Manaaki Whenua
Landcare Research

Modelling the impact of freshwater mitigation scenarios: results for the Ruamāhanga Catchment

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Modelling the impact of freshwater mitigation scenarios: results for the Ruamāhanga Catchment

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Summary

Project and Client

- The New Zealand Ministry for the Environment (MfE) has identified that freshwater contaminants such as nitrogen (N), phosphorus (P), and sediment are key water quality challenges in New Zealand. As a result, MfE contracted Manaaki Whenua – Landcare Research (MWLR) to test a number of proposed mitigation scenarios using the Ruamāhanga catchment economic model that was developed in 2017–18 for the Ruamāhanga Whaitua Collaborative Modelling Project (RWCMP).

Objective

- The aim for this project was to use an economic model that integrates science and economics to assess the potential economic impacts of meeting a range of contaminant loads and attribute states for N, P, and sediment in the Ruamāhanga catchment. The integrated model estimates a calibrated baseline (the RWCMP business-as-usual or BAU case) and compares results from more than 50 mitigation scenarios to this baseline.

Methods

- The integrated catchment economic modelling of the Ruamāhanga catchment was completed using the New Zealand Forest and Agriculture Regional Model (NZFARM), MWLR's economic land use model. The model incorporated data and estimates from economic and land use databases and biophysical models. N and P loads from representative dairy, sheep and beef, and dairy support farms were estimated using Overseer (MPI 2016). Annual sediment loads from various land uses in the Ruamāhanga catchment were estimated using the SedNet model. Land-based mitigation costs and effectiveness in reducing each of these four contaminants were estimated by AgResearch (Muirhead 2016).
- NZFARM includes several options for managing N, P, and sediment loads from MPI's representative farms, which include 3 sets of on-farm mitigation bundles (Muirhead 2016), land retirement, stock exclusion, and farm environmental plans. Land retirement and space/pole planting target sediment management while on-farm mitigation bundles target nutrient management.
- MfE specified the exact set of scenarios (ES1) as well as mitigation that should be imposed on each land use within the Ruamāhanga catchment. No other analyses were undertaken outside of those specified by MfE. The broad set of scenarios include:
  - Business-as-usual (BAU) – represents future pathways based on existing policy, practice and investment derived by Greater Wellington Regional Council. This is the scenario that we generally refer to as the 'baseline'.1

[1] N.B. this is different from 'base' in the RWC scenarios, which they refer to as the 'no policy' baseline. However, 'base' is nearly identical to BAU in the RWC analysis, as both assume all pastoral farms will implement M1 mitigation (stock exclusion) by 2025.

- Practice based scenarios – represents sets of mitigation options or land use changes specified by MfE. An assumption is that all eligible land uses will implement the scenarios. Examples of specified mitigation options include stock holding areas (SHA), stock exclusion (fencing), hill and lowland cropping mitigation bundles, wetland fencing, and intensification.
- Target-based scenarios – specifies that annual N loss rates cannot exceed 30, 50, or 70 kgN/ha/yr. On parcels that exceed that rate, the least-cost mitigation option (including afforestation) to achieve the limit will be implemented.
- Combination scenarios – combines several practice-based scenarios to estimate maximum mitigation potential in the catchment if a wider set of practices were employed.
- RWCMP 2018 – Core scenarios developed for the Ruamāhanga Whaitua Committee Modelling Project, which concluded in 2018. The 'Silver' and 'Gold' scenarios focus on two level of stringencies for water quality that were proposed, with the Gold scenario having higher levels of mitigation. For these scenarios, implementation was assumed to occur in stages, with full implementation achieved by 2080.

Results

When interpreting the economic impacts, it should be noted that all estimates are compared with a business-as-usual (BAU) baseline that assumed all pastoral streams were fenced by 2025. As MfE did not specify a timeline or pathway in which mitigation was to be implemented, all scenarios assume the practice or policy is fully achieved. In reality, implementation is likely to take 15 years or more for most of the scenarios. Estimates for the key scenarios – most of which focus on cumulative mitigation across a number of practices and/or land uses – are listed in Table ES.1.

Key findings from modelled scenarios are as follows:

- *Hill country and lowland forage cropping:* There are only a few mitigation options in the model for arable and horticulture land uses in the catchment, hence there was little change in estimated impacts for scenarios that targeted those land uses.
- *Land use intensification:* Converting dairy support to dairy with N and P limits resulted in a marked reduction in N (but little change in P and sediment losses). The BAU N and P limits were not achievable for conversions to dairy even though all implemented maximum mitigation bundles (M3).
- *Stock exclusion:* As the existing regulation (BAU) in the Ruamāhanga catchment is more stringent than most of the stock exclusion mitigation options modelled, the impact of these mitigation options on net revenue is positive compared with the BAU. The corresponding impacts on N, P, and sediment losses, however, are not favourable for most options with an increase in losses. Moreover, as stock exclusion on only wider streams (>1 m) is estimated to increase the sediment loss by up to 18% compared with the BAU, it is important to consider stock exclusion on the smaller streams for better sediment loss outcomes.
- *Stock holding areas:* Stock holding areas (SHA) for dairy and dairy support are cost-effective for mitigating N, but do not reduce total N by more than 7%. To achieve a

noticeable impact on sediment and P loss SHAs (or other mitigations) are needed for sheep and beef (S&B) farms since most dairy and dairy support farms are located on flat land with low soil loss in BAU scenario.

- *Wetlands:* A 5-m buffer fence around wetlands has a trivial impact in the Ruamāhanga catchment. This is mostly due to the small area of wetlands in the catchment (0.5% total area).
- *Targets:* 70 kg and 50 kgN/ha N limits have few N, P, or sediment benefits because the area that falls into this category is less than 1% of total catchment area, i.e. most farming systems already have lower N losses. 30 kgN/ha N limit does have a modest reduction in N and a corresponding decrease in farm revenue. Most of the mitigation to achieve the 50 kgN and 30 kgN/ha targets comes in the form of afforestation as mitigation bundles are not effective enough to achieve N reduction targets.
- *Combination scenarios:* Combination scenarios produce noticeable change in net farm revenue, between 7% and 46% reduction compared to the BAU. When multiple practices are implemented, N losses reduced by 10 to 44%, while P losses and sediment losses reduced by 5 to 64% and 3 to 48% respectively. Most of the mitigation comes from constructing SHAs on all livestock farms.

Table ES.1: Estimates of Key Ruamāhanga Scenarios for MfE Analysis

Mitigation Option	Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
BAU	BAU	BAU	$192,503,691	$375,718,558	$595,148,587	2,979	4,843,302	262,726	1,060,591
					% Change From BAU				
Hill and Lowland Cropping	1	M2 - Arable, Hort, Livestock	-11.6%	-1.5%	-1.5%	-1.4%	-10.0%	-7.0%	-10.7%
Hill and Lowland Cropping	1	M3 - Arable, Hort, Livestock	-16.8%	-3.7%	-3.7%	-3.4%	-9.7%	-46.9%	-29.4%
Hill and Lowland Cropping	2	M2 - Arable, Hort, Livestock with FEP	-14.6%	-1.5%	-1.5%	-1.4%	-16.6%	-17.5%	-35.3%
Hill and Lowland Cropping	2	M3 - Arable, Hort, Livestock with FEP	-19.8%	-3.7%	-3.7%	-3.4%	-16.3%	-51.5%	-44.7%
Hill and Lowland Cropping	3	M2 - Arable, Hort, Livestock with FEP + Retire High LUC	-17.8%	-6.2%	-6.2%	-6.0%	-20.0%	-21.5%	-36.6%
Hill and Lowland Cropping	3	M3 - Arable, Hort, Livestock with FEP + Retire High LUC	-22.8%	-8.3%	-8.3%	-7.9%	-19.7%	-52.8%	-45.4%
Stock Exclusion	1	Exclusion on SU > 18, LUC 1-5 & 1+ m wide streams	4.6%	0.0%	0.0%	0.0%	0.7%	2.7%	17.1%
Stock Exclusion	2	3m Setback on SU > 18 OR LUC 1-5 & Exclusion on LUC 6-8	-0.6%	-0.9%	-0.9%	-0.9%	-0.7%	-0.7%	-0.8%
Stock Exclusion	3	5m Setback on SU > 18 OR LUC 1-5 & Exclusion on LUC 6-8	-1.1%	-1.5%	-1.5%	-1.4%	-1.1%	-1.1%	-1.0%
Stock Exclusion	4	5m Setback on all slopes; All Dairy, all eligible S&B	0.7%	-1.7%	-1.7%	-1.6%	-1.2%	-0.8%	9.3%
Wetlands management	1	5m fencing	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.3%
SHA	1	Opt 1 SHA - All Stock	-9.9%	0.0%	0.0%	0.0%	-18.0%	-11.3%	-8.8%

Mitigation Option	Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
SHA	2	Opt 2 SHA - All Stock	-23.2%	4.4%	4.4%	4.1%	-28.8%	-22.6%	-17.5%
N limit	1	70kgN/ha	-0.1%	-0.2%	-0.2%	-0.1%	-1.6%	-0.2%	0.0%
N limit	1	50kgN/ha	-0.2%	-0.2%	-0.2%	-0.2%	-1.3%	-0.2%	0.0%
N limit	1	30kgN/ha	-6.6%	-7.0%	-7.0%	-5.6%	-6.7%	-1.7%	-0.3%
Mitigation Combo	1a	Fencing + Wetland + M2 + SHA-low	-17.4%	2.2%	2.5%	4.1%	-26.0%	-15.5%	-3.1%
Mitigation Combo	1b	Fencing + Wetland + M3 + SHA-low	-22.5%	0.0%	0.4%	2.1%	-25.7%	-50.9%	-20.2%
Mitigation Combo	2a	Fencing + Setback + Wetland + M2 + FEP + SHA-high	-36.9%	5.7%	6.0%	7.3%	-41.3%	-36.4%	-38.9%
Mitigation Combo	2b	Fencing + Setback + Wetland + M3 + FEP + SHA-high	-42.1%	3.5%	3.8%	5.3%	-41.1%	-62.7%	-46.7%
Mitigation Combo	3a	Fencing + Setback + Wetland + M2 + FEP + Ret + SHA-hi	-40.6%	0.4%	0.7%	2.2%	-44.0%	-39.8%	-40.2%
Mitigation Combo	3b	Fencing + Setback + Wetland + M3 + FEP + Ret + SHA-hi	-45.6%	-1.7%	-1.4%	0.3%	-43.8%	-64.1%	-47.5%
RWC 2018	n/a	Silver 2080	-24.3%	-7.6%	-7.5%	-6.9%	-9.1%	-52.6%	-32.9%
RWC 2018	n/a	Gold 2080	-22.3%	-6.4%	-6.4%	-5.9%	-8.7%	-52.1%	-36.8%

1 Introduction

The New Zealand Ministry for the Environment (MfE) has identified that freshwater contaminants such as nitrogen (N), phosphorus (P), and sediment are key water quality challenges in many of the regions in New Zealand. As a result, MfE contracted Manaaki Whenua – Landcare Research (MWLR) to test a number of proposed mitigation scenarios using the Ruamāhanga catchment economic model that was developed in 2017–18 for the Ruamāhanga Whaitua Collaborative Modelling Project (RWCMP).

The state of water quality across the Ruamāhanga catchment ranges from very good in the fast flowing rivers of the Tararua hills, to quite poor in the streams and rivers that run across the valley floor (Ruamāhanga Whaitua Committee (RWC) 2018). The current state of most Freshwater Management Units (FMU) is below the community's and the RWC's expectations, and sometimes below National Objectives Framework (NOF) standards (RWC 2018). Main water quality issues in the catchment include many rivers and streams failing to meet the NOF standards for *E. coli* (primary contact recreation), periphyton biomass, and nitrate toxicity, sedimentation from soil and streambank erosion affecting water bodies, and seriously degraded quality of Lake Wairarapa and Lake Onoke mainly due to high phosphorous levels (RWC 2017, Mitchell and Heath 2018, Hickson Rowden 2019). To address those issues GWRC proposed to introduce rules that require nitrate reduction of 9%, phosphorus reduction of 34% and sediment reduction of 28% in the Ruamāhanga catchment (RWC 2018).

This report provides an assessment of the economic impacts of nutrient and sediment reduction scenarios proposed by the Ministry for the Environment (MfE) and applied to the Ruamāhanga catchment. The following process was followed to assess the economic impacts, where steps 1–3 were conducted during the initial RWCMP, while steps 4–6 were followed as a result of the work commissioned by MfE and featured in this report:

1 Parminter and Grinter (2016) developed 16 base or representative farms.

2 AgResearch (Muirhead et al. 2016) developed a series of cost-abatement curves for each farm describing the relative cost and potential reduction of Nitrogen (N), Phosphorus (P), and sediment losses.

3 Jacobs New Zealand Limited (hereafter 'Jacobs') brought the above information together to estimate the environmental impacts on all land uses in the catchment.

4 MfE identified a range of mitigation options that could be implemented in the catchment such as Farm Environmental Plans (FEP) and Stock Holding Areas (SHA).

5 MfE specified a set of scenarios to consider for the economic modelling. These were primarily practice-based scenarios with a few outcome-based scenarios (e.g. limit N leaching to 50 kgN/ha/yr or less)

6 Manaaki Whenua – Landcare Research (MWLR) used their catchment-scale economic model developed for the Ruamāhanga in 2017–18 to estimate the on-farm and wider regional economic impacts for the range of scenarios specified by MfE for the catchment.

This report presents the results of the economic modelling for the scenarios specified by MfE. The economic modelling was undertaken using the integrated model of the Ruamāhanga catchment. The modelling consisted of two key components: (1) baseline contaminant losses for each hectare of land in the study area; and (2) analysis showing how these loads change with the implementation of various on-farm mitigation options. The model allows for any combination of mitigation option to be applied at farm, sub-catchment, and catchment levels to achieve spatially distributed environmental objectives. The objectives are represented as percentage changes in contaminant loads and their related attributes.

The Ruamāhanga catchment economic model is based on the New Zealand Forest and Agriculture Regional Model (NZFARM), MWLR's economic land use model. NZFARM is designed for detailed modelling of land uses at a catchment scale. It enables the consistent assessment of multiple scenarios by estimating and comparing the relative changes in economic and environmental outputs. The Ruamāhanga catchment version of NZFARM includes several farm- or parcel-level management options for managing N, P, and sediment loads: implementing farm soil management plans; fencing streams; riparian planting; and more. While the list of feasible farm management options for the representative pastoral farms is considered extensive, we do not necessarily include all possible options to mitigate losses from diffuse sources into waterways. The results from NZFARM are reliant on input data (e.g. farm budgets, mitigation costs, and contaminant loss rates) from external sources and may vary if alternative data are utilised. NZFARM also does not account for the broader impacts of changes in land use and land management beyond the farm gate. Instead, the broader economic impacts of the scenarios are estimated using a multiplier approach (see section 2.2.3).

This report presents estimates from a calibrated baseline and results from scenarios initially created for the RWCMP in 2018. These include both practice-based approaches, such as having all eligible farms implement a specific on-farm mitigation bundle, to undertaking space/pole planting or land retirement on steep-sloping land with high sediment rates to achieve MfE's specific objectives in the Ruamāhanga catchment. This report only analysed those scenarios specified by MfE.

A list of key caveats, assumptions, and limitations for this analysis is included in Box 1. A comprehensive list of caveats, assumptions, and limitations is included in Section 3.

Box 1: key caveats, assumptions, and limitations for this analysis

- For this analysis, NZFARM has been programmed such that all landowners are assumed to collectively implement the exact set of practices specified by the scenarios. Thus NZFARM is not utilised as an 'optimisation' model that takes into account land use and land management change. This did not capitalise on the flexibility of the model to explore other policy options or a mix of mitigation options to potentially achieve the same objective. In reality, it is likely to be more cost-effective if the landowner has a greater degree of flexibility to choose from a range of management practices to improve water quality.
- The results of this analysis should not be interpreted as the actual impacts on individual farms. Rather the analysis is an estimation of the catchment-wide economic impacts of the scenarios using representative farm responses to the specified mitigation and management options in each scenario in the catchment
- Our economic analysis largely depends on the datasets and estimates provided by GWRC and RWCMP partners. Estimates derived from other data sources may provide different results for the same catchment. Thus, the tools and analysis presented here should be used in conjunction with other information during the decision-making process.
- This analysis includes an extensive list of N, P, and sediment mitigation strategies that could be implemented in the Ruamāhanga catchment. However, including additional mitigation options could lower both the overall cost of the policy and the cost to individual landowners.
- This analysis does not explicitly account for all administrative and transaction costs of the various scenarios. Doing so could alter both the estimates for the distributional impacts to landowners, as well as the overall cost of the different policies.
- The modelling exercise assumes that technology, climate, input costs, and output prices are all constant for the duration of the policy, since the aim of this modelling exercise is to focus on comparing a range of scenarios at specific points in time.

2 Methodology

This report presents the assessment of the potential economic and environmental impacts of reducing N, P, and sediment loss in the Ruamāhanga catchment. The economic analysis is conducted using the NZFARM model. NZFARM is a comparative-static, non-linear, partial equilibrium mathematical programming model of New Zealand land use operating at the catchment scale (Daigneault et al. 2012, 2013). Farm-level N and P losses for 16 representative dairy, sheep and beef, and dairy support farms were estimated by Parminter and Grinter (2016), while loss figures for other land uses were defined by Jacobs (2017, 2018). Baseline estimates of sediment were obtained by Jacobs (2018) using the SedNetNZ model. The cost and effectiveness of mitigating the contaminants from the representative farms were estimated by AgResearch (Muirhead et al. 2016). Economic impacts are estimated as the cost to landowners of implementing mitigation options relative to their current (baseline) management practices. Environmental impacts are measured as percent changes in N, P, and sediment loads relative to the current baseline. Figure 1 shows how the components of the integrated economic analysis are linked within NZFARM. Key components of the analysis are presented in the following subsections, while a more detailed description of the model is presented in Appendix 1.

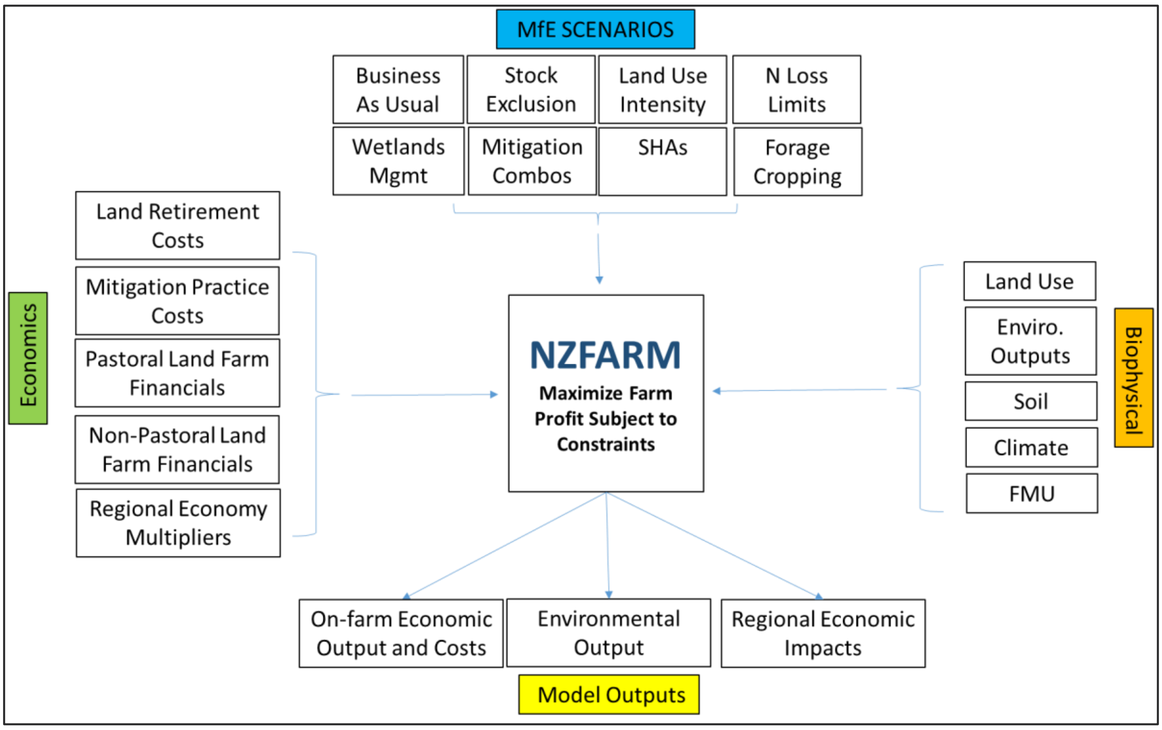

Figure 1: Flow Diagram of Integrated Economic Modelling.

2.1 Model Data and Parameterisation

NZFARM accounts for a variety of land use, enterprise, and land management options in a given area. The data required to parameterise each land use, enterprise, and land management combination include financial and budget data (e.g. inputs, costs, and prices), production data, and environmental outputs (e.g. nutrient loads, sediment loads, etc.). Table 1 lists the key variables and data requirements used to parameterise NZFARM. Note that nutrient and sediment load estimates represent losses from a given parcel of land, but not necessarily the amount that will reach a given waterbody by a particular time. More details on the key data and assumptions used to populate the Ruamāhanga catchment version of the model are provided below. All the figures in the NZFARM are converted to per hectare values and 2015 NZD so that they are consistent across sources and scenarios.

Table 1: Data sources for NZFARM's modelling of Ruamāhanga Catchment

Variable	Data requirement	Source	Comments
Geographic area	GIS data identifying the catchment area	Catchment and sub-catchments based on REC	Provided by GWRC and Jacobs [a]
Land cover and enterprise mix	GIS data file(s) of current land use within the catchment Key enterprises (e.g., dairy).	Regional land use map broken out by key land uses	Provided by GWRC and Jacobs [a]
Management practices	Distribution of feasible management practices (e.g. stream fencing, farm, management plan, etc.)	Muirhead et al. (2016)	Data and assumptions verified by project partners
Climate	Temperature and precipitation	Jacobs (2016)	Analysis assumes constant climate and production
Soil type	Soil maps used to divide area into dominant soil types	Jacobs (2018)	Used for distribution of representative farms and nutrient losses
Input costs	Stock purchases, electricity and fuel use, fertiliser, labour, supplementary feed, grazing fees, etc.	MPI representative farms: Parminter & Grinter (2016) Other Land Uses: A mix of: pers. comm. with farm consultants and regional experts, MPI farm monitoring report, Lincoln Financial Budget Manual	Verified with Whaitua committee and industry consultants
Product outputs	Milk solids, Dairy calves, Lambs, Mutton, Beef, Venison, Grains, Fruits, Vegetables, Timber, etc.	MPI representative farms: Parminter & Grinter (2016) Other land uses: Used yields for Greater Wellington Region, but nothing specific to Ruamāhanga Catchment	Verified with Whaitua committee and industry consultants
Commodity Prices	Same as outputs, but in $/kg or $/m3	MPI representative farms: Parminter & Grinter (2016) Other land uses: MPI (2015) and other sources	Other land uses assume 5-year average
Environmental indicators	N leaching P loss Soil Erosion/Sediment Stream *E. coli* [b]	N and P: Parminter & Grinter (2016) Sediment and *E. coli*: Jacobs (2018)	Data supplied by project partners. Nutrient and sediment figures are for farm-level losses.
Regional Economic Multipliers	Regional employment Regional economic output	Butcher Partners Ltd (2017)	Data supplied by project partners

a: the data are provided by GWRC and Jacobs as GIS maps

b: Jacobs (2018) estimated scenario impacts on physical *E.coli* loads, but they did not provide the data for the economic analysis. This omission has no impact on the economic impact estimates.

