Estimated on-farm economic impacts of selected mitigation options

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Perrin Ag Consultants Ltd

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1. Introduction

There is a significant range of farm systems and land uses across New Zealand. Each of these businesses has a unique combination of biophysical factors (e.g. climate and soil) as well as farm management (including system decisions, management skill levels and ownership structures). Therefore, when each farm tries to mitigate its contaminant losses to water, a specific mitigation action can have a wide variation of economic impacts and benefits on any specific farm, even within the same region and land use category.

To estimate the on-farm economic impact of mitigation strategies, the difference in economic impact should be considered across the range of applicable land uses as well as across a range of biophysical factors and farm management types. For example, to estimate the impact of proposed regulation on farms in Southland, the *Southland Economic Joint Venture* considered 41 dairy farms in order to capture a reasonable range of farm system and biophysical factors (Moran et al., 2019) across the approximate 980 dairy farms in Southland. However, this type of estimate is incredibly time consuming and data hungry.

When there is not the scope and capacity to undertake this level of economic analysis an alternative is to draw on the best estimates of on-farm economic impacts available through existing literature. The key challenge with this method is that these estimates are not always consistent, or clear, across studies in relation to underlying assumptions including what costs are included or excluded and how the mitigation has been applied on any specific type of farm. This makes them challenging to extrapolate and caution should be taken when extrapolating data generated using this method.

Another challenge with estimating on farm economic impacts is that farm systems are a complex biophysical system which requires feed supply and demand to be balanced across all sources within a farm, through a season and between seasons. For this reason, any mitigations which impact feed demand (related particularly to stock and production) or feed supply (including bought in and home-grown supplement), should be modelled in specialist software which enables a user to ensure a viable farm system is maintained.

Regardless of which method is employed to estimate the economic impacts of strategies to mitigate contaminant losses to water, all assumptions should be clearly stated and where possible, a breakdown of cost components should be provided. This will help users to understand how it is appropriate to utilize these estimates of on-farm impacts.

Perrin Ag Consultants Ltd (Perrin Ag) has been engaged by the Ministry for the Environment (MfE) to estimate the on-farm economic impact of a range of specified mitigation strategies. These mitigation strategies were pre-determined, and every effort has been made to align the economic assumptions with the assumptions made in relation to estimates of the benefits on contaminants and the macro scale economic modelling being undertaken. Perrin Ag has utilized existing literature as well as expertise in agricultural economics and farm systems to provide these estimates of on-farm economic impacts. However, no specific farm systems modelling was included in the project scope. In addition, Perrin Ag cannot be responsible for how the economic impacts provided in this report are utilized and extrapolated into other models, including how they are extrapolated across New Zealand. However, Perrin Ag has, where appropriate, made every effort to provide clarity on the assumptions underlying the estimates on on-farm economic impacts which will help in considering how these impacts can be extrapolated.

Initially, some general assumptions are provided which apply across all mitigation strategies, unless otherwise stated. Following this, mitigation strategies are considered in groupings based on which contaminant is being targeted.

For ease, the on-farm economic impacts are also referred to as costs for the rest of this report. However, where there are positive economic impacts on-farm, these are also noted.

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2. General Assumptions

The following assumptions apply to all mitigation strategies, unless explicitly stated elsewhere.

- The mitigation strategies were pre-determined (based on associated work completed by MfE), and every effort has been made to align the economic assumptions with the assumptions made in relation to estimates of the benefits on contaminants and the macro scale economic modelling being undertaken. Details of how the mitigation options were considered from an on-farm economic impact perspective are detailed for each mitigation.
- This report makes no assumptions about the current or future rates of adoption of each mitigation, or therefore, how these costs should be extrapolated. The costs are provided on the most appropriate per unit basis (e.g. per hectare, per meter or per mitigation etc.). How applicable or how widespread these are across the country is beyond the scope of this report. However, Perrin Ag has, where appropriate, made every effort to provide clarity on the assumptions underlying the cost estimates which will help in considering how these costs can be extrapolated.
- Perrin Ag has utilized existing literature as well as expertise in agricultural economics to provide these estimates of on-farm economic impacts. No specific farm systems modelling was included in the project scope, although the firm's underlying expertise in farm systems has been applied to ensure the application of mitigations make sense.
- Given that existing literature forms the basis of some of these economic impacts, care has been taken, where possible to provide the assumptions underlying these costs when including them in the results in this report. However, in some cases detailed information is not provided in relation to what costs are included or excluded, where studies are used that do not detail these assumptions this is noted.
- Where estimates of costs are provided but there is only one estimate available the minimum and maximum estimates were generated using a +/- 20% range. Where this has been applied, it is noted in each mitigation strategy.
- This report has attempted to consider the breadth of literature available on the on-farm economic impacts of applicable mitigation strategies. However, it is acknowledged that there are some studies which have not been included due to, for example, how benefits have been calculated. Studies that have no detailed breakdown of costs or assumptions were excluded where better information existed. Studies that consider costs as a dollars per unit of contaminant removed were considered where they present the best information, but expressing costs per unit of contaminant increases uncertainty when extrapolating results from this report as both the costs and benefits have uncertainty given the range of farm contexts.
- Care needs to be taken when considering how each cost category is presented. For example, for some industries, operating profit is the preferred metric, while others use earnings before interest and tax and the methodology behind metrics can be different, even if they are essentially measuring the same thing. In some cases there is enough detailed information to adjust these to the same basis, in other cases there is not and results are presented using the appropriate metric.
- Costs are 2019 New Zealand Dollars (2019 $NZD) and are GST (goods and services tax) exclusive. Where costs were extracted from other studies to adjust all values to 2019 $NZD, the Farm Expenses Price Index (FEPI) was used. Specifically, the FEPI- All Farms Excluding Livestock index. Prices were adjusted to 2019 Quarter 1. Where the data sources did not specify what dollar values they were using, quarter 1 of the year the study was published was assumed, which provides some minimisation of seasonal differences.

- Costs represent an indicative cost per unit, they are likely to vary based on specific site conditions. As such, estimates of minimum, average and maximum are presented. However, there is still likely to be considerable variation across specific farm contexts.
- Where applicable, cost estimates assume that solutions are implemented using best practices. For example, when fencing in flood prone areas best practices are followed such as, putting fence wires on the paddock and/or downstream side of posts so they pop their staples and drop rather than breaking and using un-barbed staples so wires can pop more easily. This will minimise maintenance costs.
- Where possible, more granular data has been included, for example costs per region relative to New Zealand aggregate data. This will enable more granular estimates of costs to be included where possible in any further modelling MfE undertakes, alternatively in further modelling MfE can chose how they aggregate these costs, for example by land use, or nationally based on the best fit for their models.
- No economic impact has been quantified for any impact these mitigations might have on land values.

3. Multiple Contaminants

3.1. Stream fencing

3.1.1. Definition

This mitigation refers to the fencing of waterways to prevent stock access. It works on the assumption of a five-meter buffer strip and excludes any costs of planting. The type of waterway to which it is applied is not considered in this report.

Electric two-wire fencing has been assumed as appropriate on dairy farms. Single wire electric fencing was not considered appropriate as it will not exclude young stock (calves) on dairy farms. A variety of fencing types may be needed on sheep and beef farms depending on factors such as stock type and terrain. This could range from two-wire electric on cattle farms while areas that are predominantly sheep will require eight-wire post and batten fencing. For the purpose of this work sheep and beef farm fencing estimates include eight-wire non-electric post and batten fence at the maximum estimate and an electric four-wire fence on flat land for the minimum estimate.

Three terrain types are considered which is considered a big driver in fencing cost. While there is likely to be some objection to fencing on steep slopes, the costs were included here given that how these costs are applied and to what terrain types is beyond the scope of this report. Providing this breakdown enables the steep costs to be excluded if appropriate.

The capital costs for fencing are sourced from The Agribusiness Group (2016) which is the most comprehensive study of fencing costs to date. These costs were adjusted to 2019 $NZD.

The most appropriate fencing costs from the information provided in this report should be applied to the relevant applicable farm types when extrapolating data. In addition, any extrapolation should consider how many waterways this applies to and exclude the proportion of waterways that are already fenced.

3.1.2. Capital cost

Table 1: Capital costs of fencing

	Capital cost of fencing ($/m)											
Land use type	Deer			Sheep/Cattle						Cattle		
Fencing type	Non-electric netting			Electric 4 wire			Non-electric 8 wire			Electric 2 wire		
Region	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep	Flat	Rolling	Steep
Northland	18.62	19.15	22.96	7.09	7.09	8.57	13.01	13.23	16.72	5.18	5.18	6.67
Auckland	22.54	23.28	30.26	7.94	8.36	10.79	15.87	16.29	22.75	5.40	5.40	7.72
Waikato	20.84	21.59	23.07	6.56	7.20	7.83	14.39	15.34	16.29	4.66	12.17	5.61
BOP	18.41	18.41	20.84	6.03	6.03	6.88	13.12	13.54	15.98	4.02	4.02	4.76
Gisborne	22.96	22.96	25.61	8.25	8.46	9.52	15.24	15.24	17.56	5.50	5.50	6.35
Hawke's Bay	20.53	20.95	25.39	7.72	8.04	11.53	14.28	15.34	19.47	5.18	5.18	7.41
Taranaki	21.06	23.70	27.41	6.24	6.35	8.36	13.65	14.50	16.61	4.44	4.66	5.93
Horizons	17.25	18.31	20.74	6.14	6.56	7.83	12.91	14.18	17.35	4.66	4.97	6.03
Greater Wellington	20.42	22.11	27.51	8.99	9.52	11.11	14.28	15.55	20.10	6.56	7.51	8.68
Marlborough	18.62	20.21	22.11	6.67	6.88	8.04	14.07	14.50	17.46	4.55	4.55	5.40
West Coast	20.53	21.06	24.44	5.71	6.35	8.36	15.98	16.51	20.00	5.61	5.61	6.88
Canterbury	16.40	17.46	21.06	5.82	6.45	8.46	11.75	12.38	14.81	3.60	3.81	4.44
Otago	20.95	21.90	26.03	6.35	7.20	9.21	13.54	13.97	17.25	4.34	5.29	6.98
Southland	16.40	16.51	20.00	4.97	4.97	6.35	10.79	11.00	12.59	3.81	3.81	4.87
NZ average	19.68	20.54	24.10	6.75	7.10	8.77	13.78	14.40	17.50	4.82	5.55	6.27

The New Zealand average is a simple (non-weighted) average across the regions provided. Using the New Zealand average a simplified cost estimate can be provided in the table below. The maximum applies to steep farm land, while the minimum is likely to apply to flat land.

Table 2: Simplified capital cost of fencing

	Capital Cost $/m		
Fencing type	Minimum estimate	Median	Maximum estimate
Dairy	4.82	5.54	6.27
Sheep and beef	6.75	12.12	17.50
Deer	19.68	21.89	24.10

3.1.3. Operational cost

There are two operational costs to be considered; maintenance and the ongoing lost opportunity cost from the land retired between the stream and the fence. A simplified operational cost of fencing is included in Table 3, which considers average New Zealand costs of land retirement. Table 4 provides the cost of land retirement by region and farm types (where available).

There is debate about the opportunity cost of land retirement with estimates ranging from 0% productive value to 100% (Daigneault, Eppink & Lee, 2017). In some instances the land will be relatively unproductive, or the land removed will not change the associated farm system (with the balance of the farm intensifying to compensate for the lost area). Given the discrepancy in the literature around this, the minimum estimate here is provided based on a 0% loss in productive value (i.e. the rest of the farm production remains at the same totals), while the maximum is based on a 100% loss in productive value, the average is based on 50%.

