BEFORE COMMISSIONERS APPOINTED
BY THE WAIKATO REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the First Schedule to the Act
AND	
IN THE MATTER	of Waikato Regional Plan Change 1 - Waikato and Waipā River Catchments and Variation 1 to Plan Change 1
AND	
IN THE MATTER	of submissions under clause 6 First Schedule
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

BRIEF OF EVIDENCE OF JANE MARIE CHRYSTAL
9 May 2019

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QUALIFICATIONS AND EXPERIENCE

1. My name is Jane Marie Chrystal.

2. I am currently employed by Beef + Lamb New Zealand Ltd as Senior Environment Data Analyst. I began in this role in April 2018.

3. I hold a Doctor of Philosophy (PhD) degree in Soil Science from Massey University (2017), a postgraduate diploma in Agricultural Science (Massey University, 2011), and a Bachelor of Applied Science majoring in Agriculture (Massey University, 2000). I have a certificate in Advanced Sustainable Nutrient Management (Massey University, 2007).

4. My area of expertise is the loss of nutrients and contaminants from pastoral farming systems. I have over 12 years' experience in specialising in farm systems analysis, farm system modelling and optimisation and soil science and nutrient management.

5. I gave evidence for Beef + Lamb New Zealand Ltd (B+LNZ) as part of its case on the Hearing Stream 1 (HS1) topics. In my HS1 evidence, dated 15 February 2019, I set out my qualifications, current employment and employment history and professional affiliations. I confirm those details remain current.

6. In addition, I was a member of the Technical Working Group (November 2018 – April 2019) formed by the GMP Implementation Working Group involved in work on Plan Change 5 ("PC5") to the Environment Canterbury Regional Council ("ECan") Land and Water Regional Plan. This group was tasked with investigating issues identified with the fertiliser and irrigation proxies used in the ECan Portal.

7. In preparing this evidence I have reviewed:

   (a) The reports and statements of evidence of other experts giving evidence relevant to my area of expertise, including:

      (i) Mr Richmond Beetham;

      (ii) Dr Timothy Cox;

(iii) Dr Alison Dewes;

(iv) Dr Alec Mackay;

(v) Mr Richard Parkes;

(vi) Mr Simon Stokes;

(b) The Council Officers' section 42A report;

(c) Plan Change 1 and Variation 1; and

(d) The section 32 report.

8. I reconfirm that I have read the Code of Conduct for Expert Witnesses in the Environment Court's 2014 Practice Note and agree to comply with it. I confirm that the opinions I have expressed represent my true and complete professional opinions. The matters addressed by my evidence are within my field of professional expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

9. I have been asked by B+LNZ to prepare evidence in relation to the sheep and beef sector generally and the implications of Plan Change 1 and Variation 1 (PC1) to the sector in the Waikato.

10. I am aware of the directions of the Hearing Panel that it will allocate blocks of time for particular topics. This brief of evidence relates primarily to hearing stream 2 (HS2) and builds on the evidence provided for HS1.

11. I have been asked by B+LNZ to prepare evidence in relation to PC1's proposed management approaches to farming and nutrient management and its implications for pastoral land uses. In particular, I consider application of the Nitrogen Reference Point (NRP) and its effects on extensive farming systems. My analysis includes consideration of:

(a) How nutrient losses have changed over time in both the sheep and beef, and dairy industries.

(b) The use of OVERSEER® and grandparenting to 2014-15 or 2015-16 and the implications of grandparenting to those years.

(c) Providing analysis of case study farms that assesses the impacts on the financial performance of those farms were nitrogen leaching limits to be imposed.

(d) A summary of the input protocols for OVERSEER® that Waikato Regional Council ("WRC") has established compared with Best Practice Data Input Standards.

12. In relation to considering alternative approaches to managing nutrient losses from pastoral agriculture I have also considered the Nitrogen Risk Scorecard approach presented by Mr Richard Allen of Fonterra Co-operative Group Ltd in his Evidence-in-Chief for HS1.

13. I was also asked to provide an explanation of the soil orders in Waikato and the implications of different drainage characteristics.

EXECUTIVE SUMMARY

14. Sheep and beef farming intensity (stocking rate) has not increased over time. As presented in Mr Burtt's Evidence-in-Chief for HS1, since 1990 sheep and beef stocking rates have decreased from 14 to just under 12 stock units per ha (SU/ha).

15. Sheep and beef nitrogen leaching losses, as shown by OVERSEER®-predicted results for four farms that have been surveyed since 1993-94, show no trend of increasing N leaching loss, but are temporally variable, in that they fluctuate over time.

16. Stocking rate and N fertiliser applications of these four farms also show no increasing trend.

17. In contrast, the number of dairy cows in Waikato has increased – in both total numbers and stocking rate (cows/ha). Waikato dairy cattle numbers increased from 1.03 million in 2000-01 to 1.14 million in 2017-18 (peaking at 1.17 million in 2014-15) (DairyNZ, 2018).

18. Sheep and beef farmers farm to the pasture growth rate (PGR) curve. They use minimal nitrogen fertiliser and import no or minimal supplementary feed so their nitrogen leaching loss, which averages 17 kg N/ha/yr, is comparatively low when compared to other industries such as dairy, which has an average nitrogen leaching of 50 kg N/ha/yr.

19. APSIM-modelled PGR curves for Waikato over 12 years show a wide range in total production and monthly growth rates. The greatest between-year variation occurs during summer/autumn. As such, flexibility in stocking rate, farm system, and nitrogen leaching within a range is required to ensure the ongoing viability of the sector.

20. Optimisation of case study farms using these PGR curves results in an OVERSEER®-predicted average nitrogen leaching loss values that vary widely between scenarios. One scenario resulted in an average loss of 14 kg N/ha/yr over 10 years with a range of 12 to 21 kg N/ha/yr, which was a response to altering the farming system to maximise production as pasture production varied between years.

21. Farming to the pasture growth curve results in annual fluctuations in livestock numbers and thus nitrogen leaching losses. Constraining farms that farm to the pasture growth curve to a single nitrogen leaching loss figure significantly constrains their ability to farm and reduces their profitability.

22. Financial optimisation, without considering of regulated environmental limits such as no restriction on the application of nitrogen fertiliser, results in high nitrogen fertiliser use (in excess of 200 kg N/ha/yr in some scenarios) and high OVERSEER®-predicted nitrogen leaching losses (as high as 47 kg N/ha/yr). However, such use of nitrogen fertiliser is not something that is practiced by sheep and beef farmers due to its potential environmental impacts. As such, farm system optimisation is currently constrained by farmers through the choice of farming systems including the use of nitrogen fertilisers in consideration of their natural environment and its vulnerabilities.

23. In order for a case study farm to financially optimise its operation (without applying nitrogen fertiliser or buying in supplementary feed), livestock numbers are varied according to the pasture production within a season,

which varies. Thus, farmers need to have flexibility around a nitrogen leaching loss limit or a SU reference value to optimise their operations.

24. Using OVERSEER® as the tool to estimate nitrogen leaching losses with season-specific animal numbers, but with ~30-year annual average climate data, over-estimates the nitrogen leaching loss from the farm. I have shown in Table 4 that the OVERSEER®-predicted nitrogen leaching loss values are 6 to 21% lower than if the annual average climate data is used. In my opinion, it is more appropriate to use:

    (a) Actual annual rainfall from the NIWA weather station nearest the farm, or

    (b) Actual farm-specific rainfall data, which is something that most farmers record.

25. I support nitrogen discharge allowances based on land use capability (LUC), as shown in the table presented by Dr Tim Cox, with a suggested margin of ±30% to account for the degree of uncertainty in OVERSEER® (as discussed in my EiC for HS1[1]). However, between-season variation in pasture production should also be considered. As such, farmers should be able to adopt an approach such as assessing their five-year rolling average information against the LUC-based nitrogen leaching loss allowance.

26. I also support the LUC-based stock unit (SU) allowance table presented by Dr Alec Mackay in his EiC for HS2.

27. The Nitrogen Risk Scorecard approach, which is proposed for dairy by Fonterra, has significant merit and is worthy of further investigation for sheep and beef farms. It could be extended to consider high-risk natural landscapes and rainfall regions. It would complement the use of individual farm environment plans. Without those, however, it would require a similar method for estimating the risk of phosphorus leaching loss (which could also include sediment and *E. coli*) if the need for OVERSEER® analysis for all farms was eliminated.

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[1] Evidence in Chief Dr Jane Chrystal on Behalf of B+LNZ (2019) Hearing Stream 1, paragraph 92, page 27

28. The key points I want to get across are:

(a) Sheep and beef farms are already constraining their farming systems. My modelling shows that they could increase profitability by applying significant amounts of nitrogen fertiliser and increasing stocking rate, which would also increase nitrogen leaching losses.

(b) Sheep and beef farmers do NOT do this as they operate low-input systems and farm with their land and their land's natural ability to support their farming system. They farm to the pasture growth curve by varying their stock numbers according to how much pasture is grown in the season, rather than relying on high inputs such as bought-in feed and high levels of fertiliser use. In short, they alter their stock numbers in response to what the land can naturally sustain.

(c) Sheep and beef farmers respond to the individual season and thus stocking rates, and thus nitrogen leaching losses, vary from year to year. However, the losses are low in comparison to other high-input land users who do not farm to the pasture growth curve.

(d) OVERSEER® over-estimates nitrogen leaching losses by 7-21% when annual stock numbers and ~30-year annual average climate data are used to predict nitrogen leaching losses.

(e) The timing of when animals are on land, which Land Management Unit (LMU) they are on, and when rainfall occurs is critical in more accurately predicting the nitrogen leaching losses, which only occur when there is nitrogen in the soil available to be leached and when there is sufficient rainfall (or irrigation) to move that nitrogen through the soil profile into drainage water.

SUMMARY OF HOW NUTRIENT LOSSES HAVE CHANGED OVER TIME – SHEEP AND BEEF

29. There is an inextricable link between agricultural land uses and freshwater quality. In particular, agricultural losses of nitrogen and phosphorus from farming systems and practices to surface and groundwater, can ultimately impact on the health of freshwater ecosystems.

30. The main drivers of nitrogen leaching loss summarised from HS1 evidence[2] are urine patches (affected by livestock class and density, and concentration of nitrogen in the urine); nitrogen fertiliser and effluent applications.

31. Stocking rate (SR) is one of the key drivers for nitrogen leaching losses and there is a strong correlative relationship between SR and nitrogen leaching loss. SR is influenced by such things as:

    (a) Nitrogen fertiliser applications, which supports more animals by producing more feed (and in some dairy instances it may result in increased milk production with no increased SR);

    (b) Imported supplementary feed, which allows animals to remain on the land when there is insufficient pasture thus preventing a reduced SR;

    (c) Irrigation, which increases pasture production and thus the carrying capacity of the land;

    (d) Winter crops, which increases dry matter production during winter which influences the SR during the winter months.

32. I believe that stocking rate and presence or absence of high-risk activities (such as winter cropping) are good proxies for nitrogen leaching risk.

33. This information was generated by using information for four farm businesses in the B+LNZ Sheep and Beef Farm Survey (hereafter referred to as “Survey farms” and “the Survey”). The farms are within the

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[2] Evidence in Chief Dr Jane Chrystal on Behalf of B+LNZ (2019) Hearing Stream 1, paragraphs 43 and 53, pages 12 and 16 respectively.

Waikato-Waipā catchment and have been in the Survey since 1993-94. They were modelled using OVERSEER® for the 1993-94, 2000-01, 2005-06, 2010-11, and 2015-16 seasons. 1993-94 was selected as the first season because this was the year that the Survey first collected enough fertiliser and crop data to enable the generation of an OVERSEER® nutrient budget. We believe that being able to model the same individual farms over ~20 years provides valuable insight. The results are shown in Table 1.

34. Farms A, B, and C are North Island hill country (Farm Class 4) farms while Farm D is a North Island intensive finishing (Farm Class 5) farm. All farms have a mix of both sheep and beef cattle. Farm Classes are described in Appendix 2.

35. Farm C was not in the Survey in 2005-06 but was in the Survey in the other four years of this analysis.

36. Table 1 shows the OVERSEER®-predicted nitrogen leaching losses and actual nitrogen fertiliser use for the four case study farms. There is no trend of increasing nitrogen leaching losses. Nor is there a trend of increasing nitrogen fertiliser usage.

37. All farms had a lower stocking rate in 2015-16 than in 1993-94 and stocking rates fluctuated in the intervening seasons.

38. Farm A had two seasons of lower N leaching losses, which corresponded to the two seasons (of the five analysed) when winter crops were not used on the property.

Table 1: OVERSEER® output for four Beef + Lamb New Zealand Sheep and Beef Farm Survey farms located in the Waikato-Waipā Catchment that have been in the B+LNZ Survey since 1993-94

	Original file	Same methodology for comparison				
	2015-16	2015-16	2010-11	2005-06	2000-01	1993-94
Nitrogen leaching loss (kg N/ha/yr)						
Farm A	22	22	23	16	14	26
Farm B	23	23	22	24	24	24
Farm C	15	14	14	N/A	14	14
Farm D	23	21	14	22	21	20
Nitrogen fertiliser applications (kg N/ha/yr)						
Farm A	10	9	25	0	8	5
Farm B	0	0	0	0	0	0
Farm C	0	0	0	N/A	22	3
Farm D	23	24	0	0	0	0
Phosphorus fertiliser applications (kg P/ha/yr)						
Farm A	11	11	27	15	20	4
Farm B	17	16	17	30	33	23
Farm C	0	0	24	N/A	20	25
Farm D	16	16	13	32	27	15
Stocking Rate (SU/ha (grazed area))						
Farm A	14.3	11.0	13.4	12.1	10.1	16.9
Farm B	12.4	11.8	11.1	13.4	11.0	14.5
Farm C	15.1	13.0	13.1	N/A	14.8	14.5

	Original file	Same methodology for comparison				
Farm D	15.3	13.8	10.2	18.5	13.5	15.3
Stocking Rate (SU/ha (total area))						
Farm A	12.4	9.6	11.7	10.5	8.9	14.7
Farm B	10.4	9.9	9.3	11.1	9.2	12.5
Farm C	12.8	11.0	11.1	N/A	12.6	12.4
Farm D	15.2	13.7	10.1	18.4	13.4	15.1

39. Dividing the nitrogen leaching loss by the stocking rate across the total farm area gives a value for annual nitrogen leaching loss of 0.9 to 2.2 kg N/SU.

40. This methodology is consistent with that used by Dymond et al (2013), which was dividing total nitrogen leaching loss by total SU.

41. The range – 0.9 to 2.2 kg N/SU – is higher than the examples of average values estimated by Dymond et al (2013) who used OVERSEER® v5.4 to test 100 combinations of soil type and climate across New Zealand and calculated values for sheep of 0.5 to 0.8 kg N/SU (Table 2), although the range was not reported.

42. The difference between the figures I calculated and those of Dymond et al is also likely because my numbers covered both cattle and sheep. Dymond et al did not explain whether their methodology of calculating for beef or deer was different to that of sheep except to say that sheep, beef, deer and dairy were calculated separately.

43. They calculated the per cow value by multiplying the nitrogen leaching loss value for sheep by 10. This is very close to assuming that a cow is 10 SU.

Table 2: Examples of OVERSEER® (v5.4) estimated nitrate leaching per stock unit for sheep taken directly from Dymond et al 2013.

Table 2 Examples of estimating nitrate leaching per stock unit for sheep on four level II land environments.

Level II land environment	F1	B8	A5	I5
NZSC order	Brown	Pallic	Organic	Recent
Overseer soil group	Sedimentary	Yellow grey earth	Peats	Sedimentary
Stock-carrying capacity	12	9	23	26
P fertiliser requirement (kg P ha^{-1} yr^{-1})	8	3	13	9
Annual rainfall (mm)	1570	810	1340	890
N leached (kg N ha^{-1} yr^{-1})	10	5	10	13
N leached per stock unit	0.8	0.5	0.4	0.5

Notes: F1 (hilly and wet); B8 (hilly and dry); A5 (flat and wet); I5 (flat and dry). OVERSEER® is used to estimate N leached at stock-carrying capacity, which is then divided by stock-carrying capacity to give leaching per stock unit. It is assumed there is no supplementary feed in winter. For dairy, the nitrate leaching per cow is set to 10 times the nitrate leaching per stock unit (determined from a subset of LENZ level II OVERSEER® runs). It is assumed there are no feed pads and no grazing-off in winter.

SUMMARY OF HOW NUTRIENT LOSSES HAVE CHANGED OVER TIME – DAIRY

44. Ideally, some analysis of nitrogen leaching losses over time (similar to that described in paragraphs 29-39) would be completed for the dairy industry. It would be unfair to simply take the OVERSEER® nitrogen leaching loss values that have been generated over time and compare those with values for sheep and beef farms because they come from different versions of OVERSEER®. What would need to be done is to take the files (or generate files from farm data for actual farms) from a number of years and use the same version of OVERSEER® to calculate nitrogen leaching losses. This would improve the quality of comparison of the trend in nitrogen leaching losses over time.

45. In the absence of actual OVERSEER® files, I have attempted to assess the change in the dairy industry over time using cow numbers and average stocking rates, which is similar to the approach adopted by Dymond et al (2013). The difference is that I converted cow numbers to stock units rather than multiplying a nitrogen leaching loss value for sheep by 10. I did this is because, as explained in paragraph 42, my values were a combination of both sheep and cattle numbers.

46. The nitrogen leaching loss is estimated to be 1.87 kg N/SU, if the same methodology of dividing nitrogen leaching loss by stocking rate as described in paragraph 39 is:

(a) applied to the average of the nitrogen leaching loss figures presented by Richard Allen from Fonterra in his EiC for HS1, which is 47 kg N/ha/yr;

(b) combined with the average stocking rate in Waikato of 2.95 cows per ha; and

(c) assumes one cow is equivalent to 8.5 Stock Units, which is between a conservative 7.5 and 10.4 that is used in WRC's definition of a stock unit (WRC, 2018a; Page 92), though clearly it is closer to 7.5 than 10.4.

47. A lower conversion ratio of cows to Stock Units (e.g. if one cow were deemed equivalent to 7.5 Stock Units) would result in a higher calculated N leaching loss (2.14 kg N/SU).

48. A higher conversion ratio of cows to Stock Units (e.g. if one cow were deemed equivalent to 10.4 Stock Units) would result in a lower calculated N leaching loss (1.53 kg N/SU).

49. If that simple calculation applies, an increase in stocking rate (i.e. cows per hectare) would also result in an increase in N leaching loss.

50. Statistics New Zealand ("SNZ") publishes New Zealand's official livestock numbers each year, either from the returns in response to the Agricultural Production Census ("APC") or from the Agricultural Production Survey ("APS").

51. Annually, Livestock Improvement Corporation Ltd ("LIC") and DairyNZ Ltd jointly publish *New Zealand Dairy Statistics*, which contains statistical information related to the New Zealand dairy industry. While there have been some changes to the formal title of the publication and to the formal names of the publishers over time as dairy industry organisations were restructured and renamed, and to the name of the region – from "South Auckland" to "Waikato" – the publication and presentation has remained consistent. I extracted data on stocking rate for New Zealand as a whole, and for Waikato, from the 1998-99 to 2017-18 publications, which were readily available on the LIC website. I extracted the relevant data from hard copies of *Dairy Statistics* for years prior to the 1997-98 publication.

52. The data was then used to produce the graphs below, which show:

    (a) total number of cows in:

        (i) Waikato (Figure 1) using SNZ data; and

        (ii) New Zealand (Figure 2);

    (b) The change in cow numbers (Figure 3) using SNZ data; and

(c) average stocking rate on dairy farms in Waikato and New Zealand measured in:

(i) Cows per ha (Figure 4); and

(ii) Estimated Stock Units per ha (Figure 5) based on converting dairy cows to stock units using 8.5 SU per dairy cow. For comparison, Andrew Burtt's Evidence-in-Chief ("EiC") for HS1 showed an average 11.6 SU/ha in Waikato-BOP in 2016-17 for Farm Class 5 Intensive Finishing farms, which are the most production-intensive sheep and beef farms, using the same coefficient to convert the number of cows to stock units.

53. This was done because I do not have access to trends in nitrogen leaching losses specifically for dairy farms. Stocking rate is a very good indicator of nitrogen leaching losses because urinary N is one of the main contributors of nitrogen in a grazed pastoral system. Grazing animals can excrete as much as 70-95% of the nitrogen they consume (Selbie, Buckthought, & Shepherd, 2015). Further, the total amount of urinary N deposited on land in a grazed pastoral system increases with increasing stocking rate because stocking rate is a calculation based on animal intake (in OVERSEER® a revised stock unit (RSU) consumes 6000 megajoules of metabolisable energy (MJME) per year (Watkins, Wheeler, & Mercer, 2016)).

54. Figure 1 and Figure 3 show that the number of dairy cows has been steadily increasing in both Waikato and New Zealand since the mid-1970s. The total number of cows in Waikato has not increased in the same fashion as it has in New Zealand. However, it increased by 50% between 1990-91 and 2017-18 in Waikato, while the New Zealand total increased by 85% (see Figure 4). This is not a surprise because Waikato is a traditional dairying region and there was more significant growth in the number of cows in "non-traditional" regions such as Canterbury and Southland. This was shown in Andrew Burtt's EiC for HS1.

