IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Plan Change 7: Waimakariri
BETWEEN	DairyNZ Limited
AND	Environment Canterbury

STATEMENT OF EVIDENCE OF DR GRAEME JOHN DOOLE

FOR DAIRYNZ LIMITED

16 JULY 2020

Cnr Ruakura Road and SH 26

Newstead

Hamilton 3286

DairyNZ

STATEMENT OF EVIDENCE OF DR GRAEME JOHN DOOLE

1 Qualifications, experience, and background

1.1 My full name is **Graeme John DOOLE**. I am currently the Principal Economist at DairyNZ, where I lead the Economics Team. I joined this organisation two years ago, following four years as an Economic Advisor to the New Zealand Government regarding the economic impacts of water policy on rural land uses. In this position with the New Zealand Government, I worked with numerous Regional Councils to perform economic assessments of issues related to water quality and quantity.

1.2 During the time that I worked with the New Zealand Government, I was also a Professor of Environmental Economics at the University of Waikato. Prior to these appointments, I held various positions at the University of Western Australia (Perth, Australia), where I worked for fourteen years.

1.3 I have published over 60 refereed journal articles and have supervised post-graduate students for a decade. The focus of my research is the economic assessment of management strategies and policies to reduce diffuse pollutant loss, particularly nitrogen, from rural land uses. This has principally involved the development and application of environmental and economic models of farms, catchments, sectors, and regions.

1.4 I have the following qualifications: Bachelor of Applied Science (Natural Resource Management) from Massey University, Masters of Applied Economics (First Class Honours) (Natural Resource and Environmental Economics) from Massey University, and Doctor of Philosophy with Distinction (Agricultural and Resource Economics) from the University of Western Australia. I am currently a member of the Australian Agricultural and Resource Economics Society (AARES) and the New Zealand Agricultural and Resource Economics Society (NZARES).

2 Code of Conduct

2.1 While this is a Council Hearing, I acknowledge that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses, contained in the *Environment Court Practice Note 2014*. My qualifications as an expert are set out above. I confirm that the issues addressed in this statement of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I might express during this process.

3 Scope and Structure of Evidence

3.1 My evidence focuses on several areas with regards to Proposed Plan Change 7 (*PPC7*):

3.1.1 The dairy sector is a key component of the regional and national economy.

3.1.2 *PPC7* will have a negative impact on individual dairy farm profitability.

3.1.3 *PPC7* will have a negative impact on the dairy sector in aggregate.

3.1.4 *PPC7* will have large adverse impacts on the local and regional economies.

3.1.5 *PPC7* will affect individual dairy farm cashflow.

3.1.6 *PPC7* will affect individual dairy farm viability.

3.1.7 Careful, staged transition is a valuable component of *PPC7*.

3.1.8 Accelerating nitrogen limits will have enormous adverse economic impacts.

4 The Dairy Sector is a Key Component of the Regional and National Economy

4.1 The dairy sector is an important component of the New Zealand economy. It is often the nation's largest exporter by value, though this varies depending on product prices. The sector provides around a third of the value of all national merchandise exports, generating annual export revenue of around $19 billion (MPI, 2020). The national significance of the sector is reinforced by its economic resilience in the face of the Global Financial Crisis in 2008 and the COVID-19 pandemic in 2020.

4.2 Dairying employed around 38,700 people nationally in 2017, with around 70% of these jobs being on farms and the remainder in the processing sector (NZIER, 2018). The dairy sector provided around $2.5b in wages in 2017, with around 80% of these being provided in rural areas (NZIER, 2018).

4.3 These economic benefits of dairy production flow onto other sectors of the economy. Dairy farmers are the largest purchasers of agricultural support services, basic wholesale materials, and veterinary services in New Zealand. Further, dairy-processing companies are the largest consumers of polymer and rubber products, as well as rail transport.

4.4 The benefits of dairy production for other sectors in the economy are highly favourable for regional development, particularly in areas where other sources of revenue and jobs can be limited (NZIER, 2018).

4.5 Dairy farming is a particularly important part of the Canterbury economy. Canterbury contains around 11% of the nation's herds, 16% of the national dairy area, and produces around 400,000 tonnes of milk solids annually, which is around 22% of the national milk supply. Canterbury dairy farms are New Zealand's most-profitable and most-productive farms on a per-hectare basis (DairyNZ, 2019, 2020).

4.6 The Canterbury dairy sector contributes around $1.5 billion to regional GDP per annum, around 80% of this from on-farm activity and around 20% coming from the processing sector (NZIER, 2018). This is around 4% of regional GDP in Canterbury, and places the dairy sector as the third most-important sector in terms of generating economic growth in the region.

4.7 The dairy sector employed 7,740 workers in Canterbury in 2018-19. The on-farm sector accounted for 70% of these jobs, with dairy processing providing the rest.

4.8 Dairy employment growth in the Waimakariri district was 6% from 2000-17, whereas total employment growth was 4% over this time (NZIER, 2018). This rate is around three times the national rate of employment growth. Dairy production also supports 1,372 jobs in other sectors—such as agricultural equipment and support services—each year in Canterbury (ibid.).

5 *PPC7* Will Have a Negative Impact on Individual Dairy Farm Profitability

5.1 Harris (2019) assesses the economic impacts of nitrate reductions under *PPC7*.

5.2 This modelling indicates how nitrate reductions will reduce operating profit on dairy farms. Yet, it provides a limited snapshot of the economic impact because:

5.2.1 Its aggregate approach ignores the diverse effects that the policy will have on individual farm units.

5.2.2 It does not evaluate the cost of moving to Good Management Practice (*GMP*).

5.2.3 It only looks at one scenario—the 2030 scenario involving a 15% reduction in nitrogen loss past Good Management Practice (*GMP*) for dairy farms.

5.3 I believe that these limitations are considerable and limit the insight that this work provides into the economic impacts of *PPC7*.

5.4 I have developed an economic model to address these limitations. A description of the development and application of the model is presented in Appendix 1.

5.5 Figure 1 presents the distribution of operating profit across three different scenarios: *Base*, *GMP*, and *PPC7*. *Base* represents current profit without *GMP*, *GMP* represents profit under PC5, and *PPC7* represents profit under Proposed Plan Change 7. Model output is presented for 2030, 2040, and 2050.

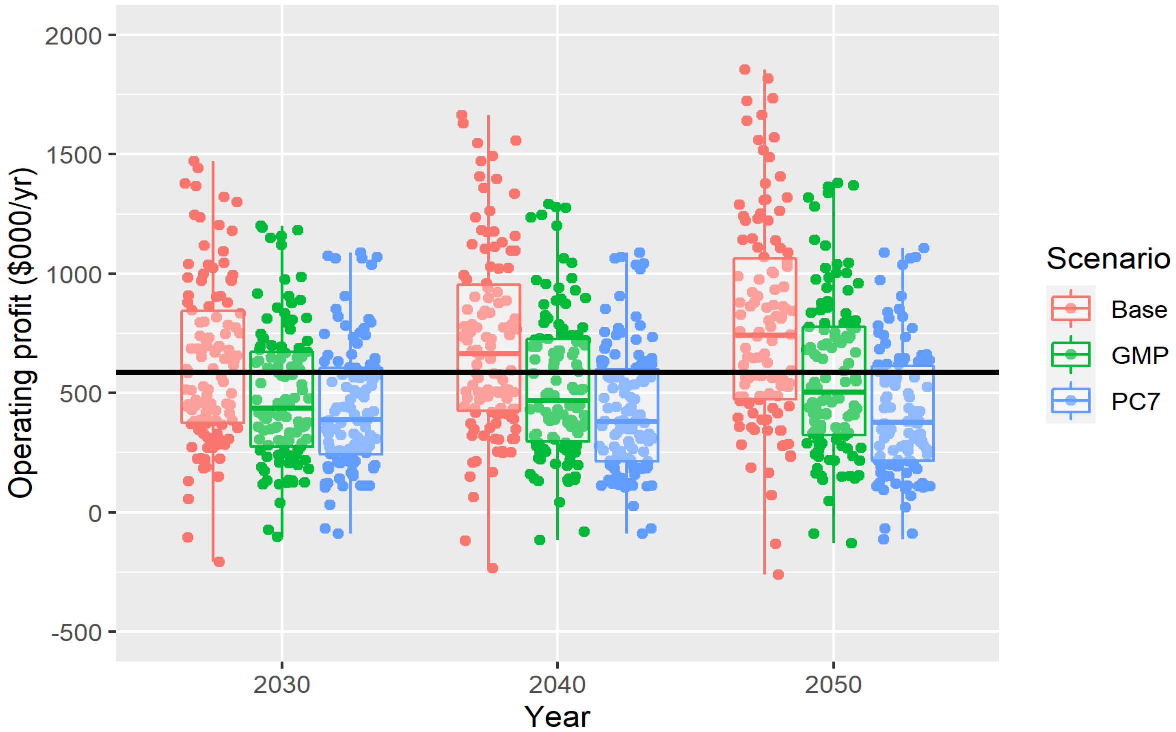
5.6 Each dot in each scenario in Figure 1 represents the outcome for an individual farm. The black line in Figure 1 is the median level of operating profit in the Base scenario in 2030. It is used as a point of reference below.

