BEFORE THE HEARING COMMISSIONERS APPOINTED BY THE MANAWATU WANGANUI REGIONAL COUNCIL (HORIZONS)

IN THE MATTER	of the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	of Proposed Plan Change 2 to the Horizons One Plan

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STATEMENT OF EVIDENCE OF STUART JOHN FORD (COMMERCIAL VEGETABLE GROWING SYSTEMS AND ECONOMICS) FOR HORTICULTURE NEW ZEALAND

25th September 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 extensive experience in the use of Overseer in the pastoral, arable and horticultural sectors throughout New Zealand and have undertaken training in the use of APSIM.

5. I have undertaken analysis of the nutrient (using Overseer) and financial performance of commercial vegetable growing (**CVG**) operations in South Auckland / Northern Waikato, Hawkes Bay, Manawatu, Tasman, Canterbury and Southland for HortNZ.

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

7. 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.

Expert Witness Code of Conduct

8. 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.

Purpose and scope of evidence

9. I have been retained by Horticulture New Zealand (**HortNZ**) to provide evidence on the economic and resource use impacts of plan Change 2 (**PC 2**) on the commercial vegetable growers (**CVG**) within the Horizons region.

10. I gave evidence for HortNZ in the original One Plan hearings.

11. I prepared the report "Nutrient Performance and Financial Analysis of Horticultural Systems in the Horizons Region" for HortNZ in 2014 and subsequently was the author of "Farm Scale Economic Impact Analysis of One Plan Intensive Land Use Provisions" for Horizons in 2017.

12. I took part in expert witness conferencing on;

    (a) the 21st and 22nd July in respect to Farming and Growing management practices; Farm systems modelling and farm scale economics;

    (b) the 27th July in respect to Farm Scale Economics;

    (c) the 12th August in respect to Farming and Growing management practices and;

    (d) the 19th August in respect to Macro Economics.

13. In preparing my evidence I have reviewed the following documents and evidence:

    (a) Parminter T (2018); A Comparison of Changes to Nitrogen Loss Allowances on Dairying in the Upper Manawatu River Catchment.

    (b) Collins H (2018); Social Impact Assessment of Plan Change 2.

    (c) Hanly Dr J, Hedley Prof M, Horne Assoc Prof (2018); Sensitivity of values in Table 14.2 of the 'One Plan' to a change in the version of OVERSEER®.

    (d) Horticulture New Zealand (2019). Submission on Horizons One Plan – Proposed Plan Change 2, Existing intensive farming land uses.

    (e) Bloomer D, Posthuma L, O'Brien G (2020): Modelled Loss of Nutrients from Vegetable Growing Scenarios in Horowhenua. Report prepared for Pattle Delamore Partners.

(f) Hopkins C (2018); Manawatu-Wanganui Regional Council One Plan section 35 report: Intensive Farming.

(g) Foster C (2020); Section 42a report of Christine Foster on behalf of Manawatū-Whanganui Regional Council: Planning. Volume 1 and 2.

(h) Horne D (2020); Section 42a technical report of David John Horne; On farm management practices.

(i) Jolly A-M (2020); Section 42a technical report of Anne-Maree Jolly; Technical – GMP and Overseer modelling for commercial vegetable growers.

(j) McNally S (2020); Section 42a technical report of Stephen McNally; Technical – farm scale cost impact assessment.

(k) Clough P W J (2020); Section 42a technical report of Peter William John Clough, Technical – macro economic impacts.

(l) Collins H (2020); Section 42a technical report of Heather Collins, Technical – social impact assessment.

(m) The evidence of:

i. Michelle Sands;

ii. Andrew Barber;

iii. Damien Farrelly;

iv. Claire Conwell; and

v. Vance Hodgson.

Summary of conclusions

14. It is my opinion that it would be more realistic to expect N reductions closer to the 10 to 20% range as being possible from the adoption of the appropriate range of GMP's and BMP's across a whole property as is indicated by the Bloomer modelling across a total whole property system.

15. It is my opinion that because of the inaccuracies that are inherent in modelling of the CVG sector in Overseer, and the inordinate amount of cost of achieving this inaccurate figure, it would be more cost efficient to adopt a look up table approach to establishing the baseline values. It would then by appropriate to manage the achievement of each farmer

adopting what is appropriate from the list of GMP's and BMP's within the toolbox by running either an FEP or EMS audited approach.

CVG VEGETABLE ROTATION FARM SYSTEMS

16. CVG is identified as an intensive farming land use (**IFLU**) in the One Plan.

17. The nature of CVG 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 repeatedly; 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.

18. This adoption of a rotation enables the growers to ensure that their systems are sustainable in the long term for both economic and environmental considerations.

19. The most up to date and the most comprehensive analysis of the range of crop rotations grown can be found in the Hokio 1a Targeted Water Management Sub Zone (**TWMSZ**)in the Horowhenua area is represented in the "Modelled Loss of Nutrients from Vegetable Growing Scenarios in Horowhenua – May 2020" (Bloomer) report which is attached in **Appendix 1**.

20. In the Bloomer report[1] they identify three major types of crop rotations;

 (a) An onion / potato rotation,

 (b) A brassica dominant rotation, and;

 (c) An intensive fresh vegetable rotation.

21. The onion / potato rotation used follows the following pattern:

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[1] Bloomer D, Posthuma L, O'Brien G (2020): Modelled Loss of Nutrients from Vegetable Growing Scenarios in Horowhenua. Report prepared for Pattle Delamore Partners.

> *Potato > Potato > Onion > Onion > Ryegrass > Ryegrass > Ryegrass > Beetroot.*

22. The brassica dominant rotation is designed to ensure that brassicas are available for sale year round. This means that smaller areas of the crop are planted twice weekly. Bloomer found when he talked to the growers that to represent their system in Overseer would require modelling 36 different blocks in order to correctly represent the complexity of their operations. Bloomer chose to represent 12 of these variations in his Overseer modeling. The general theme of these 12 variations followed the following pattern:

> *Cauliflower / Broccoli / lettuce > Broccoli / lettuce > cabbage / Onion > cabbage / cauliflower > cabbage / broccoli > onion / cauliflower > celery / cabbage > cauliflower / potato > pumpkin / cauliflower > cauliflower / leek.*

23. The intensive fresh vegetables rotation is described in the Bloomer report as "*the most complex with numerous crops and multiple sowings and plantings to meet daily market demands*." And that "*To model this in detail in OverseerFM we would need to create hundreds of blocks of 0.1 – 1.0 ha each. Once plantings were clumped into months and some other rationalisation was done, 38 different blocks representing different crops and rotations were identified and modelled*."

24. The range of crops represented in the Bloomer modeling include; Beetroot, Cabbage, Celeriac, Celery, Coriander, Fennel, Ryegrass, Kale, Leek, Lettuce, Maize, Melon, Oats, Parsley, Pumpkin, Radish, Red Cabbage, Shanghai, Spinach, Spring Onion, White PakChoi and Wongbok.

25. In my 2014 report I modelled what I call a 'Waimarino rotation', which is representative of the types of rotations grown in the Ohakune area. These include crops such as carrots and winter greens which are grown on quite extensive rotations which include a significant proportion of pasture as a restorative crop in the rotation. These crops are grown across the free draining deep soils found in the area and are grown on a mixture of grower owned land and leased land from pastoral famers. These operations are not part of a IFLU area and can quite easily meet the relevant cumulative leaching maximums in Table 14-2.

26. The other sort of rotation which I model in both my 2014 and 2017 reports is part of what I call an arable rotation. It includes

potatoes and onions grown as part of a mixed arable rotation incorporating crops such as barley and a significant proportion of pasture. Again this rotation is carried out on both owned and leased land across the Rangitikei area on the deeper soils. Most of these rotations are grown outside of a TWMSZ.

27. All of the area CVG which is grown in Horowhenua is grown on flat land with 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.

28. These soils are all in the Land Use Class (**LUC**) 1 and 2. The core characteristics of LUC Class 1 and 2 are that they are all soils with a deep profile having a rooting depth of 70 cm to 1 m plus which means that they are ideally suited to growing horticultural crops. They are all classified as having a low N leaching vulnerability.

29. The climate in Horowhenua is also ideal for the growing of horticultural crops with a relatively high proportion of sunlight hours and a relatively even supply of rainfall which means that there is only an occasional requirement for irrigation to maintain the soil moisture within the ideal range to maximise plant growth.

30. Horowhenua is close to an abundant source of labour which is required to grow and harvest the majority of the horticultural crops which are grown in the area. It is also relatively close to the combined markets of both Wellington and Palmerston North which means that delivery of the produce grown in the area can be carried out in an efficient manner in terms of both timeliness and cost.

31. The area defined by the Horowhenua TWMSZ is an ideal location to grow CVG due to its soil types, climatic factors and location. That is in fact the reason why some of the most productive horticultural growers in the country are situated there.

NITRATE MANAGEMENT

32. It is recognised that there are a number of issues related to horticulture production which result in high Nitrate (**N**) leaching and the potential relative inefficiency of N use compared to other pastoral land uses. However, many CVG growers have continued to refine their use of N inputs, which has resulted in reduced use of the total volume of N applied

to the growing area and therefore the total amount of N leaching has reduced significantly over time.

33. The following quote on the nature and impact of horticultural land use on the rate of N leaching is taken from a report prepared for Environment Bay of Plenty[2] and explains the relative inefficiency of the use of N in horticultural systems. It is concluded that the major source of N leaching is derived from fertiliser and crop residue and that fertiliser N management strategies are key when devising mitigation strategies. The use of mitigation techniques concentrates on the two strategies of the timing and volume of N application.

> *The main factors responsible for nitrate leaching in these systems are: high N use (fertiliser and manure), frequent cultivation, relatively short periods of plant growth, low nutrient use efficiency by many vegetable crops, and crop residues remaining after harvest (Di and Cameron, 2002a).*
>
> *Compared to other agricultural systems, market gardens are the most intensively fertilised and cultivated production systems - hence their propensity to leach N. N application rates used in vegetable crops can be as high as 600 kg N ha-1 yr-1 (Wood, 1997). Large application rates are used to ensure maximum growth because vegetable crops have sparse root systems that are inefficient at recovering applied fertiliser. Also, vegetables typically have short growing periods and are also grown over winter when plant growth and N uptake is slow (Haynes and Francis, 1996; Haynes, 1997). Therefore, the recovery of applied N by vegetable crops is often less than 50%, and can be as low as 20% (Di and Cameron, 2002a). Consequently, a large quantity of fertiliser N remains in the soil surface layers and is susceptible to leaching during rainfall or irrigation. Additionally, following crop harvest large amounts of plant residues are usually incorporated into the soil which, following decomposition, release mineral N into soil. The amount of mineral N derived from fertiliser and crop residue that is present in the soil after harvest can be as high as 200-300 kg N ha-1, and is the major source of leached N, indicating that fertiliser N management strategies are the key to nitrate leaching intervention in these systems.*

34. The issues which cause N leaching in vegetable growing operations therefore are:

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[2] Meneer J C, Ledgard S F, Gillingham A G: Land use impacts on nitrogen and phosphorous loss and management options for intervention.

(a) High use of applied N as a result of sparse root systems for the crops (particularly when they are immature).

(b) Poor N use efficiency.

(c) Short growth periods and therefore (in some cases) multiple crops in one year.

(d) Many crops are grown over winter when leaching rates are high due to high rainfall and saturated soils.

(e) Large amounts of crop residue left in the paddock after harvest which is often worked into the soil.

35. The instances of when N leaches through the soil and is able to reach the water table are characterised by a situation where the amount of latent Nitrate is present in the soil, for example as a result of a new crop being planted with the resultant high rates of N applied to the ground and not yet taken up by the plant , and an extraordinary amount of rain which induces sufficient flushing of the moisture through the soil profile which takes with it , and therefore leaches, the Nitrate.

36. The soils in the Horowhenua are deep (1m plus), meaning that they can hold a large amount of water within the soil profile and so the amount of leaching in normal circumstances is relatively low, it is just when there is an excess amount of rain that the N is able to be flushed through.

