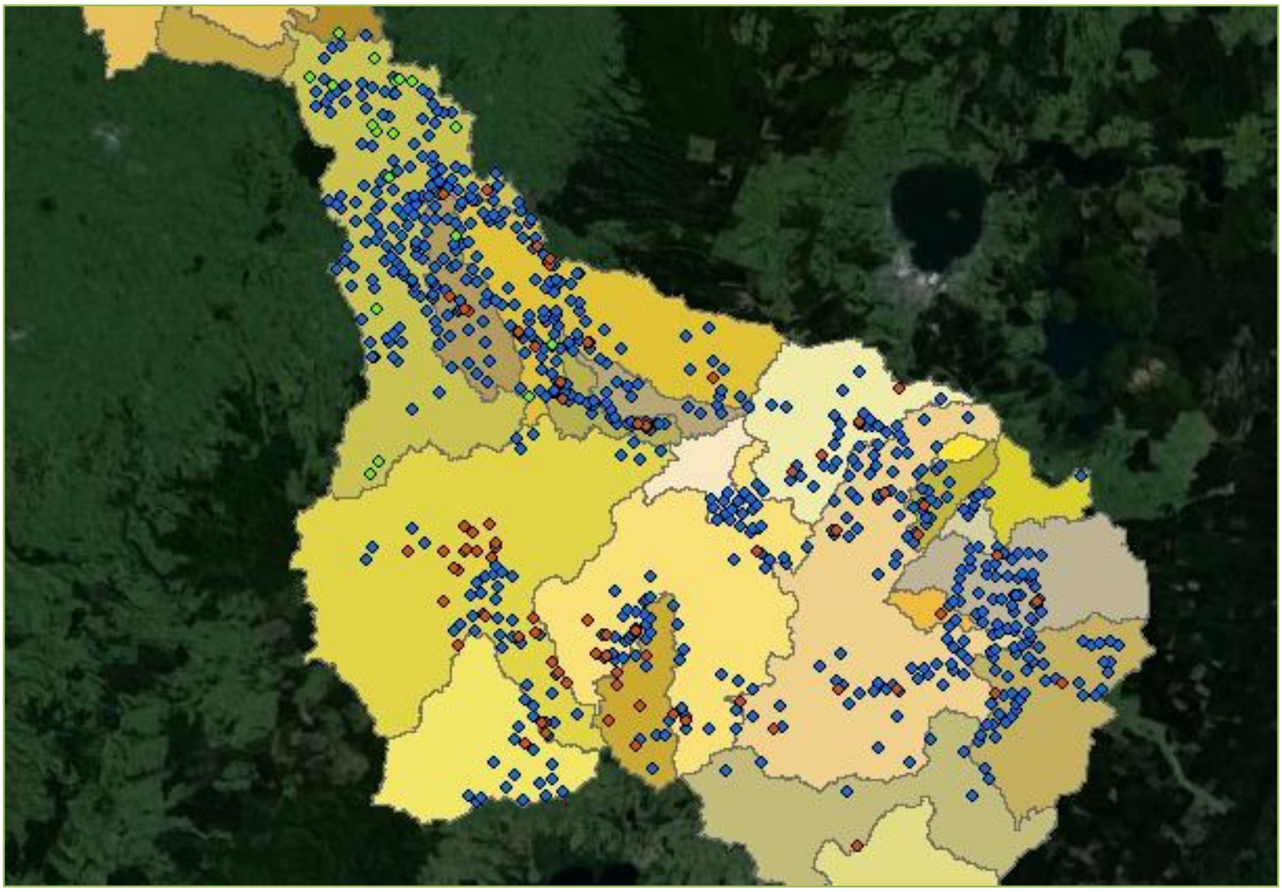
Potential reductions in farm nutrient loads resulting from farmer practice change in the Upper Waikato catchment:

SMP Final Call analysis



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Executive summary

Potential reductions in nutrient losses following the successful implementation of all recorded on-farm actions were estimated for 594 farms which have completed the full Sustainable Milk Plan (SMP) process in the Upper Waikato catchment. For each farm nitrogen (N) and phosphorus (P) reductions were calculated based on individual farm Overseer® Nutrient Budget (hereafter referred to as *Overseer*) information and nutrient reduction efficacy rates assigned to each specific mitigation strategy. Given the uncertainties and variability associated with quantifying efficacy rates attributable to different mitigation strategies, several approaches were trialled using a combination of existing studies published in the scientific literature as well as *Overseer* modelling. It is important to note that the analysis only includes those actions where direct contaminant loss reductions could be attributed based on expert knowledge and/or published estimates. Many other actions are likely to have indirect or long-term benefits, but these are difficult to quantify.

Mean reductions in farm nutrient losses following the successful implementation of SMP actions are estimated to be 5% for N and 12% for P. This is based on the 594 farms that had completed the full SMP process by the end of July 2015. These reduction estimates are expected to increase to 8% for N and 21% for P when all actions across all 642 SMP farms are fully implemented.

Potential load reductions on individual farms ranged from 0 to 35% for N and 0 to 73% for P, depending on the number and combination of actions being implemented. The greatest N reductions were observed for farms implementing multiple strategies involving stock exclusion from streams and optimised effluent/fertiliser application. Riparian and critical sources area management, stock exclusion and optimised effluent applications were the most effective measures for reducing P losses to water. These estimates reflect the potential reduction in farm nutrient losses as calculated from *Overseer* nutrient budget outputs and other methods, and therefore do not reflect attenuation processes prior to discharge direct to surface waters. Not all farms recorded actions with a direct impact on nutrient losses, however, all action types recorded through the SMP process will ultimately lean to improvements in farm environmental performance over the long-term.

This report represents a first analysis of potential N and P load reduction based on an action completion rate of 70% across all farms which have completed the full SMP process. This analysis will now be expanded in a second phase to also assess the benefits of SMP implementation for reducing sediment and bacteria loads, Loadings to surface waters after attenuation will be considered for all variables.

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1 Introduction

1.1 Study aims and objectives

The Upper Waikato Sustainable Milk Project, co-funded by the Waikato River Authority (WRA), PGP and DairyNZ, is the largest environmental good-practice catchment project ever undertaken by the New Zealand dairy industry. The primary aim of the project is to support on-farm changes that will enhance water quality and ecosystem health in the Waikato River and demonstrate to policy-makers and the wider community the collective commitment of farmers to sustainable dairying in the catchment. The Vision and Strategy for the Waikato River (WRA, 2013) has been a key influencing factor in the design and operation of the project.

The project is focused on the Upper Waikato Catchment (area 465,871 ha) which extends from Huka Falls in the south to Lake Karapiro Dam in the north (Fig. 1.1). Between June 2012 and May 2015, all 700 dairy farms in the catchment were offered one-on-one advice and support via the development of a farm-specific DairyNZ Sustainable Milk Plan (SMP).

The SMP process involves consultants working with farmers individually to assess the current status of their farming system and to identify risks in the key areas of nutrient, effluent, waterways and land management, and water use efficiency. An action plan is developed and follow-up support provided by a farming consultant. A follow-up visit is carried out at the end of the process (6-10 months after the initial visit) to verify which of the intended actions have been completed. The SMP enables farmers to prioritise their existing and intended activities into one simple document. A key characteristic of the SMP is that it is voluntary and therefore contains the farmers' own agreed actions and a timeline for implementation.

All actions implemented through the SMP process were documented to enable potential changes in nitrogen (N), phosphorus (P), sediment and *E. coli* losses off-farm to be estimated after plan completion. The success of the project is being measured by the collective actions of 700 farmers demonstrably reducing dairy farm-sourced nutrients, sediment and faecal contaminants discharging to the Waikato River, and an improvement in water use efficiency on farms.

1.2 SMP management target areas

The SMP process is focused on five main management target areas: nutrients, effluent, land and waterways management, and water use efficiency (Table 1.1). These broadly reflect a wide range of management actions related to all aspects of farming operations including farm planning, infrastructure, maintenance, monitoring and training and education. Four of the five management areas are directly focused on nutrient (N and P), sediment and/or bacteria (Table 1.1). While many actions categorised under effluent management are also directly related to nutrient management, effluent was included as a separate target area due to the large emphasis being placed by farmers on this activity.

Project targets for each management area were developed through the project Steering Group and wider stakeholder discussions. These were focused on objectives which would provide long-term benefits for the health of the Waikato River, in particular reductions in contaminant loadings. The final targets agreed to by the Steering Group provide direction and formed a critical element of the initial discussions between farmers and their project consultant.

