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Modelling Farm-scale Mitigation Options for the Ruamahanga Whaitua Collaborative Modelling Project

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Report prepared for MPI

June 2016

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1. Summary

This report has been prepared for the Ministry for Primary Industries (MPI) as a component of the larger Ruamahanga Whaitua Collaborative Modelling Project. Previous work by MPI had established 16 base farms to be used as representative farms for the Economic modelling project. MPI supplied AgResearch with the OVERSEER and FARMAX models for the 16 base farms. AgResearch then worked with Greater Wellington Regional Council, MPI and the Ruamahanga Whaitua Committee to select three mitigation bundles to apply to the 16 base farms. The purpose of this project was to develop an understanding of the potential effectiveness of contaminant mitigation options relevant to productive land in the Ruamahanga catchment, and also the relative cost of implementing these mitigations on farms.

The selected mitigation bundles were applied to the farms to generate estimates of the change in profit as well as nitrogen, phosphorus, sediment and *E. coli* losses from the farms. Over all the mitigation bundles, changes in profit ranged from nil to a decrease of 66%. Nitrogen and phosphorus losses from the farms were reduced by 0 to 52% and 0 to 82%, respectively. Sediment and *E. coli* losses from the farms were reduced by 0 to 72% and 0 to 28%, respectively. These results can now be used in the subsequent Landcare Research analysis that forms the final step in this Economic Modelling process.

2. Purpose

This report has been prepared for the Ministry for Primary Industries (MPI) as a component of the larger Ruamahanga Whaitua Collaborative Modelling Project. MPI has a joint venture with GWRC to provide an Economic Modelling component to potential scenario analyses through a 3 stage process, of which this report describes step 2. Step 1 was the development of 16 base farms that are described in the report by Parminter and Grinter (2016). Step 2 (this report) is the development of the cost effectiveness data for applying a series of mitigations to each base farm. This data includes, where possible, the effectiveness for potential reductions of nitrogen (N), phosphorus (P), sediment (sed) and *E. coli* losses to water from the base farms. The third step will be the application of this farm-scale cost effectiveness data in a catchment-scale economic model that will be undertaken by Landcare Research. It is recommended that this report be read in conjunction with the reports produced in step 1 and step 3 of this process.

3. Introduction

3.1 Introduction to this report

This report is a component of the larger Ruamahanga Whaitua Collaborative Modelling Project led by Greater Wellington Regional Council (GWRC) that has the aim of providing the community-based Ruamahanga Whaitua with information about water and contaminant flows through the Ruamahanga catchment to support the limit setting process. MPI contracted AgResearch to model up to 3 mitigation bundles per farm for the 16 base farms previously described in Parminter and Grinter (2016). Given the remit to identify reductions for 4 contaminants per farm, this could require a total of 48 separate model combinations. The N and P mitigation options were to be modelled using the OVERSEER® nutrient budgeting model (hereafter referred to as OVERSEER). Losses of sediment and *E. coli* were to be estimated using the best available data on farm-scale losses of these contaminants, as these two contaminants cannot currently be modelled in OVERSEER. The financial implications were to be modelled using FARMAX with the work to be conducted by an experienced FARMAX modeller with intimate knowledge of the farms and farm systems in the Ruamahanga catchment. AgResearch contracted John Stantiall of Stantiall & Partners, Agricultural Consultants, to undertake the financial analysis as John had been involved in the base farm analysis from the first report (Parminter and Grinter, 2016).

This report has been structured in several sections that describe different stages of the development of the modelling approach. Section 3.2 provides an introduction to the range of mitigation options that can be applied to farms. Section 4 describes the methods used in the project. Section 5 contains the summary of the farm-scale results that Landcare Research can use for the catchment-scale modelling, and a brief description of the overall results. Section 6 provides some more detailed description of the individual mitigations applied and some of the financial implications for each of the 16 farms.

3.2 Introduction to on-farm mitigation options

Mitigation options can be applied at different scales and to different parts of a catchment (McDowell et al., 2013). This section contains a brief description of the individual mitigation options that can be applied to agricultural land in a catchment. These descriptions provide brief explanations of the contaminant targeted, other potential benefits and how the mitigation works. More detailed descriptions of the options and the general modelling approach can be found in McDowell et al. (2013), Monaghan (2009), and Vibart et al. (2015). Further information is also available on many websites. Two good websites are: DairyNZ (http://www.dairynz.co.nz/environment/) and the Waikato Regional Council (http://www.waikatoregion.govt.nz/menus/).

Stock exclusion from streams

Preventing livestock access to streams decreases stream bank damage (and sediment inputs via bank erosion), bed disturbance of sediments (and entrained *E. coli*, N and P) and stops the direct deposition of excreta into streams. Planted riparian margins provide a number of ancillary benefits that help to improve the ecological function of waterways. These include the provision of shade to minimise fluctuations in stream temperatures, stabilisation of stream banks, uptake of nutrients from riparian margins, increased biodiversity and improved aesthetic values.

Deferred and/or low rate effluent irrigation

The risk of waterway contamination via land application of farm dairy effluent (FDE, otherwise known as dairy shed effluent) is high on soils with a propensity for preferential flow (rapid drainage via artificial drainage networks or due to coarse structure) or surface runoff (due to an infiltration or drainage impediment, or sloping topography). Deferred irrigation, which involves storing FDE in ponds when soil moisture is close to or at field capacity and applying FDE to land otherwise, has proven effective at decreasing N, P and *E. coli* losses. Low rate effluent application systems typically use sprinkler-type delivery nozzles to deliver instantaneous rates of effluent application of 10 mm per hour or less. This is much lower than delivered by a rotating twin gun travelling irrigator and allows effluent more time to infiltrate the soil, helping to ensure the liquid and nutrients contained in the effluent remain in the root zone, available for plant uptake. Runoff or drainage that may occur will at least have had some degree of filtering by the soil if a low rate application system has been used.

Efficient water irrigation

This is similar to the principles for managing FDE as above. Efficient water irrigation also involves changing to efficient spray systems that apply water at low rates to minimise water losses and also only applying water when there is sufficient soil water deficit to absorb the applied water. Any excess water losses will also carry contaminants, thus increasing losses from the farm. These systems can also include precision agriculture tools such as detailed soil mapping, variable rate irrigation and automated soil moisture monitoring systems.