Figure 1: Number of Dairy Cows in Waikato

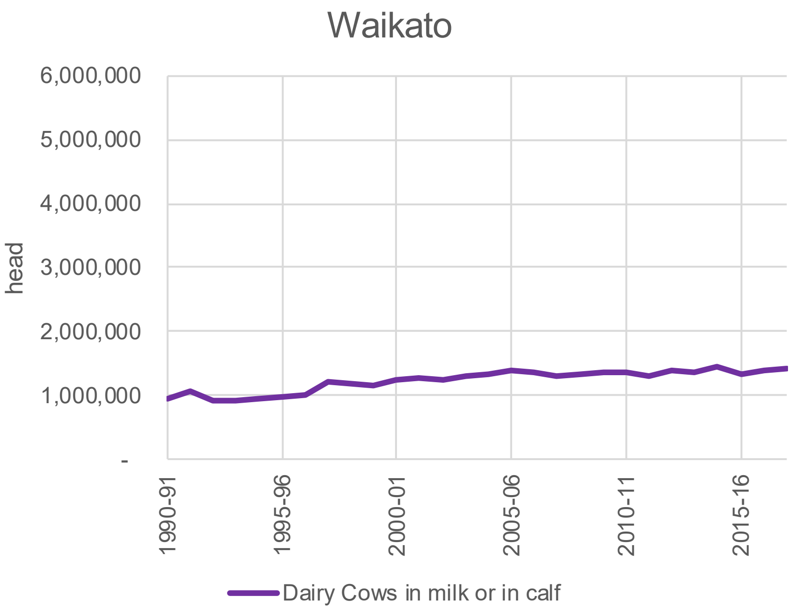


Figure 2: Number of Dairy Cows in New Zealand

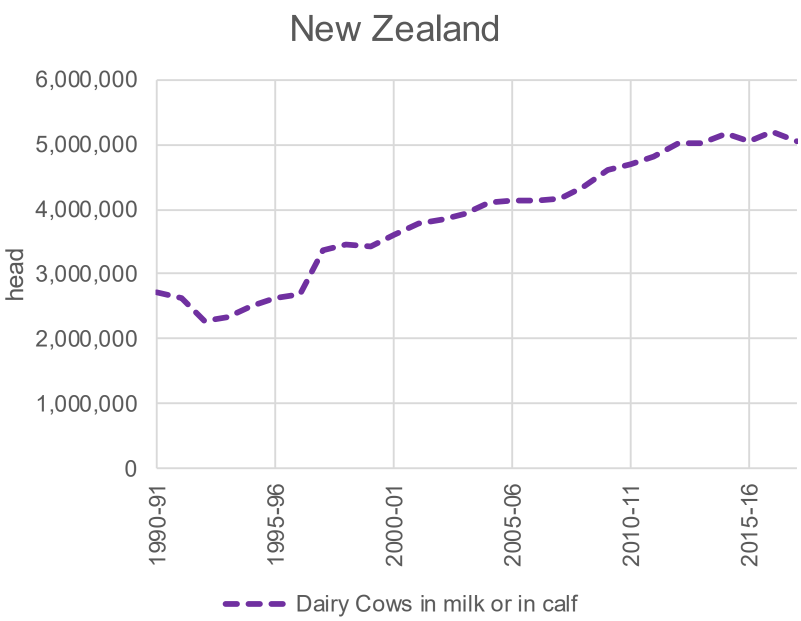


Figure 3: Change in the Number of Dairy Cows since 1990-91

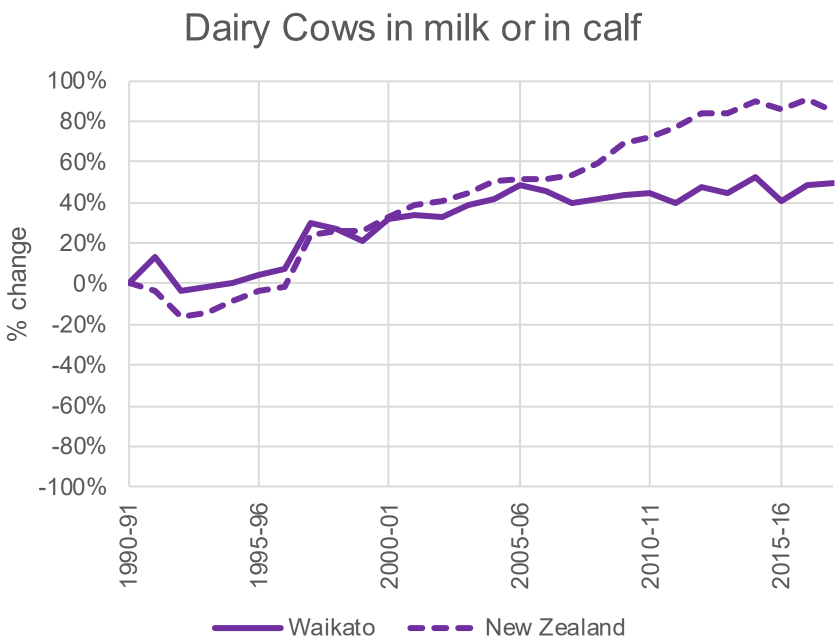


Figure 4: Average Stocking Rate on Dairy Farms – cows per ha

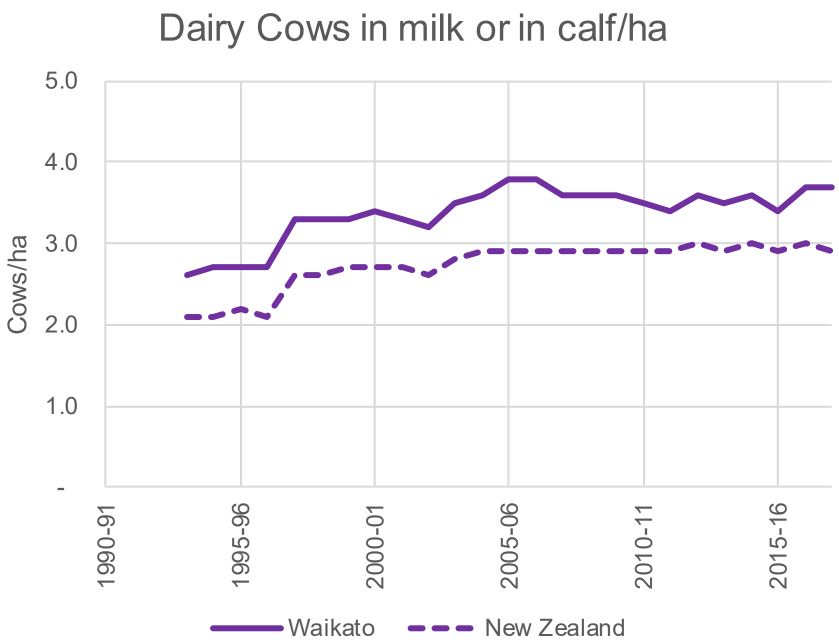
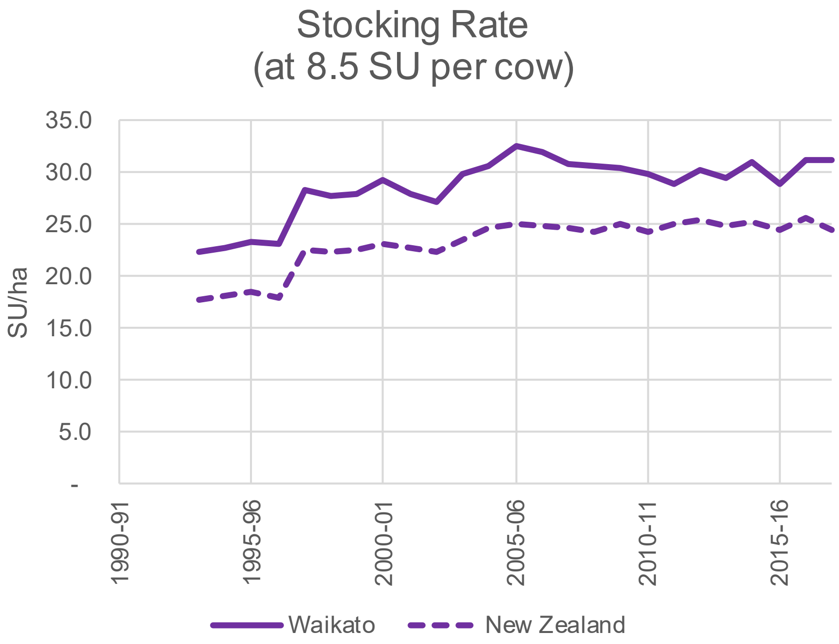


Figure 5: Average Stocking Rate on Dairy Farms – Stock Units per ha



55. In comparison, in his EiC submitted for HS1, Andrew Burtt showed that the average stocking rate on sheep and beef farms in Waikato-BOP decreased between 1990-91 and 2016-17. This was shown in Figures 21 to 23 of the EiC for each Farm Class in the Survey, and is summarised here in Figure 6 as a weighted average of all farm classes. The ratio of sheep stock units to cattle stock units has also decreased.

Figure 6: Average Stocking Rate of Sheep and Beef Farms – Waikato-BOP

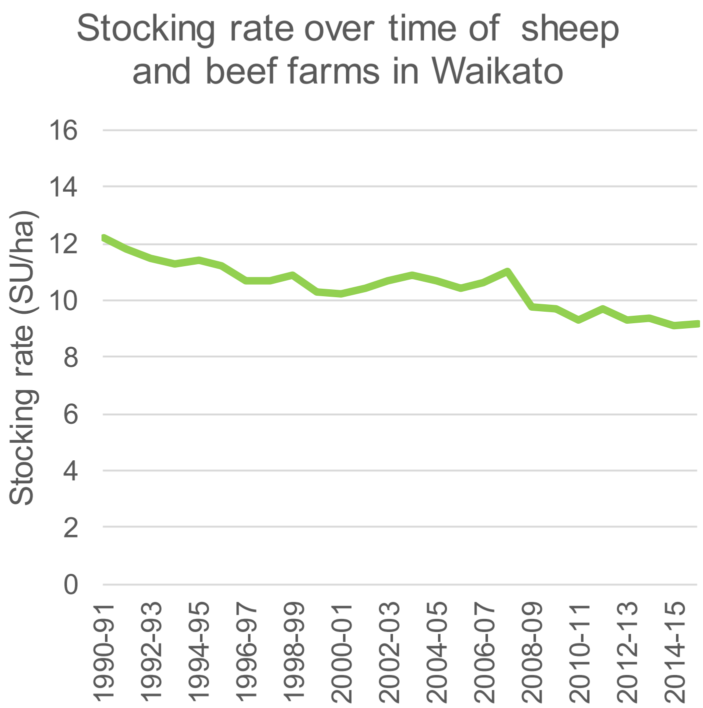
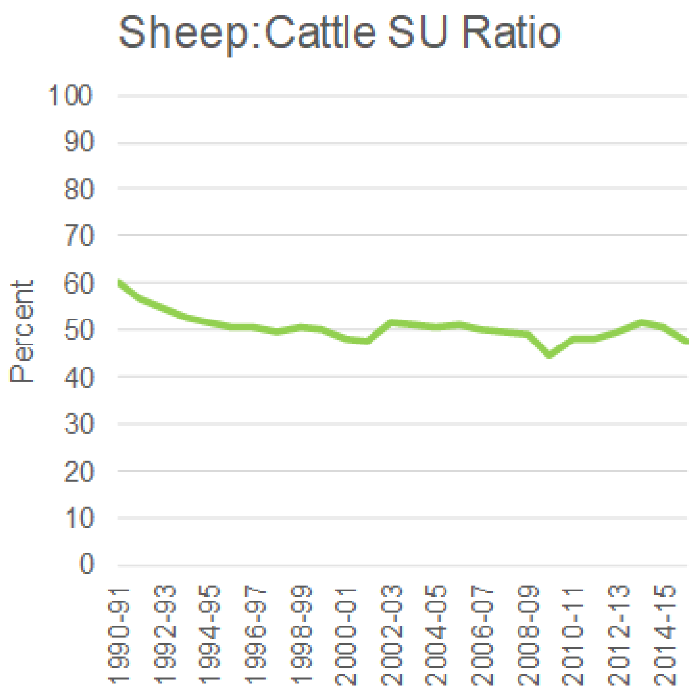


Figure 7: Average Sheep to Cattle Ratio Stock Units – Waikato-BOP



56. All the evidence presented earlier is supported by this powerful quote from Dymond et al (2013):

“Generally, nitrate leaching in the North Island is trending down because sheep numbers are reducing faster than equivalent dairy cattle numbers are increasing…..The exception to this is the Waikato region where dairy cattle numbers have increased by a half.”

SUMMARY OF THE USE OF OVERSEER® AND GRANDPARENTING ("GP") TO 2014-15 OR 2015-16 SEASONS AND THE IMPLICATIONS OF GP TO THOSE YEARS[3]

57. Three case study farms were modelled using AgInform®, which is strategic optimisation software described in detail in Appendix 3, in conjunction with OVERSEER® to determine the impact on financial outcomes of a range of scenarios including the application of a NRP or requirements for further reductions in nitrogen discharges.

58. The three case study farms that were selected from B+LNZ Sheep and Beef Farm Survey farms are operated by top farmers who have financially and environmentally sustainable farming systems. They have already undertaken significant environmental work (e.g. native regeneration, closely matching stock and soil type to minimise contaminant losses at high-risk times of the year).

59. AgInform® can also be used to optimise a farm under other environmental considerations such as greenhouse gas (GHG) emissions and biodiversity considerations. AgInform® was used by AgResearch scientists to analyse the implications of retiring high-risk areas of land on a Waikato sheep and beef property while increasing production on the remaining lower-risk land areas (Dominati, Maseyk, Mackay, & Rendel, 2019). The outcome of this was that phosphorus leaching loss was reduced by 15%, and erosion and run-off from the farm by 20%. Nitrogen leaching loss was increased slightly from 17 to 18 kg N/ha/yr with some N mitigations not accounted for in that analysis (Bailey, 2019).

60. The inputs for AgInform® were farm-specific data, including:

    (a) annual pasture growth rates;

    (b) livestock information; and

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[3] Descriptions of the models presented in this section are provided in Appendix 3. Descriptions of the sources of data and linkages between the models are provided in Appendix 4.

(c) financial information.

61. AgInform® financially optimises the farm over multiple years.

62. A key component of the model is that the farm is split into Land Management Units (LMUs) that are based on the natural capital of that land in terms of:

(a) soil type;

(b) pasture production;

(c) potential carrying capacity;

(d) risk of leaching; and

(e) risk of erosion.

63. To assess the LMUs for the case study farms, AgFirst was employed to undertake a field assessment of the farms and provide for each farm:

(a) A Land Use Capability (LUC) map;

(b) A summary of the different LUCs; and

(c) The area of each LMU.

64. These are provided in Appendices 6 – 11.

65. The outputs from AgInform® were:

(a) stock number information;

(b) sales dates;

(c) Nitrogen fertiliser use; and

(d) EBITDA[4] as a financial measure.

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[4] EBITDA: Earnings before interest, taxes, depreciation and amortization.

66. The model is designed so that urinary nitrogen levels are an input that can be altered as a proxy to reduce stocking rate and N leaching. Reducing the maximum urinary N permitted within AgInform® and then running the optimised farm system through OVERSEER®, the nitrogen leaching loss values can be estimated. The process is repeated until the nitrogen leaching loss value calculated by OVERSEER® reaches the "grandparented" value.

67. Three scenarios were tested:

    (a) Restricting urinary nitrogen excretions ("urinary N");

    (b) Restricting nitrogen fertiliser applied in winter; and

    (c) Completely removing nitrogen fertiliser applications.

68. Sheep and beef farmers manage their businesses in response to the pasture growth curve. This means that they are constantly changing their farming system within, and between, seasons in response to climate-induced changes in pasture growth rates, while taking into account other objectives for their businesses.

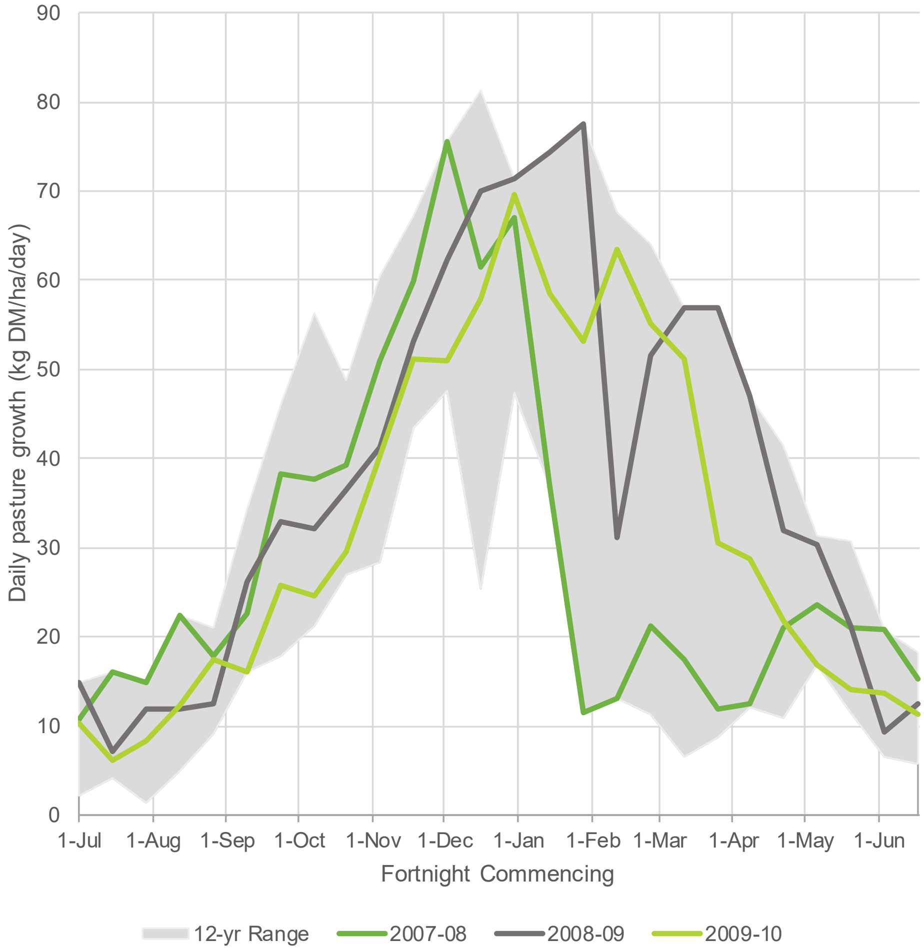
69. A key input in the AgInform® model is multiple-year pasture growth rates. As a first stage of the modelling process, I generated estimated daily pasture growth rates for a Waikato pastoral farm on an Otorohanga soil type (Appendix 5). Pasture growth rates from 2006 to 2018 were generated using APSIM, which is described in Appendix 4, using climate data from two NIWA sites (26117 and 23899) located at Ruakura (near Hamilton) and Te Kuiti respectively (NIWA, 2019).

70. However, one of the assumptions applied to APSIM is that the land is flat. Thus, these pasture growth rates represent flat land while hill country pasture growth rates are likely to be marginally lower given slope and aspect considerations. I discuss further below, in paragraphs 84 to 92, how I altered the pasture growth rates generated by APSIM to account for the different pasture production on hill country.

71. A simple fortnightly average of the APSIM-generated daily estimated PGRs was calculated for use in AgInform®. The PGRs for the Ruakura site for three consecutive seasons (2007-08, 2008-09, and 2009-10), and the range

over the 12-year period from 2006-07 to 2017-18 (grey areas), are shown in Figure 8. The sharp drop in the low pasture production in December occurred in December 2010 after 80 mm rain was received over four days, 70 mm of which fell in 48 hours. This graph highlights the large variation between consecutive years.

Figure 8: APSIM-predicted daily pasture growth rates – Ruakura, Waikato



72. Figure 8 shows the APSIM-generated PGRs for 2014-15 and 2015-16, which are the seasons the WRC has proposed establishing the Nitrogen Reference Point (NRP) for each farm and the 12-year range from 2006-07 to 2017-18 (grey area).

73. It highlights:

(a) The wide range in pasture growth rates that occur in response to annual climate patterns; and

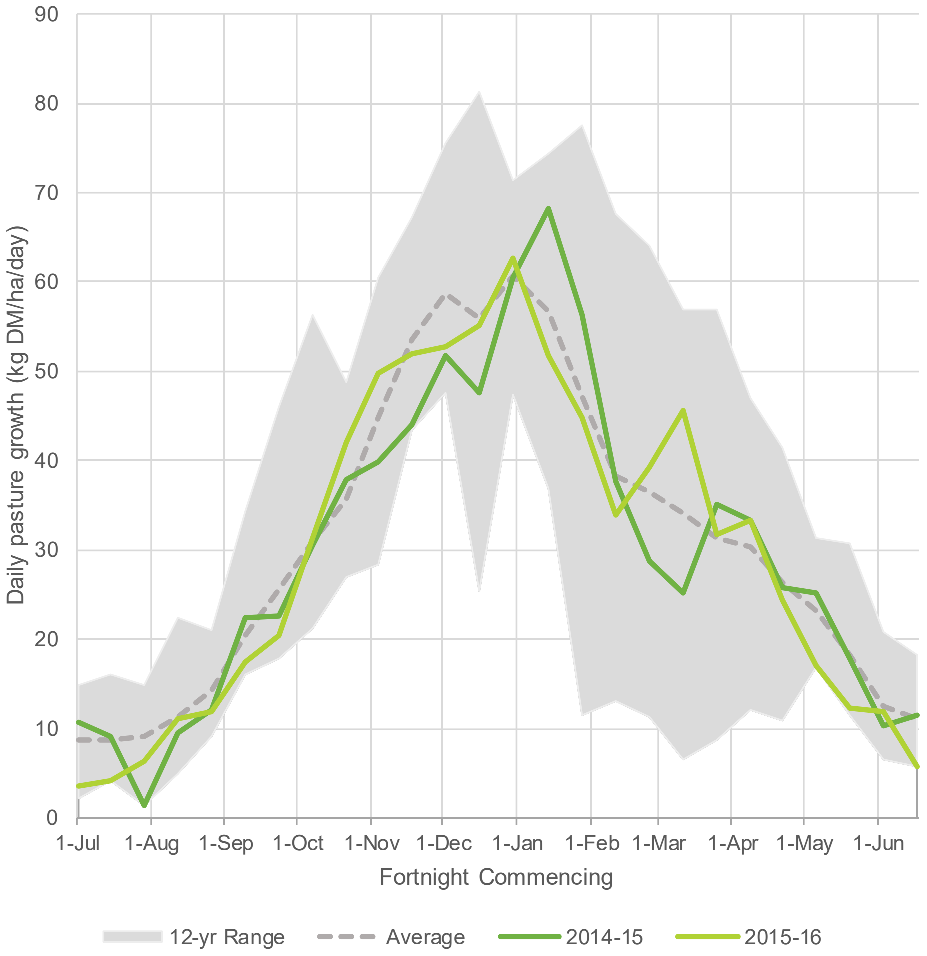
(b) The variation in daily pasture growth rates between seasons, which is greatest during summer/autumn.

74. The PGRs shown are those without fertiliser applications and therefore indicate the pasture growth curve that sheep and beef farmers who apply minimal nitrogen fertiliser are farming to. These farmers manage to the pasture growth curve, which means they do not specifically alter pasture growth by applying nitrogen fertiliser, nor are they bringing in large amounts of supplementary feed to feed animals at times when pasture growth is low. The AgInform® scenarios presented below will show that farmers require room to alter their livestock system in response to PGRs to maximise annual profitability, while achieving other objectives. This will be explained further in paragraphs 96 to 125.