2.2 Land use

Observed baseline land-use information is required to fit the model to an empirical baseline. Baseline land use areas for this catchment model are based on a GIS-based land-use map created by GWRC and updated by Jacobs (Figure 2). The catchment is approximately 359 000 ha in size, and key land uses by percent of total area include sheep and beef (46%), native bush (24%), dairy (8%), mixed cropping (5%), dairy support (3%), and forestry (3%).

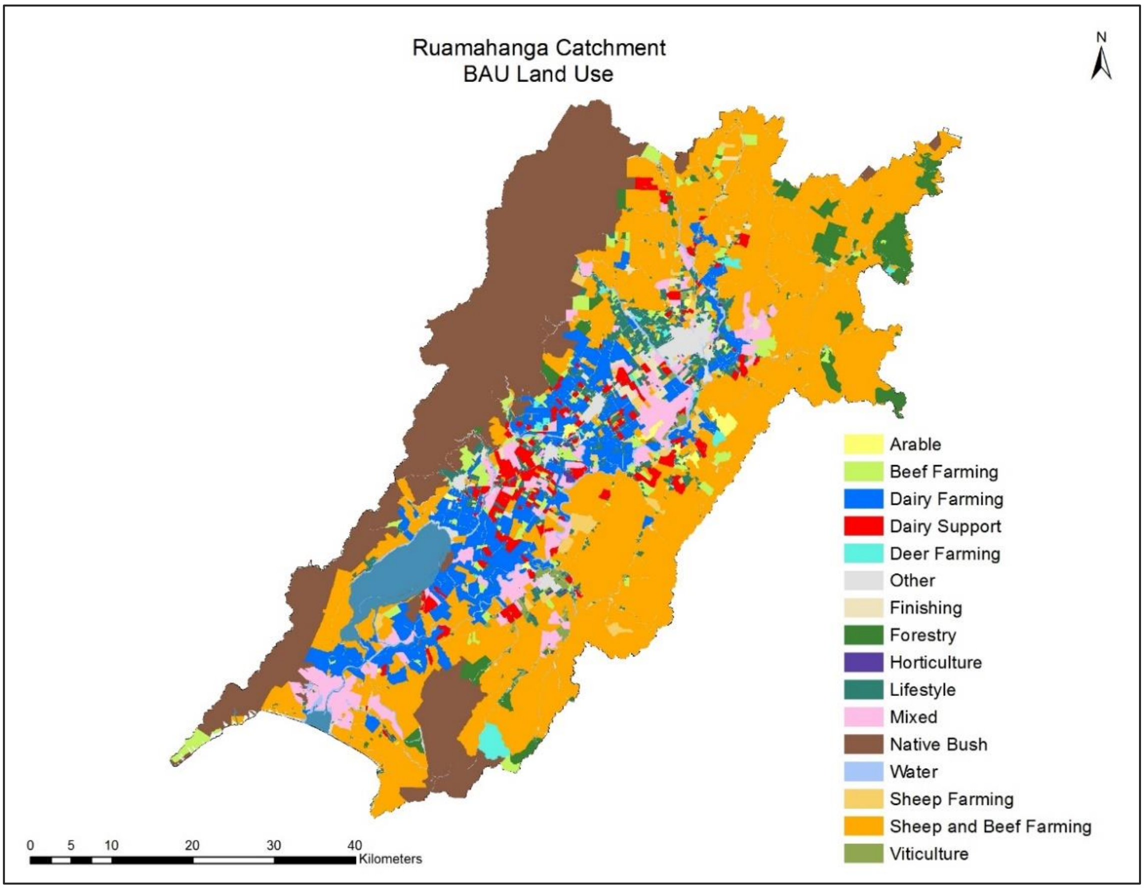

Figure 2: Ruamāhanga Catchment land use based on map from GWRC.

The map provided by GWRC did distinguish between some sheep and beef systems, but it did not differentiate dairy or dairy-support systems. Parminter and Grinter (2016) and KapAg (2016), however, estimated farm and nutrient budgets for 6 dairy, 8 sheep and beef, and 2 dairy-support systems, which then had to be spatially assigned across the catchment by Jacobs. NZFARM used this land use configuration. The name and description of each of the 16 MPI representative farm categories are listed in Table 2, while the spatial distribution is shown in Figure 3. About 58% of the total catchment area, or 207 000 ha, is covered by the 16 representative farm types.

Table 2: Details of representative farm types in Parminter and Grinter (2016) and KapAg (2016)

Farm system	MPI Farm type
4.1 Dry flat dairy (low rainfall and high prod)	1b
4.2 Dry flat dairy (low rainfall and mod prod)	1b2
4.3 Dry flat dairy (moderate rainfall)	1a
4.4 Dry flat dairy (high rainfall)	3
4.5 Irrigated flat dairy	2
4.6 Organic dairy	4
4.7 Sheep and beef finishing, summer dry	5
4.8 Sheep and beef breeding, summer wet	6a
4.9 Sheep and beef finishing, summer wet	6b
4.10 Sheep and bull finishing	7
4.11 Irrigated sheep and beef trading	8a
4.12 Lamb and bull trading, 20% cropping	8b
4.13 Sheep and beef breeding, summer dry	9
4.14 Finishing beef, 65% cropping	10
4.15 Dairy support, 15% cropping, summer dry	11b
4.16 Dairy support, 48% cropping, summer wet	11a

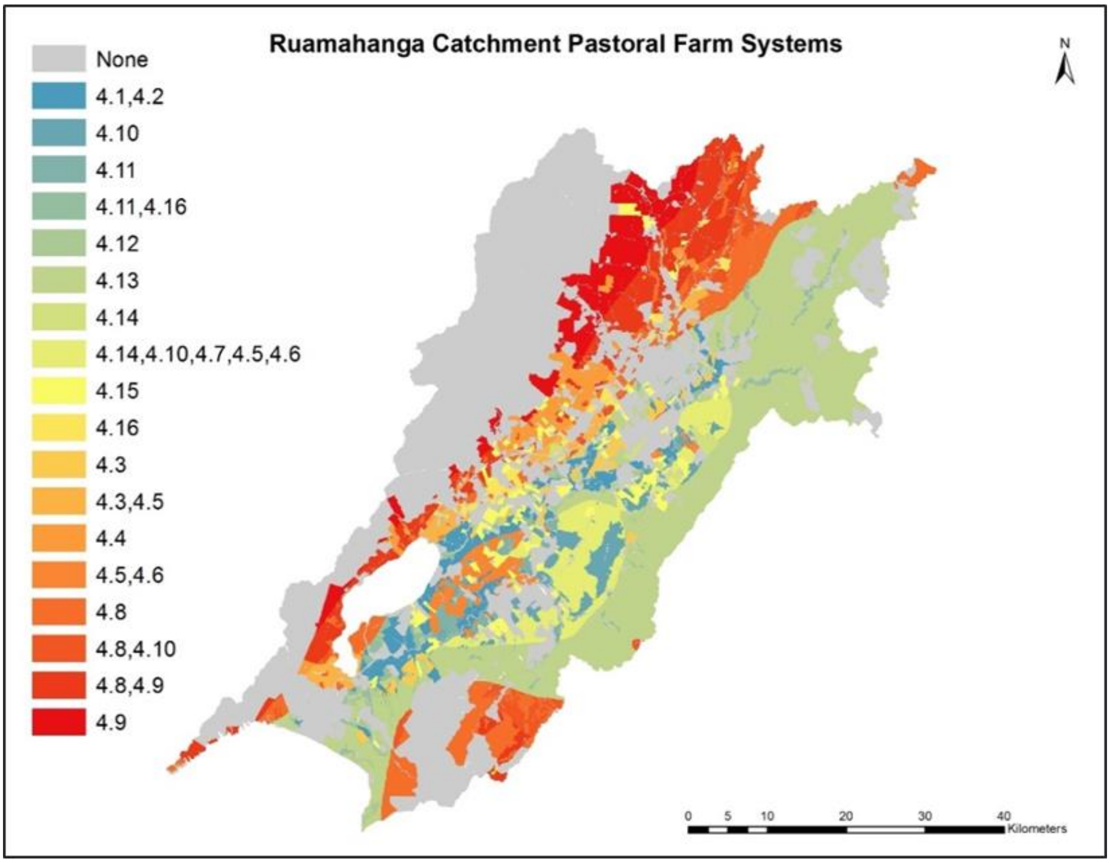

Figure 3: Spatial distribution of MPI representative farms in Ruamāhanga catchment.

Several scenarios included specific criteria for whether streams had to be fenced for stock exclusion or not. These criteria include average slope and carrying capacity (measured in Stocking Units, SU) of a parcel, or width of the stream (see Figure 4 and Figure 5). In addition, other scenarios sought to fence off existing wetlands (Figure 6) or target parcels with annual N leaching rates greater than 30, 50, or 70kgN/ha/yr (Figure 7).

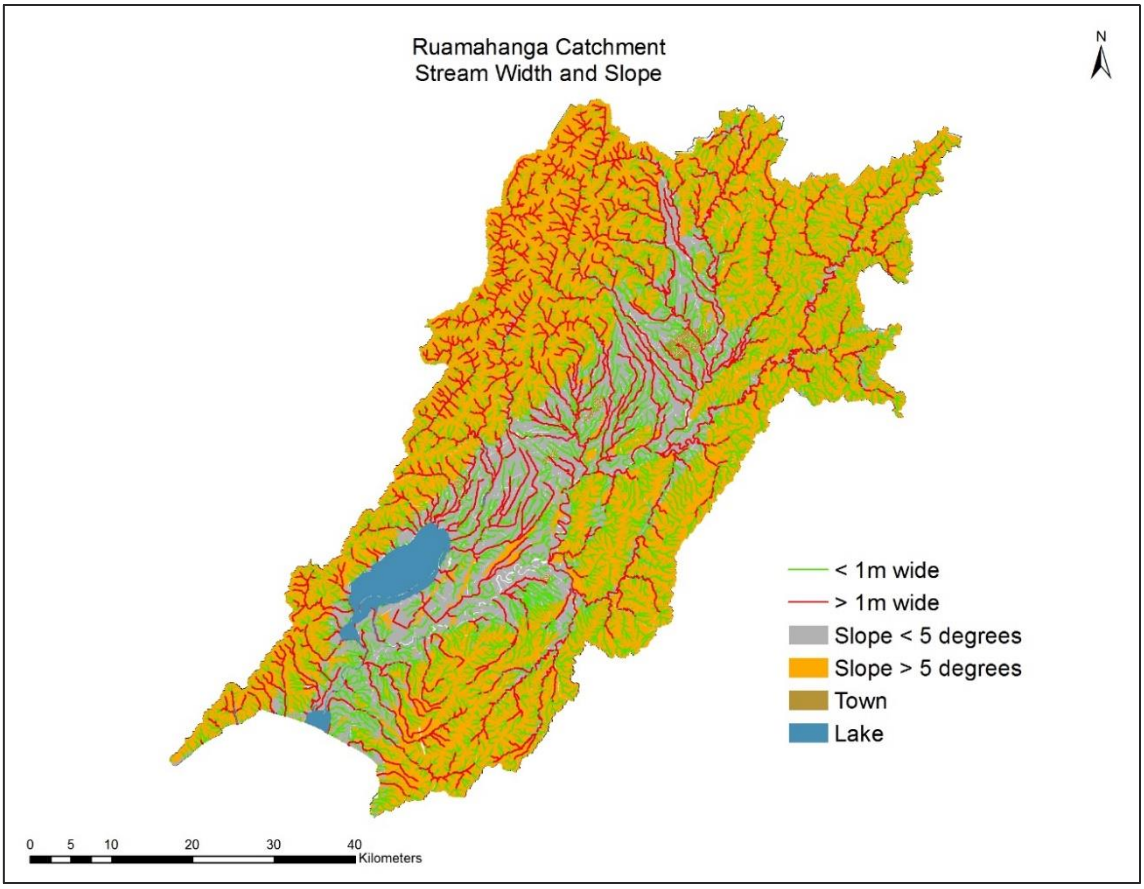

Figure 4: Spatial distribution of stream width and slope in Ruamāhanga catchment.

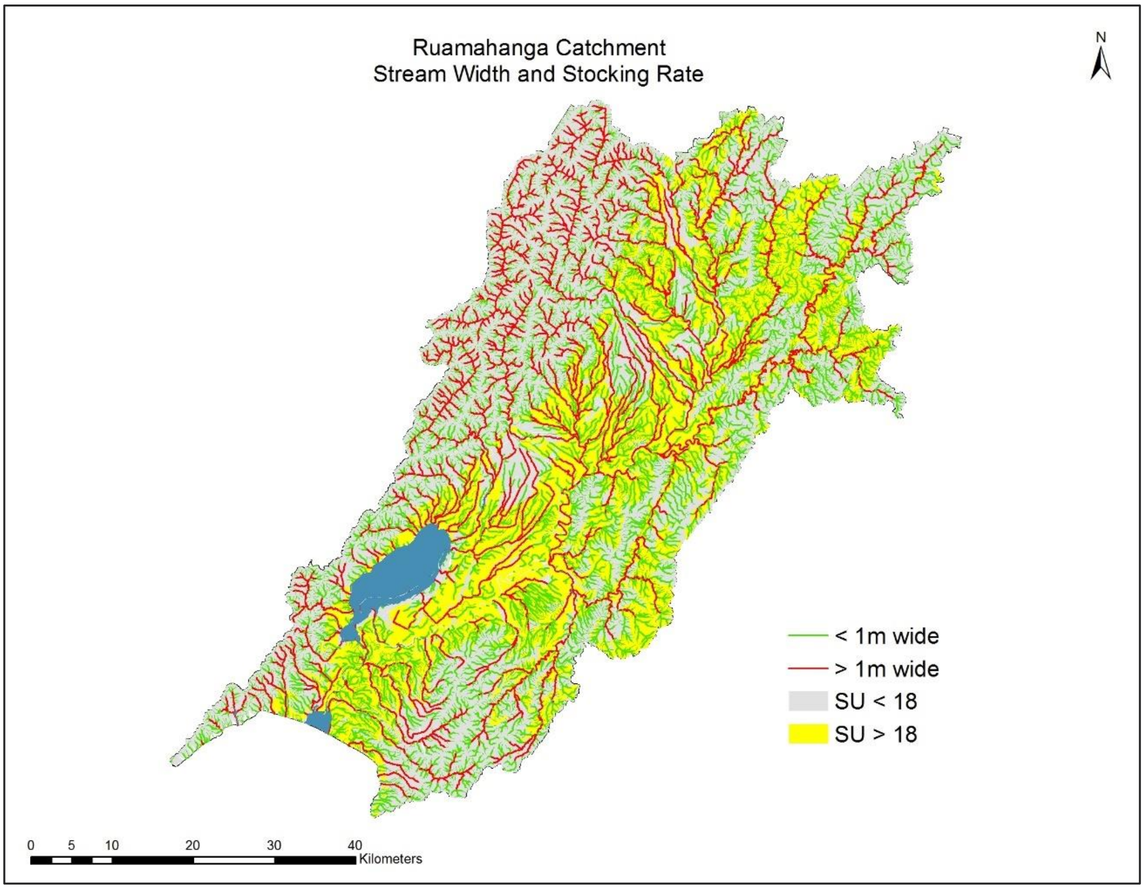

Figure 5: Spatial distribution of stream width and stocking rate in Ruamāhanga catchment.

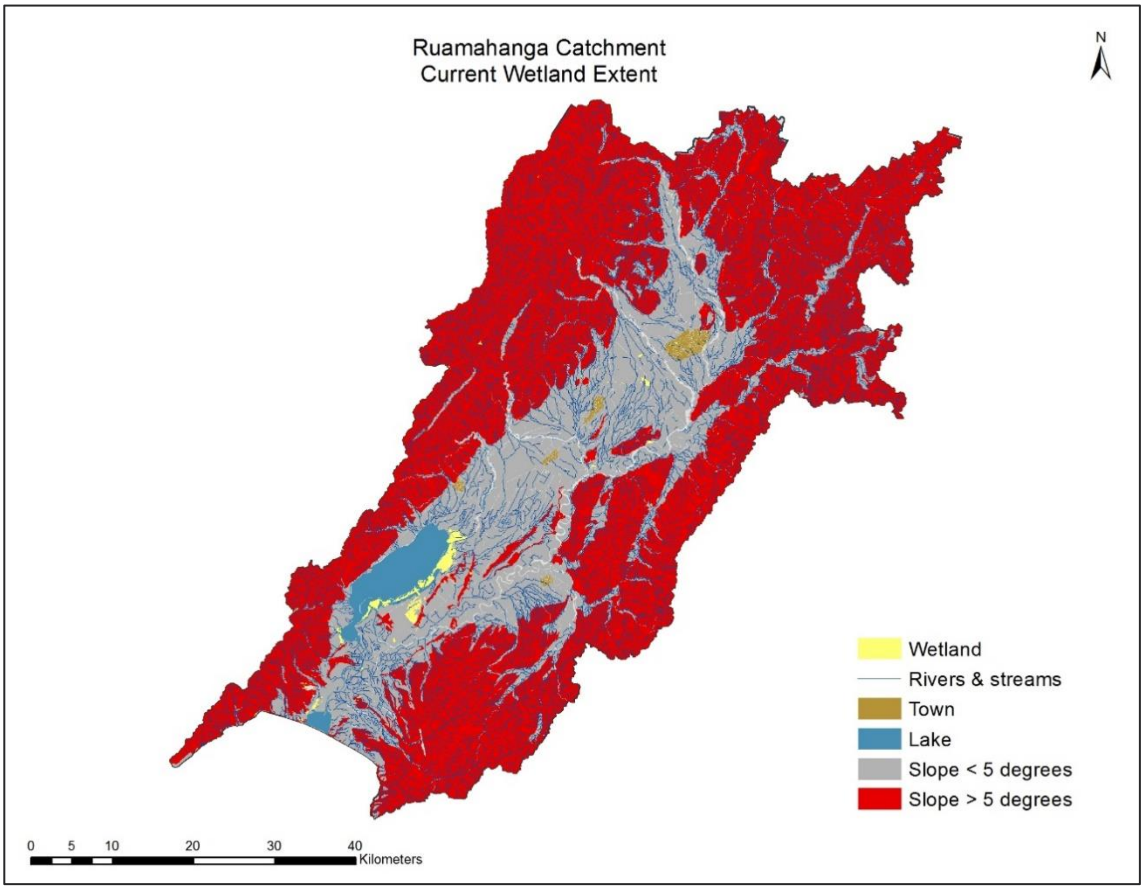

Figure 6: Spatial distribution of current wetlands in Ruamāhanga catchment.

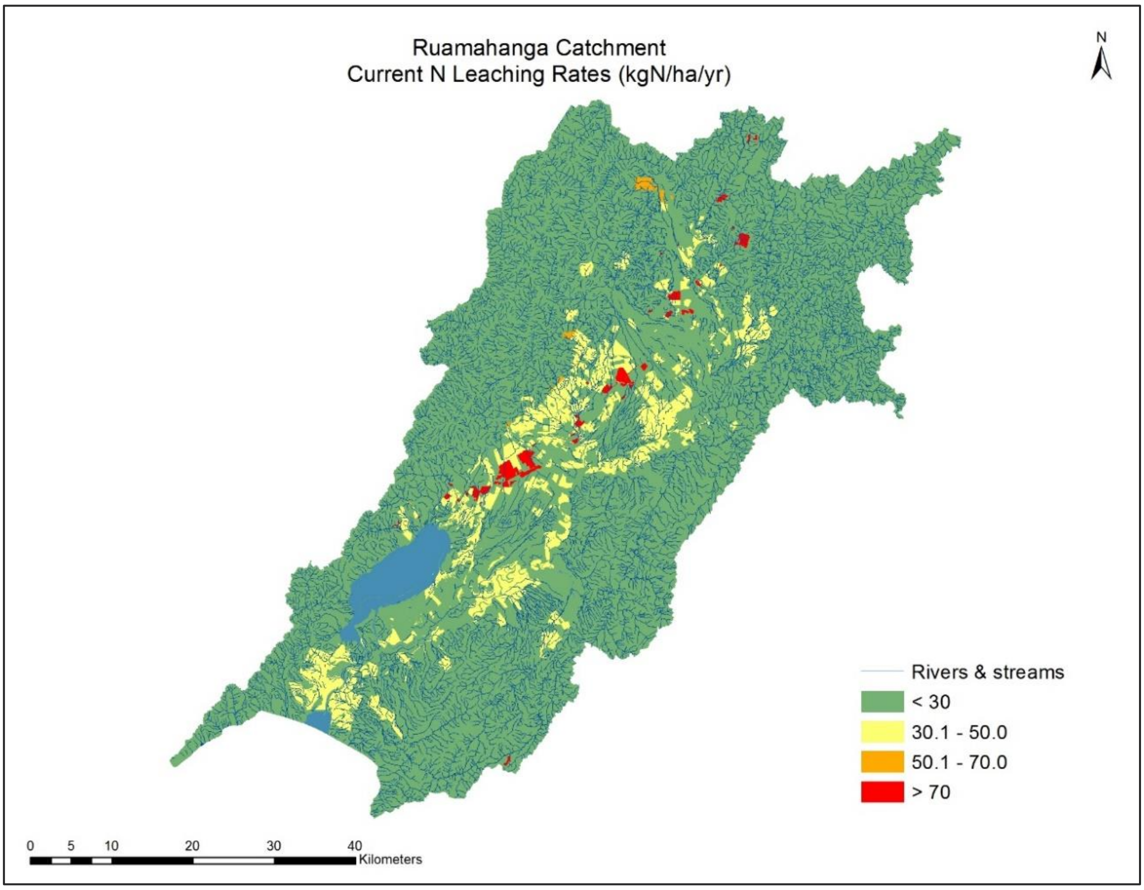

Figure 7: Spatial distribution of current N leaching rates in Ruamāhanga catchment.