37. This is why in reality the pattern of leaching is very erratic with very long periods of little or no leaching of N through the soil profile and then large flushing events occurring when there is a combination of excess N sitting within the soil profile and an excess of moisture.

The use of Overseer to model Nitrate leaching for Commercial Vegetable Growing activities

38. It is not possible to model the true pattern of N leaching using Overseer as a modeling tool because Overseer uses an average of the 30 years climatic data when it calculates the amount of N leached and therefore it reports a thirty year average N leaching figure for the system being modelled. It is not possible to model the true nature of the leaching occurring on anything less than a 30 year average result.

39. It is very important to note that the derivations of the values that populate Table 14-2 have all come from modelling

different intensities of dairy farming systems in Overseer[3]. As I have pointed out, the cause of the N leaching from CVG systems is entirely different from the cause of N leaching from Dairy systems, which is predominantly from the deposition of urine. The use of dairy systems to set hard line values that must be adhered to by the CVG system is a somewhat incongruous situation in my opinion and puts the CVG sector at a major disadvantage.

40. I agree with Dr Hanly where he points out that "*changes in OVERSEER® estimates will not result in changes to the real or actual nutrient losses from farms, or the attenuation factors that account for the denitrification that occurs between the farm and the receiving water body, or the N load received in the rivers*." The changes which occur in Overseer are a result of the calculation of the same system which is run through an updated version of Overseer. The changes which occur between different versions of Overseer as a result of the correction of what are euphemistically called "bugs" by Overseer, they are in fact correction of programming errors which lead to an inaccurate result, or the inclusion of new science into the model. As I have point out later in my evidence there have been very few instances of the introduction of new scientific information into Overseer which improve the accuracy of modelling for the CVG sector.

41. That being said, I commend the recommendations made in Mr D Horne's section 42A report at Section H. Managing Effects of Version Changes to Overseer as being a very important methodology for ensuring that the values in Table 14-2 are kept as accurate as is possible over time.

42. In terms of Overseer as an analysis tool for CVG, 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.

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3 Hanly Dr J, Hedley Prof M, Horne Assoc Prof (2018); Sensitivity of values in Table 14.2 of the 'One Plan' to a change in the version of OVERSEER®.

(b) The modelling of Phosphorus (**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 input of time steps 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 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.

43. In a paper written for ECan, Hulme[4] identified 21 examples of complexities that were encountered during modelling in Overseer for the arable and commercial vegetable production sector and detailed the work arounds that she had to adopt to make the modelling work.

44. 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[5].

45. 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

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

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

the performance of the sector in terms of both N and P leaching.

46. In the report[6] which I wrote for HortNZ in 2015 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.

47. In that report, the Technical Advisory Group 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."*

48. 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.*

49. 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 was commenced in 2014 with 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.

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

50. The second recommendation in the FAR review 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.*

51. 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[7] in early 2017.

52. 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 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.

53. 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.

54. 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.*

55. As far as I am aware none of the three recommendations made in that report have been completed. This is at least

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

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.

56. There still remains a high degree of uncertainty as to the results produced by Overseer in the commercial vegetable production sector.

57. In the Bloomer report they traverse the major work arounds which they encountered in attempting to model the systems which they were told by the growers they were practicing as accurately as possible so that they were satisfied that they were able to model them as closely as possible to reality. These included;

(a) The choice of surrogate crops for the crops that weren't able to be modelled in Overseer. They list 17 crops which required choice of a surrogate.

(b) The requirement to ensure that the surrogate crop has its yield chosen appropriately to fully utilise the nitrogen in the soil profile.

(c) The requirement to enter grower operations by month in Overseer leads to simplification of crop plans and leads to excess fertiliser that is assumed by Overseer to not being taken up by the plant being diverted to the soil mineral pool.

(d) The requirement to substitute alternative crop to ryegrass to avoid the unrealistic plant uptake results that Overseer assumes occurs with ryegrass.

58. I am of the opinion that it is important to point out to you that when Dr D Horne says at paragraph [1(b)] of his Section 42 A report that "*I am of the view that OVERSEER@ is 'fit for purpose' and in all probability the best model available*" that his report does not consider its use in the CVG sector.

59. I also note that Dr Anne Maree Jolly at paragraph [35] of her Section 42A report says that "*However, I accept that for systems other than pastoral systems this error margin is likely to be higher due to the limited data available. It is therefore advisable to consider setting relative percentage nitrogen leaching reductions alongside absolute targets*" and at paragraph [36] she notes that "*There are known limitations for*

all land uses, however the accuracy of Overseer® is the most questionable for CVG"

60. Then at paragraph [37] Dr Jolly is of the opinion that "*There are a range of suitable 'work arounds' that can be used when modelling CVG. In my view, the methodology developed by Bloomer et al (2020) shows it is possible to model nitrogen losses using Overseer® for CVG. However, to achieve consistency in modelling approaches and agreement on suitable 'work arounds' it is recommended that an Overseer® User Guide for CVG in the Horizons region be considered*."

61. It is not clear from Dr Jolly's reporting exactly which of these work-arounds that she has used or her estimate of how the use of them have improved the accuracy of the N leaching from the "most questionable level of accuracy" which she says is recorded from the use of Overseer in the CVG sector. Therefore, it is difficult to determine exactly how much she believes it is possible to improve the accuracy of the Overseer modeling by the use of the work arounds developed by Bloomer.

62. I am also of the opinion that Dr Jolly's contention that an Overseer Users Guide for CVG should be "considered" is somewhat weak. It leaves us in the position of being in the position that if it isn't enacted she still believes that the use of Overseer in the CVG sector is acceptable despite the wide error margin and the fact that its accuracy is questionable in the CVG sector. It is my impression that the use of Overseer in the CVG sector is damned with faint praise by Dr Jolly.

63. It is my opinion that the Overseer modelling that was carried out by Dr Jolly was designed to test the efficacy of some of the GMP and BMP's on a very limited range of rotations. I note that she used eight of the 82 blocks that were modelled by Bloomer in her analysis and at no stage attempted to model a real, or even a representative, whole rotation. I therefore question how much confidence she can have in the degree of accuracy of the GMP and BMP's in her modelling compared to the actual array of blocks which Bloomer found it necessary to model to try and accurately portray what was happening in practice.

64. It is my opinion that Dr Jolly's modelling is very technical and does not explore the huge array of block data that it is possible to model so I cannot agree with the degree of confidence which she has in her results.

65. It is important to note that Dr Jolly's results cannot be used in determining the average rate of N losses for testing whether the total farm meets the cumulative leaching maximums in Table 14.2 and determining which is the appropriate pathway.

66. I think that it is important to be reminded that in the expert conferencing when answering the question "Can N loss from commercial vegetable growing and arable intensive farming land use activities be represented and modelled by Overseer FM", that it is recorded that we all agreed that "there are issues for vegetables, arable and forage crops for modelling and is therefore unreliable for depending on its use for absolute numbers, but it does provide a view on trend within the same system.

67. Therefore I have severe reservations about the use of Overseer in its ability to accurately model a CVG system in both the Brassica and the Fresh Vegetable rotations in order to meet the requirements of Table 14-2 and effectively be the drafting gate between the two pathways, one of which incurs considerable cost on the grower for an unknown amount of gain in N leaching reductions.

OVERSEER MODELLING

68. In the two reports which I refer to in paragraph 12 in which I carried out Overseer modelling of three different rotations within the Horizons region the core data which I used to construct the rotations was taken from a survey of growers across the whole of the Manawatu Region not just within the Horowhenua IFLU. This survey was carried out in 2014 and it was a construction of the three rotations from the quite diverse range of responses that we received to our request for survey information.

69. The modelling that was carried out by Bloomer was directly related to the Hokio 1a TWMSZ and was taken after gathering detailed information from the growers in that area. The modelling undertaken by Dr Jolly was initially constructed from previous work carried out in the Horizons region, including my earlier work and was latterly influenced by reference to the Bloomer modelling. As I have already pointed out the modelling carried out by Dr Jolly was in no way a comprehensive representation of the rotations used in the area and were not used to report a total N leaching figure for a whole of operation rotation. It was used to gather some

information on the effects of various mitigation practices which were only compared against six CVG crops that can be modelled in Overseer, and two that cannot. Dr Jolly did not attempt to adopt the work-arounds as described in the Bloomer report which attempted, with much difficulty, to adopt surrogate crops for the crops which it was not possible to model in Overseer.

70. It is my opinion that the Bloomer Overseer modelling (which has been externally peer reviewed by Plant and Food Research) is by far the best possible and most accurate representation of Overseer modelling that is available to us for use in both determining both the properties status in terms of either meeting or exceeding the cumulative leaching maximums in Table 14-2 and the likely percentage changes possible as a result of adopting the various mitigations which we agreed upon in the expert conferencing.

71. The Bloomer modelling reports that for the Potato / Onion rotation that when the yields modelled were the accurate grower yields were entered that the N leaching values for the total rotation were below the cumulative leaching maximums values listed in Table 14-2.

72. For the Brassica dominant rotation the pre 2018 model had an N leaching value of 109 kg N / ha / annum and the post 2019 (which is used to represent the adoption of the majority of GMP's and BMP's) has an N leaching value of 99 kg N / ha / annum. Neither rotation meets the target value in Table 14-2.

73. For the intensive fresh vegetable rotation the pre 2018 model had an N leaching value of 98 kg N / ha / annum and the post 2019 (which is used to represent the adoption of the majority of GMP's and BMP's and in this case also has a considerable amount of what I refer to as system change which incorporates a substantial change in the total crop mix which includes a substantial amount of pasture added into the rotation and a consequential reduction in the area cropped) has an N leaching value of 61 kg N / ha / annum. Neither rotation meets the target value in Table 14-2.

74. Dr Jolly in her partial modelling reports individual crop N leaching values ranging from 22 kg N / ha / annum to 226 kg N / ha / annum.

75. Dr Jolly then reports the percentage of N reductions possible from what she refers to as her Original, which represents grower practice at the reference year (2014) and the results

from modelling of adoption of both GMP and BMP. She reports that she would expect individual crops to achieve reductions of between 36 – 94% for GMP and 55 – 94% for BMP. I believe that it is very important to note that Dr Jolly is reporting a very limited proportion of the results from individual crops which represent the total number of crops grown in the CVG sector in the Horowhenua TWMSZ (38 vegetable crops are grown in the Horowhenua District)and hasn't attempted to represent a total whole property N leaching result. While these results are interesting, I do not believe that they are able to give us an insight into what is happening on individual properties and don't believe that they are able to offer us any guidance in determining what would be an appropriate setting in a planning context.

76. Therefore I would suggest considerable caution in adopting a possible range of 35% to 45% as an acceptable range of N reductions possible as suggested by Ms Christine Foster in her Section 42A report where she relies on the report of Dr Jolly and proposes that "For CVG, implementation of GMP and BMP that will achieve a minimum 35% reduction of N leaching compared to the baseline year (2013/2014) within three years of lodging the application."

77. I am of the opinion that the Bloomer work gives us a realistic view of the whole property outcomes.

78. It is my opinion that it would be more realistic to expect N reductions closer to the 10 to 20% range as being possible from the adoption of the appropriate range of GMP's and BMP's across a whole property as is indicated by the Bloomer modelling across a total whole property system.

79. If we assess the list of GMP's and BMP's that were agreed at the expert conferencing as being appropriate to be used in a toolbox of appropriate measures for the CVG sector the vast majority of them describe practices that cannot directly be modelled in Overseer. Some such as the grassing of buffer strips and planting catch crops during fallow periods are able to be directly modelled. The vast majority of the remainder require the modeller to make some sort of assumption as to the impact of the practice on the model input parameters and then input them appropriately into the model.

80. The biggest impact in this respect is applying the appropriate amount of N fertiliser which both will enable the crop to achieve the desired level of productivity and which takes into

account the residual amount of N still available in the soil. Although we have a significant amount of knowledge about the first factor we are left as to being unable to estimate the second factor as in Overseer the residual amount of N that is available in the soil is driven by Overseer which makes an assumption as to the amount and therefore it is not possible for the modeller to alter that assumption. It means that for some of the most important variable factors which would influence the outcome of the modelling the modeller is stuck with a fixed assumption rather than being able to influence the result by having the opportunity to enter a variable array of values.