75. Farmers will buy in livestock when they anticipate high PGRs, or have extra feed available as a result of seasonal conditions, and sell livestock when pasture availability is low. Total livestock numbers carried on an annual basis will depend on the pasture production of the particular season. However, as there is less between-year variation during winter, animal numbers at 1 July are likely to have less between-year variation.

76. APSIM-predicted pasture production from 2006-07 to 2017-18 averaged 11.3 t DM/ha/yr and ranged from 9.1 to 14.6 t DM/ha/yr, so there was a 60 percent difference between the lowest and highest pasture production. This was base pasture production, i.e. with no fertiliser applied.

Figure 9: APSIM-generated Daily Pasture Growth Rates for the two Nitrogen Reference Point seasons (2014-15 and 2015-16) within the 12-year Range of Pasture Growth Rates - Waikato



77. Figure 9 includes the PGRs predicted by APSIM for the Nitrogen Reference Point years (i.e. 2014-15 and 2015-16). This shows average daily PGRs were:

(a) Lower than average in December of those seasons (particularly in 2014-15);

(b) Lower than average from January until mid-February in 2015-16; and

(c) Significantly lower than average from February until mid-March in 2014-15.

78. Despite PGRs in some periods of the proposed NRP years being above average and some being below average, the total annual production was 10.85 and 10.82 t DM/ha/yr for 2014-15 and 2015-16 respectively, both of which are below the average of the 12 years modelled (11.3 t DM/ha/yr).

79. Management decisions to mitigate this lower-than-average feed supply would include:

(a) Applying nitrogen fertiliser;

(b) Buying in supplementary feed;

(c) Feeding as supplementary feed pasture that was conserved on the farm earlier;

(d) Selling livestock;

(e) Buying in fewer livestock to finish;

(f) Irrigation; or

(g) A combination thereof.

80. Due to the extensive nature of many sheep and beef farms, the most likely scenario is that livestock was sold sooner. For example, lambs sold in store condition rather than prime, or sold prime at a younger age (lighter), or fewer store stock may be bought in to finish than in other years.

81. The result of adopting management decisions 79(d) or 79(e) would most likely result in a lower nitrogen leaching loss than average.

82. Farms that are more intensive, but where animal numbers are held constant regardless of the annual pasture growth rates, would most likely employ management decisions 79(a), 79(b), and 79(c). The result of these management decisions (particularly Applying nitrogen fertiliser; and Buying in supplementary feed;) would most likely be an increase in the nitrogen leaching loss compared to an average year.

83. A potential, unintended consequence of using years in which pasture production was lower than average overall (also noting that when the pasture production occurs will impact management decisions) is that more intensive systems that produce more feed (by applying fertiliser) or bring in feed (supplement) will be granted a higher NRP value than they would have in an average year, whereas less-intensive farms, that destocked in response to lower-than-average pasture production are likely to receive a lower NRP value than they would have received in an average year.

84. The second stage of the generation of farm-specific PGRs was to use the LUC information provided by AgFirst, which is presented in full in Appendices 6 – 11, and adjust the APSIM-predicted values for flat land to those for the different LUC classes.

85. This was done by taking the LUC unit tables from each of the three Land Use Capability Tables (Appendices 6, 8, and 10) and grouping the LUC units according to the figure given for ‘Top’ stock carrying capacity.

86. In Case Study 1, this gave three AgInform® LMU groups with carrying capacities of 18, 14 and 11 SU/ha (Table 11).

87. In Case Study 2, there were three LMUs with carrying capacities of 18, 12 and 10 SU/ha (Table 11).

88. In Case Study 3, there were two LMUs with carrying capacities of 18 and 10 SU/ha (Table 11).

89. In instances where there was a small LUC class with a different top carrying capacity (for example 0.7 ha of LUC 2w1 in Case Study 2) this was just

grouped with the LMU 1 class carrying 18 SU instead of separating it out with its 25 SU top carrying capacity.

90. Assuming that a SU equalled 550 kg DM, then each carrying capacity was multiplied by 550 kg DM to give a value for annual pasture production.

91. The PGRs were then scaled for each LMU to the annual pasture production of that LMU.

92. A value for utilisation was not taken into account because the values used were already top values.

Table 3: Carrying capacities and annual pasture production of the LMUs on the three case study farms

	Carrying Capacity	**Grazable area**	**Pasture Production**
	SU/ha	**ha**	**kgDM/yr**
Case Study 1			
LMU 1	18	224.2	9,900
LMU 2	14	141.7	7,700
LMU 3	11	9.1	6,050
Total		***375.0***	***23,650***
Case Study 2			
LMU 1	18	124.0	9,900
LMU 2	12	59.2	6,600
LMU 3	10	37.0	5,500
Total		***220.2***	***22,000***
Case Study 3			
LMU 1	18	89.4	9,900
LMU 2	11	81.6	6,050
Total		***171.0***	***15,950***

93. The next stage of the modelling was to combine the PGRs shown in Table 3 with Survey data collected for the 2014-15 and 2015-16 seasons and run AgInform® to provide an estimate of the optimised farming system.

94. It is important to note that the level of detail and accuracy of this model and the time constraints to undertake the analysis mean that the absolute values provide an estimate of the optimised farming system. The modelling necessarily simplifies the system and additional considerations would be taken into account by the farmer when assessing the ability of the farming business to run the system suggested. However, the **comparison** between scenarios **is** relevant.

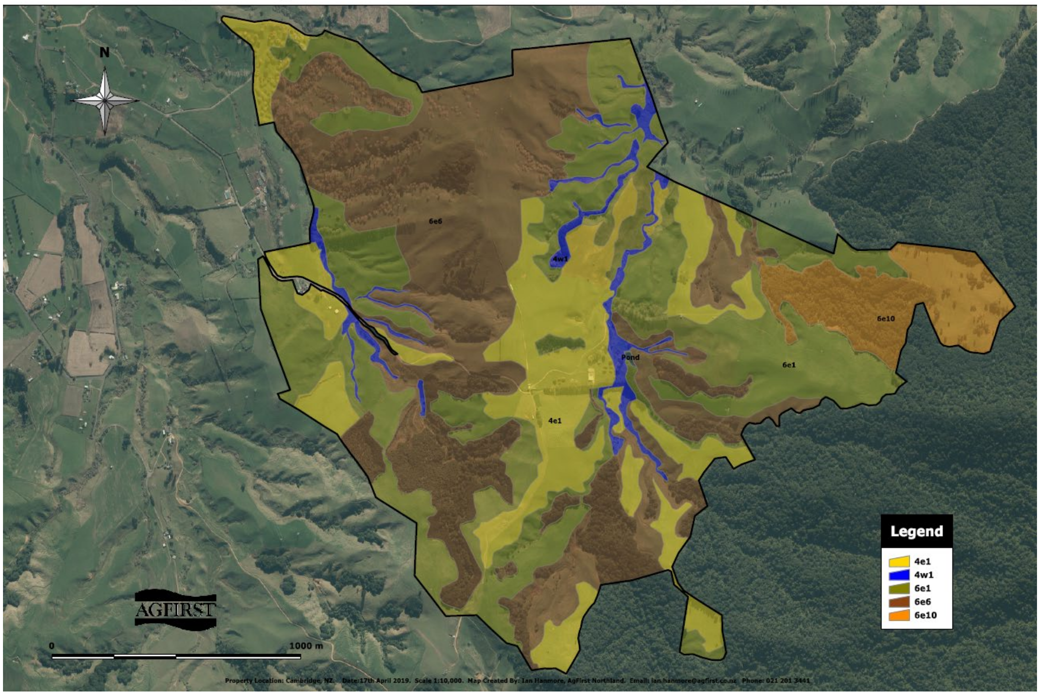
95. This is the same situation as the base modelling undertaken in the PC1 analysis. There is not enough robust data to say that the base file is an absolute representation of reality, however using a base file and applying scenarios and then considering the relative difference between the base and the scenarios tested, is valuable.

96. The three case study farms comprise of:

(a) Case Study 1 (Figure 10): A Cambridge sheep and beef farm running a breeding ewe flock, and buying and finishing cattle. The farm is a total of 414.9 ha with 375.0 ha grazed. In 2015-16, the farm's stocking rate was 12.4 RSU/total ha (Revised Stock Units, according to OVERSEER®), made up of 6.3 RSU of sheep/ha and 6.1 RSU of beef cattle/ha. The application of elemental nitrogen in fertiliser averaged 1 kg N/ha/yr over the farm and was applied to an 8 ha soft turnip block. OVERSEER®-predicted losses for the season were 15 kg N/total ha/yr and 1.3 kg P/total ha/yr (Appendix 15).

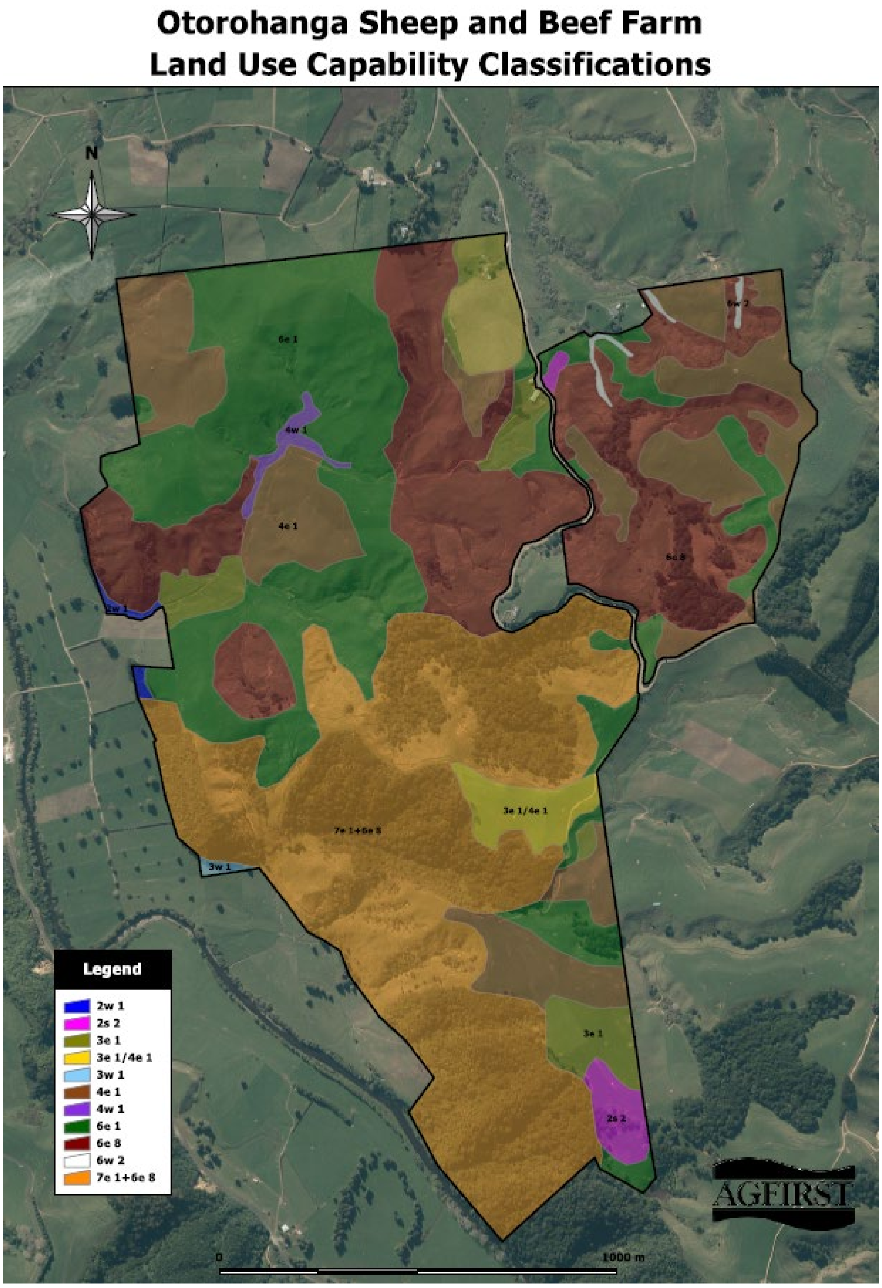
Figure 10: Case Study 1 Farm Map

Cambridge Sheep and Beef Farm Land Use Capability Classifications



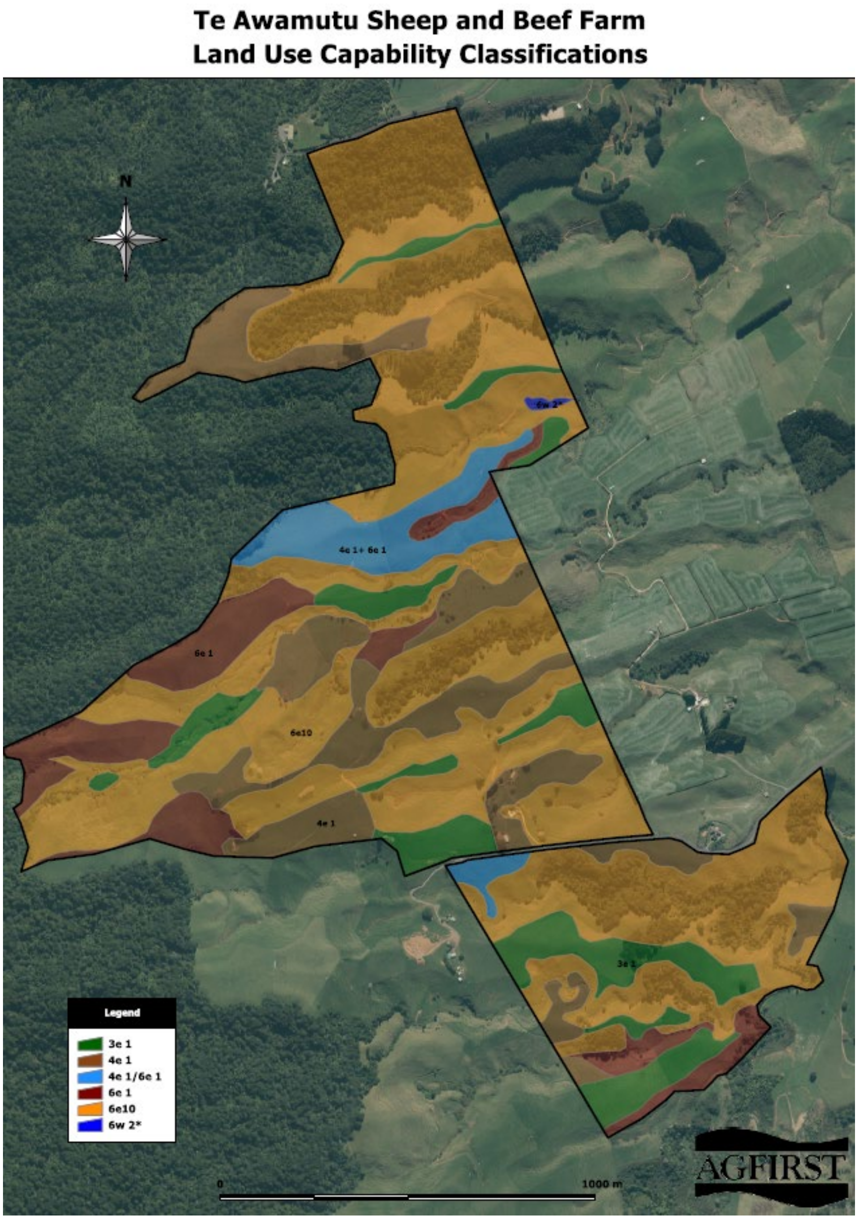
Case Study 2 (Figure 11): A Otorohonga sheep and beef breeding and finishing property. The farm is a total of 270.2 ha of which 220.2 ha is grazed. In 2015-16, the stocking rate was 10.6 RSU/total ha/yr comprising 5.2 and 5.4 RSU/total ha/yr of sheep and cattle respectively. N leaching was 19 kg N/ha/yr and P loss was 0.7 kg P/ha/yr (Appendix 16).

Figure 11: Case Study 2 Farm Map



(b) Case Study 3 (Figure 12): Te Awamutu sheep and beef breeding property selling prime lambs and store cattle. The farm is a total of 222.4 ha of which 171.0 ha is grazed. In 2015-16, the stocking rate was 9.6 RSU/total ha/yr comprising 7.4 and 2.2 RSU/total ha/yr of sheep and cattle respectively. N leaching was 20 kg N/ha/yr and P loss was 0.5 kg P/ha/yr (Appendix 17).

Figure 12: Case Study 3 Farm Map



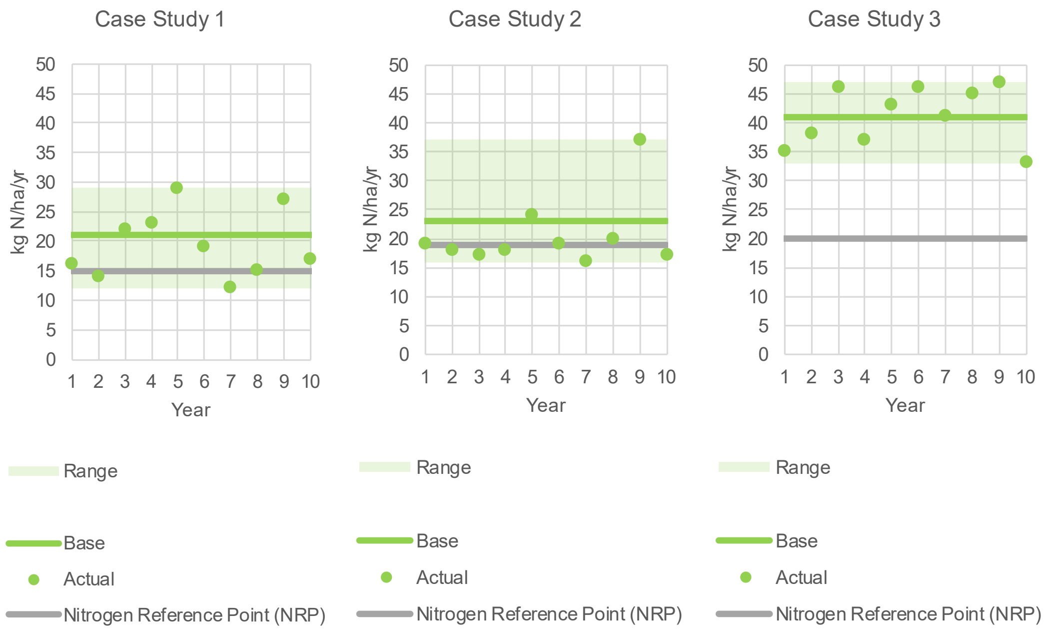
97. For all three farms, a number of scenarios were run using AgInform®. The output was then run through OVERSEER® to obtain N leaching loss and SU values. The outputs from all scenarios are presented in Appendices 18-20 and summarised here.

98. AgInform® was used to run a particular scenario keeping breeding and replacement stock numbers constant across the 10-year modelled period. This was done because it is generally difficult for farmers to easily change their breeding stock in response to a changing season. A last resort for a farmer would be to sell breeding stock because they contain the genetics suited to the farm and they are hard to replace. Instead, the model kept the same breeding and replacement stock and altered trading and finishing animal numbers according to the season.

99. The first scenario for each case study was "Base", which financially optimised the farm given the farm-specific inputs.

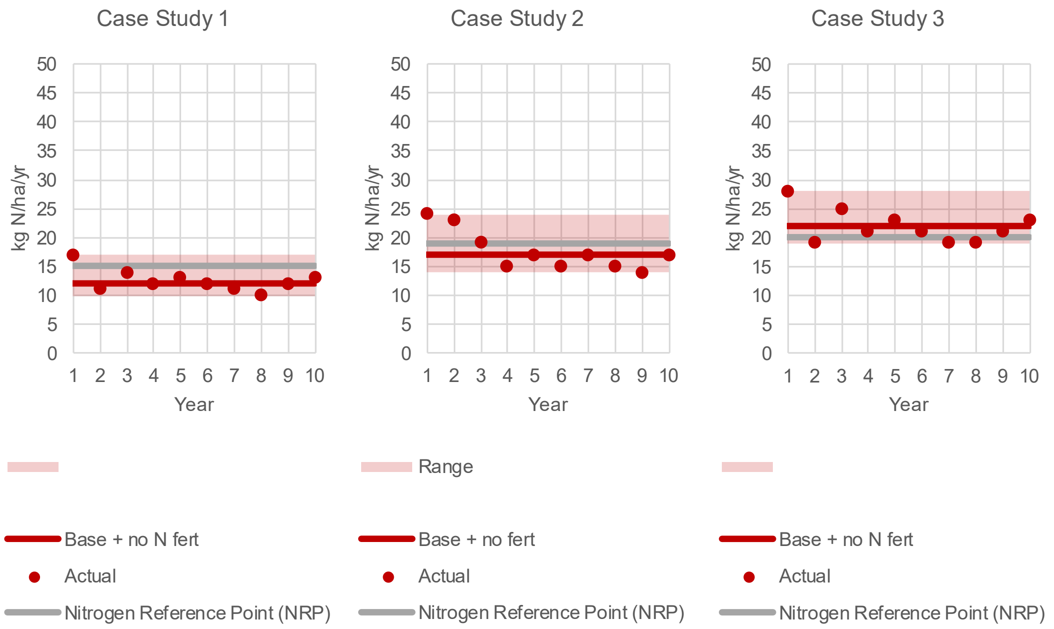
100. The result was the financial optimum for each farm, but to achieve that there was a lot of fertiliser applied in winter, which resulted in excessively high nitrogen leaching loss values but the highest EBITDA. This scenario resulted in the best financial outcome for the farmer (at the expense of the environment) and each alternative scenario resulted in a reduction in profitability from the base (Figure 13).

Figure 13: OVERSEER®-predicted N leaching from AgInform® financially optimised scenarios for three Case Study farms. 10 individual years and an average N leaching loss values are presented with the 2015-16 Nitrogen Reference Point for the farm.



101. Next, I asked the model to optimise the farms with either no winter N fertiliser (Case Study 2) or no N fertiliser at all (Case Studies 1 and 3). This resulted in a reduction in EBITDA but also reduced the N leaching (Figure 14).