Table 3: Simplified operational cost of fencing

	Operational Cost (per year)		
	Minimum estimate	Median	Maximum estimate
Maintenance ($/m)	0.05	0.20	0.50
Land retirement – dairy (operating profit $/5m^2)	0.00	0.44	0.90
Land retirement – sheep and beef (farm profit before tax $/5m^2)	0.00	0.03	0.06
Land retirement – deer (farm profit before tax $/5m^2)	0.00	0.04	0.08

Table 4: Land retirement costs ($/5m^2) as part of stream fencing - breakdown by region and farm type (where available)

	Operational Cost (per year)		
Land retirement– dairy (operating profit $/5m^2)	Minimum estimate	Median	Maximum estimate
New Zealand	0.00	0.47	0.95
Northland	0.00	0.29	0.58
Waikato	0.00	0.46	0.93
Bay of Plenty	0.00	0.45	0.90
Taranaki	0.00	0.47	0.94
Lower North Island	0.00	0.41	0.82

West Coast Tasman	0.00	0.18	0.36
Marlborough-Canterbury	0.00	0.56	1.13
Otago Southland	0.00	0.51	1.02
North Island	0.00	0.43	0.87
South Island	0.00	0.49	0.97
Land retirement – sheep and beef (farm profit before tax $/5m^2)			
New Zealand (All classes)	0.00	0.03	0.06
Northern North Is. (Class 3 Hard Hill Country)	0.00	0.06	0.12
Northern North Is. (Class 4 Hill Country)	0.00	0.08	0.15
Northern North Is. (Class 5 Intensive finishing)	0.00	0.16	0.32
Northern North Is. (Class 9 All Classes)	0.00	0.08	0.16
Eastern North Is. (Class 3 Hard Hill Country)	0.00	0.05	0.10
Eastern North Is. (Class 4 Hill Country)	0.00	0.07	0.14
Eastern North Is. (Class 5 Intensive finishing)	0.00	0.08	0.16
Eastern North Is. (Class 9 All Classes)	0.00	0.07	0.13
Western North Is. (Class 3 Hard Hill Country)	0.00	0.04	0.08
Western North Is. (Class 4 Hill Country)	0.00	0.07	0.13
Western North Is. (Class 5 Intensive finishing)	0.00	0.08	0.17
Western North Is. (Class 9 All Classes)	0.00	0.06	0.11
Northern-Central South Is. (Class 1 High Country all regions)	0.00	0.01	0.01
Northern-Central South Is. (Class 2 Hill Country)	0.00	0.02	0.05
Northern-Central South Is. (Class 6 Finishing breeding)	0.00	0.05	0.11
Northern-Central South Is. (Class 8 Mixed finishing)	0.00	0.05	0.11
Northern-Central South Is. (Class 9 All Classes)	0.00	0.03	0.06
Southern South Is. (Class 1 High Country all regions)	0.00	0.01	0.01
Southern South Is. (Class 7 Intensive breeding)	0.00	0.11	0.22
Southern South Is. (Class 6 Finishing breeding)	0.00	0.06	0.12
Southern South Is. (Class 9 All Classes)	0.00	0.04	0.08

3.1.4. Assumptions

- The fence costs are based on the costs associated with a 1 kilometer fence with 9 angle assemblies and 1 gateway assembly (at one end of the fence). If another option is chosen, then the costs may differ.
- It is assumed that where relevant, fence posts are spaced at 4 meters for non-electric fences and 10 meters for electric fences.
- Fence costs for flat to rolling contour assume a post driver can be used.
- Fencing costs are based on reasonable ground conditions, anything on rocky, swampy or extremely heavy clay soils may increase costs.
- These costs do not include additional stock water reticulation costs.
- If land retirement costs are included they should not be also included when considering vegetated buffer strips as this would double count the cost of the retired land area.
- Maintenance refers only to fencing, for maintenance of riparian planting, e.g. weed spraying, see vegetated riparian buffers.

- Land retirement costs for sheep and beef and dairy are based on 5-year average annual profit, translated from operating profit per hectare to 5m^2. This metric was chosen as for every one meter of fencing, the retired area is five meters wide. The minimum is based on no loss of productive area, the median is based on 50% loss of production on the relevant land area and the maximum is based on 100% loss of production on the relevant land area.
- For deer, farm profit before tax is based on Moran et al. (2019) which estimates profit from deer farms in Southland for 2013-14. While this is not a national or long term average, there is no database of deer farm profitability and as such this was considered the next best option.

3.1.5. References

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3.2. Vegetated buffer strip

3.2.1. Definition

This mitigation refers to the planting of an area of land, typically between a waterway and a fence (as considered in the stream fencing mitigation). The costs for this therefore only include the costs associated with vegetation. In order to estimate the total cost of fencing a waterway and planting a riparian buffer, the costs from this mitigation and the stream fencing mitigation (section 3.1) should be added together to include the total cost of planting, fencing and land retirement and the relevant assumptions and references from section 3.1 also apply). Based on this, these costs apply to a five-meter vegetated buffer strip (which aligns with the stream fencing mitigation).

3.2.2. Capital cost

The capital costs included here relate to planting only. These costs will not apply if the vegetated buffer strip is not planted and is for example left as rank grass.

Table 5: Capital cost of planting a vegetated buffer strip

	Capital Cost $/m^2		
	Minimum estimate	Median	Maximum estimate
Vegetated buffer strip, planting	3.70	4.20	6.40

3.2.3. Operational cost

The operational costs considered here relate solely to maintaining the plantings in the vegetated buffer strip. They exclude the ongoing maintenance of fencing and the loss of productive land (see section 3.1.).

Table 6: Operational cost of a vegetated buffer strip (plantings only)

	Operational Cost ($/m^2/ year)		
	Minimum estimate	Median	Maximum estimate
Maintenance	1.00	1.47	1.87

3.2.4. Assumptions

- Assumptions are made that the vegetated buffer strip is five-meters wide.
- Costs per plant include the cost of plants and ground preparation and are priced using mostly native plants as a base. Additional costs such as plant protection guards and weed-matting costs are excluded.
- Plant spacing is based on 1.5m per plant and the range is based off typical pot sizes; while not a direct correlation, typically smaller pots include plants like sedges and flaxes whereas the larger pots include plants more like trees.
- Maintenance is calculated based on a cost per plant and the number of plants per square meter.

3.2.5. References

The Agribusiness Group (TAG). (2016). Ministry for Primary Industries Stock Exclusion Costs Report. Report prepared for Ministry for Primary Industries. Available from https://www.mpi.govt.nz/dmsdocument/16537-ministry-for-primary-industries-stock-exclusion-costs-report

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3.3. Wetlands (constructed and natural seepage)

3.3.1. Definition

Wetlands are a challenging mitigation to price as they are incredibly context specific, largely depending on the amount of earthworks that are required. Two key types of wetlands are priced, constructed wetlands and natural seepage (or facilitated) wetlands. In this context natural seepage wetlands represent restoring areas that are old wetlands or are partially acting as wetland areas already, these require minimal earthworks to construct. Costs are based on wetland less than one hectare in size. Costs for wetlands over 1 hectare should be based on the base cost (wetlands up to 1 hectare) and the relationship described in Kadlec & Wallace (2009), which is defined as reference price x $area^{0.69}$.

The different types of wetlands considered here should not be extrapolated together, i.e. in the same location. For example you cannot apply a constructed wetland in the same place as a natural seepage wetland. Care should also be taken to consider the extent of existing wetlands when extrapolating the costs and benefits from these mitigations.

3.3.2. Capital cost

The capital costs of constructing wetlands are included in Table 7. These include the construction costs, fencing costs (using simplified New Zealand average capital costs of fencing) and planting of the area around the wetland.

Table 7: Capital costs of wetland construction

	Capital Cost		
	Minimum estimate	Median	Maximum estimate
Constructed wetlands ($/m^2)	13.00	15.50	20.00
Natural seepage wetlands ($/m^2)	6.60	8.00	10.00
Fencing Dairy ($/m)	4.82	5.54	6.27
Fencing Sheep and beef ($/m)	6.75	12.12	17.50
Fencing Deer ($/m)	19.68	21.89	24.10
Vegetated buffer strip, planting ($/m^2)	3.70	4.20	6.40

3.3.3. Operational cost

The operational costs presented here include the maintenance of the wetland and planting but exclude maintenance of fencing (see section 3.1). The ongoing cost related to the loss of productive land is included here, it uses the same base data as in section 3.1 but presents the data on a per hectare value. It should be noted that these values are presented as per hectare of wetland, other studies use per hectare of catchment values and care should be taken when comparing estimates.

Table 8: Simplified operational cost of wetland

	Operational Cost ($/ha of wetland per year)		
	Minimum estimate	Median	Maximum estimate
Maintenance	50	200	300
Land retirement – dairy (operating profit)	0	900	1,800
Land retirement – sheep and beef (farm profit before tax)	0	58	117
Land retirement – deer (farm profit before tax)	0	78	156

Table 9: Land retirement costs ($ha^2) as part of stream fencing - breakdown by region and farm type (where available)

	Operational Cost (per year)		
Land retirement– dairy (operating profit $/ha of wetland)	Minimum estimate	Median	Maximum estimate
New Zealand	0	900	1,799
Northland	0	579	1,159
Waikato	0	928	1,855
Bay of Plenty	0	897	1,795
Taranaki	0	942	1,884
Lower North Island	0	825	1,650
West Coast Tasman	0	365	729
Marlborough-Canterbury	0	1,126	2,253
Otago Southland	0	1,025	2,050
North Island	0	865	1,731

South Island	0	971	1,941
Land retirement – sheep and beef (farm profit before tax $/ha of wetland)			
New Zealand (All classes)	0	59	117
Northern North Is. (Class 3 Hard Hill Country)	0	118	236
Northern North Is. (Class 4 Hill Country)	0	150	300
Northern North Is. (Class 5 Intensive finishing)	0	316	632
Northern North Is. (Class 9 All Classes)	0	157	314
Eastern North Is. (Class 3 Hard Hill Country)	0	102	204
Eastern North Is. (Class 4 Hill Country)	0	142	284
Eastern North Is. (Class 5 Intensive finishing)	0	157	313
Eastern North Is. (Class 9 All Classes)	0	131	262
Western North Is. (Class 3 Hard Hill Country)	0	83	166
Western North Is. (Class 4 Hill Country)	0	133	266
Western North Is. (Class 5 Intensive finishing)	0	165	330
Western North Is. (Class 9 All Classes)	0	113	226
Northern-Central South Is. (Class 1 High Country all regions)	0	14	28
Northern-Central South Is. (Class 2 Hill Country)	0	50	99
Northern-Central South Is. (Class 6 Finishing breeding)	0	108	217
Northern-Central South Is. (Class 8 Mixed finishing)	0	107	215
Northern-Central South Is. (Class 9 All Classes)	0	58	116
Southern South Is. (Class 1 High Country all regions)	0	14	28
Southern South Is. (Class 7 Intensive breeding)	0	219	438
Southern South Is. (Class 6 Finishing breeding)	0	120	240
Southern South Is. (Class 9 All Classes)	0	81	163

3.3.4. Assumptions

- Land retirement has been included here but it must be noted that estimates in the literature for this range from 0% to 100% loss of productivity for land retired in the buffer.
- Assume surface drainage wetlands not sub-surface for constructed wetlands
- Land retirement costs are based on 5-year average annual profit. The minimum is based on no loss of productive area, the median is based on 50% loss of production on the relevant land area and the maximum is based on 100% loss of production on the relevant land area.
- The maintenance costs presented here include the maintenance of the wetland and planting but exclude maintenance of fencing (see section 3.1).
- The construction costs of the wetlands include earthworks and design but not consent costs. The fencing and planting included as separate options to be added in.
- Costs are based on a wetland of less than or equal to 1 hectare in size. As per Kadlec & Wallace (2009) the cost relationship changes for wetlands over 1 hectare in size due to economies of scale.
- Planting assume same assumptions as previous the vegetated buffer strips (section 3.2).