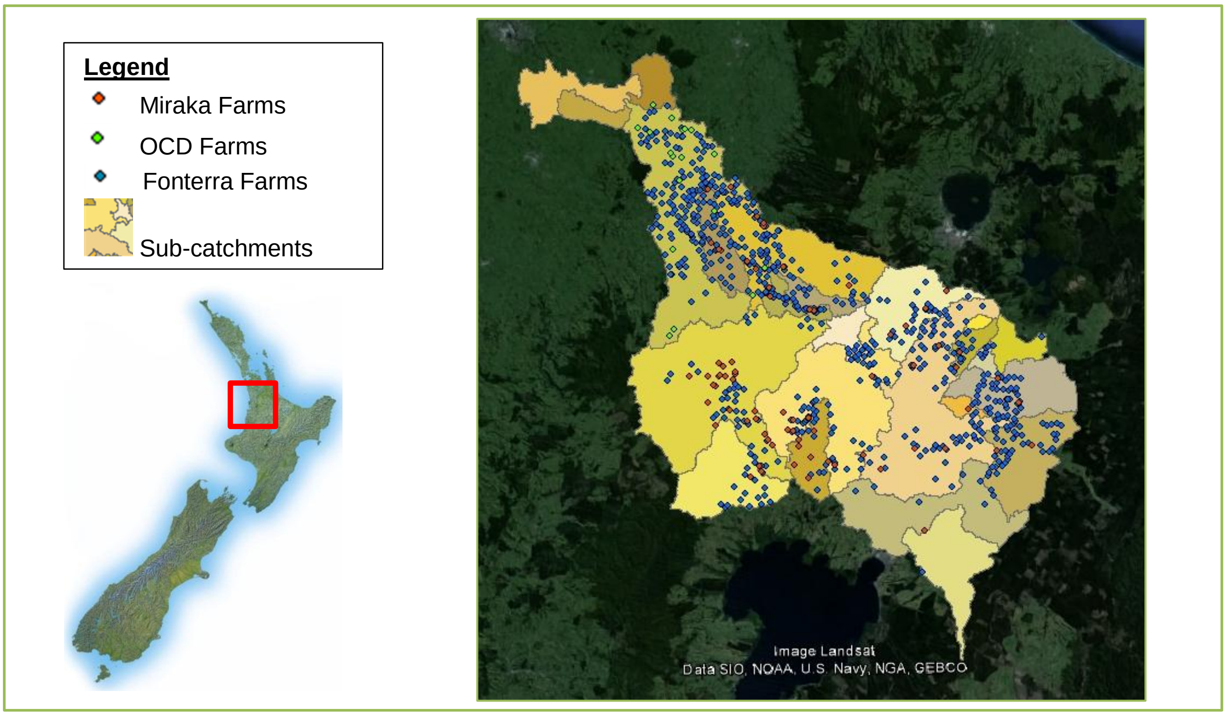


Figure 1.1: Location of the Upper Waikato Catchment and the 700 dairy farms by milk supplier. The 24 individual sub-catchments are shown in various shades of brown. OCD is Open Country Dairy.

Table 1.1: Description of the SMP key management target areas and water quality parameters considered

Target area	Description of key included actions	Key parameter targeted			
		N&P	Bacteria	Sediment	Water use
Nutrients:	Actions related to all aspects of nutrient management except effluent, including nutrient budgeting, fertiliser application, stocking rates and feed management.	√			
Effluent:	Actions relating to the collection, containment and application of dairy effluent, including planning, infrastructure, operation, monitoring and training.	√	√		
Waterways:	Actions related directly to the management of runoff to waterways, including stock exclusion, riparian planting and wetlands.	√	√	√	
Land:	Practices related to land management practices, including cropping, pasture, erosion control and critical source areas (tracks, laneways and crossings).	√	√	√	
Water use:	Actions related to water use efficiency, including consents, monitoring and practices, or the implementation of new infrastructure to reduce water consumption.				√

***Key program targets*[1]**

Nutrient Management Targets:

- Catchment farmers have an up-to-date nutrient budget (*Overseer* v. 6) and are implementing appropriate actions to improve nitrogen use efficiency within their current system.
- Catchment farmers understand current N losses in the context of their farm system and the potential options for reducing losses if required in future. In recognition of the potential business risk associated with "High" levels of N-loss (i.e., > 43 kg N/ha/yr), farms in this category are implementing appropriate actions to reduce N-loss. Existing estimates of Low, Medium and High N losses from milking platforms in the catchment are 30 (<25% of all farms leach less than this value), 36 (<50% of farms) and 43 (<75% of farms) kg N/ha/yr, respectively.
- Catchment farmers have identified current P loss risk (e.g. *Overseer*; Critical Source Areas) and are implementing appropriate actions to minimise this risk for their farm

Waterway Management Target:

- Catchment farmers have identified stream, lake and wetland areas on their properties and are implementing appropriate actions to improve biodiversity and water quality outcomes.

Land Management Target:

- Catchment farmers have identified areas of soil loss risk on their properties and are implementing appropriate actions to reduce erosion and sediment & faecal runoff to waterways.

Water Use target:

- Catchment farmers understand their obligations and associated business risks under the Variation 6 (Water Allocation) rules of Waikato Regional Council's Regional Plan and have applied for required consents before December 2014.
- Catchment farmers have identified opportunities for improving water use efficiency and are implementing appropriate actions to provide flexibility during times of water shortage (i.e., when water takes become restricted).

Additional industry expectations around minimum standards:

- 100% of dairy farms exclude dairy cattle from significant waterways, irrespective of whether regional council rules apply
- 100% compliance with regional council nutrient management rules and/or resource consent conditions,
- 100% compliance with regional council effluent management rules and/or resource consent conditions
- 100% of dairy farms will comply with water take and use rules and/or resource consent conditions.

[1] *Note targets for effluent management were not set as the Steering Group felt that compliance with existing council rules around meeting permitted activity rules was already a minimum expectation for all farms.*

1.3 Scope of this report

This study quantifies potential reductions in nutrient losses following the assumed successful implementation of all recorded on-farm actions for all 642 farms participating in the SMP process. For each farm, reductions in farm nitrogen and phosphorus are calculated based on individual farm *Overseer* loading information and nutrient reduction efficacy rates assigned to each specific mitigation strategy. Given the uncertainties and variability associated with quantifying efficacy rates attributable to different mitigation strategies, several approaches were trialled, using a combination of existing studies published in the scientific literature and *Overseer* modelling.

This analysis will be expanded in a second phase to quantify the benefits of SMP implementation for reducing sediment and bacteria loads. Loading to surface waters after attenuation will also be considered for all variables.

1.4 Data availability

Actions targeting identified risks in the key target areas of nutrient, effluent, waterways and land management and water use efficiency were recorded individually for each farm through the Initial SMP process. Completion of these actions were verified and recorded through the SMP final call.

In addition to the recorded actions, N and P losses to the root zone were documented for each farm at the start of the SMP process based on a farm-wide nutrient budget derived from *Overseer* (version 6). Loss estimates were available for 599 farms for N and 595 farms for P.

2 Analysis of SMP actions

2.1 Approach

The SMP process was carried out on 642 of the 700 farms in the study catchment between June 2013 and July 2015 (Brocksopp et al., 2014; Brocksopp et al., 2015). An initial SMP call was conducted for each farm at the start of the process to develop and document farmer-agreed actions within the five SMP target areas (Table 1.1). A final SMP call was carried out 6-10 months later to review these actions and verify and document completion. Follow-up support and advice were provided for the period between the two SMP calls.

As of July 2015, 598 farms representing 90% of all Initial Calls had completed the full SMP process. An additional five farms have completed the initial SMP call and 22 farms the final SMP call since July 2015 but this information was not available at the time of this analysis. Overall, a total of 647 farms are now involved in the full SMP study.

All actions documented through the Initial and Final calls were collated for all farms and coded into specific categories to provide a more comprehensive analysis of the individual actions within each management target area. A total of 41 action categories and 141 sub-categories were defined. Categories were chosen to broadly reflect various stages of farm planning and development, infrastructure investment, implementation, operational management and training and education (Table 2.1). Consideration was also given to separating actions associated with investigating or considering a change versus actually implementing a change. A small number of actions not directly associated with the five SMP target areas were dealt with separately.

All individual actions recorded through the Initial Calls were reviewed at the end of the study and documented as complete, incomplete or pending. Pending was only assigned to individual actions carried out on the 62 farms where a final SMP call has not yet been completed or received.

2.2 Key results all recorded actions

A total of 5921 individual actions were recorded across all 642 farms taking part in the study. This reflects an average of 9.2 actions per farm across the five management target areas (effluent, waterways, nutrients, land and water use). Actions not directly associated with these target areas represented less than 1% of the total number of actions.

The majority of all actions were focused on nutrient (31%) and effluent management (27%), followed by water use (19%), land (12%) and waterways (11%) management (Fig. 2.1). While waterways management had the least number of actions recorded, this target area is only applicable to farms with surface waters present, either within or adjacent to the farm boundary. Further results within each management area are summarised in Tables 2.1 & 2.2.

Nearly 95% of all actions have now been reviewed through the Final Call process. Of these, 70% have been successfully completed. This is equivalent to 67% of all actions, including those farms which have not yet completed the final call. Around 5% of all initial call actions still need to be reviewed and documented through the Final Call process.

The highest rates of completion (79%) were observed for all actions related to nutrient management (Fig. 2.1). Completion rates within all other target areas were around 60% (range 55-66%). Overall, 30% of all actions documented through the initial call were not complete at the time of the final call. Of these, 35% were associated with effluent management (Fig. 2.1).

The distribution of actions within each management and category area are summarised in Table 2.1. In addition, the top five individual actions within each management area expressed as a percentage of the total number of farms are listed in Table 2.2. Actions categories which are more difficult to implement over the short time scale of the SMP process (for example, actions related to the implementation of effluent infrastructure, expansion of effluent block size, fencing and land retirement) generally had lower rates of completion (< 50%) (Tables 2.1 & 2.2).