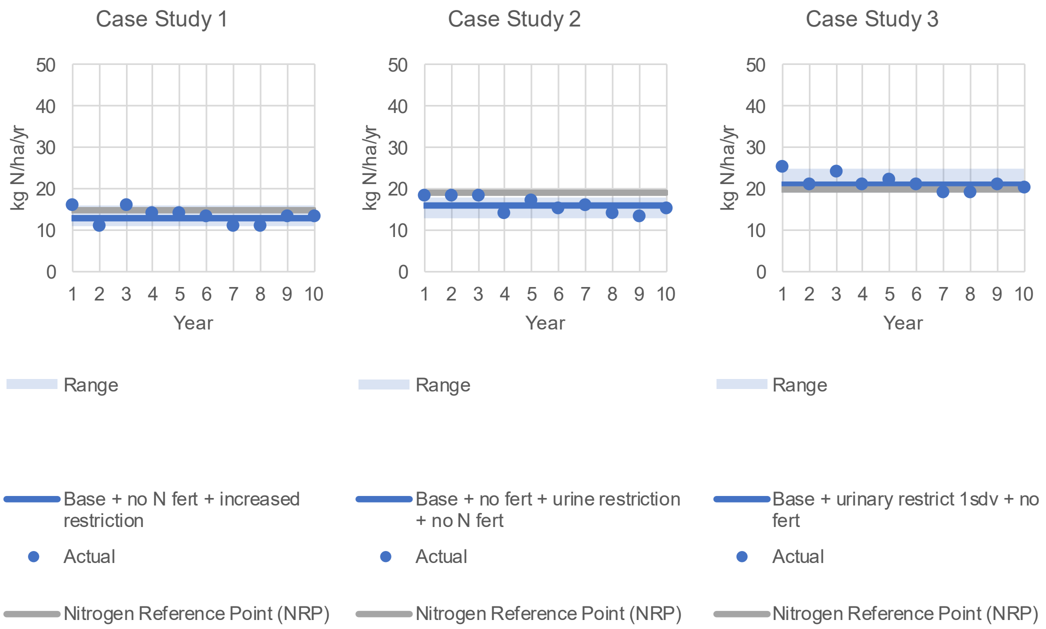
Figure 14: OVERSEER®-predicted N leaching from AgInform® financially optimised scenarios for three Case Study farms with a constraint of applying no N fertiliser. 10 individual years and an average N leaching loss values are presented with the 2015-16 Nitrogen Reference Point for the farm.



102. I also asked the model to restrict urinary N and either had no restriction in N fertiliser (case study 1, 2 and 3; file numbers[5] 303, 304, 404, 503 and 506) or restricted urinary N with no winter applied N fert (case study 2 and 3; file numbers 403 and 504) or restricted urinary N and no N fertiliser (Case studies 2 and 3; file numbers 405 and 505). See Figure 15.

[5] File numbers 30X, 40X and 50X are found in the table of AgInform® and OVERSEER® outputs supplied in Appendices 18, 19 and 20 respectively.

Figure 15: OVERSEER®-predicted N leaching from AgInform financially optimised scenarios for three Case Study farms with a constraint of applying no N fertiliser and restricting urinary nitrogen. 10 individual years and an average N leaching values are presented with the 2015-16 nitrogen reference point for the farm.



103. In summary, in the modelling scenarios it is financially beneficial to apply some nitrogen fertiliser even with a restriction of urinary N. Restricting the application of N fertiliser so than none can be applied in winter, reduces N leaching but also reduces profit (EBITDA).

104. The case study farms are already significantly reducing their ability to increase carrying capacity and thus profit by not applying N fertiliser. They have already, naturally, constrained their system to a low-input system. Further constraining their N leaching further reduces their profitability and thus the finances they have available to put towards mitigation of other contaminants (phosphorus, sediment, *E. coli*) or towards improving biodiversity.

105. In all scenarios, stock numbers change from year to year to optimise the use of pasture grown. This results in a range of nitrogen leaching loss values over the 10-year period modelled. For example, when Case Study 1 was optimised with the constraints of no N fertiliser and an increase in urinary N restriction (see File number 304 in Appendix 18) it had an average

nitrogen leaching loss of 13 kg N/ha/yr and a range over the 10 years from 11 to 16 kg N/ha/yr.

106. To further constrain their system to a single nitrogen leaching loss value (or lower) does not acknowledge the fact that they have already, voluntarily, constrained their systems.

107. The most important factor to understand is that when farming to the pasture curve there will be variations in nitrogen leaching loss as stock numbers change year-to-year in response to pasture production on the property. Constant capital (breeding) stock numbers were used in the AgInform® scenarios but lamb sale dates and the number and timing of cattle changed.

108. OVERSEER® uses ~30-year annual average climate data and specific annual animal numbers. However, the use of OVERSEER® to predict nitrogen leaching loss values from the AgInform® scenarios is relevant because this is what the WRC has proposed using to generate the Nitrogen Reference Point for farms.

109. If actual rainfall is used instead of the annual average rainfall, which would be logical given that annual actual stock numbers are used and for sheep and beef, unlike dairy, the stock numbers are not constant across years, then the OVERSEER®-predicted losses are different.

110. For Case Study 1, the actual monthly rainfall number for each scenario for years 1 and 2 was entered in OVERSEER® instead of using the 30-year annual average figure. The results, which are shown in Table 4, are that the predicted nitrogen leaching and phosphorus loss risk values are lower than using the 30-year annual average rainfall data.

Table 4: OVERSEER®-predicted nitrogen leaching loss and phosphorus loss risk values for scenarios using either 30-year annual average climate data or monthly rainfall for the actual year from the NIWA climate site located closest to the farm.

Scenario number	Year	Nitrogen leaching loss		Phosphorus loss risk	
		kg N/ha/yr		kg P/ha/yr	
		Using annual average climate data	Using specific monthly rainfall	Using annual average climate data	Using specific monthly rainfall
301	1	17	16	0.8	0.5
301	2	15	12	0.7	0.3
302	1	19	17	0.8	0.5
302	2	12	10	0.7	0.3
303	1	14	13	0.8	0.5
303	2	24	19	0.8	0.3
304	1	17	15	0.8	0.5
304	2	12	10	0.7	0.3

111. From the modelling analyses conducted here, I believe that sheep and beef farmers should be given between-year flexibility and that they should be farming to the natural capital of the land.

112. I used the LUC N leaching table presented by Dr Tim Cox in his evidence and I used it to asses these three case study farms.

Table 5: Table 4-1 from Dr Cox's Evidence. LUC-Based Allocation Modelling Results: Nitrogen Allocations to Achieve Future Targets

LUC Class	Upper Waikato kg N/ha/yr	Middle Waikato kg N/ha/yr	Lower Waikato kg N/ha/yr	Waipā kg N/ha/yr
I	29.7	29.7	26.4	29.7
II	25.3	24.2	22.0	25.3
III	17.6	18.7	19.8	19.8
IV	17.6	18.7	17.6	19.8
V	15.4	15.4	15.4	15.4
VI	13.2	15.4	13.2	15.4
VII	8.8	9.9	8.8	11.0
VIII	4.4	4.4	4.4	4.4

113. I used the LUC maps and tables presented in Appendices 6 - 11 to work out the N allocation for each case study farm. The results for each region and each Case Study Farm are presented in Appendix 13.

114. To calculate the total N allowance for each farm the LUC specific N allowances were multiplied by the total hectares in that LUC class. The sum of these was then divided by the total area (ha) which gave the LUC allowance for the farm.

115. The three case study farms were in the Waipā region, however, the LUC N allowance was calculated for each region for comparison (Appendix 13).

116. From the base LUC N allowance figure a value ± 30% of that value was used to give a buffer zone to account for the variation in N leaching as stock numbers change to account for the annual pasture production and the degree of uncertainty in OVERSEER®.

117. The NRP value was taken from each Case Study farm's actual OVERSEER® file for 2015-16.

118. The LUC allowance for each of the case study farms with a ± 30% tolerance gives the results below. This compares to the N loss value for the 2015-16 year as would currently be their NRP.

Table 6: LUC N leaching allowances for three Case Study farms using Table 5 data.

	Case study 1	**Case study 2**	**Case study 3**
LUC N leaching allowance kg N/ha/yr	16	15	17
Plus 30%	21	20	22
Minus 30%	12	11	12
NRP 2015-16	15	19	20

119. I agree with the use of LUC to allocate N leaching. I believe that the values in the table require a buffer to account for:

(a) uncertainties in the OVERSEER® model;

(b) The use of annual average climate data; and

(c) The fact that low and medium input farm systems farm to the grass curve and thus their stock numbers vary year on year depending on the seasonal pasture production.

120. I have used a value of 30% but believe that the actual value used requires further investigation by experts in this area.

121. I also believe that a table of LUC based N allocation needs to be region specific to account for:

(a) Soil types; and

(b) Rainfall.

122. As well as modelling a LUC approach to providing flexibility for low intensity farming systems, Dr Cox modelled a flexibility cap scenario which

comprised set thresholds of intensity. These include enabling land uses to discharge nitrogen up to 15 kg N/ha/yr, and some farmers through consent to discharge up to 20 kg N/ha/yr. The scenario and justification is set out in Appendix 23.

123. I used the same methodology for calculating the average stock units for each farm as was used for calculating the LUC N allocation described earlier to assess the stock unit allocation for the three case study farms using Table 1 presented on page 19 of Dr Mackay's evidence. That table is reproduced here (Table 7).

Table 7: The weighted average stocking rate for each LUC class in each of the three freshwater management units within Waikato.

Freshwater management unit	Weighted average stock units/ha	Land Use Capability (LUC) Class							
		1	2	3	4	5	6	7	8
Upper Waikato	Top Farmers	27	23	16	16	14	12	8	0
	Average farmers	18	17	13	13	12	11	4	0
Waipa	Top Farmer	27	23	18	18	14	14	9	0
	Average Farmer	18	17	14	13	12	11	6	0
Middle Waikato	Top Farmer	27	22	17	17	14	14	9	0
	Average Farmer	18	16	14	12	12	11	6	0
Lower Waikato	Top Farmer	24	20	18	16	14	12	8	0
	Average Farmer	17	16	15	12	12	9	4	0

124. Using that table gives the following SU allocations for the three case study farms. The SU/total ha from the OVERSEER® files for the properties is also given as a reference. A complete table for all four freshwater catchments is found in Appendix 14.

Table 8: Stocking Rate allowances for three Case Study farms using Table 7 data.

	Case study 1	**Case study 2**	**Case study 3**
SR allowance SU/ha	13	12	13
Plus 30%	17	15	17
Minus 30%	9	8	9
SU2015-16	12	11	10

SUMMARY OF THE INPUT PROTOCOLS OF THE WRC VS BEST PRACTICE DATA INPUT STANDARDS

125. OVERSEER® files were generated using the data input protocols defined by Waikato Regional Council (Table 1; WRC (2018c)).

Table 9: Data input methodology for ensuring consistency of nitrogen reference data using the OVERSEER® model

OVERSEER® Parameter	Setting that must be used	Explanatory note
Farm model Pastoral and horticulture	To cover the entire enterprise including riparian, retired, forestry, and yards and races. The model is to include noncontiguous properties that are part of the enterprise that are in the same sub-catchment. If the farm (for example where dairy animals are grazed or wintered) is part of another farming business such as a drystock farm, the losses from those animals will be represented in the drystock farms' OVERSEER® model.	To capture the "whole farm" in one OVERSEER® file, where possible, to truly represent N losses from farms in the plan change area.
Location Pastoral and horticulture	Select Waikato Region	This setting has an effect on climate settings and some animal characteristics and is required to ensure consistency
Animal distribution – relative productivity pastoral only	Use "no differences between blocks" with the following exceptions: • Grazed pines or other woody vegetation. In this case use "Relative yield" and set the grazed pine blocks to 0.4 (40%) • Where the farm has a mixture of irrigated and non-irrigated areas. In this case use "Relative yield" and set the irrigated area to 1 (100%), and the non-irrigated areas to 0.75 (75%)	
Wetlands	Entered as Riparian Blocks	As per the 2016 OVERSEER® Best Practice Data Input Standards.

OVERSEER® Parameter	Setting that must be used	Explanatory note
Stock number entry	Based on specific stock numbers only	To ensure consistency and accuracy of stock number inputs.
For Animal weights	Only use OVERSEER® defaults – do not enter in weights and use the age at start setting where available (national averages)	Accurate animal weights are difficult to obtain and prove.
Block climate data	Only use the Climate Station tool For contiguous blocks use the coordinates from the location of the dairy shed or the middle of the farm area (for non-dairy) For non-contiguous blocks use individual blocks' climate station coordinates	
Soil description	Use Soil Order – obtained from S-Map or where S-Map is unavailable from LRI 1:50,000 data or a soil map of the farm.	To ensure consistency between areas of the region that have S-Map data and those that don't.
Missing data	In the absence of Nitrogen Referencing information being provided the Waikato Regional Council will use appropriate default numbers for any necessary inputs to the OVERSEER® model (such default numbers will generally be around 75% of normal Freshwater Management Unit^ average values for those inputs).	Some farms will not be able to supply data, therefore a default must be established.

126. I agree with the majority of WRC's data input methodology.

127. I disagree strongly with the use of Soil Order instead of S-Map (an online soils database provided by Manaaki Whenua-Landcare Research; https://smap.landcareresearch.co.nz/) is that not all land is mapped on S-Map. Indeed, anecdotal comment suggests that over half of New Zealand is not. Appendix 21 shows the areas of Waikato in the Waikato-Waipā catchment that are not on S-Map. My view is that using Soil Order rather than the more detailed S-Map Soil Series may result in large variations in

nitrogen leaching loss values calculated by OVERSEER® for some soil types.

128. Table 10 shows the results of using Soil Order and S-Map in OVERSEER® analysis of actual dairy farms. There are substantial differences in the nitrogen leaching losses resulting from the two input methodologies. These differences range from -7% to +90%.

Table 10: Whole farm N leaching losses predicted by OVERSEER® using WRC data input methodology with Soil Order, and S-Map soil information

	2017-18 Using Soil Order	2017-18 Using S-Map	Difference
	kg N/ha/yr		%
Farm A – Dairy	37	43	+16%
Farm B – Dairy	47	52	+11%
Farm C – Dairy	38	39	+3%
Farm D – Dairy	51	48	-6%
Farm E – Dairy	59	69	+17%
Farm F – Dairy	23	26	+13%
Farm G – Dairy	37	42	+14%
Farm H – Dairy	45	46	+2%
Farm I – Dairy	30	45	+50%
Farm J – Dairy	41	43	+5%
Farm K – Dairy	41	78	+90%
Farm L – Dairy	32	37	+16%
Farm M – Dairy	29	33	+14%
Farm N – Dairy	29	27	-7%
Farm O – Dairy	40	40	0%
Farm P – Dairy	38	45	+18%
Farm Q – Dairy	53	61	+15%
Farm R – Dairy	29	29	0%

129. However, the HRWO Nitrogen Development Guidelines state that “it is envisaged that in the near future the plan will allow for soils to be entered via the S-Map database” (WRC, 2018a).

130. This is most likely due to the introduction of OverseerFM®, which is linked to the Manaaki Whenua-Landcare Research S-Map database. In OverseerFM®, the user "draws" block boundaries on a map which then brings up the S-Map soil types and the soil characteristics for the area.

131. There are significant areas of the Waikato-Waipā region not mapped by S-Map (Appendix 21) which under the Best Practice Data Input Standards for OverseerFM® (Figure 16) would be either a farm-specific soil map done by a trained pedologist, soil order from a national scale soil map, or soil group (OverseerFM, 2019)

Figure 16: OverseerFM® user guide best practice data input standards for soil type (page 24; OverseerFM, 2019)

The Best Practice Data Input Standards – Soil:

1. If available use farm-specific soil map (enter specific soil moisture values or a sibling name) as identified by a trained soil pedologist. http://nzsss.science.org.nz/professional.html . This can be done by first selecting the appropriate Soil order and then adding further definition within the Soil Detail and Advanced Soil Properties section.

2. S-map data - OverseerFM obtains the S-map Online information for the area mapped. Soils can be added to the block as described below.

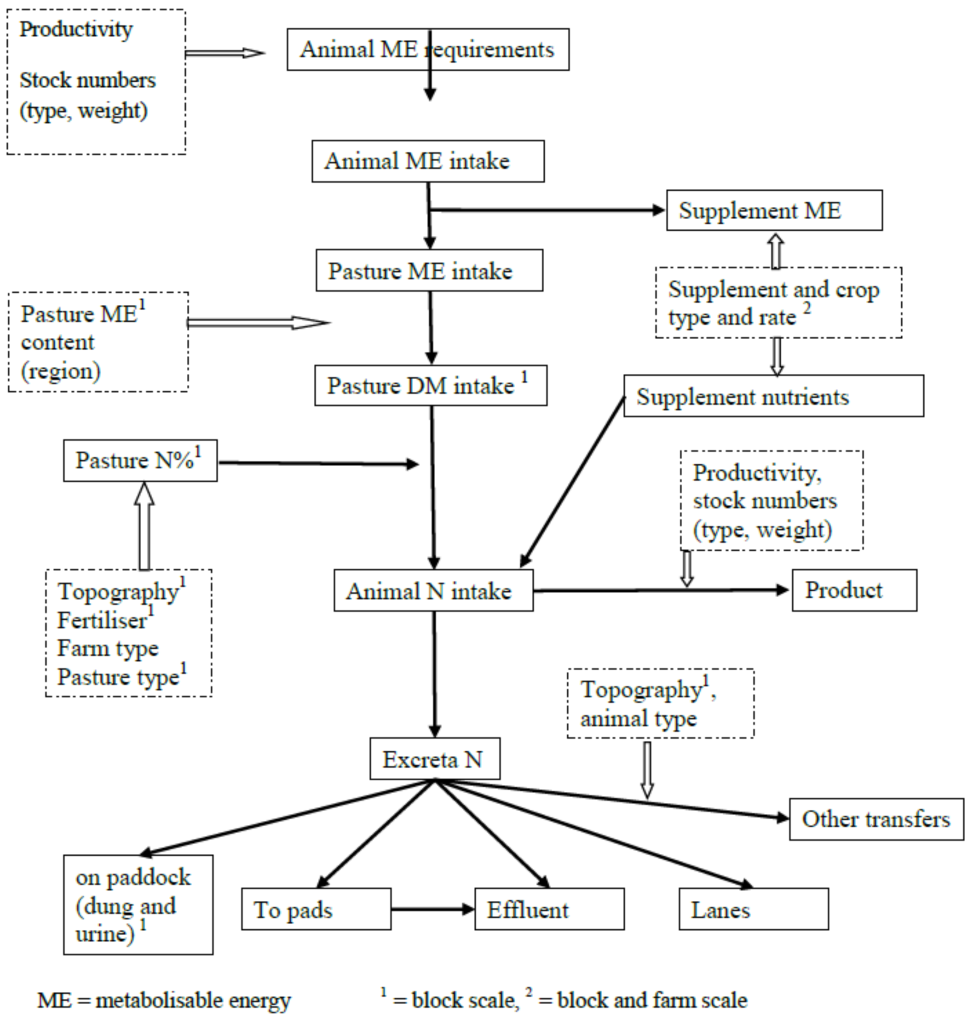
4. Soil Order – sourced from national scale soil map (Fundamental Soil Layer (FSL).

5. Soil Group – choose from drop-down menu.

132. Default liveweights are used in OverseerFM®, which will impact nitrogen leaching losses because pasture production is calculated from animal ME intake via Animal ME requirements which is calculated by user input values for stock numbers (type, weight, breed, age) and productivity (

133. Figure 17). Thus, a farm that has actual animal liveweights heavier than the default in OVERSEER® (or OverseerFM®) would be estimated to have lower ME requirement, lower ME intake, lower pasture production and thus less excretal N and less nitrogen cycling through the system so the estimate of nitrogen leaching loss would be lower than if actual animal liveweights were used. The opposite is true for those farms with animals lighter than the default liveweights.

Figure 17: Schematic diagram of the elements that constitute the animal framework in OVERSEER® (Wheeler, Shepherd, & Selbie, 2013)



134. The climate data used in OVERSEER® is a long-term average pattern of rainfall, temperature and potential evapotranspiration (PET). However, farmers are required by the HRWO Nitrogen Development Guidelines (WRC, 2018a) to enter livestock, fertiliser and supplementary feed data that is specific to one particular farming season (1 July – 30 June). This has the potential to over- or under-predict nutrient losses, particularly if farm management practices are conducted in response to a particularly wet or dry season as outlined in paragraphs 68 to 81.

NITROGEN RISK SCORECARD PRESENTED BY FONTERRA LTD

135. I have reviewed the Nitrogen Risk Scorecard (Scorecard) presented as Appendix 1 in the Evidence in Chief of Richard Allen of Fonterra Co-operative Group Ltd in HS1.

136. The scorecard highlights the high-risk activities that result in increased risk of N leaching. These are the same activities I identified in paragraph 17 of my HS1 Evidence in Chief. These are;

    (a) Stock Management (including stocking rate);

    (b) Nitrogen fertiliser applications;

    (c) Imported feed;

    (d) Cropping and cultivation (including method of cultivation, grazing management, and timing of grazing);

    (e) Irrigation;

    (f) Effluent management.

137. I believe that the Scorecard provides an easy visual representation on the level of nitrogen loss risk on a farm (designed specifically for dairy farms) caused by farm management decisions and practices.

138. I believe that the Scorecard approach could also be used across sheep and beef farms.

139. In my opinion, many sheep and beef farms would fall into the green, low-risk, category. They have lower stocking rates, apply minimal nitrogen fertiliser, don't import feed, are less likely to irrigate, and don't have effluent systems.

140. The management practice on sheep and beef farms most likely to receive an amber score is cropping and cultivation. These are high-risk activities for nutrient loss and the Scorecard would highlight cropping management that was undesirable while showing farmers alternative methods that would reduce their risk (Figure 18 - Figure 20).

Figure 18: Fonterra Nitrogen Risk Scorecard risk points calculation for conventional cultivation of crop

Answer	Points	Risk
2% or less of farm cultivated annually	10	
2-4% of farm cultivated annually	20	
4-6% of farm cultivated annually	30	
6-8% of farm cultivated annually	40	
8-10% of farm cultivated annually	50	
10-15% of farm cultivated annually	70	
15-20% of farm cultivated annually	90	
>20% of farm cultivated annually	120	

Figure 19: Fonterra Nitrogen Risk Scorecard risk points calculation for minimum tillage cultivation of crop

Answer	Points	Risk
2% or less of farm cultivated annually	0	
2-4% of farm cultivated annually	5	
4-6% of farm cultivated annually	10	
6-8% of farm cultivated annually	15	
8-10% of farm cultivated annually	20	
10-15% of farm cultivated annually	30	
15-20% of farm cultivated annually	40	
>20% of farm cultivated annually	50	

Figure 20: Fonterra Nitrogen Risk Scorecard risk points calculation for season of crop harvest

Answer	Points	Risk
Summer Harvest	-30	
Winter Harvest	30	

SOIL ORDERS IN WAIKATO AND THEIR DIFFERENT DRAINAGE CHARACTERISTICS

141. New Zealand soils are split into 15 Soil Orders in the New Zealand Soil Classification (NZSC). Of which 14 are used in OVERSEER® legacy. Soil Orders are subdivided further into Groups, Subgroups, Families and Siblings (Hewitt, 2010) (see Figure 21).