5.7 Each boxplot displayed in Figure 1 summarises the distribution of the individual farm data presented for each scenario. The horizontal line in the middle of each box is the median, the middle value of the dataset for each scenario. For the *Base* Scenario in 2030, this value is $587,500.

5.8 The horizontal line at the top of each box is the 75th percentile, the middle value between the median and the maximum value for this dataset. For the *Base* Scenario in 2030, this value is $843,600. The horizontal line at the bottom of each box is the 25th percentile, the middle value between the median and the minimum value. For the *Base* Scenario in 2030, this value is $375,400.

5.9 Observations along the lines or whiskers emanating from the box upwards or downwards signify the points beyond which observations are classified as outliers. Outliers are the individual points shown beyond the extent of these whiskers. A single outlier is found below the whisker for the *Base* scenario in 2030. This is the minimum value in the *Base* scenario in 2030 of -$207,300. In contrast, the maximum value (i.e. the highest dot) shown for this scenario is $1,472,200.

5.10 **Figure 1.** The distribution of operating profit for dairy farms in the Waimakariri region in 2030, 2040, and 2050 under different scenarios.

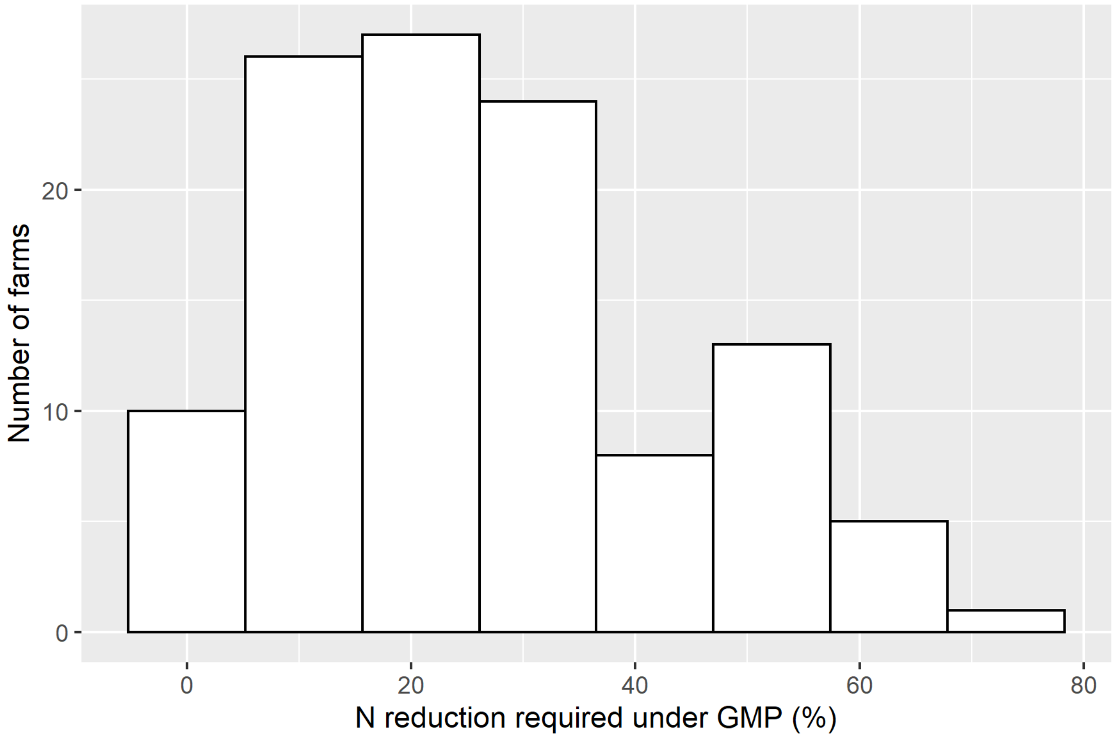


5.11 Cost efficiency measures the ability of a farmer to produce more revenue for a given level of cost. Operating profit will continue to increase across time because of efficiency gains, in the absence of regulation. An example is how operating profit grows across 2030, 2040, and 2050 in the *Base* scenario (Figure 1). These gains are typically associated with behaviour change and/or the adoption of technical innovations. Efficiency gains have been low over the last 30 years in the NZ dairy sector—between -1.5% and 1%—because growth has been driven primarily through higher input use (DairyNZ, 2019, 2020) (Appendix 1). However, efficiency gains will likely be more prominent moving forward because of limits to further intensification.

5.12 Figure 1 shows that *GMP* imposes a considerable cost on farmers, a point absent from much of the evidence put forth by Environment Canterbury. Figure 1 shows that *GMP* reduces median profit below *Base* by 25% and 35% in 2030 and 2040, respectively. The effects are broadly distributed across farms (Figure 1), given broad diversity between farms in the baseline (Appendix 1) that impacts how far each unit has to go to achieve the required level of nitrogen-loss reduction (Figure 2). With *GMP*, an additional 12% and 16% of farms move below median profit in 2030 and 2040, respectively.

5.12.1 Harris (2019) does not study the economic impacts of farms moving to *GMP*, and asserts that, "in most cases there should not be any major profitability implications" (p. 20). In my view, it is not sufficient to state that most farmers will be able to reach *GMP* and then exclude this from the assessment. Indeed, *GMP* requires substantial practice change to occur on some farms (Figure 2), placing them at heightened risk of their businesses being adversely affected by *PPC7*. This aligns with a wealth of evidence showing that many farms will be required to make a reduction to reach *GMP* and this will be costly (Davidson and Chikazhe, 2018; DairyNZ Economics Group, 2019; Reese and Bunning, 2020).

5.13 **Figure 2.** The distribution of how far different farms are required to reduce their nitrogen loss to achieve Good Management Practice (*GMP*).



5.14 Figure 1 also shows that *PPC7* reduces median profit below *Base* by 30% and 43% in 2030 and 2040, respectively. However, as above, the impacts are felt very differently across the set of individual farms present in the model. In the *PPC7* scenario, an additional 22% and 34% of farms move below median profit in 2030 and 2040, respectively (Figure 1).

5.15 Harris (2019, p. 26) states that, "Achieving major reductions in N loads beyond GMP is possible but can cause significant costs in terms of reduced profit and land use change." Based on my modelling evidence, I believe this assertion is incorrect. I believe based on my experience and analysis here that that *any* significant reduction in nitrogen leaching, whether beyond *GMP* or not, will incur notable reductions in farm profit.