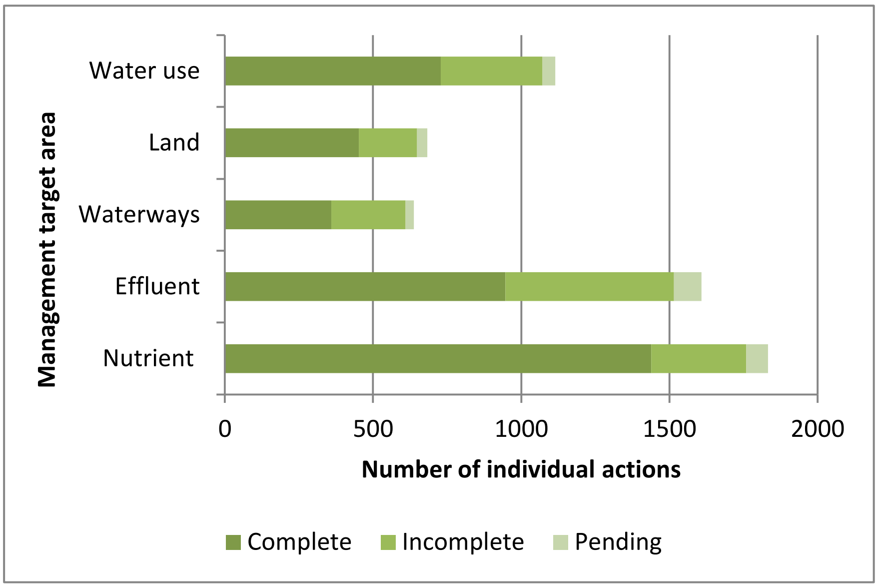


Figure 2.1. Total number of on-farm actions within each management target area for the 642 farms with completed SMPs analysed for this report. Complete and incomplete relate to the actions on the 594 farms which have completed the final call process. Pending relates to the remaining farms which have not yet completed a final call.

Table 2.1: Overview of actions for each sub-category within the five management target areas. % actions completed reflect final call farms only (580 of 642 farms).

Management Area	Category	% of actions within each management target area	% actions completed
Nutrient	Nutrient budgets and understanding	48%	84%
(1833 actions)	Review and manage nutrient use	3%	88%
	Stocking rate	0%	38%
	Effluent nutrient management	14%	65%
	Fertiliser application practices	16%	75%
	Feed management	2%	71%
	Records and Monitoring	15%	74%
	Education	3%	94%
Effluent	Effluent planning	35%	68%
(1609 actions)	Infrastructure/inflow volume reduction	6%	48%
	Infrastructure/inflow capture	8%	56%
	Infrastructure/feed storage, wintering/feed pads	3%	55%
	Infrastructure/storage	5%	48%
	Infrastructure/application	8%	69%
	Infrastructure/health and safety	1%	25%
	Operation	6%	66%
	Monitoring	24%	47%
	Training and education	4%	67%
Waterways	Waterways planning	5%	76%
(638 actions)	Training and education	12%	82%
	Fencing and riparian	67%	50%
	Wetlands	8%	45%
	Significant natural areas	0%	100%
	In-stream	5%	76%
	Monitoring	1%	60%
	Other	2%	27%
Land	Cropping	28%	73%
(683 actions)	Pasture	2%	50%
	Tracks, races, stream crossings, critical source areas	25%	63%
	Off pasture (wintering, pugging, steep areas)	17%	72%
	Erosion control	13%	55%
	Planting for aesthetics, bees	3%	52%
	Drainage	3%	42%
	Farm waste	8%	74%
	Other	2%	82%
Water use	Consents	27%	74%
(1115 actions)	Water meters	34%	52%
	Investigate water use efficiency options	29%	76%
	Improve dairy efficiency	3%	53%
	Improve efficiency of water reticulation	7%	58%
Other (41 actions)	Other	100%	77%

Table 2.2: Summary of the top five actions within each management target area expressed as a percentage of the total number of farms. % actions completed reflect final call farms only (580 of 642 farms).

Management area	Agreed actions	% of farms	% actions completed
Nutrient	Utilise nutrient budget and scenarios to understand nutrient loss drivers, optimal nutrient requirements, efficiency rates and strategies to manage nutrient losses	65%	82%
	Update whole-farm nutrient budget to *Overseer* V6	60%	87%
	Improve records of fertiliser, effluent and/or supplementary feed applications (Dairy diary)	26%	80%
	Review optimal effluent block size, location and/or application rate	24%	76%
	Increase effluent area	17%	49%
Effluent	Assess current and/or future effluent storage requirements (Dairy Effluent Storage calculator)	33%	78%
	Review/investigate effluent infrastructure upgrade (pond size, additional travellers, increase sprinklers, irrigator line, hydrants, pipeline leaks, filtration systems, solids separator, underground network, increased pump capacity, K-Line pods on slopes).	22%	58%
	Monitor application depth	20%	52%
	Monitor nutrient concentrations	17%	41%
	Improve solids capture and management (install and upgrade sand and stone traps, regular cleaning and spreading of trapped material, install solids separator, improve storage of removed solids, install dung buster, improve wash down, adjust flow rates, sand trap overflow to pond)	15%	58%
Waterways	Carry out/re-establish Riparian planting	21%	50%
	Fence off waterways according to Accord requirements	19%	60%
	Education (weed control, riparian species and management, waste and chemical disposal, chemical spraying around waterways, economical source of plants)	12%	82%
	Develop riparian planting plan	10%	28%
	Fence off waterways additional to Accord requirements (seeps, springs, ponds, wet areas, drains)	10%	38%
Land	Manage runoff from tracks and races (divert or contain runoff, maintain track condition, improve drainage, fence races)	18%	73%
	Improve crop cultivation practices (use minimum tillage forage crops, immediately re-sow crop paddocks to pasture after harvesting, spray and direct drill re-grassing procedures to minimise soil disturbance, chicory on winter crop paddocks, reduce crops near waterways, lengthen crop rotation, reduce crop area, thicken swards, cultivate along contours)	15%	73%
	Retire and/or plant pasture for erosion control (steep sidelings and gullies, bluffs and slips)	14%	55%
	Improve waste management (remove rubbish, re-assess farm waste disposal sites relative to groundwater table, chemical handling practices, recycle, pesticide collection)	8%	74%
	Improve crop grazing practices (review, change to graze hotspots at appropriate times to reduce erosion and runoff)	8%	74%
Management area	Agreed actions	% of farms	% actions completed
Water use	Investigate efficiency options (Smart water use booklet, leak detector,	43%	81%

	reduce wash-down water, water savings)		
	Complete/Apply/Submit consent	29%	70%
	Install water meter	27%	49%
	Monitor water use (establish baseline flow, meters, leak detection devices, measuring water used in tank, establish water requirements	25%	55%
	Investigate variation 6 consent requirements and options	14%	80%
Other	Other	7%	77%

2.3 Selection of actions with a direct impact on contaminant loading

While all actions recorded through the SMP process will ultimately lead to an improvement in environmental practices on farm, not all have a direct and quantifiable impact on farm nutrient losses. For example, actions related to the reviewing of information, farm planning and environmental education will not lead to a direct reduction in farm contaminant losses. As this analysis was focused on quantifying reductions in farm nutrient losses, only those actions with a direct impact on contaminant loading were assessed.

Of the 141 individual action sub-categories defined through the SMP process, 19 mitigation strategies representing a total of 44 individual actions (Table 2.3) were assumed to have a direct impact on contaminant loading. These strategies mostly reflect actions related to improved effluent, nutrient, cropping, feed and wintering practices, as well as improved waterways management and the elimination of critical source areas. All strategies target either phosphorus, nitrogen or both nutrients, although many also have potential to influence sediment and bacterial loadings (Table 2.3).

A number of additional mitigation strategies with a direct impact on farm contaminant loss were excluded from the quantification framework due to the absence of site-specific information which would be required to make an accurate assessment. For example, the impact of land retirement and planting for sediment control is highly dependent on areal extent, slope and existing erosion present. This information is not recorded through the existing SMP process.

Controlled grazing regimes and cut and carry pasture management were also excluded from the analysis framework as these actions were not recorded for any of the current SMP farms.

Table 2.3: Summary of selected SMP mitigation strategies with a direct impact on nitrogen (N), phosphorus (P), sediment (S) and bacteria (B) loads. % farms carrying out each strategy is calculated from the first 642 farms which have completed the full SMP process.