2.2.1 Farm Financial Budgets

The farm financial budgets for the 16 representative pastoral farms were estimated by Parminter and Grinter (2016) and Muirhead et al. (2016). Farm financial budgets for the other land uses in the catchment were based on estimates for production yields, input costs, and output prices that come from a wide range of literature and national-level databases (e.g. MPI SOPI 2013a; MPI Farm Monitoring 2013b; Lincoln University Budget Manual 2013). These farm budgets form the foundation of the baseline net revenues earned by landowners and are specified as earnings before interest and taxes (EBIT). These figures assume that landowners currently face no mitigation costs such as fencing streams or retiring steep land (more below). The figures have been verified with agricultural consultants and enterprise experts, and have been documented in Daigneault et al. (2018). In addition, the Ruamāhanga catchment-level figures were shared with members of the Ruamāhanga Whaitua Committee and agricultural consultants working in the catchment for further validation.

The distribution of net farm revenue across the catchment is shown in Figure 8. Sheep and beef farming is estimated to produce the greatest proportion of net farm revenue in the catchment (39%), followed by dairy (31%), mixed and arable (15%), horticulture (7%), and dairy support (3%).

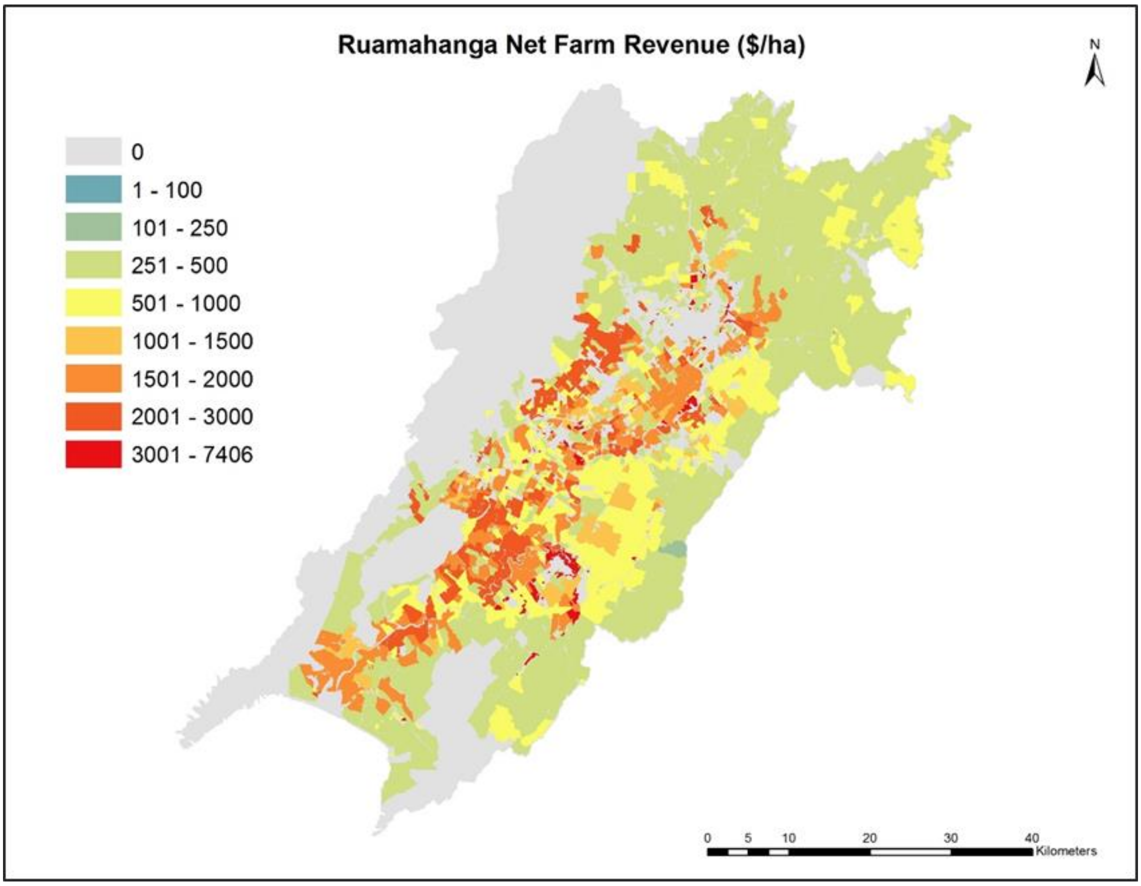

Figure 8: Baseline net farm revenue ($/ha/yr).

For these analyses, the net farm revenue figures are used to estimate the cost of implementing the different mitigation bundles relative to a no policy baseline (see Muirhead et al. 2016). Many of the pasture-based mitigation options estimate an increase in capital and maintenance expenses relative to the baseline but not necessarily opportunity costs for production losses. In addition, the Ruamāhanga catchment version of the model is currently focused on the impacts of management change within the current land uses as opposed to land use change.

2.2.2 On-Farm Mitigation Options

Assumptions about mitigation costs and effectiveness in reducing N, P, and sediment from implementing bundles of mitigation practices in three 'tiers' were estimated by AgResearch (Muirhead et al. 2016). The tiers (M1, M2, M3) represent bundles of mitigation options based on cost and difficulty of implementation. These mitigation bundles were developed in collaboration with the Ruamāhanga Whaitua committee.

The costs are separated into initial capital, ongoing and periodic maintenance, and opportunity costs of taking land out of production. A summary of these costs and effectiveness are outlined in Table 3. Note that they only apply to the 16-representative dairy, sheep and beef, and dairy-support farm systems developed by Parminter and Grinter (2016). The Ruamāhanga Whaitua committee did not specify any scenarios where other land uses, such as horticulture or forestry, implemented any mitigation bundles. More details on the mitigation bundles are provided in the Muirhead et al. (2016) report.

In addition to the M1, M2, and M3 mitigation bundles, the analysis also considered the following on-farm mitigation options, all of which were specified by the MfE or the Ruamāhanga Whaitua Committee:

- **Retiring land on steep slopes**. The cost of retirement is assumed to be a complete loss in net revenue earned on the area that is taken out of production, while the level of effectiveness is specified in Jacobs (2017).
- **Pole planting on steep slopes**. Cost data of space/pole planting ($1500/ha) is obtained from Fernandez and Daigneault (2017) and confirmed with GWRC. The level of effectiveness is specified in Jacobs (2017).
- **Extending the width of riparian planting** in M3 bundles from 5 to 10m. Costs are assumed to follow the 'medium-cost' scenario assumptions in Daigneault et al. (2017) and varied by land use type and stream length. The level of effectiveness is specified in Jacobs (2017).
- **Farm Environmental Plans** add a suite of potential mitigation practices targeted at reducing sediment (e.g. bunds, constructed wetlands, etc.) but can also have some benefits for mitigating N and P too. Estimates are primarily taken from Fernandez and Daigneault (2017).
- **Stock Holding Areas (SHA)** develops specific areas for livestock to congregate. These are essentially different forms of uncovered feed pads. Cost and effectiveness vary largely by the material and methods used to construct the feed pad and are based on the literature. Low cost feed pad estimates were obtained from Crystal et al. (2016), while the high cost SHAs were obtained from Lincoln University (2016).

Scenarios that assumed several mitigation options on the same land were assumed to have a cumulative effect as environmental outputs flowed across the landscape. For example, if a mitigation option called for stock reduction and a farm environmental plan, the mitigation effectiveness of the stock reduction was first accounted for before the farm environmental plan, as the FEP would only 'mitigate' the environmental impacts created by the remaining cows on the land. Furthermore, if stock exclusion was also added to that mitigation package, then the mitigation would only be based on the amount of N, P, and sediment that would likely reach the streambank if those other two mitigation options were simultaneously implemented as well.

All mitigation costs are converted to an annual figure so that they can be directly comparable to the costs already included in the baseline net farm revenue calculation. Initial capital and periodic maintenance costs are annualised over 25 years using a discount rate of 8%. Annual maintenance and opportunity costs are assumed to accrue on a yearly basis and thus are directly subtracted from the base net farm revenue figure.

Table 3: Ruamāhanga catchment on-farm mitigation bundle effectiveness assumptions for MPI representative farms

Mitigation Bundle[2]	Metric	MPI Representative Farm Scenario															
		Dairy_FD_LRHP 1b	Dairy_FD_LRMP 1b2	Dairy_FD_MR 1a	Dairy_FD_HR 3	Dairy Irrigated 2	Dairy_Organic 4	SNB Finish_SD 5	SNB Breed_SW 6a	SNB Finish_SW 6b	SNB Finish 7	SNB Irrigated 8a	SNB trade_20crop 8b	SNB Breed_SD 9	SNB Finish_65crop 10	Dairy Support_SD 11b	Dairy Support_SW 11a
M1	Net Revenue	1%	2%	2%	2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	N leaching	–2%	6%	0%	2%	0%	–3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	P loss	–10%	13%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sediment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	E. coli	28%	28%	28%	21%	28%	21%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
M2	Net Revenue	18%	21%	5%	17%	-4%	6%	16%	17%	20%	31%	18%	7%	20%	34%	0%	6%
	N leaching	45%	24%	8%	11%	21%	51%	10%	9%	10%	11%	20%	20%	0%	5%	7%	27%
	P loss	10%	7%	17%	6%	11%	38%	0%	0%	20%	22%	33%	17%	0%	0%	0%	10%
	Sediment	0%	19%	0%	22%	0%	0%	18%	27%	13%	10%	21%	0%	19%	0%	0%	17%
	E. coli	28%	28%	28%	21%	28%	21%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
M3	Net Revenue	24%	24%	12%	22%	1%	7%	25%	25%	25%	47%	27%	12%	31%	46%	0%	15%
	N leaching	43%	24%	8%	11%	17%	51%	0%	9%	10%	11%	20%	20%	0%	5%	7%	27%
	P loss	20%	7%	17%	6%	11%	38%	50%	78%	82%	56%	56%	17%	50%	20%	0%	30%
	Sediment	8%	72%	65%	39%	65%	22%	52%	50%	54%	38%	33%	0%	52%	33%	0%	44%
	E. coli	28%	28%	28%	21%	28%	21%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

[2] N.B. These are referred interchangeably as Tier 1/M1, Tier 2/ M2, and Tier 3/ M3 bundles by RWC.

2.2.3 Wider Regional Economic Impacts

Wider economic impacts of the proposed scenarios are estimated using regional multipliers. Multipliers for the Wellington Region are obtained from Butcher Partners Ltd. For this report, we estimated the wider regional impacts on the economic output (i.e. revenue) and employment, which include direct, indirect and induced impacts. Direct impacts are the impacts on the revenue that Ruamāhanga catchment farmers face, estimated from the NZFARM economic modelling analysis.[3] Indirect impacts are the impacts faced by the suppliers of the Ruamāhanga catchment farmers, where the farmers themselves obtain their goods and services. Finally, the induced impacts are further household impacts of the direct and indirect impacts. Table 4 shows the multipliers used for this analysis. For example, for dairy farming the multiplier for economic output means that the regional output is 1.6 times of every dollar of revenue generated at the farm-gate. For every one-million dollar of farm-gate revenue generated, 7.8 full time equivalent (FTE) jobs are created at the regional level, based on the employment multiplier for this industry. As a result, a collection of dairy farms that produces $100 million in annual farm-gate revenues is estimated to create $160 million of total regional economic output and 780 FTEs (including the direct revenue earned and jobs created on the farms). We refer to these impacts as wider regional economic impacts throughout the document.

Table 4: Regional multipliers obtained from Butcher Partners Ltd

Industry	Regional Economic Multiplier (Total $ per revenue earned on farm)	Regional Employment Multiplier (FTEs per $1 million in farm-gate revenue)
Horticulture and fruit growing	1.71	11.3
Sheep, beef cattle, and grain farming	1.56	7.0
Dairy cattle farming	1.60	7.8

3 Model Limitations

NZFARM has been developed to assess economic and environmental impacts over a wide range of land uses, but it does not account for all sectors of the economy. NZFARM should be used to provide insight on the relative impacts and trade-offs across a range of scenarios (e.g. practice v. outcome-based targets), rather than explicitly modelling the absolute impacts of a single scenario. It should be used to compare impacts across a range of scenarios or policy options. The parameterisation of the model relies on biophysical and economic input data from several different sources. Therefore, the estimated impacts produced by NZFARM should be used in conjunction with other decision support tools and information not necessarily included in the model to evaluate the 'best' approach to manage N, P, and sediment the Ruamāhanga catchment. Some of the modelling limitations from the current version of the model include:

[3] Note that this revenue is referred to as 'farm-gate' revenue in later tables.

1 **Input data** – The quality and depth of the economic analysis depend on the datasets and estimates provided by biophysical models, farm budgeting data based on information published by MPI and industry groups, and spatial datasets such as maps depicting current land use and sub-catchments. Estimates derived from other data sources or models not included in this analysis may provide different results for the same catchment. Thus, the analysis presented here should be used in conjunction with other information (e.g. input from key stakeholders affected by policy, study of health and recreational benefits from water quality improvements) during any decision making process.

2 **Representative farms** – The model includes detailed financial, environmental, and mitigation practice data for representative farms for the Ruamāhanga catchment that were parameterised based on their physical characteristics (e.g. land use capability, slope, etc.) and annual financial returns. It does not explicitly model the economic impacts for specific farms in the catchment. As a result, some landowners in the catchment may actually face higher or lower costs than those that are modelled using this representative farm approach. Furthermore, this means that the estimates published in this report should be interepreted as industry-wide impacts, not farm-specific.

3 **Baseline conditions** – The NZFARM baseline assumed that (1) land use in the catchment was the same as the year the GWRC land use map was produced (i.e. 2015), (2) that net farm revenue for non-representative farms (i.e. non-pastoral land uses) was based on a 5-year average of input costs and output prices, and (3) that all landowners were implementing the same set of baseline management practices in the catchment. The third assumption is likely to have the greatest impact on model estimates, as some farms in the catchment are likely to have already implemented practices that are included in the M1, M2 and M3 mitigation bundles as well as space/pole planting on steep slopes. However, the number of farms that have implemented these management options to their maximum effectiveness is uncertain but likely to be relatively small.

4 **Management practices** – The model only includes some management practices deemed feasible and likely to be implemented on the 16 representative farm types, given the current state of knowledge and technology available. It does not account for new and innovative management options that might be developed in the future as a result of incentives created through policy. Although not all possible management options may be included in the model, the suite of management practices should be large enough to account for a wide-range of mitigation costs (e.g. change in farm profit) and total effectiveness (e.g. change in sediment or *E. coli* loads). In this case, N and *E. coli* reductions were relatively small even if all farms implemented M3 practices, thereby limiting the feasibility to achieve stringent reduction targets. In addition, bundled mitigation options were only estimated for the 16 representative farms. Adding additional mitigation practices beyond space/pole planting and land retirement to other land uses is likely to lower the cost of reducing contaminant loads.

5 **Mitigation effectiveness** – Each management practice included in the model is assumed to have a fixed relative rate of effectiveness for reducing environmental outputs at a given point in time (e.g. 25% of baseline loads). In reality, the actual

impact of a given practice is likely to vary depending on where, when, and how well the practice is implemented.

6 **'Optimisation' routine** – For this analysis, NZFARM has been programmed such that all landowners are assumed to collectively implement the exact set of practices specified in the MfE scenarios (e.g. stock exclusion, option 1). In reality, it is likely to be more cost effective if the landowner has a greater degree of flexibility to choose from a range of management practices. While it is possible that not all landowners will necessarily select the option that is considered most cost-effective, other farmers may find ways to meet the environmental objectives in the Ruamāhanga catchment at a lower cost than what was directly imposed on them in this modelling exercise.

7 **Wider regional economic impacts** – This analysis took a regional multiplier approach to account for the broader impacts of changes in land use and land management beyond the farm-gate. These wider impacts were estimated using a 'regional multiplier' approach, with the multipliers provided by Butcher Partners Ltd (2017) for the Wellington region. These multipliers allow us to roughly estimate changes in regional economic output (revenue) and employment based on historical data for pastoral and arable farming sectors. It did not take into account the flow-on effects that the labour-generating mitigation practices such as space/pole planting and riparian planting could have on regional employment and GDP. In addition, this analysis did not account for any of the other social and cultural impacts of these scenarios. The estimates produced by NZFARM and multiplier analysis provide a subset of possible metrics that could be used to determine the 'best' option to manage environmental outputs at the catchment-level.

8 **Administrative and transaction costs** – This analysis does not explicitly account for all administrative and transaction costs of the various scenarios. Doing so could alter the estimates for the distributional impacts to landowners, as well as the overall cost of the different policies.

4 Scenarios

MfE provided a set of scenarios to be analysed. These scenarios contain a range of management options and are presented as packages. A summary of these scenarios is presented in Table 5. The scenarios assessed in this report are as follows:

- **Business-as-usual (BAU)** – represents future pathways based on existing policy, practice and investment derived by GWRC. This is the scenario that we generally refer to as the 'baseline.'[4]
- **Practice-based scenarios** – represents sets of mitigation options or land use changes specified by MfE. An assumption is that all eligible land uses will implement the scenarios. Examples include stock holding areas, stock exclusion (fencing), hill and lowland cropping mitigation bundles, wetland fencing, and intensification.

[4] N.B. This is different from 'base' in the RWC scenarios, which they refer to as the 'no policy' baseline. However, base is nearly identical to BAU in the RWC analysis, as both assume that all pastoral farms implement M1 mitigation (stock exclusion) by 2025.

- **Target-based scenarios** – specifies that annual N loss rates cannot exceed 30, 50 or 70 kgN/ha/yr. Parcels that exceed that rate will implement the least-cost mitigation option (including afforestation) to achieve the limit.
- **Combination scenarios** – combines several practice-based scenarios to estimate the maximum mitigation potential in the catchment if a wider set of practices were employed.

Figure 9 shows a graphical description of the logic of how NZFARM solves each scenario, using hill and lowland cropping as an example. In this scenario, the starting condition (BAU) is that all farms in the catchment are assumed to have already implemented the M1 mitigaiotn bundle. Next, the model constraints are defined, in this case which farm types are mandated to implement certain mitigation practices (i.e. M2 or M3 mitigation, Farm Environmental Plans, or land etirement). The model is then run with these constraints to estimate the cost and effectiveness of implementing the defined practices or outcomes (i.e., targets). The final step is to record the model solution, which lists the estimated economic and environmental impacts of the defined scenairo.

More details on the assumptions behind each of the specific scenarios modelled for this analysis are included in Appendix 2.

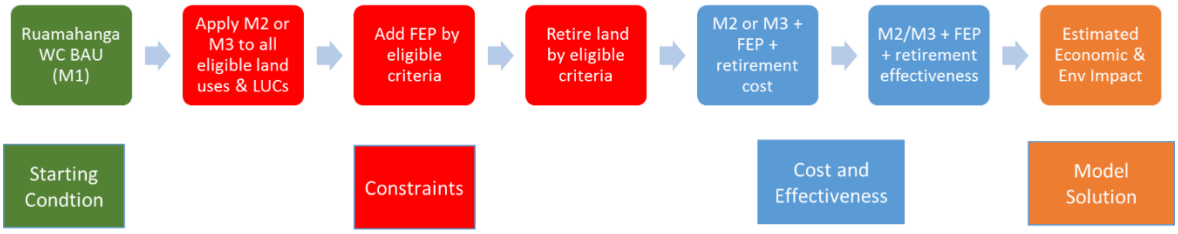

Figure 9: Hill country and lowland cropping scenario model logic.

Table 5 : Summary of MfE practice-based mitigation scenarios

Option	Stock Exclusion	Hill Country and Lowland forage Cropping	Land use intensification	Wetlands Management	Stock Holding Areas
Option 1	Measure impacts of: • Stock exclusion on all LUC 1–5 • Stock exclusion on all properties where stock density exceeds 18 stock units per hectare Applies to: • All livestock except sheep • Exclusion from the beds and margins of streams and waterbodies over 1 m wide and/or 300 mm deep Eligible mitigation practices: • Stock exclusion, class 1 mitigation bundle (M1)	Measure the impacts of: • Implementing Class 2 mitigation bundle (M2) • Implementing Class 3 mitigation bundle (M3) Applies to: • All livestock farm systems • Vegetable and arable growing Eligible mitigation practices: • M2 mitigation bundle • M3 mitigation bundle	Measure the impacts of: • A consent requirement to change land use, with a condition to demonstrate no increases in N and P discharges Applies to the following land use changes: • Dairy support to dairy • Sheep to dairy • Beef to dairy • Sheep to beef • Forest to S&B • Forest to Dairy Eligible mitigation practices: • All practices included in the original RC model	Measure the impacts of: • Requirement to fence off with a setback of 5m • Prohibition on further draining of wetlands • Prohibition on draining within 50 m of wetlands • Prohibition on draining within 200 m of wetlands Applies to: • All farms in catchment with wetlands.	Measure the impacts of requirements: • to use bunding or other measures to prevent runoff entering or leaving the SHA • For base to be carbon material (sawdust, wood chip, etc.) or better, disposed of in ways that meet regional plan rules. • Compliance with animal welfare code (shade, shelter, drinking water, etc.). Applies to: • All livestock farm systems
Option 2	As for option 1, plus • 3m setbacks on all LUC 1–5 • 3-m setbacks on all properties where stock density exceeds 18 stock units per hectare • Stock exclusion based on FEPs on LUC 6–8 Applies to: • All livestock except sheep	As for option 1, plus • Require a Farm Environment Plan prepared by a registered consultant, assuming that some areas of class 6e and 7 are still cropped with wider riparian setbacks Applies to: • All livestock farm systems Vegetable and arable growing	As for option 1, plus: • A consent requirement to intensify an existing land-use, with a condition to demonstrate no increases in N and P discharges Applies to: • Any plausible increase in stock units or cropping area (depending on farm type)	n/a	As for option 1, plus: • Wash-down water or storm water containing animal effluent to be collected and disposed of to a consented animal effluent collection and storage system; seal base or treat it Applies to: • All livestock farm systems

Option 3	As for option 2, plus: • 5m setbacks and riparian planting on all LUC 1–5 • 5m setbacks and riparian planting on all properties where stock density exceeds 18 stock units per hectare • Stock exclusion based on FEPs on LUC 6–8 Applies to: • All livestock except sheep	As for option 2, plus: • No HCC on LUC 6e, 7 and 8 are no-go zones (i.e. land retirement) Applies to: • All livestock farm systems • Vegetable and arable growing	n/a	n/a	n/a	
Option 4	Starting from baseline with no stock exclusion: • On any land <5 degrees in slope all farms along permanent and intermittent streams will need to: (a) exclude cattle, deer and pigs (b) require a 5m setback on either side of the stream • On any land >5 degrees in slope all farms along permanent and intermittent streams will need to: (a) exclude all dairy and pigs (b) exclude all cattle (including dairy support) or deer where the stocking rate exceeds 14SU or 18SU (c) require a 5-m setback on either side of the stream	n/a	n/a	n/a	n/a	

Option 5	Starting from baseline with no stock exclusion: • On any land <7 degrees in slope all farms along permanent and intermittent streams will need to: (a) exclude cattle, deer and pigs (b) require a 5m setback on either side of the stream • On any land >7 degrees in slope all farms along permanent and intermittent streams will need to: (a) exclude all dairy and pigs (b) exclude all cattle (including dairy support) or deer where the stocking rate exceeds 18SU (c) require a 5-m setback on either side of the stream	n/a	n/a	n/a	n/a

5 Scenario Analysis

The estimates in this section compare the BAU baseline to each scenario after they have been fully implemented.[5]

5.1 Business as Usual (BAU) "Baseline"

Before conducting any scenario analysis in NZFARM a baseline needs to be estimated for the Ruamāhanga catchment. When the baseline has been generated the distribution of enterprise area in NZFARM matches the land use map. The BAU baseline assumes some N, P, sediment or *E. coli* on-farm mitigation bundles (e.g. M1) have been implemented (Jacobs 2018).[6] In addition, we note that the BAU scenario is different than the pure 'no policy' baseline that many analyses of this type measure impacts against. Collectively, our use of the BAU as the scenario to compare other estimates with may mean the model's aggregate reduction results may be an underestimate of the actual reduction that could occur under the different modelled scenarios, as not all farms may currently have stock exclusion fully implemented on their land.