6 *PPC7* Will Have a Negative Impact on the Dairy Sector in Aggregate

6.1 The 2040 target of a 30% decrease in nitrate leaching is identified by Harris (2019) as reducing operating profit in the dairy sector by 8% or $4.93 million per annum. This is much lower than what I predict.

6.2 Table 1 shows the estimated cost in the dairy sector across the nine scenarios explored in my analysis. *GMP* is shown to decrease operating profit relative to the *Base* case by 21, 24, and 27% as we move across 2030, 2040, and 2050. In contrast, *PPC7* is demonstrated to decrease profit relative to the *Base* case by 30, 40, and 46% as we move across 2030, 2040, and 2050. Additionally, *PPC7* is shown to decrease profit relative to the *GMP* case by 11, 21, and 26% across 2030, 2040, and 2050, respectively.

6.3 **Table 1.** Estimated operating profit and loss, relative to *Base* and *GMP* output, in the dairy sector for each scenario (Scen.).

Year	**Scen.**	**Farm profit ($m)**	**Change from *Base* ($m)**	**Change from *Base* (%)**	**Change from *GMP* ($m)**	**Change from *GMP* (%)**
2030	*Base*	71	-	-	-	-
	GMP	56.1	-14.9	-21	-	-
	PPC7	50	-21	-30	-6.1	-11
2040	*Base*	80.3	-	-	-	-
	GMP	60.8	-19.5	-24	-	-
	PPC7	48.3	-32	-40	-12.5	-21
2050	*Base*	89.5	-	-	-	-
	GMP	65.3	-24.2	-27	-	-
	PPC7	48.5	-41	-46	-16.8	-26

6.4 All the predicted losses reported in Table 1 are larger than the ~$5m loss estimated by Harris (2019) for *PPC7* in 2040. This reinforces that (a) farm profits will be affected by moving to *GMP*, and (b) the nitrate reductions defined in *PPC7* place increasing financial pressure on dairy farms in the Waimakariri.

7 *PPC7* Will Have Large Adverse Impacts on the Local and Regional Economies

7.1 The costs imposed on the dairy sector by *PPC7* will have substantial flow-on impacts for other sectors of the economy. There are backward linkages; that is, there will be effects on the suppliers of services and goods to farms in the Waimakariri District and the broader Canterbury region. Additionally, there are forward linkages as well, given that dairy farmers supply dairy-processing companies and meat processors also. These backward and forward impacts will, in turn, affect the expenditure of households that receive monies from these linked businesses.

7.2 Mr Copeland in his evidence employs district- and regional-level multipliers of 1.5 and 2, respectively, while noting their limitations as an analytical tool. These multipliers are used to generate the data presented in Table 2 below. These data indicate the scale of the flow-on impacts. However, it is important to recognise that this methodology is coarse and more sophisticated techniques are available.

7.3 Table 2 demonstrates how the substantial annual cost imposed on dairy farms under each policy scenario (Section 6) is magnified once we account for their connections with other sectors. A loss in operating profit for these farms decreases the revenue for other, connected businesses. Moving from *GMP* to *PPC7* imposes a cost in the Waimakariri District of an additional $9m, $19m, and $25m in 2030, 2040, and 2050, respectively. In comparison, moving from *GMP* to *PPC7* imposes a cost in the Canterbury region of an additional $12m, $25m, and $34m in 2030, 2040, and 2050, respectively.

7.4 **Table 2.** Estimated annual changes in district- and regional-level business revenue in each scenario (Scen.).

Scenario (Section 6)			**Waimakariri District**		**Canterbury region**	
Year	**Scen.**	**Farm cost ($m)**	**Other sectors ($m)**	**Total change ($m)**	**Other sectors ($m)**	**Total change ($m)**
2030	*GMP*	-14.9	-22.35	-37.3	-29.8	-44.7
	PPC7	-21	-31.5	-52.5	-42	-63
2040	*GMP*	-19.5	-29.3	-48.75	-39	-58.5
	PPC7	-32	-48	-80	-64	-96
2050	*GMP*	-24.2	-36.3	-60.5	-48.4	-72.6
	PPC7	-41	-61.5	-102.5	-82	-123

8 Proposed Plan Change 7 Will Affect Individual Dairy Farm Cashflow

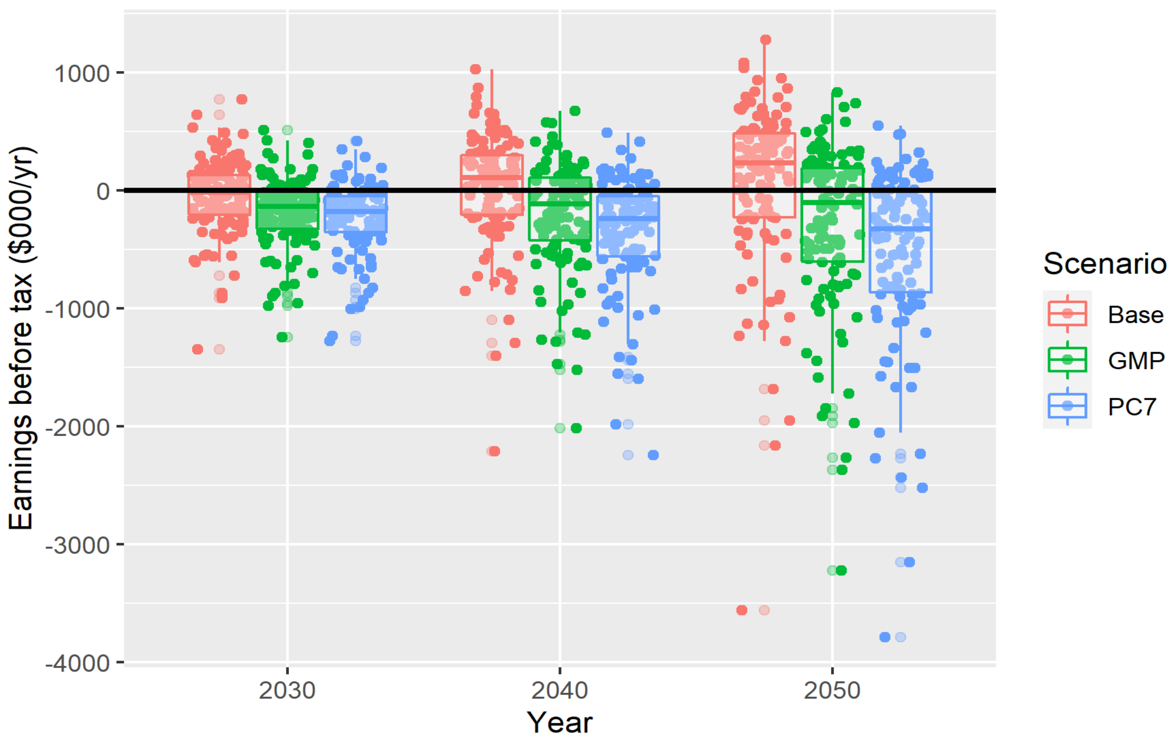
8.1 Harris (2019) determines the effects of nitrogen loss reductions on operating profit only and not cashflow. Cashflow impacts are particularly important because these include the consideration of important factors that do not enter into discussions of operating profit. Key examples are principal and interest payments, alongside drawings that are the monies that a farmer withdraws from a business to sustain themselves and their dependents. A key measure of the cash surplus or deficit available to a business is Earnings Before Tax (EBT). Tax is excluded here because of the diverse tax circumstances faced by various farming operations.

8.2 Figure 3 displays the distribution of EBT per farm for each scenario. Each dot is the predicted level of EBT for each farm. A horizontal black line is drawn to represent EBT=0. This threshold is important because a negative value signifies that the business is not earning enough funds each year to cover debt obligations and the cost of living, let alone tax payments.