3.3.5. References

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3.4. Preventing fence line pacing (deer only)

3.4.1. Definition

There are two primary options for this mitigation. One is to provide a vegetated screen between two paddocks (including another fence) and the second is to use electric wands. Costs for both are provided here although the most appropriate one to align with the estimates of benefits should be used. If a vegetative barrier is used the cost of planting, fencing and loss of productive area need to be considered. If a vegetated screen is used the vegetation must be tall and thick enough to screen the view of the deer from the neighboring paddock. If using electric wands construction and maintenance need to be included and are only suitable where an electric supply can be accessed. In addition, it should be applied on both sides of the fence where stock are in adjacent paddocks.

3.4.2. Capital cost

Table 10: Capital cost of vegetated screen to prevent fence pacing

	Capital Cost		
	Minimum estimate	Median	Maximum estimate
Fencing ($/m)	19.68	20.54	24.10
Planting ($/m^2)	5.50	6.25	9.60

Table 11: Capital cost of electric wands to prevent fence pacing

	Capital Cost ($/m)		
	Minimum estimate	Median	Maximum estimate
Wands (both sides)	0.35	0.44	0.53
Installation	1.28	1.60	1.92
Total	1.63	2.04	2.45

3.4.3. Operational cost

Table 12: Operational cost of vegetated screen to prevent fence pacing

	Operational Cost		
	Minimum estimate	Median	Maximum estimate
Maintenance (fencing) ($/m)	0.05	0.20	0.50
Maintenance (planting) ($/m^2)	1.00	1.47	1.87
Land retirement – deer ($/2m^2)	$0	0.02	0.03

Table 13: Operational cost of electric wands to prevent fence pacing

	Operational Cost		
	Minimum estimate	Median	Maximum estimate
Maintenance (fencing) ($/m)	$0.05	$0.20	$0.50

3.4.4. Assumptions

- For vegetated screens, trees and/or shrubs are planted at 1-meter spacing to ensure an adequate screen is created.
- While it is possible that some trees/shrubs could provide fodder, this is unlikely with deer netting to be significant.
- The vegetated screen assumes a buffer width of 2-meters and the existing fence line is suitable to provide one side of the buffer and only one new line of fencing is required.
- The costs per plant include the cost of plants and ground preparation and are priced using mostly native plants as a base. Additional costs such as plant protection guards and weed-matting are not included.
- Maintenance for vegetated buffer screens is calculated based on a cost per plant and the number of plants per square meter.
- The same assumptions apply to fencing as in section 3.1.
- The land retirement is based on the range of 0% to 100% loss in productive area (see section 3.1).
- The costs associated with electric wands are based on Stewart (2018) and assume no change in price based on changes in demand or location.
- It is assumed that wands are required on both sides of the deer fence and the existing deer fence can be retained. Therefore, the new capital costs relate to the electric wand itself (which are attached to each post, assuming posts are spaced at 20-meters), an electric wire and outriggers to attached to the existing fence, and labour to install these.
- No additional electricity costs are included and a suitable electric supply is assumed.
- The costs of the electric wire and labour to install this are based on one third of the costs for a 2-wire electric dairy fence (including only the wire of materials and a proportion of time).

- Given there is only one estimate of costs for this mitigation, min and max estimates are based on +/- 20% of the average.

3.4.5. References

The Agribusiness Group (TAG). (2016). Ministry for Primary Industries Stock Exclusion Costs Report. Report prepared for Ministry for Primary Industries. Available from https://www.mpi.govt.nz/dmsdocument/16537-ministry-for-primary-industries-stock-exclusion-costs-report

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3.5. Sediment traps

3.5.1. Definition

There is very limited information on the breakdown of costs associated with sediment traps. In addition, the costs will be highly variable based largely on each site and the required earthworks. Given this limited information, highly variable costs and scope of this report, Daigneault and Elliot (2017) was used, despite the lack of clarity available on the assumptions underpinning the cost estimates in their work. Extreme caution should be used when extrapolating these costs as it is not clear what is included or what type of sediment trap has been priced. Because of the lack of clarity on cost components, it is unclear what costs are included or how these may vary across farms. Given there is only one estimate of costs for this mitigation, minimum and maximum estimates are based on +/- 20% of the average.

3.5.2. Capital cost

Daigneault and Elliot (2017) included initial capital and periodic maintenance costs as annualised estimates, over a 25 years using a discount rate of 8%. As there is no breakdown on what is capital and what is periodic maintenance, these could not be separated out. In addition, there is no clarity if costs per hectare relate to hectare of catchment or catchment of sediment trap. It is assumed that it is cost per hectare of catchment which drains into the sediment trap.

Table 14: Annualised capital cost and periodic maintenance of sediment traps

	Annualised cost ($/ha/yr)		
	Minimum estimate	Median	Maximum estimate
Dairy	58	73	88
Sheep and beef	30	37	44

3.5.3. Operational cost

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. However, the annual operational impact is based on a percentage reduction in earnings before interest and tax (EBIT). This is detailed in Daigneault and Elliot (2017) as $3,418 net farm revenue per hectare per year for dairy and $127 for sheep and beef farms.

While the 20% reduction in EBIT seems high for sheep and beef farms, there are no detailed assumptions in Daigneault and Elliot (2017) that can be validated. Without this information, the median cost is based on what is in Daigneault and Elliot (2017), while the minimum and maximum are based on +/- 20%.

Table 15: Operational cost of sediment traps

	Reduction in EBIT (%)		
	Minimum estimate	Median	Maximum estimate
Dairy	-1.6	2.0	2.4
Sheep and beef	-16	-20	-24

3.5.4. Assumptions

- Costs are adjusted to 2019 $NZD.
- Costs are not adjusted based on components as no information on cost components was available. The operational impact is based on different net farm revenue figures to the other mitigations in this report, however, without the breakdown of these costs components it is hard to adjust these.
- Given there is only one estimate of costs for this mitigation, min and max estimates are based on +/- 20% of the average.

3.5.5. References

Daigneault, A. & Elliot, S. (2017). Land-use contaminant loads and mitigation costs. Motu Economic and Public Policy Research.

3.6. Alternative wallows (deer only)

3.6.1. Definition

The on-farm economic impact of this mitigation includes the costs of creating a new wallow and the costs of remediating an old wallow deemed inappropriate. The costs associated with this mitigation are largely dependent on size and the size of the old site and new site. Which in this report have been set to match the benefit estimates completed for the MfE in associated work. The new wallow is based on a 30m^2 site, while the wallow being remediated is based on a 300m^2 site. The costs are also largely dependent on the costs of digger work and the assumption that materials for the new site can be sourced on farm.

3.6.2. Capital cost

Table 16: Capital costs of creating alternative wallows

	Capital Cost		
	Minimum estimate	Median	Maximum estimate
Construct new wallow ($/30m^2)	600	850	1,100
Remediate old wallow (300m^2)			
Fencing - deer ($/100m)	1,968	2,189	2,410
Planting ($/300m^2)	1,250	1,560	1,875
Total remediation of old wallow	3,818	4,599	5,385
Total of constructing new wallow and remediating old wallow	4,418	5,449	6,485

3.6.3. Operational cost

Table 17: Operational costs of alternative wallow

	Operational Cost (per year)		
	Minimum estimate	Median	Maximum estimate
Fencing maintenance ($/100m)	5	20	50
Planting maintenance ($/300m^2 site)	300	375	450
Land retirement – deer (farm profit before tax $/30m^2 site)	0	0.23	0.47

3.6.4. Assumptions

- Constructing a new wallow is based on a 30m^2 site.
- It is assumed that farm material is available to create bund (e.g. rocks from the farm) and underline wallow with stones/rubble, gravel and topsoil mix.
- The construction costs are based on a 6tonne digger which requires cartage. The digger is priced at $130/hour and transport of $350. The hours the digger is required for is varied to generate a minimum and maximum expected cost.
- It is assumed that the land area occupied by the old wallow was not productive (hence the contaminant loss) and therefore there was no loss of productive land for this.
- There is however, a loss of productive land from the area selected for a new wallow. The estimates of this are based on 0% productive loss (minimum) through to 100% productive loss (maximum).
- Planting is based on a medium pot size and plant spacing varies from 1 meter, to 1.2 meter and 1.5 meter.

- Maintenance for planting is varied based on the number of plants required (based on the spacing) and is assumed at $1.50 per plant.
- Costs per plant include the cost of plants and ground preparation and are priced using mostly native plants as a base. Additional costs such as plant protection guards and weed-matting costs are excluded.
- 100m of new fencing is assumed to be required. For other fencing assumptions see section 3.1.

3.6.5. References

The Agribusiness Group (TAG). (2016). Ministry for Primary Industries Stock Exclusion Costs Report. Report prepared for Ministry for Primary Industries. Available from https://www.mpi.govt.nz/dmsdocument/16537-ministry-for-primary-industries-stock-exclusion-costs-report

Brown, P. & Mackay, S. (2000). Case Study — Riparian Management on the Piako River: A New Approach to Costs and Benefits. Environment Waikato Internal Series 2000/09, Environment Waikato, Hamilton, New Zealand, 40 pp.

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DairyNZ. (2018). Riparian Planner. Accessed June 2018. Retrieved from https://www.dairynz.co.nz/environment/waterways/riparian-planner/

3.7. Restricted grazing of winter forage crops (multiple contaminants)

3.7.1. Definition

This mitigation applies to cattle grazing on winter crops and restricts their grazing on crop before moving them to a stand-off area which has the ability to capture effluent. It has a wide variance in cost depending on if it is applied to farms that already have a suitable stand-off area or farms that would need to build something. While milk shed yards could be used, often dairy cows grazing winter crops are not on the milking platform (i.e. wintered off farm), or for reasons such as animal health or space it is not appropriate to stand cows off on the milk shed yards. Standing cows off in races or sacrifice paddocks would not suffice as the effluent cannot be captured.

The on-farm economic impact will also depend on a number of factors, specific for each farm. The cost will also depend significantly on the type of stand-off pad created and associated factors such as if additional effluent storage is needed. For the purpose of this report it is assumed a stand-off pad that is suitable for cows to spend their majority of time on and effluent is able to be captured. Modelling these in detail is beyond the scope of this report and as such a suite of assumptions are made.

Consideration needs to be given to how this data is extrapolated based on assumptions about who has suitable stand-off facilities, and acknowledging that this doesn't just apply to dairy farms, but anywhere cattle are wintered on crop which will include farms that winter dairy cows (e.g. some sheep and beef farms, some dedicated dairy support farms, and some dairy farms).

3.7.2. Capital cost

The capital costs of this mitigation will depend significantly on the type of stand-off pad created and associated factors such as if additional effluent storage is needed and required size. The capital cost for the minimum estimate assumes there is no capital cost as there is already an existing suitable structure. The maximum estimate assumes a purpose built facility needs to be constructed from scratch. The capital costs are based on paying upfront and it is likely that the structure will have a 20 year life. No annual fixed costs such as depreciation or interest have been included.

Table 18: Capital cost of stand-off pad per cow

	Capital cost ($/cow)		
	Minimum estimate	Median	Maximum estimate
Stand-off pad construction costs	0	530	1,600

3.7.3. Operational cost

The operational cost for this mitigation is based on additional labour, given the assumptions made.

