BEFORE THE HEARING COMMISSIONERS PANEL APPOINTED BY ENVIRONMENT CANTERBURY

IN THE MATTER	of the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	of Proposed Plan Change 7 to the Canterbury Land and Water Regional Plan

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STATEMENT OF EVIDENCE OF STUART JOHN FORD FOR HORTICULTURE NEW ZEALAND (ECONOMICS)

17 JULY 2020

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INTRODUCTION

Qualifications and experience

1. My full name is Stuart John Ford. I am a Director of The AgriBusiness Group and work as an agricultural and resource economist based in Christchurch. I have a Diploma in Agriculture and Bachelor of Agricultural Commerce from Lincoln University and have undertaken post graduate studies in Agricultural and Resource Economics at Massey University.

2. I am a member of the New Zealand Agriculture and Resource Economics Society and the Australian Agriculture and Resource Economics Society. I am also a member of the New Zealand Institute of Primary Industry Management.

3. I have spent 37 years as a consultant in the agricultural industry, with the last twenty years specialising in agricultural and resource economics and business analysis.

4. I have undertaken a wide range of economic impact and cost benefit assessments of proposed statutory planning proposals.

5. I have prepared evidence and presented it to District and Regional Council Hearings Panels as well as the Environment Court and Special Hearing Panels on Conservation Orders.

Code of Conduct

6. I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Practice Note dated 1 December 2014. I have read and agree to comply with that Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Involvement in Plan Change 7

7. My involvement in Plan Change 7 (**PC7**) started when The Agribusiness Group (**TAG**) was engaged to provide Environment Canterbury (**ECan**) with the report "*Overseer nutrient modelling of commercial vegetable production*" in February 2019, attached as **Appendix A**. I was the principal author of that report.

8. ECan requested that TAG provide advice on the application of Overseer nutrient modelling for commercial vegetable growing operations in Canterbury.

9. A common aspect of commercial vegetable operations is complicated rotational operations and some of the land utilised being held in both short term and long term lease hold agreements. The Canterbury Land and Water Regional Plan (**CLWRP**) assigns nitrogen loss rates to land, resulting in commercial vegetable producers finding it difficult to access land with sufficient nitrogen allocation. This is mainly because the majority of land taken up in lease agreements has a nutrient allocation which is lower than the nutrients leached (predominantly nitrogen) under commercial vegetable production (**CVP**).

10. The objective of this work was to "calculate the total amount of nitrogen leached in each nutrient allocation zone by commercial vegetable growing operations across Canterbury".[1]

11. To carry out this report we analysed existing Overseer files of a range of commercial vegetable growing properties in Canterbury. We then created representative crop rotation scenarios which depict a range of standard rotations used in Canterbury in the CVP. These scenarios were made in Overseer and based on representative and the Matrix of Good Management (**MGM**) files, which were developed by ECan, to represent the range of Overseer files found throughout Canterbury.

12. The rotations which we modelled were green vegetables, root vegetables, intensive vegetables and intensive vegetables with fallow.

13. We then altered these scenarios to account for various soil and climatic effects within the Canterbury Region and were then able to calculate the current nitrogen losses for commercial vegetable operations for each CLWRP sub-region catchment.

14. This report was used to inform the discussions between ECan planning staff and the horticulture sector in Canterbury as to the appropriate planning framework that could be used in

[1] The Agribusiness Group, *Overseer nutrient modelling of commercial vegetable production,* February 2019.

PC7 to enable the allowance for the inconsistencies between the actual land use requirements for horticulture and the requirements in the LWRP.

Purpose and scope of evidence

15. I have been asked by Horticulture New Zealand (**HortNZ**) to provide this evidence for the Commissioners on the potential economic impacts on the horticultural sector of the proposed PC7.

16. In preparing this witness statement I have read:

    (a) Proposed Plan Change 7 to the Canterbury Land and Water Regional Plan;

    (b) Section 32 Evaluation Report for Plan Change 7 (Omnibus, Orari-Temuka-Opihi-Pareora and Waimakariri) to the Canterbury Land and Water Regional Plan and Plan Change 2 to the Waimakariri River Regional Plan (**section 32 report**);

    (c) Section 42A Report: Plan Change 7 to the Canterbury Land and Water Regional Plan; and Plan Change 2 to the Waimakariri River Regional Plan (**s42A Report**); and

    (d) Statements of Evidence of Ms McClung, Ms Goodfellow, Mr Hodgson, Mr Barber, Mr Farrelly, Mr Scherberg and Mr Nation on behalf of HortNZ.

17. In my evidence I consider the following:

    (a) The use of Overseer in the Commercial Vegetable Production Sector;

    (b) Typical horticultural rotations;

    (c) Leaching impacts of typical rotations;

    (d) The area of CVP grown and the impact on nitrogen leaching;

    (e) Expansion of vegetable growing for domestic supply;

    (f) The costs of expansion of CVP into another land use;

    (g) Expansion of vegetables for export;

(h) The range of possible leaching reductions at Good Management Practice and Best Management Practice;

(i) The use of Farm Environment Plans;

(j) The impact of low environmental intensity horticulture;

(k) An assessment of the requirement for root stock protection water; and

(l) Conclusions and recommendations.

THE USE OF OVERSEER IN THE COMMERCIAL VEGETABLE PRODUCTION SECTOR

18. I agree with the section 32 report where it seeks to adopt a cap on the land area rather than the specific amount of nitrogen (**N**) leached from a property because of "the difficulties with modelling losses from complicated vegetable production rotations in overseer".[2] The section 32 report analyses an appropriate use of Overseer for commercial vegetable producers. In terms of Overseer as an analysis tool for CVP, I consider:

(a) Overseer is a "black box" piece of software which means that its operation is not open sourced and therefore it is not able to be reviewed as to the accuracy of what it is modelling. At the same time, it has not been externally reviewed in any form, although I understand that it is currently undergoing some form of external review.

(b) The modelling of phosphate (**P**) is crude in the way that Overseer analyses and reports the transfer of P across the surface of the ground.

(c) The gross nature of the inputs used in entering data into Overseer (monthly data is the finest input timeframe) are unable to accurately reflect the complexities of relatively fine scale vegetable production systems.

(d) Overseer is not currently capable of modelling all possible crop types and therefore forces the modeller

[2] ECan (2020): Section 32 Evaluation Report for Plan Change 7 Section 5.7 Commercial vegetable growing operations.

to choose proxy crops to represent the crop being analysed.

(e) Overseer is a long term averaging tool which has a fixed, and somewhat limited, array of long term climatic data which it uses to spread the climatic data entered over, which represents an average of thirty years data.

19. In a paper written for ECan, Hulme[3] identified 21 examples of complexities that were encountered during modelling in Overseer for the arable and CVP sector and detailed the work arounds that she had to adopt to make the modelling work.

20. I also note that the Parliamentary Commissioner for the Environment (**PCE**) released his report "Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways December 2018" where he concludes that " *a significant amount of information needed to confirm Overseer's use in a regulatory setting is lacking*". He then goes on to make a number of recommendations as to what needs to be done to make Overseer suitable for use in a regulatory setting[4].

21. It is HortNZ's policy to work with Overseer to try and improve the accuracy of the N leaching figures produced by the tool. However, when councils seek to use Overseer as a tool to aid their legislative intentions in the horticulture sector I have some serious doubts about Overseer's ability to accurately predict the performance of the sector in terms of both N and P leaching.

22. In the report[5] which I wrote for HortNZ I identified a number of challenges related to modelling vegetable crops in Overseer which had a potential negative effect on our ability to accurately model the N leaching performance of the vegetable growing sector.

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[3] Hume et al 2015. MGM Technical Report Arable and Horticultural crop modelling. Report written by Plant and Food for ECan.

[4] https://www.pce.parliament.nz/media/196493/overseer-and-regulatory-oversight-final-report-web.pdf

[5] The AgriBusiness Group (2015): Nutrient Performance and Financial Analysis of Lower Waikato Horticulture Growers

23. In that report, TAG commented on a review of the use of Overseer in the arable and horticultural sector as follows:

> *The Foundation for Arable Research carried out an independent review of the use of Overseer in the arable sector, which incorporated consideration of the horticultural sector. It came up with the following conclusion:*
>
> > *Overseer is the best tool currently available for estimating N leaching losses from the root zone across the diversity and complexity of farming systems in New Zealand. This review sets out a pathway for improving its fitness for this purpose in the arable sector (see recommendations). It also highlights that the new challenges facing OVERSEER® place demands on the development team and model owners that need to be acknowledged and resourced appropriately."*

24. The Foundation for Arable Research (**FAR**) review came up with the following recommendations which are relevant to the horticultural sector. The first of which is:

> *Overseer crop model estimates of N leaching should be evaluated against measurements of N leaching to identify whether there are any systematic errors in predictions.*

25. We note that this has been the subject of new projects facilitated and led by HortNZ and FAR through the "Rootzone Reality" Programme establishing a national network of lysimeters. The work commenced in 2014 with the installation of sites. It will take at least 3-4 years to establish measurements that are useful. It will take additional time for the Overseer owners to incorporate the new information into modelling predictions.

26. The second recommendation was:

> > *Overseer crop model estimates of N leaching should be evaluated against predictions of long term leaching produced by established, detailed research models e.g. APSIM.*

27. HortNZ, FAR and the Fertiliser Association of New Zealand contracted Plant and Food Research to test Overseer results in comparison with Agricultural Productions Systems Simulator (APSIM). The project was started in early 2015 and delivered its final report[6] in early 2017.

28. The analysis identified that there were key places in the calculations where differences are occurring in the output of N leaching data in both the arable and horticultural rotations

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[6] Khaembah E, Brown H (2016): OVERSEER crop module testing – end of project report

which they ran through both models. It was the opinion of the authors that these differences were caused by inaccuracies in the way that Overseer was modelling both the arable and horticultural rotations.