142. Soils in the Waikato-Waipā catchment area fall predominantly into nine of the 15 Soil Orders, which are classified as young, mature and old:

(a) Young soils

(i) Recent (58,962 ha; 5%)

(b) Mature soils

(i) Pumice (293,514 ha; 27%)

(ii) Allophanic (272,968 ha; 25%)

(iii) Podzol (107,968 ha; 10%)

(iv) Organic (73,182 ha; 7%)

(v) Brown (69,917 ha; 6%)

(vi) Gley (59,190 ha; 5%)

(c) Old soils

(i) Ultic (56,892 ha; 5%)

(ii) Granular (81,906 ha; 7%)

143. The areas of these soils add up to 97% of the total 1,098,344 ha. The remaining 3% are characterised as rivers, towns, and lakes. The area data was sourced from the Ministry for the Environment online NZ Fundamental Soil Layers dataset (MfE, 2016). These are shown in Appendix 22.

Figure 21: Organisation of NZ Soil Classification (NZSC) soil orders taken from Hewitt, A (2013). (Table 1, p 122)

Young soils		Raw Soils Recent Soils Anthropic Soils
Mature soils *Soils that have well developed topsoil and subsoil horizons*	***Climate*** *Soils formed in quartz rich materials that show the effects of climate*	Semiarid Soils Pallic Soils Brown Soils Podzols
	Wetness *Soils with prolonged high water tables*	Gley Soils Organic Soils
	Rock *Soil parent materials formed from rocks that dominate the soil character, e.g. lime-stone, basalt, pumice and volcanic ash*	Melanic Soils Pumice Soils Allophanic Soils
Old soils *On land surfaces with parent materials that have attributes of advanced weathering*		Ultic Soils Granular Soils Oxidic Soils

144. Young soils are weakly developed and occur on young parts of the landscape. Recent soils are usually fertile and deep rooting and occur on areas such as alluvial floodplains, sand dunes, unstable steep slopes and slopes mantled by volcanic ash (Hewitt, 2013).

145. Both Allophanic and Pumice soils are mature soils that were dominated by rock type in their formation (Figure 21). Allophanic soils are among the most versatile of New Zealand soils (Hewitt, 2013) because they resist the impact of heavy machinery and animals during winter, they have little resistance to root growth and retain large amounts of Phosphorus. These soils occur predominantly in the North Island. Allophanic soils are dominant in the Waipā region (see Appendix 22).

146. Pumice soils have a rapid drainage of excess water but they have a large plant-available water storage. These soils have low soil strengths when disturbed and thus the potential for erosion by water is high when the

surface vegetation or topsoil are removed. Historically, they have also been poor soils to raise animals due to being deficient in trace elements (Hewitt, 2013). These soils are dominant in the Upper Waikato see Appendices 21 and 22.

147. Organic soils were influenced by wetness in their formation (Figure 21). These soils were formed in the wetland areas of New Zealand and have been formed from decomposing peat or forest litter (Hewitt, 2013). These soils are in areas with a high-water table and are prone to waterlogging. They often have been drained to sustain farming systems. When drained, and fertilised, these soils can be highly productive but are prone to shrinkage when drained. They have a very high-water storage capacity.

148. Brown soils and Podzols were influenced by climate in their formation (Figure 21). The soil orders in the group of mature soils influenced by climate (Semiarid, Pallic, Brown soils and Podzols) cover over 73% of New Zealand (Hewitt, 2013). Brown soils are found in mountainous areas and extend into moist lowlands where summer droughts are uncommon. In the north, these soils occur in areas receiving more than 1000 mm rain annually. Historically, this has resulted in the leaching of nutrients (during formation of the soils) and thus in their natural state they have limited fertility. These soils respond well to fertiliser and are good for pastoral farming and are the most extensive soils in New Zealand covering 43% of the country (Hewitt, 2013).

149. Podzols occur in areas of high rainfall. They often have slow permeability and limited rooting depth. These occur largely in the Upper Waikato see Appendix 22.

150. Old soil orders occur on the rolling lands from Northland to northern Waikato in relatively stable areas of the landscape that escaped disruption from volcanic ash deposits. They have very low natural fertility, and very high clay contents and acidity. These can be seen by the Ultic, Granular and Oxidic soils located predominantly in the Lower Waikato (Appendix 22).

151. Ultic soils have low permeability and may become wet in winter. They are often susceptible to damage from livestock treading and can be prone to erosion (Hewitt, 2013). They cover 3% of New Zealand.

152. Granular soils occur in the lowlands of Waikato and South Auckland. They cover 1% of New Zealand and are prone to erosion when they are under long-term cultivation (Hewitt, 2013). When well-managed, these soils can support successful horticultural systems (e.g. around Pukekohe).

153. Two maps of the Soil Orders in the Waikato-Waipā catchment are shown in Appendices 21 and 22.

154. Appendix 21 shows the areas of Waikato-Waipā that are not covered by S-Map are predominantly areas in the Lower Waikato.

155. The legacy versions of OVERSEER®, which Overseer Ltd has announced will be replaced by OverseerFM® in mid-2019, allow for soils to be split into five drainage categories:

(a) well;

(b) moderately well;

(c) imperfect;

(d) poor; and

(e) very poor.

156. This option is also available in OverseerFM®, the cloud-based product that will be the only version of OVERSEER® available by mid-2019, however it is not as obvious. Default drainage characteristics are taken from the S-Map information and unless the user clicks on the S-Map soil type and scrolls down to soil profile and drainage class and alters the drainage there then it will remain the default.

157. When considering the relationship between drainage and the magnitude of nitrogen leaching from a soil, it is important to account for the water-holding capacity (measured as plant available water) and drainage porosity of that soil. A soil can be well-drained, which means that there is no impediment to drainage (such as a clay pan or high-water table) but that doesn't necessarily mean that the soil is prone to excessive drainage and thus leaching.

158. It helps to think of a soil profile as a sponge. A sponge has the ability to hold water up until a certain point, after which the addition of more water will result in drainage out the bottom of the sponge. The bigger the sponge, the more water it can hold. So, a soil that has a large water-holding capacity (the "size of the sponge") can hold a large volume of water before the commencement of drainage. Soils with a large water holding capacity have a relatively large capacity to store rainfall in the late spring to autumn period and so drainage is less unlikely in this period. Furthermore, as it takes more rainfall to fully re-wet soils with large water holding capacities, the drainage season will typically start later in late autumn- winter. Numerous free draining soils have deep soil profiles coupled with large water holding capacities and so result in higher storage and evapotranspiration and subsequently smaller annual drainage volumes.

159. A given quantity of surplus rainfall will 'flus' the pore system with a large drainable porosity (measured as a soils pore volume of water) fewer times in the winter/spring seasons and so leach less nitrogen than is the case for a soil with a small pore volume. Again, many free draining soils have a relatively large drainable porosity.

160. Thus, a well-drained soil is not necessarily what is colloquially called a "leaky" soil.

161. Excessively well drained soils that have a small water holding capacity and small pore volume (e.g. stony soils with large macropores) and a poorly developed shallow topsoil depth have less ability to hold on to the water before it is lost as drainage and excess rainfall will result in a through flushing of the pore system. These soils are 'leaky'.

162. Waikato does not have many 'leaky' soils as the soils are predominantly well-developed soils with a deep profile and without many course texture river valleys or sand dune country.

163. In terms of the soils found in the Waikato-Waipā region the soils orders that would be termed 'leaky' are shallow recent soils (where they exist) and then pumice soils where they are shallow in depth. These are found, predominantly, in the lower Waikato (Recent) and in the Upper Waikato

(Pumice). Although of the large area of Pumice soils in the Upper Waikato I am unsure what proportion of those are shallow in depth.

164. In terms of soils that have a relatively low risk of N leaching these would be the Organic soil orders because of their high C content. However, they have a very high P leaching risk because of a low anion storage capacity (ASC). Organic soil orders are located mainly in the lower Waikato.

Jane Marie Chrystal
9 May 2019

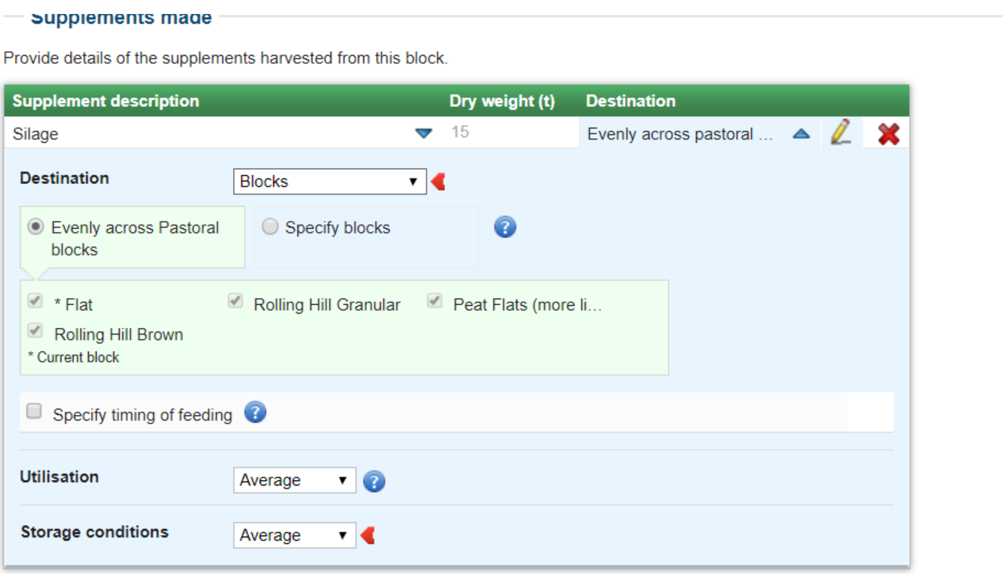
APPENDIX 1: ASSUMPTIONS USED IN MODELLING MULTIPLE YEARS USING B+LNZ SHEEP AND BEEF FARM SURVEY DATA

165. The farms were not re-visited or contacted to provide in-depth information on their farming systems in previous seasons. Thus, the OVERSEER® files were created using available Survey information, and assumptions.

166. It was necessary to make a number of assumptions about the OVERSEER® blocks to which fertiliser was applied and about crop types for the early seasons because the data collected in the Survey did not contain those details. The initial files for 2015-16 were re-calculated using the same methodology as for the rest of the years. For this reason, the values under the heading “Same methodology for comparison” in Table 1 should be used for comparison, not the initial values resulting from OVERSEER® analysis presented in Hearing Stream 1 (under the heading “Original file” in Table 1).

167. Survey data provided the total area of hay/silage production. I assumed that silage was made on the flattest farm blocks and produced 3 t DM/ha, which is an average yield in Waikato (Richmond Beetham pers comm) and that it was fed evenly across all blocks.

Figure 22: OVERSEER® input assumption data used for silage production



168. In 1993-94, one farm had 113 goats so they were entered as a breeding ewe. This was because OVERSEER® has a goat enterprise for dairy goats only and I had no information to suggest that these goats were dairy

goats. They were entered as a ewe as they would be an equivalent stock unit.

169. If winter crops were used in years prior to 201516, they were assumed to be the same crop as used in 201516 (the Survey only recorded winter crop areas not type prior to this time).

170. If there was no winter crop in 201516, but there was prior to that then it was assumed to be kale grazed by cattle.

APPENDIX 2: FARM CLASS DESCRIPTIONS

Farm Class and Descriptor	**Description**
Class 1 - South Island high country	Extensive run country at high altitude carrying fine wool sheep, with wool as the main source of revenue. Located mainly in Marlborough, Canterbury and Otago.
Class 2 - South Island hill country	Mainly mid-micron wool sheep mostly carrying between two and seven stock units per hectare. Three quarters of the stock units wintered are sheep and one quarter beef cattle.
Class 3 - North Island hard hill country	Steep hill country or low fertility soils with most farms carrying six to 10 stock units per hectare. While some stock are finished a significant proportion are sold in store condition.
Class 4 - North Island hill country	Easier hill country or higher fertility soils than Class 3. Mostly carrying between seven and 13 stock units per hectare. A high proportion of sale stock sold is in forward store or prime condition.
Class 5 - North Island intensive finishing	Easy contour farmland with the potential for high production. Mostly carrying between eight and 15 stock units per hectare. A high proportion of stock is sent to slaughter and replacements are often bought in.
Class 6 - South Island finishing-breeding	A more extensive type of finishing farm, also encompassing some irrigation units and frequently with some cash cropping. Carrying capacity ranges from six to 11 stock units per hectare on dryland farms and over 12 stock units per hectare on irrigated units. Mainly in Canterbury and Otago. This is the dominant farm class in the South Island.
Class 7 - South Island intensive finishing	High producing grassland farms carrying about 10 to 14 stock units per hectare, with some cash crop. Located mainly in Southland, South and West Otago.
Class 8 - South Island mixed cropping and finishing	Located mainly on the Canterbury Plains. A high proportion of their revenue is derived from grain and small seed production as well as stock finishing.

APPENDIX 3: DESCRIPTIONS OF THE MODELS USED TO GENERATE AGINFORM OUTPUT DATA

APSIM

171. The **A**gricultural **P**roduction **S**ystem S**IM**ulator (APSIM; Holzworth et al. (2014)) version 7.10 r4158 was used to model nitrogen leaching losses. APSIM is a farm systems model with modules simulating soil functions, crop and pasture growth and nutrient uptake, and the impacts of livestock production systems on cycling of nitrogen in soils. It enables users to assess the impacts of a range of systems and scenarios on a number of variables including nitrogen leaching loss (Holzworth et al. 2014). APSIM's soil modules simulate the processes occurring in the soil profile, including water infiltration and movement, runoff and drainage, evaporation, nitrogen transformations and cycling, and soil organic matter decomposition (Holzworth et al. 2014).

AgInform®

172. AgInform® Integrated Farm Optimisation and Resource Allocation Model (Rendel et al., 2016) is a farm financial optimisation tool created by AgResearch Ltd. It takes into account the natural capital of the land and the user splits a farm into land management units (LMUs). The user enters farm-specific data and the tool then optimises the farm financially. This tool works at a strategic level rather than a tactical level as Farmax, which is a farm planning software tool – also originally developed by AgResearch.

173. With Farmax, the farm optimisation is very much dependant on the user's concept of the optimal farming system for that property. A strength of AgInform® is that it can identify optimal systems under alternative boundary conditions (for example limits on nitrogen leaching losses) and gives the user an understanding of the financial and system implications of such constraints (Hendy et al., 2018). Another strength is that AgInform® is run as a multi-year model that uses estimated pasture growth over a period of years determined from actual climate data over that period then the model is optimised for the farm over that multi-year period. Thus, the resulting optimal farming system takes into account the between-year variation in

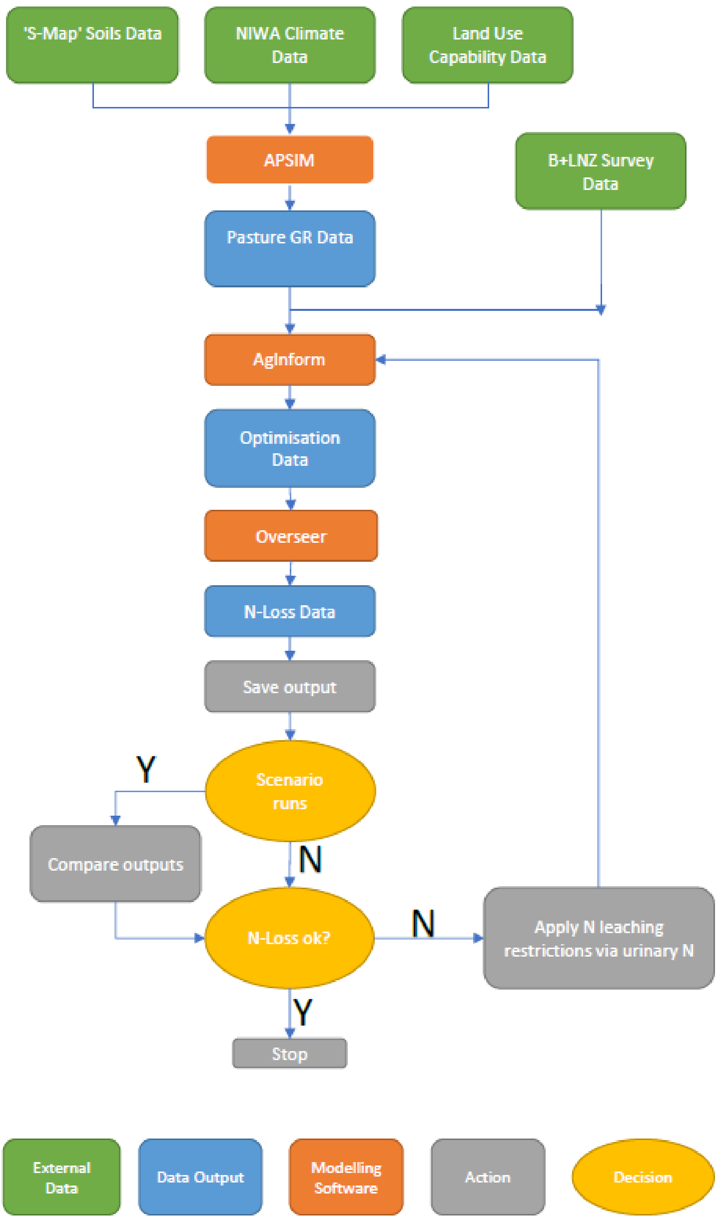
climate and pasture production, which is something that steady-state models like OVERSEER® and Farmax do not do.

APPENDIX 4: DESCRIPTIONS AND SOURCES OF DATA AND LINKAGES BETWEEN MODELS TO OBTAIN AGINFORM-OPTIMISED OUTPUT DATA

Overview

174. The generation of AgInform® models required a number of inputs from other data sources and/or models. The source of data and modelling process is shown in the flow diagram in Figure 23.

Figure 23: Flow diagram of the data sources, simulation models, and process used to calculate farm optimisation scenarios for case study sheep and beef farms



Process

175. For each farm, climate data was taken from NIWA's weather site information on the Cliflo website (NIWA, 2019). The site used (station number #26117) was selected according to three criteria:

(a) Multiple years of records (at least 10 consecutive years);

(b) Measurements of the required attributes: maximum temperature, minimum temperature, daily rainfall, daily radiation; and

(c) The closest weather station to the farm that met criteria a. and b. above.

176. Soils information originally sourced from Manaaki Whenua (Landcare Research) for Otorohanga soil type was provided by Dr Iris Vogeler from Plant and Food Research. This was the dominant soil type for all three properties so was used for all. A soil report for this soil is presented in Appendix 5 (Manaaki_Whenua, 2019).

177. The climate and soils data was then used in the APSIM model to generate daily pasture growth rates (PGRs) for the case study farm.

178. The APSIM output assumed that the farm was flat land. LUC data was then used to alter the pasture growth rates for each LMU according to the carrying capacity of the LUCs.

179. Farm livestock data and financial data was taken from the B+LNZ Sheep and Beef Farm Survey records for the 2014-15 and 2015-16 farming seasons.

180. These data were then used to populate AgInform®, which financially optimised the farm given the data supplied.

181. The output of this was then entered in OVERSEER® to obtain an estimate of nutrient leaching loss values for the optimised scenario.

182. In order to assess the impacts of a restricted nitrogen leaching loss value on the financial optimisation of the farm, the urinary nitrogen value was reduced in AgInform® and the resulting output run through OVERSEER®.

183. The next step was to remove the use of nitrogen fertiliser applied as a proxy to lower N leaching. This was done realising that N fertiliser would be linked to higher stocking densities.

184. The resulting farm profit resulting from the optimisation and the base (with no N restriction) were compared.

APPENDIX 5: SOIL REPORT – OTOROHANGA SOIL TYPE

Source: https://smap.landcareresearch.co.nz/

Manaaki Whenua Landcare Research

SOIL REPORT

Environment Waikato

Report generated: 4-Apr-2019 from https://smap.landcareresearch.co.nz

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks.

S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Family: Mairoa*f*

Smap ref: Mai_4a.1

Otorohanga (Mairoa_4a.1)

Key physical properties

Depth class (diggability)		Deep (> 1 m)
Texture profile		Clay
Potential rooting depth		Unlimited
Rooting barrier		No significant barrier within 1 m
Topsoil stoniness		Stoneless
Topsoil clay range		25 - 38 %
Drainage class		Well drained
Aeration in root zone		Unlimited
Permeability profile		Moderate
Depth to slowly permeable horizon		No slowly permeable horizon
Permeability of slowest horizon		Moderate (4 - 72 mm/h)
Profile available water	(0 - 100cm or root barrier)	High (191 mm)
	(0 - 60cm or root barrier)	Very high (125 mm)
	(0 - 30cm or root barrier)	High (68 mm)
Dry bulk density, topsoil		0.78 g/cm³
Dry bulk density, subsoil		1.26 g/cm³
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	High (83%)

About this publication

- This information sheet describes the *typical average properties* of the specified soil.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz
- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
- This information sheet is licensed by Landcare Research on an "as is" and "as available" basis and without any warranty of any kind, either express or implied.
- Landcare Research shall not be liable on any legal basis (including without limitation negligence) and expressly excludes all liability for loss or damage howsoever and whenever caused to a user of this factsheet.

Manaaki Whenua Landcare Research

Environment Waikato

Family: Mairoa*f*

Smap ref: Mai_4a.1

Otorohanga (Mairoa_4a.1)

Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Soil structure integrity

Structural vulnerability	Very low (0.20)
Pugging vulnerability	not available yet

Water management

Water logging vulnerability	Very low
Drought vulnerability - if not irrigated	Low
Bypass flow	Low
Hydrological soil group	A

Contaminant management

N leaching vulnerability	Low
P leaching vulnerability	not available yet
Bypass flow	Low
Dairy effluent (FDE) risk category	C if slope > 7 deg otherwise D

Relative Runoff Potential

Slope	0-3°	4-7°	8-15°	16-25°	>25°
Risk	VL	VL	VL	VL	L

Additional information

Soil classification	Typic Orthic Allophanic Soils (LOT)
Family	*Mairoaf*
Sibling number	4
Profile texture group	Clayey
Soil profile material	Tephric soil
Rock class of stones/rocks	Not applicable
Rock origin of fine earth	From rhyolitic and andesite rock
Parent material origin	Tephra

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Weak, Acidic Tephric	15 - 22 cm	0 %	25 - 38 %	10 - 18 %
Clayey Weak, Acidic Tephric	35 - 50 cm	0 %	40 - 60 %	6 - 18 %
Clayey Fine Sl Firm, Acidic Tephric	35 - 45 cm	0 %	30 - 65 %	10 - 15 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

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Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

1. Select **Link to S-map**
2. Under S-map sibling data enter the S-map name/ref: **Mai_4a.1**

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Manaaki Whenua datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates supplied by the web service have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER.