81. This all explains the result of the expert conferencing which agreed that Overseer may have some value in comparing the direction of travel, ie: having a deteriorating or improving amount of N leaching, of a CVG operation but is not accurate enough to report the actual value.

Approach of other councils to Overseer limitations

82. I have considerable experience with dealing with the vagaries of modelling the CVG sector in Overseer across several Regional Councils.

83. In Canterbury ECan recognised this problem and worked with the horticultural sector to adapt an alternative pathway for the CVG sector. This resulted in them adopting the N Check system for the CVG sector which established the individuals baseline leaching figure by them adopting a very limited range of alternative CVG rotations which was then run through their online portal calculation method. This methodology effectively provides for the growers to adopt a look up table approach to assessing their baseline values. This establishes their baseline value and growers are then required to make reductions to this value according to the zone requirements of their location of operation. The majority of these requirements are for reductions of 5%. Performance towards achieving this figure is managed through an audited Farm Environment Planning (**FEP**) system.

84. In the Waikato, which still is awaiting to go to the Environment Court, the proposal is for their baseline to be determined through modelling and then this is managed to ensure that the baseline is not exceeded by an audited FEP system.

Recommended approach to Overseer modelling

85. It is my opinion that because of the inaccuracies that are inherent in modelling of the CVG sector in Overseer, and the inordinate amount of cost of achieving this inaccurate figure, it would be more cost efficient to adopt a look up table approach to establishing the baseline values. It would then by appropriate to manage the achievement of each farmer adopting what is appropriate from the list of GMP's and BMP's within the toolbox by running either an FEP or EMS audited approach.

86. I am fully in support of the recommendations in Ms Fosters S42A which propose amendments to the definition of a Nutrient Management Plan because I am of the opinion that it creates an avenue for this type of proxy modelling being recognised in the Horizons Region. I understand Mr Hodgson is providing a slight refinement to Ms Foster's amendments which I also support.

ECONOMIC IMPLICATIONS OF ACHIEVING GMPS AND BMPS ON THE CVG SECTOR

87. In order to model the financial impact of achieving GMP's and BMP's on the CVG sector I have adopted the same modelling framework as I used in my report to Horizons and have adjusted it to reflect the rotations reported by Bloomer both in terms of the total crop mix and the yields. I have not included the Potato / Onion rotation because it is assessed as giving a N leaching result below the cumulative leaching maximums in Table 14-2.

88. I have adopted the same framework of costs as Mr Stephen McNally has in his economic report which were gained from discussions with a grower. I am not able to determine exactly the values that Mr McNally has adopted therefore the values can be considered as coming from the same source, but they will most probably differ in the quantum.

89. The results from my financial modelling of the Brassica dominant model are shown in **Table 1** below. The first column represents the baseline year or it portrays the operation as it was in 2014. The second column represents the result after the adoption of all of the GMP's and the third column represents the result after adoption of the majority of the BMP's. The revenue has been kept static.

90. The first row reports Gross Farm Revenue which is the total income to the property. The second row reports the Total Farm Operating Expenses so if we are to deduct the second row from the first row we report the Cash Operating Surplus which is effectively earnings before Interest, Tax, Capital Expenditure and Repayments and owners drawings. The Net Cash Position row reports the surplus available to the owners after all payments have been made ie: the true surplus.

Table 1: Financial modelling results of the Brassica dominant rotation as a result of the adoption of GMP and BMP

	Baseline Year	GMP	BMP
Gross Farm Revenue	1,020,450	1,020,450	1,020,450
Total Farm Operating Expenses	586,601	657,671	731,171
Cash Operating Surplus	433,849	362,779	289,279
Net Cash Position	**261,079**	**197,223**	**131,423**
Return on Investment	8.0%	6.1%	3.8%

91. As can be seen from Table 1 the impact is quite severe, effectively halving the Net Cash Position, which is effectively the operations net cash profit and more than halving the Return on Investment. These are not the level of reductions which can be readily absorbed by the growers. Reductions in the profitability of the average operation of this order would result in the owners taking some sort of remedial action to try and maintain the profitability of the operation.

92. Unfortunately, the CVG growers are price takers in the sale of their product. This position as 'price takers' means therefore that there is no opportunity for them to demand higher prices in order to maintain the profitability of their operations as a result of them having to absorb the increased costs of meeting the GMP's and BMP's.

93. The results from my financial modelling of the **Intensive Fresh Vegetable** model are shown in **Table 1** below.

Table 2: Financial modelling results of the Intensive Fresh Vegetable rotation as a result of the adoption of GMP and BMP

	Baseline Year	GMP	BMP
Gross Farm Revenue	1,618,669	1,618,669	1,618,669
Total Farm Operating Expenses	1,069,438	1,164,380	1,262,568
Cash Operating Surplus	549,231	454,289	356,101
Net Cash Position	**347,185**	**264,431**	**185,881**
Return on Investment	9.9%	7.6%	5.3%

94. As can be seen from Table 2 the financial impact of the growers adopting all of the GMP's and BMP's are also quite severe with the Net Cash Position reducing by approximately 45% and the return on investment reducing by about the same amount. These results would force the owners to seek to make some quite major changes to the way that their business is structured to ensure that they are able to maintain their level of profitability.

95. It is my conclusion that achieving the full range of GMP's and BMP's for both the Brassica dominant and the Intensive Fresh Vegetable rotations will not be economically achievable for the majority of growers.

COMMENT ON THE COUNCIL'S ECONOMIC MODELLING

96. In the expert conferencing we were only presented with a brief PowerPoint presentation of the economic modelling used by WSP on the Farm Scale Economics. Both Dr Graeme Doole and I stated that a full enterprise model should be used rather than a Gross Margin analysis. I also stated that the approach used may be valid for representing change but not representing whole farm viability.

97. Dr Doole and I also stated that the methodology used was not suitable to inform regional modelling.

98. On reading the report of the farm scale economic modelling contained in Mr McNally's section 42A report our concerns about the suitability of the methodology used to represent farm viability under PC 2 have not been alleviated.

99. Mr McNally's economic modelling is based on the Overseer models developed by Dr Jolly. As I have previously pointed out Dr Jolly has not attempted to model a whole farm rotation - instead she has modelled a very limited range of the total number of crops grown in the area and at no point has she attempted to model them in what could be called a rotation.

100. Mr McNally recognises this fact where he states in his section 42A report that:

> *The modelling is not looking at an overall individual property, or enterprise combining several properties, but rather models nitrogen losses for a selective group crop rotation examples that commonly occur on CVG operations in Horowhenua. Modelling rotations results in a nitrogen loss value for each specific rotation being modelled. These values may produce higher or lower*

nitrogen losses outcomes compared to that of modelling the nitrogen loss from a whole property or total enterprise, which is required for consent applications.

101. I believe that Mr McNally has incorrectly used the term 'rotation'. What I believe that he is referring to is an individual crop or small group of groups which does not constitute a full rotation. So what Mr McNally has represented in his modelling is not a whole farm or enterprise rotation but a very small sub section of the total range of the possible land uses.

102. Mr McNally has chosen to model this limited range of crops by the use of a Gross Margin approach. A gross margin approach only calculates the direct revenue and costs of growing an individual crop. It does not include the costs of owning and running the land and conducting the business of farming the land. A gross margin approach is usually used as a means of comparing the returns from a range of crops.

103. I used a gross margin approach in my 2014 report where I was comparing the costs and benefits of a range of mitigations but in my 2017 report I used a full farm financial model in order to report the impact on the total farm business of the growers attempting to achieve the cumulative leaching maximums in Table 14-2.

104. Mr McNally then reports his results as Net Present Values which is the result of calculating a discounted cash flow over time. This is an appropriate means of comparing cash flows which have different make up of costs and expenditures over time as it is able to present the values of the different cash flows in one standard comparative value. It is my opinion that it does not add anything to our understanding of the different cash flows in this case because there are no substantial differences in the costs and benefits that are able to be modelled from achievement of both GMP and BMP. It is my opinion that reporting his results in this way is an incorrect method of portraying his results and potentially leads us to misinterpret the results of his modelling.

105. It is my opinion that Mr McNally's modelling is incomplete in that it only considers a very small proportion of the total available crops and that it can be considered partial in that it only calculates it in gross margin terms. Therefore his modelling may be appropriate to calculate the change in financial performance of a range of crops as a result of adopting GMP and BMP but it is not adequate in order to calculate the financial impact on the total farm of adopting GMP and BMP.

106. The NZIER Macro Economic modelling is informed by Mr McNally's work. In his section 42A report Mr McNally reports that :

> *The outputs of the farm financial model required by NZIER for their District and Regional scale CGE model include:*
>
> *(a) Area of land (ha);*
>
> *(b) Total production (kg);*
>
> *(c) EBIT ($/ha);*
>
> *(d) Profit per unit area ($/ha);*
>
> *(e) Employment (number in dollar value);*
>
> *(f) Fertiliser use (tonne/ha); and*
>
> *(g) Percentage commercial vegetables in catchment.*

107. Because he has only calculated his model on a gross margin basis Mr McNally is not able to supply NZIER with either Earnings before Interest and Tax (**EBIT**) or Profit per unit area.

108. The only reference to Mr McNally being able to contribute this information in his section 42A report is where he says:

> *Based on available industry information, prior work done by others and specific operational information obtained during the course of the WSP work program we have been able to estimate overall enterprise profit margins that take into account additional overheads.*

109. It is my opinion that we can have very little confidence on the NZIER results as they are based on a limited range of the potential crops grown and on estimates of the two key factors which drive their results.

CONCLUSIONS AND RECOMENDATIONS

110. The area defined by the Horowhenua TWMSZ is an ideal location to grow CVG due to its soil types, climatic factors and location. That is in fact the reason why some of the most productive horticultural growers in the country are situated there.

111. There are a number of issues related to horticulture production which result in high N leaching and the potential relative inefficiency of N use compared to other pastoral land uses. However, many CVG growers have continued to refine their use of N inputs, which has resulted in reduced use of the total

volume of N applied to the growing area and therefore the total amount of N leaching has reduced significantly over time.

112. It is not possible to model the true pattern of N leaching using Overseer as a modeling tool because Overseer uses an average of the 30 years climatic data when it calculates the amount of N leached and therefore it reports a thirty year average N leaching figure for the system being modelled. It is not possible to model the true nature of the leaching occurring on anything less than a 30 year average result.

113. It is very important to note that the derivations of the values that populate Table 14-2 have all come from modelling different intensities of dairy farming systems in Overseer[8]. As I have pointed out, the cause of the N leaching from CVG systems is entirely different from the cause of N leaching from Dairy systems, which is predominantly from the deposition of urine. The use of dairy systems to set hard line values that must be adhered to by the CVG system is a somewhat incongruous situation in my opinion and puts the CVG sector at a major disadvantage.

114. In my opinion it is important to point out to you, that when Dr D Horne says at paragraph [1(b)] of his Section 42 A report that "*I am of the view that OVERSEER@ is 'fit for purpose' and in all probability the best model available*", that his report does not consider its use in the CVG sector.

115. I have severe reservations about the use of Overseer in its ability to accurately model a CVG system in both the Brassica and the Fresh Vegetable rotations in order to meet the requirements of Table 14-2 and effectively be the drafting gate between the two pathways, one of which incurs considerable cost on the grower for an unknown amount of gain in N leaching reductions.

116. It would be more realistic to expect N reductions closer to the 10 to 20% range as being possible from the adoption of the appropriate range of GMP's and BMP's across a whole property as is indicated by the Bloomer modelling across a total whole property system.

---

8 Hanly Dr J, Hedley Prof M, Horne Assoc Prof (2018); Sensitivity of values in Table 14.2 of the 'One Plan' to a change in the version of OVERSEER®.

117. It is my opinion that because of the inaccuracies that are inherent in modelling of the CVG sector in Overseer, and the inordinate amount of cost of achieving this inaccurate figure, it would be more cost efficient to adopt a look up table approach to establishing the baseline values. It would then by appropriate to manage the achievement of each farmer adopting what is appropriate from the list of GMP's and BMP's within the toolbox by running either an FEP or EMS audited approach.