Optimal P fertility and fertiliser form, including low solubility P fertiliser application to sloping land

The magnitude of P losses from soil via surface runoff or subsurface flow is generally proportional to soil P concentration. Hence, maintaining a soil test P concentration in excess of the optimum for pasture production represents an unnecessary source of potential P loss. Achieving an optimal soil test P concentration (e.g. Olsen P) can be achieved through regular soil testing and use of nutrient budgeting software, such as OVERSEER, to guide P inputs. Reducing P inputs and soil test P levels to agronomically-optimum levels will always represent a profitable strategy. The magnitude for P loss mitigation is dependent on how excessive soil Olsen P is. Furthermore, low water solubility P fertilisers decrease P loss risk by maintaining a smaller pool of soluble P in soil solution soon after application than highly water soluble P fertilisers (e.g. superphosphate), thereby minimising the potential for loss should runoff occur. Reactive phosphate rock (RPR) fertiliser has little water soluble P and has been shown to decrease dissolved P losses. However, reactive phosphate rock should not be used where annual rainfall is < 800 mm and soil pH is > 6. Given that about a third of the applied P in RPR becomes available per annum, a lead-in time is usually required if changing to a fertiliser that has such low levels of water soluble P.

Enlarged effluent area

Enlarging the effluent area involves increasing the land application area to ensure N, P and potassium (K) returns are not excessive. Because effluent is a particularly rich source of N, P and K, it makes good economic sense to ensure that inputs of these effluent nutrients are matched to provide the agronomic requirements of pastures on the effluent-treated parts of the farm. The preparation of a nutrient budget will help determine the appropriate area that could be treated with effluent and the fertiliser applications required to balance nutrient inputs to plant growth requirements.

Early re-establishment of summer crops

Re-sowing areas of bare or damaged soil as soon as practically possible will help to minimise periods when exposed soil may be prone to erosion, overland flow or leaching. The rapid establishment of crops or pastures will maximise the opportunity for plants to take up N from the soil, thus reducing the risk of N leaching. This can be particularly important for summer-grazed forage crops that will have urinary N deposited onto bare soil.

Diverting laneway runoff

Putting in culverts or bridges at regular stock crossings will prevent animals from fording streams and thus avoid the direct entry of faeces, urine and entrained hoof mud. It will also avoid disturbance of the stream bed. Reticulating stock water supplies and planting shade trees away from water will help to reduce animal trafficking through and around stream locations. Reducing runoff from tracks and races using cut-offs and shaping is another particularly important measure that will prevent faecal microorganisms, sediment and P entering streams.

Reduced use of fertiliser N

Nutrient budgets account for nutrient flows into and away from farm blocks in fertiliser, feed, animal transfer, animal product and via loss pathways such as leaching, runoff and volatilisation. The planning objective is to ensure that nutrient inputs and outputs are balanced to avoid situations of deficit or surplus. OVERSEER is a tool that has been developed to assist with such planning decisions.

Facilitated or constructed wetlands

Facilitated wetlands utilise naturally poorly drained parts of the landscape where seepage flows can more easily be intercepted. Fencing and planting of these areas helps to create a wetland environment where sediment, entrained in flow, can be captured, and N removed by denitrification. The beneficial effects of wetlands can be negated if they are left un-fenced or do not have buffers when over-sowing or topdressing (or, for some alpine landscapes, are burnt). Constructed wetlands involve modification of landscape features such as depressions and gullies to form wetlands. These types of wetlands have also been designed to capture sediment and N discharging from tile drains. Compared to many natural wetlands, constructed wetlands can be designed to remove contaminants from waterways by: 1) decreasing flow rates and increasing contact with vegetation – thereby encouraging sedimentation; 2) improving contact between inflowing water, sediment and biofilms to encourage contaminant uptake and sorption; and 3) creating anoxic and aerobic zones to encourage bacterial N processing, particularly denitrification loss to the atmosphere.

Autumn substitution of N-fertilised pasture with low N feeds

The use of “low N feeds” involves substituting part of the animals diet with feeds, such as maize, that provide for the animals’ energy needs but contain less N. Animals therefore excrete less N in their urine and hence reduce N leaching risk from the farm.

Split grass/clover swards

Using grass–clover monocultures strategically across a dairy farm may decrease P loss to surface water and improve profitability compared with a mixed pasture. The principle of this technique is to ensure that plants that have a relatively high P demand, such as clover, are located away from near-streams areas. Conversely, grasses that have a lower P demand can be located in near-stream areas (or "Critical Source Areas", also referred to as CSAs) and fertilised to maintain a lower soil Olsen P test and thus a smaller reservoir of P that could potentially be transported in overland flow (or subsurface drainage).

Catch crops following winter crops

Preliminary research trials in Canterbury have established that N leaching from winter forage crop paddocks can be reduced by planting an oat crop immediately after cows harvest the kale. The oats crop in this sequence is a "catch crop", with its purpose being to capture urinary N from the soil, while increasing overall crop yield when compared to a standard kale crop. Sequence cropping can provide all the feed needed for wintering, whereas kale-only systems require supplements to be brought in to balance the diet. Sequence cropping will only be successful on free-draining soils where machinery can operate soon after kale grazing is completed, where there is irrigation or good rainfall from early December onwards, and where kale is well-utilised during winter grazing so the residues do not interfere with sowing of the oats.

Protection of CSAs on grazed forage crops

Winter grazing of a forage crop can often lead to large losses of sediment, P and faecal microorganisms in surface runoff that occurs in gullies and swales. Protection of soils in these areas has been shown to be a particularly cost-effective way to minimise the amount of surface runoff that is generated:

- Graze from the top of the slope toward the CSA (such as a gully or swale) – this uses the remaining crop as a filter for sediment and dung that might be transported in surface runoff. Ensure the CSA is the last break to be grazed by stock.
- Restrict the time spent grazing in the CSA to 3-4 hrs so animals get their maintenance feed requirements whilst minimising the extent of soil treading damage and thus potential for surface runoff.
- Back fence stock off land that has already been grazed to minimise further soil damage.

Ideally, avoid cultivating the CSA and leave it in pasture to act as a filter for any surface runoff that may occur.

Sediment traps

Sediment traps are engineered structures designed to slow water flows, reduce energy, filter sediment and allow grass growth. Examples of such structures include decanting dams, detainment bunds, stock ponds or earth reservoirs constructed at natural outlets of zero-order catchments. In-stream sediment traps are useful for the retention of coarse-sized sediment and sediment-associated N and P, but do little to retain N and P bound to fine sediment. As the P sorption capacity of fine particles is much greater than coarse particles (on a w/w basis), sediment traps can be ineffective at decreasing P loss if the soil is finely textured and/or surface runoff is dominated by fines.