8.3 Around half of the farming population in the *Base* year do not earn enough funds to cover debt and living expenses. This is expected given the high debt levels present within the NZ dairy sector (Dunstan et al., 2015; DairyNZ, 2019, 2020) and the inclusion in the model of the expectation that all farmers will be required to pay principal on outstanding loans by 2030. The need to pay principal on borrowed funds will be observed in the sector during the same period that transition towards *PPC7* will be required. This will impose a significant financial burden on some farmers, given that around 70% of NZ dairy farms still pay interest only on their farm debt.

8.4 *GMP* and *PPC7* consecutively place greater financial pressure on the dairy farm population of the Waimakariri District. Around 73, 63, and 55% of the population cannot cover debt and living costs under *GMP* in 2030, 2040, and 2050, respectively. In comparison, around 83, 79, and 75% of the population cannot cover debt and living costs under *PPC7* in these years. Thus, moving from *GMP* to *PPC7* means that an additional 10, 17, and 20% of farms cannot cover debt and living costs in 2030, 2040, and 2050, respectively.

8.5 **Figure 3.** The distribution of Earnings before Tax (EBT) for dairy farms in the Waimakariri region in 2030, 2040, and 2050 under different scenarios.



8.6 The model used here does not represent the exit of farms from the dairy sector as they start to exhibit the characteristics of insolvency (Appendix 1). For this reason, the level of EBT reported for some farms in the model will keep decreasing over time, as these farms are repeatedly required to borrow to meet their short-term needs, rather than leaving the farm population. Thus, the spread of farms within the population presented for each scenario in Figure 3 is greater than what would be expected to occur in reality. This limitation also is present in the subsequent section, where we discuss farm viability.

9 Proposed Plan Change 7 Will Affect Individual Dairy Farm Viability

9.1 Harris (2019) outlines several facts with respect to farm viability:

9.1.1 Land value will fall under *PPC7* due to increased operating costs, reduced operating profit, and reduced potential for capital gain.

9.1.2 Lower asset prices will adversely affect debt to asset ratios (DARs), increasing the probability of business insolvency.

9.1.3 These adverse shifts in the DAR therefore have the potential to become problematic before operating profit is affected by mitigation policy.

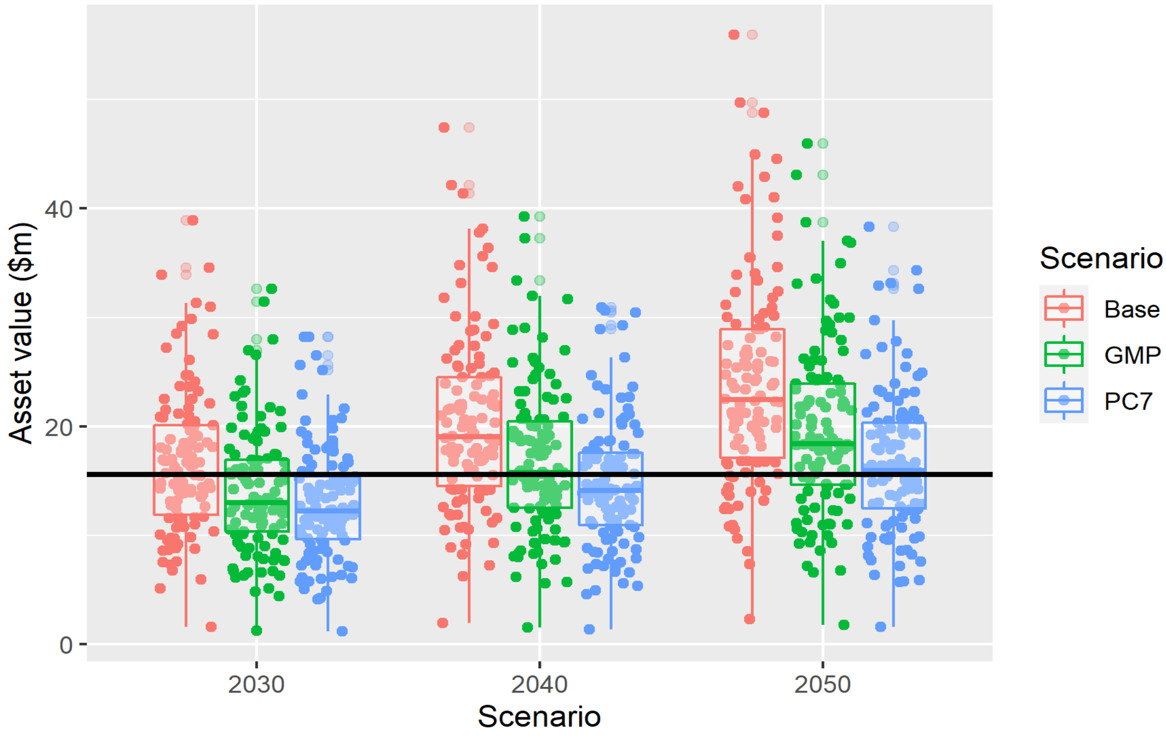
9.2 These points align with what I would expect, given my experience.

9.3 The fall in dairy asset prices associated with the nitrogen limits in *PPC7* will happen quickly, well before 2040. Indeed, I believe these will be observed as soon as 2025, if not sooner. This point is supported by the statements of Harris (2019, p. 30), who outlined, "The impact on land values will however be more immediate for a number of reasons. The uncertainty associated with the likely future impacts of mitigation will reduce the desirability of land in the affected areas, and thus sales price. It has also been true over the last 2-3 decades that increases in land value have been a major component of the returns experienced by landholders. Thus the mitigation pathway outlined in the ZIPA will cause an increased operating cost, reduced operating profit and reduced potential for capital gain. *The combination of these factors is likely to see a more immediate reduction in land value for properties in the affected areas.*" [emphasis added]

9.4 The economic model that I have developed (Appendix 1) shows that these effects may be significant.

9.5 The impact of the various scenarios on total asset values in 2030 for the simulated farm population is shown in Figure 4. It is observable that the nitrate reductions in *PPC7* introduce downward pressure to the asset values of the dairy farms in the Waimakariri District. These impaired values have a significant flow-on impact for farm management, primarily because they inflate the DARs of the affected businesses. A higher DAR makes it more difficult for farmers to borrow money to fund mitigation expenses. For example, a lower asset price erodes the capital strength of these businesses, as measured by the DAR, making it more difficult to lend money to fund the construction of a stand-off pad. Moreover, a higher DAR moves a farm closer towards a point where the business may become insolvent.

9.6 **Figure 4.** The distribution of total asset values ($m) for dairy farms in the Waimakariri region in 2030.



9.7 The effect of nutrient-loss reductions on asset value is particularly of concern because it can initiate a downward spiral of farm financial position. Here, several steps are important:

9.7.1 *Step 1*: Mitigation costs negatively affect farm profitability.

9.7.2 *Step 2*: Lower farm profits affect the ability of farms to service debt.

9.7.3 *Step 3*: Higher insolvency of dairy farm businesses leads to more farms for sale, relative to an unregulated state.

9.7.4 *Step 4*: More farms for sale means the market for dairy land becomes saturated, with excess supply driving down prices.

9.7.5 *Step 5*: Lower asset prices increase DARs, leading to higher rates of insolvency.

9.7.6 *Step 6*: Higher rates of insolvency lead to more farms for sale, forcing a return to Step 4.

9.8 In Table 12, Mr Harris goes on to highlight how dairy farms will be affected by different reductions in N loss over 2030-40. (This is the period that I believe Mr Harris is considering, though it is not stated explicitly.) Key information from this table is repeated in Table 3 below.

9.9 **Table 3.** Extract of information presented for the dairy sector in Table 12 of Harris (2019).

Reduction in N loss (%)	**Dairy effects**
5	Low impact
10	Low impact for most farms, depends on baseline
20	Heavily indebted farms are non-viable
30	Farms with average performance and debt loadings non-viable

9.10 These insights are the results of a qualitative assessment performed by Mr Harris, which he states as being, “subjective” (Harris, 2019, p. 28). They emphasise the stylised fact that farms will be more adversely affected as nitrogen limits become more stringent. This aligns with general theory (Hanley et al., 2007; Doole, 2012) and empirical results for this specific catchment (Section 5).