Management area	Mitigation strategy	Corresponding individual actions	N	P	S	B	% farms
Nutrients	**Review optimal effluent block and management**	-Review optimal effluent block size, location and/or application rate -Increase effluent area -Apply effluent to forage crops/crop effluent block/sidelings -Export effluent solids to cropping or runoff blocks -Reduce effluent application rate	√	√		√	34%
	N fertiliser management	-Manage fertiliser application based on nutrient budget -Reduce N application (rates, timing, no winter application) -Improve N efficiency (N application with Progibb, LessN or sulphur, use of Ammo instead of urea, gibberellic acid, EcoN options, slow release products (Sustain) monitoring of soil temperature during application)	√				16%
	P fertiliser management	-Manage/target P application to optimal Olsen P levels (apply P only for maintenance) -Reduce P application; use less soluble P fertiliser products where necessary		√			17%
	Improve feed management to reduce N inputs	-Lower quantities of higher quality feed, improve feed efficiency, reduce imported protein feeds, feeding infrastructure, reduce wastage, import maize silage rather than using pastoral, silage, build a better bin	√				2%
Effluent	**Improve effluent capture**	-Improve shed effluent capture and diversion to pond (extend nibbed area around shed, drain diverters) -Improve solids capture and management (install and upgrade sand and stone traps, regular cleaning and spreading of trapped material, install solids separator, improve storage of removed solids, install dung buster, improve wash down, adjust flow rates, sand trap overflow to pond) - Improve storm water runoff diversion -Improve rain water capture and recycling -Improve sludge management	√	√	√	√	25%
	Improve containment of feed stores, feed pads	-Improve containment of feed stores -Improve effluent containment from feed pads, herd homes, -Improve storage of solids from feed pad	√	√		√	3%
	Improve pond infrastructure and storage	-Install new (lined) pond, -Upgrade storage capacity - Improve pond lining -Improve pond agitation/stirring	√	√		√	11%

Management area	Mitigation strategy	Corresponding individual actions	N	P	S	B	% farms
	Upgrade effluent infrastructure	- Upgrade effluent infrastructure (additional travellers, increase sprinklers, irrigator line, hydrants, pipeline leaks, filtration systems, solids separator, underground network, increased pump capacity, K-Line pods on slopes). -Install safety/alert systems -Improve effluent system application and performance	√	√		√	23%
Waterways	**Stock exclusion**	-Fence off waterways according to Accord requirements -Fence off waterways additional to Accord requirements (seeps, springs, ponds, wet areas, drains)	√	√	√	√	26%
	Riparian planting	-Carry out/re-establish Riparian planting	√	√	√	√	20%
	Wetlands management	-Fence off/retire existing swamp and wetland areas -Plant existing swamp/ wetland areas - Restore natural or implement constructed wetlands; protect wetland through covenant -Maintain wetland water levels	√	√	√	√	7%
Land	**Improve crop cultivation practices**	-Use minimum tillage forage crops, immediately re-sow crop paddocks to pasture after harvesting, spray and direct drill re-grassing procedures to minimise soil disturbance, chicory on winter crop paddocks, reduce crops near waterways, lengthen crop rotation, reduce crop area, thicken swards, cultivate along contours, no crops on slopes - Reduce cropping on steeper slopes	√	√	√		15%
	Reduce crop runoff	- Reduce crop runoff through buffer strips -Improve crop grazing practices	√	√	√	√	12%
	Time N fertiliser to crop demand	- Time N fertiliser application to meet crop demand	√				0%
	Critical source areas laneways	- Manage runoff from tracks and races	√	√	√	√	16%
	Critical source areas gates & troughs	-Manage runoff around gates and troughs	√	√	√	√	1%
	Sediment management	-Implement/maintain sediment traps, settling ponds, detainment bunds, grass filters	√	√	√	√	4%
	Manage stock crossings	-Put in/manage culverts, bridges	√	√	√	√	3%
	Implement wintering strategies	-Build infrastructure shelters, loafing pads, stand-off/winter pads - Apply controlled grazing regimes	√	√	√	√	3%

3 Effectiveness of on-farm mitigation strategies

3.1 Initial estimate of effectiveness for individual mitigation actions

The likely effectiveness of individual mitigation strategies on nutrient loss reductions were initially derived from a review of existing best practice guidelines and scientific publications. Many studies examine the performance of on-farm mitigation strategies although most are focused on the evaluation of single measures. The following publications provide a comprehensive review of the current state of existing knowledge about on-farm mitigation practices in New Zealand, and suggest estimates of likely effectiveness for a range of strategies as a percent reduction of total loading.

- WRC (2013) - Best dairy practice guidelines and summary of likely water quality benefits and farm business impacts for 25 mitigation strategies across nine management areas, including planning, nutrients, effluent, off-pasture systems, critical source areas and riparian management. Estimated water quality benefits are expressed as a % reduction of whole-farm loads for N, P, sediment and bacteria.
- Ballance MitAgator model supporting documentation developed by AgResearch (Lucci & Smith, 2014) – summarizes the likely impact (% reduction) of 24 mitigation strategies on N, P and sediment loading. Strategies include on-farm practices and down-stream options (i.e. wetlands, tile drain amendments). Data is based on a review of approximately 70 New Zealand scientific publications. Suggested efficacy rates as used in the MitAgator model are for block as opposed to farm scale.
- McDowell et al. (2013) – Review of strategies to mitigate the impact of contaminant losses from agricultural land. Produced for MfE by AgResearch, NIWA and the University of Waikato. Summarises the likely effectiveness of a range of on- and off-farm mitigation strategies that have been developed to reduce N, P, sediment and bacteria losses.
- McDowell (2010) – Literature-based review of 14 potential strategies to mitigate agricultural P losses in the Lake Rotorua catchment.
- McKergow et al. (2007) - Review of diffuse pollution attenuation tools for New Zealand pastoral farming systems. Reports potential reduction ranges for a range of strategies (percent load or concentration reduction). Focuses on the implementation of mitigation tools (i.e. wetlands, buffer strips) as opposed to changes in farm practice.

The efficacy values reported in WRC (2013), as reported in Table 3.1, were considered to be the best starting point for the current SMP analysis for the following reasons:

a) This review is recent and based on the existing literature as well as expert judgement from a wide range of technical experts.
b) The reported efficacy rates are suggested to represent likely reductions at the farm scale as opposed to the block scale. This corresponds best to the SMP data set which reports *Overseer* nutrient budget results at the farm scale as opposed to the block scale.
c) The recorded actions are most similar to what has been recorded in the SMP data set.

Lucci and Smith (2014) compared the WRC estimates with those in MitAgator and found a high level of agreement in likely effectiveness for similar mitigation actions.

Table 3.1: Summary of initial (WRC, 2013) and revised efficacy rates applied to individual on-farm action strategies within each management target area. Rank represents the order in which the strategy was included in the quantification process used to determine overall % reductions in contaminant loss.

Target area	Mitigation strategy	Efficacy WRC[1]		Revised efficacy values applied				Analysis method[3]	Rank
		N	P	N	N min[2]	N max[2]	P		
Nutrients	Review optimal effluent block and management	5%	10%	3%	0%	8%	2%	O	2
	Improve fertiliser application methods*	5%	20%						
	N fertiliser management	10%	n/a	7%	0%	32%	0%	O	3
	P fertiliser management	n/a	20%	0%	0%	0%	0%	O	4
	Improve feed management	10%	n/a	12%	0%	28%	2%	O	17
Effluent	Improve effluent capture	5%	10%	10%			22%	L	5
	Improve containment of feed stores, feed pads			4%			2%	L	6
	Improve pond infrastructure and storage	5%	20%	3%			8%	L	7
	Upgrade effluent infrastructure			0.01%			0.02%	L	8
	Effluent solids management*	10%	10%						
	Low rate effluent irrigation*	5%	20%						
Waterways	Stock exclusion	5%	20%	4%	3%	7%	21%	O	1
	Riparian planting	5%	20%	3%	n/a	n/a	47%	BMP	14
	Wetlands management	5%	10%	2%	0%	8%	0%	O	18
Land	Improve crop cultivation practices	5%	50%	0%	0%	2%	0%	O	11
	Reduce crop runoff	5%	20%	3%	n/a	n/a	8%	BMP	10
	Improve crop grazing practices*	5%	20%						
	Time N fertiliser to crop demand	25%	n/a	0.4%	0%	3%	0%	O	9
	Critical source areas laneways	5%	20%	0.1%	n/a	n/a	1%	BMP	12
	Critical source areas gates & troughs	5%	20%	0.1%			0.4%	L	13
	Sediment management	5%	20%	0%			0%	L	16
	Manage stock crossings	5%	20%	0.4%			1.3%	L	15
	Implement wintering strategies	25%	50%	21%	7%	29%	0%	O	19
	Apply controlled grazing regimes*	5%	20%						
	Cut and carry pasture management*	25%	50%						

[1] Represents the minimum of the estimated efficacy range for each action. For some strategies where the reported minimum was zero, the mean between the minimum and maximum was applied.
[2] The minimum and maximum for N represents the range of % reductions or the 12 case study farms modelled though Overseer. As most P reduction measures could not be modelled on Overseer, minimum and maximum values for P could not be estimated.
[3] O is *Overseer* modelling, L literature and/or expert judgement and BMP is from AgResearch BMPToolbox modelling.
* Action not present in data set or not applied due to uncertainties

3.2 Initial estimate of farm nutrient reduction for selected farms

Initial calculations of load reduction potential were carried out for a sub-set of SMP farms to evaluate the suitability of the selected efficacy values for computing reductions in N and P losses at the farm scale as a result of successful implementation of all intended SMP actions. For each test farm the recorded *Overseer* N and P loss estimates (loss to water, kg/year) were reduced by the sum of the individual percent reductions for each action documented on that farm, using the WRC (2013) efficacy values for each mitigation strategy (Table 3.1).