29. The Plant and Food Research team recommended that it would be worthwhile to carry out further investigation into:

(a) Creating outputs of all the components of the water and nitrogen balances in Overseer and SCRUM-APSIM and key predictor variables to enable full comparison of the models.

(b) Further investigation into the Overseer hydrology model in order to identify what is causing it to over-estimate leaching rates and the possible methods of improvement; and

(c) A detailed comparison of the components of the N balance is needed in order to determine where improvement is required.

30. The third recommendation from the FAR review into Overseer was to:

> *The testing outlined in recommendations (1) and (2) is likely to identify and justify areas for further development of Overseer to improve N leaching predictions.*

31. As far as I am aware none of the three recommendations made in that report have been completed. This is at least partially due to the development of Overseer being limited by the expenditure of capital and partially due to the low priority put on the development of vegetable production capability by Overseer.

32. There still remains a high degree of uncertainty as to the results produced by Overseer in the CVP sector. I therefore support the recommendation that it is not appropriate for its use in PC7 in the CVP sector.

TYPICAL HORTICULTURAL ROTATIONS

33. The nature of CVP is that the crops that are grown are part of a rotation. This is a practice which is carried out for a number of reasons including:

(a) To spread the financial risk of growing just the one crop;

(b) To spread the risk of pests and diseases building up from the growing of the one crop; and

(c) Providing for restorative crops that are designed to bring the growing environment back into the desired state after a number of years of the growing of depletive crops.

34. This adoption of a rotation enables the growers to ensure that their systems are sustainable in the long term.

35. In our report "Overseer nutrient modelling of commercial vegetable production" at Section 3 we discuss our choice of the appropriate rotations that could be used to model the CVP sector. It should be noted that the purpose of our modeling was to establish a long term leaching profile for the CVP sector:

> *It was decided to use the crop rotations which represented the rotations used in the Canterbury Matrix of Good Management (MGM) process which best represented commercial vegetable growing. The following MGM Overseer files were obtained from ECan:*
>
> *a) Crop rotations with greater than 80% of intensive vegetables*
>
> *b) Crop rotation with greater than 10% of green vegetables*
>
> *c) Crop rotation with greater than 10% root vegetables.*
>
> *Because the MGM Overseer files represent a proportion of non-horticultural land uses, the make-up of the rotations was altered to be most representative of a commercial vegetable growing operation.*

36. The rotation scenarios which we created and modelled are outlined in the following sections.

Green Vegetables

37. Broccoli > Peas > Broccoli > Squash > Broccoli > Ryegrass > Onions > Ryegrass > Cauliflower > Peas

38. The green vegetable rotation represents the range of predominantly green vegetables that are grown above the ground and on a relatively large scale. This rotation is spread over six years and you can see that the depletive crops are mixed with the restorative crops (ryegrass and peas).

Root Vegetables

39. Onions > Potato > Ryegrass > Onions > Ryegrass > Carrots > Potato > Ryegrass

40. The root vegetable rotation represents the root vegetables that are grown below the ground which are interspersed with some crops that are grown above the ground. The restorative crop is ryegrass that you can see is grown in this rotation for three years out of the seven.

Intensive Vegetables

41. Cauliflower > Spinach > Onions > Broccoli > Squash > Spinach > Cabbage > Broccoli > Sweetcorn

42. The intensive vegetable rotation represents more of a "market garden" situation where crops are grown for fresh consumption and they are generally planted in small volumes with a number of differing planting dates for each crop class. Although this rotation is much more intensive, the fallow periods when the crop is planted in some form of restorative crop is very prevalent.

Intensive Vegetable with Fallow

43. Fallow > Cauliflower > Fallow > Spinach > Fallow > Onions > Fallow > Broccoli > Fallow > Squash > Fallow > Spinach > Fallow > Cabbage > Fallow > Broccoli > Fallow > Sweetcorn > Fallow.

44. The root vegetable rotation is the dominant rotation taking up 8,995 ha or 79% of the total CVP area while the Green Vegetable area at 1,275 ha is 11% of the total and the Intensive Vegetable rotation at 1,141 ha is 10% of the total area.

45. While the intensive vegetable and intensive vegetable with fallow rotations demonstrate the average rotations there are a myriad of alternative rotations that are used. This is because within the constraints of the requirements to rest land from particular crops in order to avoid the build-up of pests and diseases and to have the correct balance between depletive and restorative crops, the main factor which determines the crop mix to be planted is demand for the crop from the market. This demand is normally created and signalled at market.

Crop types

46. Within the crops included in the green vegetable and intensive market garden rotations there is a very high degree of substitutability between the range of crops available. The decision is made on the market signals as to which is the best mix of crops for the grower to plant within that year and even within the season. Subsequently, there is considerable range in the crop mix grown in any one season and therefore, potentially, the amount of N leached from the farm in that one year. Other factors such as the severity of rainfall will be bigger determinants of the amount of N leached in any one single year.

47. The actual crop mix which a CVP grower will plant in the ground is driven by a complicated mix of drivers. This is partly the reason for the relatively large area of leased land used in the CVP sector because the opportunity for a grower to grow on "new" ground opens up the opportunity for them to grow a much wider range of crops and so react to the market signals as to the best crop mix to grow.

48. In the case of the leased land, which is quite predominant in Canterbury, the period of the leases are relatively short term and in the case of potatoes it is only for one to two years and then the land is returned to its former land use.

49. Many of the arable rotations in Canterbury also have an element of CVP in them with crops such as potatoes, onions and carrots interspersed with the more traditional arable crops of seed and grain crops (arable farming operations).

LEACHING IMPACTS OF TYPICAL ROTATIONS.

50. Despite the inaccuracies that are experienced with the use of Overseer to model CVP crops, it is currently the only way that we can model them to determine the relative amounts of N and P from a range of land uses.

51. The amount of N leached from a farming system is affected by the amount of N introduced to the system which is not able to be used by the plants and is leached through the soil profile. However, this is in itself greatly affected by the soil type and the climatic zone that it is grown in.

52. The majority of CVP grown in Canterbury is grown on deep soils that have a relatively high Plant Available Water (**PAW**) which means that they can store, and therefore not leach,

large volumes of water. These soils are all in the Land Use Class (**LUC**) 1 and 2.

53. The climatic zone also has a significant impact on the amount of N leaching from a soil type because the amount of rainfall and evapotranspiration influences the impact of irrigation in causing leaching of nutrients.

54. In our ECan report we modelled a range of soil types and climatic zones for the same rotation. The soil types were called S2 which represented a PAW of 90-120 and S3 which represented a PAW of 120+. The climatic zones modelled represented a coastal climate (C1) with 656 mm rainfall per year, a mid plains climate (C2) which represented a 554 mm rainfall per year and an upper plains climate (C3) which represented a 714 mm rainfall per year climate.

55. The impact of these two factors is shown in **Table 1** which reports the impacts of the variables of soil type and climate on the N leaching performance of the four rotations. One should note that for each of the four rotations exactly the same rotation has been used in all cases, the only variable factors are the soil type and climate.

Table 1: N leaching results of the variables of soil type and climate on the N leaching performance of the four rotations.

Soil and climate combination	Green	Root	Intensive	Intensive Fallow
C1 S2	62	46	56	66
C1 S3	46	34	42	53
C2 S2	42	36	43	55
C2 S3	36	29	33	40
C3 S2	63	52	58	73
C3 S3	50	39	48	57

56. **Table 1** shows that while individual crops have the potential for high leaching rates (due to the requirement for relatively high amounts of N at planting when the plants root system is relatively immature), when considered over the total rotation the CVP sector has N leaching rates which are very comparable with other land uses (arable, dairy farming and dairy support) when they are compared on the same soil type and climate zone.

57. It is my opinion that the CVP sector does warrant special treatment to be able to rotate freely across the land that it is

suitable to grow in. However, the CVP sector doesn't warrant the restrictions placed on it by the PC7 which restrict the area that it can be grown on to the existing footprint.

58. It is my understanding that HortNZ seeks a viable pathway for existing production and a small area of expansion for the intensive rotations (Green and Intensive Rotations) because they are important for domestic food supply.

59. It is also my understanding that it seeks a flexible pathway for the extensive rotations that enables them to expand, because they have similar impacts to other farming, but have the need to rotate.

60. In my opinion the scale of the intensive rotations is so small that granting that viable pathway will have no discernible impact on the water quality in any of the nitrogen allocation zones and that the N leaching from the extensive rotations is very similar to the other possible land uses and therefore will have no different an impact on water quality than those other land uses.

THE AREA OF CVP GROWN AND THE IMPACT ON NITROGEN LEACHING

61. In our report to ECan we estimated that the area used for growing CVP crops is approximately 12,275 ha. We also note that this area has remained static from about 2013. There is no doubt that the mix of crops which make up this total will have varied greatly during that time.

62. The location of where they have been grown will have changed dramatically during that time with changes in both the climatic zone and on the soil type on which they are grown. You can see from **Table 1** that this change in location and soil type can have a very large difference in the amount of N leached from the various locations. All the combinations of climatic zone and soil type are present in the three major growing areas in Canterbury.

63. The process vegetable crops which make up the Root Vegetable rotation, like peas, carrots, potatoes and onions, are largely grown for further processing and then export. They can be quite successfully grown as part of more extensive rotations which have a much lower annual N leaching result and as can be seen by reference to Mr Nation's Table 2[7] have

[7] Evidence of Tom Nation, dated 17 July 2020, Appendix 3.

considerable potential to be grown in some existing arable and pastoral rotations within the same N leaching parameters as the land use that they are grown on. This means that under PC7 there is potential for them to expand their growing area.