A summary of the main economic outputs for the aggregate land use categories tracked in NZFARM is listed in Table 6. Total net farm revenue from land-based operations with the current land use mix is estimated at $192.5 million/yr or $536/ha for all land and $801/ha for land that is currently earning revenue from farming and forestry. Total N leaching and P losses are 4,843 and 263 t/yr respectively. The total sediment load is about 1,061,000 tonnes, of which around 40% comes from land uses other than pastoral land uses. At the Ruamāhanga catchment level, the sheep and beef sector is the land use with the largest area in the catchment. As a consequence, the sheep and beef sector is estimated to earn the highest total net revenue and also to produce the highest environmental outputs.

[5] For this analysis, we assume that the policy is fully implemented. This is likely to take at least 15 years to achieve.

[6] N.B. Jacobs (2018) estimated scenario impacts on physical *E.coli* loads, but they did not provide the data for the economic analysis. This omission has no impact on the economic impact estimates as we account for the cost of mitigation practices intended to reduce *E.coli* loads in each scenario.

Table 6: Total BAU baseline area, farm earnings, and environmental outputs by aggregated land use*

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$59.5	$151.6	$242.6	1,184	900	28.7	8.0
Dairy Sup	10,008	$6.2	$15.5	$24.2	108	368	2.6	4.8
Sheep & Beef	165,132	$74.7	$167.4	$262.0	1,184	2,282	170.5	614.4
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7.1
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	1.8
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6.2
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0.1
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24.1
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	381.7
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	1.6
Other	20,972	$192.5	$383.5	$608.5	0	404	33.4	10.8
Total	**359,103**	**$192.5**	**$383.5**	**$608.5**	**3,067**	**4,843**	**262.7**	**1,061**

*N, P, and sediment load estimates represent losses from a given parcel of land, but not necessarily the amount that will reach a given waterbody by a particular time.

Per hectare estimates are presented in Table 7. As expected, there is a wide distribution in per hectare values across the various land uses. Highest net revenue is estimated to come from horticulture, followed by dairy while the lowest net revenue is estimated for sheep and beef. Mixed, dairy support, and dairy land uses have the highest N leaching while dairy and sheep and beef have the highest P losses of the pastoral uses. Sheep and beef sector is estimated to be the highest contributor of sediment loss. Estimated scenario results at the land use level (see Appendices 3 and 4) also show how there is a wide distribution in net revenue and environmental impacts across the different farm systems and thus applying the same mitigation practices on different farm systems is likely to lead to wide variation across farm systems in contaminant reductions.

Table 7: Per hectare baseline annual farm earnings and environmental outputs by aggregated land use

Land Use	Net Farm Revenue ($/ha)	N leaching (kg/ha)	P loss (kg/ha)	Sediment (t/ha)
Dairy	$1,976	29.9	1.0	0.3
Dairy Support	$615	36.8	0.3	0.5
Sheep and Beef	$452	13.8	1.0	3.7
Other Animal	$853	18.0	0.1	2.6
Arable	$1,149	28.1	0.4	1.1
Mixed	$1,650	39.0	0.4	0.4
Horticulture	$5,614	8.4	0.0	0.0
Forestry	$627	3.0	0.1	2.1
Native Bush	$0	1.0	0.2	4.4
Water	$0	0.0	0.0	0.0
Other	$0	13.8	1.2	0.4
Total	**$536**	**13.5**	**0.7**	**3.0**

5.2 MfE Scenario Estimates

The following sections provide the estimated on-farm impacts and wider regional economic impacts of the modelled mitigation scenarios compared to the BAU baseline. Impacts by land use are listed in Appendix 4.

5.2.1 Hill Country and Lowland Forage Cropping

The hill country and lowland forage cropping scenarios looked at the impacts of implementing M2 or M3 mitigation bundles on a mix of all arable, horticulture, and livestock farms over three options or mitigation practice intensities. Option 1 evaluated the impact of implementing M2 or M3 mitigation bundles on all eligible land uses. Option 2 then added farm environmental plans (FEP) that largely targeted sediment, but also had a minor benefit on N and P loss as well. In addition, Option 3 retired all arable, horticulture, and livestock farms located on LUC 6–8 land (approx. 9,690 ha, of which 77% is on sheep and beef farms, and 26% is on dairy farms). Estimates for the various mitigation scenarios are listed in Table 8.

Table 8: On-farm impacts and wider regional economic impacts of hill country and lowland forage cropping (percentage change from BAU)

Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1	M2 - Arable + Hort	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1	M2 - Livestock	-11.3%	-1.5%	-1.5%	-1.4%	-10.0%	-7.0%	-10.7%
1	M2 - Arable, Hort, Livestock	-11.6%	-1.5%	-1.5%	-1.4%	-10.0%	-7.0%	-10.7%
1	M3 - Arable + Hort	-0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
1	M3 - Livestock	-16.3%	-3.7%	-3.7%	-3.4%	-9.6%	-46.9%	-29.4%
1	M3 - Arable, Hort, Livestock	-16.8%	-3.7%	-3.7%	-3.4%	-9.7%	-46.9%	-29.4%
2	M2 - Arable + Hort with FEP	-0.4%	0.0%	0.0%	0.0%	-0.2%	0.0%	-0.1%
2	M2 - Livestock with FEP	-14.2%	-1.5%	-1.5%	-1.4%	-16.4%	-17.5%	-35.2%
2	M2 - Arable, Hort, Livestock with FEP	-14.6%	-1.5%	-1.5%	-1.4%	-16.6%	-17.5%	-35.3%
2	M3 - Arable + Hort with FEP	-0.5%	0.0%	0.0%	0.0%	-0.2%	-0.1%	-0.1%
2	M3 - Livestock with FEP	-19.3%	-3.7%	-3.7%	-3.4%	-16.1%	-51.4%	-44.6%
2	M3 - Arable, Hort, Livestock with FEP	-19.8%	-3.7%	-3.7%	-3.4%	-16.3%	-51.5%	-44.7%
3	M2 - Arable + Hort with FEP + Retire High LUC	-0.7%	-0.3%	-0.3%	-0.4%	-0.2%	0.0%	-0.1%
3	M2 - Livestock with FEP + Retire High LUC	-17.2%	-6.0%	-6.0%	-5.6%	-19.8%	-21.4%	-36.5%
3	M2 - Arable, Hort, Livestock with FEP + Retire High LUC	-17.8%	-6.2%	-6.2%	-6.0%	-20.0%	-21.5%	-36.6%
3	M3 - Arable + Hort with FEP + Retire High LUC	-0.8%	-0.2%	-0.3%	-0.3%	-0.2%	-0.1%	-0.1%
3	M3 - Livestock with FEP + Retire High LUC	-22.0%	-8.1%	-8.0%	-7.5%	-19.5%	-52.7%	-45.3%
3	M3 - Arable, Hort, Livestock with FEP + Retire High LUC	-22.8%	-8.3%	-8.3%	-7.9%	-19.7%	-52.8%	-45.4%

Key findings from these scenarios are as follows:

- There are only a few available mitigation options for arable and horticulture land uses in the catchment modelled, hence there was little change for scenarios that targeted those land uses
- As expected reductions in revenue increase with mitigation bundle (i.e. move to M3 from M2) and where all land uses are covered
- Adding FEPs to the M2 and M3 mitigation bundles had a large impact on reducing sediment, while reducing net farm revenue in the catchment by an additional 3% compared to BAU

- Retiring close to 10,000 ha of farms area located on LUC 6–8 land reduced net farm revenue by an additional 3% compared with Option 2. It also increased the amount of N mitigated by an additional 3% regardless of the mitigation bundle implemented compared to the scenarios where pasture was not retired. However land retirement had less of an impact on P loss and sediment
- According to cost-effectiveness analysis,[7] livestock should be targeted with M2 for N mitigation; adding FEP suggests Livestock + M2 is also cost effective at reducing sediment. For P, M3 (riparian buffers) are more cost effective.

5.2.2 Land use intensification

The land use intensification scenarios estimated impacts if land was converted from lower environmental intensity uses to higher intensity uses, namely dairy and beef. Impacts were measured in two stages. The first stage estimated the impact of converting land but not requiring additional mitigation practices to be applied. The second stage constrained the intensified land use category to implement mitigation practices to ensure that there were no increases in catchment N and P relative to the BAU case. A third stage attempted to investigate the impact if converted land uses were required to meet a N and P loss target 10% below BAU; however, the current set of mitigation options included were not effective enough to allow these targets to be achieved. Catchment-wide estimates for these scenarios are listed in Table 9 (mitigation area) and Table 10 (economic and environmental impacts).

[7] Cost-effectiveness was measured by dividing the net farm revenue lost in a given scenario by the reduction in farm-level N, P, and S losses. For example if stock exclusion had an annualized cost of $40/ha and reduced annual N, P, and S losses from that farm by 5 kgN, 0.5 kgP, and 2 tS per hectare, then, the cost-effectiveness figure would be $8/kgN, $80/kgP, and $20/tS. As a result, different scenarios and practices can be more cost-effective for a particular environmental output than another.

Table 9: Mitigation area of land use intensification scenarios

Option	Scenario	New Land Use	Total Land Use Change	Total LU Area, inc. existing	M1 (BAU)	M2	M3
1	Dairy Support to Dairy - No Limit	Dairy Farming	10,008	40,097	40,097	0	0
1	Dairy Support to Dairy - BAU N and P Limit	Dairy Farming	10,008	40,097	0	0	40,097
1	Sheep-only to Beef-only - No Limit	Beef Farming	4,498	14,003	14,003	0	0
1	Sheep-only to Beef-only - BAU N and P Limit	Beef Farming	4,498	14,003	2,892	11,111	0
1	S&B LUC 1-4 to Dairy - No Limit	Dairy Farming	26,335	56,425	56,425	0	0
1	S&B LUC 1-4 to Dairy - BAU N and P limit	Dairy Farming	26,335	56,425	0	0	56,425
1	Forestry to Dairy - No Limit	Dairy Farming	11310	41,400	41,400	0	0
1	Forestry to Sheep & Beef - No Limit	Sheep and Beef Farming	11310	153,388	153,388	0	0
3	Sheep-only to Beef-only - BAU N and P 10% below BAU	Beef Farming	4,498	14,003	0	0	14,003

Table 10: On-farm impacts and wider regional economic impacts of land use intensification (percentage change from BAU)

Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1	Dairy Support to Dairy - No Limit	7.1%	17.3%	18.1%	21.0%	-1.4%	2.6%	-0.2%
1	Dairy Support to Dairy - BAU N and P Limit	-0.1%	15.2%	16.0%	18.9%	-6.8%	1.0%	-0.6%
1	Sheep-only to Beef-only - No Limit	0.1%	8.0%	8.6%	11.4%	0.3%	0.5%	0.4%
1	Sheep-only to Beef-only - BAU N and P Limit	-0.4%	7.9%	8.6%	11.3%	-0.2%	0.0%	-0.1%
1	S&B LUC 1-4 to Dairy - No Limit	20.9%	36.2%	37.2%	39.8%	8.7%	-1.1%	-8.1%
1	S&B LUC 1-4 to Dairy - BAU N and P limit	10.8%	33.3%	34.3%	36.9%	1.1%	-3.5%	-8.7%
1	Forestry to Dairy - No Limit	7.9%	18.4%	19.4%	17.2%	6.3%	3.5%	20.4%
1	Forestry to Sheep & Beef - No Limit	-1.0%	6.4%	7.2%	5.0%	2.4%	3.8%	20.4%
3	Sheep-only to Beef-only - N and P 10% below BAU	-0.7%	7.8%	8.4%	11.2%	-0.3%	-4.2%	-1.6%

Key findings from these scenarios are as follows:

- Horticulture (mostly grapes) is a low N leaching option but also a high profit earning land use in the catchment. Thus, the pasture to horticulture options moves all the land to horticulture.
- The initial MfE interpretation of 'horticulture' conversion was that land would be converted to high N leaching vegetables, which is not currently prevalent in the catchment and thus not modelled due to lack of data.
- The BAU N and P limits were not achieved for conversions to dairy even though all implemented max mitigation (M3).
- For dairy support converting to dairy P is the limiting nutrient. Moreover, the BAU nutrient limit has little impact on net revenue but there is a marked reduction in N (while little change in P and sediment losses).
- There are positive revenue benefits to converting S&B on LUC1-4 land to dairy with relatively little increase in N and reductions in P and sediment. However, it should be noted that this is an upper bound on the area that would convert and it is unlikely to that conversion at this scale would actually occur.
- The 10% reduction target was not achieved for N or P (option 3), even if all beef farms implemented max mitigation (M3). Therefore, in this catchment it is not possible for this conversion to occur and achieve the desired reduction in N and P (or at least with the mitigation options modelled for the catchment).

5.2.3 Stock exclusion

The stock exclusion scenarios evaluated the impact of various stringencies of fencing and setbacks of pastoral land in the catchment. Option 1 assumed all streams greater than 1m wide and running through LUC 1–5 pasture were fenced on both sides. In addition, streams running through land capable of supporting a carrying capacity greater than 18 sheep stocking units (SU) was also assumed to be fenced. Option 2 widened the setback on eligible land to 3 m, and also assumed that livestock in LUC 6–8 had to be excluded regardless of the land's carrying capacity (but no 3-m setback). Option 3 extended the setback on eligible land to 5 m. Option 4 was a new set of scenarios defined by MfE after the project commenced that focused on differentiating stock exclusion based on whether streams flowed through land with slopes greater or less than 5 degrees, where all eligible land had to be fenced with a 5m setback on both sides of the stream. A summary of the fenced and setback areas for each scenario option is listed in Table 11, while the economic and environmental impact summary is listed in

Table 12.

Note that these impacts are compared to the BAU where existing regulation is more stringent (fencing on all pastoral land uses) than most of the stock exclusion mitigation options modelled by these scenarios.

Table 11: Fenced and setback area (ha) of stock exclusion scenarios

Option	Scenario	Fenced Area (ha)	Setback Area (ha)
No Exclusion	No Exclusion (Baseline)	0	0
1	Existing Reg (BAU)	207,596	0
1	Exclusion on LUC 1–5, 1+ m wide streams	28,281	0
1	Exclusion on SU > 18, 1+ m wide streams	29,551	0
1	Exclusion on SU > 18, LUC 1–5 & 1+ m wide streams	32,979	0
2	3-m Setback on LUC 1–5	106,514	1,505
2	3-m Setback on SU > 18	117,599	1,748
2	Exclusion on LUC 6–8	68,435	0
2	3-m Setback on SU > 18 OR LUC 1–5	133,418	1,917
2	3-m Setback on SU > 18 OR LUC 1–5 & Exclusion on LUC 6–8	201,853	1,917
3	5-m Setback on LUC 1–5	106,514	2,509
3	5-m Setback on SU > 18	117,599	2,913
3	5-m Setback on SU > 18 OR LUC 1–5	133,418	3,196
3	5-m Setback on SU > 18 OR LUC 1–5 & Exclusion on LUC 6–8	201,853	3,196
4	5-m Setback on slope < 5 degrees	83,785	1,872
4	5-m Setback on slope > 5 deg, All Dairy; S&B > 14 SU	54,565	1,481
4	5-m Setback on all slopes; All Dairy, all eligible S&B (>14 SU)	138,350	3,353
4	5-m Setback on slope > 5 deg, All Dairy; S&B > 18 SU	54,565	1,481
4	5-m Setback on all slopes; All Dairy, all eligible S&B (>18 SU)	138,350	3,353
5	5-m Setback on slope < 7 degrees	72,071	1,380
5	5-m Setback on slope > 7 deg, All Dairy; S&B > 18 SU	51,379	2,133
5	5-m Setback on all slopes; All Dairy, all eligible S&B (>18 SU)	123,450	3,514

Table 12: On-farm impacts and wider regional economic impacts of stock exclusion (percentage change from BAU)[8]

Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1	Exclusion on LUC 1–5, 1+ m wide streams	4.8%	0.0%	0.0%	0.0%	0.7%	2.7%	17.8%
1	Exclusion on SU > 18, 1+ m wide streams	4.7%	0.0%	0.0%	0.0%	0.8%	2.8%	17.3%
1	Exclusion on SU > 18, LUC 1–5 & 1+ m wide streams	4.6%	0.0%	0.0%	0.0%	0.7%	2.7%	17.1%
2	3-m Setback on LUC 1–5	2.3%	-0.8%	-0.8%	-0.8%	-0.4%	0.4%	14.0%
2	3-m Setback on SU > 18	1.7%	-0.8%	-0.8%	-0.8%	-0.3%	0.5%	10.6%
2	Exclusion on LUC 6–8	3.7%	0.0%	0.0%	0.0%	0.8%	2.9%	8.5%
2	3-m Setback on SU > 18 OR LUC 1–5	1.3%	-0.9%	-0.9%	-0.9%	-0.5%	0.1%	9.7%
2	3-m Setback on SU > 18 OR LUC 1–5 & Exclusion on LUC 6–8	-0.6%	-0.9%	-0.9%	-0.9%	-0.7%	-0.7%	-0.8%
3	5-m Setback on LUC 1–5	1.9%	-1.4%	-1.4%	-1.3%	-0.8%	0.0%	13.9%
3	5-m Setback on SU > 18	1.3%	-1.4%	-1.4%	-1.3%	-0.7%	0.0%	10.3%
3	5-m Setback on SU > 18 OR LUC 1–5	0.8%	-1.5%	-1.5%	-1.4%	-1.0%	-0.4%	9.4%
3	5-m Setback on SU > 18 OR LUC 1–5 & Exclusion on LUC 6–8	-1.1%	-1.5%	-1.5%	-1.4%	-1.1%	-1.1%	-1.0%
4	5-m Setback on slope < 5 degrees	2.9%	-1.1%	-1.1%	-1.0%	-0.6%	0.4%	15.5%
4	5-m Setback on slope > 5 deg, All Dairy; S&B > 14 SU	1.6%	-0.9%	-0.9%	-0.8%	0.0%	1.7%	4.9%
4	5-m Setback on all slopes; All Dairy, all eligible S&B (>14 SU)	-1.1%	-2.0%	-2.0%	-1.9%	-1.5%	-1.5%	1.4%
4	5-m Setback on slope > 5 deg, All Dairy; S&B > 18 SU	3.4%	-0.6%	-0.6%	-0.5%	0.3%	2.4%	12.7%
4	5-m Setback on all slopes; All Dairy, all eligible S&B (>18 SU)	0.7%	-1.7%	-1.7%	-1.6%	-1.2%	-0.8%	9.3%
5	5-m Setback on slope < 7 degrees	2.7%	-1.7%	-1.7%	-1.6%	-0.7%	0.5%	16.2%
5	5-m Setback on slope > 7 deg, All Dairy; S&B > 18 SU	3.5%	-0.5%	-0.5%	-0.5%	0.4%	2.5%	12.8%
5	5-m Setback on all slopes; All Dairy, all eligible S&B (>18 SU)	0.6%	-2.2%	-2.2%	-2.1%	-1.3%	-0.7%	10.2%

[8] N.B., Some estimates are higher than BAU because the business as usual scenario defined by the RWCMP assumed that all pastoral land was fenced in the 'baseline' while these scenarios only fenced the area that matched MfE's specific criteria.

Key findings from these scenarios are as follows:

- As the existing regulation (BAU) in the Ruamāhanga catchment is more stringent than most of the stock exclusion mitigation options, the impact on net revenue is positive. However, the corresponding impacts on N, P, and sediment losses are not favourable for most options
- Option 2 and Option 3 with the additional combination of all stock exclusion mitigations result in negative economic impacts and better environmental impacts compared to the BAU
- Stock exclusion on wider streams only (>1 m) is estimated to increase the sediment loss by up to 18% compared to the BAU. It is thus important to also consider stock exclusion on the smaller streams for better sediment loss outcomes.
- Options 4 and 5 were found to have relatively similar results to Options 2 and 3 as criteria did not differ much across the options.

5.2.4 Stock holding areas (SHA)

The stock holding area (SHA) scenarios evaluated the impact of constructing and maintaining two different kinds of uncovered stand-off pads that all livestock could utilize. The Option 1 SHA assumed that the stand-off pad was constructed with low-cost materials and could potentially be portable. The Option 2 SHA assumed construction out of concrete and is thus more durable and effective. Each option evaluated the impact of targeting specific types of livestock. The total area impacted by the SHAs is listed in Table 13, while broader catchment-level impacts are listed in Table 14.[9]

Table 13: Area impacted by SHAs (ha)

Option	Scenario	SHA Impact Area (ha)
BAU	BAU	0
1	Opt 1 SHA - Dairy	30,090
1	Opt 1 SHA - Dairy Support	10,008
1	Opt 1 SHA - Sheep & Beef	160,634
1	Opt 1 SHA - All Stock	200,732
2	Opt 2 SHA - Dairy	30,090
2	Opt 2 SHA - Dairy Support	10,008
2	Opt 2 SHA - Sheep & Beef	160,634
2	Opt 2 SHA - All Stock	200,732

[9] N.B. The original MfE list of scenarios requested another set of options that estimated the impact of requiring the SHAs to be a given distance from existing structures and waterways. We were unable to find any data on the effectiveness of implementing this option and hence excluded it from the modelling exercise.