118. I conclude that achieving the full range of GMP's and BMP's for both the Brassica dominant and the Intensive Fresh Vegetable rotations will not be economically achievable for the majority of growers. These results would force the owners to seek to make some quite major changes to the way that their business is structured to ensure that they are able to maintain their level of profitability.

119. In my opinion that Mr McNally's modelling is incomplete in that it only considers a very small proportion of the total available crops and that it can be considered partial in that it only calculates it in gross margin terms. Therefore his modelling may be appropriate to calculate the change in financial performance of a range of crops as a result of adopting GMP and BMP but it is not adequate in order to calculate the financial impact on the total farm of adopting GMP and BMP.

120. For the reasons outlined in this evidence we can have very little confidence on the NZIER results as they are based on a limited range of the potential crops grown and on estimates of the two key factors which drive their results.

Stuart John Ford

25 September 2020

APPENDIX A: MODELLED LOSS OF NUTRIENTS FROM VEGETABLE GROWING SCENARIOS IN HOROWHENUA.

MODELLED LOSS OF NUTRIENTS FROM VEGETABLE GROWING SCENARIOS IN HOROWHENUA

OverseerFM 6.3.2 Modelling of Representative Rotations within Hokio_1a, Hokio_1b, and Ohau_1b WMSZ

Report for Pattle Delamore Partners

5 May 2020

Dan Bloomer, Luke Posthuma, Georgia O'Brien
Page Bloomer Associates Ltd

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1 Executive Summary

As part of the project, "Environmental Effects of Horticultural Practices in the Manawatu-Whanganui Region", OverseerFM modelling of vegetable production scenarios was completed. The results apply only to the study area of known vegetable production in the Hokio 1a and 1b, and northern edge of Ohau_1b Water Management Sub-Zones (WMSZ) (see Figure 1, page 4).

The tonnages of nitrogen and phosphorous entering the hydrological system were calculated for both pre-2019 and post-2019 using grower supplied data for planted areas, crop rotations and nutrient management practices.

- The total amount of nitrate-N lost by leaching from vegetable growing areas in the study area was calculated to be between 29.6 and 31.4 tonnes pre-2019 and 17.6 and 17.8 tonnes post-2019. One scenario suggested higher losses of 32.8 tonnes pre-2019 and 22.7 tonnes post-2019.
- The total amount of phosphate-P lost by leaching from the vegetable growing areas in the study area was calculated to be 0.66 tonnes pre-2019 and 0.43 tonnes post-2019.

To derive these results, many assumptions and compromises were required. We modelled a range of crop rotations in each of three production system scenarios; an onion/potato rotation, brassica dominated fresh vegetables and intensive fresh vegetables. To estimate catchment impacts, we applied the results on a pro rata basis according to cropped areas provided by growers and Horticulture New Zealand.

We have compared new practice with recommendations in the 2019 guidelines, "*Nutrient Management for Vegetable Crops"*. In general, we find growers often using less fertiliser than the new guidelines might suggest as good practice.

We note that many crops grown are not included in OverseerFM and some alternative must be selected. When selecting surrogate crops, a first option was to select a surrogate from the same family, but in some cases the actual crop has very different yield and different plant parts are harvested. In such cases, a closer representative was selected. We also identify that including grass in a rotation appears to generate unrealistically high levels of crop nitrogen accumulation and subsequent leaching.

Levin currently has no S-Map soil map layer. For modelling, onion/potato crops are on Waitohu deep silt loam (Moko_2a.1) and brassica and intensive fresh vegetable production are on Shannon deep silt loam (Paha_29a.1), both with adjustments to S-Map defaults.

Modelling cropping systems in OverseerFM had limitations. The need to enter grower operations by month in Overseer leads to simplification of crop plans. N leaching increased when we modelled best practice fertiliser management recommendations to split fertiliser applications. The model can give variable results when incorrect yields are entered. However, different growers can use quite different definition of yield, and yield values are further compounded when using surrogates for crops not in the OverseerFM catalogue. For ryegrass as a cover crop, the model predicts very high N leaching from unrealistic N plant uptake results. We modelled ryegrass as Forage Oats (Autumn sown) which gave N values closer to published results.

Our observations are that growers in Levin are generally efficient with their fertiliser use and with current technology there are few opportunities to further reduce rates of N applied without increasing the risk of crop failure. In most cases, current applications are near or below those recommended in the latest science-based nutrient management guidelines.

2 Introduction

This report was prepared for Pattle Delamore Partners as part of the project, "Environmental Effects of Horticultural Practices in the Manawatu-Whanganui Region". It presents the purpose of, inputs to and results from OverseerFM modelling of vegetable production scenarios was completed. The OverseerFM results used in this report were generated on 24 April 2020 and will not reflect any changes made to the OverseerFM model or sub-models made since then.

Page Bloomer Associates was contracted to:

1. **Characterise processes occurring on commercial vegetable farms, particularly in the Horowhenua area.**
- Produce a typical annual cycle of processes and develop an understanding of the inputs into the system, including fertilisers. This stage will also include a review of 'best practice' operations.

2. **Provide Overseer modelling for three to four different cropping scenarios to help characterise potential nutrient losses from 'typical' farms in the area.**
- Practices on these farms have changed within the past 18 months to 2 years, and the scenarios will include the following:
    - Historical scenarios (baseline) representing practices that took place two years ago (i.e. between 2016 and 2018). These will allow for temporal variability over the two years where required
    - Scenarios representing current practices. These will fall into two categories with one representing Overseer 'good practice' and a second representing a more detailed interpretation of the actual farming operations, to allow for limitations of Overseer.
- This work was to provide information on the expected, or potential, effect of commercial vegetable growing and will act as a benchmark against which the actual effects can be compared. The results were to be discussed with the growers to ensure that the assumptions behind the assessments are reasonable.

3. **Consider whether the existing practices that occur on the commercial vegetable farms in the Horowhenua area could be improved.**
- Provide commentary on practices being adopted by growers and areas where further improvements might realistically be considered.

We note OverseerFM consists of proprietary source code with a number of underlying "sub-models" details of which are not available to us, and which operate at coarse spatial and temporal scales. With this in mind, we have had to make many decisions on how best to operate the software and choose appropriate scenarios for input data. In addition, we note the present version of OverseerFM does not include many of the crop types grown in the study area.

In undertaking the above tasks, we have used data provided by the growers wherever possible in the belief that this project will be best achieved via use of actual information that is pertinent to, and derived from, horticulture in the region. We also considered theoretical data to cross-validate the modelling and considered outputs against results from our own research and consultancy. In a number of cases we checked grower records to determine the typical rates and timing of fertiliser applied.

The information presented in this report is restricted by a Memorandum of Understanding between Horizons Regional Council and Horticulture New Zealand that prevents us from disclosing information specific to any individual grower. Only representative information that is not grower specific can be made available. As the modelled scenarios include individual grower information, we have compiled outputs into a whole of catchment sum.

We recognise that land use for commercial vegetable production can be extremely variable, with different areas of land used in different ways at different times. This occurs within paddocks, from paddock to paddock and in and out of sub-catchments and changes seasonally and annually.

We modelled a range of crop rotations in each of three production system scenarios; an onion/potato rotation, brassica dominated fresh vegetables and intensive fresh vegetables.

To estimate catchment impacts, we applied the results on a pro rata basis according to cropped areas provided by growers and Horticulture New Zealand. The relative contribution of each has changed with a much reduced area in intensive fresh vegetables and relatively little change in area for the other scenarios. We have restricted areas of vegetable crops to those in the study area, covering the Hokio 1a and 1b, and northern edge of Ohau_1b Water Management Sub-Zones (WMSZ) (see Figure 1).

In the last 12 - 24 months there have been significant changes in growing practices, particularly responding to the new nutrient management requirements. Growers are moving from the 1984 fertiliser recommendations to those in the 2019 recommendations and are adopting the Nitrate Quick Test strip approach. Some are testing very regularly, generally before any fertiliser application, and adjusting fertiliser prescriptions accordingly.

The land area to which no fertiliser is applied has increased significantly. About 40% of cropped area has greatly increased areas of headland and half now has crop-free tramlines for irrigation, spraying and harvest lanes. Growers have retired land and shifted crops out of the catchment.

To understand the likely load entering ground water before present we have modelled scenarios using typical crop rotations, fertiliser practices and areas as they were in years prior to 2019 ("old practice"). To compare this with the likely load in the future we repeated this using the practices growers report they use now and will use in the future ("new or good management practice").

We have compared new practice with recommendations in the 2019 guidelines, "*Nutrient Management for Vegetable Crops"*. In general, we find growers often using less fertiliser than the new guidelines might suggest as good practice. In about half of cases, our OverseerFM modelling shows a crop nitrogen deficit. Where we identified potential to further reduce nutrient inputs, we have modelled accordingly and reported future results reflect this.

We have been forced to make many assumptions. The assumptions and their rationale are described in the following sections. Importantly we note that soils in the area are not mapped, many crops grown are not included in OverseerFM, and there is not always a logical substitute available in OverseerFM so some alternative must be selected.

We also identify that including grass in a rotation appears to generate unrealistically high levels of crop nitrogen accumulation and subsequent leaching. Therefore, as described we have replaced grass with forage oats which tends to generate numbers that seem more plausible. This is considered in more detail in Section 5.4.

3 Vegetable Growing Areas Used in Modelling

The area selected for this study is focused on the ground water catchment for Lake Horowhenua. The majority of the vegetable growing is located on the flatter parts of the Arawhata Catchment south-east of Levin. The area includes Hokio 1a and 1b, and northern edge of Ohau_1b and extends from the Ohau River to Lake Horowhenua with vegetable growing sited on the deeper silt loam soils.

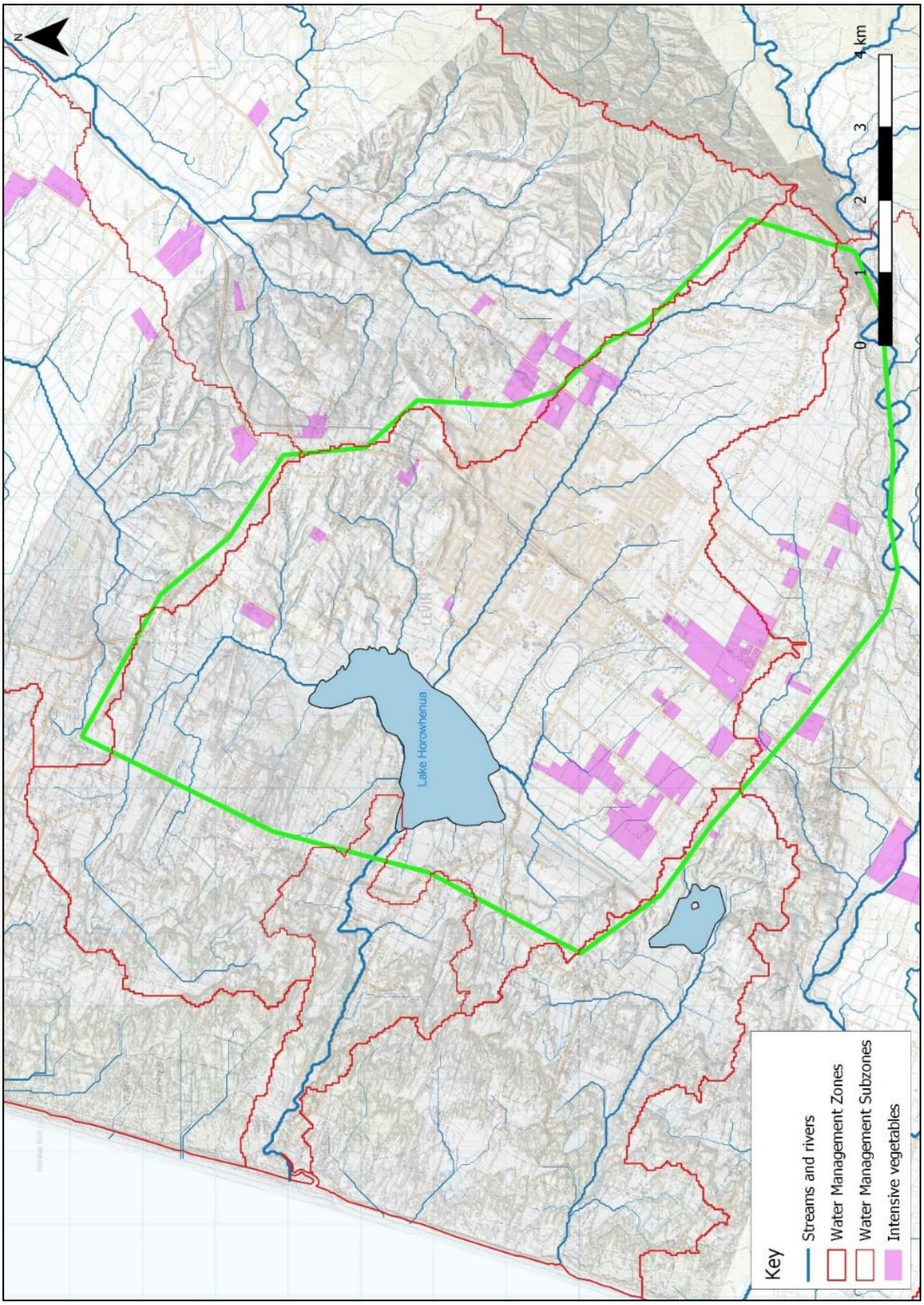


Figure 1 Location of Vegetable Growing within Water Management Sub-Zones around Lake Horowhenua

4 Details of Assumptions

We note OverseerFM consists of proprietary source code with a number of underlying “sub-models” details of which are not available to us, and which operate at coarse spatial and temporal scales. With this in mind, we have had to make many decisions on how best to operate the software and choose appropriate scenarios for input data. In addition, we note the present version of OverseerFM does not include many of the crop types grown in the study area.