EXPANSION OF VEGETABLE GROWING FOR DOMESTIC SUPPLY

64. The greens and intensive vegetable rotations grow a wide range of crops predominately for domestic supply. These rotations are more intensive in that the turnover of crops is higher and are therefore higher leaching. These crops also do not have the required opportunity to expand through grandparenting of their existing footprint or to replace another land use with a similar leaching number.

65. I note that Mr Nation has calculated that for a N load increase per sub catchment of 0.5% and 1%.[8] In my opinion both of these estimates are well within the natural variability which occurs in these estimates: that the total area of expansion for the Green Vegetable rotation would be approximately 8,500 ha and 16,900 ha respectively and for the Intensive Vegetable rotation would be approximately 10,200 ha and 20,400 ha respectively.

66. These figures show that the scale of the CVP industry on the Canterbury landscape is small and therefore the impact of it is equally miniscule. Therefore, it is not justifiable to limit its footprint as is proposed in PC7. The expansion in area as proposed by HortNZ to keep up with population growth, which at 1,000 ha is a tiny proportion of the total area, is justified particularly when it is considered in the light of providing for an essential New Zealand food supply.

THE COSTS OF EXPANSION OF CVP FOR DOMESTIC SUPPLY INTO ANOTHER LAND USE

67. There is theoretically the potential for a CVP grower of green or intensive vegetables to expand their area through the purchase of an area of land which is in another land use and offsetting the amount of N leached by either;

    (a) De-intensifying the productive system;

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[8] Evidence of Tom Nation, dated 17 July 2020, Appendix 3.

(b) An enterprise offset whereby additional productive land is purchased, and it is converted to low leaching land use; and / or

(c) An on-farm offset whereby an existing high leaching land use activity is replaced with CVP production.

68. Deintensification is modelled as the new CVP producer buying an existing dairy farm and operating it at its existing leaching value which means that there is a much higher proportion of a low leaching crop, eg: barley, grown on it.

69. The enterprise example models a new CVP producer buying an existing dairy farm and planting as much of it as is required in Forestry to ensure that the N leaching value is the same as the existing use.

70. The on-farm offset models a new CVP producer leasing land off a dairy farmer (the feed cropping block) and the dairy farmer winter grazing their cows elsewhere and the loss of some milksolids production.

71. This is the approach that would have to be taken for expansion of intensive and greens rotations to meet the requirements of the proposed discretionary pathway.

72. The result of each of these options are reported as the additional area required per ha of CVP area, the additional revenue required per ha to maintain existing gross margin and the percentage change in average crop revenue to maintain the existing gross margin. These are all reported in **Table 2**.

Table 2: The cost of maintaining the current CVP gross margin in various offset scenarios-Canterbury.

	Deintensification	Enterprise	On farm
Additional area required per ha of CVP area.	0.54	0.38	-
Additional revenue to maintain existing gross margin.	4,009	3,646	5,886
Change in average crop revenue to maintain the existing gross margin.	20%	19%	30%

73. **Table 2** shows the additional revenue required to maintain the existing gross margin ranges between approximately $3,600 and $5,900 or between 19% and 30%. These are all increases which for most of the crops grown would more than double

the average cost of the vegetables for the consumers. The majority of vegetables have very definite price points where the price exceeds the consumers' willingness to pay and so they substitute that purchase for an alternative item.

74. In short, at the current price of land the option for a CVP producer to expand onto land which is currently in an alternative land use is very unlikely.

75. PC7 effectively prohibits the expansion of intensive or green rotations if they can't offset, and therefore unless the additional 1,000 ha proposed by HortNZ is provided for, the supply of a range of vegetables for domestic supply will not keep up with projected population growth, and the price of vegetables will likely increase.

EXPANSION OF VEGETABLES FOR EXPORT

76. The process vegetable crops which make up the Root Vegetable rotation, like peas, carrots, potatoes and onions, are largely grown for further processing and then export. They can be quite successfully grown as part of more extensive rotations which have a much lower annual N leaching result and, as can be seen by reference to Mr Nation's Table 2,[9] have considerable potential to be grown in some existing arable and pastoral rotations within the same N leaching parameters as the land use that they are grown on.

77. Mr Nation estimates that this means that under PC7 there is potential for approximately 9,115 ha of root vegetable rotation expansion with minimal water quality impact. This expansion would be able to be consented without the need for offsetting.

THE RANGE OF POSSIBLE LEACHING REDUCTIONS AT GOOD MANAGEMENT PRACTICE AND BEST MANAGEMENT PRACTICE.

78. As I understand it PC7 is designed to accommodate the constraints in growing CVP crops while at the same time improving or maintaining water quality. For the Selwyn-Waihora, Hinds and the Waimakariri zones, that is to achieve reductions above Good Management Practice (**GMP**), for the remainder of the zone it is to farm at GMP. This is to be achieved by adherence to the provision of Farm Environment

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[9] Evidence of Tom Nation, dated 17 July 2020, Appendix 3.

Plans (**FEP**) which exclude the provision for a nutrient management plan.

79. The horticulture sector has done a considerable amount of work around both Good and Best Management Practices which resulted in the publication of the document "Code of Practice for Nutrient Management August 2014". A copy is attached as **Appendix B.**

80. The code is based on a risk assessment approach which is based on assessing the risks and identifying and implementing appropriate management practices which are designed to address those risks. The management practices are based on the different stages of the crop cycle.

81. As can be seen from the information provided in Appendix B the GMPs which the document lists are a far more stringent set of practices than those currently relied upon across Canterbury. The best management practices which it also lists are, in my experience, very widely adopted across the CVP sector. In other words, it is my considered opinion that the CVP sector across Canterbury are already performing, in terms of both N and P loss, at levels which far exceed our expectations of them under other arable and pastoral land uses.

THE USE OF FARM ENVIRONMENT PLANS

82. TAG have four staff that are certified as FEP auditors. This means that they have reached a high standard of performance in both compiling and auditing FEP's. Annually we carry out approximately 350 FEP audits, the majority of these are carried out for the large irrigation schemes across Canterbury. We have been carrying out this exercise ever since the first FEP's were written for the Morven Glenavy Irrigation Scheme over ten years ago.

83. It is our experience FEPs have been embraced by the majority of growers and farmers who are now almost competitively trying to improve their grading or maintain their grade at the highest A level.

84. From an ECan perspective, the audit system is constantly improving in its ability to assist the farmers to achieve the required water quality standards. The requirements of the auditing as set by ECan is constantly getting more comprehensive and the audit standards are constantly expanding.

85. It is my opinion that the operation of FEP's alone will provide a very real improvement in water quality metrics across the CVP sector in Canterbury.

THE IMPACT OF LOW ENVIRONMENTAL INTENSITY HORTICULTURE.

86. Low intensity horticulture is not land uses that are not intensive in their land use, it is more a reflection that they have a low environmental footprint. This is generally because they are very low in the amount of synthetic N which is introduced to their system on a per ha basis and that they generally use more direct application of irrigation to the plants root system. Therefore the amount of N in the soil is very low and the amount of irrigation applied is low and so the chances of what N is available to be leached through is also very low.

87. I would refer you to the evidence of Ms McClung and the case study of Peelview orchard to verify my contention.[10]

88. In **Table 33** I list the horticultural areas of the Canterbury Region as listed in the Fresh Facts[11] document. These crops make up the low environmental crops.

Table 3: Areas of horticultural crops grown in Canterbury (2019).

Crop	Area (ha)
Apples	312
Wine Grapes	1,769
Summerfruit	81
Berryfruit	1,103
Nuts	478
Olives	133
Other subtropical	17
Other fruit	67
Total	3,960

[10] Evidence of Rachel McClung, dated 17 July 2020, Appendix 5.

[11] Plant and Food 2019: Fresh Facts New Zealand Horticulture.

89. It is my opinion that the total area of these crops in the Canterbury region is an incredibly small proportion of the total area and the amount of N leaching is also an incredibly small proportion of the total N leaching from the area.

90. It is my opinion that they are better served as a permitted activity.

91. I do however note the opinion of Mr Hodgson for HortNZ that this is part of HortNZ's policy from a national perspective and that in his opinion the section 42A report is correct that this activity is sufficiently managed within the existing planning framework.[12]

AN ASSESSMENT OF THE REQUIREMENT FOR ROOT STOCK PROTECTION WATER.

92. What HortNZ are proposing is that allowance should be made for the provision of sufficient water to maintain root stock during prolonged periods of drought. I refer you to Ms McClungs evidence. HortNZ have successfully advocated for provision of horticultural protection water in other constituencies throughout the country and the local authorities have recognised the potential for economic harm from not providing for it. HortNZ is not proposing that sufficient water is made available to maintain the productive capacity of the plants, just that sufficient water is made available to keep the plants alive.

93. In this respect it is exactly the same as the provision of livestock drinking water which is designed to keep the animals alive. What HortNZ is proposing is that the same facility is provided for the horticultural producers in that they can retain the core of their businesses, their rootstock.

94. This is primarily because the loss of the plants would mean that the growers and the wider economy would have to survive for a prolonged period of time before the land can come back into full production and be able to provide a positive financial return.

95. It is my opinion that livestock can either have sufficient drinking water shipped into them at their present location or the stock can be moved out to a reliable source of drinking water. In the case of the crops that rely on their rootstock to

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[12] Evidence of Vance Hodgson, dated 17 July 2020, Para 99

maintain their production neither of these alternatives is open to them.

96. The majority of the crops which would take advantage of this root stock protection water have a higher economic output than the vast majority of livestock land uses.

97. I believe that there is a sound economic argument to allow for the provision of root stock protection water.

98. I note that in his evidence for HortNZ Mr Hodgson is of the opinion that a method to include the provision of root stock protection water needs consideration in a future plan review.[13]

CONCLUSIONS AND RECOMENDATIONS

99. I would agree with the Section 32 report where it seeks to adopt a cap on the land area rather than the specific amount of N leached from a property because of "the difficulties with modelling losses from complicated vegetable production rotations in Overseer".