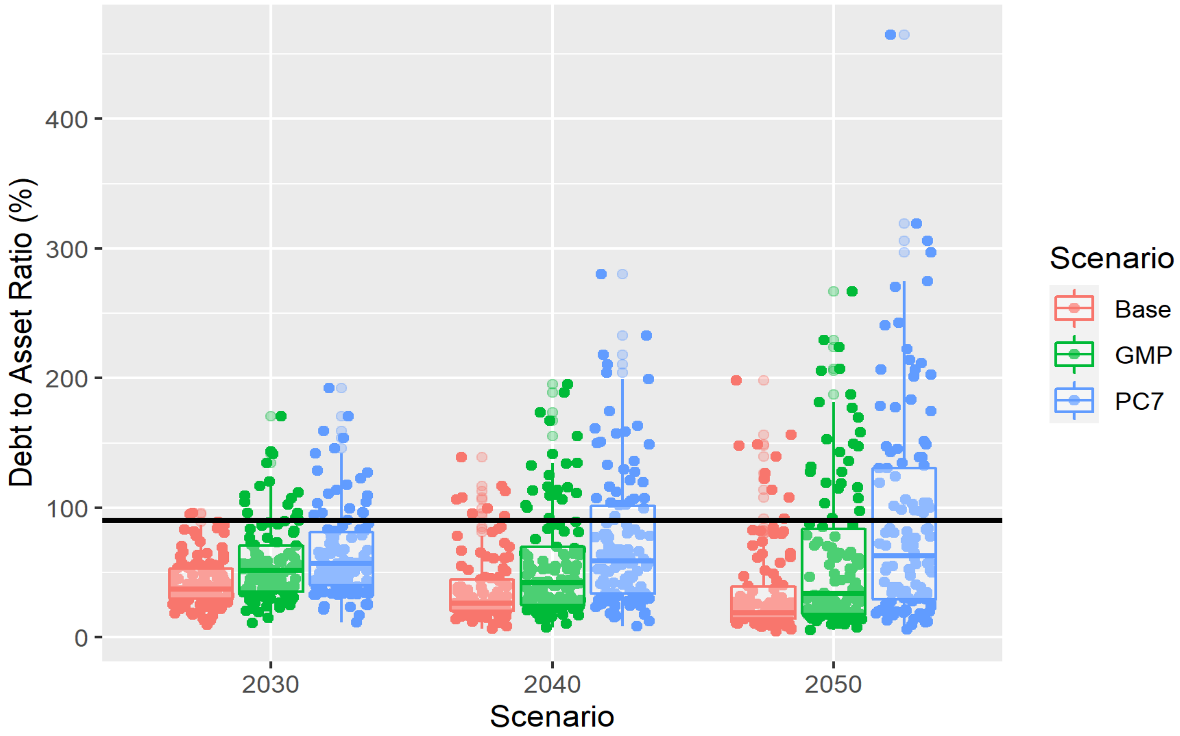
9.11 However, the use of such a subjective approach to assessment abstracts from the fact that individual farms will be affected at all nitrogen-loss reductions, given the presence of wide differences between farms. Indeed, farms with high DARs and low operating profit could be adversely affected even at a required reduction in N loss of only 5%.

9.12 Figure 5 displays the distribution of Debt to Asset Ratios (DARs) for the simulated population of individual farms in the catchment (see Section 5). Each dot represents an individual farm in a given scenario. A DAR of 25% or below is considered very good, while a DAR of around 50% is average for the NZ dairy sector (DairyNZ, 2020). The Reserve Bank of New Zealand utilise a DAR of 90% to classify a non-performing loan, provided the farmer is also unable to earn positive profits in the current year and at the long-term average milk price (Dunstan et al., 2015).

9.13 Figure 5 shows that the *GMP* and *PPC7* scenarios both severely challenge the solvency of many farm businesses in the Waimakariri District. The black horizontal line in this figure denotes the DAR at which a farm is typically considered to be at high risk of insolvency. The percentage of the total dairy farm population with a DAR above 90% under the *GMP* scenario is 13, 19, and 23% in 2030, 2040, and 2050, respectively. In comparison, the percentage of the total dairy farm population with a DAR above 90% under the *PPC7* scenario is 18, 28, and 37% in 2030, 2040, and 2050, respectively. Moving from *GMP* to *PPC7* means that an additional 5, 9, and 14% of farms are at risk of insolvency in 2030, 2040, and 2050, respectively.

9.14 These detrimental impacts on farm solvency arise from several drivers. First, the presence of nitrogen limits serves to decrease operating profit (Figure 1). Second, farms must borrow when they are unable to cover their debt and living expenses in any given year (Figure 3). Last, capital values are adversely affected by the impact of nitrogen limits on farm profitability (Figure 4).

9.15 **Figure 5.** Distribution of Debt to Asset Ratio for the Waimakariri dairy farm population in 2030, 2040, and 2050.



10 Careful, Staged Transition is a Valuable Component of *PPC7*

10.1 The importance of the dairy sector to the Canterbury region emphasises the need for careful transition and setting of nitrogen-leaching limits. It emphasises the potential for stringent nitrogen leaching limits to impose far-reaching negative economic consequences, both on the dairy sector and the broader regional economy.

10.2 The dairy sector in the Waimakariri district is economically important (see Section 4). Also, it was established using a significant amount of debt capital. Our current estimates suggest that around $778 million in debt is currently held by farms in the Waimakariri District. These factors emphasise the importance of a well-planned and executed transition.

10.3 A valuable part of *PPC7* is the proposal to implement a staged transition. This has several advantages:

10.3.1 It ensures that a strong foundation for implementation, monitoring, and enforcement is developed and applied.

10.3.2 It takes time to design, pilot, and introduce programmes to implement environmental management.

10.3.3 It allows time for those affected by regulation to develop skills that help with adaptation.

10.3.4 It builds trust and engagement between regulators and farmers, laying a foundation for an effective and efficient transition.

10.3.5 It allows diversity between farms, farmers, and the risk of contaminant loss to be pragmatically considered in research, development, and extension.

10.3.6 It increases the feasibility of implementing research outcomes associated with mitigation strategies at scale.

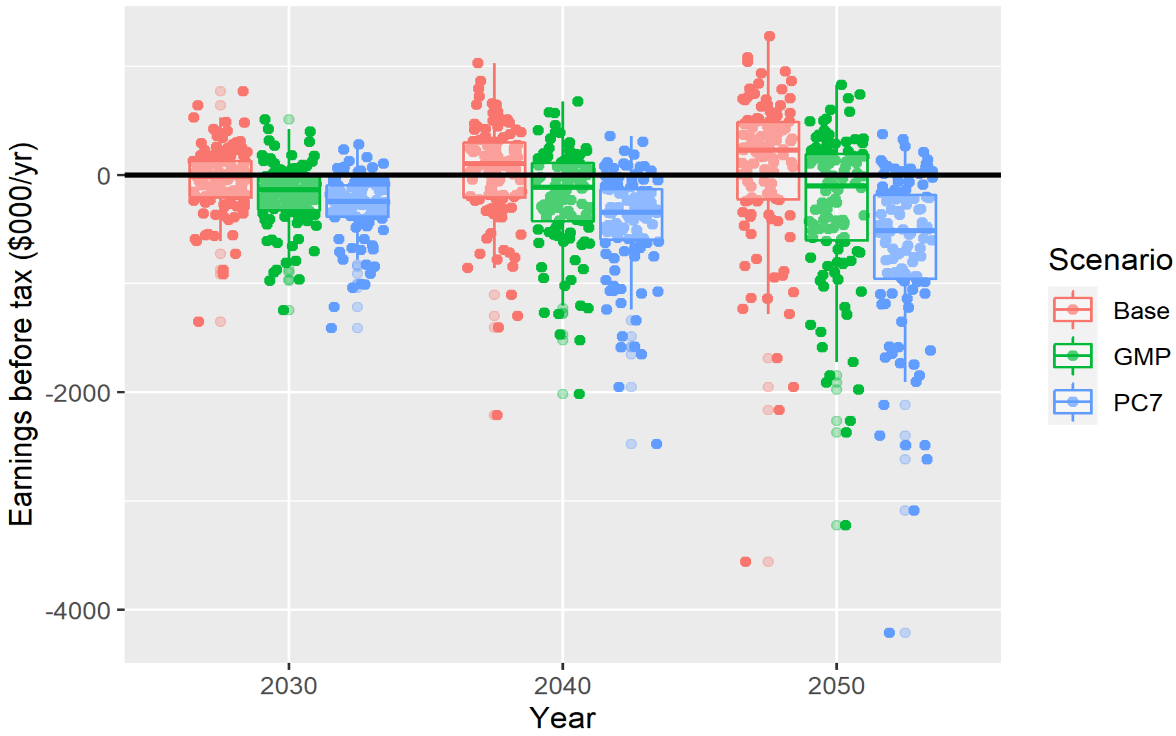
11 Accelerating Nitrogen Limits Will Have Enormous Adverse Economic Impacts