Table 14: On-farm impacts and wider regional economic impacts of stock holding areas (percentage change from BAU)

Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1	SHA - Dairy	-3.4%	0.0%	0.0%	0.0%	-4.6%	-1.6%	-0.1%
1	SHA - Dairy Support	-0.6%	0.0%	0.0%	0.0%	-1.9%	-0.2%	-0.1%
1	SHA - Sheep & Beef	-6.0%	0.0%	0.0%	0.0%	-11.4%	-9.5%	-8.6%
1	SHA - All Stock	-9.9%	0.0%	0.0%	0.0%	-18.0%	-11.3%	-8.8%
2	SHA - Dairy	-7.9%	2.0%	2.0%	2.0%	-7.4%	-3.3%	-0.2%
2	SHA - Dairy Support	-1.3%	0.2%	0.2%	0.2%	-3.0%	-0.3%	-0.1%
2	SHA - Sheep & Beef	-14.0%	2.2%	2.1%	1.9%	-18.3%	-19.0%	-17.1%
2	SHA - All Stock	-23.2%	4.4%	4.4%	4.1%	-28.8%	-22.6%	-17.5%

Key findings from these scenarios are as follows:

- SHAs for dairy and dairy support are cost-effective for N mitigation, but do not reduce total N by more than 7%.
- SHAs for S&B have the largest absolute impacts due to total area covered (about 160,000 ha)
- SHAs (or other mitigation) are needed to be applied to S&B farms to achieve noticeable impact on sediment, as most dairy and dairy support farms located on flat land have low soil loss in BAU scenario.
- Revenue, Regional Output, and Employment all increase for Option 2 because permanent SHAs are assumed to result in improved productivity and output per animal, which translates to higher revenue, even if it has a negative impact on profit (net farm revenue).

5.2.5 Wetland management

The wetland mitigation scenario estimated the impact of creating a 5m buffer and constructing a fence around current wetlands in the Ruamāhanga catchment. Analysis based on wetland extent maps estimated that there are approximately 1,983 ha of wetlands in the catchment, which would require 100 km of fencing to enclose (including the 5m buffer). A summary of the region-wide impacts of the scenario is listed in Table 15.

Table 15: On-farm impacts and wider regional economic impacts of wetland management (percentage change from BAU)

Option	Scenario	NetRev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1	5-m fencing	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.3%

Key findings from this scenario as follows:

- A 5-m buffer fencing around wetlands has a trivial impact in the Ruamāhanga. This is due to the limited area of wetlands currently in the catchment (0.5% of total area) as well as the N, P, and sediment loss rates on adjacent land that it would help filter.

5.2.6 N Limit

The N limit scenarios estimated the impact of requiring all farms that currently have N leaching rates greater than 30, 50, or 70 kgN/ha/yr to implement mitigation to get their average rate to meet the specified target. Landowners had the option to implement any of the mitigation practices included in the model. NZFARM then used its optimization routine to select the combination of practices that would achieve the target at the least cost (i.e. loss in net farm revenue). The area of land impacted and the mitigation implemented is listed in Table 16, while the catchment-wide economic and environmental impacts are listed in Table 17.

Table 16: Mitigation area for land required to achieve the N limit targets (ha)

Land use	Afforestation	M2 Bundle	Total Mitigation Area
	70 kgN/ha limit		
Arable	40	0	40
Beef Farming	153	0	153
Dairy Support	0	2,193	2,193
Sheep Farming	86	0	86
Dairy Farming	0	0	0
Mixed	0	0	0
Total Area	**278**	**2,193**	**2,472**
	50 kgN/ha limit		
Arable	40	0	40
Beef Farming	153	0	153
Dairy Support	2,722	2	2,725
Sheep Farming	86	0	86
Dairy Farming	107	53	160
Mixed	0	0	0
Total Area	**3,108**	**56**	**3,163**
	30 kgN/ha limit		
Arable	252	348	600
Beef Farming	153	0	153
Dairy Support	3,923	0	3,923
Sheep Farming	86	0	86
Dairy Farming	8,969	5,267	14,236
Mixed	16,742	0	16,742
Total Area	**30,124**	**5,615**	**35,739**

Table 17: On-farm impacts and wider regional economic impacts of N limit (percentage change from BAU)

Option	Scenario	Net Rev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1	70kgN/ha	-0.1%	-0.2%	-0.2%	-0.1%	-1.6%	-0.2%	0.0%
1	50kgN/ha	-0.2%	-0.2%	-0.2%	-0.2%	-1.3%	-0.2%	0.0%
1	30kgN/ha	-6.6%	-7.0%	-7.0%	-5.6%	-6.7%	-1.7%	-0.3%

Key findings from these scenarios are as follows:

- 70 kg and 50 kgN/ha N limits have few N, P or sediment benefits. This is because most of the land area in the catchment currently has losses less than 50 kgN/ha; less than 1% of total catchment area has losses more than 50 kgN/ha
- 30 kgN/ha does have a modest reduction in N and there is a corresponding decrease in revenue
- Most of the mitigation to achieve the 50 kgN and 30 kgN/ha targets comes in the form of afforestation as M2 and M3 bundles are not effective enough to achieve N reduction targets
- Costs and impacts are relatively higher for the 30 kgN limit because about 10% of the catchment area is affected by this target. Most of the land that is impacted is dairy farming or mixed arable.
- In terms of mitigation, there is a switch in the predominant mitigation bundles adopted between 70 and 50 kgN/ha limits, i.e. mostly mitigation bundles (M2/M3) adopted to achieve the 70 kgN/ha limit and mostly afforestation adopted to achieve the 50 kgN/ha limit. This is because the 70 kgN/ha limit is less stringent, so most land uses can meet that limit with the modelled mitigation options. However, the mitigation options alone cannot achieve the 50 kgN/ha limit so it results in more afforestation on the dairy support blocks (it is likely because they are less profitable than the dairy platforms). At 30 kgN/ha a mix of the mitigation options and afforestation is needed to achieve the limit.
- Recalling that GWRC proposed to reduce nitrate in the catchment by 9%, much of this objective could be met following the 30 kgN/ha limit, which reduces farm-based N losses by 6.7% compared with BAU.

5.2.7 Mitigation Combinations

The mitigation combination scenarios looked at the combined effect of implementing all of the practice-based mitigation scenarios specified by MfE simultaneously. The exact set of mitigation practices varied for each farm in the catchment based on the specific criteria under each option. Furthermore, we differentiated these scenarios based on whether SHAs were included or not in order to measure the relative impact of including one of the more expensive mitigation options included in this study. A summary of the practices implemented for each scenario is listed in Table 18, while the catchment-wide impacts are summarized in Table 19.

Table 18: On-farm mitigation practices for mitigation combination scenarios (ha)

Option	Scenario	Fenced Area	Setback Area	Land Retirement	Wetland Area	M2	M3	SHA
BAU	Ruamāhanga BAU	207,596	0	0	0	0	0	0
1a	Fencing + Wetland + M2	32,979	0	0	1,983	206,887	0	0
1b	Fencing + Wetland + M3	32,979	0	0	1,983	0	206,887	0
2a	Fencing + Setback + Wetland + M2 + FEP	133,418	1,917	0	1,983	206,887	0	0
2b	Fencing + Setback + Wetland + M3 + FEP	133,418	1,917	0	1,983	0	206,887	0
3a	Fencing + Setback + Wetland + M2 + FEP + Retirement	133,418	3,196	9,954	1,983	196,933	0	0
3b	Fencing + Setback + Wetland + M3 + FEP + Retirement	133,418	3,196	9,954	1,983	0	196,933	0
1a-SHA	Fencing + Wetland + M2 + SHA-low	32,979	0	0	1,983	206,887	0	200,732
1b-SHA	Fencing + Wetland + M3 + SHA-low	32,979	0	0	1,983	0	206,887	200,732
2a-SHA	Fencing + Setback + Wetland + M2 + FEP + SHA-high	133,418	1,917	0	1,983	206,887	0	200,732
2b-SHA	Fencing + Setback + Wetland + M3 + FEP + SHA-high	133,418	1,917	0	1,983	0	206,887	200,732
3a-SHA	Fencing + Setback + Wetland + M2 + FEP + Retirement + SHA-high	133,418	3,196	9,954	1,983	196,933	0	190,778
3b-SHA	Fencing + Setback + Wetland + M3 + FEP + Retirement + SHA-high	133,418	3,196	9,954	1,983	0	196,933	190,778

Notes: Mitigation areas are not necessarily additive, as fencing and M2 or M3 and SHAs can be implemented on the same area. Combinations with SHA added as an additional set of scenarios to differentiate between the cost and effectiveness of including this option in addition to everything else.

Table 19: On-farm impacts and wider regional economic impacts of mitigation combinations (percentage change from BAU)

Option	Scenario	Net Rev ($)	Revenue ($)	Reg Output ($)	Reg Employ (#)	N Loss (kg)	P Loss (kg)	Sed Loss (t)
1a	Fencing + Wetland + M2	-7.4%	0.1%	0.3%	1.1%	-9.7%	-4.7%	6.2%
1b	Fencing + Wetland + M3	-12.6%	-2.1%	-1.9%	-0.9%	-9.4%	-44.7%	-12.6%
2a	Fencing + Setback + Wetland + M2 + FEP	-13.7%	-0.8%	-0.6%	0.2%	-17.5%	-17.9%	-26.0%
2b	Fencing + Setback + Wetland + M3 + FEP	-18.9%	-3.0%	-2.8%	-1.8%	-17.3%	-51.8%	-35.3%
3a	Fencing + Setback + Wetland + M2 + FEP + Retirement	-17.4%	-6.1%	-6.0%	-4.9%	-21.4%	-22.3%	-27.5%
3b	Fencing + Setback + Wetland + M3 + FEP + Retirement	-22.4%	-8.2%	-8.0%	-6.8%	-21.1%	-53.6%	-36.4%
1a	Fencing + Wetland + M2 + SHA-low	-17.4%	2.2%	2.5%	4.1%	-26.0%	-15.5%	-3.1%
1b	Fencing + Wetland + M3 + SHA-low	-22.5%	0.0%	0.4%	2.1%	-25.7%	-50.9%	-20.2%
2a	Fencing + Setback + Wetland + M2 + FEP + SHA-high	-36.9%	5.7%	6.0%	7.3%	-41.3%	-36.4%	-38.9%
2b	Fencing + Setback + Wetland + M3 + FEP + SHA-high	-42.1%	3.5%	3.8%	5.3%	-41.1%	-62.7%	-46.7%
3a	Fencing + Setback + Wetland + M2 + FEP + Retirement + SHA-high	-40.6%	0.4%	0.7%	2.2%	-44.0%	-39.8%	-40.2%
3b	Fencing + Setback + Wetland + M3 + FEP + Retirement + SHA-high	-45.6%	-1.7%	-1.4%	0.3%	-43.8%	-64.1%	-47.5%

Key findings from these scenarios are as follows:

- Mitigation combinations will produce noticeable reductions in net revenue – between 7% and 46% reduction in net revenue. This makes sense given that several practices are being implemented on the same land, with the variability in costs attributed to the stringency of mitigation across the different scenarios
- With multiple practices implemented, N losses is reduced by 10 to 44%. This relatively low figure for the non-SHA mitigation combinations is due to limited effectiveness of the various mitigation options considered for the catchment
- Effectiveness is higher for P and sediment, especially for M3 and FEPs, which include a mix of riparian buffers and pole planting. M3 targets P and sediment reductions

- Other economic impacts besides net revenue are not affected as much because most of the costs are for implementation rather than have any opportunity costs (e.g, land retirement)
- In terms of cost-effectiveness, option 3a is the most cost-effective for reducing N loss, 1b for P loss and Ruamāhanga BAU for sediment loss
- Adding SHA has the largest impact on N, although net revenue declines noticeably as a result
- Only cost-effectiveness of N improves as a result of adding SHAs to the mitigation combinations; both cost/kg of P and cost/t of sediment increase
- Regional economic indicators could increase due to SHAs

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Appendix 1 – Detailed Methods

A1.1: New Zealand Forest and Agriculture Regional Model (NZFARM)

NZFARM is a comparative-static, non-linear, partial equilibrium mathematical programming model of New Zealand land use operating at the catchment scale developed by MWLR (Daigneault et al. 2012, 2013). Its primary use is to provide decision-makers with information on the economic impacts of environmental policy as well as how a policy aimed at one environmental issue could affect other environmental factors. It can be used to assess how changes in technology, commodity supply or demand, resource constraints, or in farm, resource, or environmental policy could affect a host of economic or environmental performance indicators that are important to decisions-makers and rural landowners. The version of the model used for the Ruamāhanga catchment analysis can track changes in land use, land management, agricultural production, and N, P, and sediment loads by imposing policy options that range from having landowners implement specific mitigation practices to identifying the optimal mix of land management to meet a particular target. The model is parameterised such that responses to policy are not instantaneous but instead assume a response that landowners are likely to take over the specified period (i.e. full implementation by 2030).

Simulating endogenous land management is an integral part of the model, which can differentiate between 'business as usual' (BAU) farm practices and less-typical options that can change levels of environmental and agricultural outputs. Key land management options in the NZFARM version used for the Ruamāhanga catchment include three mitigation bundles that include fencing streams, constructing wetlands, enlarging effluent area, and adjusting fertiliser and stocking rates. Including a range of management options allows us to assess what levels of regulation might be needed to bring new technologies into general practice. Landowner responses to N, P, and sediment load restrictions in NZFARM are parameterised using estimates from biophysical and farm budgeting models.

The model's objective function maximizes the net revenue[10] of agricultural production across the entire catchment area, subject to land use and land management options, agricultural production costs and output prices, and environmental factors such as soil type, water available for irrigation, and any regulated environmental outputs (e.g. sediment load limits) imposed on the catchment. Catchments can be disaggregated into sub-regions (i.e. zones) based on different criteria (e.g. land use capability, irrigation schemes), and in this case are divided into Freshwater Management Units (FMU) (see Fig. A1.1), as described in Snelder and Fraser (2016) and Thompson et al. (2018).

The objective function, total catchment net revenue (π), is specified as:

[10] Net revenue (farm profit) is measured as annual earnings before interest and taxes (EBIT), or the net revenue earned from output sales less fixed and variable farm expenses. It also includes the additional capital costs of implementing new land management practices.

$$Max\ \pi = \sum_{r,s,l,e,m} \left\{ \begin{matrix} PA_{r,s,l,e,m} + Y_{r,s,l,e,m} - \\ X_{r,s,l,e,m}\left[\omega^{live}_{r,s,l,e,m} + \omega^{vc}_{r,s,l,e,m} + \omega^{fc}_{r,s,l,e,m} + \tau\gamma^{env}_{r,s,l,e,m}\right] \\ -\omega^{land}_{r,s,l} Z_{r,s,l} \end{matrix} \right\} \quad (1)$$

where P is the product output price, A is the product output, Y is other gross income earned by landowners (e.g. grazing leases), X is area of the farm-based activity, ω^{live}, ω^{vc}, ω^{fc} are the respective livestock, variable, and fixed input costs, τ is an environmental tax (if applicable), γ^{env} is an environmental output coefficient, ω^{land} is a land use conversion cost, and Z is the area of land use change from the initial (baseline) allocation. Summing the revenue and costs of production across all reporting zones (*r*), soil/rainfall combinations (*s*), land covers (*l*), enterprises (*e*), and management options (*m*) yields the total net revenue for the catchment.

The level of net revenue that can be obtained is limited not only by the output prices and costs of production but also by a number of production, land, technology, and environmental constraints.

The production in the catchment is constrained by the product balance equation and a processing coefficient (α^{proc}) that specifies what can be produced by a given activity in a particular part of the catchment:

$$A_{r,s,l,e,m} \leq \alpha^{proc}_{r,s,l,e,m} X_{r,s,l,e,m} \quad (2)$$

Landowners are allocated a certain amount of irrigation (γ^{water}) for their farming activities, provided that there is sufficient water (*W*) available in the catchment:

$$\sum_{s,l,e,m} \gamma^{water}_{r,s,l,e,m} X_{r,s,l,e,m} \leq W_r \quad (3)$$

Land cover in the catchment is constrained by the amount of land available (*L*) on a particular soil type in a given zone:

$$\sum_{e,m} X_{r,s,l,e,m} \leq L_{r,s,l} \quad (4)$$

and landowners are constrained by their initial land allocation (L^{init}) and the area of land that they can feasibly change:

$$L_{r,s,l} \leq L^{init}_{r,s,l} + Z_{r,s,l} \quad (5)$$

The level of land cover change in a given zone and sub-catchment is constrained to be the difference in the area of the initial land-based activity (X^{init}) and the new activity:

$$Z_{r,s,l} \leq \sum_{e,m}\left(X^{init}_{r,s,l,e,m} - X_{r,s,l,e,m}\right) \quad (6)$$

and we can also assume that it is feasible for all managed land cover to change (e.g., convert from pasture to forest). Exceptions include urban, native bush and tussock grassland under conservation land protection, which are fixed across all model scenarios:

$$L_{r,s,fixed} = L^{init}_{r,s,fixed} \quad (7)$$

The model also includes a constraint on changes to enterprise area (*E*), if desired:[11]

$$E_{r,s,l,fixed} = E^{init}_{r,s,l,fixed} \quad (8)$$

In addition to estimating economic output from the agriculture and forest sectors, the model also tracks a series of environmental factors, and in this study focuses on N, P, sediment and *E. coli* loads. In the case where farm-based loads (γ^{env}) are regulated by placing a cap on a given environmental output from land-based activities (*ENV*), landowners could also face an environmental constraint[12]:

$$\sum_{s,l,e,m} \gamma^{env}_{r,s,l,e,m} X_{r,s,l,e,m} \leq ENV_r \quad (9)$$

Finally, the variables in the model are constrained to be greater or equal to zero such that landowners cannot feasibly use negative inputs such as land and fertiliser to produce negative levels of goods:

$$Y, X, L \geq 0 \quad (10)$$

The 'optimal' distribution of land-based activities based on soil/rainfall type $s_{1...i}$, land cover $l_{1...j}$, enterprise $e_{1...k}$, land management $m_{1...l}$, and agricultural output $a_{1...m}$ are simultaneously determined in a nested framework that is calibrated based on the shares of initial enterprise areas for each of the zones. Detailed land use maps of the catchment are used to derive the initial (baseline) enterprise areas and a mix of farm surveys and expert opinion is used to generate the share of specific management systems within these broad sectoral allocations.

The main endogenous variable is the physical area for each of the feasible farm-based activities in a catchment ($X_{r,s,l,e,m}$). In the model, landowners have a degree of flexibility to adjust the share of the land use, enterprise, and land management components of their farm-based activities to meet an objective (e.g. achieve a nutrient reduction target at least cost). Commodity prices, environmental constraints (e.g. nutrient cap), water available for irrigation, and technological change are the important exogenous variables, and, unless specified, these exogenous variables are assumed to be constant across scenarios.

NZFARM has been programmed to simulate the allocation of farm activity area through constant elasticity of transformation (CET) functions. The CET function specifies the rate at which regional land inputs, enterprises, and outputs produced can be transformed across the array of available options. This approach is well suited for models that impose resource and policy constraints as it allows the representation of a 'smooth' transition across production activities while avoiding unrealistic discontinuities and corner solutions in the simulation solutions (de Frahan et al*.* 2007).

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[11] N.B. The Ruamāhanga catchment analysis was primarily focused on the effects of land management on N, P, sediment, and *E. coli* loads. As a result, all the scenarios in this report assume all enterprises areas are fixed at baseline levels with exception of the scenarios that estimate the impacts of including afforestation as a management option.

[12] N.B. This constraint can be placed on the farm, sub-catchment, or catchment level, depending on the focus of the policy or environmental target.

At the highest levels of the CET nest, land use is distributed over the zone based on the fixed area of various soil types. Land cover is then allocated between several enterprises such as arable crops (e.g. process crops or small seeds), livestock (e.g. dairy or sheep and beef), or forestry plantations that will yield the maximum net return. A set of land management options (e.g. fencing streams, reduced fertiliser regime) are then applied to an enterprise which then determines the level of agricultural outputs produced in the final nest.

The CET functions are calibrated using the share of total baseline area for each element of the nest and a CET elasticity parameter, σ_i, where $i \in \{s, l, e, m, a\}$ for the respective soil/rainfall type, land cover, enterprise, land management, and agricultural output. These CET elasticity parameters can theoretically range from 0 to infinity, where 0 indicates that the input is fixed, while infinity indicates that the inputs are perfect substitutes (i.e. no implicit cost from switching from one land use or enterprise activity to another).

The CET elasticity parameters in NZFARM typically ascend with each level of the nest between land cover, enterprise, and land management. This is because landowners have more flexibility to change their mix of management and enterprise activities than to alter their share of land cover. For this analysis the CET elasticities are specified **to focus specifically on the impact of holding land cover and enterprise area fixed**, as requested by the RWCMP, which allows us to focus on the impacts of imposing mitigation practices on existing farms. Thus, the elasticities are as follows: land cover ($\sigma_L = 0$), enterprise ($\sigma_E = 0$), and land management ($\sigma_M = \infty$). An infinite CET elasticity value was used in the land-management nest to simulate that landowners are 100% likely over the long-run to **exactly employ mitigation practices that were specified in each scenario developed by MfE**[13] on their existing farm to meet environmental constraints rather than change land use. The CET elasticity parameter for each soil/rainfall combination (σ_S) is set to be 0, as that area is fixed. In addition, the parameter for agricultural production (σ_A) is also assumed to be 0, implying that a given activity produces a fixed set of outputs.

We note that this specification, along with equation (7), essentially re-specifies NZFARM to solve without needing to use the PMP-like formulation because it now includes additional levels of constraints. In this case, the only thing that is allowed to change is land-management, which is now assumed to be completely substitutable over the long run. That is, the landowner will choose whatever land management option is most profitable for the farm without any reservation. However, this approach also constrains changes in land use, and thus although a farm may be more profitable if it switches from sheep and beef to forestry, this specification prohibits it from doing so. As a result, the simulated costs of the policy are the same as those estimated using catchment economic modelling methods discussed in Doole (2015).

[13] N.B. This approach is different from all prior analyses conducted using NZFARM (e.g. Daigneault et al. 2013; Daigneault & Samarasinghe 2015), where at least some of the scenarios set an environmental target but then ran the 'optimization' routine of the economic land use model to estimate the most cost-effective option for landowners to achieve a given objective. In the case of the RWCMP, all scenarios assumed a fix set of practices were imposed in each parcel of land, which eliminated the flexibility of the model to explore other policy options or mix of mitigation options to potentially achieve the same objective.

The economic land use model is programmed in the modelling General Algebraic Modelling System (GAMS) software package. The baseline calibration and scenario analysis are derived using the non-linear programming (NLP) version of the CONOPT solver (GAMS 2015).