100. It is my opinion that the CVP sector does warrant special treatment as to be able to rotate freely across the land that it is suitable to grow in but doesn't warrant the restrictions placed on it by the proposed PC7 which restrict the area that it can be grown on to the existing footprint.

101. The root vegetable rotations could expand significantly with a neutral impact on water quality. The ability to rotate freely across land is essential to enabling these rotations to expand.

102. In my opinion the scale of the intensive rotations is so small that granting that viable pathway that is sought by HortNZ will have no discernible impact on the water quality in any of the nitrogen allocation zones and that the N leaching from the extensive rotations is very similar to the other possible land uses and therefore will have no different an impact on water quality than those other land uses therefore it shouldn't be restricted.

103. The scale of the CVP industry on the Canterbury landscape is so small and the impact of it is equally miniscule that it is not justifiable to limit its footprint as is proposed in PC7. The

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[13] Evidence of Vance Hodgson, dated 17 July 2020, Para 103

expansion in area as proposed by HortNZ, not subject to the nitrogen baseline, to keep up with population growth, which at 1,000 ha is a tiny proportion of the total area, is justified, particularly when it is considered in the light of providing for an essential New Zealand food supply.

104. At the current price of land the option for a CVP producer to expand onto land which is currently in an alternative land use is very unlikely. PC7 effectively prohibits the expansion of intensive or green rotations if they can't offset, and therefore unless the additional 1,000 ha proposed by HortNZ is provided for, the supply of range of vegetables for domestic supply will not keep up with projected population growth, and the price of vegetables will likely increase.

105. It is my considered opinion that the CVP sector across Canterbury are already performing, in terms of both N and P loss, at levels which far exceed our expectations of them under other arable and pastoral land uses and that the operation of FEP's alone will provide a very real improvement in water quality metrics across the CVP sector in Canterbury.

Stuart John Ford

17 July 2020

APPENDIX A - OVERSEER NUTRIENT MODELLING OF COMMERCIAL VEGETABLE PRODUCTION

“Achieving Outcomes by Building Capability”

The AgriBusiness Group™

Overseer nutrient modelling of commercial vegetable production.

Prepared for Environment Canterbury

Prepared by The AgriBusiness Group

February 2019

Contents

Please Read

Executive Summary

Background

Environment Canterbury (ECan) have requested that The AgriBusiness Group (TAG) provide advice on the application of Overseer nutrient modelling for commercial vegetable growing operations in Canterbury.

A common aspect of commercial vegetable operations is complicated rotational operations and some of the land utilised being held in both short term and long term lease hold agreements. The Canterbury Land and Water Regional Plan (LWRP) assigns nitrogen loss rates to land, resulting in commercial vegetable producers finding it difficult to access land with sufficient nitrogen allocation. This is mainly because the majority of land taken up in lease hold agreements has a nutrient allocation which is lower than the nutrients leached (predominantly N) under vegetable production.

The objective of this work was to calculate the total amount of nitrogen leached in each nutrient allocation zone by commercial vegetable growing operations across Canterbury.

Methodolgy

This report details the methodology used for the following tasks:

- Analyse existing Overseer files of a range of commercial vegetable growing properties in Canterbury.

- Create representative crop rotation scenarios which depict a range of standard rotations used in Canterbury in the commercial vegetable production sector in Overseer based on representative files and the Matrix of Good Management (MGM) files, which were developed by ECan, to represent the range of Overseer files found throughout Canterbury.

- Alter these scenarios to account for various soil and climatic effects within the Canterbury region.

- Calculate the current nitrogen losses for commercial vegetable operations for each LWRP sub-region catchment in Canterbury.

Results

- Although the methodology used to gain the total nitrogen leaching in the individual NAZ's required a degree of estimation as to the allocation of the areas by soil type and climate zone the authors believe that the methodology used to make those estimations means that the results are sufficiently robust to be used in decision making.

- Three of the LWRP sub-regional catchments have total nitrogen leaching results which exceed 20 tons per year. They are Ashburton (236 t), Selwyn (153 t) and the OTOP sub-region (64 t).

- These three sub-regional catchments account for 86 % of the total nitrogen leaching results for the Canterbury region with Ashburton being the highest with 45%, Selwyn the next at 29% and OTOP next at 12%.

- The two factors of soil type and climate have a big influence on the amount of nitrogen leached by any crop or rotation in any location.

- The Christchurch-West Melton sub-regional zone has the highest average nitrogen leaching at 61 kg N / ha / year. There is significant variation between the locations in terms of the average nitrogen leaching results which is dependent on the soil type and climatic factors and also what the rotation mix is in each sub-region.

- For the three highest total nitrogen leaching sub-regional catchments the average nitrogen leaching results vary from 50 kg N / ha / year in Ashburton to 42 kg N / ha / year in Selwyn to 39 kg N / ha / year in OTOP.

1 Introduction

Environment Canterbury (ECan) have requested that The AgriBusiness Group (TAG) provide advice on the application of Overseer[1] nutrient modelling for commercial vegetable growing operations in Canterbury.

The objective of this work was to:

Calculate the total amount of nitrogen leached in each nutrient allocation zone by commercial vegetable growing operations across Canterbury.

A common aspect of commercial vegetable operations is complicated rotational operations and some land utilised being held in both short term and long term lease hold agreements. The Canterbury Land and Water Regional Plan (LWRP) assigns nitrogen loss rates to land, resulting in commercial vegetable producers finding it difficult to access land with sufficient nitrogen allocation. This is mainly because the majority of land taken up in lease hold agreements has a nutrient allocation which is lower than the nutrients leached (predominantly N) under vegetable production. Therefore they find it difficult to access sufficient lease land which also has sufficient nutrient allocation which would allow them to grow the full range of crops required.

This report covers the methodology used and the results of the following tasks:

- Analyse existing Overseer files of a range of commercial vegetable growing properties in Canterbury. It was envisaged that those files would be contributed by the members of a working group which ECan called together for this project and some nine properties which HortNZ used to estimate the range of leaching of N in Canterbury.

- Create representative crop rotation scenarios which depict a range of standard rotations used in Canterbury in the commercial vegetable production sector in Overseer based on representative files and the Matrix of Good Management (MGM) files which were developed by ECan to represent the range of Overseer files found throughout Canterbury.

- Alter these scenarios to account for various soil and climatic effects within the Canterbury region.

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[1] A farm is a complex living system; made up of soil, plants, water and often animals – which all contain nutrients. The dynamic nature of a farm adds to the complexity of modelling nutrient flows, because different farming practices and preferences affect how nutrients cycle around the farm. To create a farm analysis, Overseer captures information about how a farm is run and models it through a series of complex sub-models that mimic the known bio-physical processes operating across a farm system. This allows Overseer to analyse the flow of nutrients through the farm and produce nutrient budgets for seven key farm nutrients and greenhouse gas footprint reports. The seven major farm nutrients include nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) and sodium (Na) – as well as acidity for pastoral blocks.

There is a full technical description of how Overseer works at: www.overseer.org.nz

- Calculate the current nitrogen losses for commercial vegetable operations for each LWRP sub-region catchment in Canterbury.

2 Analysis of Overseer files of commercial vegetable growers

2.1 Methodology

The methodology used to determine the total volume of N leaching in each NAZ consisted of first constructing three crop rotation[2] scenarios in Overseer Version 6.3.0 by reference to a wide range of Overseer inputs. These crop rotations have been developed from a number of sources including industry knowledge of the Horticultural sector and the considerable amount of work which went into the MGM project which identified 10 different farming types which were representative of farming systems across Canterbury. Although there is no statistical justification for their selection we are very confident that they are a fair representation of the types of system in place in Canterbury that can be used in this level of analysis.

2.2 The Process of the Analysis

Members of a horticultural operations working group (set up by ECan) were asked to supply their existing Overseer files. The response from the working group was not sufficient for us to establish the range of operations across the commercial vegetable growing sector in Canterbury. This was partially because most of the growers did not have Overseer files for their properties.

HortNZ then supplied TAG with a complete list of their Canterbury members which also listed the main crops which they grew. TAG went through this list and identified approximately twenty growers based on their knowledge of the growers' operations that represented the major commercial vegetable rotations (Root crops, Green vegetables and Market Garden), and also represented the range of soil drainage types, climatic conditions and geographical locations in Canterbury.

These twenty people were contacted and we requested that they share their Overseer files with us. We received nine Overseer files from four of these growers. A number of the growers that are involved in the commercial vegetable growing sector have multiple properties which all require individual Overseer files to be calculated on them.

HortNZ carried out a survey of nine Horticultural growers in 2015 and as part of that survey sufficient information on the nature and detail of their commercial vegetable growing was gathered to carry out Overseer modeling on them. This modeling was carried out by Plant and Food and TAG have the .xml files from that exercise. This data was also included in this analysis.

The following data was extracted from the nineteen Overseer files which we had access to for every crop that was grown. This data was the information which is required to be able to model the rotation in Overseer which is basically the individual crop management including such things as crop timing, fertiliser inputs and irrigation management:

- Crop rotation
- Crop type
- Sowing date

[2] A crop rotation is a description of the full range of crops which are grown in a rotation over the life of the rotation.

- Cultivation method
- Harvest date
- Yield (tonnes per hectare)
- Residual treatment[3]
- Fertiliser type, rate of application, date of application and the Nitrogen (N), Phosphorus (P) and Potassium (K) and content of each application.
- Irrigation type, amount, return period, trigger level when irrigation is started and target which represents the target level of soil moisture holding capacity which the irrigation system is designed to meet for each month of the irrigation season.