11.1 Section 10 outlines the value of a carefully designed transition period. Given these manifold benefits, it is concerning that the Section 42A report presents an option for accelerating nitrogen-leaching reductions. These accelerated limits propose that regulated sectors will achieve the total reductions by 2050, rather than 2080.

11.2 I believe that these accelerated limits will have enormous adverse impacts on dairy farms in the Waimakariri catchment, as well as the economic health of the communities that they provide for.

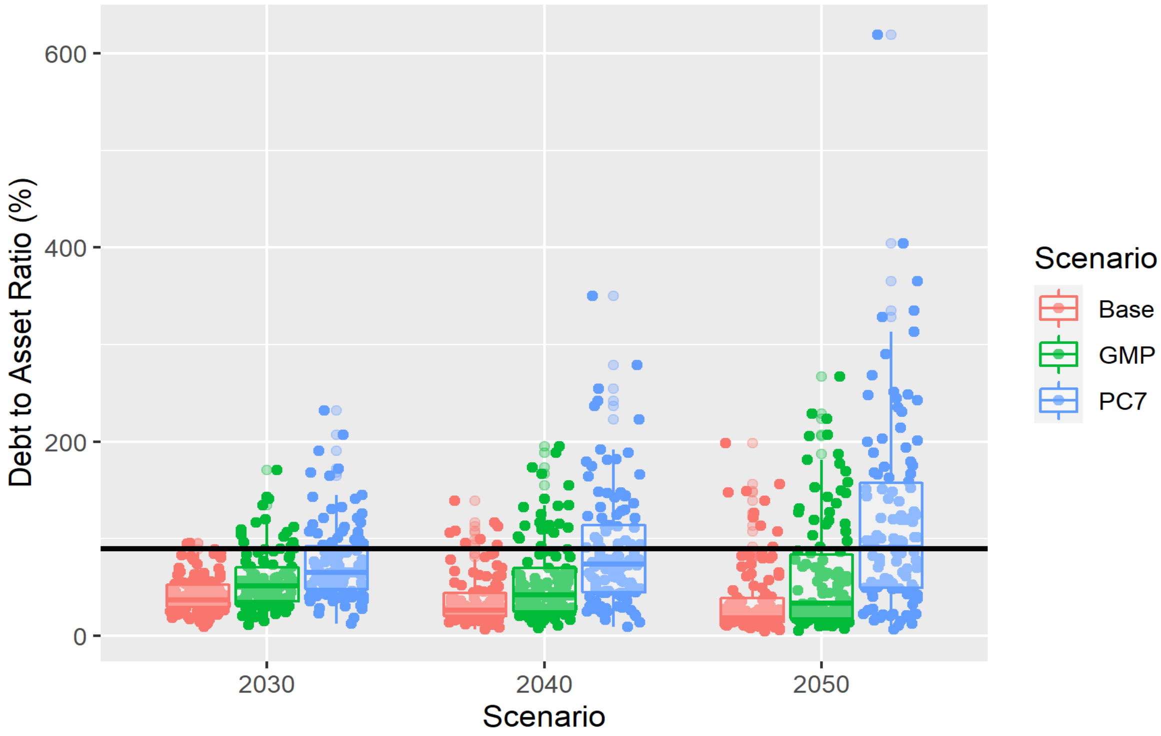
11.3 Around 75, 62, and 55% of the population cannot cover debt and living costs under *GMP* in 2030, 2040, and 2050, respectively. With accelerated nitrogen loss reductions, around 89, 88, and 85% of the population cannot cover debt and living costs under *PPC7* in these years (Figure 6). These levels are 6, 9, and 10% higher than those identified in 2030, 2040, and 2050, respectively, under *PPC7* when nitrogen loss reductions are slower (Section 8).

11.4 **Figure 6.** The distribution of Earnings before Tax (EBT) in 2030, 2040, and 2050, when the onset of the nitrogen limits are accelerated for the Waimakariri dairy farm population.



11.5 Figure 7 shows that accelerated nitrogen loss reductions also greatly harm farm solvency, as measured by the debt to asset ratio (DAR). The black horizontal line in this figure denotes the DAR at which a farm is typically considered to be a high insolvency risk. The percentage of the total dairy farm population with a DAR above 90% under the *GMP* scenario is 13, 19, and 23% in 2030, 2040, and 2050, respectively. In comparison, the percentage of the total dairy farm population with a DAR above 90% under the *PPC7* scenario with accelerated nitrogen reductions is 26, 39, and 51% in 2030, 2040, and 2050, respectively (Figure 7). These levels are 8, 11, and 14% higher than those identified in 2030, 2040, and 2050, respectively, under *PPC7* when nitrogen loss reductions are slower (Section 9).

11.6 **Figure 7.** Distribution of the Debt to Asset Ratio in 2030, 2040, and 2050, when nitrogen limits are accelerated for the Waimakariri dairy farm population.



11.7 These forecast outcomes emphasise the need to carefully design transition pathways to: (a) minimise economic cost to the dairy sector, (b) reduce adverse flow-on benefits for the district and region, and (c) exploit the benefits of a staged transition outlined in Section 10 above.

12 Conclusions

12.1 I believe that the current proposal falls short on several criteria that determine whether a policy instrument is suitable for achieving water quality improvement. These criteria are:

12.1.1 The *evidence base* for the proposed policy is uncertain. The existing economic evidence put forth by Environment Canterbury underestimates the economic cost of *PPC7* to dairy farms and the communities in which they are found.

12.1.2 The *efficiency* of the proposed policy is questionable. The policy instrument requires a resilient, proven contributor to the district, regional, and national economy to make radical changes to its mode of operation.

12.1.3 The *equity* of the proposed policy is questionable. Many dairy farms in the Waimakariri now potentially face undue economic burden after making significant investment when the current level of intensification was permissible.

12.2 The setting of 2030 reductions of 15% for nitrogen loss in Nitrate Priority Areas is forecast to impose an additional 11% loss of operating profit, on top of the cost required to reach *GMP*. They also lead to an additional 5% of farms being at high risk of insolvency, on top of those placed at risk through *GMP*.

12.3 The setting of 2040 reductions of 30% for nitrogen loss in Nitrate Priority Areas is forecast to impose an additional 10% loss of operating profit, on top of the cost required to reach *GMP*. They also lead to an additional 9% of farms being at high risk of insolvency, on top of those placed at risk through *GMP*.

12.4 *PPC7* is shown to decrease dairy-sector profit relative to the *GMP* case by 11, 21, and 26% across 2030, 2040, and 2050, respectively.