WRC (2013) present a likely efficacy range (as a percent load reduction) for each mitigation strategy. For the SMP analysis the minimum of the reported range for each action was applied (Table 3.1) in the first instance. For some strategies where the reported minimum was zero, the mean between the minimum and maximum was applied. The results suggest that this approach generates a significant over-estimation of load reductions for farms where multiple actions are being applied. This is due to the assumed additive effect of individual actions on the total load reduction potential, which is significant for some action combinations. For example a farm carrying out actions related to effluent block size, improving fertiliser application practices, riparian planting and targeted P application around optimal Olsen P levels would generate a 10% + 20% + 20% +20% (Table 3.1) respective reduction in the total P load under this approach. The resulting 70% total P reduction seems relatively high and unlikely given that the beneficial impacts of individual strategies are not necessarily additive. For example, edge-of-field measures such as vegetated buffer strips or wetlands will typically remove only a proportion of incoming loads; if this load has already been mitigated by other source measures, then the proportional removal by buffer strips or wetlands can only apply to this incoming (mitigated) load rather than the original load calculated for the farm.

While the WRC (2013) values are intended to represent a reduction at the whole farm scale, it is clear that this approach is more suited to evaluating the impact of individual actions at the paddock or block scale. This is in contrast to the cumulative effects of multiple strategies implemented collectively across the whole farm, which is the main focus of the SMP program.

3.3 Final estimate of effectiveness for mitigation actions targeting N and P

Due to the uncertainties associated with applying the WRC (2013) values at the farm scale, the effectiveness of each mitigation strategy for N and P was further refined based on a combination of *Overseer* modelling, BMP Toolbox modelling, expert judgement and existing literature values (Table 3.1).

Overseer modelling was carried out on 12 representative farms from the Upper Waikato catchment to determine efficacy values for N and P for eight mitigation strategies (DairyNZ, unpublished data). *Overseer* is currently the only model framework available in which the collective impacts of multiple measures can be implemented and assessed in a systematic and sequential way at the farm scale. While other model frameworks exist or are under development, for example MitAgator and BMP Toolbox, not all are fully validated or the model cannot reliably compute the net results of a range of combined strategies that are implemented concurrently.

Baseline *Overseer* files for each of the 12 case study farms were derived from the DairyNZ Waikato Economic Study (DairyNZ, unpublished data). Collectively these farms represent a wide range of nutrient loss rates, soil types, system, types and rainfall as typically found in the study area (Table 3.2). Individual mitigation strategies were modelled for each farm using the assumptions and protocols summarised in Table 3.3. The effectiveness of each strategy for reducing N and P was assumed to be the % difference between the initial and final loads for each model simulation. The mean of all 12 case study farms was used to derive the final % effectiveness values. For N, the minimum and maximum % effectiveness across all case study farms was also recorded for each individual action (Table 3.1).

Several of the recorded mitigation strategies (for example, actions related to upgrading farm dairy effluent infrastructure) represent improvements towards good practice. As *Overseer* assumes best practice is always occurring, not all actions could be modelled through the *Overseer* model framework. Therefore a combination of BMP-Toolbox modelling and expert judgement was applied to define efficacy rates for the 11 strategies that could not be simulated through the *Overseer* model (Table 3.1). A number of assumptions were also applied to these strategies, as summarised in Table 3.3.

The final efficacy rates derived for all mitigation strategies are listed in Table 3.1.

Table 3.2: Summary characteristics for the 12 representative farms modelled in Overseer.

Farm number	System type	Dominant soil type	Effective area (ha)	Vulnerability class (5=very high)	Structures present	N loss, kg/ha	P loss, kg/ha
1	2	Tirau Ash	81	2		25	0.6
2	3	Maeroa Ash	289	4		32	1.9
3	3	Taupo pumice	170	5		58	6
4	2	Pumice	576	3		30	1.4
5	3	Maeroa Ash	355	4		41	0.5
6	3	Tirau Ash	130	4	SO pad	52	1.1
7	4	Taupo pumice	220	5		55	4.7
8	2	Pumice	139	5		48	4.0
9	3	Ash	128	4	Irrigation	34	0.9
10	3	Pumice & peat	83	2		35	3.5
11	2	Ash/pumice/peat	130	1		26	0.4
12	4	Pumice	55	3		29	2.5
Mean farm nutrient loss						**39**	**2.3**

Table 3.3: Assumptions used to derive estimates of mitigation effectiveness for Upper Waikato Dairy Farms

Management area	Mitigation strategy	Assumptions/protocols

Nutrients	Review optimal effluent block and management	• *Overseer* modelling of the 12 Case Study Farms:
		  ○ Farm Dairy Effluent (FDE) blocks balanced to ensure total N inputs (fertiliser, supplement and effluent) did not exceed 200 kg N/ha/year.
		  ○ Effluent areas enlarged as appropriate and/or fertiliser N inputs reduced.
		  ○ FDE application method set to "low rate" (although had little effect on overall N or P loss risk).
		• Increasing effluent area was assumed to be identical to reviewing optimal effluent block size, location and/or application rate.

	N fertiliser management	• *Overseer* modelling of the 12 Case Study Farms:
		  ○ May, June and July applications of N fertiliser to all blocks removed
		  ○ Fertiliser N inputs to all blocks reduced to ensure total N input from fertiliser, effluent and supplement <200 kgN/ha/yr.

	P fertiliser management	• *Overseer* modelling of the 12 Case Study Farms to reduce Olsen P to <45 (only relevant to 1 farm)

	Improve feed management	• *Overseer* modelling of the 12 Case Study Farms:
		  ○ Rate of all fertiliser N applications to pasture halved. This resulted in farm fertiliser N inputs of between 70 and 120 kg N/ha/yr, depending on each individual farm.
		  ○ Pasture silage import replaced with equivalent (lower N content) maize silage.

Effluent	Improve effluent capture	• Reductions due to improved effluent capture around standoff facilities and stone traps. Metrics taken from report of Longhurst et al (2013).
	Improve containment feed stores, feed pads	• Reductions due to silage leachate capture and improved effluent capture around feedpads and animal shelters. Metrics taken from report of Longhurst et al. (2013).
	Improve pond infrastructure and storage	• Sealing of leaky ponds; metrics also derived from Longhurst et al. (2013). • A reduction in effluent volume was assumed to be identical to increasing effluent storage.
	Upgrade effluent infrastructure	• Elimination of leaks and drips from effluent pipe network; estimates taken from Longhurst et al. (2013). Represents very minor sources.
Waterways	Stock exclusion	• *Overseer* modelling of the 12 Case Study Farms: ○ Effectiveness of stock exclusion modelled by turning off in *Overseer* . This typically increased losses by c. 1 - 2 kgN/ha/yr and 0.3 - 0.5 kgP/ha/yr.
	Riparian planting	• Metrics derived from BMP Toolbox, which effectively assumes that the N effectiveness is equivalent to the land taken out of production. • P effectiveness assumed as per reviews and studies cited in Parkyn (2004), Smith (1989), Dillaha et al (1989) and elsewhere, and applied to surface runoff pathway only.
	Wetlands management	• *Overseer* modelling based on the assumption that wetlands intercept and process only 5% of the effective farm area. • Highly convergent wetland modelled.
Land	Improve crop cultivation practices	• Crop cultivation method changed to minimum tillage for forage crops • Immediately re-sow crop paddocks to pasture after harvesting (no bare paddock months - only 1 farm where this is relevant though).
	Reduce crop runoff	• Derived from BMPToolbox assessments (McDowell & Houlbrooke 2009; Orchiston et al. 2012)

Management area	Mitigation strategy	Assumptions/protocols
	Time N fertiliser to crop demand	• *Overseer* modelling of the 12 Case Study Farms: ○ Fertiliser N inputs constrained to 150 kg N/ha/yr on all crops. ○ Fertiliser+ effluent+ supplement N constrained to < 200 kg N/ha/yr on all crop blocks ○ Late autumn (Apr, May) and winter applications of fertiliser N removed ○ No individual applications of fertiliser N greater than 60 kg N/ha.
	Critical source areas laneways	• Diversion or containment of laneway runoff assumed. Metrics derived from BMPToolbox.
	Critical source areas gates & troughs	• Scaling of results from Lucci et al (2010) and Monaghan and Smith (2012). • For gates: ○ assume 1 gateway in 4 might contribute flow to stream ○ assume each gateway contributing area is 5 * 10 m ○ based on above, only 4 m2/farm ha is contributing flow (very minor source). • For troughs: ○ assume 1 trough in 4 might contribute flow to stream ○ assume each trough contributing area is an 8 m diameter circle; equals 50 m2 ○ based on above, only 4 m2/farm ha is contributing flow (very minor source).
	Sediment management	• No assessments made
	Manage stock crossings	• Underpass management; stream crossings avoided. • Estimates derived by scaling results from Lucci et al (2010) and Monaghan and Smith (2012)
	Implement wintering strategies	Implement an on-off autumn and winter grazing strategy to reduce urinary returns to pastures • *Overseer* modelling of the 12 Case Study Farms to take cows off-paddock into a wintering barn ○ Implemented from April until July (inclusive). ○ Assumed cows were allowed to on-off graze (5 hours/day grazing) pastures or crops (to minimise purchased feed that would have otherwise been required)

3.4 Estimate of effectiveness for sediment and bacteria

The effectiveness of individual mitigation strategies for sediment and bacteria (*E. coli*) reduction were in the first instance derived from WRC (2013) best dairy practice guidelines (Table 3.4). As for N and P, the minimum of the reported range for each action as documented in WRC (2013) was applied. For some strategies where the reported minimum was zero, the mean between the minimum and maximum was applied.