Reduce the proportion of farm livestock as cattle

Animal type influences N leaching due to inherent differences in the spread of urinary N (the major source of N loss in grazed pastures). Increased urinary spread results in a lower rate of N deposited in urine, greater utilisation by plants and less surplus N that contributes to N losses. Research has shown that N leaching from sheep and deer is approximately half that from beef cows at the same level of feed intake. Potentially, differences also exist between male and female cattle; losses from male cattle being about two-thirds that of female cattle, although there is high uncertainty with this. Similarly, young cattle are assumed to have greater urinary N spread than larger older cattle due to greater animal numbers per unit of feed consumed and thus a greater number of urinations; however, there is limited data on this aspect.

Duration-controlled crop grazing

Research in Manawatu (and elsewhere) has shown that restricting autumn grazing rounds to 3-4 hours per break, then excluding the animals (removing them to a pad or barn) can significantly decrease urine deposition to land prior to the on-set of winter drainage. This management system has been shown to decrease nitrate leaching losses in drainage from the milking platform by up to 40%; this does however depend on the extent to which duration-controlled grazing is implemented during autumn months. This principle of reducing urinary N deposition to land as a strategy for reducing N leaching is likely to also apply to grazed winter forage crops, although research quantifying this effect is still in a preliminary stage.

Off-paddock wintering

On-going research in Southland indicates that grazed winter forage crops are a significant source of N leaching losses from the dairy farm system. Strategies that avoid or minimise the deposition of urine to these grazed crops can help to decrease these leaching losses. Stand-off pads (preferably covered) or wintering barns are some of the infrastructure options that could be considered to allow for capture of urinary N that would otherwise be deposited directly in the paddock. Cut-carry fodder crop systems are one example of an off-paddock wintering strategy that might be practical and affordable for some; other approaches that are more commonly used are based around providing ensiled feeds whilst animals are off-paddock during winter.

4. Methods

4.1 Selection of mitigation options to be modelled

The selection of mitigation options to be modelled was developed as a collaborative process with the Ruamahanga Whaitua committee. Firstly, MPI provided AgResearch with an early draft of the Farm-scale Modelling Report which contained some details on the farm systems aspects of the base farms to be modelled. Based on this information AgResearch then selected a list of farm-scale mitigations that could potentially be applied to the base farms from the Best Management Practice Toolbox (Monaghan, 2009). The aim at this stage was to provide the Whaitua Committee a wide scope of potential mitigation options for their input into the selection process. These potential mitigations followed a similar pattern for dairy, sheep and beef and dairy-support farming types. Because there are a large number of mitigation options available it can be prohibitively expensive to model each mitigation individually so the option to bundle multiple mitigations into groups for modelling was proposed.

Within these farm types the list of mitigations were initially bundled into 3 potential groups of mitigation options that represent those that are easy, moderately difficult and challenging/expensive to implement on farm (Monaghan, 2009). Two other potential mitigations options (or bundles) that were also considered for modelling are (i) the proposed GWRC policy that is currently undergoing consultation, and (ii) “reduced stocking rate” options. This would give a total of 5 different mitigation bundles. These 5 different bundles of mitigation options and the types of information that each bundle could potentially provide were presented to and discussed with the Whaitua committee who then had to select which bundles they wanted modelled. The 3 options selected by the Whaitua committee were (1) current GWRC policy, (2) the easy and medium mitigation options combined and (3) the challenging/expensive mitigation options. Feedback from the Whaitua committee was that they wanted the scenario options to span the range from the current trajectory to an extreme level of mitigation.

Tables 1 to 3 provide a list of mitigation options that could be applied to the dairy, sheep and beef, and arable and dairy support farms, respectively.

Table 1. Potential Good Management Practices (GMPs) that could be applied to dairy farms. The target in bold indicates the key contaminant(s) that the mitigation targets as well as other potential benefits. Estimates of effectiveness, rated as low (L), medium (M), high (H) or uncertain (?), are also indicated for the target contaminant.

GMP	Target	Effectiveness	Bundle*
Stock exclusion from streams and wetlands	P, ***E. coli***, NH_4-N, sediment	High for ***E. coli***	1
Deferred and/or low rate effluent irrigation	***E. coli***, P	M	1
Efficient water irrigation	**N**	L	2
Optimal P fertility & fertiliser form	P	?	2
Enlarged effluent area	**N**	L	2
Early re-establishment of summer crops	**N**	L	2
Diverting laneway runoff	***E. coli*, P,** NH_4	L-H	2
Reduced use of fertiliser N	**N**	M	2
Facilitated or constructed wetlands	**N, sediment**, *E. coli*	L-M	2
Autumn substitution of N-fertilised pasture with low N feeds	**N**	L	2
Split grass/clover swards	**P**	L-M	3

*The Bundle refers to the mitigation bundle (1, 2 or 3) that the specific mitigation would be applied in. The bundling decisions were made in consultation with the Whaitua Committee as described in the text.

Table 2. Potential Good Management Practices (GMPs) that could be applied to sheep and beef farms. The target in bold indicates the key contaminant(s) that the mitigation targets as well as other potential benefits. Estimates of effectiveness, rated as low (L), medium (M), high (H) or uncertain (?), are also indicated for the target contaminant.

GMP	Target	Effectiveness	Bundle*
Cattle exclusion from streams and wetlands	P, ***E. coli***, NH_4-N, sediment	High for ***E. coli***	1
Protection of CSAs+ on grazed forage crops	**Sediment, P, *E. coli***	H	2
Efficient water irrigation	**N**	L	2
Low solubility P fertiliser to sloping land	**P**	L	2
Early re-establishment of summer crops	**N**	L	2
Facilitated or constructed wetlands	**N, sediment**, *E. coli*	L-M	2
Catch crops following winter crops	**N**	L	2
Planted buffer strips	**Sediment, P**	M	3
Sediment traps	**Sediment, P**	?	3

*The Bundle refers to the mitigation bundle (1, 2 or 3) that the specific mitigation would be applied in. The bundling decisions were made in consultation with the Whaitua Committee as described in the text.
+CSA – Critical Source Area. See text for further detail.

Table 3. Potential Good Management Practices (GMPs) that could be applied to dairy support farms. The target in bold indicates the key contaminant(s) that the mitigation targets as well as other potential benefits. Estimates of effectiveness, rated as low (L), medium (M), high (H) or uncertain (?), are also indicated for the target contaminant

GMP	Target	Effectiveness	Bundle*
Stock exclusion from streams and wetlands	P, ***E. coli***, NH_4-N, sediment	High for ***E. coli***	1
Protection of CSAs+ on grazed forage crops	**Sediment, P, *E. coli***	H	2
Optimal P fertility & fertiliser form	**P**	?	2
Early re-establishment of cropped land	**N**	L	2
Catch crops following winter crops	**N**	L	2
Reduced use of fertiliser N	**N**	L	2
Facilitated or constructed wetlands	**N, sediment**, *E. coli*	L-M	2
Reduce % as cattle	**N**	M	2
Duration-controlled crop grazing	**N,** sediment	L	3
Off-paddock wintering	**N,** sediment	H	3
Sediment traps	**Sediment, P**	L	3
Planted buffer strips	**Sediment, P**	L	3

*The Bundle refers to the mitigation bundle (1, 2 or 3) that the specific mitigation would be applied in. The bundling decisions were made in consultation with the Whaitua Committee as described in the text.