Table 19: Operational cost of restricted grazing of winter forage crops

	Operational cost ($/yr)		
	Minimum estimate	Median	Maximum estimate
Hourly wage	20	22	25
Hours required	1	2	4
Days of additional work (North Is.)	42	56	70
Days of additional work (South Is.)	70	84	98
Maintenance of stand-off	0	1,500	3000
Total operational cost (North Is.)	840	3,964	10,000
Total operational cost (North Is.)	1,400	5,196	12,800

3.7.4. Assumptions

- It is assumed that there is no change in animal feed requirements due to the increased walking as it is possible that some of this could be offset by being moved to a stand-off area with no mud and potentially a warmer environment due to the proximity of other cows.
- It is assumed that the cows can access all their energy requirements from the crop before being moved to the stand-off pad and that any additional supplement that was fed out in conjunction with the crop (e.g. hay or silage) is either still fed out on the crop and able to be eaten in the restricted time, or is fed out on the stand-off pad.
- Due to a lack of information, any additional cost for farm equipment such as repairs and maintenance or fuel for bikes to facilitate moving the cows is not considered.
- The operational costs are best costed on an annual basis (season) based on the number of days on winter crop and therefore the additional days were labour is required to be utilized. This was assumed to be 8 weeks for the North Island and 12 weeks for the South Island, both including transitions.
- It is likely that labour is a sticky cost, i.e. doesn't vary based on a small change in hours, however, it is important this cost is included as the time taken will likely take time off other tasks if a labour unit is not changed. This will eventually need to be balanced out elsewhere. For this report, labour was assumed to be $22 per hour and approximately 2 hours were needed daily.
- Additional operational costs for the standoff pad were based on being $0 for the minimum (assuming the farm already has a suitable area that they already use) with costs being included as median (some additional use in existing area) and maximum (maintenance costs on a new stand-off pad).
- The yearly cost of scrapping the standoff-pad material ranges from nothing assuming that there is a material like rubber matting, while the maximum is likely to be bark which is taken off and spread through the farm in suitable areas.
- It is assumed that there is no change in cropping costs or fertilizer use.

- The capital cost for the minimum estimate assumes that there is no capital cost as there is already an existing suitable structure. The maximum estimate assumes a purpose built facility needs to be constructed from scratch.
- There is no capital cost associated with changes in effluent storage that may be required. This would increase the capital cost if needed for a farm.
- It has not been considered how the stand-off pad is used during the production season.
- The capital costs are based on paying upfront and it is likely that the structure will have a 20 year life. No annual fixed costs such as depreciation or interest have been included.

3.7.5. References

Beukes, P., Romera, A., Clark, D., Dalley, D., Hedley, M., Horne, D., Monaghan, R., & Laurenson, S. (2013). Evaluating the benefits of standing cows off pasture to avoid soil pugging damage in two dairy farming regions of New Zealand, *New Zealand Journal of Agricultural Research*, 56:3, 224-238, DOI: 10.1080/00288233.2013.822002

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4. Phosphorus

4.1. Applying alum to forage cropping

4.1.1. Definition

This relates to applying aluminium sulphate (alum) to winter crop after grazing at 20 kilograms of aluminium per hectare. It is assumed that only one application is applied and there is no impact on crop production or future pasture/crop production following re-planting. It is assumed that this is applied within 24 hours of cattle finishing in a crop paddock and only applies to crop grazed by cattle. It is also assumed that there is no impact on animal health.

When extrapolating these costs it should only be applied to winter forage crop areas and only winter forage crop areas grazed by cattle.

Given that this is a relatively novel mitigation, there is very limited information on the costs associated with this mitigation. Costs of alum are therefore based on those associated with science trials (R. McDowell, pers comm).

4.1.2. Capital cost

There is no capital cost only operational costs of this mitigation.

4.1.3. Operational cost

Table 20: Operational cost of applying alum to forage cropping

	Operational Cost ($/ha/yr)		
	Minimum estimate	Median	Maximum estimate
20kg Al/ha/yr (one application)	66	83	100
Transport and spreading	5	6	7
Total	71	89	107

4.1.4. Assumptions

- This applies aluminium sulphate (alum) to winter crop after grazing at a rate of 20 kilograms of aluminium per hectare.
- It is assumed that only one application is applied.
- There is no impact on crop production or future pasture/crop production following re-planting.
- It is assumed that there is no impact on animal health.
- Alum contains 18% aluminium and costs $750 per tonne with a transport and spreading cost of $55 per tonne.
- Given there is only one estimate of costs for this mitigation, min and max estimates are based on +/- 20% of the average. This change in price could relate to the costs of applying a different rate or a change in the price of alum.

4.1.5. References

Askin, D. & Askin, V. (2018). Financial Budget Manual 2018. Lincoln University. Lincoln, New Zealand.

4.2. Applying alum to pasture

4.2.1. Definition

This relates to applying aluminium sulphate (alum) to pasture after phosphorus fertilizer is applied or following grazing when conditions are such that surface runoff could be an issue (e.g. late autumn or early spring). From an economic impact perspective, it does not matter when this is applied, only how much is applied in how many applications. The economic impacts are based on one application of 20 kilograms of aluminium per hectare. It is assumed that there is no impact on pasture production immediately or into the future and that there is no impact on animal health.

Given that this is a relatively novel mitigation, there is very limited information on the costs associated with this mitigation. Costs of alum are therefore based on those associated with science trials (R. McDowell, pers comm).

Daigenault and Elliot (2017) do consider the application of alum to pasture. However, there is no specific cost break down so it is not possible to work out what costs are included. They assume 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. Annualised costs for dairy were estimated at $36/ha/yr, while sheep and beef was estimated at $68/ha/yr. The impact on EBIT was estimated as -1% for dairy and -50% for sheep and beef, from a base net farm revenue of $3,418 (dairy) and $127 (sheep and beef). Given these costs from Daigenault and Elliot (2017) have no breakdown or clear assumptions they should be used with extreme caution.

4.2.2. Capital cost

There is no capital cost only operational costs of this mitigation.

4.2.3. Operational cost

Table 21: Operational cost of applying alum to forage cropping

	Operational Cost ($/ha/yr)		
	Minimum estimate	Median	Maximum estimate
20kg Al/ha/yr (one application)	66	83	100
Transport and spreading	5	6	7
Total	71	89	107

4.2.4. Assumptions

- This applies aluminium sulphate (alum) to pasture once a year in times when runoff could be an issue.
- There is no impact on pasture production immediately or in the future.
- It is assumed that there is no impact on animal health.
- Alum contains 18% aluminium and costs $750 per tonne with a transport and spreading cost of $55 per tonne.
- Given there is only one estimate of costs for this mitigation, min and max estimates are based on +/- 20% of the average. This change in price could relate to the costs of applying a different rate or a change in the price of alum.

4.2.5. References

Askin, D. & Askin, V. (2018). Financial Budget Manual 2018. Lincoln University. Lincoln, New Zealand.

4.3. Sorbents in and near streams

4.3.1. Definition

This mitigation has been costed as a mesh sock of 1 meter long and 9cm in diameter filled with 85% steel melter slag, 20% electrical furnace slag and 5% basic slag. These can then be applied to areas of high phosphorus loss, such as gateways, lands and around structures. This report makes no estimation on how many of these are needed across different land uses or contexts and so costs are provided on a cost per unit basis (i.e. cost per phosphorus sock). The fill material can differ if other products can effectively filter phosphorus.

Given that this is a relatively novel mitigation, there is very limited information on the costs associated with this mitigation. Costs are therefore based on McDowell (2007) and adjusted to New Zealand dollars and for inflation. There is no cost breakdown provided and so no further adjustments were made.

The cost in McDowell (2007) are based on using steel melter slag from Auckland in the Bay of Plenty. The costs therefore will likely change around the country depending on access to suitable material and transport costs.

No assumptions have been made about the duration of this mitigation option, it is likely that this should be determined by science to ensure the estimate of benefits is robust and the costs adjusted for how regularly these phosphorus socks need to be replaced.

4.3.2. Capital cost

No estimates have been made on the durability of this mitigation and therefore how often these need to be replaced. The capital cost is based on a per phosphorus sock basis and costs were varied by +/- 20%.

Table 22: Capital cost of sorbents in and near streams

	Capital Cost ($ per sock)		
	Minimum estimate	Median	Maximum estimate
Cost (per sock)	1.76	2.20	2.64

4.3.3. Operational cost

There is assumed to be no operational costs associated with this mitigation option.

4.3.4. Assumptions

- To adjust the values to New Zealand dollars the average 2007 United States to New Zealand Dollar exchange rate was used as this was the year of the study. FEPI was then used to adjust the values to 2019 $NZD.
- There is no impact on pasture production.
- The cost in McDowell (2007) are based on using steel melter slag from Auckland in the Bay of Plenty. The costs therefore will likely change around the country depending on access to suitable material and transport costs.
- No assumptions have been made about the duration of this mitigation option, it is likely that this should be determined by science to ensure the estimate of benefits is robust and the costs adjusted for how regularly these phosphorus socks need to be replaced.
- This mitigation has been costed as a mesh sock of 1 meter long and 9cm in diameter filled with 85% steel melter slag, 20% electrical furnace slag and 5% basic slag.

- This report makes no estimation on how many of these are needed across different land uses or contexts and so costs are provided on a cost per unit basis (i.e. cost per phosphorus sock).
- The fill material can differ if other products can effectively filter phosphorus.
- No consent costs are included which may be required depending on placement.

4.3.5. References

McDowell, R. (2007). Assessment of altered steel melter slag and P-socks to remove phosphorus from streamflow and runoff from lanes. Report prepared for Environment B.O.P. Retrieved from https://www.researchgate.net/profile/Rich_Mcdowell/publication/242239475_Assessment_of_altered_steel_melter_slag_and_P-socks_to_remove_phosphorus_from_streamflow_and_runoff_from_lanes/links/544951fd0cf2ea6541309333/Assessment-of-altered-steel-melter-slag-and-P-socks-to-remove-phosphorus-from-streamflow-and-runoff-from-lanes.pdf

4.4. Tile drain amendments

4.4.1. Definition

There are potentially two different ways to cost this mitigation, and this should be driven by what farms these are applied to. The costs could apply to digging up existing tile drains and altering the backfill material from conventional clean gravel, to a material with a high phosphorus sorption capacity like steel melter slag, or to laying new tile drains with the backfill containing a material with a high phosphorus sorption capacity. However, it is unlikely that there is that much difference between the costs and digging up and extracting conventional backfill is likely to require more time than laying new tile drains, though some of the existing tiles may be able to be reused if they are undamaged. Given there is also not much cost information available on this mitigation and the costs are likely to be highly variable, only the cost of new tile drains are included here.

The costs are likely to vary significantly based on land characteristics (including gradient and soil texture), required earthworks, outflows, fences and stock water pipes, type of pipe used, size of the job and source location of backfill material. Costs were based on BakerAg (2012) and R. McDowell (pers. Comm) for the difference in high phosphorus sorption capacity backfill material.

It is not suitable to just consider the cost difference in backfill material as if applying this to existing tile drains there is an additional cost associated with amending the tile drain, and if no tile drains exist then the cost must include laying the tile drain. Care should also be taken when extrapolating the costs of this mitigation to consider what land already has tile drains and what further land is suitable for tile drains and does not already have them.