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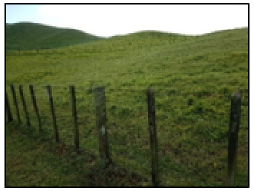
APPENDIX 6: CASE STUDY 1 LUC TABLE

Cambridge Sheep and Beef Farm Land Use Capability Table

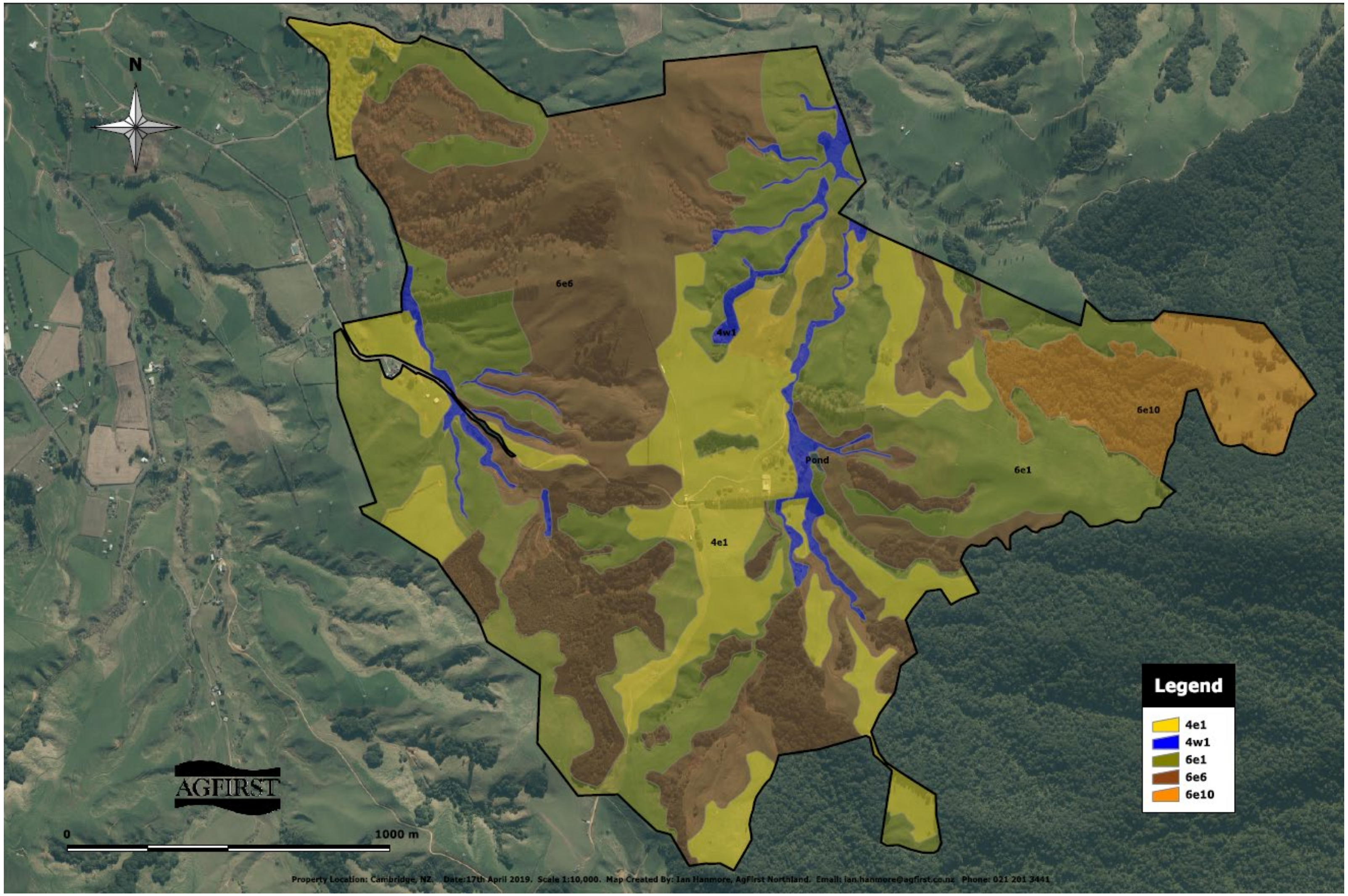
Farm resource information	Luc unit	Total area (ha)	Parent material Dominant soil type and characteristics	Slope degree	Land Cover	Erosion degree & severity		Strengths	Limitations	Landuse suitability	Stock carrying capacity (su/ha)	Conditions of use
						Actual	Potential					
4e 1 Strong rolling slopes on yellow-brown loams with a moderate to severe erosion hazard when cultivated. 		78.9	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil • Well drained • Stoneless • No significant rooting barrier within 1m • Moderate permeability • High P retention (83%) • Low N leaching vulnerability • Very low structural vulnerability (0.2) • Very low water logging vulnerability	8-20°	Pasture	Nil	Slight gully. Moderate to severe sheet and rill and moderate gully when cultivated	• Contour • Accessibility • Free draining soil • Supports high producing pasture	• Moderate to severe erosion limitation under cultivation	Intensive grazing Occasional cropping. Forestry	Average: 14 Top: 18 Potential: 20	• Avoid structural degradation of soils under intensive, regular cropping • Contour cultivation required and minimum tillage practices required
4w 1 Narrow stream terraces and valley bottoms with moderately highwater table and subject to runoff from adjacent hills, dissected by meandering streams. 		13.2	**Parent:** Alluvium and peat **Soil:** Peat soil • Poorly drained/high water tables • Low pH • High carbon:nitrogen ratio • Low mineral content and therefore deficient in all major elements required for plant growth	0-7^{0}		Nil	Moderate to severe streambank and deposition	• Contour • Accessibility • Greater pasture water availability under drought conditions	• Streambank erosion potential • Seasonal wetness limitation • Seasonal pugging risk	Grazing	Data not available	• Keep heavy stock off when soils are wet • Possible streambank erosion control planting needed
6e 1 Moderately steep to strong rolling slopes on yellow-brown loams over various lithologies. 		132.1	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	16-25^{0}	Pasture	Negligible.	Slight sheet and soil slip	• Free draining soil • Stable, high producing hill country	• Steep gradient precludes cropping • Gradient gives slight erosion risk	Intensive grazing Forestry	Average: 13 Top: 18 Potential: 21	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines.

Farm resource information	Luc unit	Total area (ha)	Parent material Dominant soil type and characteristics	Slope degree	Land Cover	Erosion degree & severity		Strengths	Limitations	Landuse suitability	Stock carrying capacity (su/ha)	Conditions of use
						Actual	Potential					
6e 6 Moderately steep to steep greywacke slopes where rainfall is less than 1500mm p.a. 		161.5	**Parent:** Patchy Mairoa ash over Greywacke **Soil:** Mairo clay	$21-35^{0}$	Pasture Indigenous vegetation	Slight to moderate sheet, soil slip and gully	Moderate sheet, soil slip and gully	• Good natural fertility • Indigenous vegetation adds biodiversity value and shade and shelter for stock	• Steep gradient precludes cropping • Gradient gives a moderate erosion risk • Difficult to revegetate erosion scars • Prone to reversion	Intensive grazing Forestry	Average: 11 Top: 14 Potential: 16	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines. • Open plant poplar poles on steep slopes to help control/prevent erosion • Pair plant willow poles in gullies to help prevent gully erosion
6e10 Strong rolling to steep slopes on Mairoa ash and andesite. 		29.1	**Parent:** Patchy Mairoa ash over andesite **Soil:** Mahoenui loam • Well drained • Moderately stony topsoil • Potential rooting depth 60-80cm, massive rock barrier • Slightly limited aeration in the root zone • Moderate over slow permeability • Low P retention (22%) • High structural vulnerability (0.67) • Low water logging vulnerability • Medium N leaching vulnerability	$16-35^{0}$	Pasture Indigenous vegetation	Negligible	Moderate sheet and soil slip	• Free draining soil • Stable hill country	• Steep gradient precludes cropping • Gradient gives a slight to moderate erosion risk	Intensive grazing Forestry	Average: 10 Top: 11 Potential: 12	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines. • Open plant poplar poles to help prevent/control erosion

LUC Unit	Area (Ha)
4e 1	78.9
4w 1	13.2
6e 1	132.1
6e 6	161.5
6e10	29.1
Pond	0.1
Total Area	**414.9**

APPENDIX 7: CASE STUDY 1 LUC MAP

Cambridge Sheep and Beef Farm Land Use Capability Classifications

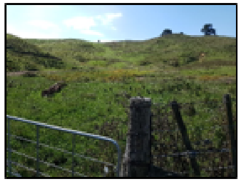


APPENDIX 8: CASE STUDY 2 LUC TABLE

Otorohanga Dairy Farm Land Use Capability Table

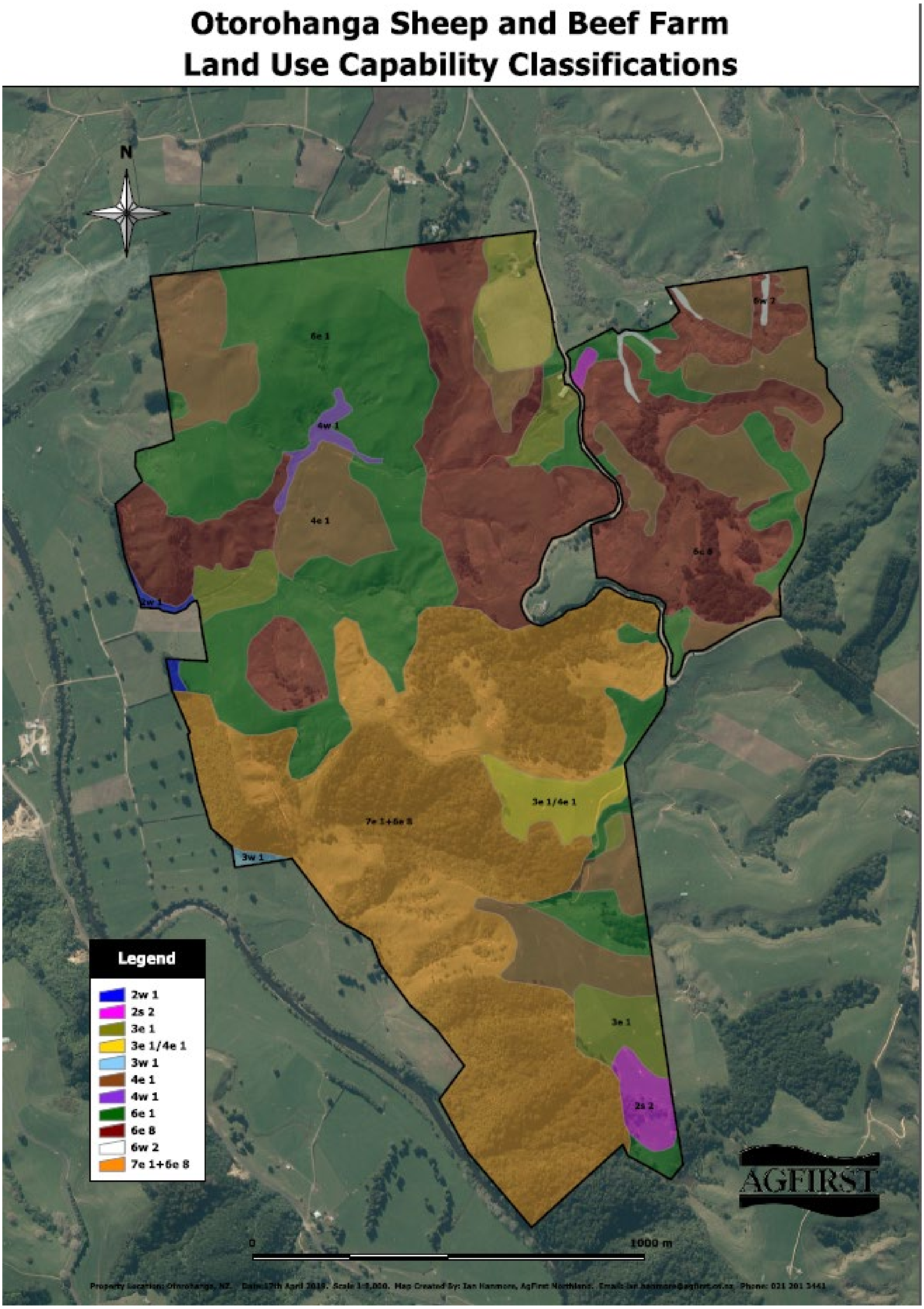
Farm resource information	Luc unit	Total area (ha)	Parent material Dominant soil type and characteristics	Slope degree	Land Cover	Erosion degree & severity		Strengths	Limitations	Landuse suitability	Stock carrying capacity (su/ha)	Conditions of use
						Actual	Potential					
2w 1 Low river terraces with a continuing slight wetness limitatio after drainage. 		88.6	**Parent:** Alluvium **Soil:** Awatere sandy loam • Well drained • Slightly stony • No significant rooting barrier within 1m • Rapid permeability • Low P retention (19%) • Low N leaching vulnerability • High structural vulnerability (0.61) • Very low water logging vulnerability	0-3⁰	Pasture	Nil	Nil.	• Contour • Accessibility • Supports high producing pasture and cropping	• Slight soil limitation for cropping use .	Intensive grazing Intensive cropping Forestry	Average: 17 Top: 25 Potential: 28	• Avoid structural degradation of soils under intensive, regular cropping • Careful control of ground water tables necessary
3e 1 Rolling slopes on yellow-brown loams with slight to moderate erosion hazard when cultivated. 		4.8	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil • Well drained • Stoneless • No significant rooting barrier within 1m • Moderate permeability • High P retention (83%) • Low N leaching vulnerability • Very low structural vulnerability (0.2) • Very low water logging vulnerability	8-15⁰	Pasture	Nil	Slight to moderate sheet and rill when cultivated.	• Contour • Accessibility • Free draining soil • Supports high producing pasture and cropping	• Moderate erosion limitation under cultivation	Intensive grazing Cropping Forestry	Average: 14 Top: 18 Potential: 21	• Avoid structural degradation of soils under intensive, regular cropping • Contour cultivation required
3w 1 Narrow river terraces with a moderately high water table and subject to runoff from adjacent hills. 		2.3	**Parent:** Colluvium, alluvium **Soil:** Sandy loam over sandy alluvial soils over lying poorly drained colluvium from surrounding hills. Fine textured • No significant rooting barrier within 1m • Low N leaching vulnerability • Low P retention • Imperfectly drained	0-3⁰	Pasture	Nil	Moderate streambank	• Contour • Accessibility • Supports high producing pasture and cropping	• Moderate wetness limitation to cropping	Intensive grazing Cropping	Average: 12 Top: 16 Potential: 20	• Drainage and streambank protection maybe needed in some places

4e 1 Strong rolling slopes on yellow-brown loams with a moderate to severe erosion hazard when cultivated. 		5.3	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	8-20°	Pasture	Nil	Slight gully. Moderate to severe sheet and rill and moderate gully when cultivated	• Contour • Accessibility • Free draining soil • Supports high producing pasture	• Moderate to severe erosion limitation under cultivation	Intensive grazing Occasional cropping. Forestry	Average: 14 Top: 18 Potential: 20	• Avoid structural degradation of soils under intensive, regular cropping • Contour cultivation required and minimum tillage practices required

Farm resource information	Luc unit	Total area (ha)	Parent material Dominant soil type and characteristics	Slope degree	Land Cover	Erosion degree & severity		Strengths	Limitations	Landuse suitability	Stock carrying capacity (su/ha) Forestry site index (FSI)	Conditions of use
						Actual	Potential					
6e 1 Moderately steep to strong rolling slopes on yellow-brown loams over various lithologies. 		3.7	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	16-25⁰	Pasture	Negligible.	Slight sheet and soil slip	• Free draining soil • Stable, high producing hill country	• Steep gradient precludes cropping • Gradient gives slight erosion risk	Intensive grazing Forestry	Average: 13 Top: 18 Potential: 21	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines.
6e 8 Moderately steep to steep slopes om Mairoa ash over Tertiary sedimentary lithologies. 		0.5	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	21-35⁰	Pasture	Slight soil slip	Moderate sheet and soil slip	• Free draining soil • Stable, high producing hill country	• Steep gradient precludes cropping • Gradient gives a moderate erosion risk	Intensive grazing Forestry	Average: 9 Top: 12 Potential: 14	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines. • Open plant poplar poles on steepest slopes to control/prevent erosion

LUC Unit	Area (Ha)
2w 1	88.6
3e 1	4.8
3w1	2.3
4e 1	5.3
6e 1	3.7
6e 8	0.5
River	2.8
Total Area	**108.0**

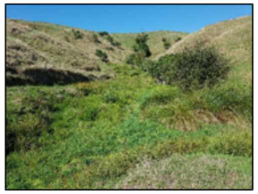
APPENDIX 9: CASE STUDY 2 LUC MAP



APPENDIX 10: CASE STUDY 3 LUC TABLE

Te Awamutu Sheep and Beef Farm Land Use Capability Table

Farm resource information	Luc unit	Total area (ha)	Parent material Dominant soil type and characteristics	Slope degree	Land Cover	Erosion degree & severity		Strengths	Limitations	Landuse suitability	Stock carrying capacity (su/ha)	Conditions of use
						Actual	Potential					
3e 1 Rolling slopes on yellow-brown loams with slight to moderate erosion hazard when cultivated. 		23.2	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil • Well drained • Stoneless • No significant rooting barrier within 1m • Moderate permeability • High P retention (83%) • Low N leaching vulnerability • Very low structural vulnerability (0.2) • Very low water logging vulnerability	8-15⁰	Pasture	Nil	Slight to moderate sheet and rill when cultivated.	• Contour • Accessibility • Free draining soil • Supports high producing pasture and cropping	• Moderate erosion limitation under cultivation	Intensive grazing Cropping Forestry	Average: 14 Top: 18 Potential: 21	• Avoid structural degradation of soils under intensive, regular cropping • Contour cultivation required
4e 1 Strong rolling slopes on yellow-brown loams with a moderate to severe erosion hazard when cultivated. 		39.1	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	8-20⁰	Pasture	Nil	Slight gully. Moderate to severe sheet and rill and moderate gully when cultivated	• Contour • Accessibility • Free draining soil • Supports high producing pasture	• Moderate to severe erosion limitation under cultivation	Intensive grazing Occasional cropping. Forestry	Average: 14 Top: 18 Potential: 20	• Avoid structural degradation of soils under intensive, regular cropping • Contour cultivation required and minimum tillage practices required
6e 1 Moderately steep to strong rolling slopes on yellow-brown loams over various lithologies. 		27.1	**Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	16-25⁰	Pasture Indigenous vegetation	Negligible.	Slight sheet and soil slip	• Free draining soil • Stable, high producing hill country	• Steep gradient precludes cropping • Gradient gives slight erosion risk	Intensive grazing Forestry	Average: 13 Top: 18 Potential: 21	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines.

Farm resource information	Luc unit	Total area (ha)	Parent material Dominant soil type and characteristics	Slope degree	Land Cover	Erosion degree & severity		Strengths	Limitations	Landuse suitability	Stock carrying capacity (su/ha)	Conditions of use
						Actual	Potential					
6e10 Strong rolling to steep slopes on Mairoa ash and andesite. 		132.7	Andesite **Parent:** Tephra – Mairoa ash **Soil:** Mairoa clay soil	16-35^0	Pasture Indigenous vegetation	Negligible	Moderate sheet and soil slip	• Free draining soil • Stable hill country	• Steep gradient precludes cropping • Gradient gives a slight to moderate erosion risk	Intensive grazing Forestry	Average: 10 Top: 11 Potential: 12	• Maintain good pasture cover. • Carefully plan all earthworks and minimize exposure of bare ground. • When harvesting plantation trees follow industry best practice guidelines. • Open plant poplar poles to help prevent/control erosion
6w 2* Hillside springs and narrow seeps with a severe wetness limitation. Surface water present during the winter with high water tables through the rest of the year. 		0.3	**Parent:** Colluvium and swamp material **Soil:** Unnamed soil Material located at the bottom of narrow gullies fed by hillside springs and runoff. Material to wet and undeveloped to be called a soil.	0-7^0	Rushes, pasture	Severe debris flow	Moderate to severe streambank and debris flow	• If retired water quality and biodiversity benefits	• Severe wetness limitation • Erosion potential	Retirement Light sheep grazing in summer	Data not available	• Pair plant willow poles at the edges of seeps to help stabilize slopes above and prevent slumping and to stabilize seep soil material and vegetation during high rainfall events. • Willow poles will help to dry out the seeps and minimize pugging damage.