Table A1.1 shows the key components of NZFARM specific to Ruamāhanga catchment.

Table A1.1: List of key components of NZFARM Ruamāhanga Catchment

Enterprise (E)	Mitigation Practice (M)	Soil/Rainfall (S) mm	Freshwater Management Units (R)	Environmental Indicators (ENV)
Arable_4.14	None	BROWN_>2450	Eastern Hill streams	N leaching
Beef Farming_4.10	M1	BROWN_1050-1250	Eastern hill rivers	P loss
Beef Farming_4.11	M2	BROWN_1250-1650	Valley floor streams	Sediment
Beef Farming_4.11,4.16	M3	BROWN_1650-2050	Main stem Ruamāhanga River	
Beef Farming_4.12	Afforest	BROWN_2050-2450	Lake Onoke	
Beef Farming_4.13	FEP	BROWN_750-850	Western hill rivers	
Beef Farming_4.16	Land retirement	BROWN_850-1050	Northern rivers	
Beef Farming_4.8	SHA	BROWN_850-1250	None	
Beef Farming_4.8,4.10	Stock Exclusion	GLEY_<750		
Beef Farming_4.8,4.9	Wetland mgt	GLEY_1050-1250		
Beef Farming_4.9		GLEY_1250-1650		
Dairy Farming_4.1,4.2		GLEY_1650-2050		
Dairy Farming_4.3		GLEY_2050-2450		
Dairy Farming_4.3,4.5		GLEY_750-850		
Dairy Farming_4.4		GLEY_850-1050		
Dairy Farming_4.5,4.6		lake_1050-1250		
Dairy Support_4.15		lake_1250-1650		
Dairy Support_4.16		lake_850-1050		
Finishing_4.10		MELANIC_1050-1250		
Finishing_4.11		MELANIC_1250-1650		
Finishing_4.11,4.16		MELANIC_750-850		
Finishing_4.12		MELANIC_850-1050		
Finishing_4.13		ORGANIC_1650-2050		
Finishing_4.8		ORGANIC_750-850		
Finishing_4.8,4.10		ORGANIC_850-1050		
Finishing_4.8,4.9		PALLIC_<750		
Finishing_4.9		PALLIC_1050-1250		
Sheep and Beef Farming South-East_4.8		PALLIC_1250-1650		
Sheep and Beef Farming_4.10		PALLIC_1650-2050		
Sheep and Beef Farming_4.11		PALLIC_750-850		
Sheep and Beef Farming_4.11,4.16		PALLIC_850-1050		
Sheep and Beef Farming_4.12		RAW_<750		
		RAW_1050-1250		
		RAW_1250-1650		
		RAW_1650-2050		
		RAW_2050-2450		

Enterprise (E)	Mitigation Practice (M)	Soil/Rainfall (S) mm	Freshwater Management Units (R)	Environmental Indicators (ENV)
Sheep and Beef Farming_4.13		RAW_750-850		
Sheep and Beef Farming_4.14,4.10,4.7,4.5,4.6		RAW_850-1050		
Sheep and Beef Farming_4.8		RECENT_<750		
Sheep and Beef Farming_4.8,4.10		RECENT_>2450		
Sheep and Beef Farming_4.8,4.9		RECENT_1050-1250		
Sheep and Beef Farming_4.9		RECENT_1250-1650		
Sheep and Beef		RECENT_1650-2050		
Sheep Farming_4.10		RECENT_2050-2450		
Sheep Farming_4.11		RECENT_750-850		
Sheep Farming_4.11,4.16		RECENT_850-1050		
Sheep Farming_4.12		river_1050-1250		
Sheep Farming_4.13		river_1250-1650		
Sheep Farming_4.16		river_1650-2050		
Sheep Farming_4.8		river_850-1050		
Sheep Farming_4.8,4.10		town_1050-1250		
Sheep Farming_4.8,4.9		town_1250-1650		
Sheep Farming_4.9		town_850-1050		
Horticulture		ULTIC_1050-1250		
Lifestyle		ULTIC_1250-1650		
Native Bush				
Urban				
Utility				
Equine				
Viticulture				
Recreation				
Mixed				
Poultry				
Waterway				
River				

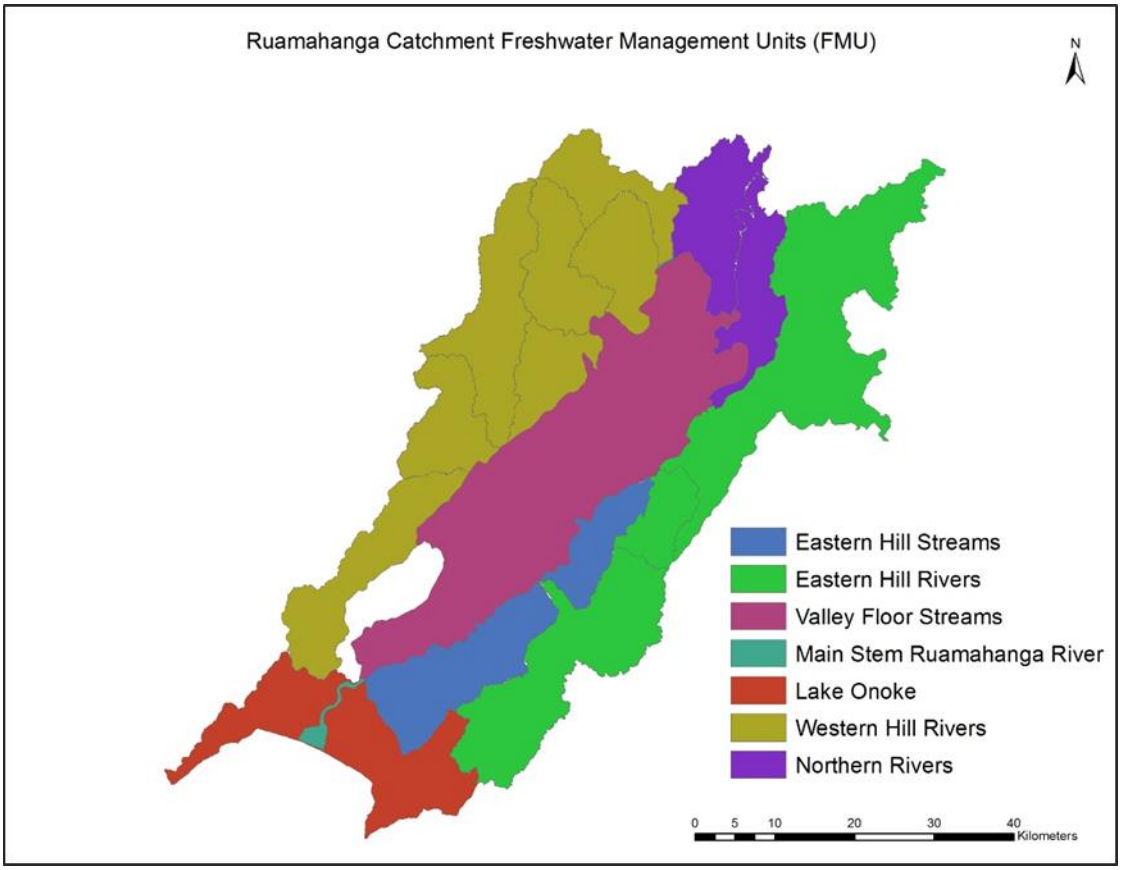

Figure A1.1: Ruamāhanga Catchment FMUs.

A1.2: Nutrient Modelling

Nutrient modelling was conducted in Overseer. Methods for estimating baseline figures for the 16 representative farms were presented in Parminter and Grinter (2016), while methods for estimating per hectare figures for the mitigation practices are discussed in Muirhead (2016). Estimates for other land uses not covered by the representative farms, as well as adjustments to nutrient losses provided by the other two sources were specified by Jacobs (2018) along with insight from other stakeholders participating in the RWCMP.

A1.3: Sediment Modelling

Jacobs was contracted by GWRC to undertake an analysis of baseline erosion rates and sediment yields in the Ruamāhanga catchment using the SedNetNZ model. The catchment erosion and sediment model simulate several erosion processes, sediment storages, and transfers. For this analysis, SedNetNZ has been calibrated for the Ruamāhanga catchment and downscaled to a grid scale. Sediment is estimated as total sediment and thus expected to come from a range of sources that include landslide, earthflow, gully, and surficial erosion, as well as floodplain deposition and streambank erosion. More details on how sediment was modelled are available in Jacobs (2018).

A1.4: *E. coli* Modelling

Jacobs (2018) used the CLUES model to estimate baseline annual-average *E. coli* loads in the Ruamāhanga catchment. The estimated loads are broken down to river environment classification level 1 (REC1) sub-catchment scale, of which there are more than 7,000 in the Ruamāhanga. NZFARM has incorporated the baseline *E. coli* estimates by intersecting the GIS layer of *E. coli* loads provided by Jacobs with the Ruamāhanga catchment land use map. Note that the impacts of modelled scenarios on *E. coli* loads were not provided by Jacobs for this analysis. However, while the *E. coli* impacts are not included in this report the mitigation options and costs to reduce *E. coli* loads have been included in the economic analysis. More details on how *E. coli* was modelled available in Jacobs (2018).

A1.5: Mitigation practices

AgResearch was contracted to model up to 3 set of mitigation bundles for each of the 16 representative farms for the RWCMP (Muirhead et al. 2016). The three bundles are grouped base on how easy (M1), medium (M2), and difficult (M3) they are to implement on farm, both in terms of financial cost and technical expertise (Monaghan 2009). The N and P mitigation options were modelled using Overseer, while the losses of sediment and *E. coli* were estimated using the best available data on farm-scale losses of these contaminants. The financial implications were modelled using Farmax. Additional mitigation practices requested by MfE were added to the analysis, and parameterized based on the literature. A summary of the mitigation options considered for dairy, sheep and beef, and dairy support farms are listed in Table A1.2.

Table A1.2: Potential Good Management Practices (GMPs) that could be applied to 16 MPI representative farms. The data indicates the key contaminants that the mitigation targets as well as an estimate of the effectiveness rated as low (L), medium (M), high (H) or unsure (?). The Bundle refers to the mitigation bundle (1, 2 or 3) in which the specific mitigation would be applied

GMP	*Target*	*Effectiveness*	*Bundle*
	Dairy		
Stock exclusion from streams, wetlands	P, *E. coli*, NH_4-N, sediment	High for *E. coli*	1
Deferred and/or low rate effluent irrigation	*E. coli*, P	?	1
Efficient water irrigation	N	L	2
Optimal P fertility & fert form	P	?	2
Enlarged effluent area	N	L	2
Early re-establishment of summer crops	N	L	2
Diverting laneway runoff	*E. coli*, P, NH_4	LH	2
Reduced use of fertiliser N	N	M	2
Facilitated or constructed wetlands	N, sediment, *E. coli*	L–M	2
Autumn substitution of N-fertilised pasture with low N feeds	N	L	2
Split grass/clover swards	P	L–M	3
	Sheep and Beef		
Cattle exclusion from streams, wetlands	P, *E. coli*, NH_4-N, sediment	High for *E. coli*	1
Protection of CSAs on grazed forage crops	Sediment, P E. coli	H	2
Efficient water irrigation	N	L	2
Low solubility P fertiliser to sloping land	P	L	2
Early re-establishment of summer crops	N	L	2
Facilitated or constructed wetlands	N, sediment, *E. coli*	L–M	2
Catch crops following winter crops	N	L	2
Planted buffer strips	Sediment, P	M	3
Sediment traps	Sediment, P	?	3
	Dairy Support		
Stock exclusion from streams, wetlands	P, *E. coli*, NH_4-N, sediment	High for *E. coli*	1
Protection of CSAs on grazed forage crops	Sediment, P, *E. coli*	H	2
Optimal P fertility & fert form	P	?	2
Early re-establishment of cropped land	N	L	2
Catch crops following winter crops	N	L	2
Reduced use of fertiliser N	N	L	2
Facilitated or constructed wetlands	N, sediment, *E. coli*	L–M	2
Reduce % as cattle Sus	N	M	2
Duration-controlled crop grazing	N, sediment	L	3
Off-paddock wintering	N, sediment	H	3
Sediment traps	Sediment, P	L	3
Planted buffer strips	Sediment, P	L	3

Appendix 2 – Scenario Descriptions

Table A2.1: Business as usual (BAU) scenario description

Management option	Description
Land retirement	Retirement of very steep slopes and afforestation/ reversion to bush on Class 8 and 7e land Retire at the rate of 18 ha per year
Space/pole planting	Space planting on steep slopes (Class 7 land and above) Plant at the rate of 135 ha per year
Stock exclusion from water ways	All Category 1 and 2 water bodies as defined in the PNRP (includes wetlands, estuaries, lakes, water races and large drains – see page 19 of PNRP)
Wastewater treatment	Wastewater treatment plant are discharging partially to land % volume of discharge to land: Masterton: • 60% (summer) and 5% (winter) by 2025, • 100% (summer) and 80% (winter) by 2040 • 100% (summer) and 97% (winter) by 2080 Carterton: • 35% by 2025 • 60% by 2080 Martinborough: • 24% by 2025 • 100% by 2040 Greytown: • 20% by 2025 • 100% by 2040 Featherston: • 0% (full course of model)
Minimum flows	Minimum flows and allocation amounts based on limits set in Proposed Natural Resources Plan (PNRP) on all rivers and streams and groundwater Minimum flows are identified in Tables 7.1 and 7.2 of the PNRP
On-farm mitigation	Mitigation practices from M1, 2, and 3 good management practices applied to all dairy, dairy support and sheep and beef farms. M1 is applied immediately

Table A2.2: Detailed description of Hill and Lowland Cropping Scenarios

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land
BAU	BAU	Same as original report/analysis – all livestock, arable, and hort employ M1 mitigation bundle	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report
1	M2 - Arable + Hort	All arable and hort land implement M2 mitigation bundle	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report
1	M2 - Livestock	All livestock farms implement M2 mitigation bundle		
1	M2 - Arable, Hort, Livestock	All arable, hort, and livestock farms implement M2 mitigation bundle		
1	M3 - Arable + Hort	All arable and hort land implement M3 mitigation bundle	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report
1	M3 - Livestock	All livestock farms implement M3 mitigation bundle		
1	M3 - Arable, Hort, Livestock	All arable, hort, and livestock farms implement M3 mitigation bundle		
2	M2 - Arable + Hort with FEP	All arable and hort land implement M2 mitigation bundle + Farm Environment Plan (FEP)	M2 + additional 10% N, 15% P, and 50% sed reduction, based on literature	Option 1 + $5000/farm + $250/ac to implement; Costs annualized over 25 years using rate of 8%
2	M2 - Livestock with FEP	All livestock farms implement M2 mitigation bundle + FEP		
2	M2 - Arable, Hort, Livestock with FEP	All arable, hort, and livestock farms implement M2 mitigation bundle + FEP		
2	M3 - Arable + Hort with FEP	All arable and hort land implement M3 mitigation bundle + Farm Environment Plan (FEP)	M3 + additional 10% N, 15% P, and 50% sed reduction, based on literature	
2	M3 - Livestock with FEP	All livestock farms implement M3 mitigation bundle + FEP		
2	M3 - Arable, Hort, Livestock with FEP	All arable, hort, and livestock farms implement M3 mitigation bundle + FEP		
3	M2 - Arable + Hort with FEP + Retire High LUC	Option 2 M2 + retired LUC 6e, 7, 8 arable and hort	M2 + FEP + additional 90% reduction in N, P, sediment on LUC 6e, 7, 8 land retired)	Option 2 + 100% opportunity cost on land eligible for retirement (approx 10,000 ha of livestock, arable, and hort combined)
3	M2 - Livestock with FEP + Retire High LUC	Option 2 M2 + retired LUC 6e, 7, 8 Livestock		
3	M2 - Arable, Hort, Livestock with FEP + Retire High LUC	Option 2 M2 + retired LUC 6e, 7, 8 arable, hort, livestock		
3	M3 - Arable + Hort with FEP + Retire High LUC	Option 2 M3 + retired LUC 6e, 7, 8 arable and hort	M3 + FEP (+ additional 90% reduction in N, P, sediment on LUC 6e, 7, 8 land retired)	
3	M3 - Livestock with FEP + Retire High LUC	Option 2 M3 + retired LUC 6e, 7, 8 Livestock		
3	M3 - Arable, Hort, Livestock with FEP + Retire High LUC	Option 2 M3 + retired LUC 6e, 7, 8 arable, hort, livestock		

Table A2.3: Detailed description of land-use intensification

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land	Other Notes
BAU	BAU	Same as original report/analysis - all livestock, arable, and hort employ M1 mitigation bundle	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	
1	Dairy Support to Dairy - No Limit	All 10,008 ha of dairy support converted to dairy farming with M1 mitigation	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report	
1	Dairy Support to Dairy - BAU N and P Limit	All 10,008 ha of dairy support converted to dairy farming, M2 and M3 bundles applied, if required			Requires all current dairy farms may to employ mitigation to get close to P target
1	Sheep-only to Beef-only - No Limit	All 4,498 ha of sheep farming converted to beef farming with M1 mitigation	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report	
1	Sheep-only to Beef-only - BAU N and P Limit	All 4,498 ha of sheep farming converted to beef farming, M2 and M3 eligible			Requires some current beef farms may to employ mitigation to get close to N target
1	S&B LUC 1-4 to Dairy - No Limit	26,335 ha of Sheep and beef farms on LUC 1-4 and in current dairy soil and rainfall zones converted to dairy farming with M1 mitigation	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report	Not all S&B land may in fact be suitable for dairy, so likely to be an over-estimate of impact
1	S&B LUC 1-4 to Dairy - BAU N and P limit	26,335 ha of Sheep and beef farms on LUC 1-4 and in current dairy soil and rainfall zones converted to dairy farming, M2 and M3 applied, if required			Requires all current dairy farms to employ mitigation to get close to N target
1	Forestry to Dairy - No Limit	11,310 ha of Forestry converted to Dairy Farms with M1 mitigation	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report	Did not run with BAU target, as would not be met, even with max mitigation
1	Forestry to Sheep & Beef - No Limit	11,310 ha of Forestry converted to Sheep & Beef Farms with M1 mitigation			
3	Sheep-only to Beef-only - BAU N and P 10% below BAU	26,335 ha of Sheep and beef farms on LUC 1-4 and in current dairy soil and rainfall zones converted to dairy farming, M2 and M3 applied, if required	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report	Requires all current and new beef farms may to employ M3; N and P targets of 10% below BAU still not met

Table A2.4: Detailed description of stock exclusion

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land	Other Notes
No Exclusion	No Exclusion (Baseline)	No stock exclusion within catchment	None	Profits increase over BAU based on average regional cost of constructing fence and length of stream through each parcel	Used Jacobs (2017) Table 3.3 to estimate N, P, and Sediment rates for baseline, which needed to be adjusted from M1 BAU (Ruamāhanga base)
1	Existing Reg (BAU)	Same as original report/analysis - all livestock, arable, and hort employ M1 mitigation bundle regardless of LUC, carrying capacity or stream width	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Need to fence both sides of the stream
1	Exclusion on LUC 1-5, 1+ m wide streams	Non-sheep pasture land on LUC 1-5 with streams 1m or more	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Need to fence both sides of the stream
1	Exclusion on SU > 18, 1+ m wide streams	Non-sheep pasture land with carrying capacity of 18 or more of stocking units and streams 1m wide or more	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Need to fence both sides of the stream
1	Exclusion on SU > 18, LUC 1-5 & 1+ m wide streams	Non-sheep pasture land with carrying capacity of 18 or more of stocking units OR LUC 1-5 and streams; all 1m wide or more	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Need to fence both sides of the stream
2	3-m Setback on LUC 1-5	3-m Setback on Non-sheep pasture land on LUC 1-5	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit
2	3-m Setback on SU > 18	3-m Setback on Non-sheep pasture land with carrying capacity of 18 or more	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit
2	Exclusion on LUC 6-8	Non-sheep pasture land on LUC 6-8	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1	No 1-m stream width limit; Only stock exclusion (no Setback)
2	3-m Setback on SU > 18 OR LUC 1-5	3-m Setback on Non-sheep pasture land with carrying capacity of 18 or more of stocking units OR LUC 1-5	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit
2	3-m Setback on SU > 18 OR LUC 1-5 & Exclusion on LUC 6-8	3-m Setback on Non-sheep pasture land with carrying capacity of 18 or more of stocking units OR LUC 1-5 OR stock exclusion on LUC 6-8	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit; Setback does not apply to LUC 6-8
3	5-m Setback on LUC 1-5	5-m Setback on Non-sheep pasture land on LUC 1-5	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit; Does not include additional benefits of riparian planting
3	5-m Setback on SU > 18	5-m Setback on Non-sheep pasture land with carrying capacity of 18 or more	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit; Does not include additional benefits of riparian planting
3	5-m Setback on SU > 18 OR LUC 1-5	5-m Setback on Non-sheep pasture land with carrying capacity of 18 or more of stocking units OR LUC 1-5	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit; Does not include additional benefits of riparian planting
3	5-m Setback on SU > 18 OR LUC 1-5 & Exclusion on LUC 6-8	5-m Setback on Non-sheep pasture land with carrying capacity of 18 or more of stocking units OR LUC 1-5 OR stock exclusion on LUC 6-8	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit; Does not include additional benefits of riparian planting; setback does not apply to LUC 6-8
4	5-m Setback on slope < 5 degrees	5-m Setback on Non-sheep pasture land with slope < 5 degrees	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	No 1-m stream width limit
4	5-m Setback on slope > 5 deg, All Dairy, S&B > 14 SU	5-m Setback on Non-sheep pasture land with slope > 5 degrees; All Dairy; Other pasture > 14 SU	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	Do not account for option to vary setback through FEP/consent
4	5-m Setback on all slopes; All Dairy, all eligible S&B (14+ SU; +/- 5 deg)	Combined impact of previous two scenarios (+/- 5 degrees)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	Do not account for option to vary setback through FEP/consent
4	5m Setback on slope > 5 deg, All Dairy, S&B > 18 SU	5m Setback on Non-sheep pasture land with slope > 5 degrees; All Dairy; Other pasture > 18 SU	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	
4	5m Setback on all slopes; All Dairy, all eligible S&B (18+ SU; +/- 5 deg)	Combined impact of two scenarios (+/- 5 degrees, 18 SU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	
5	5m Setback on slope < 7 degrees	5m Setback on Non-sheep pasture land with slope < 7 degrees	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	
5	5m Setback on slope > 7 deg, All Dairy, S&B > 18 SU	5m Setback on Non-sheep pasture land with slope > 7 degrees; All Dairy; Other pasture > 18 SU	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	
5	5m Setback on all slopes; All Dairy, all eligible S&B (18+ SU, +/- 7 deg)	Combined impact of previous two scenarios (+/- 7 degrees, 18 SU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	M1 + opportunity cost for land lost to setback	

Table A2.5: Detailed description of stock holding areas (SHA)

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land	Other Notes
BAU	BAU	Same as original report/analysis - all livestock, arable, and hort employ M1 mitigation bundle regardless of LUC, carrying capacity or stream width	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	
1	SHA - Dairy	All dairy farms construct low-cost SHA	Affects entire farm area. Used lower values of literature: 25% N, 15% P, 15% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
1	SHA - Dairy Support	All dairy support farms construct low-cost SHA	Affects entire farm area. Used lower values of literature: 25% N, 15% P, 15% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
1	SHA - Sheep & Beef	All sheep and beef farms construct low-cost SHA	Affects entire farm area. Used lower values of literature: 25% N, 15% P, 15% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
1	SHA - All Stock	All livestock farms construct low-cost SHA	Affects entire farm area. Used lower values of literature: 25% N, 15% P, 15% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
2	SHA - Dairy	All dairy farms construct SHA with concrete pad and effluent management	Affects entire farm area; Used med-high values of literature: 40% N, 30% P, 30% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
2	SHA - Dairy Support	All dairy support farms construct SHA with concrete pad and effluent management	Affects entire farm area; Used med-high values of literature: 40% N, 30% P, 30% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
2	SHA - Sheep & Beef	All sheep & beef farms construct SHA with concrete pad and effluent management	Affects entire farm area; Used med-high values of literature: 40% N, 30% P, 30% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on
2	SHA - All Stock	All livestock farms construct SHA with concrete pad and effluent management	Affects entire farm area; Used med-high values of literature: 40% N, 30% P, 30% S	Opportunity cost of lost land for SHA, construction and maintenance, additional feed	measures impact relative to stock winter on

Table A2.6: Detailed description of Wetland management

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land
BAU	BAU	Same as original report/analysis - all livestock, arable, and hort employ M1 mitigation bundle	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report
1	5m fencing	5m buffer + fencing around all current wetlands, based on NZ LRI. (approx 1,983 ha total)	100% reduction in N, P, S within fenced area.	100% opportunity cost within fenced area; Fencing cost based on regional averages in MPI's 2016 National Stock Exclusion Study, and varies by land use.