2.3 Results of the data gathering from the Overseer files.

Data which was extracted from the Overseer files was collected on the following commercial vegetable crops, the restorative[4] crops which are part of the rotation, and the crops[5] which are grown during the winter to avoid N leaching:

- Annual ryegrass
- Beans
- Cabbage
- Broccoli
- Cauliflower
- Carrots
- Forage Oats
- Onions
- Peas
- Potato
- Pumpkin
- Spinach
- Squash
- Sweet corn.

For some of these crops such as the market garden crops only one example was received. For other crops there were multiple examples which represented the range of alternative sowing dates and yields that are used by commercial vegetable growers across Canterbury as many of the crops are sown at different times of the year, their management and inputs and the ultimate yields are different according to when they are sown. TAG is comfortable that the range of information gained from the Overseer files received was sufficient to carry out the modelling and analysis required to fairly represent the range of alternative grower examples.

[3] Residual treatment refers to the manner in which the residual material which is left in a paddock after the crop is harvested is treated. Options include working it back into the soil, grazing or bailing it and removal.
[4] Restorative crops are crops which restore the texture and the fertility of the soil. They include white clover and ryegrass seed crops.
[5] Crops which are grown during the winter in order to avoid N leaching include lupins,oats and short term ryegrass.

2.3.1 Fertiliser Inputs Gathered

This data was then analysed to get the average fertiliser inputs (kg/ha) for each crop. These are shown in Table 1. In Table 1 the first column lists the crop grown, the second column represents the month that the fertiliser is applied, the next column "fertiliser type" reports the brand name of the fertiliser, the next column represents the rate that the fertiliser is applied at and the next four columns report the kilograms of each element (N = Nitrogen, P = Phosphorus, K = Potassium and S = Sulphur) applied per application.

Table 1. Average fertiliser inputs for individual crops.

Crop	Month ***	Fertiliser type	Rate (kg/ha)	N (kg)	P (kg)	K (kg)	S (kg)
Broccoli	Mar	Potash Gold	375	26	58	47	23
	May	CAN*	150	40	-	-	-
	Aug	Urea	175	80	-	-	-
Peas	Sept/Oct	DAP **	100	18	20	-	1
		Muriate of Potash	100	-	-	50	-
Squash	Oct	YaraMila	350	43	18	15	28
	Dec	Urea	80	37			
Onions	Jun	DAP	200	35	40	-	2
	Jun	Sulphur Gain	30	-	-	-	27
	Sep	YaraMila Complex	375	46	20	56	30
	Oct	DAP	125	22	25	-	1
	Dec	YaraMila Complex	90	11	5	14	7
Cauliflower	Jan	YaraMila Complex	375	46	20	56	30
	Feb	YaraMila Complex	150	19	8	22	12
	Mar	YaraMila Complex	150	19	8	22	12
	Apr	YaraMila Complex	150	19	8	22	12
Potato	Oct	DAP	350	62	70	-	4
	Oct	Kieserite	75	-	-	-	12
	Nov	DAP	140	25	28	-	1
	Nov	Kieserite	60	-	-	-	10
	Nov	Muriate of Potash	80	-	-	40	-
	Dec	Urea	200	92	-	-	-
Carrots	Oct	YaraMila Comple	250	31	13	38	20
	Dec	CAN	125	34	-	-	-
Spinach	Jan + Apr	Cropmaster Brassica	550	78	88	55	4
	Jan + Apr	Kieserite	100	-	-	-	20
Cabbage	Sep	Cropmaster Brassica	550	78	88	55	4
	Oct	YaraMila Complex	150	19	8	22	12
	Nov	YaraMila Complex	150	19	8	22	12
	Dec	YaraMila Complex	150	19	8	22	12
Sweetcorn	Oct	Cropmaster Brassica	550	78	88	55	4
	Oct	Urea	50	23	-	-	-
	Dec	YaraMila Complex	200	25	10	30	16

*CAN = calcium ammonium nitrate.

**DAP = di-ammonium nitrate.

*** in some months there are multiple applications of fertiliser of different types.

2.3.2 Irrigation Inputs Gathered.

The Overseer files were also analysed to obtain data for typical irrigation inputs used by commercial vegetable growers including the irrigation application system, irrigation amount and return period, and the trigger and target irrigation application rates for each month of the irrigation season. There was considerable variability in the irrigation inputs used across the various Overseer growers files, some which exceeded Good Management Practices[6] (GMP) and some which did not meet the GMP standards.

Because this exercise is designed to reflect GMP the growers' Overseer data for irrigation was not used. Therefore, irrigation is modelled as the following input options which are entered into Overseer:

- Soil Moisture sensors: the soil moisture probes option was chosen,
- Trigger point and depth applied to achieve target was chosen and,
- The Overseer default was chosen to determine the management systems.

The result of the choices made in electing the irrigation information into Overseer is that the irrigation modelling meets the GMP standards.

3 Commercial vegetable crop rotation scenarios

3.1 Methodology

The Overseer files supplied by the growers were examined to determine whether they represented a standard rotation for root vegetables and green vegetables production types. Each of these types represent a standard rotation used in the commercial vegetable growing sector in Canterbury. It should be noted there were no market garden (the third representative production type) Overseer files available, however two Canterbury growers were interviewed to ascertain their practices and a standard rotation.

It was very difficult to ascertain an appropriate representative commercial vegetable crop rotation from the growers' rotations for a number of reasons, in particular because operations were integrated with a myriad of other non-vegetable land uses. Therefore, it was decided to use the crop rotations which represented the rotations used in the Canterbury Matrix of Good Management (MGM) process which best represented commercial vegetable growing. The following MGM Overseer files were obtained from ECan:

- Crop rotations with greater than 80% of intensive vegetables
- Crop rotation with greater than 10% of green vegetables
- Crop rotation with greater than 10% root vegetables.

Because the MGM Overseer files represent a proportion of non-horticultural land uses, the make-up of the rotations was altered to be most representative of a commercial vegetable growing operation and to only include the data from the crops which we collected from the Overseer files.

[6] GMP refers to the practices described in the document entitled "Industry-agreed Good Management Practices relating to water quality" which represent the standards of operation that famers have to comply with.

The crop practices which we collected were then substituted into the MGM rotations to more accurately reflect the GMP practices which are being undertaken in the vegetable growing sector.

3.2 Crop rotation scenarios

The scenarios which we created are:

Green Vegetables

Broccoli > Peas > Broccoli > Squash > Broccoli > Ryegrass > Onions > Ryegrass > Cauliflower > Peas

The green vegetable rotation represents the range of predominantly green vegetables that are grown above the ground that are grown on a relatively large scale.

Root Vegetables

Onions > Potato > Ryegrass > Onions > Ryegrass > Carrots > Potato > Ryegrass

The root vegetable rotation represents the root vegetables that are grown below the ground which are interspersed with some crops that are grown above the ground.

Intensive Vegetables

Cauliflower > Spinach > Onions > Broccoli > Squash > Spinach > Cabbage > Broccoli > Sweetcorn

Intensive Vegetable with Fallow

Fallow > Cauliflower > Fallow > Spinach > Fallow > Onions > Fallow > Broccoli > Fallow > Squash > Fallow > Spinach > Fallow > Cabbage > Fallow > Broccoli > Fallow > Sweetcorn > Fallow.

The intensive vegetable rotation represents more of a “market garden” situation where crops are grown for fresh consumption and they are generally planted in small volumes with a number of differing planting dates for each crop class.

A more detailed depiction of each crop with its planting date at the start and the harvest date at the end and the way that they make up the land use of the area for the total period of the rotation is in Appendix 1.

The three modelled rotations were shared with the working group and the growers who contributed their Overseer files, in order to seek feedback on the typical crop rotations and Overseer inputs. The feedback identified a requirement to include a fallow period[7] within the intensive vegetable model. Therefore, a second intensive vegetable model was created (‘Intensive Vegetable with added fallow’) following the same crop rotation with fallow periods following each crop and a rotation having fallow over the winter months.

After discussion with representatives from within the Horticulture industry who were on the working group it was determined that the area under Intensive Vegetable in each NAZ was to be split 50/50 between the original model (Intensive Vegetable) and the model with added fallow periods (Intensive Vegetable with Fallow).

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[7] A fallow period is a period between crops when the land is not producing anything.

3.2.1 Overseer nitrogen losses for the crop rotations

The nitrogen losses derived from each of the rotations chosen are as shown in Table 2.

Table 2: Nitrogen losses for each of the rotations modelled.

Crop Rotation	N loss (kg / ha / year)
Green Vegetables	52
Root Vegetables	39
Intensive Vegetables	43
Intensive Vegetables with Fallow	55

4 Overseer files adjusted for soil type and climate

4.1 Methodology

The Overseer files were then modelled to reflect the range of soil types and climatic variables across commercial horticulture land use areas in Canterbury. This activity was informed by reference to a map generated from a HortNZ grower survey undertaken in 2018, which located each of their growers by crop type throughout the Canterbury region by their main address, as shown in Figure 1. It should be noted that the growers may lease land in different areas to the location of their main address.