Therefore, throughout data procurement, input and analysis, compromises and assumptions had to be made in order to enter suitable data into OverseerFM.

4.1 Cropped Area

These results apply only to the area of known vegetable production in the study area. We were supplied with details from the main eight growers who believe they represent 95% of all production in the area covered.

A vast array of potential crops, planting times and rotations are possible and realistically not all can be modelled.

Since 2019, the area in intensive fresh vegetables has reduced much more than brassicas or onion/potato rotations because some land is no longer used for cropping, headlands are much wider, and areas used for unplanted tramlines have increased. Therefore, the relative areas of each farm system scenario changed between pre- and post-2019.

We believe that pre-2019 there were 419 title hectares of which 90% or 377 hectares were cropped. Post-2019 the title area reduced by 9.5% to 379 ha, but the area with crops reduced by 20% to 302 ha or about 80% of title area cropped (Table 1).

Table 1 The extent and relative contributions of different vegetable farm system types pre- and post-2019

	Pre-2019		Post-2019	
Farm System Type	Title Area	Cropped Area	Title Area	Cropped Area
All Vegetable Areas	419 ha	377 ha	379 ha	302 ha
Intensive Fresh Vegetables		62%		52%
Brassica Dominant Rotation		11%		13%
Onion/Potato Rotation		27%		34%

The OverseerFM modelling has been completed assuming blocks have 100% of their area cropped. The catchment load is derived from the modelled losses from each block and each farm system scenario on a pro rata basis according to the actual area in crop once buildings, driveways, headlands and uncropped irrigator/sprayer alleys are deducted.

4.2 Crop Rotations

4.2.1 Onion/Potato Rotation

The onion/potato system typically sees each crop type grown for two years in a paddock before it switches to the other crop type for two more years. Planting and harvest dates, nutrient additions and yields vary according to variety and timing, so a range of scenarios were determined and modelled. The weighted average N and P losses were used to determine the resultant quantity of nutrient loss in total from the full cropped area.

The two year OverseerFM period may have onion-onion and potato-potato or onion-potato and potato-onion or some combination of these. We have compared the results of repeating and switching crops and get very minimal difference across the total modelled area.

We did identify that using the OverseerFM defaults for inter-crop annual ryegrass phases greatly increased the modelled leaching, even more so than if land was left fallow. In the modelling reported here, we substituted the grass with forage oats. This is discussed further in Section 5.4.

Figure 2 The modelled farm system scenario for onion and potato cropping as practised in Arawhata shows crops and dates in a range of representative blocks.

4.2.2 Brassica Dominant Vegetables

A significant part of the WMSZ is used to produce brassicas for year-round sales. To ensure sufficient crop is available every day, multiple smaller plantings are made approximately twice weekly. A degree of crop rotation is needed for disease management and some alternative crops are grown.

To fully represent this system, a rolling rotation with 36 variations was designed and twelve of these selected for OverseerFM modelling. These are weighted by crop area and harvest time to give a fair overall average leaching value for the scenario as a whole.

The same rotation is used for both pre- and post-2019 scenarios, but cropped area and fertiliser applied vary somewhat. We noted that if we split fertiliser into three or more applications, OverseerFM generated increased leaching values. This appears to be due to the OverseerFM algorithm assuming the crop finishes growing and stops taking up nutrients so later fertiliser applications enter the soil nitrogen pool and are subsequently wasted. The experience of growers, published trial results and best practice recommendations suggest otherwise. This is discussed further in Section 5.3.

Block	3	5	7	11	13	15	19	21	23	27	29	31
Oct		Cauliflower									Pumpkin	
Not												Cabbage
Dec							Broccoli			Lettuce		
Jan				Cabbage		Lettuce			Cauliflower			
Feb	Broccoli											
Mar			Lettuce		Cabbage			Celery		Cauliflower		
Apr		Broccoli										
May						Cabbage					Cauliflower	
Jun												
Jul			Broccoli				Onion					
Aug												Cauliflower
Sep	Lettuce								Potato			
Oct				Cauliflower						Pumpkin		
Nov												
Dec		Lettuce			Cauliflower	Broccoli		Cabbage				
Jan	Cabbage										Broccoli	
Feb			Lettuce									
Mar		Broccoli					Cauliflower					Leek
Apr				Lettuce								
May									Cauliflower	Cabbage		
Jun					Lettuce							
Jul			Onion								Lettuce	
Aug						Cauliflower		Broccoli				
Sep	Potato			Cabbage								

Figure 3 The modelled farm system scenario for Brassica dominant cropping as practised in Arawhata shows crops and dates in a range of representative blocks.

4.2.3 Intensive Fresh Vegetables

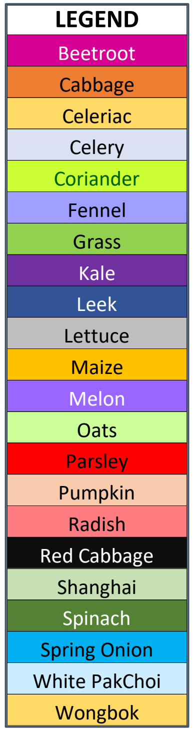
The Intensive Fresh Vegetables scenario is the most complex with numerous crops and multiple sowings and plantings to meet daily market demands. This scenario has also seen more significant change since pre-2019.

The introduction of tramlines has increased average planted-area yields, the amount of fertiliser used is much reduced, there has been a reduction or removal of some crop types, and catch-crops (maize, grass and oats) have been introduced. Because of these changes, two related but significantly different scenarios were modelled, one pre-2019 and one post-2019.

The post-2019 scenario is based on actual grower planting plans for the 2019-2022 period, block by block and planting by planting. To model this in detail in OverseerFM we would need to create hundreds of blocks of 0.1 – 1.0 ha each. Once plantings were clumped into months and some other rationalisation was done, 38 different blocks representing different crops and rotations were identified and modelled.

These 38 blocks were adjusted for the pre-2019 scenario, replacing catch-crops with fresh vegetables or fallow. Replacement crops were selected from the other fresh vegetables grown according to grower advice of historic practice. Yields and fertiliser applications were adjusted to reflect changes between pre- and post-2019.

Figure 4 PRE-2019 Intensive Fresh Vegetable Rotations



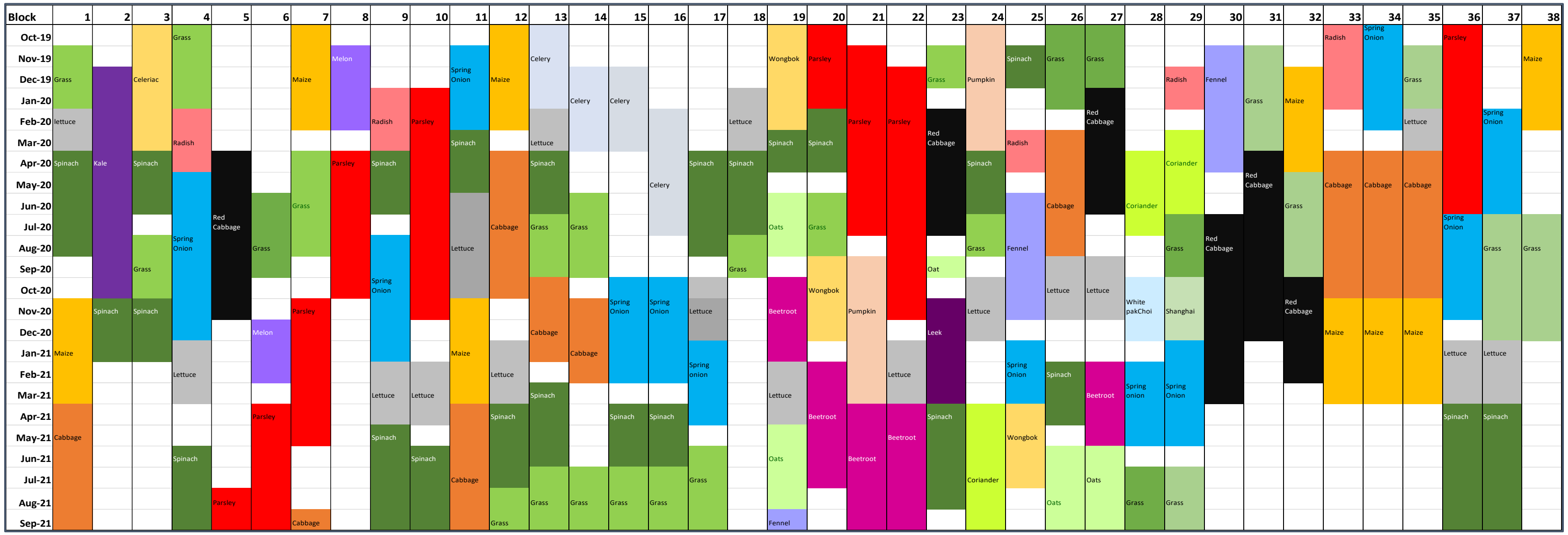


Figure 5 POST-2019 Intensive Fresh Vegetable Rotations

4.3 Crop Assumptions

Many vegetable crops grown are not included in the OverseerFM options so surrogates must be chosen. When selecting surrogate crops, we considered information from other sources including "*Nutrient Management for Vegetable Crops in NZ*"[1] and the UK Agriculture and Horticulture Development Board "*Nutrient Management Guide (RB209)*"[2]. A first option was to select a surrogate from the same family, but in some cases the actual crop has very different growth form and yield and different plant parts are harvested. In such cases, a closer representative was selected.