The effectiveness of each strategy was reviewed as part of the study. As sediment and bacteria cannot be modelled through the *Overseer* and BMP Toolbox frameworks, revised estimates for each mitigation action were derived from the available scientific literature and expert judgment (Table 3.3). Due to the uncertainties associated with quantifying the effects of different mitigation strategies on sediment and bacteria loading, likely efficacy was categorised as low, medium or very high. These categories are suggested to be similar to the ranges applied by WRC (2013).

In the absence of individual farm bacterial and sediment loss estimates, the benefits of SMP implementation for reducing these contaminants could not be reliably estimated in the current phase of the study. This will instead be addressed in a second phase of the analysis work.

Table 3.4: Summary of initial (WRC, 2013) and revised efficacy rates for individual on-farm action strategies within each management target area for sediment and bacteria (E. coli).

Target area	Mitigation strategy	Efficacy WRC min[1]		Revised efficacy values	
		Sediment	Bacteria	Sediment	*E. coli*
Nutrients	Review optimal effluent block and management	10%	20%	n/a	Low
	Improve fertiliser application methods*	n/a	n/a		
	N fertiliser management	n/a	n/a	n/a	n/a
	P fertiliser management	n/a	n/a	n/a	n/a
	Improve feed management	n/a	n/a	n/a	n/a
Effluent	Improve effluent capture	10%	10%	n/a	High
	Improve containment of feed stores, feed pads			n/a	High
	Improve pond infrastructure and storage	20%	50%	n/a	High
	Upgrade effluent infrastructure			n/a	High
	Effluent solids management*	10%	20%		
	Low rate effluent irrigation*	10%	20%		
Waterways	Stock exclusion	50%	50%	High	High
	Riparian planting	50%	50%	High	High
	Wetlands management	50%	20%	Med	Med
Land	Improve crop cultivation practices	50%	n/a	High	n/a
	Reduce crop runoff	50%	n/a	High	High
	Improve crop grazing practices*	20%	20%		
	Time N fertiliser to crop demand	n/a	n/a	n/a	n/a
	Critical source areas laneways	20%	20%	Low	Med
	Critical source areas gates & troughs	20%	20%	Low	Med
	Sediment management	20%	10%	High	Low
	Manage stock crossings	50%	50%	High	High
	Implement wintering strategies	50%	50%	Med	Low
	Apply controlled grazing regimes*	20%	20%		
	Cut and carry pasture management*	50%	50%		

[1] Represents the minimum of the estimated efficacy range for each action. For some strategies where the reported minimum was zero, the mean between the minimum and maximum was applied.
* Action not present in data set or not applied due to uncertainties

4 Quantification of mean farm nutrient loss reductions

4.1 Quantification approach

Mean reductions in farm N and P loss achieved through the completion of actions documented through the SMP process were quantified for all farms that had completed the Final SMP process by July 2015. Load reductions were estimated based on individual farm *Overseer* information, the actions successfully completed on each farm (Section 2) and the efficacy values assigned to each mitigation strategy (Section 3). In addition, mean reductions in farm nutrient loss, should all intended actions be completed in future, were also estimated. The following methodology was applied to determine these estimates.

For each farm:

1. Total annual farm N and P losses were derived from baseline *Overseer* output collected through the SMP process.
2. As *Overseer* cannot be applied to test scenarios related to best practice (as the model framework already assumes this is being followed), an additional load to reflect poor practice was estimated based on a combination of *Overseer* modelling, expert judgment and standalone simulations with the BMP toolbox. If the farm documented specific actions focused on achieving good practice, this additional load was added to the *Overseer* "base" loss/load to obtain a better estimate of total load prior to the implementation of these strategies. The additional load was calculated to be:
    a. 4% of the total *Overseer* load for N and 21% for P to reflect actions related to restricting stock access to waterways.
    b. Up to 10% of the total *Overseer* load for N and up to 8% for P for each poor effluent management practice action described for the farm (Table 3.1).
3. The revised *Overseer* N and P loss estimates were then sequentially reduced by the efficacy values documented in Table 3.1 for each mitigation strategy undertaken on the farm.
4. The final reductions in total farm N and P losses were calculated as the difference between the revised base load and final load after implementation of actions.

The sequence in which each mitigation strategy was implemented in the load reduction calculation was based on how change on farm would most likely be implemented (Table 3.1). Actions which are becoming mandatory, for example through the Sustainable Dairying: Water Accord (SDWA, 2013), or have little cost or provide cost savings were implemented first (i.e. stock exclusion, optimisation of effluent block size, N fertiliser management). This was followed by actions associated with farm dairy effluent management (infrastructure, containment, infrastructure), and actions that were relatively cost-effective (i.e. critical source area management). Actions which influence the farm system, or require time or capital to undertake were implemented last (i.e. the implementation of wintering strategies, feed management, wetland management).

A number of action categories were excluded from the analysis due to the substantial uncertainty or variability associated with quantifying the likely effectiveness of these strategies (as described in Section 3.3.).

4.2 Mean reductions in farm N and P losses

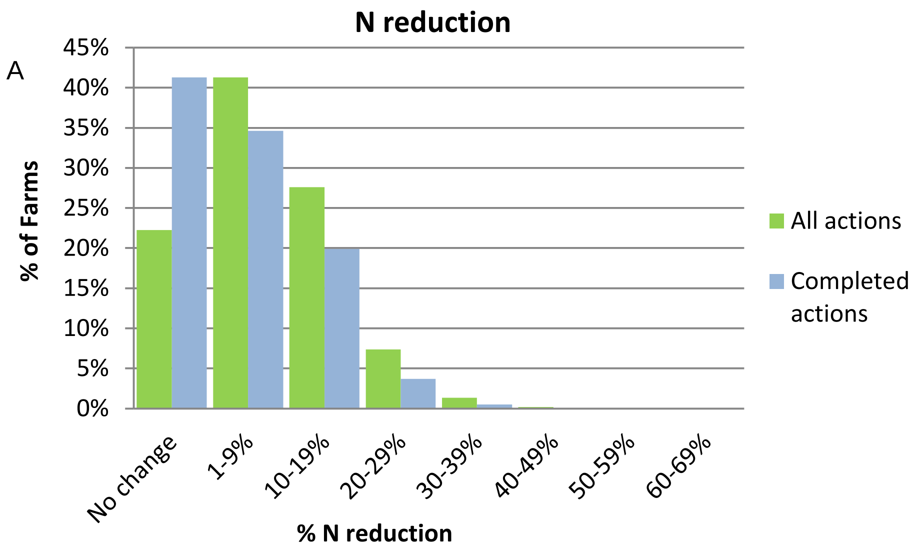
Mean potential reductions in farm nutrient losses following the successful completion of 70% of all intended SMP actions across all farms are estimated to be **5% for N** (based on 598 farms) and **12% for P** (594 farms) (Fig. 4.1). These values are expected to increase to **8% for N** and **21% for P** should all actions across all 642 SMP farms become complete.

Potential reductions in N loss on individual farms ranged from 0 to 35% where actions targeting N were successfully completed (Fig. 4.2). Nearly 23% of farms did not record a reduction in nitrogen losses as a result of SMP actions, as not all actions specifically targeted N reduction. Actions around wintering strategies and improved feed management had large impacts on reducing nitrogen losses on some farms (>20% farm N reduction) but these strategies are being implemented only on a small number of farms overall.

There is a 3% difference in estimated N loss reduction between completed and intended actions. Most of the actions not yet complete relate to strategies targeting farm dairy effluent, for example effluent storage and infrastructure. These strategies were undertaken on many of the study farms and in turn have potentially large impacts on farm N loss compared to many of the other strategies applied.

Reductions in farm P loss ranged from 0 to 73% across individual farms for completed actions focusing on P (Fig. 4.2). The largest reductions (>45% P reduction) occurred on farms where a combination of riparian management, management of critical source areas, stock exclusion and dairy effluent nutrient application was collectively carried out (Fig. 4.3). Riparian planting was documented on 20% of farms analysed. Reductions in P losses were not observed for 42% of farms. This number is expected to decrease to 25% should all actions be competed (Fig. 4.1).

Most incomplete actions for P were related to riparian planting, stock exclusion and farm dairy effluent. Collectively these strategies have large benefits for reducing farm P loss but may take much longer to implement than the current 6-10-month SMP project duration. Mean reduction in farm P loss is estimated to double should all actions be completed in future (Fig. 4.1).



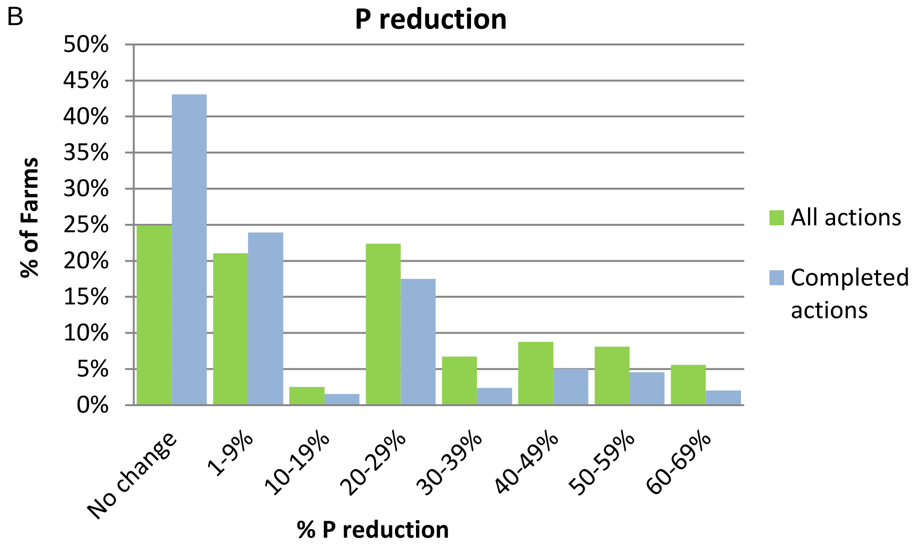


Figure 4.1: Distribution of farm (A) nitrogen (N) and (B) phosphorus (P) % reductions across individual farms for all actions (642 farms) and competed actions only (598 farms for N and 594 farms for P). No change reflects farms where recorded actions are not likely to impact N and/or P loading directly, although all actions will ultimately lead to improved environmental performance and load reductions over the long term.