12.5 These adverse financial impacts introduce substantial economic risk to the broader district and regional economies. Moving from *GMP* to *PPC7* imposes a cost in the Waimakariri District of an additional \$9m, \$19m, and \$25m in 2030, 2040, and 2050, respectively. In comparison, moving from *GMP* to *PPC7* imposes a cost in the Canterbury region of an additional \$12m, \$25m, and \$34m in 2030, 2040, and 2050, respectively.

12.6 Accelerated nitrogen loss reductions augment the adverse impacts imposed by the *PPC7* policy mechanism, above and beyond those accruing to the *GMP* scenario. The percentage of farmers unable to meet debt and living expenses under *PPC7*, relative to *GMP*, increases by an additional 6, 9, and 10% in 2030, 2040, and 2050, respectively, when nitrogen loss reductions are accelerated. Further, the percentage of dairy businesses at high risk of insolvency under *PPC7*, relative to *GMP*, increases by 8, 11, and 14% in 2030, 2040, and 2050, respectively, when nitrogen loss reductions are accelerated.

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Name: Dr Graeme John Doole

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relationships between many of the individual variables. Thus, covariances between the set of variables were also estimated.

The distributions were then generated for farm size, milk production per cow, stocking rate, asset value per hectare, equity per hectare, non-milk revenue per unit of output, grazing cost per unit of output, labour cost per unit of output, livestock husbandry cost per unit of output, miscellaneous cost per unit of output, nitrogen fertiliser cost per unit of output, non-nitrogen fertiliser cost per unit of output, repairs and maintenance cost per unit of output, supplement cost per unit of output, overhead cost per unit of output, depreciation cost per unit of output, and adjustments per unit of output. We used these distributions to initialise each farm represented in the model and ensure realistic diversity across key metrics of farm performance.

The number of farms in the Waimakariri District and each Nitrate Priority Zone were then identified using a GIS mapping approach. The features of these farms were then validated through consultation with experts in the study region. A broad range of data fields were then generated for each farm using multiple-imputation methods (Enders, 2010). The use of this approach allowed the consideration of non-normal distributions and broad diversity in the covariances among each variable.

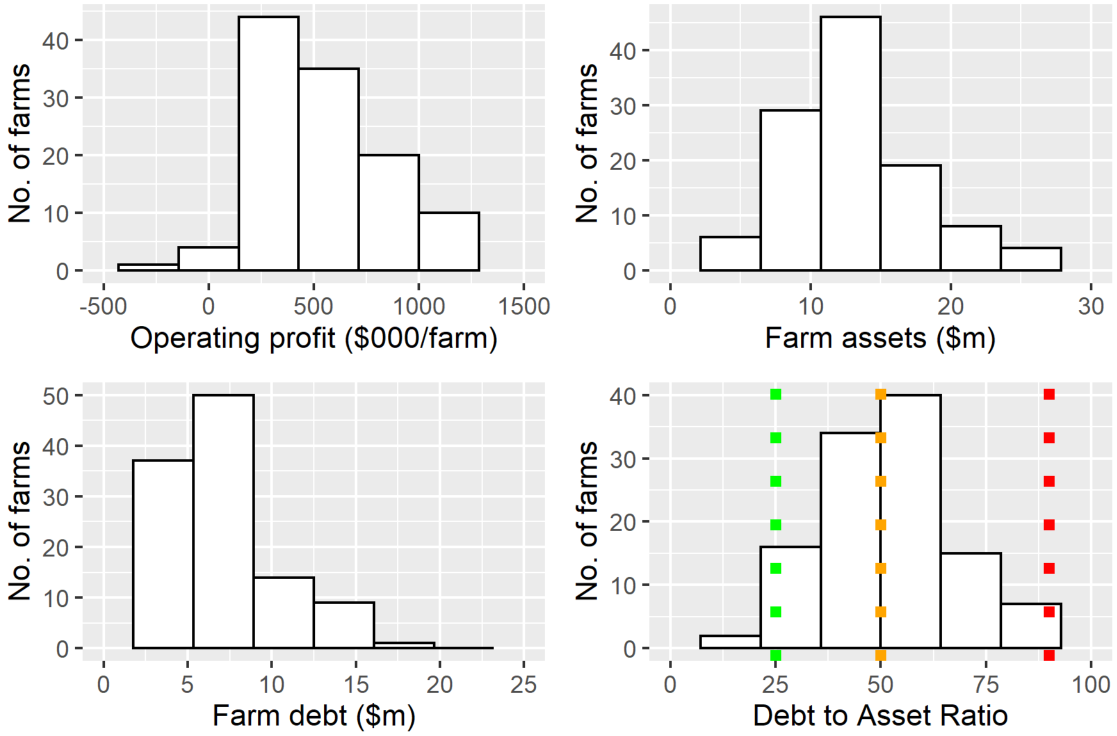
Significant variation is present between farms in the synthetic population, both in terms of physical (Figure A1) and financial (Figure A2) characteristics.

Several levels of debt to asset ratio (DAR) are demarcated in Figure A2. These indicate the following levels. A DAR of 25% or below is considered very good, while a DAR of around 50% is average for the NZ dairy sector (DairyNZ, 2020). The Reserve Bank of New Zealand utilise a DAR of 90% to classify a non-performing loan, provided the farmer is also unable to earn positive profits in the current year and at a long-term average milk price (Dunstan et al., 2015).

resulted in 66 wells with depths greater than 120m, 10 of which were based on the measured September 2017 data, minus 1.8m, and the rest on the average of 2 or more readings

6.14 When interpolating groundwater levels, it is important to use data that is consistent, for example using data from a particular date, or if that is not possible, from known times of high or low groundwater levels. If some data are from a time of high groundwater levels, and other from times of low groundwater levels, then the results will be skewed. The limitations of the approach taken mean that, when using the data for model calibration, or to infer piezome

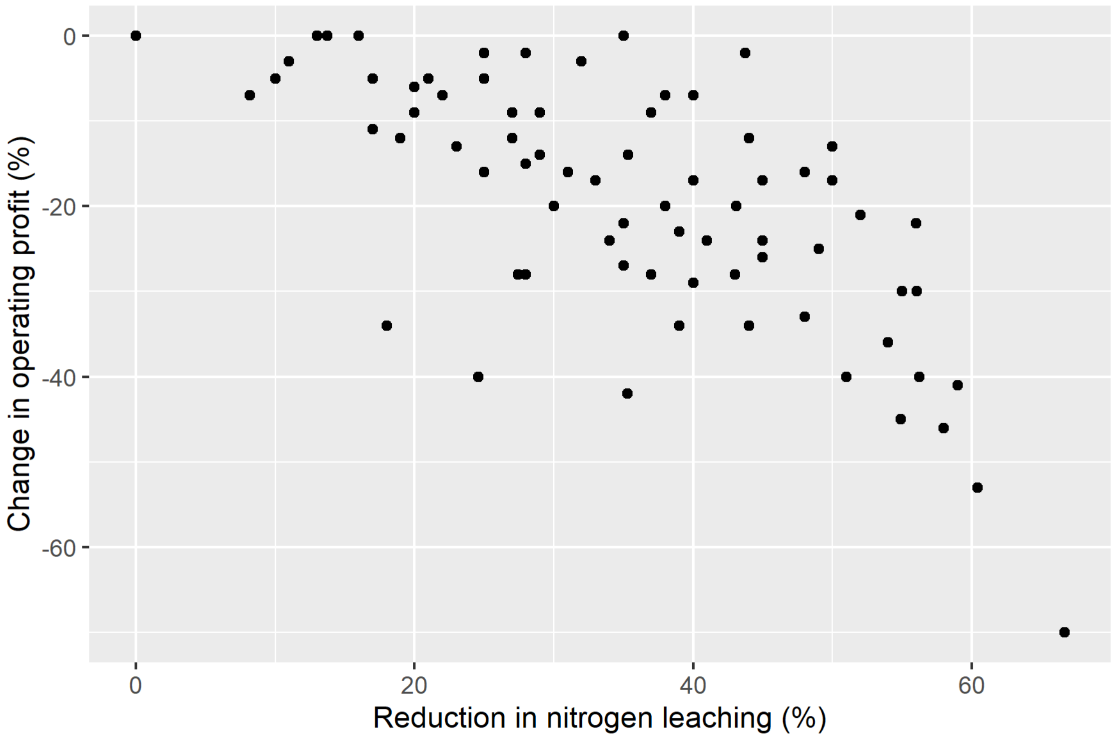
Figure A2. Distribution of the financial attributes of the synthetic dairy farm population established for the Waimakariri District.