Table A2.7: Detailed description of N limit

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land
BAU	BAU	Same as original report/analysis - all livestock, arable, and hort employ M1 mitigation bundle	Same as original report/analysis, based on AgResearch report	Same as original report/analysis, based on AgResearch report
1	70kgN/ha	Model chooses most cost-effective mitigation option to achieve average farm N leaching rate of 70kgN/ha/yr (applies to 2,472 ha)	Varies by mitigation practice (options are M2, M3, M3 + Farm Env Plan, Afforestation)	Varies by mitigation practice
1	50kgN/ha	Model chooses most cost-effective mitigation option to achieve average farm N leaching rate of 50kgN/ha/yr (applies to 3,163 ha)	Varies by mitigation practice (options are M2, M3, M3 + Farm Env Plan, Afforestation)	Varies by mitigation practice
1	30kgN/ha	Model chooses most cost-effective mitigation option to achieve average farm N leaching rate of 730kgN/ha/yr (applies to 35,721 ha)	Varies by mitigation practice (options are M2, M3, M3 + Farm Env Plan, Afforestation)	Varies by mitigation practice

Table A2.8: Detailed description of Mitigation combinations

Option	Scenario	Assumption 1 - implementation	Assumption 2 - effectiveness on eligible land	Assumption 3 - cost on eligible land	Other Notes
BAUa	No Stock Exclusion Baseline	No stock exclusion within catchment	None	Profits increase over BAU based on average regional cost of constructing fence and length of stream through each parcel	Used Jacobs (2017) Table 3.3 to estimate N, P, and Sediment rates for baseline, which needed to be adjusted from M1 BAU (Ruamahanga base)
BAUb	Ruamahanga BAU	Same as original report/analysis - all livestock, arable, and hort employ M1 mitigation bundle regardless of LUC, carrying capacity or stream width	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Same as original report/analysis, based on AgResearch report (M1 for BAU)	Baseline' we have been using to compare most of the individual mitigation options scenarios (with exception of Stream Exclusion, which assumes baseline has no fences)
1a	Fencing + Wetland + M2	Stock exclusion on all option 1 eligible pasture; wetland fencing and buffer; M2 mitigation on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
1b	Fencing + Wetland + M3	Stock exclusion on all option 1 eligible pasture; wetland fencing and buffer; M3 mitigation on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
2a	Fencing + Setback + Wetland + M2 + FEP	Stock exclusion on all option 2 eligible pasture; wetland fencing and buffer; M2 mitigation + Farm Environmental Plan (FEP) on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
2b	Fencing + Setback + Wetland + M3 + FEP	Stock exclusion on all option 2 eligible pasture; wetland fencing and buffer; M3 mitigation + Farm Environmental Plan (FEP) on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
3a	Fencing + Setback + Wetland + M2 + FEP + Retirement	LUC 6-8 pasture retirement; stock exclusion on all remaining option 3 eligible pasture; wetland fencing and buffer; M2 mitigation + Farm Environmental Plan (FEP) on all remaining pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
3b	Fencing + Setback + Wetland + M3 + FEP + Retirement	LUC 6-8 pasture retirement; stock exclusion on all remaining option 3 eligible pasture; wetland fencing and buffer; M3 mitigation + Farm Environmental Plan (FEP) on all remaining pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
1a	Fencing + Wetland + M2 + SHA-low	Stock exclusion on all option 1 eligible pasture; wetland fencing and buffer; M2 mitigation + low cost SHA on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
1b	Fencing + Wetland + M3 + SHA-low	Stock exclusion on all option 1 eligible pasture; wetland fencing and buffer; M3 mitigation + low cost SHA on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
2a	Fencing + Setback + Wetland + M2 + FEP + SHA-high	Stock exclusion on all option 2 eligible pasture; wetland fencing and buffer; M2 mitigation + Farm Environmental Plan (FEP) + high cost SHA on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
2b	Fencing + Setback + Wetland + M3 + FEP + SHA-high	Stock exclusion on all option 2 eligible pasture; wetland fencing and buffer; M3 mitigation + Farm Environmental Plan (FEP) + high cost SHA on all pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
3a	Fencing + Setback + Wetland + M2 + FEP + Retirement + SHA-high	LUC 6-8 pasture retirement; stock exclusion on all remaining option 3 eligible pasture; wetland fencing and buffer; M2 mitigation + Farm Environmental Plan (FEP) + high cost SHA on all remaining pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	
3b	Fencing + Setback + Wetland + M3 + FEP + Retirement + SHA-high	LUC 6-8 pasture retirement; stock exclusion on all remaining option 3 eligible pasture; wetland fencing and buffer; M3 mitigation + Farm Environmental Plan (FEP) + high cost SHA on all remaining pasture	varies by practice (see individual mitigation options)	varies by practice (see individual mitigation options)	

Appendix 3 – Detailed RWC Scenario Results

A3.1: RWC Scenario results by disaggregated land use

Table A3.1: Total baseline area, net farm revenue, and environmental outputs by disaggregated land use

	Area (ha)	Net Farm Revenue ($)	N leaching (kg)	P Loss (kg)	Sediment (t)
Arable	1,658	$1,904,611	46,598	610	1,757
Beef Farming	9,505	$3,832,390	168,630	11,509	27,819
Dairy Farming	30,090	$59,452,530	900,217	28,708	8,048
Dairy Support	10,008	$6,151,398	368,101	2,634	4,762
Deer Farming	2,367	$2,354,707	49,697	237	7,053
Equine	384	$0	0	92	62
Finishing	1,915	$763,742	29,511	2,638	1,323
Forestry	11,310	$7,087,498	33,931	1,470	24,065
Horticulture	732	$5,419,367	5,122	29	14
Other Land use	60	$0	0	0	0
Lifestyle	12,210	$0	329,659	16,361	4,778
Mixed	16,744	$27,626,885	652,980	6,865	6,205
Native Bush	85,853	$0	85,853	15,453	381,679
Poultry	11	$0	0	0	0
Recreation	695	$0	18,076	56	1,542
River	3,876	$0	0	0	0
Sheep and Beef Farming	142,078	$65,285,066	1,880,983	145,234	541,570
Sheep and Beef Farming South-East	7,137	$3,126,016	138,756	7,087	35,174
Sheep Farming	4,498	$1,713,861	64,544	4,013	8,547
Urban	3,182	$0	22,274	6,746	249
Utility	4,826	$0	33,782	10,231	4,109
Viticulture	1,620	$7,785,619	14,583	65	100
Waterway	8,346	$0	0	0	0
Total	**359,103**	**$192,503,691**	**4,843,302**	**262,726**	**1,060,591**

Table A3.2: Per hectare baseline net farm revenue, and environmental outputs by disaggregated land use

	Area (ha)	Net Farm Revenue ($/ha)	N leaching (kg/ha)	P Loss (kg/ha)	Sediment (t/ha)
Arable	1,658	$1,149	28	0.4	1.1
Beef Farming	9,505	$403	18	1.2	2.9
Dairy Farming	30,090	$1,976	30	1.0	0.3
Dairy Support	10,008	$615	37	0.3	0.5
Deer Farming	2,367	$995	21	0.1	3.0
Equine	384	$0	0	0.2	0.2
Finishing	1,915	$399	15	1.4	0.7
Forestry	11,310	$627	3	0.1	2.1
Horticulture	732	$7,404	7	0.0	0.0
Other Land use	60	$0	0	0.0	0.0
Lifestyle	12,210	$0	27	1.3	0.4
Mixed	16,744	$1,650	39	0.4	0.4
Native Bush	85,853	$0	1	0.2	4.4
Poultry	11	$0	0	0.0	0.0
Recreation	695	$0	26	0.1	2.2
River	3,876	$0	0	0.0	0.0
Sheep and Beef Farming	142,078	$460	13	1.0	3.8
Sheep and Beef Farming South-East	7,137	$438	19	1.0	4.9
Sheep Farming	4,498	$381	14	0.9	1.9
Urban	3,182	$0	7	2.1	0.1
Utility	4,826	$0	7	2.1	0.9
Viticulture	1,620	$4,806	9	0.0	0.1
Waterway	8,346	$0	0	0.0	0.0
Total	**359,103**	**$536**	**13**	**0.7**	**3.0**

Table A3.3: Total cost ($/yr) of modelled scenarios by disaggregated land use

Disaggregated land use	BAU	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Arable	$0	$168,540	$293,400	$292,126	$295,088	$333,647	$333,647
Beef Farming	$6,383	$1,021,986	$1,707,774	$1,610,338	$1,460,383	$1,744,188	$1,744,188
Dairy Farming	$798,924	$7,488,039	$9,136,179	$9,382,477	$9,504,781	$10,505,893	$10,505,893
Dairy Support	$0	$349,266	$463,547	$467,974	$366,905	$467,974	$467,974
Deer Farming	$0	$217,329	$242,130	$242,130	$224,028	$242,130	$242,130
Equine	$0	$967	$1,889	$1,889	$967	$1,889	$1,889
Finishing	$0	$266,150	$322,947	$320,176	$324,654	$351,684	$351,684
Forestry	$227	$105	$106	$106	$105	$106	$106
Horticulture	$0	$0	$5,592	$5,592	$0	$5,592	$5,592
Other Land use	$0	$0	$0	$0	$0	$0	$0
Lifestyle	$843	$33,680	$264,800	$264,800	$33,673	$264,800	$264,800
Mixed	$386	$73,930	$244,563	$244,563	$153,928	$244,563	$244,563
Native Bush	$0	$0	$0	$0	$0	$0	$0
Poultry	$0	$0	$0	$0	$0	$0	$0
Recreation	$0	$0	$0	$0	$0	$0	$0
River	$0	$0	$0	$0	$0	$0	$0
Sheep and Beef Farming	$604,824	$9,753,158	$24,674,607	$27,322,641	$21,550,399	$29,647,395	$29,647,395
Sheep and Beef Farming South-East	$90,331	$587,531	$1,630,863	$1,892,877	$1,480,434	$2,000,917	$2,000,917
Sheep Farming	$13,678	$567,639	$854,566	$918,638	$792,518	$990,993	$990,993
Urban	$0	$0	$0	$0	$0	$0	$0
Utility	$58	$29	$40	$40	$29	$40	$40
Viticulture	$0	$0	$4,596	$4,596	$194	$4,596	$4,596
Waterway	$0	$0	$0	$0	$0	$0	$0
Grand Total	**$1,515,654**	**$20,528,348**	**$39,847,600**	**$42,970,964**	**$36,188,085**	**$46,806,409**	**$46,806,409**

Table A3.4 Per hectare cost ($/ha/yr) of modelled scenarios by disaggregated land use

	BAU	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Arable	$0	$102	$177	$176	$178	$201	$201
Beef Farming	$1	$108	$180	$169	$154	$184	$184
Dairy Farming	$27	$249	$304	$312	$316	$349	$349
Dairy Support	$0	$35	$46	$47	$37	$47	$47
Deer Farming	$0	$92	$102	$102	$95	$102	$102
Equine	$0	$3	$5	$5	$3	$5	$5
Finishing	$0	$139	$169	$167	$170	$184	$184
Forestry	$0	$0	$0	$0	$0	$0	$0
Horticulture	$0	$0	$8	$8	$0	$8	$8
Other Land use	$0	$0	$0	$0	$0	$0	$0
Lifestyle	$0	$3	$22	$22	$3	$22	$22
Mixed	$0	$4	$15	$15	$9	$15	$15
Native Bush	$0	$0	$0	$0	$0	$0	$0
Poultry	$0	$0	$0	$0	$0	$0	$0
Recreation	$0	$0	$0	$0	$0	$0	$0
River	$0	$0	$0	$0	$0	$0	$0
Sheep and Beef Farming	$4	$69	$174	$192	$152	$209	$209
Sheep and Beef Farming South-East	$13	$82	$229	$265	$207	$280	$280
Sheep Farming	$3	$126	$190	$204	$176	$220	$220
Urban	$0	$0	$0	$0	$0	$0	$0
Utility	$0	$0	$0	$0	$0	$0	$0
Viticulture	$0	$0	$3	$3	$0	$3	$3
Waterway	$0	$0	$0	$0	$0	$0	$0
Grand Total	**$4**	**$57**	**$111**	**$120**	**$101**	**$130**	**$130**

A3.2: RWC environmental responses at disaggregated land use level

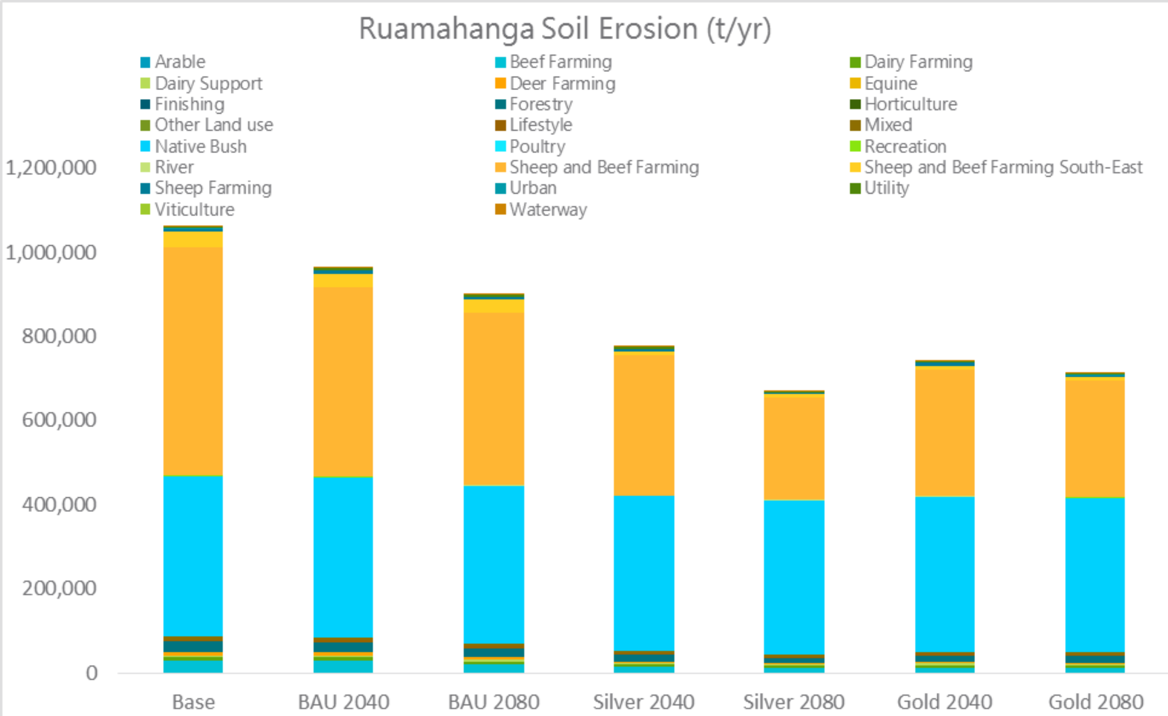

Figure A3.1: Sediment loss (t/yr) for disaggregated land use, by scenario.

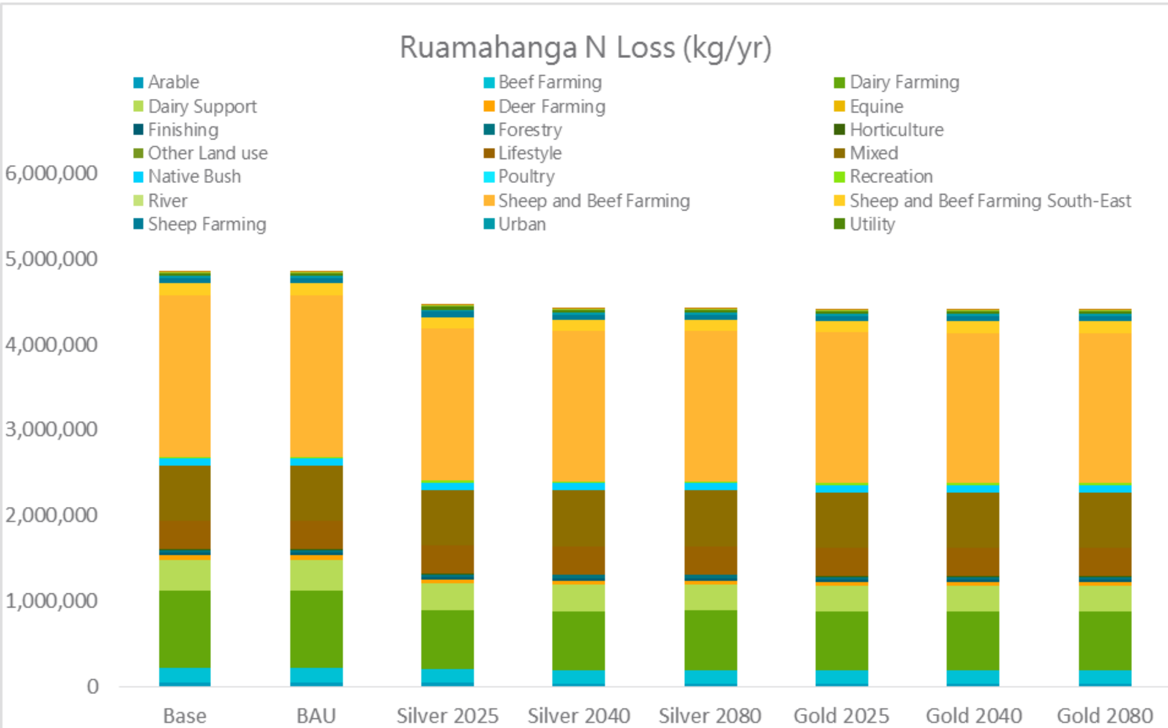

Figure A3.2: N leaching loss (kg/yr) for disaggregated land use, by scenario.

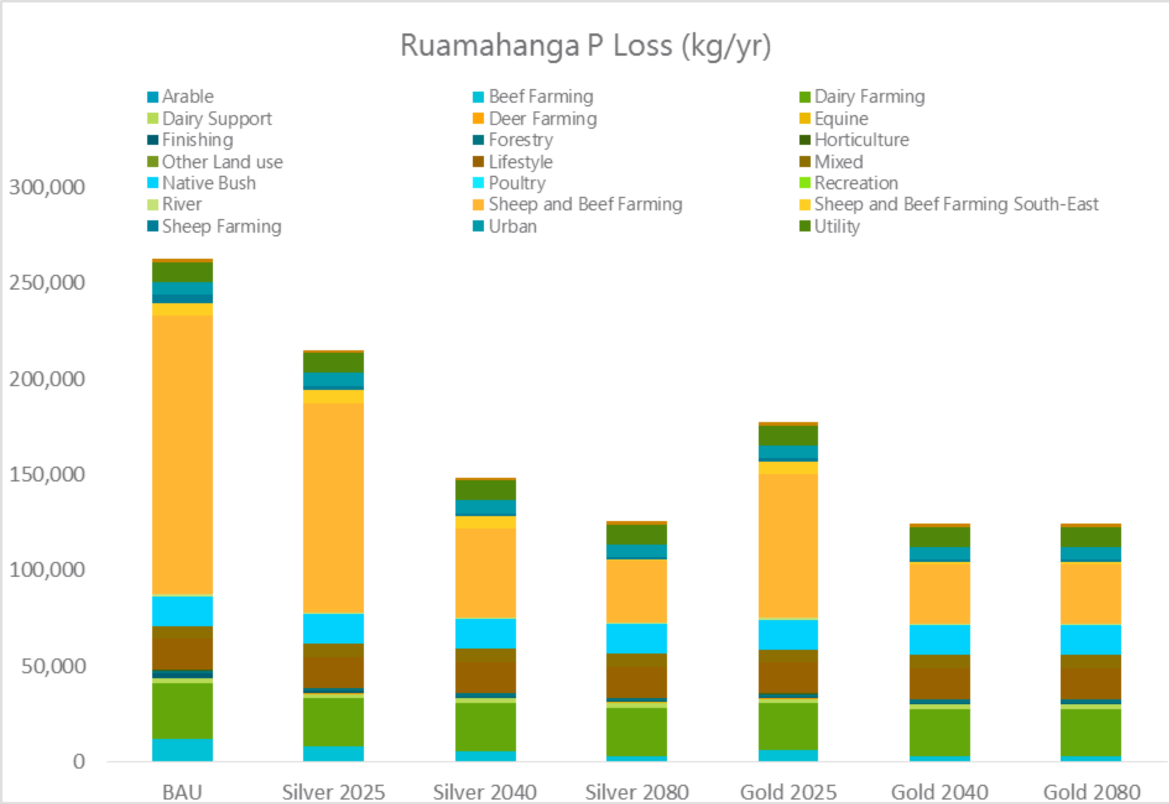

Figure A3.3: P loss (kg/yr) for disaggregated land use, by scenario.