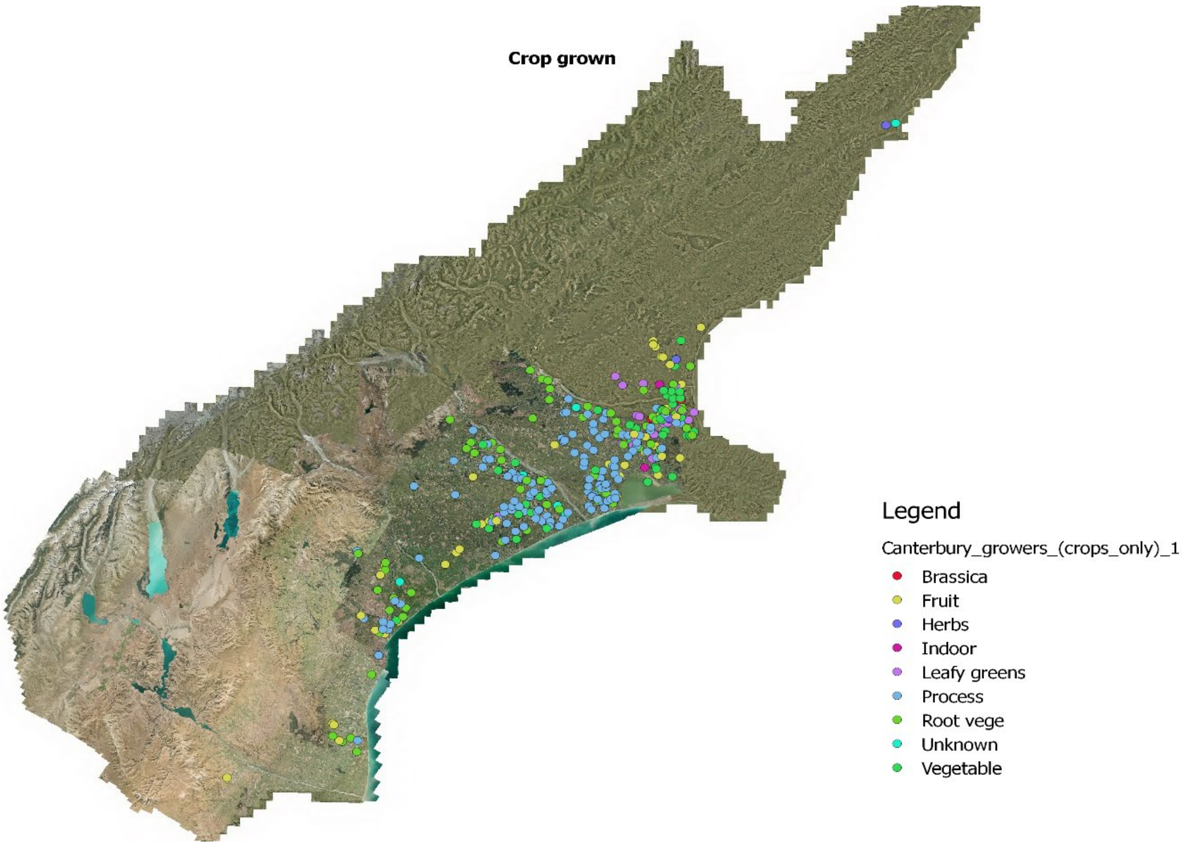

Figure 1. Location of horticultural growers represented by HortNZ in Canterbury.

In Figure 2 the map represents the prime land use for each of the growers surveyed by nutrient allocation zone.

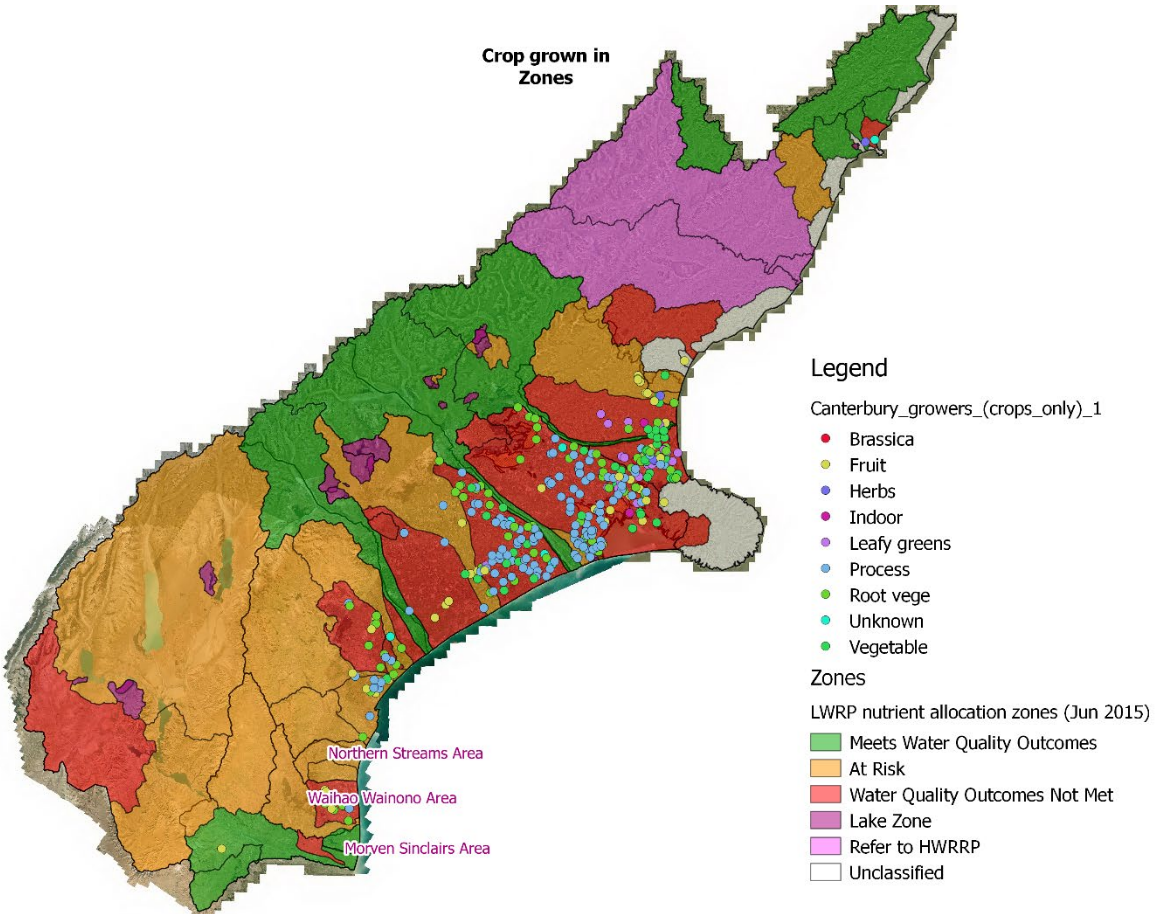

Figure 2. Location of Canterbury growers in nutrient allocation zones

It should be noted that Figure 2 lists a range of crops that are grown in Canterbury. In this exercise we only took account of the 'leafy greens', 'process', 'root vege', 'unknown' and 'vegetable'.

From reference to this map (within GIS) and the soils data available in the Overseer files, we chose the parameters to best represent the range of soil type and climatic variability within the growing area (as shown in **Table 3** and **Table 4**).

The choice of the parameters that were used in describing each of the climate zones that were modelled in Overseer are shown in **Table 3**. The rainfall, temperature and evapotranspiration factors were each calculated by the Overseer tool by nominating a location. The position relative to State Highway 1 (SH1) reflects whether the operation is East or West of SH1.

Table 3: Climatic factors and location used in the Overseer modeling.

Climate Zone Name	Rainfall (mm / year)	Temperature (%)	Evapotranspiration (mm / year)	SH 1
1	656	11.7	888	East
2	554	10.7	752	West
3	714	11.5	879	West

The information used in the choice of the soil types that were modelled were taken from observation of the Landcare soil maps (SMap). They were chosen to represent the range of Plant Available Water (PAW) regimes on which the commercial vegetable crops are grown across Canterbury. The soil descriptions chosen for this exercise are shown in **Table 4**.

Table 4: Soil descriptions used in the Overseer modeling.

Soils	Soil Name	SMap Description	PAW Representative Range (mm)
1	Lismore	Lism_1a.1	60-90
2	Templeton	Temp_2a.1	90-120
3	Waterton	Long_3a.1	+120

4.2 Results

Each of the modelled crop rotations has been modelled in Overseer by each of the climatic zones (C) by each of the soil types (S). This has meant that 36 individual models have been created to reflect the range of these soil and climate variables that commercial vegetables are grown in across Canterbury. The results of this combination of models which was used in the next section of the report are shown in

Table 5,**Table 6** , **Table 7** and

Table 8. The first column of each table specifies the climate (C) and the Soil (S) parameters which were modelled and in the second column it reports the results of the modelling for that combination of parameters as the annual amount of nitrogen leached as Kg N per hectare per year.

Table 5: 'Green Vegetable' rotation soil/climate combinations and nitrogen leaching results.

Soil and climate combination	Kg N / ha / year
C1 S1	71
C1 S2	62
C1 S3	46
C2 S1	49
C2 S2	42
C2 S3	36
C3 S1	74
C3 S2	63
C3 S3	50

Table 6: ‘Root Vegetable’ rotation soil/climate combinations and nitrogen leaching results.

Soil and climate combination	Kg N / ha / year
C1 S1	54
C1 S2	46
C1 S3	34
C2 S1	40
C2 S2	36
C2 S3	29
C3 S1	58
C3 S2	52
C3 S3	39

Table 7: ‘Intensive Vegetable’ rotation soil/climate combinations and nitrogen leaching results.

Soil and climate combination	Kg N / ha / year
C1 S1	68
C1 S2	56
C1 S3	42
C2 S1	52
C2 S2	43
C2 S3	33
C3 S1	69
C3 S2	58
C3 S3	48

Table 8. ‘Intensive Vegetable with Fallow’ rotation soil/climate combinations and nitrogen leaching results.

Soil and climate combination	Kg N / ha / year
C1 S1	84
C1 S2	66
C1 S3	53
C2 S1	67
C2 S2	55
C2 S3	40
C3 S1	86
C3 S2	73
C3 S3	57

5 Typical nitrogen losses for commercial vegetable crops per nutrient allocation zone

5.1 Methodology

In order to model the typical nitrogen losses for commercial vegetable crops in each nutrient allocation zone[8], we calculated, as accurately as possible, the growing area (in hectares) of each of the four crop rotation models. To carry out this exercise we have analysed two different data sources, the Agribase data and the results of the HortNZ growers survey.