4.4.2. Capital cost

Table 23: Capital cost of tile drain amendments

	Capital Cost ($/ha/yr)		
	Minimum estimate	Median	Maximum estimate
Using conventional backfill	2,068	3,548	5,028
Using high phosphorus sorption capacity backfill	2,121	3,601	5,081

4.4.3. Operational cost

Table 24: Operational costs of tile drain amendments

	Operational Cost ($/ha/year)		
	Minimum estimate	Median	Maximum estimate
Maintenance	74	93	112

4.4.4. Assumptions

- Assume that if at installation or amendments to existing no change in pasture production from earthworks or ongoing changes in pasture production.
- Assume if excavating existing drains (or installing new drains) the farm has somewhere on farm to utilise or dispose of excavated material.
- Conventional backfill was priced at $50/ha and high phosphorus sorption capacity backfill was $100/ha.
- The maintenance costs include mole plough, clean open drains and jet pipes and does not differ by backfill material type.
- Given there is only one estimate of costs for this mitigation, min and max estimates are based on +/- 20% of the average.

4.4.5. References

BakerAg (2012). AgLetter. 19th November 2012. Retrieved from http://www.bakerag.co.nz/show_pdf.php?id=8415&pcode=6jWDubuLZ8sBuSO6DHJto6LVEI4Jcq7qZJlmvuqsxEpf4xu6yaEMjS

4.5. Low water soluble phosphorus fertilizer

4.5.1. Definition

This mitigation was priced based on the assumption that farms are applying maintenance phosphorus fertilizer to maintain optimum Olsen P levels based on their stocking rate. It is assumed that this is based on the use of superphosphate in the base and the fertilizer use is transitioned (over three years) to dicalcic phosphate. Dicalcic phosphate was chosen as it maintained a similar N:P:K:S ratio as superphosphate but was less than 10% water soluble. It was also available nationwide while some alternatives are not. In addition, reactive rock phosphate (RPR) is also low water soluble, however requires specific characteristics to work.

Care should be taken when interpreting and extrapolating the results of this mitigation. Primarily because not every farm is currently applying maintenance phosphorus fertilizer, not all are using superphosphate and not all will transition to dicalcic phosphate.

4.5.2. Capital cost

Given the assumption that farms are applying maintenance levels of phosphorus there is no capital requirement.

4.5.3. Operational cost

Because the maintenance phosphorus fertilizer requirements are based on stocking rates the sheep and beef and dairy results are presented separately.

Table 25: Operational cost of changing to a low water soluble phosphorus fertiliser - dairy

Region	Dairy cows/ha	Maintenance phosphorus requirements (kgP/ha)	Operational cost ($/ha)			
			100% Superphosphate	67% Superphosphate 33% Dicalcic phosphate	33% Superphosphate 67% Dicalcic phosphate	100% Dicalcic phosphate
			Base	Year 1	Year 2	Year 3 >
Bay of Plenty	2.8	35	142	168	193	219
Canterbury	3.4	40	162	191	221	250
Hawkes Bay	2.9	35	142	168	193	219
Manawatu	2.7	35	142	168	193	219
Northland	2.3	25	101	120	138	156
Otago	2.95	35	142	168	193	219
Southland	2.7	35	142	168	193	219
Taranaki	2.8	35	142	168	193	219
Waikato	2.9	35	142	168	193	219
Wellington-Wairarapa	2.4	25	101	120	138	156
West-coast Tasman Marlborough-Nelson	2.3	25	101	120	138	156

Table 26: Operational cost of changing to a low water soluble phosphorus fertiliser – sheep and beef

Region and land use class	Stock units/ha	Maintenance phosphorus requirements (kgP/ha)	Operational cost ($/ha)			
			100% Superphosphate	67% Superphosphate 33% Dicalcic phosphate	33% Superphosphate 67% Dicalcic phosphate	100% Dicalcic phosphate
			Base	Year 1	Year 2	Year 3 >
New Zealand (All classes)	6.3	6	16	29	37	37
Northern North Is. (Class 3 Hard Hill Country)	7.9	12	32	57	75	75
Northern North Is. (Class 4 Hill Country)	9.8	12	32	57	75	75
Northern North Is. (Class 5 Intensive finishing)	12.6	16	43	77	100	100
Northern North Is. (Class 9 All Classes)	9.7	12	32	57	75	75
Eastern North Is. (Class 3 Hard Hill Country)	8.3	12	32	57	75	75
Eastern North Is. (Class 4 Hill Country)	9.5	12	32	57	75	75
Eastern North Is. (Class 5 Intensive finishing)	9	12	32	57	75	75
Eastern North Is. (Class 9 All Classes)	8.9	12	32	57	75	75
Western North Is. (Class 3 Hard Hill Country)	8	12	32	57	75	75
Western North Is. (Class 4 Hill Country)	8.9	12	32	57	75	75
Western North Is. (Class 5 Intensive finishing)	10.4	16	43	77	100	100
Western North Is. (Class 9 All Classes)	8.6	12	32	57	75	75

Northern-Central South Is. (Class 2 Hill Country)	3.9	6	16	29	37	37
Northern-Central South Is. (Class 6 Finishing breeding)	8.2	12	32	57	75	75
Northern-Central South Is. (Class 8 Mixed finishing)	8.7	12	32	57	75	75
Northern-Central South Is. (Class 9 All Classes)	4.4	6	16	29	37	37
Southern South Is. (Class 1 High Country all regions)	1.5	6	16	29	37	37
Southern South Is. (Class 7 Intensive breeding)	11	16	43	77	100	100
Southern South Is. (Class 6 Finishing breeding)	8.1	12	32	57	75	75
Southern South Is. (Class 9 All Classes)	5.2	6	16	29	37	37
South Is. (Class 2 Hill Country)	4.4	6	16	29	37	37
South Is. (Class 5 Intensive finishing)	11	16	43	77	100	100
South Is. (Class 6 Finishing breeding)	8.2	12	32	57	75	75
South Is. (Class 8 Mixed finishing)	8.7	12	32	57	75	75
North Is. (Class 3 Hard Hill Country)	8.1	12	32	57	75	75
North Is. (Class 2 Hill Country)	9.5	12	32	57	75	75
North Is. (Class 5 Intensive finishing)	10.2	16	43	77	100	100

4.5.4. Assumptions

- Given the nature of dicalcic phosphate there is a three year transition period utilized, where superphosphate is gradually reduced.
- Stocking rates are based on 2018-19 data.
- It is assumed that maintenance phosphorus fertilizer requirements are based on the mid-point of the relevant stock unit range in Morton and Roberts (2016; 2018).
- Superphosphate prices are based on average of Ballance and Ravensdown's main superphosphate product between 1/1/2015 and 1/1/2020, which equates to $315 per tonne (excl GST, freight and handling). An additional $50 per tonne is included for transport.
- Dicalcic phosphate is based on the most recent available (as no long term data is available) prices from Balance and Ravensdown which equated to $215.50 per tonne (excl GST, freight and handling). An additional $50 per tonne is included for transport.
- It is assumed that superphosphate has an N:P:K:S ratio of 0:9:0:11.
- It is assumed that dicalcic phosphate has an N:P:K:S ratio of 0:4.25:0:5.1, which is an average of the relevant Ballance and Ravensdown products.
- Timing of fertilizer use was not considered as this does not impact on economic impact, assuming that there is no change in other fertilizer use.
- While every care was taken to get as similar N:P:K:S ratio as superphosphate, no consideration was given to lime or other nutrient concentrations and requirements.

4.5.5. References

Morton, J. & Roberts, A. (2016). Fertiliser use on New Zealand Dairy Farms. Retrieved from http://www.fertiliser.org.nz/includes/download.ashx?ID=147241

Morton, J. & Roberts, A. (2018). Fertiliser use on New Zealand Sheep and Beef Farms. Retrieved from http://www.fertiliser.org.nz/includes/download.ashx?ID=153081

Ravensdown. (2020). Price List. Date Accessed 10 Feb. 2020.

Ballance. (2020). Price List. Date Accessed 10 Feb. 2020.

DairyNZ. (2018). DairyNZ Economic Survey 2017-18. Retrieved from https://www.dairynz.co.nz/media/5791415/dairynz-economic-survey-2017-18.pdf

Beef + LambNZ. (2018). Sheep and beef farm survey. Retrieved from https://beeflambnz.com/data-tools/sheep-beef-farm-survey

Dairy Industry Data Center. (2020). Long term feed and fertilizer prices. Date accessed February 2020.

4.6. Optimum soil test phosphorus concentration

4.6.1. Definition

This mitigation involves ensuring that farms are operating at agronomic optimum Olsen P levels and applying maintenance fertilizer to maintain this. To achieve this, current phosphorus use (assumed to be superphosphate) is compared to the phosphorus use require for maintenance (assumed applied through superphosphate). In addition, it is noted for how long, on average, the farm could go without phosphorus fertilizer being applied before Olsen P levels reduce below agronomic optimum. This is based on the average Olsen P levels by region, soil type and land use in McDowell et al. (2020).

It is noted that agronomic optimum is likely to be different to economic optimum for some farms.

4.6.2. Capital cost

It is assumed there are no capital costs for this mitigation.

4.6.3. Operational cost

The operational costs are based on current phosphorus fertilizer use relative to maintenance requirements (using superphosphate). There is a column which indicates how many years can have no phosphorus fertilizer applied given the average regional Olsen P level (by soil type and land use) relative to the agronomic optimum.

Because the maintenance phosphorus fertilizer requirements are based on stocking rates the sheep and beef and dairy results are presented separately.

Table 27: Operational cost of moving to optimum Olsen P - dairy

Region	Dairy cows/ha	Current phosphorus application (kgP/ha)	Maintenance phosphorus requirement (kgP/ha)	Years with no phosphorus fertiliser required	Operational cost ($/ha)	
					Cost of current phosphorus	Cost of maintenance phosphorus
Bay of Plenty	2.8	35	35	2	142	142
Canterbury	3.4	30	40	0	122	162
Hawkes Bay	2.9	20	35	1	81	142
Manawatu	2.7	20	35	1	81	142
Northland	2.3	20	25	2	81	101
Otago	2.95	30	35	0	122	142
Southland	2.7	30	35	0	122	142
Taranaki	2.8	15	35	3	61	142
Waikato	2.9	30	35	3	122	142
Wellington-Wairarapa	2.4	20	25	1	81	101
West-coast Tasman Marlborough-Nelson	2.3	30	25	1	122	101

Table 28: Operational cost of moving to optimum Olsen P – sheep and beef

Region and land use class	Stock units/ha	Current phosphorus application (kgP/ha)	Maintenance phosphorus requirement (kgP/ha)	Years with no phosphorus fertiliser required	Operational cost ($/ha)	
					Cost of current phosphorus	Cost of maintenance phosphorus
New Zealand (All classes)	6.3	10	6	0	41	24
Northern North Is. (Class 3 Hard Hill Country)	7.9	16	12	1	63	49
Northern North Is. (Class 4 Hill Country)	9.8	16	12	1	63	49
Northern North Is. (Class 5 Intensive finishing)	12.6	16	16	1	63	65
Northern North Is. (Class 9 All Classes)	9.7	16	12	1	63	49
Eastern North Is. (Class 3 Hard Hill Country)	8.3	13	12	0	52	49
Eastern North Is. (Class 4 Hill Country)	9.5	13	12	0	52	49
Eastern North Is. (Class 5 Intensive finishing)	9	13	12	0	52	49
Eastern North Is. (Class 9 All Classes)	8.9	13	12	0	52	49
Western North Is. (Class 3 Hard Hill Country)	8	14	12	1	58	49
Western North Is. (Class 4 Hill Country)	8.9	14	12	1	58	49
Western North Is. (Class 5 Intensive finishing)	10.4	14	16	1	58	65
Western North Is. (Class 9 All Classes)	8.6	14	12	1	58	49
Northern-Central South Is. (Class 2 Hill Country)	3.9	7	6	1	28	24
Northern-Central South Is. (Class 6 Finishing breeding)	8.2	7	12	1	28	49