+CSA – Critical Source Area. See text for further details.

4.2 Applying the mitigations to the base farms

The selected mitigation bundles were then applied to the 16 base farms using a number of modelling approaches and tools. Changes in N and P losses from the farm were estimated using the OVERSEER model. The OVERSEER modelling was conducted using version 6.2.1 by an expert user of OVERSEER and following the OVERSEER best practice data input standards (OVERSEER, 2015). The changes in costs or production changes resulting from applying the mitigations to the farms were modelled predominantly using FARMAX. The FARMAX modelling was conducted by an expert user with over 13 years experience with using FARMAX and over 24 years experience as a farm consultant in this area. Any costs that were unable to be modelled within FARMAX were calculated separately and then used as additional inputs into FARMAX, as appropriate. Farm costs and incomes were calculated using the same values as used for the base farms. MPI provided AgResearch with the OVERSEER and FARMAX files that were used to model the 16 base farms (Parminter and Grinter, 2016).

For each of the 16 base farms the 3 bundles of mitigations were applied in order and are designated as M1, M2 and M3. Importantly, not all mitigations were applicable to every farm. Therefore, for each farm and mitigation bundle, the applicable mitigations were selected and applied. The mitigations were initially applied in OVERSEER and then the FARMAX modelling was conducted to cost the appropriate mitigations. The data generated from FARMAX was then fed back into the OVERSEER files to check for correct alignment (Parminter and Grinter, 2016). This process was repeated until the expert model operators were comfortable that they had correctly represented the farms in the models. The OVERSEER model was used to predict the changes in N and P losses from the farms and are presented as kg nutrient lost per hectare per year.

Farm-scale losses of sediment were calculated based on the median effectiveness values presented in McDowell et al. (2013) and are presented as percentage reductions relative to the base farm. When applying a mitigation to a farm the effectiveness was scaled, where appropriate, to the size of block(s) within the farm that the mitigation could be reasonably be applied to. When applying multiple sediment mitigations to a farm the mitigation closest to the source was applied first and then the next mitigation applied to the remaining sediment load, i.e. for a winter grazed forage block the “critical source area management” was applied to the paddock first which would produce a 50% reduction in sediment losses from that block. Then a constructed wetland could potentially be applied that would reduce 65% of the sediment from the remaining sediment load, which is equivalent to a further 33% reduction in sediment loss from that block. This implies a total sediment mitigation effectiveness from that winter grazed forage block of 83%. However, if the winter grazed forage block was only 2% of the total farm area then the farm-scale sediment reduction of applying these 2 mitigations is 1.7%. The potential percent reductions in sediment loads for the specific mitigation options used in this report are planted riparian buffers (65%), constructed wetland (65%) and CSA winter grazing management (50%).

Farm-scale *E. coli* losses were estimated using the data presented in Muirhead (2015), adapted to represent the change in median stream concentration as presented in Muirhead (2013) and Kaye-Blake et al. (2013). The % change in median concentration is the best metric to use for the catchment-scale *E. coli* modelling being conducted by

Jacobs as part of the wider Ruamahanga collaborative modelling project. The data supplied by MPI for all 16 base farms indicated that the streams were already fenced so the expected *E. coli* reductions from fencing in mitigation bundle one could not be applied to any farms. The key *E. coli* mitigation that could be applied to dairy farms was changing the FDE irrigation systems to deferred irrigation systems. These were estimated to result in a 21 or 28% reduction in *E. coli* losses for free-draining or poorly-draining soils, respectively.

Not all mitigations can be realistically applied on each farm. Mitigations on managing specific summer or winter crops can only be applied to the farms that grow those crops. Increasing the FDE irrigated area only applied to farms that currently have insufficient area to manage the K loads being applied. Where applicable, the FDE irrigation area was increased to balance K inputs, and other blocks on the farm reduced in size and the fertiliser and feed management on these blocks adjusted as appropriate. Where changes in FDE irrigation system or storage ponds were required, the capital costs were calculated based on recent data from the Wairarapa region and then annualised. Ponds were annualised over 25 years and the irrigation equipment over 15 years as this is the expected life of the equipment. All annualisation of capital costs were calculated assuming a 6% interest rate. For changes to the FDE management systems, the Massey University-developed “pond storage calculator” was used to determine the size of pond to be built.

Any changes to the water irrigation systems were based on changing to more efficient spray irrigation systems such as K-line pods, centre pivots or linear irrigators and then managing to implement best practice. This involves active monitoring of soil moisture levels on the farms and then accurately applying irrigation to replace any soil water deficits. On one farm where the area to be irrigated was only 40 ha we applied K-line pod irrigation systems. For all other farms with larger irrigation areas we applied centre pivot irrigators. Any capital costs of changing the irrigation systems were calculated and annualised over 15 years. It was assumed that any management required to operate these systems to best practice would be little more than the current workload of managing any irrigation system and, therefore, no additional cost to the farm.

Reducing fertiliser inputs only applied to scenarios where large amounts of fertiliser were used. The specific N fertiliser management approach was based on recent research principles identified from the Pastoral21 research programme. The N fertiliser rules were based on imported N inputs (fertiliser, imported feed and FDE, but not N fixation from clover) to individual blocks in a farm. For “System 4” dairy farms, N inputs were reduced if the imported N inputs were >150 kg N/ha. For all other farm types the N inputs were reduced if the imported N inputs were >100 kg N/ha. Reducing P fertiliser was only applied to the farm blocks where Olsen P levels were in excess of economic requirements (>30 µg/mL) and were only applied for sufficient years to reduce soil Olsen P to appropriate levels before P fertiliser inputs were again increased to maintenance levels. These changes were made following the guidance provided in OVERSEER. Changing the types of P fertiliser to RPR was only applied to blocks of sloping land. Changes in fertiliser inputs typically resulted in reduced costs which would be an on-going annual saving for the farm. These changing costs of P fertiliser inputs were averaged over a 25 year period and the average cost saving applied to the farm finances.

Planted riparian buffer strips were not applied to flat land with free draining soils. Farm blocks were assumed to have 26 m of stream length per ha and were then modelled as a 5 m wide strip with established trees. Costs for the planted riparian buffer strips were based on the cost of installing new fences and planting the area; these capital costs were then annualised over 15 years. Furthermore, the area of these planted riparian buffer strips was removed from the farmed area and the corresponding reduction in pasture production estimated. From the reduced pasture production figures, farm-scale stock numbers were adjusted and accounted for in the farm finances in FARMAX.