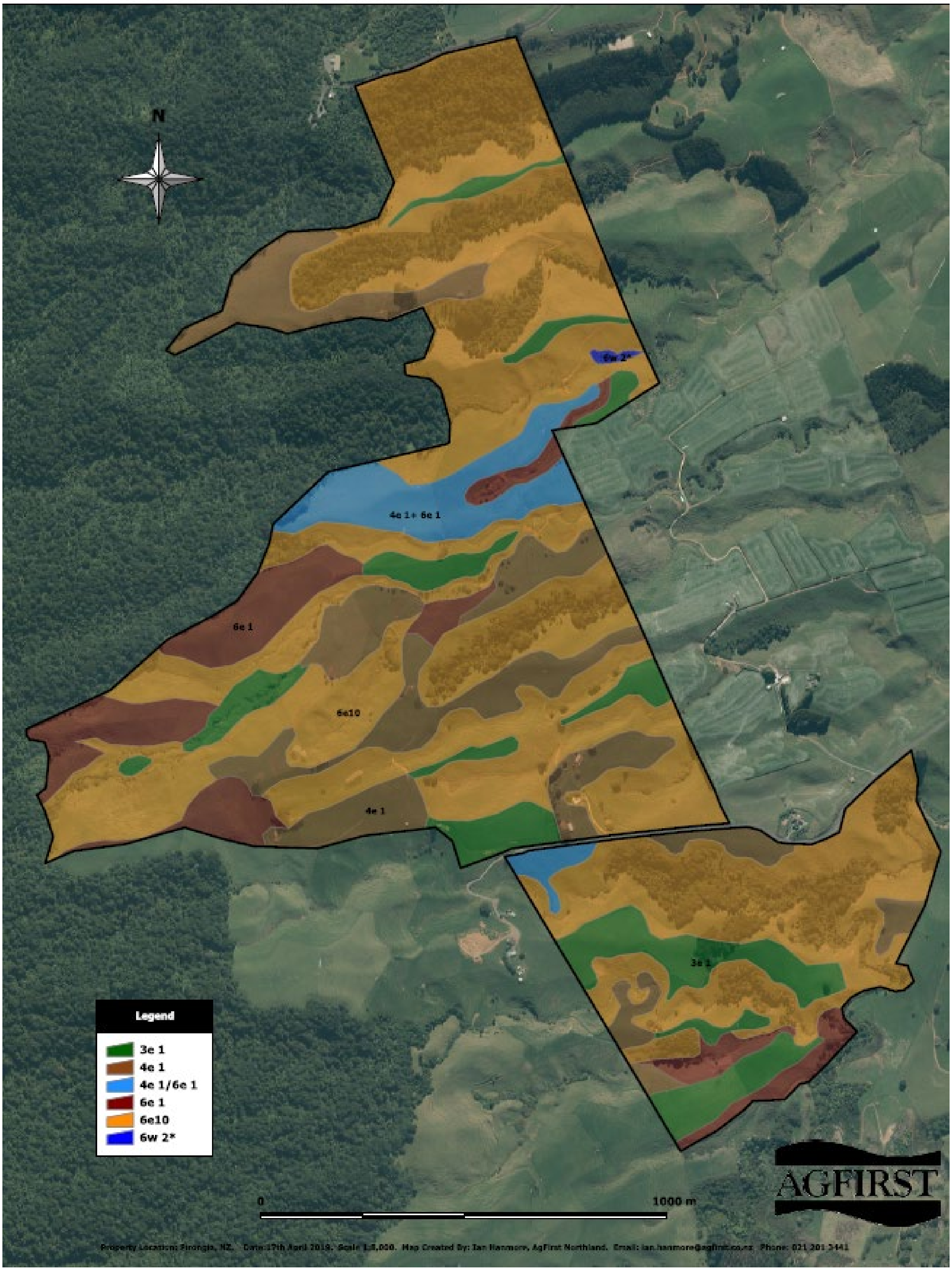
LUC Unit	Area (Ha)
3e 1	23.2
4e 1	39.1
6e 1	27.1
6e10	132.7
6w 2	0.3
Total Area	**222.4**

Note: *LUC and Soil data is obtained from:*

- *Field work*
- *Waikato Region: Land Use Capability Extended Legend*
- *Stock Carrying Capacities and Fertilizer Data for the Waikato Region 13th June 1980*
- *S-Map soil Factsheets*

APPENDIX 11: CASE STUDY 3 LUC MAP

Te Awamutu Sheep and Beef Farm
Land Use Capability Classifications



APPENDIX 12: CASE STUDY LAND MANAGEMENT UNITS (LMUs) FOR AGINFORM ANALYSIS

Table 11: LUC units and their carrying capacities for Case Study farms, split into LMUs for AgInform® modelling

Case Study 1: Cambridge Sheep and Beef Farm				
LUC unit	**Total Area**	**Carrying capacity 'top'**	**AgInform LMU group**	**Area in trees**
	ha	**SU/ha**		**ha**
4e1	78.9	18	LMU1	
4w1	13.2	Not available	LMU1	
6e1	132.1	18	LMU1	
6e6	161.5	14	LMU2	19.8
6e10	29.1	11	LMU3	20.0
Pond	0.1			
Total area	414.9			39.8
Total grazed area	375.0			
Case Study 2: Otorohanga Sheep and Beef Farm				
2s2	3.1	17	LMU 1	
2w1	0.7	25	LMU 1	
3e1	16.7	18	LMU 1	
3w1	0.4	12	LMU 1	
4e1	39.9	18	LMU 1	
4w1	1.4	?	LMU 1	
6e1	61.8	18	LMU 1	
6e8	59.2	12	LMU 2	
6w2	0.6	?	LMU 2	
7e1	86.4	10	LMU 3	50.0

Total area	270.2			50.0
Total grazed area	220.2			
Case Study 3: Te Awamutu Sheep and Beef Farm				
3e1	23.2	18	LMU 1	
4e1	39.1	18	LMU 1	
6e1	27.1	18	LMU 1	
6e10	132.7	11	LMU 2	51.4
6w2	0.3	?	LMU 2	
Total area	222.4			51.4
Total grazed area	171.0			

APPENDIX 13: CALCULATION OF LUC BASED NITROGEN ALLOCATION FOR THREE CASE STUDY FARMS

Table 12: Calculation of LUC N allowance figures for three Case Study Farms in Waikato. A LUC N allowance value is given with a ± 30% buffer zone

Waipa		Area in each LUC		
N allowance	LUC class	Case Study 1	Case Study 2	Case Study 3
29.7	1	0	0	0
25.3	2	0	4	0
19.8	3	0	17	23
19.8	4	92	41	39
15.4	5	0	0	0
15.4	6	323	122	160
11	7	0	86	0
4.4	8	0	0	0
	Total Ha	415	270	222
	Waipa			
	LUC allowance	16	15	17
	plus 30%	21	20	22
	minus 30%	11	11	12
	NRP 15/16	15	18	20
	Middle Waikato			
	LUC allowance	16	14	16
	plus 30%	21	19	21
	minus 30%	11	10	11
	NRP 15/16	15	18	20
	Lower Waikato			
	LUC allowance	14	13	15
	plus 30%	18	17	19
	minus 30%	10	9	10
	NRP 15/16	15	18	20
	UpperWaikato			
	LUC allowance	14	13	14
	plus 30%	18	17	19
	minus 30%	10	9	10
	NRP 15/16	15	18	20

APPENDIX 14: CALCULATION OF LUC-BASED STOCK UNIT ALLOCATION FOR THREE CASE STUDY FARMS

Table 13: Calculation of LUC Stock Unit allowance figures for three Case Study Farms in Waikato. A LUC Stock Unit allowance value is given with a ±30% buffer zone. Actual 2015-16 SU values (from OVERSEER®) are given as reference.

Waipa		Area in each LUC (ha)		
SU allowance	LUC class	Case Study 1	Case Study 2	Case Study 3
27	1	0	0	0
23	2	0	4	0
16	3	0	17	23
16	4	92	41	39
14	5	0	0	0
12	6	323	122	160
8	7	0	86	0
0	8	0	0	0
	Total Ha	415	270	222
	Waipa			
	LUC SU allowance	13	12	13
	plus 30%	17	15	17
	minus 30%	9	8	9
	SU 15/16	12	11	10
	Middle Waikato			
	LUC SU allowance	15	13	15
	plus 30%	19	17	19
	minus 30%	10	9	10
	SU 15/16	12	11	10
	Lower Waikato			
	LUC SU allowance	13	12	13
	plus 30%	17	15	17
	minus 30%	9	8	9
	SU 15/16	12	11	10
	UpperWaikato			
	LUC SU allowance	13	12	13
	plus 30%	17	15	17
	minus 30%	9	8	9
	SU 15/16	12	11	10

APPENDIX 15: OVERSEER® NUTRIENT BUDGET OF CASE STUDY 1 BASE FARM 2015-16 SEASON

Nutrient Budget | Nitrogen | Phosphorus | Comments | Summary | Nitrogen overview | Phos
Footprint product | Pasture production | Other values | Full parameter report

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	1	31	21	41	72	0	0
Rain/clover N fixation	76	0	1	3	2	3	10
Irrigation	0	0	0	0	0	0	0
Nutrients removed							
As products	6	0	0	1	1	0	0
Exported effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	24	0	0	0	0	0	0
To water	15	1.3	25	54	57	26	50
Change in farm pools							
Plant Material	-3	0	-3	0	0	0	0
Organic pool	32	9	0	-11	0	0	0
Inorganic mineral	0	10	-8	0	-3	-2	-9
Inorganic soil pool	3	11	8	0	19	-21	-31

APPENDIX 16: OVERSEER® NUTRIENT BUDGET OF CASE STUDY 2 BASE FARM 2015-16 SEASON

Nutrient Budget | Nitrogen | Phosphorus | Comments | Summary | Nitrogen overview | Phosp

Footprint product | Pasture production | Other values | Full parameter report

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	18	12	33	12	24	7	0
Rain/clover N fixation	65	0	2	4	3	5	18
Irrigation	0	0	0	0	0	0	0
Nutrients removed							
As products	17	3	1	2	7	0	1
Exported effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	27	0	0	0	0	0	0
To water	19	0.7	28	26	71	32	71
Change in farm pools							
Plant Material	8	1	-1	2	1	0	0
Organic pool	13	4	0	-14	0	0	0
Inorganic mineral	0	6	-7	0	-2	-1	-7
Inorganic soil pool	0	-3	13	0	-50	-18	-47

APPENDIX 17: OVERSEER® NUTRIENT BUDGET OF CASE STUDY 3 BASE FARM 2015-16 SEASON

Nutrient Budget | Nitrogen | Phosphorus | Comments | Summary | Nitrogen overview | Phosp
Footprint product | Pasture production | Other values | Full parameter report

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	0	15	0	25	186	14	0
Rain/clover N fixation	65	0	3	6	5	10	46
Irrigation	0	0	0	0	0	0	0
Nutrients removed							
As products	7	1	0	1	1	0	0
Exported effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	24	0	0	0	0	0	0
To water	20	0.5	13	37	48	31	76
Change in farm pools							
Plant Material	0	0	0	0	0	0	0
Organic pool	14	4	0	-7	0	0	0
Inorganic mineral	0	4	-11	0	-1	-1	-5
Inorganic soil pool	0	6	0	0	143	-6	-26

APPENDIX 18: AGINFORM® AND OVERSEER® RESULTS FOR CASE STUDY 1

Fie number	File name	Year	N leach total area	N leach grazed area	P grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
	ACTUAL 2015-16		15	16	1.4	12.4	6.3	6.1	13.7	7.0	6.8	$79,514	
301	**Case Study 1 Base**	**Average**	**21**	**23**	**0.8**	**14.9**	**12.1**	**8.2**	**16.5**	**13.4**	**3.1**	**$317,735**	
301	Case Study 1 Base	Yr1	16	17	0.8	19.3	12.1	21.1	21.4	13.4	8	$397,964	
301	Case Study 1 Base	Yr2	14	15	0.7	12.7	12.1	1.6	14	13.4	0.6	$208,041	
301	Case Study 1 Base	Yr3	22	24	0.8	17.5	12.7	14.0	19.4	14.1	5.3	$309,886	
301	Case Study 1 Base	Yr4	23	25	0.8	15.5	12.5	9.0	17.2	13.8	3.4	$260,223	
301	Case Study 1 Base	Yr5	29	32	0.8	17.1	12.4	13.7	18.9	13.7	5.2	$275,244	
301	Case Study 1 Base	Yr6	19	21	0.8	14.5	12.9	4.5	16	14.3	1.7	$242,034	
301	Case Study 1 Base	Yr7	12	13	0.7	12.1	12.1	0.0	13.4	13.4	0	$183,196	
301	Case Study 1 Base	Yr8	15	16	0.7	12.1	12.1	0.0	13.4	13.4	0	$193,517	
301	Case Study 1 Base	Yr9	27	30	0.8	14.6	12.1	7.4	16.2	13.4	2.8	$233,955	

Fie number	File name	Year	N leach total area	N leach grazed area	P grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
301	Case Study 1 Base	Yr10	17	18	0.8	15.1	11.4	10.8	16.7	12.6	4.1	$873,293	
302	**301 + no N fert**	**Average**	**12**	**13**	**0.7**	**12.9**	**8.9**	**11.9**	**14.3**	**9.8**	**4.5**	**$237,291**	**-$80,444**
302	301 + no N fert	Yr1	17	19	0.8	19.2	8.6	30.9	21.2	9.5	11.7	$370,177	
302	301 + no N fert	Yr2	11	12	0.7	11.4	8.6	8.2	12.6	9.5	3.1	$161,618	
302	301 + no N fert	Yr3	14	15	0.8	15.4	9.9	16.1	17	10.9	6.1	$230,727	
302	301 + no N fert	Yr4	12	13	0.7	12.7	9.3	10.0	14.1	10.3	3.8	$171,578	
302	301 + no N fert	Yr5	13	14	0.8	13.8	8.8	14.8	15.3	9.7	5.6	$209,788	
302	301 + no N fert	Yr6	12	13	0.7	12.3	9.7	7.7	13.6	10.7	2.9	$150,807	
302	301 + no N fert	Yr7	11	12	0.7	10.5	8.6	5.5	11.6	9.5	2.1	$ 75,410	
302	301 + no N fert	Yr8	10	11	0.7	11.0	8.5	7.4	12.2	9.4	2.8	$221,933	
302	301 + no N fert	Yr9	12	13	0.7	11.8	9.1	7.9	13.1	10.1	3	$174,885	
302	301 + no N fert	Yr10	13	14	0.7	12.9	8.9	11.9	14.3	9.8	4.5	$605,986	

Fie number	File name	Year	N leach total area	N leach grazed area	P grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
303	**301 + Restrict Urine N**	**Average**	**17**	**18**	**0.8**	**15.6**	**10.7**	**14.5**	**17.3**	**11.8**	**5.5**	**$145,400**	**-$172,335**
303	301 + Restrict Urine N	Yr1	13	14	0.8	15.8	11.3	13.2	17.5	12.5	5	$179,816	
303	301 + Restrict Urine N	Yr2	22	24	0.8	14.8	10.3	13.2	16.4	11.4	5	$ 45,154	
303	301 + Restrict Urine N	Yr3	16	17	0.7	11.1	10.8	0.8	12.3	12	0.3	-$361,192	
303	301 + Restrict Urine N	Yr4	16	17	0.8	17.6	10.8	19.8	19.5	12	7.5	$270,978	
303	301 + Restrict Urine N	Yr5	22	24	0.8	17.4	10.8	19.3	19.3	12	7.3	$239,821	
303	301 + Restrict Urine N	Yr6	16	17	0.8	18.4	10.8	22.2	20.4	12	8.4	$273,450	
303	301 + Restrict Urine N	Yr7	12	13	0.8	13.6	10.8	8.2	15	11.9	3.1	$154,913	
303	301 + Restrict Urine N	Yr8	13	14	0.8	15.5	10.8	13.7	17.1	11.9	5.2	$172,700	
303	301 + Restrict Urine N	Yr9	19	21	0.8	15.6	10.8	14.3	17.3	11.9	5.4	$157,126	
303	301 + Restrict Urine N	Yr10	16	17	0.8	18.0	10.8	20.9	19.9	12	7.9	$321,233	
304	**302 + increased restriction**	**Average**	**13**	**14**	**0.8**	**14.0**	**10.8**	**9.2**	**15.5**	**12**	**3.5**	**$216,432**	**-$101,303**

Fie number	File name	Year	N leach total area	N leach grazed area	P grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
304	302 + increased restriction	Yr1	16	17	0.8	19.2	10.6	25.1	21.2	11.7	9.5	$385,845	
304	302 + increased restriction	Yr2	11	12	0.7	12.1	10.6	4.5	13.4	11.7	1.7	$198,522	
304	302 + increased restriction	Yr3	16	17	0.8	16.8	11.5	15.6	18.6	12.7	5.9	$282,866	
304	302 + increased restriction	Yr4	14	15	0.8	14.2	11.4	8.2	15.7	12.6	3.1	$220,378	
304	302 + increased restriction	Yr5	14	15	0.8	14.6	10.9	10.8	16.2	12.1	4.1	$248,611	
304	302 + increased restriction	Yr6	13	14	0.7	13.5	11.7	5.0	14.9	13	1.9	$128,906	
304	302 + increased restriction	Yr7	11	12	0.7	11.6	10.6	2.9	12.8	11.7	1.1	$236,776	
304	302 + increased restriction	Yr8	11	12	0.7	11.5	10.6	2.6	12.7	11.7	1	$180,510	
304	302 + increased restriction	Yr9	13	14	0.8	13.9	10.5	10.0	15.4	11.6	3.8	$220,922	
304	302 + increased restriction	Yr10	13	14	0.7	13.3	10.8	7.4	14.7	11.9	2.8	$ 60,987	

APPENDIX 19: AGINFORM® AND OVERSEER® RESULTS FOR CASE STUDY 2

File number	File name	Year	N leach total area	N leach grazed area	P ls grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
	ACTUAL 2015-16	15/16	19	23	0.8	10.6	5.2	5.4	13.7	6.7	7	$61,218	
401	**Case Study 2 Base**	**Ave**	**23**	**27**	**0.7**	**7.5**	**6.2**	**1.3**	**9.2**	**7.6**	**1.6**	**$160,186**	
401	Case Study 2 Base	1	19	23	0.8	12.6	6.2	6.4	15.4	7.6	7.8	$ 249,866	
401	Case Study 2 Base	2	18	21	0.7	10.1	6.2	3.9	12.4	7.6	4.8	$ 218,718	
401	Case Study 2 Base	3	17	20	0.7	8.2	6.8	1.5	10.1	8.3	1.8	$ 176,082	
401	Case Study 2 Base	4	18	22	0.7	6.8	5.9	0.9	8.3	7.2	1.1	$ 131,842	
401	Case Study 2 Base	5	24	29	0.7	6.8	6.4	0.3	8.3	7.9	0.4	$ 158,334	
401	Case Study 2 Base	6										$ 146,893	
401	Case Study 2 Base	7										$ 148,527	
401	Case Study 2 Base	8										$ 136,877	
401	Case Study 2 Base	9										$ 106,333	

File number	File name	Year	N leach total area	N leach grazed area	P ls grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
401	Case Study 2 Base	10										$ 128,387	
403	**401 + no fert**	**Ave**	**17**	21	0.8	11.7	3.9	7.8	14.4	4.8	9.6	$170,884	
403	401 + no fert	1	24	30	0.9	18.3	3.8	14.5	22.5	4.7	17.8	$273,617	
403	401 + no fert	2	23	28	0.9	17.5	3.9	13.6	21.5	4.8	16.7	$209,901	
403	401 + no fert	3	19	23	0.8	13.4	3.9	9.5	16.5	4.8	11.7	$199,176	
403	401 + no fert	4	15	18	0.7	9.2	3.8	5.4	11.3	4.7	6.6	$121,766	
403	401 + no fert	5	17	21	0.8	11.6	4.2	7.4	14.2	5.1	9.1	$173,385	
403	401 + no fert	6	15	19	0.8	10.3	4.2	6.1	12.7	5.2	7.5	$150,972	
403	401 + nor fert	7	17	21	0.8	11.3	3.8	7.5	13.9	4.7	9.2	$162,689	
403	401 + no fert	8	15	18	0.7	9.2	4.1	5.4	11.6	5.0	6.6	$136,358	
403	401 + no fert	9	14	27	0.7	8.6	3.7	4.9	10.5	4.5	3.0	$144,977	
403	401 + no fert	10	17	21	0.8	11.2	4.0	7.3	13.8	4.9	8.9	$165,999	

File number	File name	Year	N leach total area	N leach grazed area	P ls grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
404	**403 + urine restriction**	**Ave**	**21**	**25**	**0.7**	**11.2**	**8.0**	**3.3**	**13.8**	**9.8**	**4**	**$135,166**	**-$25,019**
404	403 + urine restriction	1	19	23	0.8	14.0	8.1	5.9	17.2	10	7.2	$ 115,562	
404	403 + urine restriction	2	18	22	0.8	13.9	8.4	5.5	17	10.3	6.7	$ 240,031	
404	403 + urine restriction	3	20	24	0.8	12.6	8.1	4.5	15.4	9.9	5.5	$ 176,485	
404	403 + urine restriction	4	15	18	0.7	8.9	7.3	1.6	10.9	8.9	2	$ 112,187	
404	403 + urine restriction	5	24	29	0.8	12.5	8.1	4.4	15.3	9.9	5.4	$ 154,337	
404	403 + urine restriction	6	20	24	0.7	10.8	8.3	2.5	13.3	10.2	3.1	$ 108,860	
404	403 + urine restriction	7	23	28	0.7	11.2	8.1	3.1	13.7	9.9	3.8	$ 152,665	
404	403 + urine restriction	8	22	26	0.7	10.8	8.1	2.7	13.2	9.9	3.3	$ 129,378	
404	403 + urine restriction	9	19	23	0.7	8.4	7.7	0.7	10.3	9.5	0.8	$ 91,854	
404	403 + urine restriction	10	19	23	0.7	10.0	7.6	2.4	12.3	9.3	3	$ 70,307	
405	**404 + no N fert**	**Ave**	**16**	**19**	**0.7**	**11.0**	**7.4**	**3.6**	**13.5**	**9.1**	**4.4**	**$119,624**	**-$40,561**

File number	File name	Year	N leach total area	N leach grazed area	P ls grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
405	404 + no N fert	1	18	22	0.8	13.8	7.7	6.1	16.9	9.4	7.5	$ 75,369	
405	404 + no N fert	2	18	21	0.8	14.9	7.4	7.5	18.3	9.1	9.2	$ 252,930	
405	404 + no N fert	3	18	22	0.8	13.0	7.5	5.5	15.9	9.2	6.7	$ 83,146	
405	404 + no N fert	4	14	16	0.7	9.0	7.0	2.0	11	8.6	2.4	$ 188,430	
405	404 + no N fert	5	17	20	0.8	12.4	7.5	4.9	15.2	9.2	6	$ 148,236	
405	404 + no N fert	6	15	18	0.7	9.9	7.7	2.1	12.1	9.5	2.6	$ 89,593	
405	404 + no N fert	7	16	19	0.7	10.6	7.5	3.1	13	9.2	3.8	$ 121,619	
405	404 + no N fert	8	14	17	0.7	9.5	7.7	1.8	11.7	9.5	2.2	$ 75,617	
405	404 + no N fert	9	13	15	0.7	8.1	7.4	0.7	10	9.1	0.9	$ 115,000	
405	404 + no N fert	10	15	18	0.7	9.6	7.0	2.6	11.8	8.6	3.2	$ 46,305	