5.1.1 Analysis of the available data.

The Agribase data is farm location and farm type data which is collected and recorded by AsureQuality staff as and when they visit a property. The HortNZ growers survey was carried out in 2018.

Agribase data.

The Agribase data (supplied by ECan) includes:

- Catchment zone name
- Area of root vegetables
- Area of green vegetables
- Area of legumes
- Area of other vegetables
- Area of unknown fresh vegetables
- Area of unknown processed vegetables
- Area of unknown vegetables
- Area of Total vegetables.

There are limitations in the accuracy of this data due to the fact that it is collected by AsureQuality when, and if, they have some interaction with the property. Because AsureQuality are the GAP[9] auditors and also administer a number of the crop certification schemes we believe that the data is a reasonable reflection of both the total area of commercial vegetable production and the crops that are grown.

HortNZ data.

The HortNZ data from the grower survey undertaken in 2018 also provided information on crop area. However, this survey only received responses from 94 of the 444 growers (21% response rate). We do not think that this is a representative result which we can use in this analysis. It can however be used for a rough order comparison acknowledging typical response rates from surveys and the fact that the survey data does not provide details of leased land locations (only main address location). That being said, the sum of the crop areas from the HortNZ survey report a total of 8,517 ha used for commercial vegetable production in Canterbury compared with the 12,355 ha

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[8] Nutrient allocation zone refers to the allocation of the Canterbury region into geographic zones which reflect the common receiving environment for discharges of nutrients.
[9] GAP is the horticultural industries quality assurance scheme.

reported by the Agribase data, which may indicate that the majority of the survey responses were from the larger growers.

StatsNZ

It was originally thought that StatsNZ would be able to provide a source of data for this exercise, but our inquiry indicated that they do not have data as detailed as that supplied by Agribase and it is therefore not suitable for our purposes.

Consolidation of the LWRP nutrient allocation zones into the LWRP sub-region catchments.

In order for us to be able to model the total nitrogen leached by each LWRP sub-region catchment we combined the crop areas in the nutrient allocation zones in order to incorporate the area of commercial vegetables grown in each LWRP sub-region catchment.

Crop areas per nutrient allocation zone were provided by ECan, who sourced data from AgriBase and StatsNZ . The areas within the various nutrient allocation zones were consolidated to represent the eleven LWRP sub- region catchments as shown in Table 12.

Table 9. Consolidation of the NAZs into the LWRP sub-region catchments.

LWRP sub-region catchments	Nutrient Allocation Zones
Central Canterbury Alpine Rivers	Waimakariri, Rangitata, Rakaia
Ashburton	Ashburton-Rakaia, Ashburton
Banks Peninsula	Banks Peninsula
Hinds	Upper Hinds, Valetta – Hinds, Mayfield/Hinds
Hurunui-Waiau	Waipara, Kowai, Waiau
Kaikoura	Medina, Kahutara, Kowhai, Kaikoura
Orari Opihi Pareora	Washdyke, Orari, Temuka, Pareora, Ohapi Creek Opihi, Makikihi
Waitaki and South Coastal Canterbury	Wainono, Waihao, Morven, Glenavy, Otaio (Waitaki NAZ is excluded as has negligible growers)
Waimakariri	Ashley-Waimakariri, Ashley, Saltwater Creek, Amberley
Selwyn – Te Waihora	Selwyn-Waihora, Little Rakaia
Christchurch-West Melton	Christchurch-West Melton

5.2 Allocation of the areas across LWRP sub-region catcments.

The results of the allocation of areas (ha) of each rotation type into each LWRP sub- region catchment is as shown in **Table 10**.

Table 10: Allocation of areas (ha) into LWRP sub-region catchments

LWRP sub-region catchments	No of enterprises	Root Vegetables (ha)	Green Vegetables (ha)	Intensive Vegetables (ha)	Total Area (ha)
Alpine	6	10	16	18	44
Ashburton	120	3,747	431	493	4,671
Banks Peninsula	5	0	0	0.2	0.2
Christchurch-West Melton	59	81	149	109	339
Hinds	13	228	110	8	346
Hurunui	6	0.75	0	17	18
Kaikoura	6	21	23	0	44
OTOP	48	1,366	110	171	1,647
SCCS	24	434	70	11	515
Selwyn	188	2,997	350	262	3,609
Waimakariri	47	110	17	53	180
Total	**516**	**8,995**	**1,275**	**1,141**	**11,411**

5.2.1 Allocation of the area across the three climatic zones.

The data gained from these two exercises was then split according to a visual inspection of the HortNZ grower location map. This split was two thirds below State Highway One for all of the zones, and one third above (excluding the South Coastal Canterbury catchment which was split 50:50 above and below State Highway One) this split was in order to allocate the area across the climatic zones.

The area for each nutrient allocation zone was then split in climate zones, which were then multiplied by the proportion of soil in each particular nutrient management zone (shown in **Table 11**, **Table 12** and **Table 13**). These percentages were determined by visual assessment of S-Maps, and the growers' (main address) locations.

Table 11. Climate zone 1, soil proportioning per the Land and Water Regional Plan sub-region catchments

LWRP sub-region catchments	S1	S2	S3
Alpine	10%	70%	20%
Ashburton	70%	15%	15%
Banks Peninsula	15%	70%	15%
Christchurch-West Melton	80%	15%	5%
Hinds	80%	15%	5%
Hurunui	10%	45%	45%
Kaikoura	10%	50%	40%
OTOP	5%	20%	75%
SCCS	5%	20%	75%
Selwyn	5%	70%	25%
Waimakariri	10%	45%	45%

Table 12. Climate zone 2 soils proportioning per LWRP sub-region catchments

LWRP sub-region catchments	S1	S2	S3
Alpine	10%	70%	20%
Ashburton	70%	15%	15%
Banks Peninsula	15%	70%	15%
Christchurch-West Melton	80%	15%	5%
Hinds	80%	15%	5%
Hurunui	10%	45%	45%
Kaikoura	10%	50%	40%
OTOP	5%	20%	75%
SCCS	5%	20%	75%
Selwyn	5%	70%	25%
Waimakariri	10%	45%	45%

Table 13. Climate zone 3 soils proportioning per LWRP sub-region catchments

LWRP sub-region catchments	S1	S2	S3
Alpine	5%	70%	25%
Ashburton	65%	25%	10%
Banks Peninsula	15%	70%	15%
Christchurch-West Melton	80%	15%	5%
Hinds	70%	20%	10%
Hurunui	15%	45%	40%
Kaikoura	10%	50%	40%
OTOP	5%	15%	80%
SCCS	5%	15%	80%
Selwyn	5%	25%	70%
Waimakariri	15%	45%	40%

5.2.2 Allocation of the soil types

The split of the soils data was done with reference to the HortNZ grower data and an S-Map map of the soil's types across the region. These split proportions were estimated according to a visual assessment of the data and are shown in Table 15, Table 16 and Table 17.

The areas of each soil and climate combination were then multiplied by the appropriate nitrogen leaching figure which was modelled by Overseer to give the total nitrogen leaching per nutrient management zone.

The results of the allocation of the soils split are shown in **Table 14**.

Table 14: Allocation of areas into LWRP sub-region catchments based on soil type.

LWRP Sub-region Catchment	Soil type 1 Lismore	Soil type 2 Templeton	Soil type 3 Waterford	Total (ha)
Alpine	4	31	10	44
Ashburton	3,195	850	626	4,672
Banks Peninsula	0.03	0.14	0.03	0.2
Christchurch-West Melton	271	51	17	339
Hinds	266	58	23	346
Hurunui	2	8	8	17
Kaikoura	4	22	17	44
OTOP	82	303	1,261	1,647
SCCS	26	95	395	515
Selwyn	180	2,006	1,422	3,609
Waimakariri	21	81	78	179
Total	**4,052**	**3,504**	**3,856**	**11,411**

6 Results

The area of each crop rotation within each of the LWRP sub-region catchments was multiplied by the associated Overseer Nitrogen losses (kg N/ha/yr) which are shown in Tables 8 to11, which were driven by the soils and climate assumptions to get a total Nitrogen loss (kg N/year) from the nutrient allocation zone. The results of this exercise are in **Table 15**.

Table 15. Nutrient losses from the four commercial vegetable operations rotations showing the Total and Average nitrogen leaching by LWRP sub-region catchments.

LWRP sub-region catchments	Root Vegetables (kg N / year)	Green Vegetables (kg N / year)	Intensive Vegetables (kg N)	Intensive Vegetables with Fallow (kg N)	Total Nitrogen leaching (kg N/year)	Average Nitrogen leaching (kg N/ha/year)
Alpine	427	859	467	0	1,753	40
Ashburton	177,023	25,906	14,801	17,851	235,581	50
Banks Peninsula	0	0	5	6	12	58
Christchurch-West Melton	3,970	9,223	3,337	4,097	20,627	61
Hinds	11,038	6,770	252	298	18,358	53
Hurunui	30	0	392	493	916	53
Kaikoura	838	1,190	0	0	2,028	47
OTOP	50,058	5,150	3,774	4,615	63,597	39
SCCS	15,910	3,292	243	297	19,742	38
Selwyn	120,746	17,908	6,358	7,761	152,773	42
Waimakariri	4,456	871	1,256	1,580	8,162	46
Total	**384,496**	**71,170**	**30,885**	**37,000**	**523,551**	**46**