Constructed wetlands were only applied to rolling or steep land units. The suggested mitigation options of “sediment traps” and “split grass/clover swards” were not applied to any farms. This decision was made as these two mitigation options would be applied to the same area of the farms as the “wetland” or “riparian buffers” mitigation options were applied. More specifically, a well-designed constructed wetland will trap nutrients as well as sediment and, therefore, this mitigation option has multiple benefits over a sediment trap. The “split grass/clover swards” effectively targets the same critical source area in a catchment as the riparian buffer strips. But again, the planted riparian buffer strips have more environmental benefits than the “split grass/clover swards”. As there is no scientific data on the effectiveness of applying multiples of these mitigations we chose not to apply the “sediment traps” or “split grass/clover swards” but applied the constructed wetland where applicable. Furthermore, it is highly unlikely that all of the sloping land on a farm will drain to a single point on a farm with the actual proportion varying considerably due to the different landscape features on different farms. To take this into account the wetlands were modelled to intercept drainage from 50% of the sloping land on each farm. The costs were modelled in a similar approach to the riparian buffers, with estimates for the capital costs of fencing and establishing the wetlands calculated and then annualised. The changes in block size and lost pasture production from the wetland area were also accounted for. [Note – wetlands can be established in relatively flat land but, due to the complexities of hydrology and groundwater effects, it is more appropriate to model these at the catchment-scale rather than the "OVERSEER/FARMAX" farm-scale.]

The mitigation option of diverting laneway runoff was not applied to the model farms. On most farms this is only a very small proportion of the total farm load of nutrient losses. But on some farms, where there are long stretches of laneways running alongside a stream or steep laneways leading to a stream crossing at the bottom of a gully, these sources can potentially cause moderate levels of losses. However, with the modelled farms we were not provided with the detailed knowledge of these landscape features and hence any attempt to provide modelled estimates would be guess work only.

The mitigation options of duration-controlled grazing and off-paddock wintering were not applied to the dairy support farms as the area of winter crop grazing was <2% of the whole farm area. Therefore, any effect of these mitigations would be small at the whole farm-scale, i.e. <1%. These systems have reasonably high capital costs and it seems unreasonable to make these system level changes for such a small area of the farm.

Any mitigations that involved only changing the timing of operations (i.e. of fertiliser applications or establishment of crops or pasture) were assumed to have no effect on annual costs. Any changes in the types of crops grown or feed purchased were accounted for in FARMAX. Where stock numbers were reduced on sheep and beef farms due to other changes in the farm system, cattle numbers were preferentially reduced where it made sense from a farm system perspective.

On advice from MPI, the pasture utilization rate was kept constant before and after the mitigations were introduced as a way of using past farm performance to limit potential changes to keep them within existing managerial capability. To achieve this objective the farms were modelled to either sell excess pasture as silage or purchase low-N maize silage as required.

A brief description of the specific mitigations applied to the individual farms is presented in section 6.

5. Results and Discussion

A summary of the results from the dairy, sheep and beef and dairy support farms is shown in Tables 4 – 6, respectively. Note that applying the mitigation bundles sometimes resulted in small increases in nutrient losses from a farm. These changes were small and can be the result of applying a mitigation to reduce one contaminant that resulted in a small increase in losses of another contaminant. For example, increasing the area of land used for FDE irrigation will help reduce N losses, but can cause a small increase in P loss risk in some situations.

The financial data for the dairy farms showed all farms to be making annual profits of >$1100/ha, with all of the mitigation bundles reducing the profits (Table 4). Across all the dairy farms the application of mitigation bundle 1 resulted in 1 to 3% reductions in profit, whereas the application of mitigation bundles 2 and 3 resulted in profit reductions of up to 19% per bundle with an overall cost of up to 25% for applying all 3 bundles. Estimated N losses on the dairy farms ranged from 24 to 47 kg/ha/year and the application of mitigation bundle 1 had little effect on these losses. The application of mitigation bundles 2 and 3 reduced N losses to 17 to 42 kg/ha/year, representing reductions of 8 to 52% for individual farms.

Phosphorus losses from the dairy farms ranged from 0.8 to 1.5 kg/ha/year and the mitigation bundles had relatively little effect on all farms except the organic dairy farm (#4.6), which achieved a 38% reduction by increasing FDE area and improving the efficiency of the water irrigation system (Table 4). The application of mitigation bundles 2 and 3 resulted in predicted sediment reductions from 8 to 72%. However, as the dairy farms are all on predominantly flat land the relative loads will be less than from the steeper land used for dry-stock farms. The reduced *E. coli* loads are due to upgrades to the FDE irrigation systems on these dairy farms.

Table 4. Summary of the changes in the farm-scale profit, nutrient loss rates or changes in other contaminant losses for the sequential application of mitigation bundles 1-3 to the Dairy farms.

Value	**Bundle**	**Farm**					
MPI Report#		4.1	4.2	4.3	4.4	4.5	4.6
File Name		1b	1b2	1a	3	2	4
Financial	Base	1309	3277	1157	2413	1492	2428
($/ha/yr)	M1	1300	3236	1126	2368	1483	2413
	M2	1053	2961	1081	2017	1420	2334
	M3	977	2889	972	1901	1345	2311
N loss	Base	42	34	24	47	24	35
(kg/ha/yr)	M1	43	32	24	46	24	36
	M2	23	26	22	42	19	17
	M3	24	26	22	42	20	17
P loss risk	Base	1.0	1.5	1.2	1.7	1.0	0.8
(kg/ha/yr)	M1	1.1	1.3	1.2	1.6	0.9	0.8
	M2	0.9	1.4	1.0	1.6	0.8	0.5
	M3	0.8	1.4	1.0	1.6	0.8	0.5
Sediment loss	Base	0%	0%	0%	0%	0%	0%
(% reduction)	M1	0%	0%	0%	0%	0%	0%
	M2	0%	19%	0%	22%	0%	0%
	M3	8%	72%	65%	39%	65%	22%
***E. coli* loss**	Base	0%	0%	0%	0%	0%	0%
(% reduction)	M1	28%	28%	28%	21%	28%	21%
	M2	28%	28%	28%	21%	28%	21%
	M3	28%	28%	28%	21%	28%	21%