Between-crop pasture phases are a particular issue. The defaults from OverseerFM can produce crop nitrogen accumulations of 200 – 350+ kg N/ha which is much higher than our other experience shows. The excess accumulation and grower applied nutrients together predict higher leaching than should be expected. We therefore substituted grass with forage oats which generates nitrogen values of 60 - 100 kg N/ha and results from subsequent-crop balances that are more plausible. (See also section 5.4)

Table 2 Actual crops grown, the surrogate crops selected in OverseerFM and rationale for the selection

Actual Crop	Overseer Crop	Reason for crop choice	Notes
Annual Ryegrass	Forage Oats (Autumn)	Plant type - grasses	Representative N Uptake
Celeriac	Parsnips	Swollen Stem	Similar harvest index
Celery	Spinach	Petiole/leaf	Similar harvest index
Coriander	Spinach	Petiole/leaf	Significantly lower yield
Fennel	Parsnips	Plant family	Similar harvest index
Kale	Kale (Forage)	Plant family	Default yield
Leek	Onion	Plant family	Lower harvest index
Parsley	Spinach	Petiole/leaf	Similar harvest index
Pumpkin	Squash	Plant family	
Radish	Beet	Swollen stem	Similar harvest index
Red Cabbage	Cabbage	Plant type	
Rockmelon	Squash	Plant Family	
Shanghai	Cabbage	Plant family	Default yield
Spring Onion	Onion	Plant family	Similar harvest index (RB209 Guide)
Watermelon	Squash	Plant Family	
White Pak Choi	Cabbage	Plant family	Default yield
Wong Bok	Cabbage	Plant family	Default yield

4.4 Yield Assumptions

The Product yield is the harvested yield removed as product, such as grains or vegetables at harvest. It is the fresh weight of product that is harvested. In OverseerFM, the User either enters the product (crop) yield, or if not entered, then the typical crop yield (default yield) will be used. It is important that the product yield is entered consistently each year, so that you are comparing like with like.[3]

[1] JB Reid and JD Morton 2019
[2] https://ahdb.org.uk/nutrient-management-guide-rb209
[3] Sluys, C. 2020. Email from Carly Sluys, Overseer Limited. Carly@overseer.org.nz Wed 5/02/2020 1:09 PM

The base scenarios presented in this report use the OverseerFM defaults. For default yields, we selected summer (planted October – January) or winter/spring crop (planted February – September) where this is a relevant OverseerFM option.

Sensitivity scenarios used All Default yields and All Grower yields (where grower yields are known) (see Section 6.1) and a combination of the higher of Grower Reported yield or the OverseerFM defaults. A fourth scenario compared ryegrass and forage oats as cover crops (see Section 5.4).

4.5 Soil Assumptions:

Levin currently has no S-Map soil map layer. There are various indicated soil distributions, so advice was sought. The S-Map soil definitions used follow recommendations from Prof. A. Palmer who has made several local surveys including transects across the Pescini property on Kimberley Road and on the Woodhaven Gardens properties along CD Farm Road. He reports that soils do vary but are predominantly Waitohu at Pescini's and Shannon or Levin at Woodhaven Gardens. For modelling, we therefore deemed a soil change at the State Highway.

The onion/potato rotation was modelled using Waitohu deep silt loam – (Moko_2a.1) with the drainage class changed from imperfect to moderately well drained. We adjusted ASC to 60 based on results of soil tests we have had from other work on these properties.

The intensive vegetable and brassica rotations were modelled on a Shannon deep silt loam (Paha_29a.1) with the ASC changed to 25. ASC modifications were made based on past detailed soil tests indicating higher ASC content that suggested by the S-Map factsheets.

Alternative soil options are Levin deep silt loam or Levin deep silt loam on sand (Levi_1b.1 and Levi_4a.2). The proportion of cropping that might fall on these soils is unknown. Their leaching potential is lower than the two soils used for modelling for this report, so our results may over-estimate losses by some margin on some of the area.

5 Modelling Issues

Modelling cropping systems in Overseer had some technical difficulties due to limitations of the model. Some technical difficulties came with crop types and yield definitions. Overseer has a limited range of crops with unclear definitions of yield: total biomass grown, harvested plant part, exported plant part. Similarly, the portion of plant biomass returned as residues to the soil is not clear. In one instance, we noted that changing a Summer Cauliflower to a Winter Cauliflower at a critical period changed predicted N loss by 40% for that block.

5.1 Yield/Weight Definition

The Overseer model will give different results when different yields are entered. Unfortunately, growers' definitions of yield can vary greatly. Yield errors are further compounded when trying to fit actual crops to similar OverseerFM recognised crop types e.g. Asian brassicas to a cabbage or cauliflower crop based on a similar harvest index, but substantially lower yields.

To give repeatable results, yield needs to be entered consistently by all users. When there is disagreement on how yield is to be entered, there is a lower level of certainty around the accuracy of the modelled scenarios. Yield is typically defined as typical harvest portion of the crop. OverseerFM only has models for a small range of generic crops for which it has default yields. When substitute crops are used, yields entered can be widely different to the crop default yields. To give repeatable results, there needs to be further information for defining yield for each crop to allow correct entry of the correct plant parts.

5.2 Using Surrogate Crops in Overseer

Surrogate crop selection and choice of yield is crucial for accurate modelling as the crop growth is utilising the nitrogen in the soil profile. There are four aspects to the nitrogen utilisation in crop: N% in the crop and total biomass grown, which together make up the total nitrogen uptake by a crop, and the harvest index which will express how much of the accumulated nitrogen will be returned to the soil in the crop residues.

When considering crop selection, we placed priority on matching crops within similar crop types, but also tried to select a surrogate crop for the crop specified that had a similar harvest index. Previous work near Pukekohe has shown a considerable proportion of N leaching in leafy green production systems comes from mineralisation of crop residues[4]. We realise this is a key weakness in OverseerFM when considering surrogate crops.

For example, a Leek crop has an estimated harvest index of 57% versus 81% for the likely surrogate crop Onions[5], while a Spring Onion has the same harvest index of 81%. In the yield sensitivity cases 3 and 4 (see section 6.1), we have used adjusted yields for Spring Onion, Leek and Coriander. This did increase modelled leaching, mostly due to the large area of Spring Onions grown at lower yields than the onion default.

Table 3. Nitrogen Accumulation in Crops Comparing Expected N uptake based on RB209 with OverseerFM Defaults, and an adjusted yield to achieve the same N uptake as RB209

Actual Crop	Expected N uptake from RB209 (kg N/ha)	Surrogate Crop Used in OverseerFM	OverseerFM Default Yield (t/ha)	OverseerFM N uptake by default (kg N/ha)	Surrogate Yield that achieves expected N uptake of actual crop (t/ha)
Spring Onion	114	Onion	70	155.9	51.1
Leek	279	Onion	70	155.9	125.3
Coriander	25	Spinach	22	41.5	13.2

**Expected N uptake based on RB209 Guidelines. Grower yield used for Coriander with RB209 N%.*

5.3 Nutrient Uptake

The need to enter grower operations by month in Overseer leads to simplification of crop plans. This can result in a crop that grows for 14 weeks appearing to be in the ground for 5 months (20 weeks) if users are entering data from crop diaries.

Nitrogen leaching increased when we modelled best practice fertiliser management recommendations to split fertiliser applications at 50kg N/ha/application, spread monthly to match crop demand. This appears due to the limited monthly time-step in the OverseerFM model predicting that N uptake is complete when additional fertiliser is applied. In reality, the plants are still actively growing and taking up nutrients. This OverseerFM modelling appears to assume excess fertiliser goes into the soil mineral-N pool and increases leaching risk over the winter period.

[4]Francis G, Trimmer L, Tregurtha C, Williams P, Butler R 2003. Winter nitrate leaching losses from three land uses in the Pukekohe area of New Zealand. New Zealand Journal of Agricultural Research 46(3): 215-224.
[5] Agriculture and Horticulture Development Board, 2020. Nutrient Management Guide (RB209) via https://ahdb.org.uk/nutrient-management-guide-rb209

5.3.1 Case Study: Split Fertiliser Application and N Uptake for Crops in OverseerFM

Take as an example, a crop of winter cabbages planted on the 22nd March as illustrated in Figure 6, Figure 7 and Figure 8.

The crop has an estimated harvestable yield of 68t/ha in the first weeks of August. The soil has 110 kg N/ha on the potential nitrogen test. Following the fertiliser advice from the Nutrient Management for Vegetable Crops in New Zealand guidelines[6], the grower applies 134 kg N/ha.

Typically, the grower applies half the fertiliser 4 weeks after transplanting and the remainder 4-6 weeks later as the crop is rapidly growing.

When modelled in Overseer, N losses of 106 kg N/ha are reported when the grower splits fertiliser applications but N losses of 95kg N/ha if all the fertiliser was applied on the first application in April.

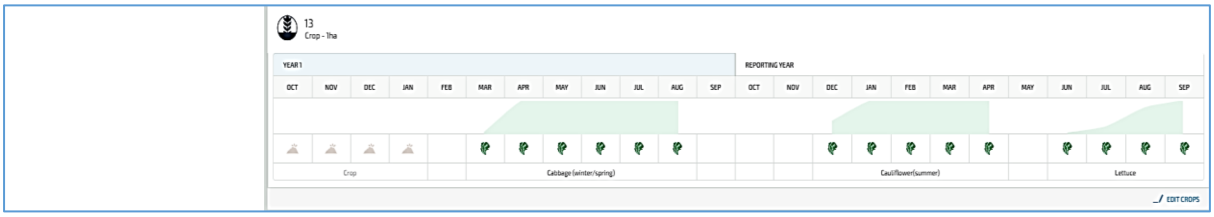


Figure 6. Block 13 Crop Rotation

Figure 7. Split fertiliser application in April/May of first year (106 kg N/ha leached)

Figure 8. Single fertiliser application in April of first year (95 kg N/ha leached)

Figure 9 and Figure 10 show the two fertiliser strategies. The Y-axes are kg N/ha, the X-axis months. Key chart lines are labelled in the diagrams. Note the colours are not consistent between the top and bottom of each pair which show slightly different things. The top of each pair shows nitrogen pools. The bottom shows change in nitrogen pools. In the top chart, the Residue Stover N (blue line) is for the residue of the whole plant. In the bottom chart, the Residue (yellow line) is for the N mineralisation of the plant residues reported as kg N/ha/month.

[6] Reid, JB and Morton, JD. 2019. "*Nutrient Management for Vegetable Crops in NZ*" Horticulture New Zealand

5.3.1.1 Results of OverseerFM Modelling of Single and Split Fertiliser Applications

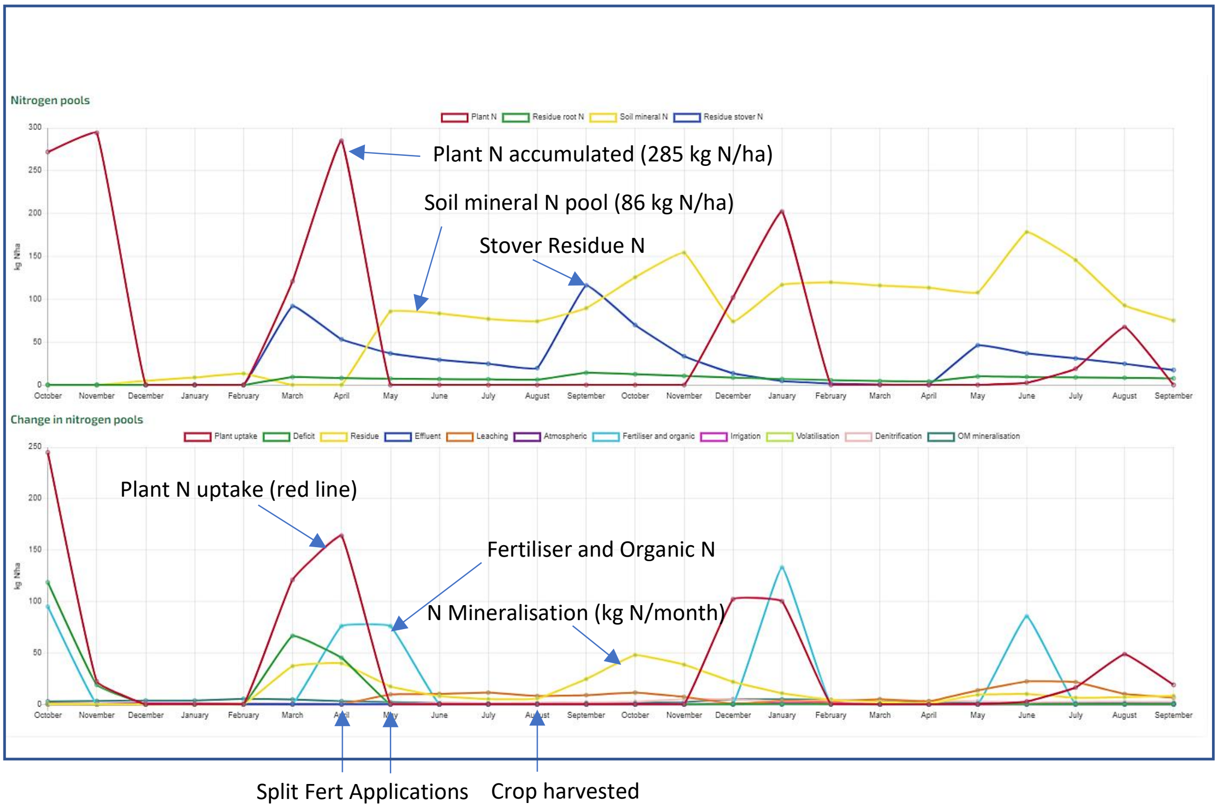


Figure 9. OverseerFM Nitrogen Graphs for Split fertiliser application (106 kg N/ha leached)