14.2 Estimation of the reduction required to reach GMP and the abatement cost curve

Three reports provide a detailed outline of the mitigation cost associated with nitrogen loss reductions within the Orari-Temuka-Opihi-Pareora (OTOP) and Waimakariri zones (Davidson and Chikazhe, 2018; DairyNZ Economics Group, 2019; Reese and Bunning, 2020). Key output from these investigations are pairs of data specifying the operating cost and the level of nitrogen loss associated with different mitigation scenarios for each farm within the sample. These data were aggregated into a single dataset, given the common methodology applied between them and the similar nature of the farming systems. Outliers were removed using a standard statistical technique. Within this, an outlier was defined using the statistical rule that an extreme observation was one that sits 1.5 times the interquartile range below the first quartile or above the third quartile (Verbeek, 2017). The final dataset is shown in Figure A3.

Figure A3. Dataset relating abatement cost and level of nitrogen loss reduction.



The dataset shown in Figure A3 was used for two purposes.

First, the percentage reduction required for each farm to meet Good Management Practice was extracted from the sample. The mean, variance, skewness, kurtosis, minimum, and maximum of these data were then estimated. These descriptive statistics were then employed to estimate a non-normal distribution—one that specified the given percentage reduction in nitrogen loss that each farm in the model must decrease to achieve *GMP*—using the method of Fleishman (1978). The estimated distribution is shown in Figure 2 above.

Second, an abatement-cost curve was estimated based on the sample data. A flexible functional form was estimated. The equation for this relationship was: *P=a*N^b*, where *P* is the percentage change in profit, *N* is the percentage change in nitrogen, and *a* and *b* are parameters. This equation will take a linear or curved form depending on the sample data. In previous work, it has been shown to provide a parsimonious yet powerful description of abatement-cost relationships on New Zealand dairy farms (Doole, 2012). The model was applied through a logarithmic transformation of both the dependent and exogenous variable. This allowed the use of linear regression to identify the parameters for a non-linear functional form. The model achieved a very good level of fit, with a R^2 of 76%. The R^2 measure denotes the strength of the linear association between two variables, with R^2=0% showing no linear association and R^2=100% denoting a perfect linear association (Verbeek, 2017).

The estimation of this abatement-cost curve differed from standard procedures used to identify them for New Zealand dairy farms. It did so through estimating the relationship with a panel-data model, which accounts for individual effects arising from the fact that data is present for individual farms (Baltagi, 2013). This provides greater nuance than the aggregated approach taken by most practitioners, such as reported in Harris (2019). A random effects model is applied, based on the outcomes of a Hausman test (Verbeek, 2017). The implementation of a random-effects approach also allows inter-farm differences in abatement cost to be recognised through the specification of the estimated equation plus a farm-specific perturbation. The latter consists of a random draw from a normal distribution parameterised using the individual random effect identified from the panel estimation. Each estimated curve is utilised to identify how profit changes for each individual farm in the sample for the defined percentage reductions outlined within *PPC7* for 2030, 2040, and 2050.

14.3 Model assumptions

The economic model contained several assumptions. The focus of this section is to summarise these assumptions, as well as providing justification for them.

All the farms that were located within the Nitrate Priority Areas were required to make a reduction of 15 and 30% in 2030 and 2040, respectively. In contrast, only those farms that were in Nitrate Priority Areas B-E were required to make 45% reductions by 2050. The specification of these limits followed those in Table 8-9 in Proposed Plan Change 7.

Cost efficiency measures the ability of a farmer to produce more revenue for a given level of cost. Multiple points of evidence show that the financial gains in NZ dairy production in the last thirty years have come from greater input use and not efficiency improvements. Indeed, in general, this evidence shows that efficiency gains have been small and suggest a rather static state of play. Examples include estimated annual rates of change as -1.5% for 2001-12 (Conway, 2016), -1% for 2002-12 (Apatov et al., 2015), -0.6% for 2001-12 (Sense Partners, 2018), 0.1% for the last decade (DairyNZ, 2019), 0.1% for the last thirty years (Romera et al., 2020), and 1% for the last 20 years (DairyNZ, 2020). This emphasises the opportunities associated with improving cost efficiency within the NZ dairy sector.

It is assumed that efficiency gains are made across the next 30 years in the New Zealand dairy sector in this analysis. It is justified to assume that efficiency gains will be observed under some circumstances because opportunities to increase profit through greater input growth will be limited by environmental regulation, primarily pertaining to nutrient losses and greenhouse-gas emissions. These benefits are experienced to different degrees across the time horizon of interest, given that gains are experienced over 10, 20, and 30 years for the 2030, 2040, and 2050 scenarios, respectively. However, this varies between scenarios.

A base rate of 1.5% growth in operating profit per year is assumed. This is halved in the *GMP* scenarios, while no efficiency gains are represented in the *PPC7* runs. These assumptions are based on the assertions that moving to *GMP* will reduce some of the opportunities to improve cost efficiency on dairy farms, while within the *PPC7* runs the levels of nutrient loss reductions that are being discussed are so significant that they provide little opportunity to offset income losses through producing more with less (Doole, 2015; Doole and Kingwell, 2015; Davidson and Chikazhe, 2018; DairyNZ Economics Group, 2019; Reese and Bunning, 2020).

A consistent set of loan assumptions is utilised, given a lack of information. All loans are assumed to be set for a 30-year period at an interest rate of 6%. The average business loan rate over the last two decades has been around 6.5%; yet, it is expected to be lower into the future because of monetary policy action aimed at maintaining growth during a prolonged period of global economic contraction.

In some periods, some farms do not earn enough operating profit to sustain their predicted level of farm drawings and debt servicing. Model output above, such as that shown in Figure 1, shows that this number of farms may be significant under the *GMP* and *PPC7* scenarios, particularly later in the time horizon of interest. When farms do not earn enough operating profit to meet these living costs and debt commitments, it is assumed that they borrow further. Drawing down on equity during periods of uneconomic conditions is a characteristic of agricultural management, given the volatility of commodity prices and the high value of most farm assets. However, this dynamic cannot be sustained indefinitely, particularly if asset prices are dropping and are therefore eroding equity also. In reality, these farms will exit the farm population—through purchase by other, more efficient dairy farmers or through land-use change—as DARs of above 90-95% are attained. This dynamic is represented in an abstract way in this model, as farms do not exit the simulated population. It does not change the chief output of the model. Indeed, its main implication is that when interpreting model output, it is important to recognise that any farm business with a DAR above 90% can be thought of as being at high risk of insolvency.

An average annual rate of capital gain of 2% was assumed. This was defined separately from those impacts arising from efficiency growth and nitrogen loss reductions. Thus, it was broadly indicative of a base rate of capital gain influenced by the relative profitability of different land uses. The chosen rate is around a quarter of the historical rate observed across the last 30 years, which is estimated using the time-trend approach of Enders (2015). This moderation of the historical rate of appreciation is appropriate given anecdotal evidence that suggests that many of the capital gains accruing to New Zealand dairy production have already been realised given a convergence of milk prices internationally. The impacts of nitrogen loss reductions and efficiency gains on land values is incorporated using the approach of Muller and Neal (2019).