Northern-Central South Is. (Class 8 Mixed finishing)	8.7	7	12	1	28	49
Northern-Central South Is. (Class 9 All Classes)	4.4	7	6	1	28	24
Southern South Is. (Class 1 High Country all regions)	1.5	10	6	0	41	24
Southern South Is. (Class 7 Intensive breeding)	11	8	16	0	32	65
Southern South Is. (Class 6 Finishing breeding)	8.1	10	12	0	41	49
Southern South Is. (Class 9 All Classes)	5.2	10	6	0	41	24
South Is. (Class 2 Hill Country)	4.4	8	6	0	32	24
South Is. (Class 5 Intensive finishing)	11	8	16	0	32	65
South Is. (Class 6 Finishing breeding)	8.2	8	12	0	32	49
South Is. (Class 8 Mixed finishing)	8.7	8	12	0	32	49
North Is. (Class 3 Hard Hill Country)	8.1	14	12	0	57	49
North Is. (Class 2 Hill Country)	9.5	14	12	0	57	49
North Is. (Class 5 Intensive finishing)	10.2	14	16	0	57	65

4.6.4. Assumptions

- Agronomic optimum is considered, not economic optimum.
- Stocking rates are based on 2018-19 data.
- Given the nature of dicalcic phosphate there is a three year transition period utilized, where superphosphate is gradually reduced.
- It is assumed that maintenance phosphorus fertilizer requirements are based on the mid -point of the relevant stock unit range in Morton and Roberts (2016; 2018).
- Prices are based on superphosphate fertilizer Superphosphate prices are based on average of Ballance and Ravensdown's main superphosphate product between 1/1/2015 and 1/1/2020, which equates to $315 per tonne (excl GST, freight and handling). An additional $50 per tonne is included for transport.
- It is assumed that superphosphate has an N:P:K:S ration of 0:9:0:11.
- Timing of fertilizer use was not considered as this does not impact on economic impact, assuming that there is no change in other fertilizer use.
- No consideration was given other nutrient requirements, only phosphorus.
- Current phosphorus use for sheep and beef farms is provided on a regional basis and so no different is assumed by farm type.
- The average years the farm can put no fertilizer on for is based on a simple average cross soil types.
- The regions across data sources do not exactly align and the best fit was used.

4.6.5. References

Morton, J. & Roberts, A. (2016). Fertiliser use on New Zealand Dairy Farms. Retrieved from http://www.fertiliser.org.nz/includes/download.ashx?ID=147241

Morton, J. & Roberts, A. (2018). Fertiliser use on New Zealand Sheep and Beef Farms. Retrieved from http://www.fertiliser.org.nz/includes/download.ashx?ID=153081

Dairy Industry Data Center. (2020). Long term feed and fertilizer prices. Date accessed February 2020.

DairyNZ. (2018). DairyNZ Economic Survey 2017-18. Retrieved from https://www.dairynz.co.nz/media/5791415/dairynz-economic-survey-2017-18.pdf

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McDowell, R., Dodd, R., Pletnyakov, P. & Nobel, A. (2020). The Ability to Reduce Soil Legacy Phosphorus at a Country Scale. *Front. Environ. Sci.* 8:6. doi: 10.3389/fenvs.2020.00006

MPI. (2020). Current phosphorus fertilizer use on dairy farms. Accessed from the Economic Data and Analysis Group. Accessed 11 February 2020.

Beef & Lamb NZ. (2019). Compendium of Farm Facts. 43rd Ed.

5. Nitrogen

5.1. Diuretic supplementation or nitrogen modifier

5.1.1. Definition

Diuretics such as common salt generally result in increased water consumption by animals with an associated increase in the spread of urinary nitrogen by the animal. While there is limited information on required rates to provide different levels of benefits without impacting pasture and animal health, Ledgard et al. (2015) does provide a rate suggestion. It is suggested that salt is provided at a rate of 150 grams per cow per day (based on the heifer rate in Ledgard et al., 2015) with the salt fed in autumn and winter (which was defined as March, April, May and June, a total of 122 days).

This mitigation was only applied to dairy cattle due to the relative ease of providing salt to cattle and the ratio of female to male cattle.

5.1.2. Capital cost

There is no capital cost associated with this mitigation given the assumptions made.

5.1.3. Operational cost

The ongoing operation costs are based on regional differences in stocking rates (cows per hectare) and the minimum, median and maximum costs are based on differences in the price of salt.

Table 29: Operational cost of diuretic supplements

			Operational Cost ($/ha/yr)		
Region	Dairy cows/ha	Kg salt /ha	Minimum	Median	Maximum
Bay of Plenty	2.8	51	23	41	51
Canterbury	3.4	62	28	50	62
Hawkes Bay	2.9	53	24	42	53
Manawatu	2.7	49	22	40	49
Northland	2.3	42	19	34	42
Otago	2.95	54	24	43	54
Southland	2.7	49	22	40	49
Taranaki	2.8	51	23	41	51
Waikato	2.9	53	24	42	53
Wellington-Wairarapa	2.4	44	20	35	44
West-Coast Tasman Marlborough-Nelson	2.3	42	19	34	42

5.1.4. Assumptions

- It is assumed that salt is provided at a rate of 150 grams per cow per day (based on the heifer rate in Ledgard et al., 2015) with the salt fed in autumn and winter (which was defined as March, April, May and June, a total of 122 days).
- This mitigation was only applied to dairy cattle due to the relative ease of providing salt to cattle and the ratio of female to male cattle.
- No impact on animal health.
- No impact on pasture production or long term soil health.
- It is assumed that the farm already has equipment to provide for feeding out the salt and assumes that this ensures cows get the right amount each.
- Prices of salt are $0.45/kg, $0.80/kg, $1.00/kg (minimum, median and maximum, respectively) and excludes delivery costs.

5.1.5. References

Askin, D. & Askin, V. (2018). Financial Budget Manual 2018. Lincoln University. Lincoln, New Zealand.

Ledgard, S., Welten, B. & Betteridge, K. (2015). Salt as a mitigation option for decreasing nitrogen leaching losses from grazed pastures. *J. Sci. Food Agric.* 95(15):3033-40 doi: 10.1002/jsfa.7179.

5.2. Denitrification beds

5.2.1. Definition

A denitrification bed (also known as bioreactor) is a trench filled with a material with woodchip to denitrify drainage. While denitrification beds can vary significantly in sizes and costs, a typical denitrification bed is normally approximately about 1.5 meters deep, by 5 meters wide and 10 meters long (75m^3). Because of the nature of the costs it is necessary to have a size in order to price each component required. The most variable and uncertain cost is the cost of the digger required to excavate and construct the denitrification bed. These denitrification beds have an approximate life of 20 years, though it is typical to replace the woodchip material at 10 years.

5.2.2. Capital cost

Table 30: Capital cost of denitrification beds

	Capital Cost ($ per denitrification bed, 75m^3)		
	Minimum estimate	Median	Maximum estimate
Liner material (100m^2)	0	400	1,000
Weed mat (50m^2)	30	50	75
Pipes and fittings at inflows/outflows	20	85	150
Digger to construct	600	1,000	1,500
Woodchip	1,125	2,100	2,600
Digger to replace woodchip at 10 years	500	800	1,300
Woodchip replacement	1,125	2,100	2,600
Total	3,400	6,535	9,225

5.2.3. Operational cost

Table 31: Operational cost for denitrification beds

	Operational Cost ($ per denitrification bed)		
	Minimum estimate	Median	Maximum estimate
Maintenance	$50	$100	$150

5.2.4. Assumptions

- It is assumed that the denitrification bed has an approximate life of 20 years, though woodchip material is replaced at 10 years.
- The denitrification be is assumed to be 1.5 meters deep, by 5 meters wide and 10 meters long (75m^3). The size of the denitrification bed is hugely dependent on the load of nitrate they are expected to treat as well as the type of catchment. Most of the tile drain woodchip denitrification beds trialed in New Zealand have ranged in size from 30-100 m^3.
- The minimum cost estimate assumed there is no lining which is suitable on clay soils but not well drained soils.

- While the material in denitrification beds can vary, untreated woodchips, either hardwood or softwood, approximately 2.0cm in size (to avoid compaction when in denitrification bed), are best. Woodchip is in general, more expensive than sawdust, but costs of sawdust are more readily available. Because of this, sawdust was used as the minimum cost estimate, while woodchip was used as the maximum.
- It is assumed that the denitrification bed is not fenced off.
- Costs excludes any possible consent costs and expert design costs.
- Depending on soil type and other local conditions, a geotextile cover should be installed, especially if farming will continue over the denitrification bed and this should be topped with soil.
- Pipes will be needed to connect the denitrification bed to inflow, outflow and overflow structures, as required. Pipes and fittings required are very variable which is reflected in the range of cost estimates.
- Maintenance will be site-specific and vary from year to year.
- After denitrification bed installation, paddock can be returned to productive land.
- It is assumed there is no change in input product pricing (e.g. woodchip).
- It is assumed that the woodchips removed from the denitrification bed can be safely disposed of on farm.

5.2.5. References

Askin, D. & Askin, V. (2018). Financial Budget Manual 2018. Lincoln University. Lincoln, New Zealand.

Goeller, B.C, Hogsden, K.L., Febria, C.M., Devlin, H.S., Collins, K.E., Harding, J.S., & McIntosh, A.M. (2018). Nutrients – Edge-of-field nitrate reduction with woodchip bioreactors, CAREX Toolbox Handout 4, University of Canterbury, Christchurch. https://figshare.com/articles/CAREX_Toolbox_Handout_4_-_Nutrients_nitrate_/6848537

5.3. Supplementary feeding with low nitrogen feeds

5.3.1. Definition

This mitigation involves replacing feed that has a high nitrogen content with feed that has a low nitrogen content. Ideally because this mitigation involves feed supply it should be modelled in farm systems software. However, due to the scope of this project a simplified calculation can be undertaken by substituting high nitrogen content feeds with low nitrogen content feeds, in this case replacing nitrogen boosted pasture with maize silage. This simplified calculation only applies to periods when the impact of varying protein content between the alternate feeds is unlikely to be limiting to production, in this case autumn.

Care should be taken when the costs (and environmental benefits) of this mitigation are extrapolated. The assumption of this mitigation is that the maize silage is able to be purchased and is therefore grown off farm. If demand for maize silage increases, then there may be a change in the area used to grow maize silage and as such costs and environmental impacts will change at an industry level.

5.3.2. Capital cost

Assuming that there is no additional infrastructure require to procure, store or feed out the maize silage then there are no capital costs of this feed.

5.3.3. Operational cost

The maize price is considered to be the most variable price component and as such the price of maize is varied to provide the minimum, median and maximum price estimates.

The cost estimates are provided on a cents per kilogram of dry matter basis. It is assumed that given the regional average growth rates in autumn a response rate of 10:1 (kgDM:kgN) removing one kilogram of nitrogen applied per hectare equates to removing 10 kilograms of dry matter per hectare.