The fencing mitigation in bundle M1 was already applied to the sheep and beef and dairy support base farms; hence there was no change in profit or contaminant losses for the M1 scenario in Tables 5 and 6. Profitability of the sheep and beef farms was significantly less than the dairy farms, with the most profitable sheep and beef farm generating approximately half the profit of the least profitable dairy farm (Tables 4 and 5). The application of mitigation bundles 2 and 3 to these sheep and beef farms resulted in profit reductions ranging from 7 to 44% per bundle; reductions of up to 66% were estimated if both bundles were applied. Estimated N losses from these sheep and beef farms ranged from 8 to 23 kg/ha/year which are less than half the N losses from the dairy farms. The application of the mitigation bundles to these sheep and beef farms did not reduce N losses from two of the farms and resulted in 9 to 20% reductions for the 4 other sheep and beef farms. The P losses from these sheep and beef farms showed a large range, from 0.2 to 5.5 kg/ha/year. Application of the mitigation bundles to these sheep and beef farms reduced these losses to a range of 0.1 to 1.0 kg/ha/year. This represents a 17 to 82% reduction on the individual farms. The farms with the highest P losses had considerable area of sloping land with high P fertiliser inputs that were able to be mitigated. The trading, 20% crop farm (#4.12) was on flat land with imperfectly drained soils; mitigations applied to this farm had no effect on sediment losses, but the base level losses would have been very small. Sediment reductions on the other sheep and beef farms ranged from 33 to 54% (Table 5).

Table 5. Summary of the changes in the farm-scale profit, nutrient loss rates and changes in other contaminant losses for the sequential application of mitigation bundles 1-3 to the sheep and beef farms.

Value	**Bundle**	**Farm**						
MPI Report#		4.7	4.8	4.9	4.10	4.11	4.12	4.13
File Name		5	6a	6b	7	8a	8b	9
Financial	Base	673	438	402	329	267	337	345
($/ha/yr)	M1	673	438	402	329	267	337	345
	M2	517	292	300	185	185	336	224
	M3	457	246	271	111	149	270	186
N loss	Base	10	23	20	9	15	20	8
(kg/ha/yr)	M1	10	23	20	9	15	20	8
	M2	9	21	18	8	12	20	8
	M3	10	21	18	8	12	20	8
P loss risk	Base	0.2	2.7	5.5	0.9	0.9	0.6	0.2
(kg/ha/yr)	M1	0.2	2.7	5.5	0.9	0.9	0.6	0.2
	M2	0.2	2.7	4.4	0.7	0.6	0.5	0.2
	M3	0.1	0.6	1.0	0.4	0.4	0.5	0.1
Sediment loss	Base	0%	0%	0%	0%	0%	0%	0%
(% reduction)	M1	0%	0%	0%	0%	0%	0%	0%
	M2	18%	27%	13%	10%	21%	0%	19%
	M3	52%	50%	54%	38%	33%	0%	52%
***E. coli* loss**	Base	0%	0%	0%	0%	0%	0%	0%
(% reduction)	M1	0%	0%	0%	0%	0%	0%	0%
	M2	0%	0%	0%	0%	0%	0%	0%
	M3	0%	0%	0%	0%	0%	0%	0%

Results for the arable and dairy support farms showed considerable variation (Table 6). The arable farm was on flat land with imperfectly draining soils, so N leaching rates were relatively low and the mitigation bundles resulted in only small reduction in nutrient losses. The sediment reductions from this arable farm were 33% but the actual amounts of sediment lost would be relatively small from the flat landscape. The dairy support, 15% crop, summer dry property (#4.15) had relatively low profitability but also had low nutrient losses. This property has almost all mitigations options already in place and hence the mitigation bundles had no effect on farm profitability, P, sediment or *E. coli* losses and only a moderate 7% reduction in N losses. The dairy support, 48% crop, summer wet property (#4.16) had the highest N losses of 93 kg/ha/year from the base farm; the mitigation bundles were only able to reduce this to 68 kg/ha/year, which was a 27% reduction. These high N losses were due to significant amounts of cropping on a well-drained recent soil type. Estimates suggest that P and sediment losses on this farm could be reduced by 30 and 44%, respectively.

Table 6. Summary of the changes in the farm-scale profit, nuturent loss rates and changes in other contaminant losses for the sequential application of mitigation bundles 1-3 to the arable and dairy support farms.

Value	**Bundle**	**Arable Farm**	**Dairy Support Farms**	
MPI#		4.14	4.15	4.16
File Name		10	11b	11a
Financial	Base	1149	537	880
($/ha/yr)	M1	1149	537	880
	M2	999	537	810
	M3	973	537	718
N loss	Base	20	15	93
(kg/ha/yr)	M1	20	15	93
	M2	22	14	68
	M3	21	14	68
P loss risk	Base	0.5	0.3	1.0
(kg/ha/yr)	M1	0.5	0.3	1.0
	M2	0.5	0.3	0.9
	M3	0.4	0.3	0.7
Sediment loss	Base	0%	0%	0%
(% reduction)	M1	0%	0%	0%
	M2	0%	0%	17%
	M3	33%	0%	44%
***E. coli* loss**	Base	0%	0%	0%
(% reduction)	M1	0%	0%	0%
	M2	0%	0%	0%
	M3	0%	0%	0%

6. Detailed descriptions of the mitigations applied to each base farm.

6.1 Dry flat dairy (low rainfall and high production)

This is a flat land dairy farm with 7% well drained, 80% imperfectly drained and 13% poorly drained soil types. The OVERSEER effective area was 367 ha. **Mitigation bundle one** consisted of improving the FDE management system by installing a storage pond. The FDE storage pond sludge was spread on the support block in March. **Mitigation bundle two** involved making 4 changes to the farm: (1) The water irrigation system was changed from a gun to a more efficient centre pivot irrigation system and was assumed to be managed according to best practice. (2) The FDE irrigation area was increased and the P fertiliser inputs adjusted accordingly on the new FDE irrigation block. (3) On 2 blocks the July applications of N fertiliser were reduced and total annual applications reduced to less than 100 kg/ha/year. (4) The block previously growing barley grain was changed to maize which has a lower N concentration for animal feed. **Mitigation bundle three** consisted of applying 2.5 km of riparian buffer strips to the large areas of poorly and imperfectly drained soil blocks.

Table 7. Summary of capital inputs and the changes in annualised costs and income for farm 4.1 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	112	-9	0	-9
M2	184	-5	-242	-247
M3	42	20	-96	-76

6.2 Dry flat dairy (low rainfall and moderate production)

This is a flat land dairy farm with 100% imperfectly drained pallic soils. The OVERSEER effective areas was 171 ha. **Mitigation bundle one** consisted of changing the FDE irrigation system to pods as there was an existing storage pond of sufficient size on the farm. **Mitigation bundle two** involved making 3 individual changes: (1) The FDE irrigation area was increased from 16 to 62 hectares and fertiliser budgets adjusted accordingly. (2) The water irrigation system was changed from a gun to a more efficient centre pivot irrigation system and assumed to be managed according to best practice. (3)

The N fertiliser inputs were reduced to <100 kg/ha/year. To maintain pasture utilisation rates additional maize silage was purchased. **Mitigation bundle three** consisted of applying 2.4 km riparian buffer strips to the whole farm.