Appendix 4 – Land Use Impacts for MfE Scenario Results

Table A4.1. Business as Usual (BAU) Scenario

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$59.5	$151.6	$242.6	1,184	900	28.7	8.0
Dairy Sup	10,008	$6.2	$15.5	$24.2	108	368	2.6	4.8
Sheep & Beef	165,132	$74.7	$167.4	$262.0	1,184	2,282	170.5	614.4
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7.1
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	1.8
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6.2
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0.1
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24.1
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	381.7
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	1.6
Other	20,972	$192.5	$383.5	$608.5	0	404	33.4	10.8
Total	**359,103**	**$192.5**	**$383.5**	**$608.5**	**3,067**	**4,843**	**262.7**	**1,061**

Table A4.2. Hill and Lowland Cropping Scenario – Option 1: M2 – arable, hort, livestock

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$51.8	$148.7	$237.9	1,161	698	25.7	7
Dairy Sup	10,008	$6.0	$15.0	$23.5	105	306	2.5	5
Sheep & Beef	165,132	$60.8	$165.1	$258.3	1,168	2,065	155.2	502
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,658	$1.3	$4.0	$6.3	28	44	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$170.2**	**$377.8**	**$599.4**	**3,025**	**4,359**	**244.3**	**947**

Table A4.3. Hill and Lowland Cropping Scenario – Option 1: M3 – Arable, Hort, Livestock

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$49.1	$145.8	$233.3	1,139	706	25.4	5
Dairy Sup	10,008	$5.9	$14.9	$23.2	104	306	2.3	5
Sheep & Beef	165,132	$54.0	$159.9	$250.1	1,131	2,073	51.0	306
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,658	$1.0	$4.1	$6.4	29	44	0.5	1
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$160.2**	**$369.6**	**$586.6**	**2,966**	**4,374**	**139.4**	**749**

Table A4.4. Hill and Lowland Cropping Scenario – Option 2: M2 – Arable, Hort, Livestock with FEP

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$50.9	$148.7	$237.9	1,161	628	21.8	3
Dairy Sup	10,008	$5.7	$15.0	$23.5	105	275	2.1	2
Sheep & Beef	165,132	$56.4	$165.1	$258.3	1,168	1,859	131.9	251
Other Animal	2,762	$2.3	$5.9	$10.1	50	45	0.3	4
Arable	1,658	$1.2	$4.0	$6.3	28	40	0.5	1
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.1	$21.3	$36.5	241	18	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$164.3**	**$377.8**	**$599.4**	**3,025**	**4,040**	**216.6**	**686**

Table A4.5. Hill and Lowland Cropping Scenario – Option 2: M3 – Arable, Hort, Livestock with FEP

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$48.2	$145.8	$233.3	1,139	635	21.6	2
Dairy Sup	10,008	$5.5	$14.9	$23.2	104	275	1.9	2
Sheep & Beef	165,132	$49.6	$159.9	$250.1	1,131	1,866	43.3	153
Other Animal	2,762	$2.3	$5.9	$10.1	50	45	0.3	4
Arable	1,658	$1.0	$4.1	$6.4	29	40	0.4	1
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.1	$21.3	$36.5	241	18	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$154.3**	**$369.6**	**$586.6**	**2,966**	**4,055**	**127.5**	**587**

Table A4.6. Hill and Lowland Cropping Scenario – Option 3: M2 – Arable, Hort, Livestock with FEP + Retire High LUC

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$47.8	$138.9	$222.3	1,085	587	20.5	3
Dairy Sup	10,008	$5.5	$14.6	$22.7	102	265	2.1	2
Sheep & Beef	165,132	$54.0	$158.7	$248.3	1,123	1,744	123.1	238
Other Animal	2,762	$2.3	$5.9	$10.1	50	45	0.3	4
Arable	1,658	$1.2	$4.0	$6.3	28	40	0.5	1
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$12.6	$20.3	$34.8	230	17	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$158.2**	**$360.1**	**$571.4**	**2,889**	**3,875**	**206.4**	**673**

Table A4.7. Hill and Lowland Cropping Scenario – Option 3: M3 – Arable, Hort, Livestock with FEP + Retire High LUC

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$45.2	$136.3	$218.0	1,064	594	20.2	2
Dairy Sup	10,008	$5.4	$14.4	$22.5	101	265	1.9	2
Sheep & Beef	165,132	$47.5	$153.6	$240.4	1,088	1,751	41.3	145
Other Animal	2,762	$2.3	$5.9	$10.1	50	45	0.3	4
Arable	1,658	$1.0	$4.1	$6.4	29	40	0.4	1
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$12.6	$20.3	$34.8	230	17	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$148.6**	**$352.4**	**$559.1**	**2,833**	**3,889**	**124.0**	**579**

Table A4.8. Stock Exclusion Scenario – Option 1: Exclusion on SU > 18, LUC 1–5 & 1+ m wide streams

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$59.8	$151.6	$242.6	1,184	928	32.8	10
Dairy Sup	10,008	$6.2	$15.5	$24.2	108	374	2.8	6
Sheep & Beef	165,132	$83.0	$167.4	$262.0	1,184	2,284	173.4	791
Other Animal	2,762	$2.5	$5.9	$10.1	50	50	0.3	9
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$201.4**	**$375.7**	**$595.1**	**2,979**	**4,878**	**269.8**	**1,242**

Table A4.9. Stock Exclusion Scenario – Option 2: 3m Setback on SU > 18 OR LUC 1–5 & Exclusion on LUC 6–8

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$58.8	$150.0	$240.0	1,172	891	28.4	8
Dairy Sup	10,008	$6.1	$15.4	$24.0	107	366	2.6	5
Sheep & Beef	165,132	$74.2	$165.8	$259.4	1,173	2,262	169.1	606
Other Animal	2,762	$2.4	$5.9	$10.0	50	50	0.3	8
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$191.3**	**$372.3**	**$589.7**	**2,954**	**4,811**	**261.0**	**1,053**

Table A4.10. Stock Exclusion Scenario – Option 3: 5m Setback on SU > 18 OR LUC 1–5 & Exclusion on LUC 6–8

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$58.4	$148.9	$238.3	1,163	885	28.2	8
Dairy Sup	10,008	$6.1	$15.3	$23.8	107	364	2.6	5
Sheep & Beef	165,132	$73.7	$164.7	$257.6	1,165	2,248	168.0	603
Other Animal	2,762	$2.4	$5.9	$10.0	50	49	0.3	8
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$190.4**	**$370.0**	**$586.1**	**2,937**	**4,790**	**259.7**	**1,050**

Table A4.11. Stock Exclusion Scenario – Option 4: 5-m Setback on all slopes; All Dairy, all eligible S&B (14 SU)

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$58.1	$148.2	$237.2	1,158	880	28.0	8
Dairy Sup	10,008	$6.1	$15.3	$23.8	107	363	2.6	5
Sheep & Beef	165,132	$74.0	$163.6	$256.0	1,157	2,235	167.2	628
Other Animal	2,762	$2.4	$5.8	$10.0	50	49	0.3	8
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$190.4**	**$368.2**	**$583.2**	**2,924**	**4,770**	**258.7**	**1,076**

Table A4.12. Stock Exclusion Scenario – Option 4: 5-m Setback on all slopes; All Dairy, all eligible S&B (18 SU)

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$58.2	$148.3	$237.3	1,159	880	28.0	8
Dairy Sup	10,008	$6.1	$15.3	$23.8	107	364	2.6	6
Sheep & Beef	165,132	$77.3	$164.7	$257.6	1,165	2,248	169.0	710
Other Animal	2,762	$2.4	$5.8	$10.0	50	49	0.3	9
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$193.8**	**$369.4**	**$585.2**	**2,932**	**4,785**	**260.6**	**1,159**

Table A4.13. Stock Exclusion Scenario – Option 5: 5-m Setback on all slopes (+/- 7 deg); All Dairy, all eligible S&B (18 SU)

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$57.3	$146.1	$233.8	1,141	868	27.6	8
Dairy Sup	10,008	$6.1	$15.3	$23.9	107	369	2.7	6
Sheep & Beef	165,132	$77.9	$164.9	$258.0	1,167	2,252	169.7	719
Other Animal	2,762	$2.4	$5.9	$10.0	50	49	0.3	9
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$193.7**	**$367.5**	**$582.1**	**2,917**	**4,782**	**260.9**	**1,168**

Table A4.14. Wetland Management Scenario – Option 1: 5-m fencing

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$58.9	$150.3	$240.5	1,174	892	28.5	8
Dairy Sup	10,008	$6.1	$15.5	$24.1	108	368	2.6	5
Sheep & Beef	165,132	$74.6	$167.2	$261.6	1,183	2,277	169.9	614
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$191.7**	**$374.1**	**$592.5**	**2,966**	**4,822**	**261.6**	**1,057**

Table A4.15. Stock Holding Area (SHA) Scenario – Option 1: SHA – All Stock

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$53.0	$151.6	$242.6	1,184	675	24.4	7
Dairy Sup	10,008	$6.2	$15.5	$24.2	108	368	2.6	5
Sheep & Beef	165,132	$74.7	$167.4	$262.0	1,184	2,282	170.5	614
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$186.0**	**$383.5**	**$608.5**	**3,067**	**4,618**	**258.4**	**1,059**

Table A4.16. Stock Holding Area (SHA) Scenario – Option 2: SHA – All Stock

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$59.5	$151.6	$242.6	1,184	900	28.7	8
Dairy Sup	10,008	$5.1	$15.5	$24.2	108	276	2.2	4
Sheep & Beef	165,132	$74.7	$167.4	$262.0	1,184	2,282	170.5	614
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,658	$1.9	$4.0	$6.2	28	47	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$191.4**	**$383.5**	**$608.5**	**3,067**	**4,751**	**262.3**	**1,060**

Table A4.17. N Limit Scenario – Option 1: 70 kgN/ha

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$59.5	$151.6	$242.6	1,184	900	28.7	8
Dairy Sup	10,008	$6.0	$15.0	$23.5	105	319	2.5	5
Sheep & Beef	164,893	$74.6	$167.2	$261.6	1,184	2,263	170.1	614
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,618	$1.9	$3.9	$6.1	28	39	0.5	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	11,587	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$192.2**	**$374.9**	**$593.9**	**2,976**	**4,768**	**262.1**	**1,060**

Table A4.18. N Limit Scenario – Option 1: 50 kgN/ha

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	29,983	$59.3	$151.4	$242.2	1,183	897	28.4	8
Dairy Sup	7,286	$6.0	$15.0	$23.5	105	317	2.5	5
Sheep & Beef	164,893	$74.7	$167.4	$261.9	1,184	2,277	170.4	614
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,618	$1.9	$4.0	$6.2	28	45	0.6	2
Mixed	16,744	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	14,417	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$192.2**	**$375.0**	**$594.0**	**2,975**	**4,782**	**262.3**	**1,060**

Table A4.19. N Limit Scenario – Option 1: 30 kgN/ha

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	21,121	$47.2	$126.4	$202.4	1,021	650	24.5	6
Dairy Sup	6,085	$6.0	$15.0	$23.5	105	313	2.5	5
Sheep & Beef	164,893	$74.7	$167.4	$261.9	1,184	2,276	170.4	614
Other Animal	2,762	$2.4	$5.9	$10.1	50	50	0.3	7
Arable	1,406	$1.5	$3.5	$5.6	27	36	0.5	1
Mixed	2	$27.6	$0.0	$0.0	0	653	6.9	6
Horticulture	2,352	$13.2	$13.5	$23.2	153	20	0.1	0
Forestry	41,433	$7.1	$17.7	$26.9	272	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	86	15.5	382
Water	12,223	$0.0	$0.0	$0.0	0	0	2.7	2
Other	20,972	$0.0	$0.0	$0.0	0	404	33.4	11
Total	**359,103**	**$179.8**	**$349.5**	**$553.5**	**2,812**	**4,521**	**258.2**	**1,058**

Table A4.20. Mitigation Combination – Option 1a

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$51.7	$147.4	$235.8	1,151	717	29.6	9
Dairy Sup	10,008	$6.1	$15.0	$23.4	105	310	2.6	6
Sheep & Beef	165,132	$68.9	$164.8	$257.9	1,166	2,062	157.5	678
Other Animal	2,762	$2.5	$5.9	$10.1	50	50	0.3	9
Arable	1,658	$1.3	$4.0	$6.3	28	44	0.6	2
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$178.2**	**$376.1**	**$596.8**	**3,012**	**4,373**	**250.2**	**1,126**

Table A4.21. Mitigation Combination – Option 1a – SHA

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$45.2	$147.4	$235.8	1,151	588	26	8
Dairy Sup	10,008	$5.0	$15.0	$23.4	105	255	2	6
Sheep & Beef	165,132	$57.3	$164.8	$257.9	1,166	1,691	140	619
Other Animal	2,762	$2.5	$5.9	$10.1	50	41	0	8
Arable	1,658	$1.3	$4.0	$6.3	28	36	1	2
Mixed	16,744	$27.5	$0.0	$0.0	0	534	6	6
Horticulture	2,352	$13.2	$29.1	$49.8	329	16	0	0
Forestry	11,310	$7.1	$17.7	$26.9	271	28	1	22
Native Bush	85,853	$0.0	$0.0	$0.0	0	70	14	346
Water	12,223	$0.0	$0.0	$0.0	0	0	2	1
Other	20,972	$0.0	$0.0	$0.0	0	327	29	10
Total	**359,103**	**$159.1**	**$383.9**	**$610.1**	**3,100**	**3,586**	**222**	**1,027**

Table A4.22 Mitigation Combination – Option 1b

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$48.9	$144.5	$231.2	1,128	726	29.3	7
Dairy Sup	10,008	$5.9	$14.8	$23.1	104	310	2.4	6
Sheep & Beef	165,132	$62.1	$159.6	$249.7	1,130	2,070	53.3	482
Other Animal	2,762	$2.5	$5.9	$10.1	50	50	0.3	9
Arable	1,658	$1.0	$4.1	$6.4	29	44	0.5	1
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$13.2	$21.3	$36.5	241	20	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$168.2**	**$368.0**	**$583.9**	**2,953**	**4,388**	**145.4**	**927**

Table A4.23. Mitigation Combination – Option 1b – SHA

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$42.4	$144.5	$231.2	1,128	595	26	6
Dairy Sup	10,008	$4.8	$14.8	$23.1	104	255	2	5
Sheep & Beef	165,132	$50.6	$159.6	$249.7	1,130	1,697	47	440
Other Animal	2,762	$2.5	$5.9	$10.1	50	41	0	8
Arable	1,658	$1.0	$4.1	$6.4	29	36	0	1
Mixed	16,744	$27.5	$0.0	$0.0	0	534	6	6
Horticulture	2,352	$13.2	$29.1	$49.8	329	16	0	0
Forestry	11,310	$7.1	$17.7	$26.9	271	28	1	22
Native Bush	85,853	$0.0	$0.0	$0.0	0	70	14	346
Water	12,223	$0.0	$0.0	$0.0	0	0	0	0
Other	20,972	$0.0	$0.0	$0.0	0	327	29	10
Total	**359,103**	**$149.1**	**$375.8**	**$597.3**	**3,041**	**3,599**	**129**	**846**

Table A4.24. Mitigation Combination – Option 2a

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$49.8	$145.7	$233.2	1,138	615	22.1	4
Dairy Sup	10,008	$5.7	$14.9	$23.2	104	273	2.1	3
Sheep & Beef	165,132	$59.3	$163.1	$255.3	1,154	1,834	131.2	349
Other Animal	2,762	$2.4	$5.9	$10.0	50	45	0.3	6
Arable	1,658	$1.2	$4.0	$6.3	28	40	0.5	1
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$13.1	$21.3	$36.5	241	18	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$166.1**	**$372.7**	**$591.3**	**2,987**	**3,994**	**215.8**	**785**

Table A4.25. Mitigation Combination – Option 2a – SHA

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$34.7	$153.3	$245.3	1,197	438	17	4
Dairy Sup	10,008	$3.1	$15.7	$24.4	109	194	2	2
Sheep & Beef	165,132	$32.3	$171.3	$268.0	1,212	1,306	102	288
Other Animal	2,762	$2.4	$5.9	$10.0	50	32	0	5
Arable	1,658	$1.2	$4.0	$6.3	28	28	0	1
Mixed	16,744	$27.5	$0.0	$0.0	0	464	5	5
Horticulture	2,352	$13.1	$29.1	$49.8	329	13	0	0
Forestry	11,310	$7.1	$17.7	$26.9	271	24	1	20
Native Bush	85,853	$0.0	$0.0	$0.0	0	61	12	313
Water	12,223	$0.0	$0.0	$0.0	0	0	0	0
Other	20,972	$0.0	$0.0	$0.0	0	327	29	10
Total	**359,103**	**$121.4**	**$397.0**	**$630.8**	**3,197**	**3,599**	**129**	**846**

Table A4.26. Mitigation Combination – Option 2b

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$47.1	$142.9	$228.6	1,116	623	21.8	3
Dairy Sup	10,008	$5.5	$14.7	$22.9	103	273	1.9	3
Sheep & Beef	165,132	$52.5	$157.9	$247.1	1,118	1,841	42.6	251
Other Animal	2,762	$2.4	$5.9	$10.0	50	45	0.3	6
Arable	1,658	$1.0	$4.1	$6.4	29	40	0.4	1
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$13.1	$21.3	$36.5	241	18	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$156.1**	**$364.5**	**$578.5**	**2,927**	**4,008**	**126.6**	**686**

Table A4.27. Mitigation Combination – Option 2b – SHA

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$31.9	$150.4	$240.7	1,175	444	17	3
Dairy Sup	10,008	$3.0	$15.5	$24.2	108	194	2	2
Sheep & Beef	165,132	$25.5	$166.1	$259.9	1,176	1,311	33	207
Other Animal	2,762	$2.4	$5.9	$10.0	50	32	0	5
Arable	1,658	$1.0	$4.1	$6.4	29	28	0	0
Mixed	16,744	$27.5	$0.0	$0.0	0	464	5	5
Horticulture	2,352	$13.1	$29.1	$49.8	329	13	0	0
Forestry	11,310	$7.1	$17.7	$26.9	271	24	1	20
Native Bush	85,853	$0.0	$0.0	$0.0	0	61	12	313
Water	12,223	$0.0	$0.0	$0.0	0	0	0	0
Other	20,972	$0.0	$0.0	$0.0	0	327	29	10
Total	**359,103**	**$111.4**	**$388.8**	**$617.9**	**3,137**	**2,897**	**100**	**565**

Table A4.28. Mitigation Combination – Option 3a

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$46.3	$134.9	$215.8	1,054	568	20.5	4
Dairy Sup	10,008	$5.5	$14.3	$22.4	100	262	2.0	3
Sheep & Beef	165,132	$56.5	$155.6	$243.5	1,102	1,706	121.3	334
Other Animal	2,762	$2.4	$5.8	$10.0	50	44	0.3	6
Arable	1,658	$1.2	$4.0	$6.3	28	40	0.5	1
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$12.6	$20.3	$34.8	230	17	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$159.0**	**$352.8**	**$559.7**	**2,834**	**3,806**	**204.2**	**769**

Table A4.29. Mitigation Combination – Option 3a – SHA

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$31.1	$142.5	$228.0	1,113	405	16	3
Dairy Sup	10,008	$2.9	$15.1	$23.6	105	186	2	2
Sheep & Beef	165,132	$29.5	$163.8	$256.3	1,159	1,215	94	275
Other Animal	2,762	$2.4	$5.8	$10.0	50	32	0	5
Arable	1,658	$1.2	$4.0	$6.3	28	28	0	1
Mixed	16,744	$27.5	$0.0	$0.0	0	464	5	5
Horticulture	2,352	$12.6	$28.1	$48.1	318	12	0	0
Forestry	11,310	$7.1	$17.7	$26.9	271	24	1	20
Native Bush	85,853	$0.0	$0.0	$0.0	0	61	12	313
Water	12,223	$0.0	$0.0	$0.0	0	0	0	0
Other	20,972	$0.0	$0.0	$0.0	0	327	29	10
Total	**359,103**	**$114.3**	**$377.1**	**$599.1**	**3,044**	**2,754**	**160**	**634**

Table A4.30. Mitigation Combination – Option 3b

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$43.7	$132.2	$211.5	1,033	575	20.2	3
Dairy Sup	10,008	$5.3	$14.2	$22.1	99	262	1.9	3
Sheep & Beef	165,132	$49.9	$150.6	$235.7	1,066	1,713	39.5	241
Other Animal	2,762	$2.4	$5.8	$10.0	50	44	0.3	6
Arable	1,658	$1.0	$4.1	$6.4	29	40	0.4	1
Mixed	16,744	$27.5	$0.0	$0.0	0	651	6.8	6
Horticulture	2,352	$12.6	$20.3	$34.8	230	17	0.1	0
Forestry	11,310	$7.1	$17.7	$26.9	271	34	1.5	24
Native Bush	85,853	$0.0	$0.0	$0.0	0	85	15.3	379
Water	12,223	$0.0	$0.0	$0.0	0	0	2.6	2
Other	20,972	$0.0	$0.0	$0.0	0	399	33.2	11
Total	**359,103**	**$149.4**	**$345.0**	**$547.4**	**2,777**	**3,820**	**121.9**	**675**

Table A4.31. Mitigation Combination – Option 3b – SHA

Land Use	Area (ha)	Net Farm Revenue ($ mil)	Fam Tot Revenue ($ mil)	Reg Output ($ mil)	Reg Employ (#)	N leaching (t)	P loss (t)	Sed (kt)
Dairy	30,090	$28.5	$139.8	$223.7	1,092	410	16	3
Dairy Sup	10,008	$2.8	$14.9	$23.3	104	186	1	2
Sheep & Beef	165,132	$22.9	$158.8	$248.4	1,124	1,220	31	199
Other Animal	2,762	$2.4	$5.8	$10.0	50	32	0	5
Arable	1,658	$1.0	$4.1	$6.4	29	28	0	0
Mixed	16,744	$27.5	$0.0	$0.0	0	464	5	5
Horticulture	2,352	$12.6	$28.1	$48.1	318	12	0	0
Forestry	11,310	$7.1	$17.7	$26.9	271	24	1	20
Native Bush	85,853	$0.0	$0.0	$0.0	0	61	12	313
Water	12,223	$0.0	$0.0	$0.0	0	0	0	0
Other	20,972	$0.0	$0.0	$0.0	0	327	29	10
Total	**359,103**	**$104.7**	**$369.3**	**$586.8**	**2,988**	**2,763**	**96**	**556**