Table 32: Operational cost of altering feed to a low nitrogen content alternative

	Operational Cost		
	Minimum estimate	Median	Maximum estimate
Pasture eaten through nitrogen (c/kgDM)	17.6	17.6	17.6
Maize silage price (c/kgDM)	27	32	37
Total maize silage price (including feed out costs) (c/kgDM)	32	38	44
Cost of maize silage to replace 1kgDM pasture grown through nitrogen (c/kgDM)	43	51	59
Total cost (maize silage minus fertiliser) (c/kgDM eaten)	25.4	33.4	41.4

5.3.4. Assumptions

- It is assumed that nitrogen boosted pasture is provide by the application of urea which costs $650 per tonne including transport and spreading and has a urea content of 46% nitrogen.
- It is assumed that pasture has 11 megajoules of metabolizable energy per kilograms of dry matter (MJ ME/kg DM), while maize silage has 10.3MJ ME/kg DM.
- It is assumed there is 80% utilization for both pasture and maize silage.
- It is assumed that no additional capital infrastructure is required but additional feeding out costs are calculated based on 20% of feed costs.
- It is assumed that there are no substitution costs related to changing feed types and that 1.067 kg DM of maize silage replaces 1kg DM of nitrogen boosted pasture from an energy perspective. This is most likely to be an appropriate assumption in autumn when reduction in protein intake is unlikely to be limiting.
- A key assumption is that the costs of maize silage and nitrogen fertilizer remain constant. If there are considerable changes in supply and/or demand then these prices are unlikely to remain constant. However, there is not data on how these will change.
- There are other potential feed options, however these should be modelled through the use of farm system modelling to ensure that feed demand and supply are in balance.
- It is assumed that the dry matter content of maize silage is 33% and pasture is 15%.
- These costs are only applicable when the response rate is 10:1, which is likely in April given regional average pasture growth rates.

5.3.5. References

Dairy Industry Data Center. (2020). Long term feed and fertilizer prices. Date accessed February 2020.

DairyNZ. (2019). DairyNZ Facts and Figures. Retrieved from https://www.dairynz.co.nz/media/5791506/facts-and-figures-updated-june-2019-web.pdf

5.4. Variable rate irrigation

5.4.1. Definition

This mitigation refers to fitting variable rate irrigation (VRI) systems to an existing, suitable, irrigation system. It is not the impact of changing from dryland to variable rate irrigation, or improving practices on irrigation systems (i.e. to good management practice). It is specifically creating a full VRI system based on IrrigationNZ definitions (2015) where each sprinkler nozzle can be controlled individually and application depth and return rate can be varied by nozzle. Care should be taken when extrapolating the results from this as it is only applicable when comparing 'uniform rate irrigation' (URI) to VRI and should only be extrapolated to systems that are suitable for VRI (where application depth and return rate can be varied) such as pivots and lateral move sprinklers.

Because changing the amount of water applied to pasture will impact on pasture grown this mitigation should be modelled using farm systems software. However, this was beyond the scope of this report and therefore existing literature is relied upon.

5.4.2. Capital cost

The capital cost of this mitigation refers to adding VRI to an existing irrigation scheme (170 hectares of pivot irrigation). There is extremely limited information on capital costs of adding VRI to existing irrigation schemes and as such this cost should be treated with extreme caution. In addition, the capital cost of $130,000 (2012 $NZD) is not detailed in Hedley et al. (2012) so there is no way of knowing what capital components are included and how much of this is fixed and variable. For example, the operating system and software may be a fixed cost but the cost of procuring suitable nozzles may be variable by area. Because there was no better information, it was assumed the whole cost was variable and therefore was divided by the number of hectares under the VRI system. Given there was no range provided, or multiple studies to draw from, the minimum and maximum cost estimates are based on +/- 20%.

Table 33: Operational cost of VRI relative to URI

	Capital Cost ($/ha)		
	Minimum	Median	Maximum
Addition of VRI to existing irrigation system	655	818	982

5.4.3. Operational cost

There is some research which estimates the impact of VRI relative to URI irrigation systems, however, the economic impact on farm is often sparse. The key economic on-farm impacts relate to the change in operating costs/benefits as a results of changing the irrigation water applied in each year (e.g. electricity and R&M), changes in pasture production and saved nutrient loss in drainage. However, most studies to date convert the change in irrigation water applied to an economic benefit utilising a figure of $2/mm/ha which is based on work done by FAR (2010). This conversion is present in most of the relative literature and therefore is utilised here, given the scope of this report. However, this should be approached with extreme caution. The FAR (2010) estimate is based on a study of five arable farms and considers operating costs (pumping, labour, R&M and supply charges) and ownership costs (including depreciation, insurance and interest). Because it is arable and a very small sample, it should be extrapolated with extreme caution. In addition, it considers costs which will not vary with the amount of water applied (e.g. insurance) and therefore is a possible overestimate.

Studies which use this value to estimate the operational economic benefits of VRI over URI include, Hedley et al. (2010a), Hedley et al. (2010b), Hedley et al. (2009), Hedley (N.D.) and Hedley and Yule

(2012). Based on these studies the range of operational value is estimated as $50-$150 per hectare per year. These were adjusted to 2019 $NZD for the operational benefit in this report. However, these studies consider pasture, arable (typically maize) and potato crops and care should be taken when extrapolating these to pasture. For example, the pasture site in Hedley et al (2009) reduced irrigation (mm applied) by 9% relative to the potato and maize grain sites (13% and 19% respectively). Likewise, the two pasture sites in Hedley (N.D.) saved 9 and 10% irrigation applied, compared to the maize grain sites (between 12 and 26%) and the potato site (15%).

Some studies consider the differences in drainage and potentially nutrient loss but these are either not quantified in economic terms, or are considered minimal. Some Hedley and Yule (2012) consider the benefits of using the saved water to irrigate dryland, however, the assumption is made for this report that farms are already irrigating their suitable land.

Most of the studies do not explicitly consider how daily pasture production changes as a result of the marginal changes in irrigation. However, Hedley and Yule (2012) note that on a case study farm (dairy farm with pivots) pasture production was maintained while saving 27% of water used. The saved water use was from not irrigating non pasture areas (e.g. laneways) as well as reducing use to pasture. Based on this, the assumption was made that there was no impact on pasture.

Table 34: Operational cost of VRI relative to URI

	Operational Benefit ($/ha/yr)		
	Minimum	Median	Maximum
Economic value of saved water	57	113	170

5.4.4. Assumptions

- It is assumed that the capital improvement costs are fully variable by hectares and that they are being fitted onto an existing, suitable, irrigation system.
- It is assumed that the economic costs/benefits relate to a 'full control' VRI system where each nozzle can be individually controlled and application depth and return period are fully variable.
- The operational cost/benefit are assumed to include only operating costs (pumping, labour, R&M and supply charges) and ownership costs (including depreciation, insurance and interest) and are fully variable based on FAR (2010).
- It is assumed that no saved water can be applied to dryland. Nor are any allowances made for benefits such as storing saved water etc.
- There is no impact on pasture considered.
- There is no economic value assigned to reduced drainage or any nutrients that may be lost in this drainage.
- Economic costs/benefits apply to pasture only and not crops.
- No additional operating costs are considered (short term such as training and development or long term such as annual subscriptions for software or increases in annual servicing costs).

5.4.5. References

Hedley, C., Yule, I. & Bradbury, S. (2010a). Analysis of potential benefits of precision irrigation for variable soils at five pastoral and arable production sites in New Zealand. 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 – 6 August 2010, Brisbane, Australia

Hedley, C., Bradbury, S., Ekanayake, J., Yule, I. & Carrick, S. (2010b). Spatial irrigation scheduling for variable rate irrigation. Proceedings of the New Zealand Grassland Association. 72: 97-102

IrrigationNZ. (2015). Precision Irrigation. Retrieved from https://www.irrigationnz.co.nz/PracticalResources/SpecialistEquipment/PrecisionIrrigation.

Hedley, C., Yule, I., Tuohy, M. & Vogeler, I. (2009). Key performance indicators for variable rate irrigation implementation on variable soils. 2009 ASABE Annual International Meeting. Reno-Nevada.

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Hedley, C. & Yule, I. (2012). Farmer uptake of variable rate irrigation technologies in New Zealand. Retrieved from https://www.ispag.org/proceedings/?action=download&item=1268.

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5.5. Change animal type – dairy

5.5.1. Definition

The mitigation of 'change animal type' can have a multitude of meanings. In dairy it could mean changing some part of the land to another land use, changing young stock or dry cow (wintering) policies, changing stocking rates or breed of cattle. These options will have differing levels of applicability for each farm situation and differing levels of both costs and benefits. In addition, because all of these mitigation impact feed supply and demand the costs and benefits should be considered in farm systems models and across a range of farm types.

Given the scope of this report changing animal type has been defined as reducing stocking rate for dairy farms. No specific farm systems modeling was undertaken due to scope and instead existing literature has been used. Farm systems modelling requires a wide range of protocols to be defined, for example input prices, and most modeling exercises are slightly different due to how the mitigations are defined and the underlying protocol, methods and assumptions. Based on this, care should be taken when extrapolating or transferring the results from relevant studies to ensure the underlying assumptions and protocols are suitable and comparable if using multiple studies.

The studies considered here primarily look at reducing nitrogen fertilizer and as a result of reducing feed supply, reduce stocking rate. However, each modelling run is a suite of complex mitigations designed to ensure the farm is a viable farm system, for example altering imported feed supply to balance reductions in fertilizer etc. Each of the modelling studies considered here have one consistent assumption, production per cow is held constant. This modelling assumption is explored in further detail in Muller (2017).

5.5.2. Capital cost

There is no capital cost of this mitigation considered here, however, some capital impacts may occur from destocking and selling cows and/or milk company shares.

5.5.3. Operational cost

The studies considered here are based on Newman and Muller (2017), DairyNZ (2014), Bell et al (2014) and DairyNZ (2015). No attempt has been made to amalgamate the results and instead the summary results are presented for each study. The summary results presented here do not encompass all the results or details of each mitigation option, e.g. how bought in feed changes or what months fertilizer is removed from.

Table 35: Operational cost of reducing stocking rate on dairy farms in the Waikato and Waipa River Catchment

KPI	Metric	Base	Mitigation run			
			1.1	1.2	1.3	1.4
Nitrogen leaching	kg/ha	30	27	25	23	22
Stocking rate	(cows/ha)	3.1	3	2.9	2.8	2.7
Nitrogen fertiliser use	(kgN/ha)	116	88	60	29	14
Milksolids	(kg/ha)	1,098	1,072	1,033	997	970
Milksolids	(kg/cow)	360	360	360	360	360
Operating profit	($/ha)	2,566	2,506	2,417	2,332	2,288
Percentage reduction in nitrogen leaching	%		-10%	-19%	-25%	-27%
Percentage reduction in operating profit	%		-2%	-6%	-9%	-11%
Percentage reduction in production	%		-3%	-6%	-9%	-11%

Table 36: Operational cost of reducing stocking rate on dairy farms in the Upper Waikato River Catchment

KPI	Metric	Base	Mitigation run		
			1.1	1.2	1.3
Nitrogen leaching	kg/ha	40	36	32	30
Stocking rate	(cows/ha)	2.8	2.7	2.6	2.5
Nitrogen fertiliser use	(kgN/ha)	161	137	113	86
Milksolids	(kg/ha)	1,063	1,030	991	958
Milksolids	(kg/cow)	381	381	382	382
Operating profit	($/ha)	2,377	2,263	2,158	2,056
Percentage reduction in nitrogen leaching	%		-10%	-18%	-24%
Percentage reduction in operating profit	%		-5%	-9%	-13%
Percentage reduction in production	%		-3%	-6%	-9%

Table 37: Operational cost of reducing stocking rate on dairy farms in the Southland region

KPI	Metric	Base	Mitigation run		
			1.1	1.2	1.3
Nitrogen leaching	kg/ha	38	34	31	27
Stocking rate	(cows/ha)	2.86	2.76	2.63	2.52
Nitrogen fertiliser use	(kgN/ha)	127	107	82	55
Milksolids	(kg/ha)	1,217	1,174	1,120	1,077
Milksolids	(kg/cow)	420	420	420	422
Operating profit	($/ha)	2,781	2,601	2,418	2,249
Percentage reduction in nitrogen leaching	%		-9%	-19%	-29%
Percentage reduction in operating profit	%		-6%	-13%	-19%
Percentage reduction in production	%		-4%	-8%	-10%