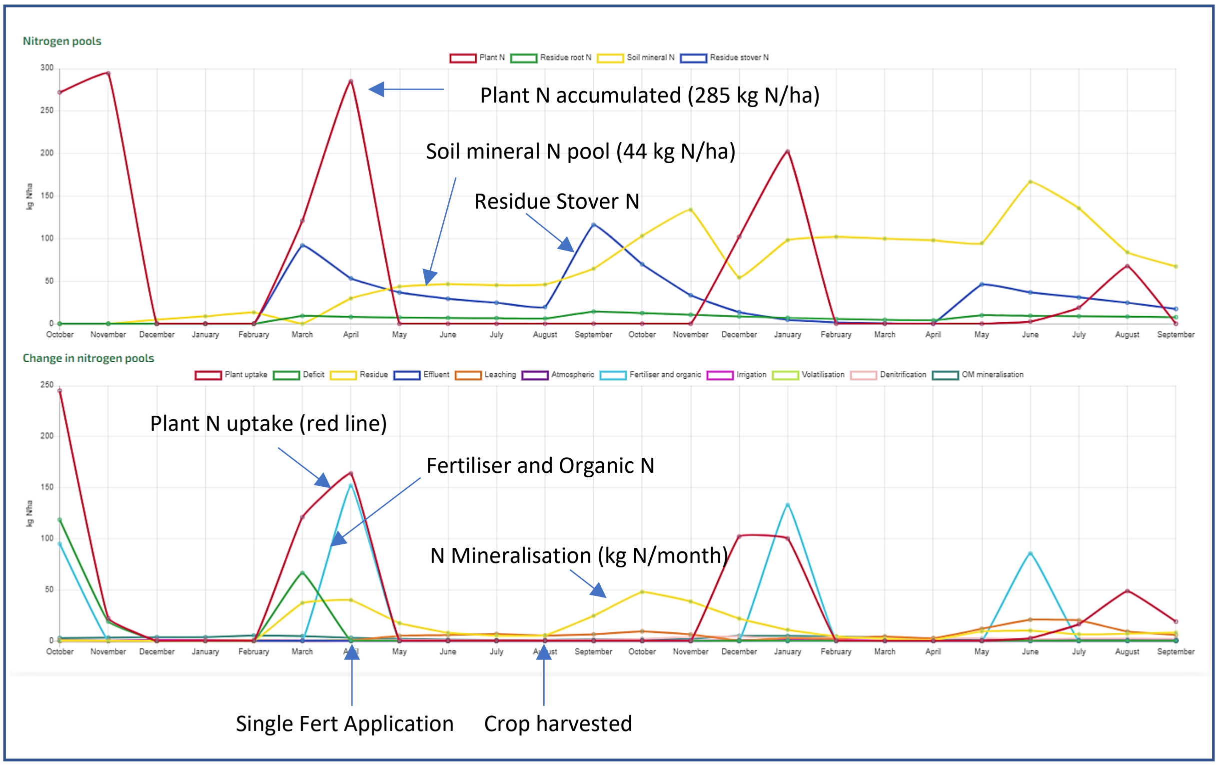


Figure 10. OverseerFM Nitrogen Graphs for single fertiliser application (95 kg N/ha leached)

5.4 Annual Ryegrass: Use of Ryegrass or an Alternative

Good grower practice is to plant cover-crops on ground that will be bare in winter. The current practice for some growers is to plant an annual ryegrass and to either graze over winter with lambs or to incorporate the grass residues to build soil organic matter.

When we enter annual ryegrass in OverseerFM, the model estimates very high plant uptake (200-350+kg N/ha) when either default grazing or estimated grazing concentration is used. When the annual ryegrass crop is terminated, the crop residue mineralises rapidly and causes a large increase in the soil mineral N pool. When the subsequent crop is grown, only a small portion of the resulting soil mineral N pool is used. During the following winter period, modelled leaching rates are high – caused by the elevated soil mineral N pool.

To avoid excessive N leaching from unrealistic N plant uptake results, in our analysis the actual planted ryegrass was modelled as Forage Oats (Autumn sown) which we believe gives a more realistic N uptake by the growing crop. When inputting forage oats into OverseerFM, the yield as tonne/ha dry matter is entered. If the crop was in the ground for 3 months or less, yield was entered as 4 t/ha. If crop was in the ground for 4 months or more yield was entered as 6 t/ha. The crop was terminated with cultivation. This generates nitrogen uptake values of 60 to 100 kg N/ha. This is less than the 134 kg N/ha for ryegrass reported by Plant and Food Research in estimates for uptake of winter grown ryegrass cover crops. Given the crops we are modelling are typically terminated earlier than those in the Plant and Food study, the lower levels we used seem reasonable.

For the Ryegrass or Oats case, we believe further work is required to quantify the accuracy of the OverseerFM model. In the context of fresh vegetable cropping rotations, we believe that the Annual Ryegrass model is causing N leaching to be overestimated but we cannot be sure because we have no knowledge of how the model operates.

In brief, our observation of modelled results suggests a leaching excess is being created in the model due to high N uptakes in ryegrass rapidly decomposing and leaving large quantities on nitrogen in the soil mineral nitrogen pool with subsequent increased leaching whenever drainage events happen. If the significant accumulation of nitrogen in ryegrass shown by OverseerFM is accurate, the increased losses modelled could be correct within the expected errors of the model.

5.4.1 Case Study: OverseerFM Reporting of Nitrogen Accumulation for Annual Ryegrass

Annual ryegrass is regularly grown over the winter period and either grazed by lambs or incorporated prior to the following crop. In the following case study of Annual Ryegrass planted in July and incorporated in November, the modelled crop in OverseerFM accumulated 379 kg N/ha using the default growth (see Figure 11). This was much higher than expected.

When forage oats with a DM accumulation of 6t/ha dry matter was modelled, nitrogen accumulation in the crop was 86kg N/ha (see Figure 12). The modelled yield was entered on the lower end of potential yields because in the high intensity vegetable cropping system, catch crops are often incorporated early so as to prevent excess residue issues with either bed preparation or seedling transplanting. This level of nitrogen accumulation is lower than suggested for either ryegrass (134 kg N/ha) or oats (112 kg N/ha) when the catch crops were grown for a full five months[7].

[7] Johnstone PR, Wallace DR, Arnold N, Bloomer D 2011. Holding it together – soils for sustainable vegetable production. A Plant & Food Research report prepared for Horticulture New Zealand. SPTS No. 5756.