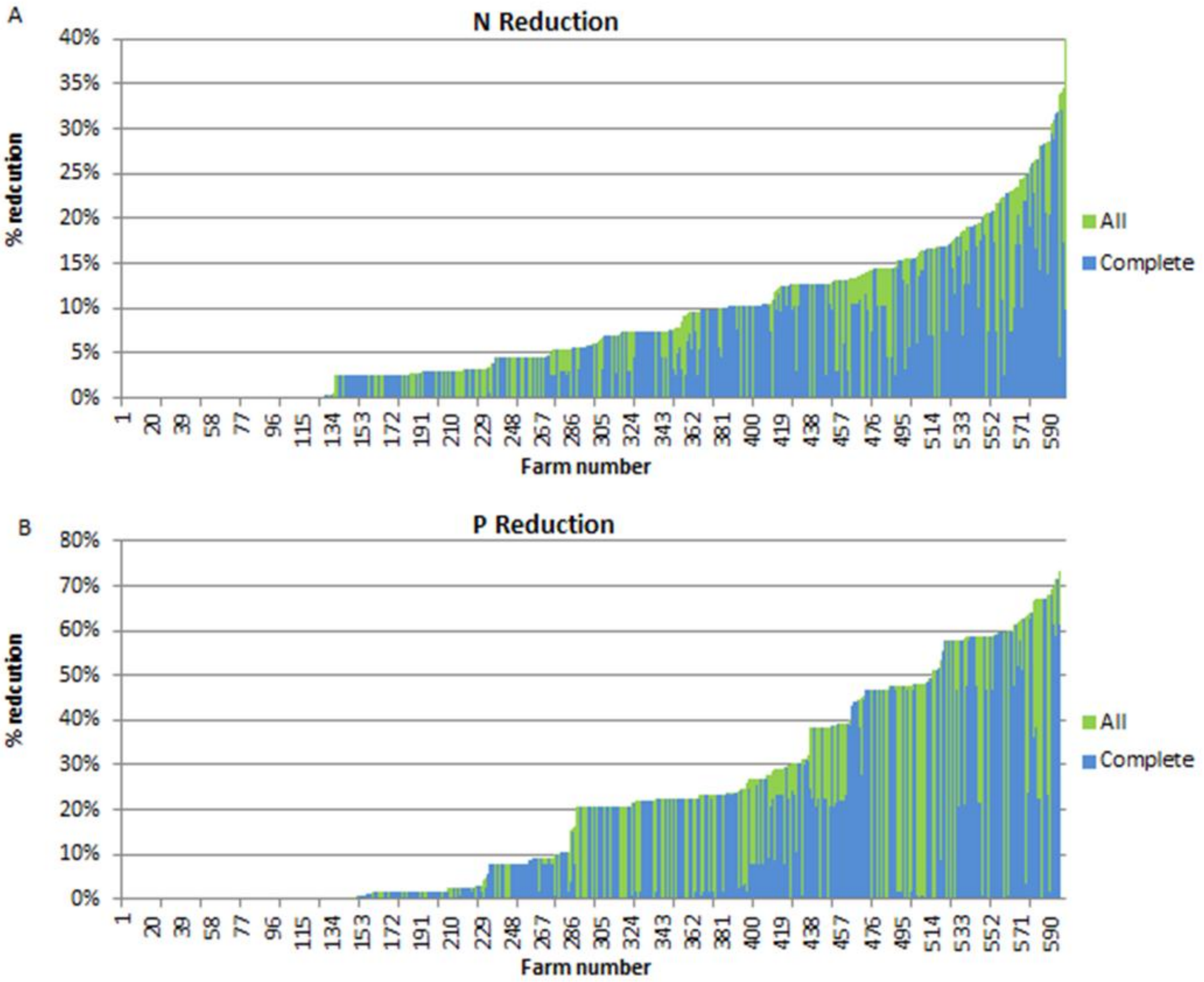


Figure 4.2: Estimated potential % reduction in farm (A) nitrogen (N) and (B) phosphorus (P) losses to water for intended and completed actions on each farm. Farms are ranked according to total % N or P reduction, and farm numbers are therefore different for N and P.

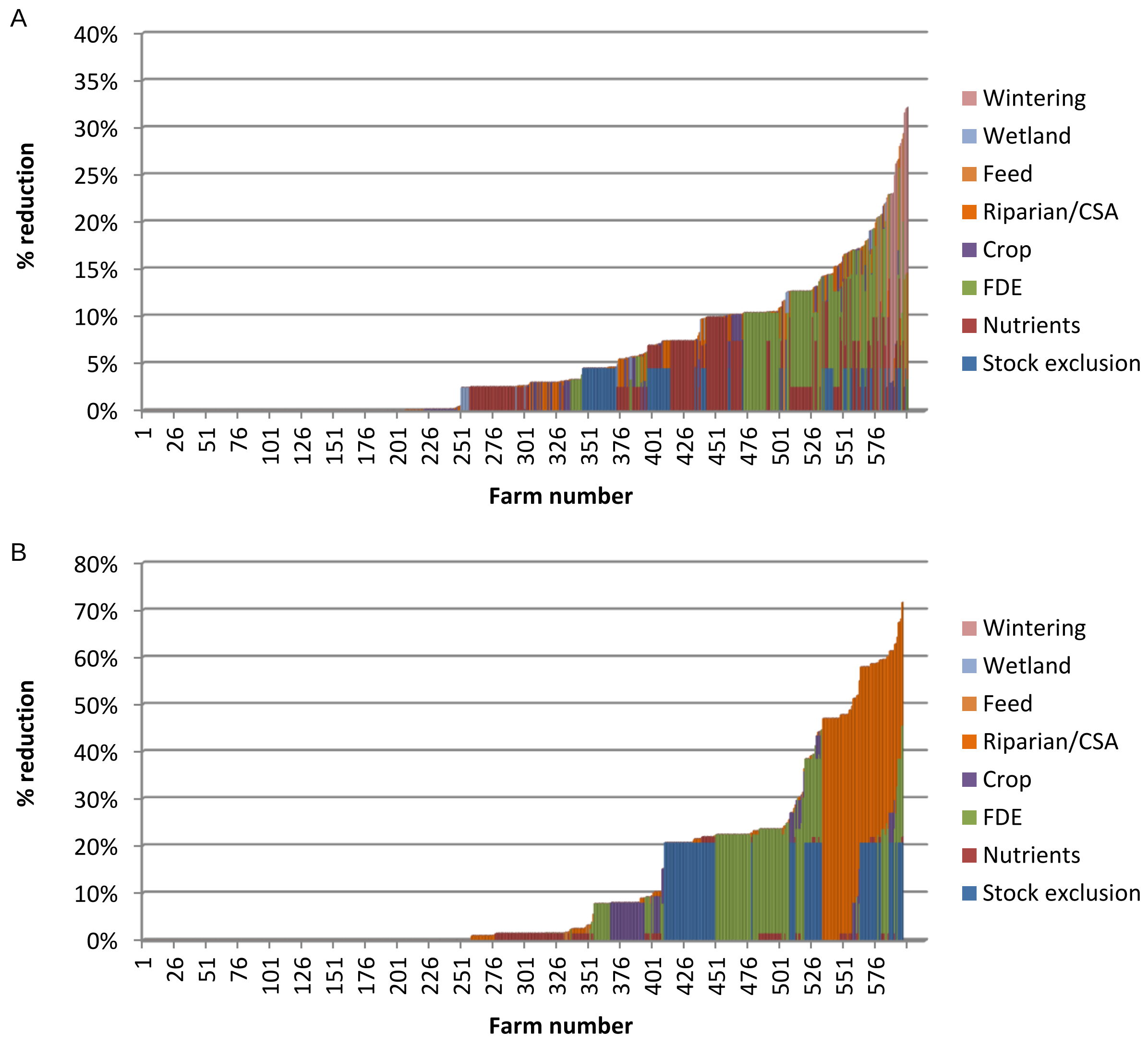


Figure 4.3: Estimated potential % reduction in farm (A) nitrogen (N) and (B) phosphorus (P) losses attributed to specific action categories following the successful completion of 70% of all SMP actions across individual farms. The mitigation actions represented in each action category are summarised in Table 2.3. Farms are ranked according to total %N or P reduction, and farm numbers are therefore different for N and P.