Table 8. Summary of capital inputs and the changes in annualised costs and income for farm 4.2 as a result of applying the individual mitigation bundles.				
Mitigation Bundle	**Capital Inputs ($/ha)**	**Annualised changes in costs and income**		
		Change in costs ($/ha)	**Change in income ($/ha)**	**Sum of change ($/ha)**
M1	108	-41	0	-41
M2	3298	-265	-10	-275
M3	84	57	-129	-72

6.3 Dry flat dairy (moderate rainfall)

This flat dairy farm was on 100% poorly draining gley soils. The OVERSEER effective area was 301 ha. **Mitigation bundle one** consisted of changing the FDE irrigation system to pods and installing a storage pond on the farm. **Mitigation bundle two** involved making 3 individual changes: (1) The water irrigation system was changed from a gun to a more efficient centre pivot irrigation system and assumed to be managed according to best practice. (2) The N fertiliser inputs were reduced to <100 kg/ha/year. (3) The P fertiliser inputs on two blocks were modified to bring the soil Olsen P levels down to an economic optimum. **Mitigation bundle three** consisted of applying 2.2 km of riparian buffer strips to the whole farm.

Table 9. Summary of capital inputs and the changes in annualised costs and income for farm 4.3 as a result of applying the individual mitigation bundles.				
Mitigation Bundle	**Capital Inputs ($/ha)**	**Annualised changes in costs and income**		
		Change in costs ($/ha)	**Change in income ($/ha)**	**Sum of change ($/ha)**
M1	399	-31	0	-31
M2	120	-5	-40	-45
M3	51	-16	-93	-109

6.4 Dry flat dairy (high rainfall)

This dairy farm was on 100% moderately well drained brown soil types with 87% rolling and 13% easy hill country. The OVERSEER effective area was 204 ha. **Mitigation bundle one** consisted of changing the FDE irrigation system to pods as a storage pond already existed. **Mitigation bundle two** involved making 4 separate changes: (1) P fertiliser inputs were managed to reduce soil Olsen P to economically optimum levels. (2) The FDE irrigation area was increased and fertiliser inputs adjusted accordingly. (3) The N fertiliser inputs were reduced. (4) A 2 ha wetland was constructed that was assumed to capture the runoff from 100 ha of rolling land. **Mitigation bundle three** involved applying 1.8 km of riparian buffer strips to the whole farm.

Table 10. Summary of capital inputs and the changes in annualised costs and income for farm 4.4 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	193	-45	0	-45
M2	2078	-55	-295	-351
M3	53	-1	-115	-116

6.5 Irrigated flat dairy

This dairy farm was on flat land with 49% poorly and 51% imperfectly drained soils. The OVERSEER effective area was 416 ha and the total area was 427 ha which included 1 ha of trees. **Mitigation bundle one** consisted of changing the FDE irrigation system and installing a storage pond. **Mitigation bundle two** involved making 5 individual changes to the farm system: (1) The water irrigation system was changed to a centre pivot and assumed to be managed to best practice. (2) The FDE irrigation area was increased from 30 to 45 ha and the fertiliser inputs adjusted accordingly. (3) The P fertiliser inputs to the runoff block were adjusted to manage soil Olsen P levels to economic optimums. (4) The N fertiliser inputs on some blocks were adjusted to reduce total N inputs. (5) The purchased pasture silage was replaced with low N maize silage. Additional maize silage was purchased to maintain pasture utilisation rates. **Mitigation bundle three** involved applying 3.2 km of riparian buffer strips to the whole farm.

Table 11. Summary of capital inputs and the changes in annualised costs and income for farm 4.5 as a result of applying the individual mitigation bundles.				
Mitigation Bundle	**Capital Inputs ($/ha)**	**Annualised changes in costs and income**		
		Change in costs ($/ha)	**Change in income ($/ha)**	**Sum of change ($/ha)**
M1	129	-9	0	-9
M2	239	-166	103	-63
M3	35	2	-77	-75

6.6 Organic dairy

This flat land dairy farm was on 34% imperfectly and 66% well drained soil types. The OVERSEER effective area was 355 ha. **Mitigation bundle one** consisted of changing the FDE irrigation system to pods as a storage pond already existed. **Mitigation bundle two** consisted of 2 individual changes: (1) The FDE irrigation area was increased and P fertiliser inputs adjusted accordingly. (2) The water irrigation system was changed to a centre pivot and assumed to be managed to best practice. **Mitigation bundle three** involved applying 400 m of riparian buffer strips to the block with imperfectly drained soils only.

Table 12. Summary of capital inputs and the changes in annualised costs and income for farm 4.6 as a result of applying the individual mitigation bundles.				
Mitigation Bundle	**Capital Inputs ($/ha)**	**Annualised changes in costs and income**		
		Change in costs ($/ha)	**Change in income ($/ha)**	**Sum of change ($/ha)**
M1	53	-15	0	-15
M2	299	-79	0	-79
M3	30	-1	-22	-23

6.7 Sheep and beef finishing, summer dry

This dry-stock farm was on moderately well drained soils with 27% flat, 42% easy and 31% steep slopes. The OVERSEER effective area was 585 ha. **Mitigation bundle one** did not involve any changes as streams on the farm were already fenced. **Mitigation**

bundle two consisted of 2 individual changes: (1) P fertiliser inputs to the easy and steep slope blocks were changed from super-phosphate-based fertiliser to the less water soluble reactive phosphate rock (RPR) form, and (2) constructing 2 wetlands with a total area of 5 ha to capture runoff from the easy and steep blocks. **Mitigation bundle three** involved applying 5.8 km of riparian buffer strips to the easy and steep blocks.

Table 13. Summary of capital inputs and the changes in annualised costs and income for farm 4.7 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	1769	-146	-10	-156
M3	69	-12	-48	-60

6.8 Sheep and beef breeding, summer wet

This dry-stock farm was on moderately well drained soils with 47% easy and 53% steep slopes. The OVERSEER effective area was 360 ha. **Mitigation bundle one** did not involve any changes as streams on the farm were already fenced. **Mitigation bundle two** consisted of changing the P fertiliser inputs from super-phosphate-based fertiliser to the less water soluble reactive phosphate rock (RPR) form and constructing a 3 ha wetland to capture runoff from the easy and steep blocks. **Mitigation bundle three** involved applying 4.7 km of riparian buffer strips to the whole farm.

