It is used in two ways; to measure the amount of irrigation water required to wet the soil, and the reduction in plant growth caused by water shortage.**
Readily Available Water Holding Capacity (RAW) or Easily Available Water (EAW):	**The difference in moisture content between field capacity and the stress point (equal to a soil suction of 200-500 kPa), expressed in millimetres depth of water over a specified depth of soil (usually equal to the expected effective root depth of a crop during periods of maximum water demand)**
N	**Nitrogen**
UV	**Ultra Violet light**

Appendix C From the Resource Management Act (1991)

Part 1 - Interpretation and Application

2. Interpretation—

Best practicable option, in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to—

(a) The nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and

(b) The financial implications, and the effects on the environment, of that option when compared with other options; and

(c) The current state of technical knowledge and the likelihood that the option can be successfully applied:

Contaminant includes any substance (including gases, **[**odorous compounds,**]** liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat—

(a) When discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or

(b) When discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged:

Regional plan means an operative plan (including a regional coastal plan) approved by a regional council or the Minister of Conservation under Schedule 1; and includes all operative changes to such a plan (whether arising from a review or otherwise):

Resource consent has the meaning set out in section 87 of the RM Act; and includes all conditions to which the consent is subject

Water

(a) Means water in all its physical forms whether flowing or not and whether over or under the ground

(b) Includes fresh water, coastal water, and geothermal water

(c) Does not include water in any form while in any pipe, tank, or cistern

Wetland includes permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions

Part 2 – Purposes and Principles

5. Purpose

(1) The purpose of this Act is to promote the sustainable management of natural and physical resources

(2) In this Act, ``sustainable management'' means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while—

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment

Part 3 Duties and Restrictions under this Act

15. Discharges of contaminants into the environment

(1) No person may discharge any—
- (a) Contaminant or water into water; or
- (b) Contaminant onto or into land in circumstances which may result in that contaminant (or any other contaminant emanating as a result of natural processes from that contaminant) entering water; or
- (c) Contaminant from any industrial or trade premises into air; or
- (d) Contaminant from any industrial or trade premises onto or into land—unless the discharge is expressly allowed by a rule [in a regional plan and in any relevant proposed regional plan], a resource consent or regulations.

(2) No person may discharge any contaminant into the air, or into or onto land, from—
- (a) Any place; or
- (b) Any other source, whether moveable or not,—

in a manner that contravenes a rule in a regional plan or proposed regional plan unless the discharge is expressly allowed by a resource consent or regulations, or allowed by section 20A (certain existing lawful activities allowed).

Appendix D Rainfall and Evapotranspiration

Table 1 Monthly and yearly average rainfall (mm) from New Zealand meteorological stations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Kaitaia Airport	87	111	81	110	139	166	148	164	118	111	101	93	1,429
Albert Park	65	96	91	117	124	141	141	139	115	99	89	88	1,305
Pukekohe	76	66	95	119	127	148	150	124	138	90	102	114	1,349
Ruakura	76	83	84	100	116	131	132	117	101	97	98	101	1,236
Tauranga AP	79	90	133	107	130	130	137	134	116	106	85	116	1,363
Taupo	74	78	69	87	87	114	116	109	94	94	83	92	1,097
New Plymouth	100	108	103	122	170	158	166	146	110	121	130	119	1,553
Wanganui	70	59	63	71	85	87	84	76	63	75	70	88	891
Gisborne AP	70	71	92	93	92	121	117	125	91	68	55	84	1,079
Napier	50	62	81	70	67	94	80	83	61	61	44	77	830
Levin	90	73	77	82	114	104	114	100	90	97	88	109	1,138
Masterton	65	51	76	81	96	99	112	92	76	76	73	83	980
Westport	161	160	173	207	224	188	177	183	173	193	210	180	2,228
Kaikoura	66	53	96	89	97	68	91	86	53	62	57	68	886
Lincoln	59	48	63	65	68	59	68	59	41	46	54	54	684
Timaru	57	47	61	57	49	34	43	40	32	49	58	59	586
Alexandra	38	27	39	31	33	22	18	19	21	32	31	35	346
Gore	88	62	81	81	84	73	57	47	58	73	80	84	868

Table 2 Monthly and yearly average evapotranspiration (mm) from New Zealand meteorological stations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Kaitaia Airport	142	116	99	63	40	29	32	46	67	96	115	138	983
Albert Park	165	134	112	73	48	33	37	52	77	111	134	160	1,136
Pukekohe	175	146	119	81	55	37	44	55	75	105	135	165	1,192
Ruakura	130	104	83	48	26	17	20	33	53	82	106	125	827
Tauranga AP	148	116	95	57	31	21	24	38	62	93	123	141	949
Taupo	140	108	84	48	27	18	20	32	53	84	111	132	857
New Plymouth	146	119	94	62	41	30	33	45	66	93	115	142	986
Wanganui	148	116	93	57	34	23	25	40	62	95	124	143	960
Gisborne AP	151	116	91	55	34	24	27	40	66	100	132	149	985
Napier	151	116	93	56	34	21	24	38	64	99	128	146	970
Levin	126	99	78	45	26	18	20	33	52	81	101	122	801
Masterton	135	106	80	43	23	15	18	30	52	82	107	127	818
Westport	128	103	78	45	28	20	21	36	51	78	101	121	810
Kaikoura	142	106	84	52	37	25	29	42	85	96	118	138	954
Lincoln	145	113	83	43	23	13	16	29	54	91	119	138	867
Timaru	123	94	71	40	21	12	15	28	49	84	109	121	767
Alexandra	134	101	74	32	12	4	6	19	47	83	112	133	757
Gore	121	91	69	38	18	10	13	26	50	82	102	118	738

Appendix E Drainage Categories of New Zealand Soils

Old Classification - 1948 NZ Genetic Classification System		**New Classification -** 1992 NZ Soil Classification System
Slow draining	Free draining	Approximate correlations
South Island soils		
Brown-grey earths >45cm deep	Brown-grey earths <45cm deep without pan	Semiarid
Brown-grey earths with a pan		Semiarid
Yellow-grey earths >45cm deep	Yellow-grey earths <45cm deep without pan	Pallic
Yellow-grey earths with pan		Pallic
Yellow-grey earths on rock <45cm deep	Yellow-grey earths stony	Pallic
	Yellow brown earths (upland and high country)	Pallic
Gley podzols	Podzols	Podzols
Brown granular loams		Brown
Recent alluvial >45cm deep	Recent alluvial <45cm deep	Recent
	Recent alluvial stony	Recent
	Yellow-brown loams	Allophonic or Pumice
Gley soils		Gley
Organic soils		Organic
Rendzinas		Melanic
North Island soils		
Central yellow-grey earths	Central yellow-grey loams	Pallic
Northern yellow-brown earths	Yellow-brown loams	Ultic
Northern podzols		Podzols
	Yellow-brown pumice soils	Pumice soils
Old red and brown loams	Young red and brown loams	Oxidic soils
Brown granular loams and clays	Yellow-brown sands	Granular/Melanic/Oxidic
	Coastal sands	Raw
	Peats	Organic

Note 1: These lists are a general guide for use when specific information on a soil's drainage characteristics is not available. Soil groups have been omitted if they include a wide range of drainage categories.

Note 2: Artificial drainage generally converts a slow-draining soil into a free draining soil.

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