7 Appendices

7.1 Appendix 1

		Year 1												Reporting year											
		Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Green Veg	Crop 1	Broccoli					Peas				Fallow		Broccoli							Squash					Broccoli
	Crop 2	Broccoli						Squash					Broccoli							Annual Ryegrass					
	Crop 3	Crop						Annual Ryegrass								Onions								Annual Ryegrass	
	Crop 4	A Ryegrass		Onions								Annual Ryegrass											Cauliflower		
	Crop 5	Grazed pasture									Cauliflower									Peas				Fallow	Broccoli
Root Veg	Crop 1	Annual Ryegrass				Onions								Forage Oats					Fallow	Potato Long					
	Crop 2	Forage Oats					Fallow	Potato Long							Annual Ryegrass			Onions							
	Crop 3	Crop	Annual Ryegrass			Onions								Annual Ryegrass						Carrots					
	Crop 4	Grazed Pasture						Carrots											Fallow	Potato Med					
	Crop 5	Crop					Fallow	Potato Med							Annual Ryegrass										Forage oats
Intense Veg	Crop 1	Fallow				Cauliflower					Spinach					Onions									Broccoli
	Crop 2	Crop		Onions									Broccoli							Squash					
	Crop 3	Crop		Annual Ryegrass				Squash						Spinach					Cabbage					fallow	Broccoli
	Crop 4	Spinach					Cabbage					Fallow	Broccoli							Sweetcorn					fallow
	Crop 5	Broccoli							Sweetcorn					fallow				Cauliflower					Spinach		
Intense Veg Fallow	Crop 1	Fallow				Cauliflower				Fallow	Spinach				Fallow	Onions								Fallow	Broccoli
	Crop 2	Crop		Onions								Fallow	Broccoli						Fallow	Squash					
	Crop 3	Crop		Annual Ryegrass			Fallow	Squash					Fallow	Spinach				Fallow	Cabbage					fallow	Broccoli
	Crop 4	Spinach				Fallow	Cabbage					Fallow	Broccoli						Fallow	Sweetcorn					fallow
	Crop 5	Broccoli						Fallow	Sweetcorn					fallow				Cauliflower				Fallow	Spinach		

APPENDIX B - CODE OF PRACTICE FOR NUTRIENT MANAGEMENT

Code of Practice for Nutrient Management

August 2014
Version 1.0

Horticulture™
New Zealand

Nutrient Management Code of Practice

Contents

INTRODUCTION

Why this Code of Practice for Nutrient Management

Purpose and scope

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

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

Background

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

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

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

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

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

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

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

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

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

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

<u>How to use this Code of Practice</u>

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

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

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

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

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

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

1. Risk based approach to nutrient management

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

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

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

Risk based approach to nutrient management

1. Understand how nutrient loss occurs and potential risk

Knowledge of movement of nutrients through soil and water

Factors contributing to nutrient loss

2. Information to help decision making

Soil tests

Paddock history

Crop history

Rotation and crop selection

Rainfall

3. Assessing the risk

Using the risk template identify the risk for each contributing factor

Determine the level of risk for the operation

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

Pre-planting

Planting and Ground Preparation

Post planting

Harvest and post-harvest

Other BMP's and GMP's

5. Maintaining records

Records should be kept to verify actions taken

2. Step 1: Understanding how nutrient loss occurs

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

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

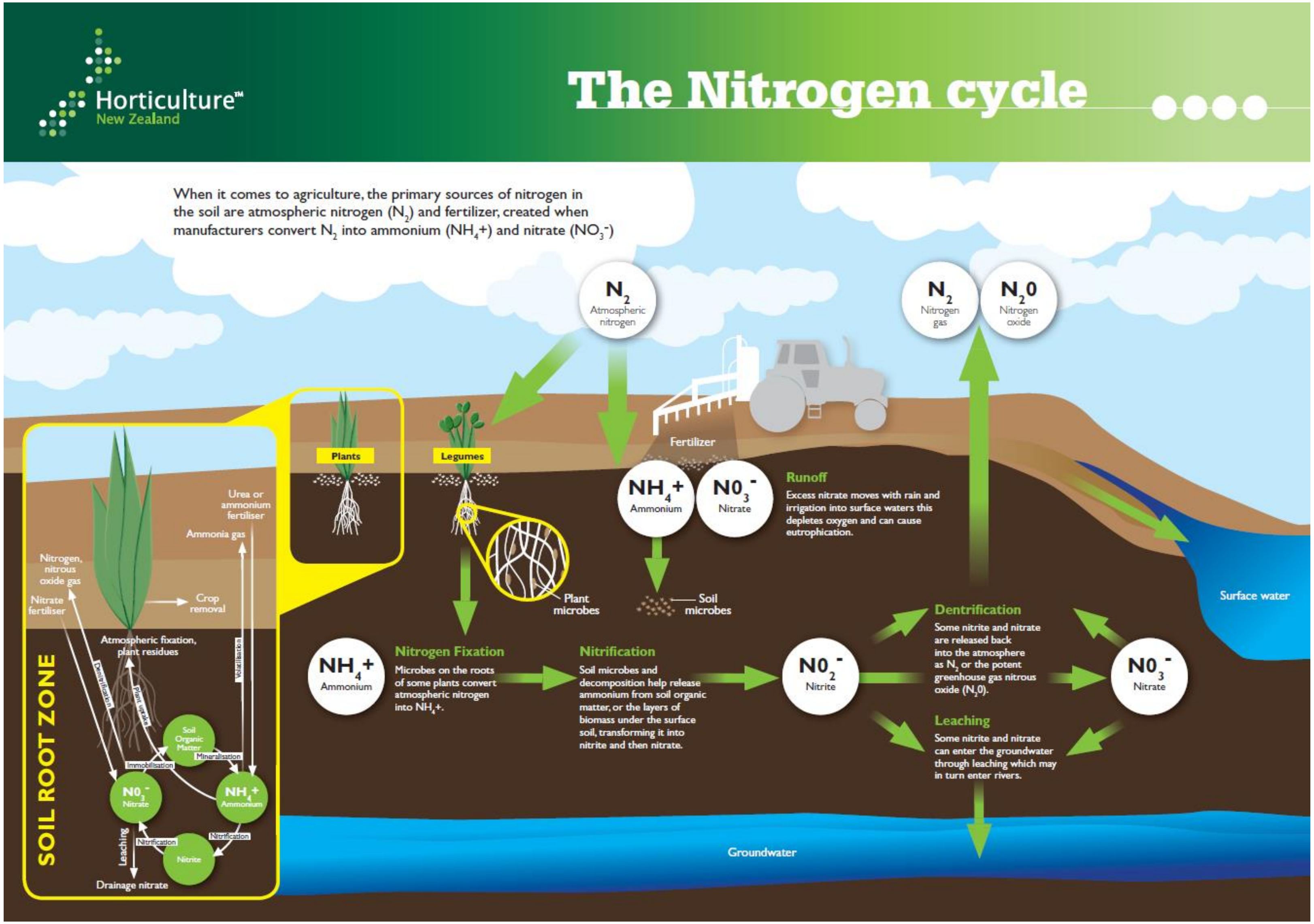
Inputs to the soil part of the nitrogen cycle include:

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

Nitrogen losses to the plant include:

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

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


Horticulture™
New Zealand
The Nitrogen cycle
When it comes to agriculture, the primary sources of nitrogen in the soil are atmospheric nitrogen (N_2) and fertilizer, created when manufacturers convert N_2 into ammonium (NH_4+) and nitrate (NO_3^-)
N_2 Atmospheric nitrogen
N_2 Nitrogen gas
N_20 Nitrogen oxide
Plants
Legumes
Fertilizer
NH_4+ Ammonium
$N0_3^-$ Nitrate
Runoff
Excess nitrate moves with rain and irrigation into surface waters this depletes oxygen and can cause eutrophication.
Plant microbes
Soil microbes
Surface water
Urea or ammonium fertiliser
Ammonia gas
Nitrogen, nitrous oxide gas
Nitrate fertiliser
Crop removal
Atmospheric fixation, plant residues
Denitrification
Plant uptake
Volatilisation
Soil Organic Matter
Immobilisation
Mineralisation
$N0_3^-$ Nitrate
NH_4+ Ammonium
Leaching
Nitrification
Nitrification
Nitrite
Drainage nitrate
SOIL ROOT ZONE
NH_4+ Ammonium
Nitrogen Fixation
Microbes on the roots of some plants convert atmospheric nitrogen into NH_4+.
Nitrification
Soil microbes and decomposition help release ammonium from soil organic matter, or the layers of biomass under the surface soil, transforming it into nitrite and then nitrate.
$N0_2^-$ Nitrite
Dentrification
Some nitrite and nitrate are released back into the atmosphere as N_2 or the potent greenhouse gas nitrous oxide (N_20).
Leaching
Some nitrite and nitrate can enter the groundwater through leaching which may in turn enter rivers.
$N0_3^-$ Nitrate
Groundwater

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

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

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

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

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

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

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

Contributing factors to nutrient losses

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3. Step 2: Information to help decision making

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

Key information includes:

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

Knowing your paddock (Paddock history)

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

Knowing your crops and rotation (Crop Selection)

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

Rotation is influenced by a number of variables:

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

These factors will influence crop selection and management.

Soil testing

3-5 yearly soil tests

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

Deep N Testing

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

4. Step 3: Assessing the risks

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

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

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

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

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

Management practices based on each stage of the crop cycle:

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

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

The management practices are grouped according to:

- Nutrient management
- Irrigation management.

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

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

Pre-planting

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

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

Good Management Practices
Best Management Practices

Management practices for the Pre-planting stage

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

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

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

Planting

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

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

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

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

Management practices for the Planting stage

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

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

<u>Post planting</u>

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

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

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

Management practices for the post planting stage

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

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

Harvest and Post-harvest

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

Other practices

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

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

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

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

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

Records need to be kept for:

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

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

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

Appendix 1: Nitrogen management and Regional Council rules

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

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

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

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

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

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

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

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

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

- Soil
- Cultivation
- Fertiliser
- Irrigation
- Other

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

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

Soil

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

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

Cultivation

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

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

<u>Fertiliser</u>

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

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

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

Irrigation

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

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

Other practices

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

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

Appendix 3: Records Templates

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

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

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