APPENDIX 20: AGINFORM® AND OVERSEER® RESULTS FOR CASE STUDY 3

File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
	ACTUAL 2015-16	15/16	20	27	0.7	9.6	7.4	2.2	12.4	9.6	2.8	$77,104	
501	**Case Study 3 - Base**	**Average**	**48**	**61**	**0.6**	**14.8**	**14.3**	**0.5**	**19.3**	**18.6**	**0.7**	**$ 169,933**	
501	Case Study 3 - Base	1	35	44	0.7	17.1	14.0	3.2	22.3	18.2	4.1	$ 231,621	
501	Case Study 3 - Base	2	38	49	0.6	13.0	13.0	0.0	16.9	16.9	0	$ 156,284	
501	Case Study 3 - Base	3	46	59	0.7	16.4	14.5	1.9	21.3	18.8	2.5	$ 210,540	
501	Case Study 3 - Base	4	37	47	0.6	14.1	14.1	0.0	18.4	18.4	0	$ 184,336	
501	Case Study 3 - Base	5	43	55	0.6	14.2	14.1	0.2	18.5	18.3	0.2	$ 179,843	
501	Case Study 3 - Base	6	46	59	0.6	14.3	14.3	0.0	18.6	18.6	0	$ 171,828	
501	Case Study 3 - Base	7	41	53	0.6	12.6	12.6	0.0	16.4	16.4	0	$ 145,360	
501	Case Study 3 - Base	8	45	58	0.6	12.8	12.8	0.0	16.7	16.7	0	$ 143,453	
501	Case Study 3 - Base	9	47	60	0.6	13.6	13.6	0.0	17.7	17.7	0	$ 168,936	

File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
501	Case Study 3 - Base	10	33	42	0.6	13.5	13.2	0.3	17.6	17.2	0.4	$ 107,127	
502	**501 + no N fert**	**Average**	**22**	**28**	**0.6**	**11.5**	**9.8**	**1.8**	**15**	**12.7**	**2.3**	**$ 143,985**	**-$ 25,947**
502	501 + no N fert	1	28	35	0.6	16.5	9.4	7.1	21.4	12.2	9.2	$ 220,491	
502	501 + no N fert	2	19	24	0.6	9.4	9.4	0.0	12.2	12.2	0	$ 123,430	
502	501 + no N fert	3	25	31	0.6	13.6	10.4	3.2	17.7	13.5	4.2	$ 169,634	
502	501 + no N fert	4	21	27	0.6	11.5	10.4	1.1	14.9	13.5	1.4	$ 147,421	
502	501 + no N fert	5	23	29	0.6	12.3	9.8	2.5	16	12.8	3.2	$ 161,671	
502	501 + no N fert	6	21	27	0.6	11.4	10.5	0.8	14.8	13.7	1.1	$ 134,259	
502	501 + no N fert	7	19	24	0.6	9.4	9.4	0.0	12.2	12.2	0	$ 123,364	
502	501 + no N fert	8	19	24	0.6	9.2	9.2	0.0	12	12	0	$ 120,768	
502	501 + no N fert	9	21	26	0.6	10.9	9.8	1.1	14.2	12.8	1.4	$ 143,318	
502	501 + no N fert	10	23	29	0.6	11.7	9.4	2.3	15.2	12.2	3	$ 95,499	

File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
503	**501 + urinary restrict 1sdv**	**Average**	**46**	**59**	**0.6**	**14.1**	**13.7**	**0.5**	**18.4**	**17.8**	**0.6**	**$ 174,440**	**$ 4,507**
503	501 + urinary restrict 1sdv	1										$ 227,101	
503	501 + urinary restrict 1sdv	2										$ 160,771	
503	501 + urinary restrict 1sdv	3										$ 210,614	
503	501 + urinary restrict 1sdv	4										$ 184,171	
503	501 + urinary restrict 1sdv	5										$ 179,811	
503	501 + urinary restrict 1sdv	6										$ 171,870	
503	501 + urinary restrict 1sdv	7										$ 145,474	
503	501 + urinary restrict 1sdv	8										$ 143,719	
503	501 + urinary restrict 1sdv	9										$ 168,174	
503	501 + urinary restrict 1sdv	10										$ 152,692	
504	**503 + no winter fert**	**Average**	**31**	**39**	**0.6**	**13.1**	**12.5**	**0.7**	**17.1**	**16.2**	**0.9**	**$ 161,170**	**-$ 8,763**

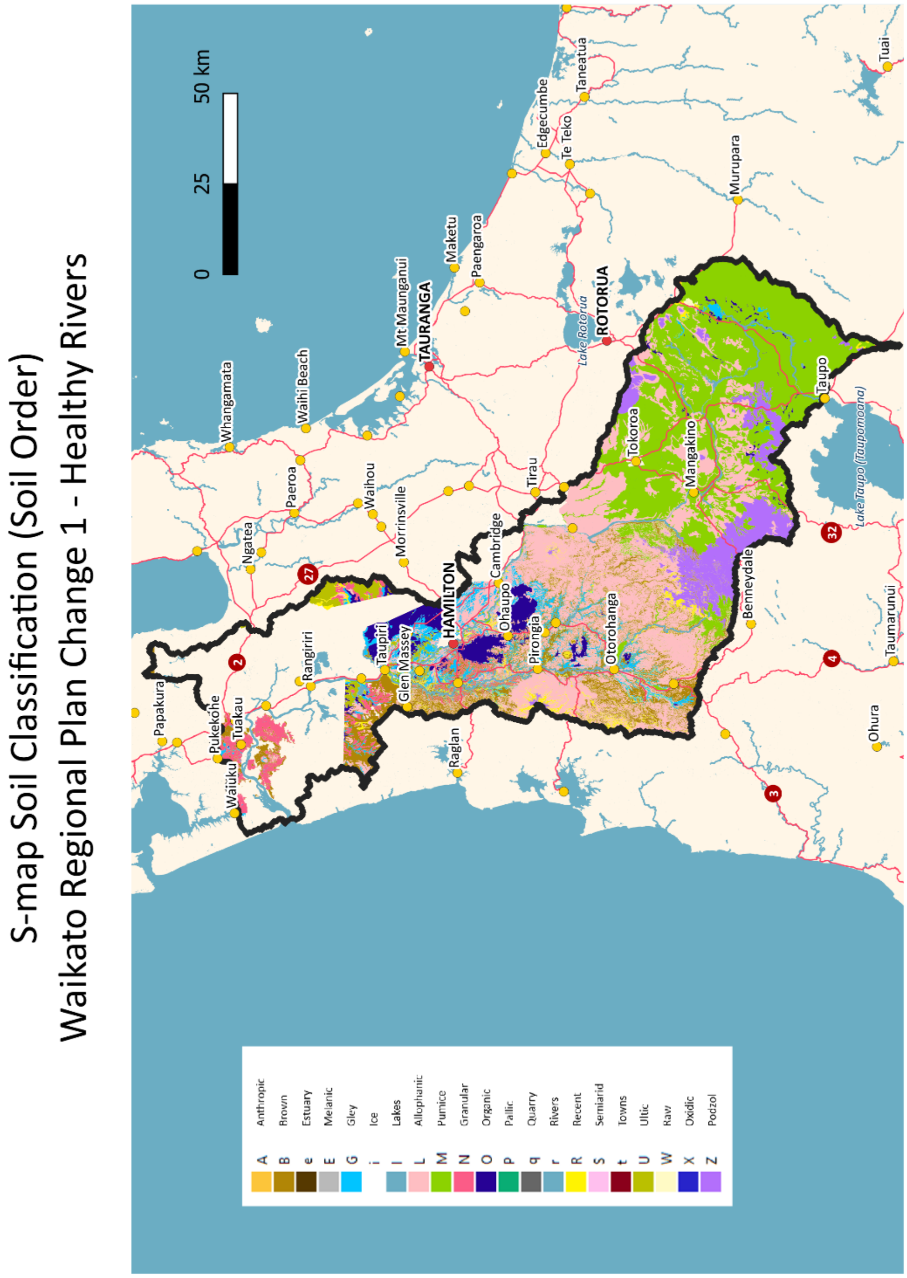
File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
504	503 + no winter fert	1										$ 216,396	
504	503 + no winter fert	2										$ 156,932	
504	503 + no winter fert	3										$ 196,349	
504	503 + no winter fert	4										$ 171,835	
504	503 + no winter fert	5										$ 178,493	
504	503 + no winter fert	6										$ 150,250	
504	503 + no winter fert	7										$ 134,535	
504	503 + no winter fert	8										$ 142,943	
504	503 + no winter fert	9										$ 161,357	
504	503 + no winter fert	10										$ 102,610	
505	**503 + no fert**	**Average**	**21**	**27**	**0.6**	**11.7**	**10.5**	**1.2**	**15.2**	**13.6**	**1.6**	**$ 140,579**	**-$ 29,354**
505	503 + no fert	1	25	31	0.6	15.0	10.4	4.6	19.5	13.5	6	$ 179,660	

File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
505	503 + no fert	2	21	27	0.6	11.0	9.7	1.3	14.3	12.6	1.7	$ 157,333	
505	503 + no fert	3	24	30	0.6	13.5	10.5	3.1	17.6	13.6	4	$ 160,479	
505	503 + no fert	4	21	27	0.8	11.5	11.1	0.5	15	14.4	0.6	$ 145,961	
505	503 + no fert	5	22	28	0.6	12.4	10.7	1.7	16.1	13.9	2.2	$ 161,173	
505	503 + no fert	6	21	27	0.6	11.7	10.7	1.0	15.2	13.9	1.3	$ 127,090	
505	503 + no fert	7	19	24	0.6	9.7	9.7	0.0	12.6	12.6	0	$ 121,689	
505	503 + no fert	8	19	24	0.6	9.7	9.7	0.0	12.6	12.6	0	$ 127,246	
505	503 + no fert	9	21	26	0.6	10.9	10.9	0.0	14.2	14.2	0	$ 141,993	
505	503 + no fert	10	20	25	0.6	10.2	9.8	0.5	13.3	12.7	0.6	$ 83,166	
506	**501 + severe Urinary N restriction**	**Average**	**33**	**42**	**0.6**	**15.6**	**15.5**	**0.1**	**20.3**	**20.2**	**0.1**	**-$ 92,972**	**-$262,905**
506	501 + severe Urinary N restriction	1										-$ 170,506	

File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
506	501 + severe Urinary N restriction	2										$ 117,488	
506	501 + severe Urinary N restriction	3										-$1,563,645	
506	501 + severe Urinary N restriction	4										-$ 167,228	
506	501 + severe Urinary N restriction	5										$ 148,898	
506	501 + severe Urinary N restriction	6										$ 147,084	
506	501 + severe Urinary N restriction	7										$ 138,970	
506	501 + severe Urinary N restriction	8										$ 133,470	
506	501 + severe Urinary N restriction	9										$ 147,058	

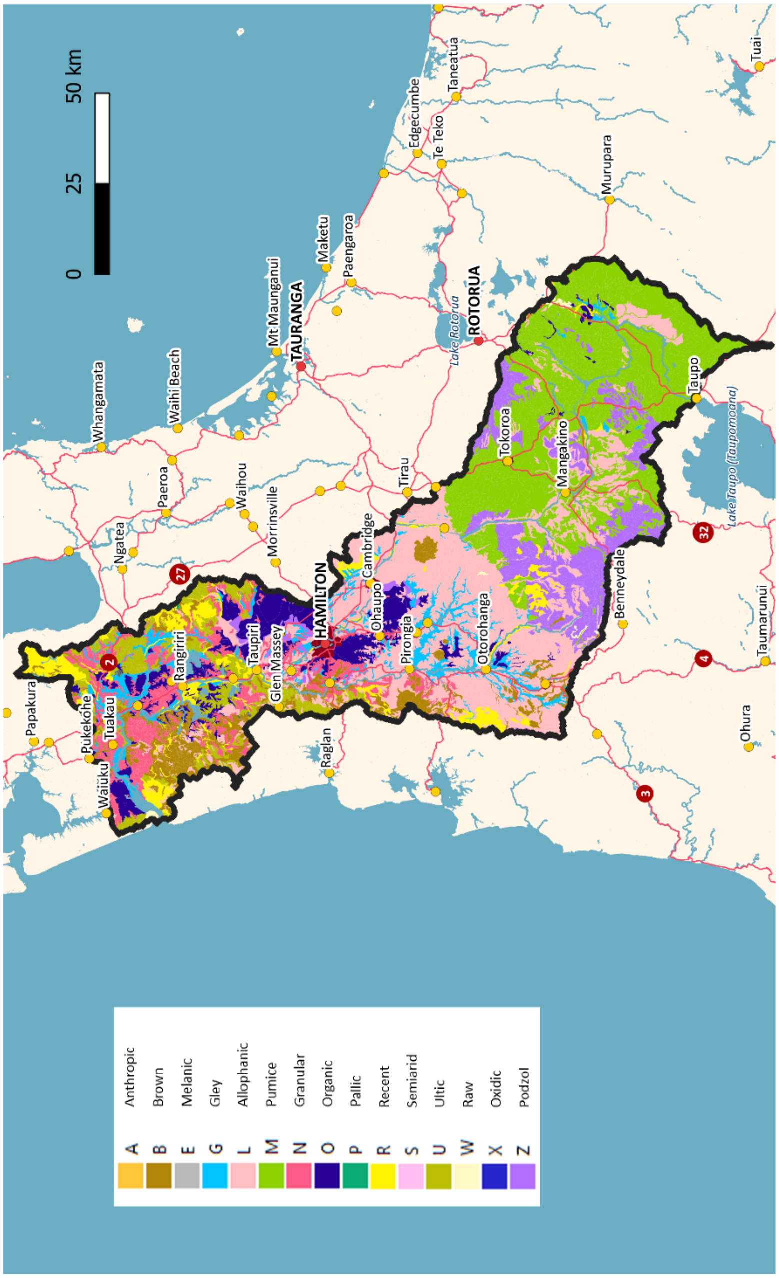
File Number	File name	Year	N leach total area	N leach grazed area	P loss grazed area	Total SU whole farm	Sheep SU whole farm	Cattle SU whole farm	Total SU grazed area	Sheep SU grazed area	Cattle SU grazed area	EBITDA	Difference from Base
506	501 + severe Urinary N restriction	10										$ 138,689	

APPENDIX 21: MAP OF SOIL ORDERS OF AREAS IN S-MAP IN THE WAIKATO-WAIPĀ CATCHMENT



APPENDIX 22: MfE-SOURCED FUNDAMENTAL SOIL ORDERS OF AREAS IN THE WAIKATO-WAIPĀ CATCHMENT

Fundamental Soil Layers
Waikato Regional Plan Change 1 - Healthy Rivers



APPENDIX 23: CLUSTERS FOR N FLEXIBILITY CAP

CLUSTER 1

- 8.8% of area of catchment
- small sheep and beef farm 50 – 100 ha
- 70% sheep/30 % cattle
- 10-13 SU/ha
- Dominated by lifestyle blocks around Hamilton and Cambridge
- Flatter areas along the river channel
- North-eastern areas of the Lower Waikato
- Type of Farm Class 5 farm – small – current Sheep and Beef survey data is 23% sheep average
- N Loss Current: 11.53 kg N/ha
- **Assume – 30% of farms take full 15 kg N/ha**

CLUSTER 2

- 62.5% of the total area
- Traditional hill country with lamb finishing
- Larger farms 165 – 450 ha
- 70%sheep/30% cattle
- 8.5 SU/ha
- 10% of effective area in steep (above 26degrees)
- N loss current: 7.8 kg N/ha/yr

- Farm Class 4 type farm – Sheep and Beef Farm Survey data
- Farm Class 3 farms included in here – breeding cows slowly reducing on these farms
- Sheep and Beef Farm Survey indicates stocking rate 9.5 – 10 SU/ha
- Upper and mid Waipā
- Western areas of Lower Waikato
- Areas within the boundary of Otorohanga and Waitomo
- **Assume 100% of farms move to 10 kg N/ha/yr**

CLUSTER 3A

- 10% of total sheep and beef area
- hill country
- 35 – 250 ha
- 80% female cattle – predominant dairy cows and heifer grazing
- 70% cropped area of farm
- N loss current: 25 kg N/ha/yr or above
- Upper Waikato intensive beef
- Predominantly pumice soils
- **Assume no change because the majority of these farms already exceed modelled N loss of 20 kg N/ha/yr and average 25 kg N/ha/yr or more**

CLUSTER 3B

- 9.4% of sheep and beef area

- hill country with predominant pasture based dairy support and some beef breeding
- Low sheep to cattle ratio 20% sheep
- 8.6 SU/ha
- N loss current: 10 kg N/ha/yr
- Farm Class 4 farms – smaller side
- Scattered evenly between FMUs/sub catchments
- Technically sheep and beef farmers – dairy support very small part – very relationship driven – e.g. small number of neighbours' cows or to support part of another farm
- High female to male cattle ratio in the modelling already
- Potentially maxed out already in terms of N loss profile and largely developed
- Significant variability from soil types
- Might choose not to take on dairy support
- Likely to be improving pasture and continuing to optimise good land
- Assumption already 100% cattle with high female/male ratio
- **Assume all move to 3A system with constraint to 15 kg n/ha/yr as permitted activity and 25% move to 20 kg N/ha/yr through controlled rule**
    - 25% area move to 15 kg N/ha/yr
    - 25% area move to 20 kg N/ha/yr

CLUSTER 4

- 9.2% of sheep and beef area
- bull and prime beef finishing - mostly all beef cattle – 100% male
- 35 - 250 ha
- 11.75 stock units/ha
- N loss current: 12.25 kg N/ha/yr
- Farm Class 5/easier Farm Class 4
- Lower Waikato concentration of predominant intensive beef
- Potential change from bull beef finishing to dairy grazing
- Historically bull/beef farming economically more productive than dairy grazing so will likely limit the amount of change in system
- Consistency of income from dairy grazing will mean that there continues to be an element of dairy grazing within this cluster
- These factors will limit balance shifting to totally dairy heifers – but will shift more on some farms than others
- Driving changes for predicted N loss are improved pasture/pasture species and change balance in crop to non-cropped area
- As a group likely to fluctuate in N loss - some likely to increase to 15 kg N/ha/yr
- More likely to adopt full suite of mitigations faster as easier country and current systems already meet some of mitigations likely to be identified in farm plans
- 20% of farms that are not fully developed increase 12.25 kg N/ha/yr to 15 kg N/ha/yr
- **Assume 20% of farms increase to 15 kg N/ha/yr and 20% from 15 to 20 kg N/ha/yr**

REFERENCES

Bailey, James (2019) *Evidence in Chief*. Plan Change One, Healthy Rivers, Wai Ora, Document number 73926

DairyNZ. (2018). *New Zealand Dairy Statistics 2017-18*. Retrieved from Hamilton, New Zealand:

Dominati, E. J., Maseyk, F. J. F., Mackay, A. D., & Rendel, J. M. (2019). Farming in a changing environment: Increasing biodiversity on farm for the supply of multiple ecosystem services. *Science of The Total Environment, 662*, 703-713.

Dymond, J. R., Ausseil, A. E., Parfitt, R. L., Herzig, A., & McDowell, R. W. (2013). Nitrate and phosphorus leaching in New Zealand: a national perspective. *New Zealand Journal of Agricultural Research, 56*(1), 49-59.

Hendy, J., Ausseil, A. E., Bain, I., Blanc, E., Fleming, D., Gibbs, J., . . . Zammit, C. (2018). *Land-use modelling in New Zealand: current practice and future needs*. Retrieved from Wellington, New Zealand:

Hewitt, A. E. (2010). *New Zealand Soil Classification* (3rd Edition ed.). Canterbury, New Zealand: Manaaki Whenua Press.

Hewitt, A. E. (2013). Survey of New Zealand Soil Orders. In J. R. Dymond (Ed.), *Ecosystem services in New Zealand* (pp. 121-131). Lincoln, New Zealand: Manaaki Whenua Press.

Holzworth, D. P., Huth, N. I., deVoil, P. G., Zurcher, E. J., Herrmann, N. I., McLean, G., . . . Keating, B. A. (2014). APSIM – Evolution towards a new generation of agricultural systems simulation. *Environmental Modelling & Software, 62*(0), 327-350. Retrieved from http://www.sciencedirect.com/science/article/pii/S1364815214002102.

Landcare_Research. (2016). S-Map Online. Fast, simple access to New Zealand soils data. *Soil Factsheets.* Retrieved from http://smap.landcareresearch.co.nz

Manaaki_Whenua. (2019). Soil Report - Otorohanga soil. (Mai_4a.1). Retrieved February 2019, from Manaaki Whenua

MfE. (2016). NZ Fundamental Soil Layers New Zealand Soil Classification. Retrieved 18 April 2019, from MfE https://data.mfe.govt.nz/layer/52766-fundamental-soil-layers-new-zealand-soil-classification/

NIWA. (2019). Tha National Climate Database. Retrieved from www.cliflo.niwa.co.nz

OverseerFM. (2019). OverseerFm User Guide. In (pp. 91). New Zealand: Overseer Limited.

Rendel, J. M., Mackay, A. D., Smale, P. N., & Vogeler, I. (2016). Moving from exploring on-farm opportunities with a single to a multi-year focus:

Implications for decision making. *Journal of New Zealand Grasslands, 78*, 57-66.

Selbie, D. R., Buckthought, L. E., & Shepherd, M. A. (2015). Chapter Four - The Challenge of the Urine Patch for Managing Nitrogen in Grazed Pasture Systems. In S. Donald L (Ed.), *Advances in Agronomy* (Vol. Volume 129, pp. 229-292): Academic Press.

Watkins, N., Wheeler, D., & Mercer, G. (2016). *OVERSEER - Guide to the Animal Reports in OVERSEER*. Retrieved from Hamilton, New Zealand:

Wheeler, D. M., Shepherd, M., & Selbie, D. R. (2013). *From stock numbers to N leaching and nitrous oxide - the progression through Overseer*. Paper presented at the Accurate and efficient use of nutrients on farms, Massey, University, Palmerston North, New Zeland.

WRC. (2018a). *Nitrogen Reference Point Development Guidelines*. Retrieved from Hamilton, New Zealand:

Supporting Document Incorporation Variation 1 Amendments to Proposed Waikato Regional Plan Change 1 - Waikato and Waipā River Catchments, (2018b).

WRC. (2018c). Table 1: Data input methodology for ensuring consistency of nitrogen reference data using the OVERSEER Model. *Schedule B - Nitrogen Reference Point.* Retrieved from https://www.waikatoregion.govt.nz/council/policy-and-plans/plans-under-development/healthy-rivers-plan-for-change/for-landowners/healthy-rivers-what-does-it-mean-for-me/schedules/