Table 38: Operational cost of reducing stocking rate on dairy farms in the South Coastal Canterbury Streams area

KPI	Metric	Base	Mitigation run				
			GMP	1.1	1.2	1.3	1.4

Nitrogen leaching	kg/ha	24	24	21	19	17	14
Stocking rate	(cows/ha)	3.3	3.3	3.2	3.0	2.9	2.8
Nitrogen fertiliser use	(kgN/ha)	233	233	215	190	159	113
Milksolids	(kg/ha)	1,361	1,361	1,315	1,271	1,217	1,163
Milksolids	(kg/cow)	418	418	417	417	417	416
Operating profit	($/ha)	2,828	2,807	2,677	2,518	2,346	2,154
Percentage reduction in nitrogen leaching	%		0%	-10%	-20%	-30%	-41%
Percentage reduction in operating profit	%		-1%	-5%	-11%	-17%	-24%
Percentage reduction in production	%		0%	-3%	-7%	-11%	-15%

Table 39: Operational cost of reducing stocking rate on dairy farms in the Selwyn Te Waihora Catchment

KPI	Metric	Base	Mitigation run		
			1.1 GMP	1.2 GMP	1.3 GMP
Nitrogen leaching	kg/ha	29	28	24	19
Stocking rate	(cows/ha)	3.53	3.53	3.46	3.24
Nitrogen fertiliser use	(kgN/ha)	214	214	185	123
Milksolids	(kg/ha)	1450	1450	1419	1349
Milksolids	(kg/cow)	411	411	413	416
Operating profit	($/ha)	2751	2705	2627	2347
Percentage reduction in nitrogen leaching	%		0%	-10%	-20%
Percentage reduction in operating profit	%		-1%	-5%	-11%
Percentage reduction in production	%		0%	-3%	-7%

5.5.4. Assumptions

- This mitigation is based on a literature review and therefore subject to the assumptions of each applicable study. This includes the input and output prices, how modelling tools are used, which years of data are used and how farms were amalgamated.
- Results are for a weighted, amalgamated farm, they are not individual farms though they are based on real farms covering a range of biophysical and farm management contexts.
- Production per cow is held constant as a proxy for assuming a constant level of management skill.
- Each mitigation run represents a complex series of farm system changes to ensure a balanced far system.
- All studies considered here used Farmax and Overseer modelling as well as relatively consistent assumptions.
- Profits are percentage based but use a different operating profit base to the land retirement option in this report due to the underlying assumptions of each studies.

5.5.5. References

DairyNZ (2015). DairyNZ Farm System Analysis: South Canterbury Coastal Streams. Appendix 1 from DairyNZ on Variation 3 to the proposed Canterbury Land and Water Regional Plan.

Bell, B., Muller, C., McDonald G. & Fairgray, D. (2014). Cost Benefit and Economic Impact Analysis for the Dairy Sector and Region of Environment Canterbury's Variation 1 Selwyn Te Waihora. A report prepared for DairyNZ.

Muller, C. (2017). Modelling dairy farm systems: processes, predicaments and possibilities. In: *Science and policy: nutrient management challenges for the next generation*. (Eds L. D. Currie and M. J. Hedley). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 30. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 15 pages.

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DairyNZ. (2014). Waikato Dairy Farm Nitrogen Mitigation Impacts: Analysis of Waipa-Franklin and Upper Waikato Dairy Farms. Report for the Economic Joint Venture (Healthy Rivers, Waikato Regional Council).

5.6. Change animal type – sheep and beef

5.6.1. Definition

As with the equivalent mitigation for dairy, the mitigation of 'change animal type' can have a multitude of meanings. For sheep and beef farms there is considerably more options than in dairy. These could include changing some part of the land to another land use, changing the ratio of stock types (e.g. sheep and cattle), changing gender of stock or changing stock purpose (e.g. breeding and finishing), changing stock units per hectare. The current choices of stock are most likely to be defined by land class and land areas as well as the relative returns from each enterprise type. These options will have differing levels of applicability for each farm situation and differing levels of both costs and benefits. In addition, because all of these mitigation impact feed supply and demand the costs and benefits should be considered in farm systems models and across a range of farm types. In addition, because the impact on returns is driven by multiple enterprises the relative impact of tis mitigation option is highly variable across time.

Given the significant variation in sheep and beef farm systems, literature that could be included in this mitigation covers a significant range of mitigations. Given the multitude of ways this mitigation could be interpreted it is not appropriate to include a single option and summarize the results from the literature as for de-stocking for dairy farms. In addition, often the mitigations that consider changes in stock policy are bundled in with other mitigations, making it hard to distill an impact of just changing stock type in a consistent way.

Due to the range in interpretations and inconsistency of modeling across the literature, there is not an appropriate source(s) to use as base results to estimate the on-farm economic impact of this mitigation in the scope of this report. Instead a range of studies which consider changing stock type (in a range of applications) for sheep and beef farms are briefly highlighted where applicable.

5.6.2. Capital cost

There is no capital cost of this mitigation considered here, however, some capital impacts may occur from selling and/or purchasing capital stock.

5.6.3. Operational cost

In the Waikato, Doole (2015) considered the impact of replacing older cattle (with a higher maintenance feed intake) with the same equivalent feed demand of cattle a year younger in a bull/prime beef finishing system. Doole's (2015) analysis estimated annual nitrogen loss reductions of up to 20% was achievable when 70% of older cattle were replaced with younger cattle, but this was accompanied by a 60.5% decline in annual profit. While not all assumptions were clearly disclosed, the impact on profit was likely to be a result of an increasing reliance on selling store cattle at inopportune times relative to their live weight in order to deliver a farm system which balances feed supply and demand.

Altering stock ratios (between sheep, beef and deer) can impact on the nutrient loss from drystock farms, but can also have a significant impact on profitability, particularly due to the relativities between the alternative commodity prices. In addition, changing stock policies, especially where breeding stock are involved, often has a significant lag period before increases in profitability are achieved, are not easily reversed once implemented and can have significant management implications.

It is challenging in literature to estimate the impact of altering stock ratios, as there is a myriad of changes, for example, the proportion of each stock type that is changed. One example is Doole (2015) which calculated a reduction in nitrogen loss to water of 20% as the sheep to cattle ratio on a hill country farm lifted from 20%:80% to 70%:30%. In this study, annual profit increased by 91%, a significant lift. This is likely due to the relative productivity of the respective livestock systems (growth rates, reproductive performance etc.) and the relative product prices, neither of which were disclosed. An alternative study, Matheson et al (2018) considered a 10% lift in the sheep to cattle ratio in two of their case studies to a maximum of 60%:40%. This led to an estimated a 2-3% reduction in nitrogen loss to water was achievable but had an associated 8-9% reduction in annual profit from the comparative scenario.

Reducing stocking rate is another mitigation which could be considered under changing animal type. Doole (2015) considered reducing stocking rate (across cattle and sheep) by 25% on a Waikato finishing operation. This led to a reduction in nitrogen loss of 19% and a 36% decline in farm profit, though it is unclear whether any allowance was made for increased productivity. Burt et al. (2017) also considered lower stocking rates (-10%) in Southland (though this was considered across a wide range of farms with starting stock policies). They estimated a reduction in nitrogen loss per hectare of 0-10 kilograms annually and an associated reduction in farm profit per hectare of $110 to $124.

5.6.4. Assumptions

- This mitigation is based on a literature review and therefore subject to the assumptions of each applicable study. This includes the input and output prices, how modelling tools are used, which years of data are used and how farms were amalgamated.
- Given the information available in each study, it is assumed that productivity is held constant in the studies discussed here, which is a proxy for assuming a constant level of management skill.
- Profits are percentage based but use a different operating profit base to the land retirement option in this report due to the underlying assumptions of each studies.

5.6.5. References

Doole, G. (2015). Description of mitigation options defined within the economic model for Healthy Rivers Wai Ora Project. Report No. HR/TLG/2015-2016/4.6

Matheson, L., Djanibekov, U., Bird, B., Greenhalgh, S. (2018). Economic and contaminant loss impacts on farm and orchard systems of mitigation bundles to address sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui water management areas. Final report, forming delivery for Milestone 2A, 2B, 2C & 2D. Version 1.3. 109 pages;

Burt, A., Sluys, C. & Fung, L. (2017). Part C: Farm Case Studies- Drystock (Sheep, Beef Cattle and Deer). In: The Southland Economic Project: Agriculture and Forestry. (Eds.: Moran, E., Pearson, L., Couldrey, M., and Eyre, K.) Technical Report. Publication no. 201904. Environment Southland, Invercargill, New Zealand.

5.7. Improved nitrogen use efficiency

5.7.1. Definition

This mitigation can relate to a number of changes on farms to improve nitrogen use efficiency. One way which is often discussed is to reduce stocking rate on dairy farms and increase per cow production. This is an increase in efficiency as the inputs are reduced (cows) and the output is increased (per cow production). Some refer to this as a 'win-win' situation as nitrogen loss is likely to reduce (due to fewer cows) and increase profits (as there will be lower costs such as animal health and increased production per cow). Others consider this inappropriate as if farmers would operate more efficient it would be logical for them to do this and there must be something holding the farmer back such as knowledge or genetic potential of the cows (Muller, 2017). This efficiency is often over and above that which could be increased over time improvements in genetic gain.

There is not as much consistency in the application of this mitigation in farm system modelling as with the mitigations which reduce stocking rate on dairy farms and maintain per cow production. Due to the range in applicability and benefits of this mitigation across farms, there is not an appropriate source(s) to use as base results to estimate the on-farm economic impact of this mitigation in the scope of this report. Instead a few examples of this mitigation from the literature have been provided, but should be extrapolated with extreme care.

5.7.2. Capital cost

There is no capital cost of this mitigation considered in this report, however, some capital impacts may occur from selling and/or purchasing capital stock as well as milk supply shares.

5.7.3. Operational cost

Perrin Ag (2014) undertook farm systems modelling, some of which included improving per cow production (and an associated bundle of farm system changes to ensure a viable farm system is maintained). In this study per cow production was allowed to increase between 4 and 8%, there was an 18 to 25% reduction in nitrogen loss and between a 0 and 6% reduction in earnings before interest and tax (Perrin Ag, 2014). This was a Rotorua based study and should not be extrapolated across the country.

Sulzberger et al. (2015) used an optimisation model to look at how a Manawatu dairy farm could meet nutrient regulations. In this modelling, one run reduced cow numbers by 23%, removed imported supplements, nitrogen fertiliser and the winter oat crop, this increased profits by 14% and decreased nitrogen loss by 43% over the base system. This study was based on just one farm and used an optimisation model to find the most profitable and lowest nitrogen loss farm system.

5.7.4. Assumptions

- This mitigation is based on a literature review and therefore subject to the assumptions of each applicable study. This includes the input and output prices, how modelling tools are used, which years of data are used and how farms were amalgamated.
- Profits are percentage based but use a different operating profit base to the land retirement option in this report due to the underlying assumptions of each studies.
- There is no inclusion of costs related to improving productivity on farm if there is a management skill gap, i.e. the cost of accessing farm consultants, or upskilling through training.

5.7.5. References

Muller, C. (2017). Modelling dairy farm systems: processes, predicaments and possibilities. In: *Science and policy: nutrient management challenges for the next generation*. (Eds L. D. Currie and M. J. Hedley). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 30. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 15 pages.

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Sulzberger, T., Phillips, T., Shadbolt, N., Ridler, B. & McCallum, R. (2015). A Whole Farm Modelling Approach To Evaluate The Economic Viability Of A Dairy Farm In A Sensitive Catchment. In: Moving farm systems to improved attenuation. (Eds L.D. Currie and L.L Burkitt). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 13 pages.