Table 14. Summary of capital inputs and the changes in annualised costs and income for farm 4.8 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	1725	-142	-4	-146
M3	92	-15	-31	-46

6.9 Sheep and beef finishing, summer wet

This dry-stock farm was on imperfectly drained soils with 86% rolling and 14% steep slopes. The OVERSEER effective area was 450 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved making 4 individual changes. (1) CSA protection was applied to the grazing management of the winter forage crops. (2) P fertiliser type was changed to the less water soluble RPR form. (3) The summer crops were re-established earlier in September (not October). (4) A 2 ha constructed wetland was installed that captured the drainage from 75 ha of rolling and 25 ha of steep land. **Mitigation bundle three** involved applying 5.7 km of planted buffer strips to the whole farm.

Table 15. Summary of capital inputs and the changes in annualised costs and income for farm 4.9 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	920	-95	-8	-102
M3	89	-15	-14	-29

6.10 Sheep and bull finishing

This dry-stock farm was on 86% poorly drained and 11% imperfectly drained soils. The farm was on 65% flat, 24% rolling and 11% steep slopes. The OVERSEER effective area was 927 ha. **Mitigation bundle one** did not involve any changes as streams on the farm were already fenced. **Mitigation bundle two** involved making 5 individual changes: (1) CSA protection was applied to the grazing management of the winter forage crops. (2) P fertiliser type was changed to the less water soluble RPR form. (3) The P fertiliser application rates on the rolling land was managed to reduce soil Olsen P levels. (4) The water irrigation system was changed to K-line pods and assumed to be managed to best practice. (5) A 2 ha constructed wetland was installed that captured the drainage from 75 ha of rolling and 25 ha of steep land. **Mitigation bundle three** involved applying 10.9 km of planted buffer strips to the whole farm.

Table 16. Summary of capital inputs and the changes in annualised costs and income for farm 4.10 as a result of applying the individual mitigation bundles.				
Mitigation Bundle	**Capital Inputs ($/ha)**	**Annualised changes in costs and income**		
		Change in costs ($/ha)	**Change in income ($/ha)**	**Sum of change ($/ha)**
M1	0	0	0	0
M2	480	-22	-122	-144
M3	82	-11	-63	-74

6.11 Irrigated sheep and beef trading

This dry-stock farm was on 70% poorly and 30% imperfectly draining soils with 70% flat, 20% rolling and 11% steep slopes. The OVERSEER effective area was 360 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved making 4 individual changes: (1) P fertiliser type applied to the rolling and steep land was changed to the less water soluble RPR form. (2) The P fertiliser application rates on the rolling and steep land were managed to reduce soil Olsen P levels. (3) The water irrigation system was already a centre pivot system but the irrigation management was changed to best practice. (4) A 2 ha constructed wetland was installed that captured drainage from 70 ha of rolling and 30 ha of steep land. **Mitigation bundle three** involved applying 3.3 km of planted buffer strips to the whole farm.

Table 17. Summary of capital inputs and the changes in annualised costs and income for farm 4.11 as a result of applying the individual mitigation bundles.				
Mitigation Bundle	**Capital Inputs ($/ha)**	**Annualised changes in costs and income**		
		Change in costs ($/ha)	**Change in income ($/ha)**	**Sum of change ($/ha)**
M1	0	0	0	0
M2	1150	-79	-3	-82
M3	64	-2	-34	-36

6.12 Lamb and bull trading, 20% crop

This dry-stock farm was on flat land with imperfectly draining soils. The OVERSEER effective area was 93 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved making 2 changes: (1) The summer barley crop paddocks were re-sown earlier in March. (2) The N fertiliser inputs were reduced to just below 100 kg N/ha/year. To maintain pasture utilisation rates pasture silage was sold. **Mitigation bundle three** involved applying 880 m of planted buffer strips to the whole farm.

Table 18. Summary of capital inputs and the changes in annualised costs and income for farm 4.12 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	0	16	-17	-1
M3	66	-9	-57	-66

6.13 Sheep and beef breeding, summer dry

This dry-stock farm had moderately well drained soils with 9% flat, 69% rolling and 22% steep slopes. The OVERSEER effective area was 920 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved making 2 changes: (1) Low solubility P fertiliser was used on sloping land. (2) A 4 ha wetland was constructed that captured drainage from 150 ha of rolling and 50 ha of steep land. **Mitigation bundle three** involved applying 4.8 km planted buffer strips to the rolling and steep land blocks.

Table 19. Summary of capital inputs and the changes in annualised costs and income for farm 4.13 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	900	-116	-5	-121
M3	37	-6	-32	-38

6.14 Finishing beef, 65% cropping

This arable farm with some beef finishing was on flat land with imperfectly drained soils. The OVERSEER effective area was 360 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved reducing N fertiliser inputs to the crops. To maintain pasture utilisation rates pasture silage was sold. **Mitigation bundle three** involved applying 2.4 km of planted buffer strips to the whole farm.

Table 20. Summary of capital inputs and the changes in annualised costs and income for farm 4.14 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	0	-172	22	-150
M3	47	-85	59	-26

6.15 Dairy support, 15% cropping, summer dry

This dairy support property was on flat land with moderately well drained soils. The OVERSEER effective area was 284 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved 2 changes: (1) CSA protection was applied to the grazing management of the winter forage crops. (2) Summer crops were re-established in pasture earlier in February or March depending on the harvest date. **Mitigation bundle three** did not apply to this farm.

Table 21. Summary of capital inputs and the changes in annualised costs and income for farm 4.15 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	0	0	0	0
M3	0	0	0	0

6.16 Dairy support, 48% cropping, summer wet

This dairy support farm was on flat land with 50% poorly and 50% well drained soils. Note that the crops were on the well-drained soils. The OVERSEER effective area was 300 ha. **Mitigation bundle one** did not involve any changes as the farm was already fenced. **Mitigation bundle two** involved 2 changes: (1) CSA protection was applied to the grazing management of the winter forage crops. (2) N fertiliser applications to crops were reduced slightly. **Mitigation bundle three** involved applying 4.4 km of planted riparian buffer strip to the block with poorly drained soils.

Table 22. Summary of capital inputs and the changes in annualised costs and income for farm 4.16 as a result of applying the individual mitigation bundles.

Mitigation Bundle	Capital Inputs ($/ha)	Annualised changes in costs and income		
		Change in costs ($/ha)	Change in income ($/ha)	Sum of change ($/ha)
M1	0	0	0	0
M2	0	131	-201	-70
M3	103	-18	-74	-92

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