5 Summary

5.1 Summary

5.1.1 Estimated N and P load reductions

The results of this analysis suggest that mean reductions in farm nutrient losses associated with all completed SMP actions are estimated to be 5% for N and 12% for P. This is based on the 594 farms that had completed the full SMP process by the end of July 2015. These reduction estimates are expected to increase to 8% for N and 21% for P when all actions across all 642 SMP farms are fully implemented.

Potential load reductions on individual farms ranged from 0 to 35% for N and 0 to 73% for P, depending on the number and combination of actions being implemented. The greatest reductions were observed for farms implementing multiple strategies around stock exclusion, optimised effluent/fertiliser applications for N, and riparian management plus critical source area protection, stock exclusion and dairy effluent nutrient applications for P. These estimates apply only to dairy farms in the catchment, which were the focus of the current study.

These estimates reflect the potential reduction in farm nutrient losses as calculated from *Overseer* nutrient budget outputs and do not reflect attenuation processes prior to discharge direct to surface waters. However, assuming that attenuation rates are likely to be similar before and after reductions in farm nutrient loading, the final % reductions in loadings to waters are likely to be similar to the estimated off-farm reductions.

Not all farms recorded actions with a direct impact on nutrient loading and this analysis therefore only focused on a sub-set of all actions undertaken through the SMP process. Irrespectively, however, all actions will ultimately lead to improvements in farm environmental performance over the long term and as a result overall reductions in N and P loading are likely to be greater than calculated here.

Our estimates of farm nutrient load reductions brought about through the SMP process are similar to the findings of Jenkins and Vant (2006), who estimated catchment-scale reductions in N and P loading for 44 Waikato peat lakes following the implementation of best and additional (beyond best) land management practices. Across all lake catchments and landuse types, mean reductions in catchment nutrient loading were estimated to be 7% for N and 18% for P following the implementation of good practices. These values increased to 36% for N and 39% for P following the implementation of strategies beyond good practice. For dairying specifically, reductions in farm N and P loading were estimated to be 8% for N and 44% for P under best practice scenarios, based on *Overseer* model simulations estimates reported by Ledgard and Power (2006).

5.1.2 Quantification approach

The initial quantification method using the sum of existing literature estimates of likely effectiveness for each mitigation strategy resulted in very high estimates of load reduction potentials, especially for farms where multiple actions were being implemented concurrently. This approach is considered more suited to evaluating the relative impact of individual actions at the paddock or block scale, as opposed to assessing the impacts of multiple, cumulative actions at the farm-scale.

Our revised estimates of % effectiveness for each mitigation strategy, derived using a combination of *Overseer* modelling, BMPToolbox modelling, literature values and expert judgment, generated load reduction values significantly lower than obtained using the initial method. The revised estimates are therefore suggested to be conservative, providing a realistic estimate of the minimum improvement achievable through the implementation of on-farm mitigation strategies.

While there is still a degree of uncertainty associated with the revised approach, the methodology is considered more robust as estimates of effectiveness for individual actions, as well as the way multiple measures are implemented consecutively, reflect impacts at the farm scale as opposed to the block scale. The revised approach also takes into consideration the fact that many farms targeting actions around effluent infrastructure, effluent application and stock exclusion are currently not operating at best practice. Baseline nutrient losses from these farms are therefore likely to be greater than has been estimated using *Overseer*.

5.2 Method uncertainties

Estimating reductions in nutrient loading associated with the implementation of on-farm mitigation measures is challenging due to uncertainties associated with the effectiveness of individual strategies, the collective impacts of consecutive measures at the farm scale and the accuracy of farm baseline nutrient loads under varying stages of best practice. Environmental factors (soil type, topography, rainfall), farm practices (i.e. system intensity) and proximity to waterways are all important variables which influence farm loading rates and load reduction potential. While the effectiveness of individual strategies under different conditions can be estimated through experimental approaches or modelling, the combined impact of a range of actions implemented concurrently is more difficult to quantify.

In this analysis the efficacy of different mitigation measures at the farm scale were estimated mostly based on *Overseer* model scenarios for 12 representative Upper Waikato catchment model farms. The most important variables governing leaching rates in *Overseer* are rainfall and soil type. These variables do not vary substantially across the study catchment with most farms situated on freely-draining ash or pumice soils. Variations in the intensity of farm systems in terms of N utilisation and imports do exist and these differences were accounted for in the model case study farms selected.

The benefit of implementing a mitigation strategy is strongly dependent on the assumed management scenario before intervention. For example, a poorly designed or leaking effluent irrigation system has greater mitigation potential than the improved operation of a well-designed system. In the current analysis it was assumed that all farms applying a particular action strategy will deliver a similar impact in terms of load reduction, irrespective of existing management practice. Further refinement of the approach is unlikely to improve the accuracy of the estimated load reduction values, due to the many additional assumptions that would need to be made to fully account for this variability.

Initial farm nutrient loss estimates calculated through *Overseer* also assume best practice is being followed for all aspects of farm operation. While the quantification approach used here assumes a higher base load for farms with actions targeting effluent management and stock exclusion, the additional load applied reflects a mean across all farms and this was not applied to farms without these recorded actions.

The impacts associated with a number of action categories were excluded from the analysis due to the uncertainties and assumptions that would need to be made to estimate a load reduction potential. For example, retiring land as a strategy to prevent erosion is difficult to address as the area and slope of the land being retired needs to be known in order to estimate net benefits. These variables were not documented though the SMP process.

5.3 Next steps

This report represents a first analysis of potential N and P load reductions based on an action completion rate of 70% across all farms in the SMP process. The benefits of SMP implementation on reducing sediment and bacteria loads will be further evaluated in a second phase of the study. Loading to surface waters after attenuation will also be considered for all variables.

The values used to define the effectiveness of individual mitigation measures and the collective impact of consecutive measures will be further underpinned in a peer-reviewed scientific publication. Therefore all estimates of N and P loss should be treated as preliminary until this peer-review process is complete.

6 References

Brocksopp, A., D. Burger, M. Bramley, N. McHaffie & M. Scarsbrook (2014). Upper Waikato Sustainable Milk Progress Report 2014/15

Brocksopp, A. M. Bramley, N. McHaffie, D.F. Burger & M. Scarsbrook (2015). Accelerating the adoption of good environmental practice on dairy farms in the upper Waikato catchment. Fertiliser and Lime Research Centre Annual Conference, February 2015.

Dillaha, T.A., Reneau, R.B., Mostaghimi, S., Lee, D. (1989). Vegetative filter strips for agricultural nonpoint source pollution control. Transactions of the ASAE 32, 513-519.

Jenkins and Vant (2006). Potential for reducing the nutrient loads from the catchments of shallow lakes in the Waikato Region. Environment Waikato Technical Report 2006/54. Waikato Regional Council, Hamilton.

McDowell, R. (2010). The efficacy of strategies to mitigate the loss of phosphorus from pastoral land use in the catchment of Lake Rotorua. Report for Environment Bay of Plenty. AgResearch Ltd.

McDowell, R., B. Wilcock & D. Hamilton (2013). Assessment of strategies to mitigate the impact or loss of contaminants from Agricultural land to fresh waters. REC500/2013/066. Report for New Zealand Ministry for the Environment. AgResearch, National Institute of Atmospheric Research, The University of Waikato

Ledgard S. and I. Power (2006). Nitrogen and phosphorus losses from "Average" Waikato farms to waterways as affected by best or potential management practices. Environment Waikato Technical Report 2006/37. Waikato Regional Council, Hamilton.

Longhurst, B., Houlbrooke, D., Laurenson, S. (2013). On-farm dairy effluent risk assessment. AgResearch Client Report to DairyNZ RE500/2013/040. 49p

Lucci, G.M., McDowell, R.W., Condron, L.M. (2010). Potential phosphorus and sediment loads from sources within a dairy farmed catchment. Soil Use and Management 26, 44-52.

McDowell, R. W. and D. J. Houlbrooke (2009). Management options to decrease phosphorus and sediment losses from irrigated cropland grazed by cattle and sheep. Soil Use and Management 25(3): 224-233.

McKergow, L., C. Tanner, R. Monaghan, G. Anderson (2007). Stocktake of diffuse pollution attenuation tools for New Zealand pastoral farming systems. Report HAM2007-161, prepared for Pastoral 21 Research Consortium, National Institute of Atmospheric Research, Hamilton New Zealand.

Monaghan, R.M., Smith, L.C. (2012). Contaminant losses in overland flow from dairy farm laneways in southern New Zealand. Agriculture, Ecosystems & Environment 159:170-175.

Orchiston, T.S., Monaghan, R.M., Laurenson, S. (2013). Reducing overland flow and sediment losses from winter forage crop paddocks grazed by dairy cows. In Accurate and efficient use of nutrients on farms (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 26. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 7 pages.

Parkyn, S.M. (2004). Review of Riparian Buffer Zone Effectiveness. MAF Technical Paper No: 2004/05. New Zealand Ministry of Agriculture & Forestry, Wellington, 37p.

Smith, C.M. (1989). Riparian pasture retirement effects on sediment, phosphorus, and nitrogen in channellised surface run-off from pastures. New Zealand Journal of Marine and Freshwater Research 23, 139-146.

SDWA (2013). Sustainable Dairying: Water Accord. A commitment to New Zealand by the Dairy Sector. Dairy Environment Leaders Group. 15p.

Waikato Regional Council (WRC) (2013). Menu of practices to improve water quality; Dairy Farms. ISBN 978-0-9876661-3-0.

.