5.4.1.1 Results of OverseerFM Modelling of Annual Ryegrass versus Forage Oats

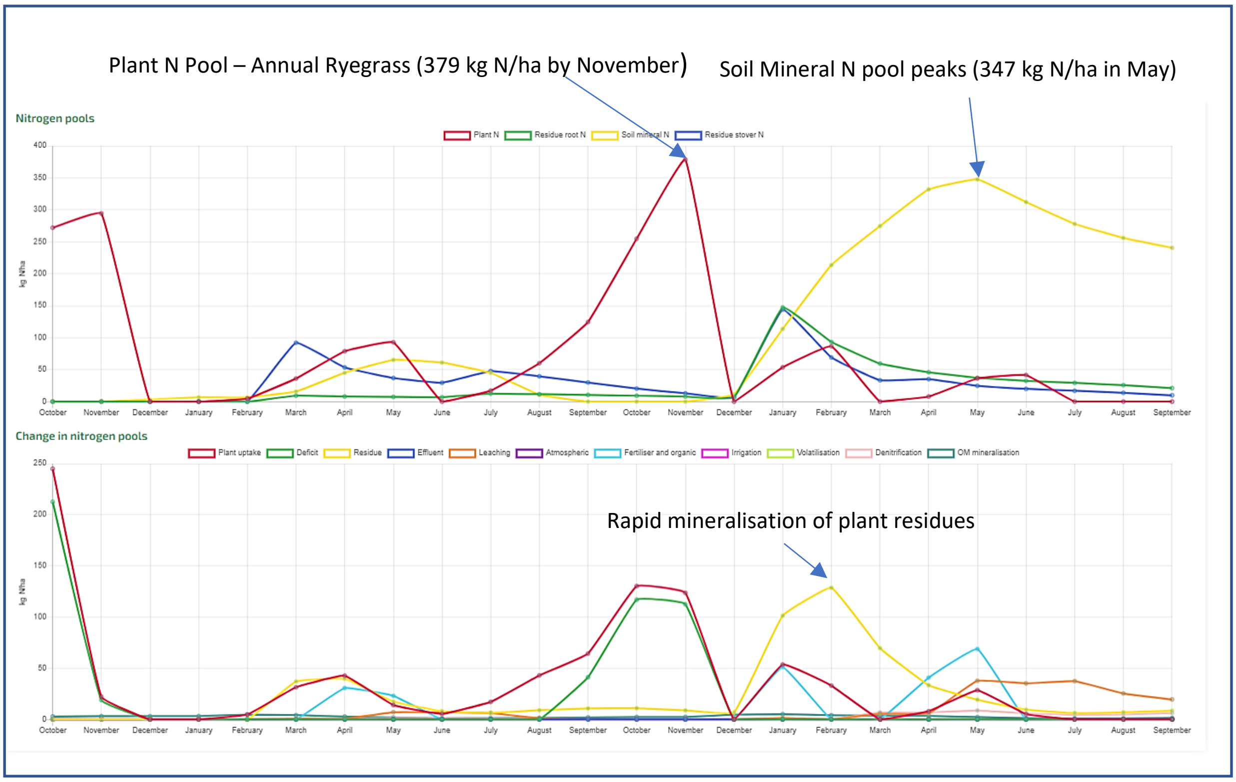


Figure 11. Nitrogen Pools with Annual Ryegrass grown

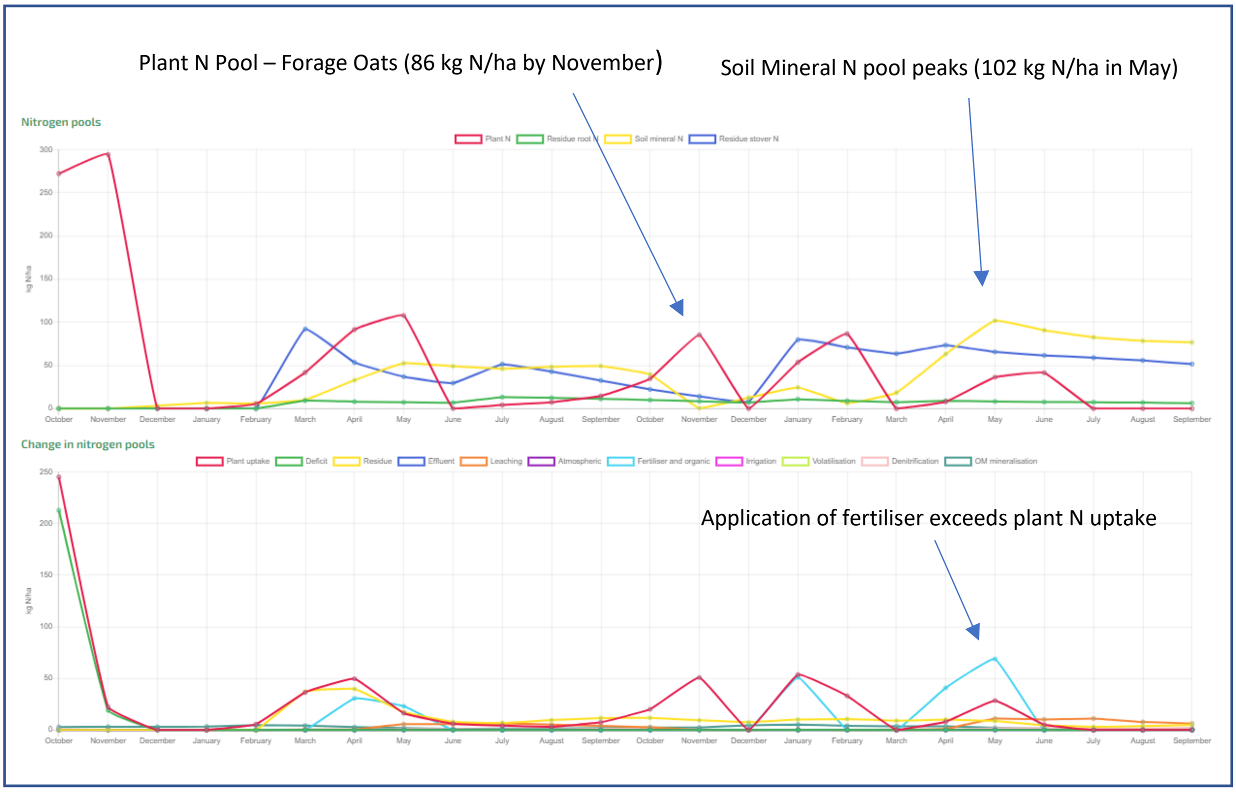


Figure 12. Nitrogen Pools with Forage Oats grown

Figure 11 and Figure 12 show the changes of N pools. Following incorporation of the ryegrass crop, the crop residue rapidly mineralises contributing to a high soil mineral N pool in May (347kg N/ha).

This led to leaching losses of 169 kg N/ha. Following the oats, mineralisation of the crop residue pool was not as large. The soil mineral N pool peaked in May (102 kg N/ha) is caused for the most part by excess fertiliser applications in April and May. The lower soil mineral N concentrations in the second example (Figure 12) led to just 51 kg N/ha leaching from the root zone.

An Observation About Spinach Modelling in OverseerFM

We note the majority of leaching from the second example (Figure 12) was due to a high level of soil mineral pool N associated with the spinach crop grown in April – September (early winter). OverseerFM shows the spinach crop accumulated just 42 kg N/ha. The Nutrient Management for Vegetable Crops in New Zealand booklet[8] would suggest an accumulation of 108 kg N/ha for a 22 t/ha marketable crop, while work in Europe[9] suggests N uptakes of between 124-141 kg N/ha.

Due to the low modelled N uptake in OverseerFM, it appears an excess of 68 kg N/ha fertiliser was applied (See Figure 12). Using a higher yield for spinach of 58 t/ha to achieve nitrogen uptake of 109 kg N/ha (equivalent to the New Zealand vegetable guidelines) the actual applied fertiliser rate is reasonable, and the OverseerFM modelled leaching for the block reduces from 51 kg N/ha to 25 kg N/ha.

6 Results of Modelling

When we determined our policy for entering yield, we had difficulty in identifying how yield should be measured and entered in Overseer. We modelled yield four different methods in an attempt to measure how sensitive the results were to the entered yield information. Due to constraints posed by the MoU we are unable to share actual nutrient loss numbers by scenario for each yield definition, but instead offer variation as % of the values for OverseerFM default yields.

6.1 Sensitivity Testing

6.1.1 Four Cases

Default Yield	Overseer Defaults for crop selected
Higher Yield	Default Yield or higher - large proportion of crops had higher estimated yields
Est Actual	Overseer Defaults for crop selected or as table below for Spring Onion, Leek, and Coriander, along with Potato Rotation being actual yields
Ryegr Est Act	Est Actual Scenario was duplicated except for Annual Ryegrass was modelled as annual ryegrass – it had previously been substituted for Oats.

In the first case (*Default Yield*), we have modelled all the blocks using only the OverseerFM default yields. This resulted in many crops having lower yields than reported by growers in the study.

The second case (*Higher Yield*) we modelled all the crops as either having the OverseerFM default yield or higher as reported by the grower.

The third case (*Est Actual*) is a hybrid and was run to test the effect of using lower yields than OverseerFM defaults where they are likely to occur. We used the grower reported yields for the Onion/Potato rotation because we have a high degree of confidence in the accuracy of these yield estimates. For the Brassica rotation, there was less confidence in the provided measurements and the definition of yield, so the OverseerFM default yields were used. For Intensive Vegetable we also

[8] Reid, JB and Morton, JD. 2019. “*Nutrient Management for Vegetable Crops in NZ*” Horticulture New Zealand
[9] Feller, C., Fink, M., Rather, K., Laber, H., Strohmeyer, K., and Ziegler, J. 2013. Düngung im Freilandgemüsebau. In: Fink, M. (Hrsg.): Schriftenreihe des Leibniz-Instituts für Gemüse- und Zierpflanzenbau (IGZ), Heft 4, 4. Auflage. Großbeeren 2013, ISBN 1437-3394

have some reservations on reported yields and grower definition of "product" and there are surrogate crops. In this case we have used OverseerFM default yields where available. The three surrogate crops Spring Onions, Leeks, and Coriander were identified as having significantly different N uptakes compared to the crops they replaced. In this case the yields have been modified to represent a nitrogen uptake closer to those suggested in the RB209 guide[10] for Leeks, Spring Onions, and Coriander (see Table 3). Spring Onions were a common crop through many blocks. Leeks and Coriander were present in only a few blocks. For the Coriander, the grower yield was used.

The fourth case (*Ryegr Est Act*) duplicated scenario 3 (*Est Actual)* except annual ryegrass was entered where the growers had planted an annual ryegrass. For the previous scenarios, oats had been substituted for annual ryegrass as there appeared to be unrealistic nitrate balances when Annual Ryegrass was entered in OverseerFM (see Section 5.4).

6.1.2 Results of Sensitivity Testing

Default Yield versus Higher Yield

While for many crops OverseerFM default yields were significantly lower than grower reported yields, this had a small impact on the Pre-2019 scenario total. Using the higher of default or grower yields reduced the total modelled kg N/ha leaching by 3%. It increased modelled leaching for the Post-2019 scenario total by 2% due to a large increase in N leaching from the Intensive Vegetable Rotation. This was due to higher brassica yields, which left more nitrogen in residues which in turn were mineralised and entered the soil mineral N pool. The modelled blocks were often left fallow and the mineral N was available to leach in the autumn winter period. This did not occur in the brassica rotation which had more rapid replanting and nutrient uptake rather than fallow.

Default Yield Versus Estimated Actual Yields (EstAct)

Reducing yields of the surrogate crops in the first two scenarios and specialty crops in the last scenario does reduce yields further, but the difference is still relatively minor, increasing total leaching relative to the Default Yield by 2% for Pre-2019 and 3% for Post-2019.

Default Yield versus Estimated Actual Yields with Ryegrass cover crop rather than Oats (Ryegr EstAct)

The last case shows the choice of crops to represent ryegrass planted in the rotations does significantly affect calculated losses. Note that in the Pre-2019 scenario, only the potato/onion scenario has ryegrass established. In the Post-2019 scenario, the Intensive Vegetable Growers have also adopted ryegrass as a cover crop as part of the crop rotation in about 20% of paddocks used in our scenario modelling. The modelled total nitrogen leaching relative to the Default Yield scenario increases by 7% for Pre-2019 and 32% for Post-2019.

The results comparing cases are summarised in Table 4.

[10] Agriculture and Horticulture Development Board, 2020. Nutrient Management Guide (RB209) via https://ahdb.org.uk/nutrient-management-guide-rb209

Table 4. N Leaching Sensitivity

	Pre 2019				Post 2019			
Scenario	Default	Higher	Est Actual	Ryegr/Est Act	Default	Higher	Est Actual	Ryegr/Est Act
Intensive Vegetable	100%	97%	102%	102%	100%	107%	103%	140%
Brassica	100%	93%	97%	97%	100%	92%	96%	96%
Onion/Potato	100%	100%	111%	151%	100%	100%	111%	151%
Total	30,625	29,590	31,374	32,816	17,259	17,567	17,825	22,742
% Change	100%	97%	102%	107%	100%	102%	103%	132%

6.2 Nitrogen Loss

The total amount of nitrate-N lost by leaching from the vegetable growing areas in the study area was calculated to be between 29.59 -32.82 tonnes pre-2019 and 17.26 – 22.74 tonnes post-2019. Comparing same cases, this is a reduction of 31-44%.

Over all blocks, leaching of nitrogen dropped from 71-78 kg N/title ha to 46-60 kg N/ title hectare as modelled by OverseerFM.

6.3 Phosphorous Loss

The total amount of phosphate-P lost by leaching from the vegetable growing areas in the study area was calculated to be 0.66 tonnes pre-2019 and 0.43 tonnes post-2019. This only considered the default case and is a reduction of 35.2%. This reflects the reduction in intensive vegetable land cropped, phosphate fertilisers applied in winter and an increase in non-fertilised catch-crops.

Our confidence in phosphate-P results is reduced, as OverseerFM default values were used for soil fertility rather than actual soil test values for each block. Also, the ASC of these soils may be higher than the amended value we used for modelling.

Over all blocks, losses of phosphate-P dropped from 1.6 to 1.1 kg P/ title hectare.

7 Discussion

We have used OverseerFM to estimate nutrient losses from fresh vegetable production but acknowledge it appears to have some shortcomings. We have considered different input policies for yield and substitute crops and find they generate slightly different leaching tonnages but, with the exception of winter ryegrass, consider the variation well within the expected error of models such as this. Our data entry choices are outlined in Section 4 of this report and we consider them reasonable. Provision of agreed data input standards would reduce the risk of different users generating significantly different results for the same or similar production scenarios.

We question the nitrogen uptake timing and accumulation apparent in some OverseerFM sub-models and are concerned by the leaching numbers generated in some situations. For example, winter ryegrass appears to accumulate too much N from unexplained sources and then release it increasing leaching. Spinach does not accumulate enough N, so an apparent fertiliser excess is available for leaching.

Many vegetable crops grow large amounts of biomass and do take up significant quantities of nitrogen (>200kg N/ha). A primary issue when growing vegetable crops is crop residue management. Crop residue breaks down and releases significant quantities of mineral N into the soil profile, but the timing is dependent on soil temperature and moisture and there is little certainty when that nitrogen might be in a plant-available form (soil mineral N pool).

Our observations are that growers in Levin are generally efficient with their fertiliser use and with current knowledge and technology there are few opportunities to significantly reduce rates of N applied without increasing the risk of crop failure. In most cases, current applications are near or below those recommended in the latest science based nutrient management guidelines. Some growers are using catch crops to remove excess N from the soil, and other growers are planning to introduce catch crops where their crop rotations allow.

Levin's climate and soils provide good winter growing conditions for many vegetable crops. If soil mineral N levels coming into winter can be minimised through good crop residue management and catch crops, winter crops will leach significantly less nitrogen. Winter/Spring crops could require increased fertiliser inputs as the soil supply of nutrients will be reduced, but the timing of these applications can be targeted to match plant requirements and minimise leaching risk.

8 References

8.1 Publications

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Reid, JB and Morton, JD. 2019. "*Nutrient Management for Vegetable Crops in NZ*" Horticulture New Zealand

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8.2 Personal Communications

Crop areas planted, rotations, yields, dates and fertiliser practices

- Jay Clarke, Woodhaven Gardens, Levin
- Chris Pescini, Pescini Bros, Levin
- Travis and Nigel Sue, B S Young, Levin
- John Young, Levin
- Jeffery Wong, Levin
- Chung Sue, Garden of York, Levin
- Harry Su, Levin
- Harry Li, Levin

Recommendations for OverseerFM input values

- Dr David Horne, Massey University
- Prof. Alan Palmer, Massey University

Appropriateness of Scenarios and OverseerFM assumptions

- Stuart Ford, Agribusiness Group
- Charlotte Irving, Agribusiness Group

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